Fodder Shrub Development in Arid and Semi-arid Zones

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Fodder Shrub Development in Arid and Semi-arid Zones

Proceedings of the Workshop on Native and Exotic Fodder Shrubs in Arid and Semi-arid Zones
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Volume I

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Foreword

In November 1995, ICARDA gathered agricultural scientists from across the region to review the progress on integration of crop–livestock systems in West Asia and North Africa. Rangelands play a key role in the region and in arid zones throughout the world. They cover vast areas of West Asia, North Africa, and Central Asia. Traditionally, they form a large percentage of the feed diet of most ruminants. However, due to human and animal population growth, cropping has expanded onto some of the most valuable rangeland. By necessity, agro-pastoral communities have gradually expanded cropping into low rainfall areas with fragile environments and soils, leaving only the poorest ranges for their flocks. Overgrazing and wood harvesting for fuel exacerbate desertification and loss of natural resources. Soil erosion also takes a toll in the deterioration process.

What can be done to make this terrible process stop? The concept of good vegetation cover as a means of soil conservation is not new. What is new is the concept of rebuilding the vegetation cover that has been destroyed. What kind of vegetation cover can be re-established on the degraded soils of eroded rangelands? What can be done to make the rangelands productive again? How can we restart the soil–plant–animal nutrient cycle? What kind of plants should we use? Where will we get the seed? What establishment techniques should we use? On which lands should we establish the vegetation cover? Who is going to do it? Who is going to pay for it? Who will be allowed to use it? Will there be free access? If not, how much will users be charged for access? When? For how long? There are many questions we must answer without delay. Desertification does not wait, the battle is on all fronts, and we have to act now. We have to integrate a technical approach with a socioeconomic element, and consider land tenure and public policies. This is what we have attempted to do at this workshop, to which the heads of tribes and agro-pastoral groups were invited, so that they might share with us the needs of their communities and tell us where they think we should focus our efforts.

This workshop helped agro-pastoralists and scientists get closer to one another, and to better understand the urgent needs and expectations of agro-pastoral communities in the dry areas. Now we must continue working together to identify, propose, develop, and test appropriate technologies and to elaborate opportune public policies for rangeland rehabilitation in semi-arid and arid zones. This is the challenge that we, the international agricultural organizations working on research for development, have to face to the best of our ability.

Prof. Dr. Adel El-Beltagy
Director General
ICARDA

Introduction

Desertification is the complex result of the overuse of natural resources. It is particularly noticeable in semi-arid and arid zones under the combined assault of climatic variability and human and animal demographic pressures. Further pressure is brought to bear on cropping zones because livestock feed on large quantities of crop residues. The use of subsidized imported feed, associated with inappropriate public policy and combined with soil-mining cultivation of low rainfall zones, has caused considerable damage to rangeland soil, water, and feed resources. Feed for most of the small ruminant flocks is no longer ensured by marginal lands and rangelands. To help slow down this trend, there is an urgent need to elaborate appropriate measures to restore rangeland feed resources. Technical options are available; one of them is the re-establishment and use of native and exotic fodder shrubs and trees, such as saltbushes (*Atriplex* spp.), *Salsola* spp., *Artemisia* spp., *Acacia* spp., Saxaoul (*Haloxylon* spp.), spineless cactuses (*Opuntia* spp.), etc. These species have been promoted as feed banks in Mediterranean semi-arid and arid zones. It is now believed that other native or exotic shrubs could play a role in rehabilitation programs of the marginal lands and rangelands of the arid and semi-arid Mediterranean zone, not only as a feed reserve but also in soil and water conservation in environmentally degraded areas.

While many countries have embarked on large-scale plantation programs of fodder shrubs for direct grazing, other countries shy away from getting involved in what they consider a risky and expensive rehabilitation exercise. Most argue that the local nomadic and settled farmer populations do not know enough about grazing management and proper use of such plantations. Costly fodder shrub projects have proved to be failures, soon destroyed by climatic accident or more often by mismanagement. In fact, proper grazing management of fodder shrub plantations remains largely uncertain, despite the large areas under fodder shrub plantations in the Mediterranean basin. In recent years, other issues have been raised by developers, government agencies, and users concerning the land tenure status of these plantations and their use by flock owners.

This regional workshop, linking Maghreb and Mashreq users and developers (national, NGO, farmer, and agro-pastoralist) with scientists from other parts of the world, was organized to update participants on the latest developments in this field and evaluate progress to date on fodder shrubs in the semi-arid and arid zones.

The objectives of our workshop were to:

- Exchange experience and information on rangeland fodder shrub development between Maghreb and Mashreq participants.

- Review and update general and regional knowledge on native and exotic fodder shrubs in arid and semi-arid zones of the Mediterranean basin and other parts of the world.

The workshop covered the following subjects:

- National experience with fodder shrubs in the Maghreb, Mashreq, and sub-Saharan zones.
- Ecology and biology of fodder shrubs.
- Plant–animal interactions.
- Socioeconomics and management of fodder shrubs.

Both basic and applied research were addressed. Multidisciplinary development involving the local population and NGOs was stressed. Despite the large number of participants, we opted for plenary sessions to allow full interaction and exchange. Posters offering technical explanations were on display for the duration of the workshop. This approach was deemed the best way to encourage full dialogue and future collaboration.

A total of 117 participants from 24 countries attended the workshop. Countries represented include: Algeria (4), Australia (2), Chile (1), Egypt (8), France (7), Greece (3), Iran (2), Iraq (1), Japan (1), Jordan (4), Kazakstan (1), Lebanon (1), Libya (2), Morocco (15), Pakistan (2), Senegal (2), South Africa (3), Spain (3), Syria (9), Tunisia (21), Turkey (1), United Kingdom (2), United States (1), and Uzbekistan (2). Of particular significance was the participation of farmers and NGOs. Farmers from Morocco (2), Syria (3), Jordan (1), Australia (1), South Africa (1), Tunisia (1), France (1), Egypt (3), and Senegal (1), and NGOs from Morocco (2), Jordan (1), Pakistan (1), and Tunisia (1), were active contributors over the course of the workshop.

Scientists from Jordan, Morocco, Pakistan, Syria, and Tunisia shared their experiences with fodder shrub plantation. In these countries, extensive research has been carried out to better understand the value and uses of native and exotic fodder shrub species. Intensive efforts are being undertaken to introduce these species on a commercial scale. Examples of the role fodder shrubs may play in rangeland rehabilitation include revegetation, filling seasonal feed gaps, and providing a strategic reserve for drought management.

International experience regarding fodder shrubs was presented and discussed with contributors from WANA, southern Europe, South Africa, South America, and Australia.

The farmer and NGO forum was especially worthy of note. Farmers, livestock owners, agro-pastoralists, and NGOs from Morocco, Tunisia, Egypt, Jordan, Syria,

Pakistan, Senegal, Australia, and South Africa presented their experiences with fodder shrubs. Their realistic assessments emphasized the importance of a participatory approach with the increased participation of farmers to ensure that new technologies will respond to real needs.

The Tunisian Ministry of Agriculture, with the efficient support of local authorities and private farmers, organized a two-day field trip to a sampling of Tunisian fodder shrub plantations. The sites visited were located in areas with rainfall ranging from 150 to 350 mm per year. Participants were able to see and discuss cases such as: (i) *Acacia cyanophylla* plantations on collective lands managed by the Tunisian Forestry Department; (ii) spineless cactus and *Acacia cyanophylla* plantations on private farms; (iii) a state farm experience with a spineless cactus plantation on "alfa" (*Stipa tenacissima*) steppe; (iv) a spineless cactus plantation for fruit and forage production on privately owned land; and (v) the introduction of native shrub species (*Periploca leavigata*, *Calycotome villosa*, *Rhus tripartitum*, and spineless cactus) on collective lands managed by the Tunisian Forestry Department. The diversity of sites and management conditions was remarkable. The warm local hospitality, experienced under traditional Bedouin tents, will be remembered by all as highlights of this 600 km field trip throughout central and southern Tunisia.

One day of the workshop was devoted to special topics presented by rapporteurs. These presentations generated lively discussion on key issues, such as native versus exotic germplasm, profitability versus land rehabilitation, cost of planting, and seed production. Farmer and NGO comments yielded useful contributions towards a better targeting of research for development and the preparation of future development projects.

Most important, however, were the personal contacts and friendships formed at this workshop. In the face of the vast amount of work still to be carried out on these topics in the future, and the vast areas to be managed (270 million ha in WANA and 260 million ha in Central Asia alone), such a joining of forces and sharing of experience are essential.

Gus Gintzburger, Mustapha Bounejmate and Ali Nefzaoui

International Experience with Fodder Shrubs

Use of Fodder Trees and Shrubs (Trubs) in the Arid and Semi-arid Zones of West Asia and North Africa: History and Perspectives

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Abstract

The use of fodder tree and shrub plantations in the Mediterranean arid and semi-arid zones (100–600 mm MAR) started, particularly in Tunisia, between World Wars I and II. Between 1950 and 1970 it expanded and diversified, but it did not reach regional significance until the 1970s. This advance was achieved by a handful of enlightened and unconventional scientists (agronomists, foresters, ecologists, livestock specialists, and veterinarians).

Surprisingly, this slow maturation process was going on at the same time, and at the same leisurely pace, in other arid zones of the world: South Africa, Australia, Chile, Brazil, and the USA.

On the eve of the third millennium, the area planted with native or exotic fodder tree and shrub species in WANA countries is nearing 1 million ha. This includes three categories of species: cacti, saltbushes, and wattles. The acreage planted to these species is expanding, and the genetic material is diversifying. This is in contrast to herbaceous fodder crops (which are not concerned with arid lands), whose acreage has stagnated at about one third that of the "trubs."

The reason for the relative success of fodder trubs is rooted in several causes:

- Their remarkable tolerance to drought and ability to accumulate green fodder over several seasons, or even years, allow for the building up of fodder reserves that can be used in times of dearth, and so constitute a true "drought insurance" for livestock. This permits the switch from transhumance to sedentary husbandry, as long as permanent water is available, in regions where conventional fodder crops are impractical.
- Their deep roots (except for the CAM carboxylation pathway species) enable them to reach permanent or temporary water resources unavailable to herbaceous species.
- They have the ability to make use of showers and of out-of-season rain, unlike most herbaceous species.
- Their rain- and water-use efficiencies increase productivity 3–5 times.

- Their above-ground biomass, important canopy ground cover, and landscape roughness make them an efficient and relatively cheap tool in erosion and desertification control and in the rehabilitation of degraded land.
- They have the ability to become established on non-farming lands (steep slopes, stony, rocky, and shallow soils, marly and shaly badlands, saline land, dunes, etc.).
- They can be combined with cereal farming in widely spaced hedgerows.
- They can be used in runoff farming systems.
- They have an impact on land fertility and productivity because of their organic matter production. This leads to a high turnover rate of geobiogene elements, structure strengthening, and stabilization, and thus to increased oxygenation and permeability, which are followed by microflora and microfauna activity, improved site-level water budget and balance, etc.
- They produce other valuable goods such as firewood, game and wildlife shelter, food, shade, etc.
- They have biological diversity, landscape amenity, and an educational role.
- They play a role as a microclimatic buffer for wind, temperature, and evapotranspiration.

But fodder trub plantations also have some serious, occasionally severe, constraints:

- The cost of establishment is sometimes excessive and unaffordable by the small farmer or grazier.
- They require long-term planning, and therefore a secure land tenure system, which is often non-existent.
- There is often an ecological adequation between the species selected and the local ecological conditions and/or managerial skills.
- Appropriate methods of establishment, cultivation, management, and use need to be adapted to the users.
- Availability of improved plant material is limited.
- Access restrictions that allow stands to regenerate after defoliation are essential.

The identification of these constraints gives an indication of the research and extension needs for the proximate future:

- Reduced-cost establishment methods, including direct seeding with or without pregerminated seed, that are affordable to small producers.
- Legal, regulatory, and administrative incentives.

- Selection of high-grade cultivars in terms of feed value, palatability, multiplication, and edapho-climatic adaptation traits.
- Perfection of improved methods of cultivation, management, and exploitation that allow higher yields of higher-quality products.
- Combination with runoff farming techniques.
- Joint land use with cereal farming.
- Integration into various production systems, animal, agricultural, and mixed, that are economically feasible and socially acceptable.
- Further research on the possible use of new native and exotic species.

Résumé

L'utilisation de plantations d'arbres et d'arbustes fourragers dans les zones arides et semi-arides méditerranéennes (100–600 mm de PMA) s'est manifestée entre la première et la seconde guerre mondiale, en particulier en Tunisie. Elle s'est ensuite développée et diversifiée entre 1950 et 1970; mais elle n'a pris d'ampleur significative que vers les années 1970. Elle a essentiellement été le fait d'une poignée de scientifiques éclairés et peu conventionnels (agronomes, forestiers, écologues, zootechniciens, et vétérinaires).

Curieusement, cette lente maturation s'est déroulée de la même manière et en même temps dans d'autres zones arides mondiales, méditerranéennes ou non: Afrique du Sud, Australie, Chili, Brésil, USA.

Les superficies plantées d'espèces naturelles et exotiques avoisinent 1 million d'hectares dans le Nord de l'Afrique et l'Asie Occidentale à la veille du 3ème millénaire. Elles sont essentiellement constituées de trois groupes d'espèces: les Cactus, les *Atriplex*, et les *Acacias* à phyllodes. On observe une nette tendance à l'expansion et à la diversification des plantations, contrairement aux cultures fourragères herbacées en culture sèche, stabilisées depuis 50 ans au tiers de cette superficie ; ces dernières ne concernent d'ailleurs pas les zones arides *s.s.* à l'inverse des ligneux.

Les raisons de ce succès relatif des ligneux fourragers tiennent à plusieurs causes:

- Leur grande tolérance à la sécheresse et leur capacité d'accumuler du fourrage vert sur plusieurs saisons, voire plusieurs années, permet de constituer des réserves fourragères mobilisables en cas de disette. Ces réserves constituent pour les troupeaux une véritable "assurance contre la sécheresse" permettant de pallier la transhumance et de sédentariser les éleveurs, sous réserve de disponibilité en eau, dans des régions où les cultures fourragères herbacées en sec sont difficiles ou impossibles.

- Leur enracinement profond (sauf les espèces à voie de carboxylation CAM), leur permet d'atteindre des ressources en eau permanentes ou temporaires auxquelles les espèces herbacées n'ont pas accès.
- Leur aptitude à utilizer de petites pluies et des pluies hors-saison, contrairement à la plupart des espèces herbacées.
- Leur Coefficient d'Efficacité Pluviale (CEP) et leur Efficacité d'Utilisation de l'Eau (EUE) très élevés et leur haute productivité (3 à 5 fois celle d'un parcours en bon état dans les mêmes conditions écologiques).
- Leur biomasse aérienne importante, leur taux élevé de recouvrement du sol et leur rugosité paysagère qui en font un outil efficace et relativement peu coûteux dans la lutte contre l'érosion et de la désertisation et dans la réhabilitation des terres dégradées.
- Leur aptitude à coloniser des terres non-agricoles (pentues, pierreuses, marneuses, dunaires, squelettiques, ou salines).
- Leur combinaison, au contraire, avec des cultures céréalières dans des plantations à grand écartement.
- Leur aptitude de conjonction avec l'agriculture de ruissellement et des systèmes de production mixtes.
- Leur action sur la fertilité et la productivité des terres, par leur taux élevé de renouvellement des éléments géobiogènes, la production de matière organique donc la cohésion et la stabilité structurale et par conséquent l'aération et la perméabilité, l'enrichissement de la microflore et de la microfaune du sol, etc.
- La production d'autres biens de consommation : bois de feu, gite et couvert du gibier et de la faune, ombre.
- La diversité écologique et paysagère qu'ils permettent, le rôle de tampon bioclimatique et leur contribution aux aménités touristiques, voire éducatives.

Mais les plantations de ligneux fourragers sont soumises à des contraintes importantes, voire sévères qui freinent leur expansion. Les principales contraintes rencontrées sont les suivantes :

- Coût d'établissement parfois prohibitif pour de petits agriculteurs ou des éleveurs modestes.
- Nécessité de planification à long terme, donc d'une tenure de terre sécurisante.
- Adéquation des espèces choisies aux contraintes édapho-climatiques, de gestion et d'exploitation.
- Méthodes appropriées d'installation, de culture, de gestion et d'exploitation.
- Disponibilité de matériel végétal adapté et amélioré.
- Discipline d'utilisation permettant la régénération des peuplements après défoliation.

L'identification de ces contraintes est une indication des programmes de recherches et de vulgarisation nécessaires à moyen et long terme pour les années qui viennent :

- Multiplication et installation à coût réduit, méthodes de semi-direct avec ou sans pré-germination, accessibles aux petits paysans.
- Incitation législative, réglementaire et administrative.
- Sélection de cultivars doués de qualités supérieures en valeur nutritive, appétabilité, multiplication et adaptation édapho-climatique.
- Mise au point de méthodes améliorées de gestion assurant des rendements plus élevés et des utilisations mieux adaptées aux systèmes de production existants.
- Combinaison avec les techniques de l'agriculture de ruissellement.
- Utilisation conjointe avec la céréaliculture.
- Intégration dans divers systèmes de production animale, agricole ou mixte, économiquement viables et socialement acceptables.
- Poursuite des recherches sur l'utilisation possible d'espèces nouvelles autochtones et exotiques.

Historical Review

The plantation of fodder trees and shrubs (trubs) for livestock feeding is a relatively recent practice. It dates back to the 1920s and 1930s in WANA, where trubs were often established on an experimental basis. The practice expanded somewhat during World War II, particularly in Tunisia.

In older times, native populations of fodder trubs, such as *Argania sideroxylon* (*A. spinosa*), *Atriplex halimus*, and *Acacia tortilis* subsp. *raddiana*, may have been maintained, or even nurtured, as valuable feed resources, but they were not deliberately planted for any other purpose.

A world-class example of a successful, time-honored, multi-purpose arid land agroforestry system is the 600,000 ha Argania parkland in southwest Morocco, with a mean annual rainfall (MAR) of 100–400 mm. The earliest plantations of any size were spineless cactus (*Opuntia ficus indica* f. *inermis*), established in the 1930s, notably in central Tunisia under strong government incentives. This stemmed from the work of D. Griffiths, who was invited by the Tunisian government to visit the country and, as a result, produced one of the best among his many research writings on cacti. Griffiths had at that time carried out over 35 years of research on cacti. His 35 page report was translated into French and widely circulated among farmers (Griffiths 1933).

One example of government incentives was the Gamouda settlement near Sidi Bouzid, where the settlers' contracts included the establishment of spineless cactus plantations on 2% of their allocated land during the first years of occupancy, with failure to comply resulting in a loss of ownership. This particular government regulation turned out to be a blessing when a devastating drought struck in 1946–1948. In contrast to most stockmen, who lost 70–75% of their flocks, these settlers went through the drought almost unharmed (Le Houérou 1951; Le Houérou and Dumont 1964). For a detailed review on fodder cacti, see Monjauze and Le Houérou (1965) and Le Houérou (1994, 1996). Of particular significance in the early period are the following publications: Beau (1940); Brichet (1942); Cordier (1947); Cottier (1934); Griffiths (1933); Jose d'Arces (1944); Miegeville (1946); Piedallu (1944); Velu (1931); Giscard (1961); Foury (1954); and Corriols (1965). At present, spineless cactus plantations cover some 300,000 ha in Central Tunisia, and perhaps some 500,000 ha in North Africa.

Wattles (Phyllodinous *acacias*, *Racosperma* spp.), particularly *Acacia saligna* (*A. cyanophylla*), were introduced to Libya in 1916 with the aim of binding sand dunes around Tripoli under 200–350 mm MAR (Leone 1924; Le Houérou and Pontanier 1987). Success was so marked that, as early as 1920, some 100,000 seedlings were being established annually. The species was then planted for binding sand dunes all over North Africa, particularly in the regions of Bizerte, Porto Farina, Cap Bon, and Tabarka in northern Tunisia, and later in the dunes of Mogador (now Essaouira) in central-western Morocco. *Acacia saligna* currently covers an area of some 200,000 ha in WANA, probably larger than in its homeland in southwestern Australia. Moreover, successful plantations are being established in WANA down to the 200 mm MAR isohyet, while in its homeland it only grows on coastal sands and dunes in the sub-humid zone under typical rainfalls of 600–900 mm per annum. It was shown in the 1970s that *A. saligna* was a useful forage amenable to the establishment of standing fodder reserves in the arid and semi-arid zones (Le Houérou and Dumancic 1981). As mentioned above, *A. saligna* plantations cover some 200,000 ha in North Africa, of which 60,000 ha are in Libya, 80,000 in Tunisia and 40,000 in Morocco, with a few thousand hectares in Algeria, Egypt, Israel, Jordan, and Palestine (Le Houérou and Pontanier 1987).

Saltbushes (*Atriplex* spp.) are partly native (*A. halimus* subsp. *halimus* and subsp. *schweinfurthii* and *A. glauca* in WANA; *A. leucoclada*, a biannual shrub-like species, in western Asia; and *A. mollis* in eastern North Africa) and partly exotic (*A. nummularia* in New South Wales and South Australia; *A. canescens* and *A. lentiformis* in North America). There is also a naturalized exotic biannual forage species with a benignly aggressive range-weed behavior throughout WANA: *A. semibaccata* from Australia (Le Floc'h et al. 1990; Le Houérou 1991).

Some native populations of *A. halimus* were once systematically used for summer/fall grazing. Such was the case in the Fermes-Francaises company,

Latifundia, in Sbikha El Alem (in the lower reaches and spreading zones of Wadis Nebhana and Marguellil) in the northern Kairouan plains. Several thousand hectares of productive saltbush rangeland were used rationally in the 1940s and 1950s during lambing.

Half a dozen exotic saltbush species were introduced to Tunisia in the late 1800s and early 1900s, and another dozen to Morocco, Algeria, Tunisia, and Libya in the 1970s (Giscard 1961, 1963; Foury 1954; Franclet and Le Houérou 1971; Le Houérou 1992).

Interest was renewed following the publication of the book on *Atriplex* spp. by Franclet and Le Houérou in 1971. Some 50,000 ha of *A. nummularia* were planted in Morocco in the 1980s and 1990s (Boulanouar et al. 1999), and some 5,000 ha each in Algeria and Tunisia. Some 40,000 ha of *A. nummularia*, *A. canescens*, and *A. halimus* were planted in Libya. A few thousand hectares were planted in Egypt, Israel, Saudi Arabia, and Jordan. Some 40,000 ha of *A. halimus* were planted in Syria, and some 40,000 ha of *A. canescens* were planted in Iran (Nemati 1986). The overall area planted to saltbushes probably does not exceed 250,000 ha in WANA countries. But how much of that land is actually productive and rationally managed is anybody's guess.

For a review of forage saltbushes in the Mediterranean basin, see Franclet and Le Houérou (1971) and Le Houérou (1992). Shrub technology was also developed in the southern states of the former USSR from the 1950s to the 1970s (Nechaeva 1974; Nechaeva and Prikhodko 1968; Petrov 1972; Paetzold 1989). It was based on direct establishment by seeding with the following desert and sub-desert shrubs: *Salsola richteri*, *S. paleztkiana*, *Aellenia subaphylla*, *Haloxylon persicum*, *H. aphyllum*, *Calligonum arborescens*, *C. caput-medusae*, *C. pellucidum*, *C. setosum*, *Artemisia badhysyi*, *Ephedra strobilacea*, *Astragalus unifoliosus*, and *Kochia prostrata*.

Bioclimatic Factors

The WANA region, as herein understood (Near and Middle East and North Africa), is considered to have a Mediterranean climate. But there are strong sub-regional variations, which stem from differences in rainfall regime, winter temperature, and MAR. For example, there is an eastern rainfall regime characterized by a monomodal rainy season, with 60–80% of annual precipitation occurring between December and March (Le Houérou 1982, 1984, 1989). In contrast, the western regime has a bimodal precipitation pattern with peaks in spring and autumn and a relatively dry winter.

The geographical boundary between these two rainfall patterns occurs roughly at the 19° E longitude meridian, which crosses the bottom of the Gulf of Sidra at

Marble Arch, west of the town of Agheila. This boundary is strongly evidenced by the biogeographic distribution of plants, animals, and crops (Le Houérou 1984, 1995). There is a sub-regime within the western regime, characterized by significant summer rains (10–20% of the annual total). This sub-regime occurs in the highlands and mountains on both sides of the Algerian–Tunisian border (Khenchela, Tebessa, Kasserine, and Thala) (Le Houérou 1969; Le Houérou et al. 1975, 1977). These various rainfall regimes have extremely important bioclimatic consequences for crop distribution and productivity, including trubs.

The eastern regime is also characterized by a long and severe summer drought, with 4–6 rainless months from May to October. The annual dry season is understood as the period when monthly $P < 0.35$ PET, or its equivalent, $P < 2t$, where "t" is expressed in °C (Le Houérou et al. 1993).

In the western lowlands, the summer drought is shorter and less severe than in West Asia; summer storms mitigate aridity and the dry season lasts only 2–4 months on average. The summer drought in the western highlands is relative, and tropical species, such as cacti, are favored as long as winter frost is moderate. On the other hand, seasonal precipitation is less variable, or rather, more dependable under the eastern monomodal regime than in the western bimodal regime (Le Houérou 1992). It follows that, all other conditions being equal, commercial farming of cereals requires a mean annual rainfall of 400 mm in the west, while 300–325 mm will produce the same yield in the east (Le Houérou 1982, 1989, 1995). Conversely, the western pattern is more favorable to the dry farming of perennial crops, since commercial rainfed olive, almond, pistachio, apricot, pomegranate, date palm, fig, and grape are grown on the deep sandy soils of Tunisia and Tripolitania with a MAR of only 200 mm. Such crops require a MAR of at least 300 mm in the east (the fig crops of northwestern Egypt are grown under runoff farming, and are therefore not directly or fully rainfed).

By and large, the above conclusions on the bioclimatic requirements of tree crops apply to the most common trubs: cacti, wattles, and saltbushes.

Cold tolerance is another factor of paramount importance in plant life and crop productivity (Emberger 1955; Le Houérou 1969, 1989). An indication of the drought and cold tolerances of various Mediterranean trubs is given in Tables 1 and 2 (Le Houérou 1995).

Table 1. Distribution of successful stands of native and exotic trubs in WANA countries, as a function of mean annual rainfall.

Species	MAR (mm)							
	50	100	150	200	250	300	350	400
Calligonum spp.	—	—	—					
Haloxylon spp. (phreatophyte)	—	—	—					
Hedysarum argyreum	—	—	—					
Acacia raddiana	—	—	—					
Prosopis koelziana (phreatophyte)	—	—	—					
Periploca angustifolia	—	—	—	—	—	—	—	—
Rhus tripartita		—	—	—	—	—	—	—
Argania spinosa			—	—	—	—	—	—
Bituminaria bituminosa			—	—	—	—	—	—
Parkinsonia aculeata			—	—	—	—	—	—
Rumex lunaria			—	—	—	—	—	—
Cassia sturtii				—	—	—	—	—
Prosopis glandulosa (phreatophyte)				—	—	—	—	—
P. chilensis (phreatophyte)				—	—	—	—	—
Geoffroea decorticans (phreatophyte)				—	—	—	—	—
Olea europea sativa				—	—	—	—	—
O. europea sylvestris				—	—	—	—	—
Rhamnus oleoides				—	—	—	—	—
Atriplex spp.				—	—	—	—	—
Acacia salicina				—	—	—	—	—
A. ligulata				—	—	—	—	—
A. cyclops				—	—	—	—	—
Agave americana				—	—	—	—	—
Colutea istria				—	—	—	—	—
Chamaecytisus mollis					—	—	—	—
Coronilla valentina glauca					—	—	—	—
Opuntia spp.					—	—	—	—
Myoporum serratum					—	—	—	—
Acacia saligna					—	—	—	—
Faidherbia albida (phreatophyte)					—	—	—	—
Rhus pentaphylla						—	—	—
Medicago arborea							—	—
Acacia pycnantha							—	—
Vitis spp.							—	—
Chamaecytisus proliferus palmensis								—
Robinia								—
Gleiditsia								—
Colutea arborea								—
Colutea atlantica								—

Table 2. Distribution of fodder trub plantations in WANA countries as a function of winter temperature.

Species	m† (°C)							
	-4	-2	0	+2	4	6	8	10
Calligonum spp.	—	—	—	—	—	—	—	—
Haloxylon spp.	—	—	—	—	—	—	—	—
Hyppophae rhamnoides	—	—	—	—	—	—	—	—
Eleagnus angustifolia	—	—	—	—	—	—	—	—
Atriplex canescens	—	—	—	—	—	—	—	—
Robinia/Gleiditsia	—	—	—	—	—	—	—	—
Vitis spp.			—	—	—	—	—	—
Colutea istria			—	—	—	—	—	—
Colutea arborescens/C. atlantica			—	—	—	—	—	—
Coronilla valentina glauca			—	—	—	—	—	—
Atriplex halimus			—	—	—	—	—	—
Prosopis glandulosa			—	—	—	—	—	—
P. chilensis			—	—	—	—	—	—
Geoffroea decorticans			—	—	—	—	—	—
Olea europaea oleaster			—	—	—	—	—	—
Parkinsonia aculeata			—	—	—	—	—	—
Atriplex nummularia			—	—	—	—	—	—
Acacia raddiana				—	—	—	—	—
Opuntia robusta				—	—	—	—	—
Rhamnus oleoides				—	—	—	—	—
Agave americana				—	—	—	—	—
Chamaecytisus mollis				—	—	—	—	—
Olea europaea sativa				—	—	—	—	—
Bituminaria bituminosa				—	—	—	—	—
Argania spinosa					—	—	—	—
Medicago arborea					—	—	—	—
Opuntia ficus indica					—	—	—	—
Rhus tripartita					—	—	—	—
Acacia saligna					—	—	—	—
Acacia karoo					—	—	—	—
Atriplex amnicola					—	—	—	—
Chamaecytisus proliferus proliferus					—	—	—	—
Myoporum serratum					—	—	—	—
Prosopis koelziana/cineraria						—	—	—
Chamaecytisus proliferus palmensis						—	—	—
Faidherbia albida						—	—	—
Prosopis juliflora						—	—	—
Rumex lunaria						—	—	—
Periploca augustifolia						—	—	—
Rhus pentaphylla						—	—	—
Hedysarum argyreum								—

† m = mean daily minimum temperature of the coldest month (January). The absolute minimum tolerated is approximately 8–12°C below m.

Native vs Exotic Species: A False Dilemma in Species Selection

Well-meaning conservation ecologists sometimes prefer native over exotic species, and thus come into opposition with foresters, agronomists, and production ecologists. In fact, both views are valid and valuable; the choice depends on the scope of the project.

In general, native species are appropriate in conservation projects when integrity of landscape is sought, economic production is not a priority, and time is not a major constraint. Since they are usually self reseeding, at least under protected conditions, they contribute to the long-term perpetuation of stands. In contrast, when economic production and short-term results are a priority, exotic species are often appropriate.

Ecological and management constraints play a major role in species selection. For example, on shallow soils or under poor management conditions, *Atriplex halimus* is preferred to *A. nummularia*, as it is more drought-tolerant. *Atriplex halimus* is not only hardier, but more tolerant to over-browsing and over-stocking, and therefore more forgiving to poor management than *A. nummularia*. Conversely, if the soil is deep, the rainfall adequate (P >200 mm), and the management appropriate (controlled grazing), *A. nummularia* is preferred because its palatability and productivity have higher potential (although it is more sensitive to excessive and too frequent defoliation). The same reasoning applies when selecting among *Acacias* (e.g. *A. saligna* vs *A. tortilis raddiana*, where the former grows faster and is more demanding, but also more sensitive to poor management).

One should, therefore, take a pragmatic approach, and try to adapt to local conditions in terms of ecology, management, and, most importantly, availability of plant material (seed of native species is not always available, in contrast to exotics produced abroad). The latter point again raises the permanent problem of seed production, which few countries in WANA have mastered. This makes them dependent upon the continuous import of exotics for trub development.

Use of Native Populations

Native trub populations have sometimes been rationally managed with a view to long-term sustainable production. This is the case in the Argania parkland of southwestern Morocco, which is protected by the enforcement of an intelligent legislation. Some *Atriplex* populations (*A. halimus*, *A. leucoclada*, and *A. mollis*) were also protected, but most have been cleared for the opportunistic cultivation of cereals, due to sharply increasing demographic pressures.

The Argania parkland, in equilibrium with the environment for centuries, is now endangered. It is disappearing at a rate of 2–3% per year (Bougrine 1989; Lyousfi and Benchekroun 1989; Benchekroun 1989; M'Hiri 1989), particularly in the Souss Plains. Large populations of *Atriplex halimus*, still in existence as recently as the 1960s in the high plains of the Constantine Province and in the Hodna Basin of Algeria (Batna, Tebessa, and Bou Saada), have now been destroyed (Le Houérou et al. 1975, 1977). The same situation has occurred in central Tunisia (Kairouan Plains, Foussana, etc.), in the Jeffara Plains of western Libya, in Sirte and southern Jebel Lakhdar, and in the Marmarica region in Egypt. Generally speaking, new plantings do not make up for the destruction of native stands (Le Houérou 1969b).

Native Fodder Trub Species: Ecology and Potential

Chenopodiaceae

There are some 12 main species and subspecies of native Chenopodiaceae used in trub plantations in the WANA region: *Atriplex halimus* subsp. *halimus*, *Atriplex halimus* subsp. *schweinfurthii*, *Atriplex glauca*, *Atriplex leucoclada* subsp. *leucoclada*, *Atriplex leucoclada* subsp. *turcomanica*, *Atriplex mollis*, *Salsola vermiculata* var. *villosa*, *Salsola richteri*, *Salsola paletzkiana*, *Haloxylon persicum* (white saxaoul), *Haloxylum aphyllum* (black saxaoul), and *Aellenia subaphylla* var. *arenaria*. Black saxaoul, *Aellenia*, *Salsola richteri*, and *S. paletzkiana* are only native in the northeastern border of WANA, in Turkmenistan and Uzbekistan.

Atriplex halimus

This is by far the most often-planted native species, totaling perhaps as many as 80,000 ha in Syria, Jordan, Egypt, Saudi Arabia, Libya, and Tunisia. It is second only to the exotic *A. nummularia* in terms of planted hectareage. It has two subspecies. Subspecies *halimus* is a plant of the semi-arid to humid zones, common all over the Mediterranean basin and the northeastern Atlantic shores from Morocco to the English Channel and up to the North Sea. It is easily identified by its short (20 cm) and leafy fruiting branches, arranged in a pseudo-scorpioid pattern, and its erect habit. This contrasts with subsp. *schweinfurthii* (Boiss.) Le Houér., which is characterized by long (>50 cm), leafless, somewhat reddish, stiff fruiting branches and an intricate bushy habit. Subspecies *schweinfurthii* is common in the arid and desert zones, but in the latter it is found only in wadis and depressions, behaving as a phreatophyte. Populations of both subspecies exhibit large variability in many traits, in particular palatability; subsp. *schweinfurthii* is the most variable in leaf/stem ratio, habit, and palatability.

Great variability also exists among individual shrubs within any population. Grazing exerts a strong counterproductive evolutionary selection pressure, as

heavily browsed individual shrubs tend to be eliminated from populations over the years or, at the very least, do not have a chance to produce seed. Fortunately, some favorable genome combinations seem to appear in each new generation, thus ensuring the survival of some palatable individuals. Because of this counterproductive natural selection, selecting new clones and cultivars from seed collected in nature seems inappropriate. Breeding from clones of heavily browsed individual shrubs collected in nature should be started (Le Houérou 1995a). Selecting individual shrubs, based on palatability, using the rodent *Psammomys obesus* could be an effective methodological tool, as no other reliable biochemical test for palatability has been found to date. However, there is believed to be a negative relationship between palatability and saponin content in leaves (Le Houérou 1995a). Be that as it may, *Psammomys obesus*, the fat sand rat, is a common rodent in the Mediterranean arid zone, feeding only on Chenopodiaceae. Deprived of Chenopodiaceae, it develops lethal diabetes. In Libya, the diet selection of individual shrubs by *Psammomys* is similar to sheep, although daily consumption by the sand rat is only a fraction of a sheep's ration—about 1/45 (45 vs 2,000 g DM/d) (Le Houérou 1984, 1992; Franclet and Le Houérou 1971).

A highly palatable clone, INRF 70100, was tested at the Bou R'bia INRAT Research Station by Sarson in Tunisia in the 1970s (El Hamrouni and Sarson 1975). This clone belongs to subsp. *halimus*. In the sterile stage, *A. halimus* subsp. *halimus* can easily be confused with exotic *A. lentiformis* subsp. *lentiformis* and subsp. *breweri* from the western deserts of Colorado, Nevada, and California in the USA. However, the latter have smaller fruit. *Atriplex halimus* subsp. *schweinfurthii* may withstand salinity concentrations comparable to seawater (40 g/L TDS, 55 mS/cm EC, or 600 mMo/L NaCl-equivalent) (Zid 1970)[1]. But fast growth and high yield (15–20t DM/ha per year) are attainable at about half such concentrations (Franclet and Le Houérou 1971; Le Houérou 1992). Populations have been known to survive under temporary soil salinity well above seawater concentrations (60 mS/cm EC and higher in the saturated extract) (Franclet and Le Houérou 1971; Malcolm 1986; Le Houérou 1986, 1993, 1996). However, *Atriplex halimus* may grow well and produce high yields in non-saline conditions.

The minimum MAR required to establish productive stands is about 120–125 mm, with no run-in. In run-in depressions or water-spreading areas, productive stands may be established under considerably lower MARs, as long as run-in or spate spreading occurs at fairly regular annual intervals.

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[1] Salinity and salt tolerance are expressed in various units: Total Dissolved Solids, Electric Conductivity, Milliequivalents, Molecular Concentration (in NaCl-equivalent), and Osmotic Potential generated. These have approximately the following equivalence: 1 $mS.cm^{-1}$EC = 1 $mmho.cm^{-1}$ 10 $Mo.m^{-}$; = 10 $mMo.l^{-1}$, 10 $Meq.l^{-1}$; 0.7$g.l^{-1}$ TDS = 700 ppm; 320 HPa = 0.32 atm. = 0.32 millibar OP.

The best-adapted soils are medium textured (silty and loamy). Heavy clays and coarse sands should be avoided. Where possible, soils should show an alkaline reaction and (as with most saltbushes) contain a minimum of 60–80 ppm Na^+, but not necessarily NaCl (Le Houérou 1994; Lailhacar et al. 1989; Sharma, 1972, 1976; Sharma and Tongway, 1973).

The optimal planting density to meet yield potential is 1,000–2,500 shrubs/ha (Franclet and Le Houérou 1971; Le Houérou 1992).

Optimal management practice requires two total defoliations per year, followed by an absolute rest from grazing for at least 4–6 months. This management strategy keeps the bushes in a juvenile stage, with a high leaf/stem ratio, high nitrogen content, and high feed value (Le Houérou 1983). After about one year of total rest, the leaf/stem ratio tends to decline, as do palatability, nitrogen content, and feed value (Le Houérou 1992). Leaf development, in no-stress conditions, takes 6–8 month.

The multiplication and establishment techniques discussed so far are essentially for nursery-grown seedlings, transplanted in the field after 3–6 months in the nursery. This costly technique, which turns out to be a liability to development, is discussed further, below.

Atriplex leucoclada

This is a biannual shrub-like species native to West Asia and Egypt. It is an aggressive species, and is easy to establish from seed in Syria (Sankary 1986). It was successfully established in eastern Libya in the late 1970s (Le Houérou and El Barghati 1982).

Atriplex glauca

This is a moderately palatable trailing perennial species, common throughout WANA on medium-textured, moderately saline land. It propagates fairly easily from seed, and for that reason, and because of its trailing habit, has been used for watershed protection, particularly on gypsiferous marl badlands (Le Houérou 1969b).

Atriplex mollis

This is a highly palatable, erect (60–120 cm high) phreatophyte from eastern Algeria, southwestern Tunisia, and Tripolitania. It grows on sandy soils with a high water table. It is also a good ornamental species, owing to its pinkish-red, bladdery fruiting bracts assembled in clustered panicles on the upper part of the shrub. Planting to date has been negligible. Salt tolerance is high, since it is often found in nature in *Athrocenemum macrostachyum* and *Sarcocornia* (*Salicornia*) *fruticosa*

communities. It seems closely akin to a species recently discovered in Malta: *Cremnophyton lanfrancoi* Brullo.

Salsola vermiculata var. villosa

This is a medium-sized xerohalophytic shrub, common on dry gypso-saline land throughout WANA. It has been planted on a few thousand hectares in Syria, mostly via direct sowing (Sankary 1986).

Salsola richteri and Salsola paletzkiana

These are tall psammophilous shrubs (1–3 m high), established in range restoration programs in Turkmenistan and Uzbekistan via direct sowing (Nechaeva and Prikhodko 1968).

Allenia subaphylla var. *arenaria*

This native shrub is a tall psammophilous Chenopodiaceae, used in range restoration in middle Asia via direct sowing (Necheaeva and Prikhodko 1968).

Haloxylon persicum

Haloxylon persicum, the white saxaoul or ghada tree, is a tall desert shrub/small tree, 2–6 m tall. It is a native of the sandy desert wadis of the Near and Middle East and Middle Asia. It is a moderately salt-tolerant phreatophyte of Jordan, Iraq, Saudi Arabia, Iran, Turkmenistan, Uzbekistan, and Kazakhstan. It has also been introduced in limited areas in Syria (Maragha), Libya (Hascian), and Tunisia (Kebilli), where it volunteers via self reseeding. In Iran, it has been established in areas with a MAR as low as 60–80 mm (Qhom, Isfahan, Yazd, Bam, Kerman, and Kashan). The total area of artificially established white saxaoul is probably in excess of 100,000 hectares in Iran (Shaidae 1974; Shaidae and Nikman 1975; Niknam and Ahranjani 1973; Le Houérou 1975; Nemati 1976, 1986; Koocheki and Mohalati 1994). Plantations were mostly established via direct seeding; seed viability does not exceed six months.

Haloxylon aphyllum

The black saxaoul is a tall shrub or small tree somewhat larger than its white cousin, growing as high as 8 m. It is more tolerant to salinity and sodicity than *H. persicum*, its natural habitat being silty and loamy depressions over more or less saline water tables that may be quite deep. It has been established on large areas in Turkmenistan, Uzbekistan, and Kazakhstan (Nechaeva and Prikhodko 1968, Nechaeva 1974, 1980). It has also been established on smaller areas in Iran (Varamin, Sabsevar). Seed viability is no better than that of white saxaoul.

Haloxylon ammodendron

The zaysan saxaoul is equated with the white saxaoul by some authors, and with the black saxaoul by others. It is common on sandy habitats in central Asia and used in revegetation programs in western China. Its habitat is close to that of *H. persicum*. The genus needs taxonomic revision, as it may well be a distinct species in its own right.

Native legumes

In contrast to exotics, native legumes have been little developed. *Acacia tortilis* subsp. *raddiana*, native to mild-winter (m >3°C) deserts and sub-deserts, has received little attention, except for some small pinpoint research projects. The usual technique of transplanting nursery-grown seedlings often results in failure or semi-failure. This may be attributed to the breaking of the seedling's fast-growing taproot during transplanting. Direct sowing of pregerminated seed in moist soil is much more advisable. Other promising native legumes, still at the research stage, are listed below (Le Houérou et al. 1982).

Hedysarum argyreum (H. argentatum)

This species, from the coastal dunes of the southwestern desert of Morocco, is cold-sensitive. *Chamaecytisus mollis*, from the central coastal plains and Anti-Atlas mountains of Morocco, is drought-tolerant and moderately cold-tolerant. *Colutea istria*, bladder senna, from West Asia (Syria, Jordan, and Sinai), is a very drought- and cold-tolerant fodder that is not used often enough. *Colutea arborescens* and *C. atlantica* are excellent browse shrubs, native to the semi-arid and subhumid forest and shrublands of North Africa and southern Europe. They have been planted occasionally in limited areas in Spain and North Africa (Le Houérou and Pontanier 1987).

Coronilla valentina subsp. *glauca*

This species, from the semi-arid shrublands of North Africa and Cyrenaica (Jebel Lakhadar, between El Merj and Tolmeitha) is both drought- and cold-tolerant. It has occasionally been planted in Tunisia.

Medicago arborea is not a native species in the strictest sense, although it is native to continental Greece, Crete, and the Balearic Islands. Cold-tolerant cultivars are being developed at Montpellier (INRA). Productive stands of tree medic require a minimum MAR of 300 mm (El-Hamrouni and Sarson 1976), although it can survive under lower rainfall.

Oleaceae

Olea europaea f. *oleaster* (*O. europaea* var. *silvestris*)

The wild olive is a heavily browsed and browse-tolerant species, common in hills and mountains down the 200 mm MAR isohyet throughout North Africa and part of West Asia. It has never been deliberately established as a browse hedgerow, as far as I am aware. *Olea europaea sativa*, the cultivated olive, is sometimes used as a browse species in failed or abandoned plantations, but its drought and salt tolerance appears to be lower than that of its wild cousin.

Eleagnaceae

Eleagnus angustifolia and *Hippophae rhamnoides*

The Russian olive and the sea buckthorn are phreatophytes native to middle and central Asia. They are very cold-tolerant and fairly tolerant to salinity. The former is often planted as a tall browse hedge on the rim of oases.

Rhamnaceae

Rhamnus oleoides

The olive-like buckthorn is a small tree, similar to the wild olive, and with a similar ecology. It is fairly common on the hills and mountains of North Africa down to the 200 mm MAR isohyet. Although heavily browsed, it has never been planted as a browse trub, as far as I am aware.

Anacardiaceae

Rhus tripartita (sumac) and *Rhus pentaphylla*

Sometimes planted on small areas, these species are very drought-tolerant but fairly sensitive to cold (m >3°C).

Asclepiadaceae

Periploca angustifolia (*P. laevigata*)

This shrub is extremely tolerant to drought (P >80 mm MAR) and to browsing, but is sensitive to cold (m >5°C). Its germination rate is good, while its feed value and productivity are fair. It has been planted on a few hundred hectares in Libya and Tunisia (Le Houérou et al. 1982; Ferchichi 1996).

Polygonaceae

Calligonum spp.

These species are widely used in range restoration and sand dune binding projects in middle Asia: *C. arborescens*, *C. caput-medusae*, *C. pellucidum*, *C. crinitum*, *C. eriopodum*, *C. setosum*, *C. elatum*, *C. paletzkiana* (Nechaeva and Prikhodko 1968) and in West Asia: *C. polygonoides*, *C. comosum* (Niknam and Ahranjani 1973, Nemati 1977; Koocheki 1995), but to a much lesser extent in North Africa: *C. comosum*, *C. azel*, *C. arich* (Le Houérou and Pontanier 1987).

The two last species reach a tree size of 6–8 m and may still be found in remote sites on the major dunes of the Great Eastern Sandsea of Algeria and Tunisia. They have good germination rates, fair feed value, good wood production, and their use in sand binding projects has been successful. Thus, one wonders why they are not used more often.

Asteraceae

Artemisia badhysi

This undershrub is widely used for range restoration in middle Asia (Nechaeva 1974, 1980; Nechaeva and Prikhodko 1968).

Due to the difficulty of seed procurement and the lack of organized seed production, *Artemisia herba-alba* has been used only occasionally in WANA range restoration (Le Houérou 1983).

Endemic Fodder Shrubs from the Canary Islands (Table 3)

The Canary Islands are located 100 km west of WANA, but have a Mediterranean climate, at least in the lowlands. They harbor a dozen species of endemic fodder shrubs, mostly legumes, two of which are shared with southwestern Morocco. As can be seen from the following table, these species offer a wide array of ecological adaptation in terms of drought and cold tolerance. Most are adapted to slightly acidic soils, some to soils with an alkaline reaction (Mendez 1992).

Table 3. Shrub species from the Canary Islands.

Taxonomic status	Island	Vernacular name	Use	P (mm)	m (°C)
Fabaceae					
Adenocarpus foliosus var. *foliosus*	TGP	Codeso	Browse, Cutting	500–600	3–7
Ad. foliosus var. *foliosus*	CP	"	Br, C	400–500	3–7
Ad. foliosus var. *spartioides*	P	"	Br	500	≤3
Ad. foliosus var. *viscosus*	T	"	Br	500	≤3
Bituminaria bituminosa var. *albomarginata*†	L	Tedera	Br	150–300	9–11
B. bituminosa var. *bituminosa*	Mor, All	"	Br, Hay.cult	200–600	>7
B. bituminosa var. *crassicuscula*	T	"	Not used	500	0–3
Chamaecytisus proliferus subsp. *anguisfolius*	TG	Escobon	Br. C.	500–600	3–7
Ch. proliferus subsp. *canariae*‡	C	Esc. blanco	C. Hay cult.	600–800	3–7
Ch. proliferus subsp. *hierrensis*	H	Escobon	Br	600–800	7–11
Ch. proliferus subsp. *meridionalis*	C	"	Br	350–500	3–11
Ch. proliferus subsp. *palmensis*	P	Tagasaste	C. Hay, cult. Br	500–900	3–7
Ch. proliferus subsp. *proliferus*	T	Escobon	Br, C.	500	0–3
Chamaecytisus mollis	T, Mor	?	Br	200–400	3–7
Ononis angustissima var. *ulicina*	CT	?	Br	200–300	>11
Teline canariensis	CT	Retamon	Br, C	600–800	5–9
T. gomerae	G	Gacia	Br, C	400–600	9–11
T. linifolia subsp. *teneriffae*	T	"	Br, C	500–600	9–11
T. microphylla	C	"	Br, C	500–600	9–11
T. nervosa	C	"	Br, C	500–600	9–11
T. splendens	P	Herdanera	Br, C	500–600	3–7
T. stenopetala var. *stenopetala*	P	Gacia	Br, C	600–800	5–9
Teline stenopetala var. *microphylla*	GH	"	Br, C	300–500	9–11
Teline stenopetala var. *sericea*	P	"	Br, C	300–500	3–7
Polygonaceae					
Rumex lunaria	All	Vinagrera	Br, C	200–350	>11

T = Teneriffe, G = Gomera, P = La Palma, L = Lanzarote, C = Gran Canaria, H = Hierro, F = Fuerte Ventura, Mor = SW Morocco; P = Mean annual rainfall; m = mean daily minimum temperature of the coldest month.

† These plants are woody-based dwarf shrubs, therefore different from the plants under the same scientific name in WANA semi-arid lands. In WANA, the species is represented by a shortly perennial herbaceous forb, unpalatable to stock, unlike the Canarian types (Mendez et al. 1991).

‡ Some subsp. of *Cytisus proliferus* are tolerant to soils with an alkaline reaction (pH 6.8–8.0), i.e. the white tagasaste and the escobon of southern Gran Canaria (Francisco-Ortega et al. 1992).

Main Exotic Species: Ecology and Development Potential

Chenopodiaceae

Saltbushes (*Atriplex*) were introduced to Tunisia as early as the late 19th century (Franclet and Le Houérou 1971). These introductions involved *A. nummularia*, *A. vesicaria*, and *A. semibaccata* from New South Wales, South Australia, and

Victoria, and *A. canescens* from the western USA (west of 100° W longitude). In the 1970s and 1980s, a wider spectrum of genomes was introduced or reintroduced:

- *A. amnicola* (*A. rhagodioides*) from Western Australia
- *A. undulata* from Argentina
- *A. lampa* from Argentina
- *A. lentiformis* from California
- *A. breweri* from California
- *A. barclayana* from California
- *A. canescens* from various parts of the Great Basin (Utah, Nevada, California, Colorado, Arizona)
- *A. isatidea* from Western Australia
- *A. paludosa* from Western Australia
- *A. cinerea* from Western Australia
- *A. polycarpa* from California and Arizona
- *A. repanda* from Chile
- *A. nummularia*, the Grootfontein cultivar, from South Africa, and various other reintroductions from Australia

Some weeds, such as *Blackiella inflata* (*A. inflata*, *A. halimoides*), were inadvertently introduced from Australia.

In total, at least 15 species of browse saltbushes have been introduced to WANA to date. Some blue bushes (*Maireana*) have also been introduced, but never very successfully. After two decades of screening trials, only seven species are still considered worthwhile for the region:

A. nummularia

This species has good ecological adaptation, production potential, overall palatability, and feed value. It represents, in my estimation, some 50% of all saltbush plantations and 80% of the exotics.

A. amnicola

This species has excellent productivity and feed value, but is fairly cold sensitive, brittle, and sensitive to browsing.

A. canescens subsp. *canescens*

This species has high frost tolerance, good grazing value, and fair productivity.

A. canescens* subsp. *linearis
This species is ideal for sandy soils and sand dunes, is frost tolerant (-20°C), and has fair feed value and high productivity.

A. undulata
This species has good cold tolerance, productivity, and forage value, although it is sometimes considered unpalatable in its homeland of Argentina.

A. lentiformis
This species from southern California offers very high productivity for both wood and forage.

A. semibaccata
This species is easy to establish from seed, but tends to disappear after 3–5 years of profuse self reseeding.

The following species tend to be eliminated from large-scale plantations for the reasons given:

A. vesicaria
This species is brittle with poor feed value and only moderate performance.

A. isatidea
This species is more an ornamental seashore species than a forage. It is very brittle and fragile under grazing regimes.

A. polycarpa
This species has poor performance and low productivity.

A. paludosa* and *A. cinerea
These species are trailing phreatophytes, brittle and fragile, and very sensitive to grazing. They have moderate grazing value, although they are productive on protected, moist soils.

A. repanda
This species is an excellent fodder, the best of all saltbushes, but very sensitive to cold. It is moderately productive and sensitive to nematodes, *Rhizoctonia*, *Fusarium*, *Alternaria*, and possibly other fungi (de Kock, personal communication, 1993).

A. barclayana

This species is a very cold-sensitive, brittle, and fragile trailing shrub.

A. nummularia

The Australian old man saltbush, or giant saltbush, warrants more comment. The species has recently been divided into three subspecies (Parr-Smith 1982):

- subsp. *nummularia*
- subsp. *omissa* Parr-Smith
- subsp. *spathulata* Parr-Smith

All three subspecies are octoploid (2n = 72). Subspecies *nummularia* is by far the most common, originating in the Northern Territories, South Australia, New South Wales, Victoria, and Queensland. Virtually all introductions belong to this subspecies. Subspecies *omissa* is a relatively rare shrub (South Australia, New South Wales, Victoria), while subsp. *spathulata* is fairly rare in West Australia. Well-managed plantations have been known to last over 75 years in South Africa and 40 years in North Africa (Franclet and Le Houérou 1971; Le Houérou 1994).

Following are further details on *A. nummularia*:

- The species is a C4, dioecious shrub.
- Productivity potential is very high, up to 30 t DM/ha per year when irrigated, with an EC of up to 15–20 mS/cm (de Kock 1980; Le Houérou 1994).
- Rain-use efficiency may be very high, up to 15–20 kg DM/ha per year per mm under rainfed, close-to-optimal conditions (Le Houérou 1992, 1994).
- Drought tolerance is fairly high: P >200 mm MAR.
- Salt tolerance is fairly high, with half-maximum yield under a saturated extract EC of 30 mS/cm.
- Tolerance to flooding is fairly high. In its homeland, its ecological niche is temporarily flooded, loamy depressions. In North Africa, it is known to have survived up to three months of winter flooding.
- Regrowth after browsing is quick and effective, because of a particular biological feature of this species: the production of epicormic buds (either dolychoblasts and brachyblasts, depending on the season).
- Roots may reach a depth of 10 m, enabling it to use moderately deep aquifers.
- High sensitivity to overbrowsing is a major problem. A full 8–10 month rest period appears necessary after each total defoliation. On the other hand, productive stands may die off from senility after 12–15 years of non-use. Rejuvenation, cutting back at 20–40 cm above ground, seems desirable every five years or so.

An eight-year mass selection based on palatability was carried out in South Africa towards the so-called Grootfontein cultivar (de Kock 1980). A further five years of mass selection, in conjunction with seed de-winging and pelleting techniques, was carried out at Gablesway in Somerset East, South Africa. Commercial pelleted seed production is now underway (Von Holdt, personal communication 1996; see also these proceedings).

Atriplex canescens

The fourwing saltbush is a very complex species, growing on the North American drylands from Mexico to Canada (20–55° N latitude). There are diploid to dodecaploid populations (2n = 18–108), autopolyploids, and allopolyploids (McArthur et al. 1984). The species crosses with several other saltbushes from the Great Basin (*A. nutallii*, *A. confertifolia*, *A. tridentata*, *A. gardneri*, *A. cuneata*, *A. acanthocarpa*, etc.). One generally distinguishes *A. canescens* subsp. *canescens*, tetraploid (2n = 36) or hexaploid (2n = 54), a rather short bush (60–150 cm) with relatively wide leaves (0.5–1.0 cm) found on medium textured to ± saline clay soils, from the diploid (2n = 18) subsp. *linearis*, a tall shrub (1–3 m) with narrow leaves (0.2–0.5 cm) usually found in sand dunes (f. *gigantea* Stutz), particularly common along the border between Mexico and New Mexico/Texas (El Paso, Las Cruces), in southern Arizona (Tucson), and in the "Little Sahara" of Central Utah.

Four cultivars have been developed in the USA:

- cv Wytana, fit for the temperate climate drylands of the northern states (Montana and Wyoming).
- cv Rincon, adapted to the Great Basin.
- cv Marana, fit for the arid Mediterranean drylands of California and the Mojave desert.
- cv Santa Rita, adapted to the bimodal rainfall subtropical drylands of southern Arizona and New Mexico.

Some 40,000 ha of *A. canescens* of unknown origin were planted in Iran in the 1970s and 1980s (Nemati 1986). Small areas were also successfully planted in Syria and Libya (Sankary 1986; Le Houérou et al. 1982). Production with subsp. *linearis* may reach 20 t DM/ha per year, with 600–700 mm of brackish water (Forti 1986). Drought and salinity tolerance appear similar to or slightly higher than that of *A. nummularia*. The great merits of *A. canescens* are its extreme cold tolerance, good forage value, and the adaptation of subsp. *linearis* to sandy habitats and sand dunes. This is in contrast to most other saltbush species fit for silty and loamy soils, such as *A. halimus* and *A. nummularia*.

Other Promising *Atriplex* Species

- *amnicola.* Formerly called *A. raghodioides*, this phreatophyte from Western Australia is a highly productive and palatable dioecious sprawling shrub, but sensitive to over-browsing and frost.
- *undulata.* This medium-sized, dioecious, semi-erect shrub is productive and palatable but, in contrast to *amnicola*, tolerant to frost and browsing. To date, it has been used only in experimental and demonstration fields within WANA.
- *lentiformis.* This large erect shrub (up to 3 m high and 5 m in diameter) is tolerant to saline sodic clays, and may self reseed profusely in WANA. As mentioned above, it is confused with *A. halimus* subsp. *halimus* in its sterile stage. Poor regrowth after cutting has been reported (Franclet and Le Houérou 1971; Forti 1971).
- *semibaccata.* The Australian trailing saltbush is a biannual species of moderate palatability, easy to establish from seed, which reseeds profusely for 2–3 years and then suddenly disappears. Groundcover may reach 100% the first or second year. Its sudden disappearance is commonplace in the many arid lands it has been introduced to around the world, as well as in its Australian homeland (Malcolm, personal communication). No convincing explanation to that behavior has been offered to date, as far as I am aware. The quick groundcover and easy establishment may be of paramount importance in conservation projects or in the first stages of rehabilitation. A perennial woody erect subspecies has been found in an introduced population and described as subsp. *erecta* by Franclet and Le Houérou (1971).

Exotic Legumes

Exotic legumes include the Australian wattles or phyllodinous (thornless) acacias (*Racosperma* spp.), the American mesquites or algarrobos (*Prosopis* spp.), the Australian *Cassias*, the American Jerusalem thorn (*Parkinsonia aculeata*), and the South American chañar (*Geoffraea decorticans* or *Gourleia chilensis*).

Acacia spp.

These are by far the most important exotic legumes in WANA. *Acacia saligna* (*A. cyanophylla*) alone covers over 200,000 ha in the region, as mentioned above. It was introduced to Algeria in the early 1870s together with a few other wattles: *A. pycnantha, A. pendula, A. melanoxylon, A. decurrens, A. glaucescens, A. calamifolia*, etc. In 1916, it was introduced to Libya for sand dune binding (Leone 1924). From there, it spread over the WANA countries through the Forest Services.

Acacia saligna is a 3–6 m tall shrub adapted to sandy soils and dunes down to the 250 mm MAR isohyet. The phyllods provide fairly good forage, with 12–15% CP. Productivity may reach 3,000–5,000 kg DM/ha per year for forage and about the

same for wood, with a density of 800–1,500 shrubs/ha. Life span does not exceed 15 years but can be greatly expanded by periodic cutting back to 40–60 cm above the ground. Cold tolerance is low; as most *Acacias*, the shrub is not found in the highlands above 800 m and in areas where m <3°C.

Genetically, the species is extremely heterogeneous in terms of habit (erect, intricate, and drooping), phyllod/stem ratio (80–120%), and phyllod morphology (long and narrow, 15–25 cm × 0.5–1 cm, vs short and wide, 10–15 cm × 1.5–3 cm). It has a seemingly positive correlation between drooping habit, long phyllods, and high phyllods/stem ratio on the one hand, and erect habit, wide phyllods, and low phyllods/stem ratio on the other. The long-phyllod type is fit for forage, while the wide-phyllod type is better adapted for firewood. Tolerance to salinity is low, in contrast to *A. cyclops* and *A. salicina*. Mass selection for either forage or wood production types is badly needed.

Other potentially important wattle species include *A. salicina*, an erect and drooping small ornamental tree, 5–10 m high, very drought tolerant (P >150 mm MAR) and quite tolerant to poor gypsic and slightly saline soils. *Acacia cyclops* is a salt-tolerant bushy shrub (2–3 m high and 3–5 m in diameter), tolerant to sea spray and moderately saline soils (perhaps 10–15 mS/cm EC in saturated extract). Due to its leathery phyllods, it makes a poor forage.

Acacia ligulata is the most drought-tolerant, 1.5–3 m high wattle introduced to date. But its forage value is poor in terms of palatability and nutrient content.

Other wattles are: *A. pycnantha*, the golden wattle, an ornamental of little forage value; *Acacia victoriae reginae*, unlike the species mentioned above, it is fit for silty soils, and has both thorny and thornless types; and *A. karoo* from South Africa (formerly known under the erroneous names of *A. horrida* and *A. eburnea*), widely used as a defensive thorn-hedge in many orchards of the mild-winter belt.

Other rather rare exotic *Acacias* include: the Australian wattles, *A. pendula*, *A. retinoides*, *A. kempeana*, *A. peuce*, *A. aneura*, *A. dealbata* (*A. decurrens*, *A. mollissima*), and *A. melanoxylon*; the South American, *A. caven* and *A. farnesiana*; and the Afro-tropica, *A. nilotica*, *A. ehrenbergiana*, *A. giraffae*, and *Faidherbia* (*Acacia*) *albida*.

Cassia spp.

Cassia sturtii, introduced to Israel in the 1960s, raised great hopes despite being considered unpalatable in its Australian homeland. But productivity proved to be low, despite a remarkable drought tolerance. It did not expand beyond the experimental stations. Similarly, *Cassia nemophila*, *C. eremophila*, and *C. artemisioides* are nice ornamental small shrubs, extremely drought-tolerant, but of little, if any, grazing value.

Prosopis spp.

Mesquites, or algarrobos, constitute a complex of species that are often difficult to differentiate from one another. Thus, the so-called *Prosopis juliflora* of North Africa, a tropical species from Central America intolerant to any freezing, belongs to this species. However, most mesquites found in North Africa are more likely to belong to the aggregate species *P. glandulosa*, which is fairly frost-tolerant. It should be remembered that *Prosopis* spp. are phreatophytes. Some of the trees planted in various sites are very productive in terms of pod yield. They may also be of interest in beekeeping because of their long flowering season (Le Houérou and Pontanier 1987).

Parkinsonia spp.

Parkinsonia aculeata is perhaps the most drought-tolerant exotic. Its cold tolerance is also remarkable. It is sometimes used in forage shrub plantations, but it requires annual cutting back to keep it in a juvenile stage with still-soft thorns that make it attractive to stock (Le Houérou 1980).

Locusts: *Gleiditsia triacanthos*

The honey locust is a semi-arid and sub-humid tree species. Some cultivars have a DM sugar content as high as 30% and constitute an energetic feed concentrate. The leaves of the black locust *Robinia pseudacacia* make a good fodder, but it is a semi-arid and sub-humid land species. Both are very cold-tolerant and need a minimum MAR of 300 mm to produce good yields. Both have thorny and thornless types.

The Chañar: *Geoffrea decorticans*

This species has been planted here and there as an individual salt-tolerant, cold-tolerant, small forage tree.

Cacti

Fodder cacti, mainly *Opuntia ficus indica* f. *inermis*, cover some 500,000 ha in North Africa, of which 300,000–350,000 ha are in Tunisia. This subject was recently reviewed by the author (Le Houérou 1996).

One of the main objectives of fodder cacti research is to identify cold-tolerant spineless clones or species for the arid highland steppes of North Africa, and for West Asia. Some of these, *O. robusta*, *O. inermis*, and *O. fusicaulis*, were introduced to Tunisia and Algeria by the author in the 1960s. There was apparently little follow-up.

Myoporaceae

Myoporum insulare, *M. serratum*, and *M. pictum* are used as ornamental hedges. The trimmings are used to feed poultry, rabbits, and other pet herbivores. *Myoporum* are phreatophytes only second to saltbushes in terms of salt tolerance. Cold tolerance is slight (m >3°C), but feed value is good, with 10–15% CP for the leaves.

Grape rootstock

Vitis rupestis, *V. berlandieri*, and *V. riparia* are sprawling creepers that provide good soil protection. They are also attractive to livestock, particularly cattle and goats. They are used as a feed reserve in abandoned vineyards.

Agavaceae

Agave americana is a very drought-tolerant and cold-tolerant species. It is used as a fencing hedge in WANA. However, in South Africa, 100,000 ha are used as a fodder crop under a cut-and-carry system (de Kock 1980; Le Houérou 1994).

Tree Crop Residues

Tree crop residues are mainly pruned olive leaves and twigs. Estimating 2.2 million ha of olive trees in WANA, with an average density of 100 tr/ha and a minimum pruned forage in excess of 5 kg/tr per year, some 1.1 million tonnes of DM forage are produced annually. This equals the annual energy equivalent requirements of 1.1 million sheep, assuming a metabolizable energy of 4.2 Mj/kg DM and a requirement of 4,200 Mj/sheep per year for a 40 kg animal (Le Houérou 1993). This contribution, however, often goes unnoticed.

Feed Value

Browse is usually rich in nitrogen but poor in energy, with some exceptions, such as cacti and *Agave*. The mean value of 1,230 chemical analyses on 485 browse species of North Africa, West Africa, and East Africa was 2% nitrogen (12.5% CP), with extreme values of 0.3 and 6.5 (2.0 and 40.0% CP) (Le Houérou 1980). Browse is also frequently rich in silica-free minerals and carotene (Le Houérou 1980).

Generally speaking, pure browse diets can maintain animals but cannot ensure production, because of the lack of energy (Le Houérou et al. 1983; Le Houérou 1992; Correal and Sotomayor 1995). The main problem with browse is that part of the nitrogen ingested is not retained by the animals. This is due either to the presence of polyphenols (tannins), as in wattles, because part of the N content is a

non-protein nitrogen such as proline or glycine betaine, as in saltbushes and other Chenopodiaceae.

The former problem is now solved by adding polyethylene glycol (PEG) to the drinking water (Ben Salem et al. 1999).

The latter problem can be solved by using animals accustomed to saltbush diets, where the micro-organisms in the gut have presumably been selected to break down non-protein nitrogen molecules and incorporate them into their own substance.

The ingestion and performance of sheep feeding on saltbush diets over several months supports these hypotheses (Le Houérou 1992a, b). It follows that browse should only be used as a nitrogen-rich complement to coarse roughage diets (such as straw, poor-quality hay, and dried-out range) and to protein-poor browse such as cacti or *Agave* (Franclet and Le Houérou 1971; Le Houérou et al. 1983; Le Houérou 1992a, b, 1994; Correal and Sotomayor 1995; Nefzaoui et al. 1999).

Integration into Production Systems: Single vs Mixed Species Stands

General

The planting of fodder trubs may have several goals:

- Rehabilitation of degraded land with a long-term conservation goal.
- Landscaping, amenities, and tourism.
- Animal production based on livestock, wildlife, or both.
- Multi-purpose production systems, including crop, animal, and wood production.

Conservation and Amenities Projects

These projects do not include any direct exploitation goals. They may therefore require only minimum management for the maintenance of any artificially revegetated land. Maximum diversity is therefore seemingly preferred, preferably based on native species, but not necessarily so. Exotics may also have high amenity and aesthetic value, particularly in terms of shape, color, and blossom exhibition.

Production Systems

There is a variety of goals in fodder production, but all situations require careful management to maintain and maximize the potential of both shrubs and land. This requires, in particular, the integration of trub plantations into production systems.

Systems may include rangeland alone, cropland alone, or a mixture of both. First, fodder trubs may be kept as a standing feed reserve for unusual inter-annual drought, i.e. as drought insurance. They may also be used on a regular basis, when feed requirements are high, e.g. during the annual bridging-up period in late summer and fall, and during late pregnancy, parturition, and early lactating, when forage is scant. Fodder trub strategies may also be used in combination, with part of the trub resource kept as a standing reserve to be used whenever appropriate, and another part used on a seasonal basis, in rotation or alternation. Second, the exploitation strategy may vary, e.g. direct browsing versus cut-and-carry or zero grazing. Some species, such as *Agave americana*, are not amenable to direct grazing and therefore require a cut-and-carry exploitation system. This method may be necessary, albeit more expensive, when control over grazing animals is poor. Third, within farming or mixed systems, fodder trubs may be associated with cereal farming. This combination was independently developed in Libya (saltbushes), South Africa, (*Agave* saltbushes), Tunisia (cacti), and southeastern Spain (saltbushes) in the early 1980s (Le Houérou 1983, 1992a, b, 1994). Single or double lines of hedgerows (usually cacti, *Agave*, or saltbushes) are established in widely spaced patterns (10–20 m apart) to allow for easy mechanical cultivation and harvesting of the cereal.

This method offers a number of advantages:

- Shrubs are established on good deep soils fit for cereal production and can thus express their production potential.
- During the 120–160 days of cereal growth and maturation, the shrubs are protected from grazing and can recover from previous defoliation (appropriate management).
- The crop benefits from the improvement of soil and microclimatic conditions provided by the shrub: reduction in wind speed and potential evapotranspiration, buffered temperatures, increased organic matter in the soil, more stable structure, higher permeability, better water budget, and quicker turnover of geobiogene elements. All of this leads to enhanced fertility and productivity.
- Reduction in cereal yield does not seem to occur. On the contrary, the space taken by the shrubs (10–20%) is more than compensated for by higher cereal productivity resulting from improved soil and microclimatic conditions (Le Houérou 1980, 1993, 1994, 1996; Monjauze and Le Houérou 1965).

In terms of diet, the combination of cereal stubble, straw, and shrub fodder is ideal: stubble, poor in nitrogen, provides the energy, while shrubs, poor in energy, provide the nitrogen, minerals, and carotene. The energy digestibility of the straw is enhanced 5–7% by the additional nitrogen from the shrub (Le Houérou et al. 1983, 1992). The combination provides a long-term balanced sheep diet allowing for both maintenance and production (Cordier 1947; Franclet and Le Houérou 1971; Le Houérou 1992a, b, 1994; Correal and Sotomayor 1999; Sotomayor and Correal 1999; Nefzaoui et al. 1999).

The combination of cereal stubble with cacti and *Agave*, however, requires an extra source of nitrogen (other shrubs, medics, or urea).

In arid rangeland systems, the ideal proportion of shrub plantations on the range seems to be about 2–5% for full drought insurance (Le Houérou and Dumont 1964; Le Houérou 1994). The distribution of planted fields on the rangeland depends on a number of factors, including, in particular, adequate soil conditions (different shrub species require different kinds of soils). The distance from permanent water sources may also be important, e.g. one can plant cacti and *Agave* away from water sources, while saltbushes must be planted closer to permanent water, since their consumption increases considerably the water intake by animals.

The normal strategy should be to establish small shrub plantations that are regularly distributed across the rangelands. Ideally, a corner of each paddock should be planted to shrubs and appropriately fenced so that access can be easily controlled.

Other strategies may be applied as well. In Tunisia and Syria, shrub plantations, established on state land by the Forest Services, are periodically opened to graziers for a given period of time and for a given grazing fee per animal per day.

Single vs Mixed Shrub Plantations

When fodder production is the main goal, mixed plantations are usually not advisable, simply because different shrubs require different management for maximum production. The rhythm varies: cacti, for instance, should be grazed every 2 to 3 years; *Acacia* can take an annual browsing; and though some *Atriplex* spp., such as *A. nummularia*, only permit one browsing per year, others such as *A. halimus* and *A. canescens linearis* warrant two annual grazings.

In addition, different species have different soil requirements. Cacti and *Acacia* spp. (except *A. victoriae*) require light or sandy soils, while saltbushes need medium-textured soils (with the exception of *A. canescens linearis*, which is adapted to sand and dunes). Saltbushes are tolerant to salinity, whereas cacti and *Acacia saligna* can hardly tolerate any salinity at all.

Palatability and preference differ among species. A given species in a given mixture may be grazed out while its companions are ignored. The repetition of grazing periods thus tends to eliminate the first species from the mixture.

A combination of various fodder trubs is desirable in any production system, but each species should be established separately, in single species fields, for the reasons mentioned above. The above considerations stem from real-life experiences and from trial-and-error; there is no speculation involved.

Other Benefits

Many fodder trubs are multipurpose species used for land partitioning and fencing (cacti, *Acacia*, *Agave*, saltbush, *Prosopis*, *Parkinsonia*), wood (*Acacia*, some saltbushes), fruit (cacti), honey (*Prosopis* spp., *Parkinsonia*), soil protection and erosion control (all species), land rehabilitation (all species), landscaping, beautification, and tourism development (all species). The overall benefits are land rehabilitation, restoration of productivity, and renewed functioning of depleted arid land ecosystems. These benefits were recently reviewed in detail by the author (Le Houérou 1993, 1994, 1995, 1996).

Constraints to Development

Constraints to development are many: scientific, technical, administrative, economic, sociological, political, and, most often, a combination of the above.

Scientific and Technical Constraints

The main constraints pertain to the availability of improved genetic material and seed production, data on management alternatives, cheap and reliable multiplication and establishment techniques, and information on the biology of some species. These are examined below under Gaps in Knowledge: Research Priorities.

Socioeconomic, Sociopolitical, and Administrative Constraints

This topic pertains to poor extension services and the minimal incentives provided by governments (with the exception of Tunisia). An example of possible government incentives is given in the appendix. Land tenure often constitutes a paramount constraint. The establishment of trub plantations requires long-term planning, relatively heavy investment, and therefore a land-tenure security that can bring sufficient returns to investment. Land tenure and the control of livestock movement are absolute requisites to fodder trub development. The author is not

aware of any successful development under conditions of nomadic pastoralism or communal use of water and land, anywhere in the world's arid lands. On the other hand, in recent years, private farmers and organizations have developed some 100,000 ha of saltbush in western Australia, 800,000 ha of saltbush, cacti, and *Agave* in South Africa, 500,000 ha of cacti in northeastern Brazil, 150,000 ha of saltbushes in the USA, and 300,000 ha of cacti in central-western Tunisia.

The planting of state-controlled land is one substitute for land reform that ensures secure tenure and control of livestock movement. Such plantations, which are protected from roaming animals (usually fenced and closed to stock), are, subject to a grazing fee, open to graziers on a temporary basis under the control of the Forest Service. The latter decides the time of opening and closing, the number of animals admitted, and the fee per animal per day. This systems is being applied in Tunisia *(Acacia saligna)* and Syria (*Atriplex halimus*). It has the merit of simplicity.

Seed Production

Seed availability is a problem in many countries where seed has to be imported. Tunisia and Jordan are exceptions in this respect. Seed production requires a complex and costly organization, including a secure market outlet. It is government's role to help break the initially vicious cycle between supply and demand.

The availability of seed or plantlets of high-quality strains would greatly enhance demand. Unfortunately, little breeding of improved plant material has taken place. What is occurring takes place outside WANA: four cultivars of *A. canescens* are available in the USA (Carlsson et al. 1994; McArthur et al. 1984), one improved cultivar of *A. nummularia* is available in South Africa (de Kock 1980), and several cvs of *A. amnicola* are available in Western Australia (Malcolm 1995). Pelleted de-winged seed of a new highly palatable strain of *A. nummularia* will soon be available in South Africa. These efforts need to be expanded to other species and to other countries. The large-scale planting of unimproved *Atriplex halimus* material could be a liability because of the counter-selection that occurs in the native populations from which seed is collected.

Acacia saligna, planted on more than 200,000 ha in WANA, is extremely heterogeneous genetically. It is badly in need of selection toward two different types, aimed at forage and wood production. But no such breeding has taken place to date, as far as I am aware.

Biotechnology and *in vitro* cloning could help, as long as the breeding is carried out on sound principles, aimed at more effective plant material with the desired forage qualities (Le Houérou 1995a). Nutritional research needs to be continued, in

particular to develop a palatability test for saltbushes, which would be a potent tool in breeding research. The possible negative linkage between palatability and saponin content in the leaves of saltbush deserves attention. At the same time, research on the adaptability of gut micro-organisms to shrub diets and their possible ability to break up non-protein nitrogen molecules and make then retainable by ruminants should be investigated. Research carried out in Australia on the mimosine tolerance of New Guinea goats and its transfer to Australian sheep and goats (shoats) via rumen liquid is a source of inspiration.

Research on management alternatives should be continued. Subjects of paramount importance for management include: (i) the height and periodicity of cutting back in many species; (ii) the possible maximum number of annual defoliations; (iii) the minimum rest period length after defoliation; (iv) the life span of leaves, phyllods, and twigs; (v) the evolution of nitrogen and protein content; and (vi) the affect of leaf/phyllod age on palatability. None require costly equipment. The perfection of feeding methods using several species of shrubs per diet should be further investigated (Le Houérou et al. 1983; Le Houérou 1992, 1994; Nefzaoui 1999; Ben Salem et al. 1999; Hoon et al. 1996).

Gaps in Knowledge: Research Priorities

The cost of establishment through the usual technique of transplanting nursery-grown seedlings is very high and beyond the reach of most farmers and graziers (Le Houérou 1989a). Techniques using bare-root seedlings, as developed in South Africa, could be expanded, particularly with saltbush (Louw 1995; Le Houérou 1994).

Direct sowing of pregerminated seed, used with *Faidherbia albida* in West Africa, could be extended to a number of hard-seeded species: *Acacia*, *Prosopis*, *Chamaecytisus*, *Coronilla*, *Colutea*, *Atriplex*, etc. This technique reduces the cost of establishment by two thirds, but requires more skill and larger quantities of seed. It is not only much cheaper but often more successful than the nursery technique, particularly with species that develop an early taproot, which undergo a heavy physiological trauma when the taproot is cut off (either in the nursery or during transplanting). Such species have a hard time recovering and sometimes never fully recover, particularly when root-coiling takes place (Le Houérou and Pontanier 1987).

Conclusions and Recommendations

On the eve of the third millennium, fodder trub plantations cover about 1 million ha in WANA. They constitute a unique tool in the rehabilitation, restoration, and development of arid and marginal semi-arid lands. But we are still at an early stage

of this development. Extensive research and extension activities need to be carried out to make fodder trubs more attractive to farmers and graziers in terms of feed value and economic benefit, particularly reducing the cost of establishment.

At the same time, governments should work out appropriate incentives and legal tools that favor land tenure security. This is mandatory for the kind of heavy and long-term investment fodder trub plantation requires (see appendix).

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Species Cited and Authority

The nomenclature combinations recognized as valid are in italic.

Acacia aneura F. Muell. ex Benth. (p.p. A. brachystachya Benth).

Acacia cyanophylla Lindl. (*A. saligna* (Labill.) Wendl.

Acacia cyclops A. Cunn. ex G. Don.

A. dealbata Link. (A. mollissima Willd.)

A. decurrens (Wendl.) Willd.

A. eburnea Boj. cf ≠ *A. karoo* Hayne

A. farnesiana (L.) Willd.

A. horrida Willd. cf ≠ *A. karoo* Hayne

A. giraffae Willd.

A. iteaphylla F. Muell. ex Benth.

A. karoo Hayne

A. kempeana F. Muell.

A. ligulata A. Cunn. ex Benth.

A. melanoxylon R. Br.

A. mollissima Willd (*A. dealbata* Link.)

A. pendula A. Cunn. ex G. Don

A. peuce F. Muell.

A. pycnantha Benth.

A. retinoides Schlect.

A. salicina Lindl.

A. saligna (Labill.) Wendl. (A. cyanophylla Lindl.)

A.tortilis (Forsk.) Hayne subsp. *raddiana* (Savi) Brenan

A. victoriae reginae Benth.

Aellenia subaphylla (C.A. Mey.) Aellen var. *arenaria*

Argania spinosa (L.) Skeels (A. sideroxylon (L.) Roem. and Shulz)

Artemisia badhysi

Artemisia herba-alba Asso (Seriphidium incultum Botsch.)

Arthrocne Artemisia mum macrostachyum (Moric.) Moris (A. indicum Emb. and Maire), (A. glaucum Ung. Sternb.)

Astragalus unifoliosus

Atriplex amnicola PG Wilson (A. rhagodioides F. Muell.)

A. barclayana De Dietr.

A. canescens (Pursh.) Nuttall.

Subsp. *canescens*

Subsp. *linearis* (S. Wats.) Hall. and Clem.

A. cinerea Poir.

A. glauca L. (A. alexandrina Boiss, A. mauritanica Boiss, and Reut. A. parvifolia Lowe)

A. halimus L. subsp. *halimus*

Subsp. *schweinfurthii* (Boiss.) Le Houér.

A. isatidea Moq.

A. lampa Gill. ex Moq.

A. lentiformis S. Wats. subsp. *lentiformis*

Subsp. *breweri* (S. Wats) Hall. and Clem.

A. leucoclada Boiss. subsp. *leucoclada*

Subsp. *turcomanica* (Moq.) Aellen

A. mollis Desf.

A. nummularia Lindl.

Subsp. *nummularia*

Subsp. *omissa* Parr-Smith

Subsp. *spathulata* Part-Smith

Atriplex paludosa Ness.

A. polycarpa (Torr.) S. Wats.

A. repanda Phil.

A. semibaccata R. Br.

A. undulata De Dietr.

A. vesicaria Heward ex Benth.

Blackiella inflata F. Muell (syn. *A. inflata* F. Muell, *A. halimoides* Lindl.)

Bituminaria bituminosa (L.) Stirton (syn. *Psoralea bituminosa* L.)

Calligonum arborescens Litw.

C. arich Le Houér.

C. azel Maire

C. caput-medusae Schrenk

C. comosum l'Herit.

C. pellucidum

C. crinitum Boiss.

C. polygonoides L.

Cassia artemisioides Gaud. ex D.C.

Cassia eremophila A. Cunn. ex R. Br.

Cassia nemophila A. Cunn. ex Vogel

Cassia sturtii R. Br.

Chamaecytisus mollis (Tav.) Greut. and Burd. (C. albidus [D.C.] Rothm.)

Chamaecytisus proliferus (L.f.) Link.

Subsp. *proliferus*

Subsp. *palmensis* (Christ) Kunkel

Colutea arborescens L.

Colutea atlantica Browicz

Colutea istria Mill. (C. haleppica Lam.)

Coronilla valentina L. subsp. *glauca* (L.) Batt and Trab.

Cremnophyton lanfrancoi Brullo (≠ Atriplex mollis Desf.)

Eleagnus angustifolia L.

Ephedra strobilacea Bge

Faidherbia albida (Del.) A. Chevall. (Acacia albida Del.)

Geoffraea decorticans (Gill. ex Hook. and Arn.) Burk (Gourleia chilensis Gill.)

Gleditsia triacanthos L.

Haloxylon ammodendron (C.A. Mey.) Bge

H. aphyllum (Minkw.) Iljin

H. persicum Bge

Hedysarum argyreum Greut. and Burd. (H. argentatum Maire)

Hyppophae rhamnoides L.

Kochia indica Wight

Kochia prostrata (L.) Schrad.

K. scoparia (L.) Schrad.

Medicago arborea L. (≠ M. citrina [F. Quer] Greut. ≠ *M. strasseri* Greut. et al.)

Myoporum acuminatum R. Br (M. ellipticum R. Br.)

M. laetum Fort (M. perforatum Hort., *M. pictum* Hort.)

M. tetrandrum (Lab.) Domin (M. insulare R. Br., M. serratum R. Br.)

Olea europea L.

Subsp. *sativa* (Loudon) Arcang.

Subsp. *oleaster* (Hoffm. and Link) Negodi (subsp. sylvestris [Mill.] Hegi

Opuntia ficus indica L. f. *inermis* (Web.) Le Houér.

O. fusicaulis Griffiths

O. inermis Burb.

O. robusta Wend.

O. undulata Griffiths.

Parkinsonia aculeata L.

Periploca angustifolia Labill. (P. loevigata Ait.)

Prosopis chilensis (Molina) Stunt. ex Burk.

P. cineraria (L.) Druce (P. spicigera L.)

P. glandulosa Torr.

P. juliflora (Swartz.) D.C.

P. koelziana Burk.

P. loevigata (Humb. and Bonpl. ex Willd) McJohnston

Rhamnus oleoides L.

Rhus pentaphylla L.

R. tripartita (Ucria) D.C.

Robinia pseudacacia L.

Rumex lunaria L.

Salsola paletzkiana Litv.

S. richteri Kar.

S. vermiculata L. var. *villosa* Del.

Sarcocornia fruticosa (L.) A.J. Scott (Salicornia fruticosa L.)

Vitis berlandieri Planch.

Vitis riparia Mich.

Vitis rupestris Scheele

Vitis vinifera L.

Appendix 1

Legal Incentives to Fodder Shrub Plantation in Tunisia

(Translated from the French by H.N. Le Houérou)

Decree No 70-523 of 6 October 1970. Journal Officiel de la République Tunisienne, October 1970. Page 1,299, Chap. 9, Art. 22, Development of Fodder Production.

The assistance of the state, when requested and economically justified, may be granted:

- For establishing permanent meadows.
- For establishing sown pastures.
- For establishing fodder shrubs plantations, in particular using spineless cacti, saltbushes, and *Acacia* spp.

Article 23: The duration of the loans thus granted and their interest rates are set as follows:

	Prior to production period		Production period	
	Duration (yr)	Interest rate (%)	Duration (yr)	Interest rate (%)
Fodder shrubs	5	-	10	4
Sown pasture	1	2	5	4
Meadows	1	2	5	4

Decree of the Ministers of Finance and Agriculture of 20 Oct. 1970, Journal Officiel de la République Tunisienne, 20–23 October 1970. Page 1,994.

Article 4: The rate of allowances, loans, and autofinancing for the establishment of meadows, sown pastures, and fodder shrub plantations is fixed as follows:

	Maximum expense per ha (TD)	Loan (TD)	Allowance (TD)	No. man days per ha	Self-financing
Within the WFP Program					
Cactus	85	34	20	90	-
Atriplex	90	18	40	95	-
Acacia	135	27	54	160	-
Other					
Cactus	85	40	60	-	-
Atriplex	90	20	80	-	-
Acacia	135	20	80	-	-

Decree No. 71-265 of 15 July 1977: Regulating Government Incentives to Soil and Water Conservation. Journal Officiel de la République Tunisienne of 23–27 July 1971. Pages 997–998.

Interest rates for fodder shrub plantation loans are as stipulated in decree 70-523 of 6 Oct. 1970 and articles 9 and 10 of decree no. 70-524 of 6 Oct. 1970 (see above).

Decree No. 77-195 of 17 Feb. 1977 on Government Incentives for Soil and Water Conservation. Journal Officiel de la République Tunisienne, 17 Feb. 1977. Pages 465–467.

Article 8: Fodder shrub plantations as in Decree No. 70-523 of 6 Oct. 1970 and Articles 9 and 10 of Decree No. 70-524 of 6 Oct. 1970 (see above).

Decree No. 77-340 of 15 April 1977, Journal Officiel de la République Tunisienne 8–12 April 1977. Page 899. Government Incentives to Soil and Water Conservation.

Article 1:

	Maximum expense considered (TD/ha)	Loan	Allowance	Self financing
Fodder shrub plantations	80	30%	60%	10%

Shrubland Management and Shrub Plantations in Southern Europe

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Abstract

Natural shrublands are a vast resource in southern Europe, covering more than 200,000 km^2. They include maquis, garrigue, and phrygana, growing mainly on rocky and friable soils. Their productivity for livestock is relatively low (about 1,000 kg DM/ha), and their feeding value is low to moderate, but their importance to ruminant production is considerable. This is because shrubs maintain sufficient levels of crude protein and minerals during the critical summer period, making them an indispensable animal feed. Several experiments have shown that this low productivity and feed value can be substantially increased by methods that aim to establish a balance between shrubs and herbaceous plants, about 50% each, and moderate stocking rates. Plantations with selected native or exotic fodder shrubs and trees have recently been established on experimental and demonstration plots. They were more productive and had higher feed value than native shrublands, but the cost of establishment was high, and there were difficulties in grazing management. The main species used were *Medicago arborea* L., *Atriplex halimus* L. and *nummularia* Lindl., *Morus alba* L., *Amorpha fruticosa* L., *Robinia pseudoacacia* L., and *Gleditsia triacanthos* L. Fodder shrub and tree plantations are recommended for use as strategic resources, to complement natural shrublands, in the form of browsing or feeding reserves, or by planting them, widely spaced, in rangelands or cereal fields.

Key words: natural shrublands, shrub plantations, productivity, feed value, improvement, grazing management, southern Europe.

Introduction

Shrubs are a common component of Mediterranean vegetation and therefore part of the landscape of southern European. They play a multiple role, because they provide a variety of products and serve numerous functions. Among these multiple products and services, forage production is the most prominent. For this reason, they have been an essential part of the traditional production systems throughout the Mediterranean basin, including southern Europe.

Despite their importance to animal production, shrubs were once considered to be of less value to livestock than herbaceous plants. Further, phytosociologists developed the theory that Mediterranean shrublands were serial communities

created by human activities and therefore should be protected and allowed to become forests (Tomaselli 1981).

However, over the last 15–20 years, this distorted attitude toward shrubs has changed. Substantial research, related to the ecology, use, and management of natural shrub communities, has begun in several countries of southern Europe. Selection, multiplication, and ecological and agronomic evaluation of native and exotic species of fodder shrubs are underway, as is the establishment and management of plantations.

In this paper, the research conducted so far on both natural shrublands and shrub plantations in southern Europe is reviewed. The advantages and limitations of using fodder shrubs to help maintain ecological and economical production systems in the Mediterranean basin are discussed.

Natural Shrublands

Distribution and Description

The natural shrublands of Europe are distributed mainly along the coasts of the southern countries bordering the Mediterranean Sea (Spain, France, Italy, Croatia, the new Yugoslavia, Albania, Greece, and Turkey). On the Iberian peninsula (Portugal and Spain), they also reach the Atlantic coast and inland. Le Houérou (1981) estimates the area covered by Mediterranean shrublands, together with Mediterranean forests, at 396,000 km^2. At least half of this area is probably shrubland.

There is no commonly accepted classification of Mediterranean shrublands. Each country uses its own vernacular names. Tomaselli (1981) suggests adopting the Spanish term *matorral* and subdividing them according to height (H) and cover (R). He distinguishes three height classes: high (>2 m), middle (0.60–2 m) and low matorral (<0.60 m); and three cover classes: dense (>75%), discontinuous (50–75%), and scattered matorral (25–50%). From the point of view of range management, a more realistic approach might be to subdivide shrublands into three categories by using the terms well known in the literature (Le Houérou 1981; Tomaselli 1981): the French terms *maquis* and *garrigue* and the Greek term *phrygana*. These categories, proposed by Tomaselli (1981), are roughly equivalent to tall and dense, middle and discontinuous, and low and scattered matorral, respectively.

- Maquis are xerophilous and sclerophyllous Mediterranean shrublands, growing mainly on siliceous soils. They are dense and impenetrable plant communities dominated by a large variety of evergreen shrub species and shrubby trees, 1–3

m tall, such as *Arbutus unedo* L., *A. adrachne* L., *Erica arborea* L., *E. manipuliflora* Salisb., *Myrtus communis* L., *Quercus ilex* L., *Q. coccifera* L., *Phillyrea media* L., *Pistacia lentiscus* L., *Cistus monspeliensis* L., etc. In the understory, perennial herbs and geophytes may be found.

- Garrigue are open communities of relatively small sclerophyllous shrubs, 0.5–1.5 m tall, growing mainly on calcareous soils. The dominant species are evergreen shrubs, especially kermes oak (*Quercus coccifera*). Sometimes, deciduous species may also be present, such as *Carpinus orientalis* Miller and *Fraxinus ornus* L., also known as *pseudo-maquis* (Tomaselli 1981).
- Phrygana are open communities of dwarf shrubs, less than 1 m high, which grow in rocky and friable soils of different origins. Among the shrubs, a rich herbaceous flora of therophytes, hemicryptophytes, and geophytes is found. Phrygana are dimorphic species, which replace their large winter leaves with smaller leaves in the summer to conserve water. For this reason, they are very resistant to dry conditions. The most common species are *Sarcopoterium spinosum* (L.) Spach., *Phlomis fruticosa* L., *Coridothymus capitatus* (L.) Reichenb. Fil., *Salvia officinalis* L., and *Cistus*.

Productivity and Feeding Value

Productivity of shrublands in southern Europe varies widely, depending on physical, biological, and land-use factors.

Although large areas of shrublands are abandoned and under-utilized (west Mediterranean) or over-utilized and degraded (east Mediterranean), with very low or nil productivity for livestock, the majority produce substantial amounts of forage. According to Le Houérou (1981), maquis and garrigue production is inversely related to aridity, ranging from 600 to 1,800 kg/ha dry matter in the semi-arid zones, and from 900 to 3,000 kg/ha dry matter in the sub-humid and humid zones.

Maquis are less productive for livestock than garrigue. This is because they are normally very dense, and although they accumulate large amounts of aboveground biomass, their annual growth is low and largely unavailable to animals. According to Talamucci (1987), a Tuscan high maquis produces 400–1,000 kg/ha of available fodder, while a dense *Cistus* maquis produces no more than 200 kg/ha. For these reasons, the grazing capacity of maquis shrublands is relatively low. Garrigue, on the other hand, are more productive to livestock than maquis because they are usually open, thus producing more available browse.

An interesting sub-category of garrigue is the kermes oak shrubland, which is very important to goats. In good soils, mature kermes oak shrublands, with an average height of one meter, may produce more than 16 t/ha of above-ground biomass, but

only 10% (about 1,600 kg/ha) is annual growth available to goats (Papanastasis 1988).

Phrygana are also important communities for livestock, but their importance lies mostly in their herbaceous rather than their shrubby component. This is because the phryganic species are not as palatable as the herbaceous, and animals only eat them in an emergency. Their production varies widely, from less than 750 to more than 1,500 kg/ha, depending on the site (Papanastasis and Gogos 1983).

The feeding value of Mediterranean shrublands is also variable. Most species have low to moderate nutritive value (Lachaux et al. 1987; Tsiouvaras and Nastis 1990). Their advantage over herbaceous plants is that they maintain sufficient nutritional levels during the summer, especially crude protein and minerals, making them an indispensable animal feed during critical periods. There are considerable differences among species in chemical composition, which also changes over the season (Table 1). In general, leguminous species are superior to non-leguminous (Tsiouvaras and Nastis 1990) and deciduous species are superior to evergreen species (Papachristou et al. 1993), but the latter permit a more extended use over the year than the former (Lachaux et al. 1987).

Table 1. Percent of crude protein (CP), cell constituent (CC), and *in vitro* dry matter digestibility (IVDMD) of native fodder shrubs at three phenological stages, average of four years (Tsiouvaras and Nastis 1990).

	Late spring			Middle summer			Early fall		
	CP	CC	IVDMD	CP	CC	IVDMD	CP	CC	IVDMD
Phillyrea media	12.5	69.0	45.5	8.5	51.7	37.0	7.8	50.5	35.9
Quercus coccifera	15.8	78.9	48.3	7.9	49.8	40.0	8.5	56.9	41.5
Arbutus andrachne	11.0	62.3	36.2	8.4	63.6	35.1	5.8	65.1	35.8
A. andrachnoides	12.1	69.0	37.4	9.1	70.5	38.8	6.6	65.8	34.4
Arbutus unedo	11.6	65.4	41.4	8.2	68.8	38.0	6.7	65.6	28.6
Colutea arborescens	25.3	79.7	70.0	28.7	70.7	67.5	23.8	67.0	66.8

Although the chemical composition of most shrubs is favorable, thus indicating high palatability, this does not necessarily translate to high digestibility. This is because anti-quality factors, such as lignin, tannins, and ash/salts, may cause poor digestibility of crude protein and crude fiber. A case in point is kermes oak, which has a high digestibility in spring that is later reduced, apparently due to the increase of lignin, as the season progresses. Thus kermes oak foliage can maintain goats only in the spring, while in the other seasons, animals lose weight (Nastis 1982).

Improvement and Grazing Management

Although browse production and feeding value of most shrublands is relatively low, their production capacity is very high. This is exemplified by the large amount of aboveground biomass they accumulate, especially when they are under-utilized

or abandoned. In a garrigue of kermes oak in southern France, 20 years after the last fire, Long et al. (1978) measured 46 t DM/ha in the first 30 cm above ground level. Shepherds traditionally use pastoral wildfires to open up the dense shrublands and replace unpalatable shrubs with more palatable-to-livestock herbaceous plants. This further deteriorates the shrubland ecosystems over the long term. This practice is still very common in Corsica, Sardinia, and Greece.

Several experiments to improve shrubland productivity have been carried out in the southern European countries. In a garrigue of *Q. coccifera* in Bas-Languedoc and in a maquis of *C. monspeliensis* in Corsica, both in southern France, Long et al. (1978) experimented with the mechanical crushing of vegetation as well as fertilization with NPK. The stocking rate for sheep was increased by a factor of four at the first site and a factor of sixteen at the second. Impressive results were also obtained in Sardinia, in a *C. monspeliensis* maquis shrubland (Bullita et al. 1989).

Mechanical crushing of shrubs is a very effective way to improve productivity, but it involves high costs. Other methods, such as burning followed by seeding with palatable grasses and legumes, clear cutting, and partial improvement by topping the tall shrubs, are less intensive and may result in significant liveweight gains for goats (Table 2).

Table 2. Liveweight gains (kg/ha) in a kermes oak garrigue subjected to different improvement treatments and grazed by goats (Liacos et al. 1980; Papanastasis and Liacos 1991).

Year	Burned and seeded †	Shrublands improved by	
		Clear cutting‡	Topping and thinning§
1976	119.4a††	-	72.8b
1977	97.7a	-	56.8b
1978	79.5a	-	55.8b
1980	61.8	-	-
1981	-	87.8a	59.9b
1982	67.2a	57.8b	48.5c
1983	74.7a	34.1a	30.5b

† Applied in 1974 and 1981.
‡ Applied in 1980.
§ Applied in 1975 and 1980.
†† Means in the same year with different letters are significantly different ($P \leq 0.05$).

There is a high correlation between available forage and animal output in shrublands. Based on data collected in a series of studies for improvement of kermes oak shrublands in northern Greece (Liacos et al. 1980; Papanastasis and Liacos 1991), the relation between available forage and liveweight gains of goat yearlings was found to be:

$$Y = 2.4952 + 0.0314X - 0.000003X^2 \qquad R^2 = 0.757$$

where Y = liveweight gains of yearling goats in kg/ha (range: 3.97–97.7); and X = available forage in kg/ha (range: 125–6,442).

The key to maintaining improved shrubland at high productivity is proper grazing management. Tsiouvaras (1984) suggests a 15 day rotational grazing of kermes oak shrublands at a stocking rate that will not remove more than 60% of the annual growth. Etienne and Lasseur (1985), on the other hand, suggest a higher stocking rate that will remove 80% of the available biomass to control shrubs in maquis shrublands. Low stocking rates will eventually lead to the increase of shrubs at the expense of herbaceous plants, while heavy stocking rates will better control shrubs but destroy the herbaceous plants and lead to soil erosion. Therefore, the best solution is to employ moderate stocking rates and control the expansion of shrubs by occasional mechanical and fertilization interventions. Browsing animals (goats, for example) should be preferred to grazing ones (sheep, for example).

The management target for Mediterranean shrublands should be to maintain a balance between shrubs and herbaceous plants so that increased productivity of livestock is ensured. By reducing the kermes oak cover from 66 to 53% and increasing the herbaceous cover, Yiakoulaki and Nastis (1995) found that the nutritive value of goat diets was significantly improved.

Shrub Plantations

Extent and Species Involved

Plantations with fodder shrubs are a relatively recent phenomenon in southern Europe. With the exception of some areas where they cover sizable tracts of land (southeastern Spain, for example), they are still restricted to the experimental or demonstration level. The main reason for this limitation of shrub plantations in southern Europe (compared, for example, to northern Africa) is the abundance of natural shrublands, which play a considerable role in animal nutrition.

Since the mid-1970s, however, research by southern European scientists has focused on the selection and cultivation of fodder shrubs and trees. This is because the scientists realized that shrubs and trees could be selected for desirable ecological, agronomic, and nutritional characters, and planted to meet specific needs in Mediterranean production systems (Papanastasis 1993).

As a result of the renewed interest in cultivated fodder shrubs and trees, attempts have been made to identify and study the most promising spontaneous or introduced multipurpose species in each country (Papanastasis 1985; Talamucci 1988; Rochon and Goby 1987; Dupraz 1987; Olea et al. 1992). The most important species are:

- In the arid to semi-arid zones: *Medicago arborea* L., *Atriplex* spp., (especially *halimus* L. and *nummularia* Lindl), and *Chamaecytisus proliferus* L.
- In the sub-humid to humid zones: *Amorpha fruticosa* L., *Colutea arborescens* L., *Coronilla emerus* L., *Robinia pseudoacacia* L., *Morus alba* L., *Vitis vinifera* L., and *Gleditsia triacanthos* L. (fodder tree).

On the other hand, research is being conducted on the variability of fodder shrubs and trees. Several studies have already been carried out for the selection, screening, and multiplication of certain species to develop improved cultivars. Species involved are: *M. arborea* (Stringi et al. 1996), *R. pseudoacacia* (Dini 1993), and *G. triacanthos* (Dupraz 1987).

Productivity and Feeding Value

Productivity of cultivated fodder shrubs varies widely depending on the particular species or cultivar and the specific environmental conditions involved.

When the appropriate accessions were used in Sicily, *Medicago arborea* was found to produce about 500 g/plant of edible biomass (leaves, twigs, and fruit) (Stringi et al. 1996). In other, less favorable areas for *M. arborea*, such as southwest Spain, production was much lower (about half), but *A. halimus* produced more (430–500 g/plant), and *C. proliferus* had an intermediate production between the two species (Olea et al. 1994).

Some deciduous fodder shrubs growing in more favorable environmental conditions have attained much higher production. For example, the Japanese *Morus alba* variety Kokuso 21 produced up to 2,000 g/plant of edible biomass (leaves) on good sites in southern France, although on less favorable sites, production was much lower (about 400 g/plant) (Armand and Meuret 1993). High edible production, amounting to 584 g/plant in the third year after establishment, was also attained by *R. pseudoacacia* at a relatively poor site in northern Greece. At the same site, *A. fruticosa* produced 233 g/plant and *C. arborescens* 160 g/plant (Platis and Papanastasis 1993). Pod yield of *G. triacanthos* varied according to variety and age (Dupraz 1987).

Feeding value of cultivated fodder trees and shrubs also varies widely, depending on species or cultivar, phenological stage, plant part, and environmental conditions, but it is generally higher than for most spontaneous species of the natural shrublands. *Medicago arborea*, *C. proliferus*, *M. alba*, and *R. pseudoacacia* are some of the most nutritious, palatable, and digestible fodder shrubs (Rios et al. 1989; Stringi et al. 1987). Deciduous fodder trees and shrubs maintain a satisfactory level of crude protein during the critical summer period, and can be an effective protein supplement to animals—more than other forage resources. Shrub supplementation with *C. arborescens*, *C. emerus*, and *M. alba* cv Kokuso 21

resulted in clear improvement of sheep performance, compared to non-supplemented animals (Ouattara 1991). High *in vivo* digestibility was found in pods of *G. triacanthos* (Dupraz 1987).

As in spontaneous shrubs, cultivated species may also present problems of low digestibility due to anti-quality factors. For example, *A. nummularia* was found to be the most productive, compared to other *Atriplex* species. However, sheep lost weight when they ate it, probably because of other nutritional limitations, such as a high proportion of non-protein nitrogen (Correal et al. 1990).

Establishment and Grazing Management

The common method of shrub establishment is the classical one using containerized seedlings or rooted cuttings. Direct seeding was tried in central Italy for *M. arborea*, but was unsuccessful, due mainly to damage by wild herbivores (Cereti and Rossini 1994). Wide spacing, which has a low establishment cost, produced high yield per plant but low per unit area. Close spacing produced high yield per unit area but has a high cost of establishment. In general, shrub establishment is a costly process.

Grazing management is a critical issue. In a plantation of *A. nummularia* in southeast Spain, Correal et al. (1990) found that grazing should be carried out every 6 months in wet years and every 12 months in dry years, while the most reliable cutting height was 50 cm. On the other hand, *A. halimus* was found to be less sensitive to cutting, because it grows much better when cut at 20 rather than 50 cm, while two cuts per year produce higher biomass and a larger proportion of leaves than one (Aouissat et al. 1993). It seems therefore that different species respond differently to cutting. Tsiouvaras and Nastis (1990) tested three cutting frequencies at 60% of current growth in nine species of fodder trees and shrubs during the summer for four years. They found that *R. pseudoacacia* and *G. triacanthos* produced the highest overall yields, when compared to other species studied.

Combination of Shrub Plantations and Natural Shrublands in Production Systems

Natural shrublands are indispensable forage resources in southern Europe, because they cover vast areas and provide feed for livestock during the critical periods of the Mediterranean climate, namely summer and winter. Although this feed is high in crude protein and crude fiber, is not always digestible by animals, resulting in bodyweight losses and therefore in reduced animal production.

Shrub plantations with fast-growing species featuring high palatability, digestibility, and crude protein are a viable alternative to costly supplementation of animals with commercial high-protein foodstuffs. Species such as *M. arborea*, *M. alba*, *C. proliferus*, *A. fruticosa*, *R. pseudoacacia*, and *G. triacanthos* are ideal for this purpose (Papanastasis 1993).

The question is, how do we combine natural and artificial plantations of high-yielding and nutritional fodder shrubs? There are several possible ways to meet the specific needs of the various production systems in southern Europe.

Browsing Fodder Reserves

Shrubs can be planted with a dense spacing in specific areas of a private farm or a communal rangeland for direct browsing by livestock. For example, a stand with 10,000 *M. arborea* plants/ha may provide 4 t DM/ha (Rochon and Goby 1987). These reserves must be established on good soil, so that yield will be as high as possible, and they must be fenced. To supplement their diet with high-quality feed, animals should graze only during critical periods, and for part of the day only. The critical issue in these reserves is grazing management. On privately owned lands, this management is easy, but on communal rangelands, it is very difficult, and unless all shepherds involved reach a consensus, proper management of such reserves is impossible.

Feeding Fodder Reserves

Shrubs are also planted with a dense spacing in specific areas for indirect rather than direct feeding of livestock. This means that fodder shrubs or trees are cut or lopped and brought green to the animals in the barn at the end of the day (after the animals have grazed the whole day out in shrublands or other resources). In the Pré-Alpes of southern France, several farmers use ancient trees or newly planted shrubs of *M. alba*, feeding their animals with leaves at the end of day during August and September as a "dessert" (Armand and Meuret 1993).

Introduction into Cereal Fields

Grazing of cereal stubble in the summer, after cereal harvest, is a traditional and widespread practice in southern Europe. Cereal fields can be improved for animal grazing if shrubs are established in widely spaced (10–20 m) rows. This technique was initiated in Libya in the early 1980s and recently applied in the southeast of Spain with great success (Le Houérou et al. 1991). Experiments in Spain have shown that such a system may increase the stocking rate to 3.3 ewes/ha per year, with a net liveweight production of 50 kg/ha per year. This is three times higher than the local traditional range–stubble–fallow system. Lactating ewes maintain

high productivity without external supplementation (Correal et al. 1990; Otal et al. 1991).

Enrichment of Rangelands with Fodder Trees

Fodder trees can be planted in rangelands to develop sylvo-pastoral systems. They should be planted far apart (8–10 m), in rows or grids, so that an overstory is created for production of foliage or fruit for the animals as well as for amelioration of the environment. The foliage may be delivered to the animals by lopping off the branches containing fruit. A seven-year-old orchard of selected improved varieties of *G. triacanthos* may produce more than 200 kg/ha of high-quality pods, providing a very valuable food resource for sheep during the critical winter months. This production was in addition to the herbage production provided by the intercropped sward of *Festuca arundinacea*, which amounted to about 2 t DM/ha (Dupraz 1995).

Conclusions

Artificial plantations of fodder shrubs and trees in southern Europe cannot substitute natural shrublands. Plantations should be maintained for use, when necessary, by improving and managing them for animal production as well as for their multiple products and services. Due to the large areas they occupy, they should make up the primary resource in support of extensive and environment-friendly livestock production systems.

Artificial plantations with high-yielding and nutritionally superior fodder shrubs and trees should be used as strategic resources to complement natural shrublands and other feed resources. This will supplement animal nutrition in the critical periods of the year.

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Management of Forage Shrub Plantations in Australia

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Abstract

As a result of agricultural development in Australia, about 2.2 million ha have become salt-affected due to groundwater recharge from cropped areas. Shrub pastures of *Chamaecytisus palmensis* are grown on deep sandy soils to reduce recharge and may improve the carrying capacity of the soil six-fold. Halophytic shrub pastures are grown in salt-affected areas that are incapable of supporting normal crops. Shrub pastures with a patchy understory of annual species that are grazed by sheep show greatly improved production in saline areas. *Maireana brevifolia*, *Atriplex amnicola*, *A. undulata*, and *A. lentiformis* are the main species used. *Maireana brevifolia* is often allowed to colonize saline areas by natural spread, while *Atriplex* species are established by direct seeding or by planting seedlings with root balls or bare-root seedlings. Examples of farmers who have used this technology for 20 years are presented. Farmers have devised stock management strategies that enable them to make profitable use of these high salt species.

Introduction

In the semi-arid regions of Australia (275–500 mm annual rainfall), millions of hectares of natural vegetation have been removed to allow crops and sown pastures to be grown. As a result, the hydrology of the landscape has been disturbed. The annual crops and pastures use less water than the removed natural perennial vegetation. The unused water recharges the aquifers and brings the water tables close to the surface, resulting in salt encroachment referred to as secondary salinity. Currently, this secondary salinity affects about 2.2 million ha of agricultural land in Australia. Approaches to the treatment of salt-affected agricultural land have included the plantation of halophytic species on the salt-affected areas for the production of forage, mainly for sheep. Woody forage species are planted on non-saline areas to increase water use and reduce groundwater recharge. This paper discusses the use of shrubs in agricultural areas in Australia.

Forage Shrub Production on Salt-affected Farmland

In southern Australia, crops such as wheat, barley, and lupine are grown using the winter rainfall. Annual legume-based pastures are grown in rotation with these crops and grazed by sheep and cattle. During the summer, after harvest, animals graze the crop stubble, and as the quality of the material available drops, the farmer feeds them grain or hay to maintain them in store condition until the autumn rains bring green feed. Some farmers, especially those with farms in the lowlands, have areas of secondary salt-affected land from which they obtain negligible production. There are three approaches to treating the problem of secondary salinity. The first is to use engineering solutions, but this is expensive and has not generally been successful. The second approach is to adjust cropping regimes and plant trees and perennial forages on recharge areas to use more water. These measures are being applied, but they take years to affect the problem and many areas are expected to remain saline despite these measures. The third, an ecological approach to the problem of salt-affected land in agricultural zones, is to plant halophytic pastures. This approach, which has been developed into a commercial reality in Australia, is low cost, environmentally friendly, and usually fits well into the farming and grazing regime of an area. Where methods are not available for returning salt-affected land to normal cropping, planting pastures of halophytic shrubs and grasses is now recommended (Davidson and Galloway 1993; Malcolm 1994; National Committee for Productive Use and Rehabilitation of Saline Lands 1996).

The technology involves: (i) identification of the best forage species; (ii) establishment of a stand; and (iii) proper use and management.

Farmers who have adopted this strategy claim that they have been able to increase the overall carrying capacity of their farms by providing feed at a critical time (e.g. Lloyd 1996).

Choosing Shrub Species for Forage Production

Both grasses and shrubs are used for forage production on salt-affected land, but only shrubs are dealt with in this paper. For information on grasses, see Barrett-Lennard and Malcolm (1995). Many characteristics determine the suitability of a species or ecotype for forage production on saline land (Malcolm 1994). The shrubs must be able to survive the conditions and recruit replacement plants under an acceptable management regime. This requires them to flower and produce seed capable of germinating and producing seedlings in the prevailing environment. The growth habit of the plants must be suited to the grazing or cutting regime used, and the forage material produced must be of sufficient quality and quantity, and available at an appropriate time of year. The forage must be non-toxic in the quantity consumed and sufficiently palatable to stock so that they will eat enough of it to benefit. It may need to be used in conjunction with other feeds. The shrubs

must be able to regrow after use (preferably many times) and survive the various vicissitudes to which the site is prone. The seed should be easily harvested, cleaned, stored, and sown, and there should be a simple, cheap method of establishment. Shrubs are tested for these characteristics on representative sites in the field, as discussed elsewhere (Malcolm 1994, 1996).

Establishing Halophytic Pastures

Halophytic shrubs may be established in salt-affected soils from cuttings, seedlings, or by direct seeding. Establishment from cuttings planted directly in the field is not reliable, but cuttings of many *Atriplex* spp. strike well in the nursery and, once struck, may be used for propagating desirable clones. Seedlings are the most reliable method of establishment. The major cost is for the seedlings, but mass propagation techniques have recently brought the cost down to about US$ .07 per seedling. These seedlings have a small root ball, are about 10–20 cm high, and are readily planted using mechanical seedling planters. An alternative is to raise seedlings in outdoor beds, remove them from the soil at planting time, and plant the bare roots. Such seedlings are available for as little as US$ 0.05 each, are readily transported by road or air, and give good establishment in moist areas of low salinity. Bare-root seedlings are less appropriate for soils of moderate to high salinity than seedlings with a soil root ball. The cost of planting, about US$ .01–.03 per seedling, must be added to the cost of seedlings.

The Mallen Niche Seeder (Malcolm and Allen 1981) was designed specifically to establish halophytic shrubs in saline soils by direct seeding. The seeder has twin opposed 670 mm discs which form a soil mound. A V-shaped press wheel rolls on the mound, producing a niche and driving a mechanism which deposits seed and mulch at intervals along the niche. Seed spacing can be adjusted, but is generally about two meters. Vermiculite is used as a mulch (about 100 mL per placement). Niche seeders manufactured in Australia are used by farmers and contract operators to sow extensive areas of halophytic shrub pastures at an inclusive cost of about US$ .06 per placement. The machine can be adjusted for various conditions. If waterlogging is likely to occur during the establishment period, the discs can be adjusted to make a higher mound, with the bottom of the niche as high as 15 cm above ground level. In dry areas, the niche is made wider and lower to collect more water.

Establishment from direct seeding can be improved by the use of black sprays to coat the vermiculite deposits (Malcolm et al. 1982), soil amendments such as gypsum (Ward, personal communication), and weed control (Vlahos 1994). These extra costs must be assessed to determine whether they are economic in a particular application. The results of direct seeding are also strongly influenced by soil type (Vlahos 1994). There is a much higher success rate with niche seeding on soils

with sandy or sandy loam surfaces than on loam to clay surfaces. On the latter, the use of seedlings is recommended.

The cost of establishment can be reduced by planting vigorous species that can be widely spacing without reducing yield per hectare. For example, *A. amnicola* Paul G. Wilson planted at 3 × 3 m intervals yields the same as at 2 × 1 m, but if *A. vesicaria* Heward ex Benth. is spaced wider than 1 × 1 m, its yield per hectare declines (Malcolm et al. 1988).

Use and Management

The biology of the shrub determines its reaction to grazing and the ease with which it can be managed. Shrubs that are eaten by grazing animals range from those that are sensitive to pruning, such as *A. vesicaria*, to those that recover readily from complete defoliation, such as *A. amnicola*. The more palatable species tend to be less sensitive to pruning. Fortunately, shrubs are less palatable than the grasses and forbs that often form an understory with the shrubs, and use may be made of the bulk of the understory before the shrubs are heavily defoliated. Shrub species also vary greatly in their ability to recruit new plants by natural seeding. This trait varies within species, so that it is possible to identify ecotypes or species with good volunteering ability. In general, shrubs need a period to recover from grazing, preferably during the active growth period, which coincides with the period during which seedlings are establishing.

Shrubs are regarded as a desirable component of a pasture because: (i) they provide a forage reserve after the ephemeral feed has been exhausted; (ii) they help control erosion by reducing wind speed; and (iii) they act as a haven for plants of other species to become established.

The use that can be made of halophytic forage shrubs depends on the livestock management context in which they are grown. In Australia, shrubs are usually grown on farms where annual crops (mainly wheat) are grown and sheep are grazed. One sheep (e.g., a 50 kg wether) requires about 2 kg of organic matter of about 70–75% digestibility per day. When the feed has dried off in the summer, sheep are unable to consume enough metabolizable energy to maintain body weight. The nitrogen content of the feed at this time is also limiting. It is possible to increase the consumption of dry feed, such as wheat straw, by adding saltbush (*Atriplex amnicola*) to the diet (Atiq-ur-Rehman 1995). This has two benefits in the field: it allows the farmer to make use of his salt-affected land, and it improves the use of the available wheat or other stubble. However, the saltbush has a high content of soluble salts (22% ash), which results in an increase in tissue water which must not be interpreted as body weight increase. It is essential to supply the sheep with low-salinity water if they are grazing halophytic shrubs. Mixed pastures of *Atriplex* spp. and dry annuals are at best a maintenance feed for dry sheep. The

value of shrub pastures in a farm context will be discussed later under Case Studies.

The use of a mixed pasture of shrubs and annuals is a complex issue. Usually, the sheep will eat the annuals first, transferring their attention to the shrubs as the annual feed becomes scarcer. The first parts of the shrub to be eaten are the leaves and very small (1–2 mm) twigs (Atiq-ur-Rehman 1995). Gradually, thicker twigs are eaten and the digestibility of the diet is correspondingly reduced. As the diet becomes poorer, the animals will lose weight and there may be a break in the wool. The farmer may feed hay or grain to maintain the condition of the animals and to eke out the shrub feed. The profitability of sheep is currently (1996) low in Australia, and as a consequence farmers are using stubble rather than planting new shrub areas for sheep feed. Those who already have shrubs established are able to use them in the winter when green annual feed is scarce because of the high percentage of the farm under crops. The carrying capacity of a farm tends to be determined by the amount of feed available at the time of least supply. By increasing the feed supply at a critical time, the shrubs increase the overall carrying capacity of the farm.

Detailed work on the value of halophytic shrubs for grazing in Australia in recent years has considered only *Atriplex* spp. Many farmers also use *Maireana brevifolia* (R. Br.) Paul G. Wilson, which has a higher protein content and lower salt content but contains a significant quantity of oxalate (Malcolm 1963). *Maireana brevifolia* grows on moderately salt-affected land not subject to waterlogging. It recovers well from severe grazing, is deep rooted, is usually associated with a productive understory of annuals, and spreads readily by natural seeding in fields protected from grazing.

Forage Shrub Production on Non-saline Land

In the last five years in Australia, farmers have commenced alley cropping (Lefroy and Scott 1994). Avenues of shrubs, some of them of grazing value, have been planted across areas where wheat is grown. The land between the avenues is cropped to wheat, etc., and the shrubs are grazed when the stubble is used. Shrubs planted in this system include *Atriplex* spp., *Acacia* spp., and *Chamaecytisus palmensis* (tagasaste) (Lefroy and Scott 1994; Snook 1995). The perennials are intended to lessen recharge to the groundwater in order to reduce salinity problems. They also provide forage and reduce wind erosion, and there is evidence that the yield of cereal crops protected by windbreaks is increased (Bicknell 1993). Tagasaste is planted extensively on deep sandy soils to provide forage, reduce wind erosion, and reduce recharge. Tagasaste will develop into a small tree and must be trimmed to keep the available forage within reach of stock. Mechanical cutters are used. Some farmers graze cattle to keep the tagasaste from growing too high.

Tagasaste planted on sandy soils has increased sheep carrying capacity six-fold, and provided 300 kg/ha liveweight gain for cattle. The plantations have been responsible for stopping wind erosion, lowering the water table, and greatly improving the aesthetics of the landscape. Tagasaste is established by means of root-ball or bare-root seedlings, or by direct seeding, and has been established on 10,000–20,000 ha over the last 5–10 years.

Case Studies

The author interviewed six Australian farmers in September 1996. Their properties were all in the wheat and sheep growing areas of southwestern Australia and ranged from south latitude 29° 31' to 34° 17'. The results of the interviews are summarized in Tables 1–3. All of the farmers interviewed graze their sheep on halophytic pastures on a regular basis. All regard them as a useful adjunct to their farm operations. All reported that shrub establishment improved the cover of annual understory plants and the overall appearance of the farm. The farmers reported no problems with sheep during shrub grazing—provided the sheep had access to other feed (e.g. dry annual pasture, stubble, hay, or grain) and fresh water. The sheep did not develop breaks in the wool. Farmers observed that the wool was cleaner for sheep grazing on shrub pastures than for those grazing on dry pastures or stubble paddocks in autumn.

The farmers found it difficult to estimate the carrying capacity of shrub pastures, because they were often grazed in conjunction with areas of stubble or pasture. Three farmers (B, D, and F) commented that the use of shrub pastures was a significant factor in enabling them to survive economically. Farmer D (who is Lloyd 1996) was able to run an additional 1,000 sheep on his property. Farmer F did not run significantly more sheep but was able to sell the grain that he would have fed to the sheep if he had not had the shrub pastures. He estimated that the carrying capacity of his salt-affected land rose from 0.5 to 3.3 sheep per ha as a result of planting shrub species. Some of this improvement was due to the improved annual pasture made possible by the lowered groundwater caused by the shrubs.

Table 1. Details of six farms with halophytic shrub pastures and annual pasture understory in southwestern Australia.

Farmer	Rain (mm)	Farm area (ha)	Saline area (ha)	Shrub area (ha)	Shrub age (years)	Shrub spp.[†]	Season of shrub use and supplemental feed
A	400	1,800	500	280	5–8	*Atu*, *Atle*, *Atam*	Summer to winter; 200g lupins/head/d
B	335	2,000	500	500	up to 14	*Atun*, *Atle*, *Atam*, *Mabr*, *Atnu*, *Atpa*, *Atbu*	Late summer to mid-winter; lupins when feed depleted
C	330	3,560	80	40	up to 8	*Atun*, *Atle*, *Atam*, *Atnu*, *Atse*	Late autumn; hay
D	325	2,160	700	350	up to 7	*Atun*, *Atle*, *Atam*, *Atnu*, *Atse*	Late spring to winter; seldom
E	325	10,000	1400	600	up to 20	*Mabr*, *Atun*, *Atle*, *Atam*	Late autumn to early spring; lupins and hay if heavily stocked
F	450	900	200	120	6–10	*Atun*, *Atle*, *Atam*, *Atnu*, *Atci*, *Atse*, *Mabr*	Late autumn to winter; if condition drops, 200g lupins /hd/wk

[†] Species abbreviations: *Atam*, *Atriplex amnicola*; *Atci*, *A. cinerea* Poir.; *Atle*, *A. lentiformis*; *Atnu*, *A. nummularia* Lindl.; *Atpa*, *A. paludosa* R. Br.; *Atse*, *A. semibaccata*; *Atun*, *A. undulata*; *Mabr*, *Maireana brevifolia*.

Table 2. Comments by farmers about the effects of halophytic shrub pastures on their saline land.

Farmer	Effect of halophytic shrub pastures						
	Annual plant cover	Ground -water levels	Wildlife increase	Erosion control	Change in salt extent	Property value	Aesthetics
A	Increase	ns[†]	Kangaroos, birds	Yes	Same or less	Increase	Improved
B	Increase	Down to 1.3 m	Birds, lizards	Yes, biggest change	No increase	ns	Improved
C	Increase under shrubs	ns	ns	Yes	Same	ns	ns
D	Increase	Down	Kangaroos, birds	Yes, wind and water	Same	ns	Greatly improved
E	Less bare areas	ns	ns	Yes, wind	Same	ns	Improved
F	Improved clover and ryegrass	Down 1 m	Kangaroos, birds, ants	Yes, wind	Reduced	ns	Greatly improved

[†] ns = not stated.

Farmer C was disappointed with the performance of *Atriplex lentiformis* S. Wats. (he used a seed mix with a high proportion of that species). The plants grew quickly but died after 4–5 years. He would not plant *A. lentiformis* again. Others appreciated the early growth of *A. lentiformis* and the shelter it provided for sheep. Farmer D managed *A. lentiformis* by grazing it to keep it within easy reach of the sheep. *Maireana brevifolia*, *A. amnicola*, and *A. undulata* D. Dietr. were generally regarded as the best species.

In 1980 Farmer E fenced in an area of 28 ha of salt-affected land and allowed it to cover with *M. brevifolia*. It is now grazed every year from late autumn to early spring. In 1996, 184 ewes were introduced to the area in the third week of June. They produced 223 lambs and were removed on 27 August (1.2 sheep per ha on a year-round basis). In late June, 150 7–8 year old cull ewes in poor condition were introduced onto another 40 ha of *M. brevifolia*, established without ever being seeded. By 6 September they had produced 151 lambs and were still in the area.

While the sheep were in the halophytic shrub pastures, Farmers D and E did not feed them supplements until most of the understory had been used.

Table 3. Farmer assessment of the effects on sheep of halophytic shrub pastures with annual understory.

Farmer	Sheep grazed on shrubs	Break in wool†	Wool cleanliness	Condition of sheep	Scouring§
A	Merino, wethers, pregnant ewes	No	Cleaner	Lambed well after shrub grazing	No
B	Merino, dry, lambing, lactating or pregnant, not weaners	No	Cleaner	Maintained	No
C	Merino	ns‡	ns	Some loss	No
D	Merino ewes, pre-mating and 1–4 months after	No	Cleaner	Maintained	No
E	Merino and Awassi ewes, dry and lambing	No	Cleaner	Maintained, not fat	No
F	Merino and Suffolk, all types except weaners	No	Cleaner	Maintained	No

† No = no discernible break in the wool related to grazing shrub pastures.
‡ ns = not stated.
§ Farmers report that only weaners scour on saltbush, so they are not grazed on it.

None of the farmers topdressed the shrub pastures. Some believed topdressing and renovation of old stands was an issue that needed research.

Despite research findings documenting the poor quality of halophytic shrub pastures for sheep, farmers have been able to devise grazing and feeding strategies that enable them to farm these species profitably and provide a range of other benefits.

Benefits from Forage Shrubs

Farmers obtain economic benefit from growing halophytic shrub pastures, but additional benefits are often overlooked. Shrubs grown on salt-affected land modify the environment. The shrub canopy provides cover and leaf litter, resulting in salinity reduction in the surface soil (Malcolm et al. 1988). As a result, annual plants become established. The shrubs use more water than is evaporated from bare saline ground by extracting water from the deep root zone (Greenwood and Beresford 1980; Malcolm et al. 1988). Farmers who have had shrubs growing on their salt-affected land for 5–10 years report a reduction in water table level (Lloyd 1996). In some cases, shrub growth declined as the site dried out, and annual pastures were greatly improved, with relatively salt-sensitive species returning. Birds, lizards, insects, and spiders have been observed to colonize the improved plant cover, creating a rich ecosystem in what was previously a sterile area (Table 2). The vegetative cover controls wind and water erosion and the shrubs provide shelter from the wind for stock, especially at critical times such as during lambing. Aesthetically, the area is greatly improved and the resale value of the farm is higher if the saline areas are vegetated than if they are bare. Some farmers even claim that their revegetation programs, which include halophytic forage shrubs on salt-affected areas and limited numbers of trees at the base of slope and on selected recharge areas, have halted further salt encroachment (e.g., K. Diamond, personal communication).

Conclusion

Forage shrubs have an important contribution to make to sustainable agricultural production and good land care. Suitable species, establishment techniques, and management methods are available and in widespread use. Farmers are solving the problems of incorporating shrubs into their farm enterprises. Halophytic shrub pastures are an established profitable farm practice. The use of tagasaste on deep sandy soils is strongly recommended.

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Shrub Introduction and Management in South America

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Abstract

South America is, on average, the continent that receives the largest water input from rainfall. However, most of its countries have arid or semi-arid zones in their territories. Some even share in the driest region of the world: the Atacama Desert. In these zones, desert expansion as a consequence of rainfall decrease and man-induced disturbances is a primary threat. While variations in climate are difficult or impossible to manage, man-made interventions, as alternatives and their environmental effects are duly identified and validated, are somewhat easier to manipulate. This paper deals with one of the options used extensively in South America to increase rangeland productivity and attenuate forage deficiencies during dry seasons and recurrent droughts: the planting of palatable shrubs. Among the aspects considered are: research performed and its evolution, species used, results obtained, transfer to users, and productive application. Besides forage production itself, the benefits that woody vegetation provides to endangered ecosystems are discussed. Emphasis is given to the Chilean experience with saltbushes (*Atriplex* spp.), both native and introduced, under arid and semi-arid Mediterranean-type conditions.

Key words: South America, arid zones, palatable shrubs, *Atriplex* plantation.

Résumé

L'Amérique du Sud est le continent qui a la plus haute précipitation moyenne, pourtant la plupart de ses pays ont des régions arides ou semi-arides qui font partie de leurs territoires. Il y en a même qui partagent la région la plus sèche de la Terre : le Désert d'Atacama. C'est justement dans ces régions arides et semi-arides où la désertification est une menace croissante à cause de la diminution des précipitations et de l'impact humain. Bien qu'il soit quasiment impossible de modifier l'effet du climat, l'intervention de l'homme peut être corrigée tant qu'il existe des options valables.

Cette contribution concerne une des options utilisées en Amérique du Sud pour accroître la productivité de ses parcours et atténuer le manque de fourrage au cours de la saison sèche, ainsi que des fréquentes sécheresses prolongées. Il s'agit des plantations d'arbustes fourragers. Les aspects considérés sont : les recherches faites et leurs evolutions, les espèces arbustives plus prometteuses, les résultats obtenus,

leur transfert aux bénéficiaires, et leur mise en pratique. En plus de leur valeur fourragère, les autres bénéfices apportés par les arbustes sont considérés. Un intérêt particulier est mis sur les espèces arbustives d'*Atriplex*, aussi bien natifs qu'introduites, pour les régions arides et semi-arides à climat méditerranéen du Chili.

Mots-clés: Amérique du Sud, régions arides, arbustes fourragers, plantations d'*Atriplex* spp.

Shrublands of South America

Latin America has a relatively low proportion of arid and semi-arid regions compared to Africa and Australia. As a matter of fact, Budico (Sale 1975) comments that Latin America has the highest mean rainfall of all continents: 1,350 mm vs a world average of 720 mm. However, its rainfall distribution is extremely variable, and except for Uruguay and the Guianas, all countries have arid and semi-arid regions in their territories.

The largest arid and semi-arid areas are found in Argentina, Brazil, Chile, Peru, and Bolivia, while the remaining countries have semi-arid or sub-humid conditions only.

Although shrubs may not always dominate, and are sometimes absent from arid and semi-arid regions, shrubs are the most frequent vegetation type found in these regions. Based on the Engler and Mattick cartography of South American vegetation (Fig. 1), Cabrera and Willink (1973) state that low woody vegetation is dominant or subordinated in the provinces, as described below.

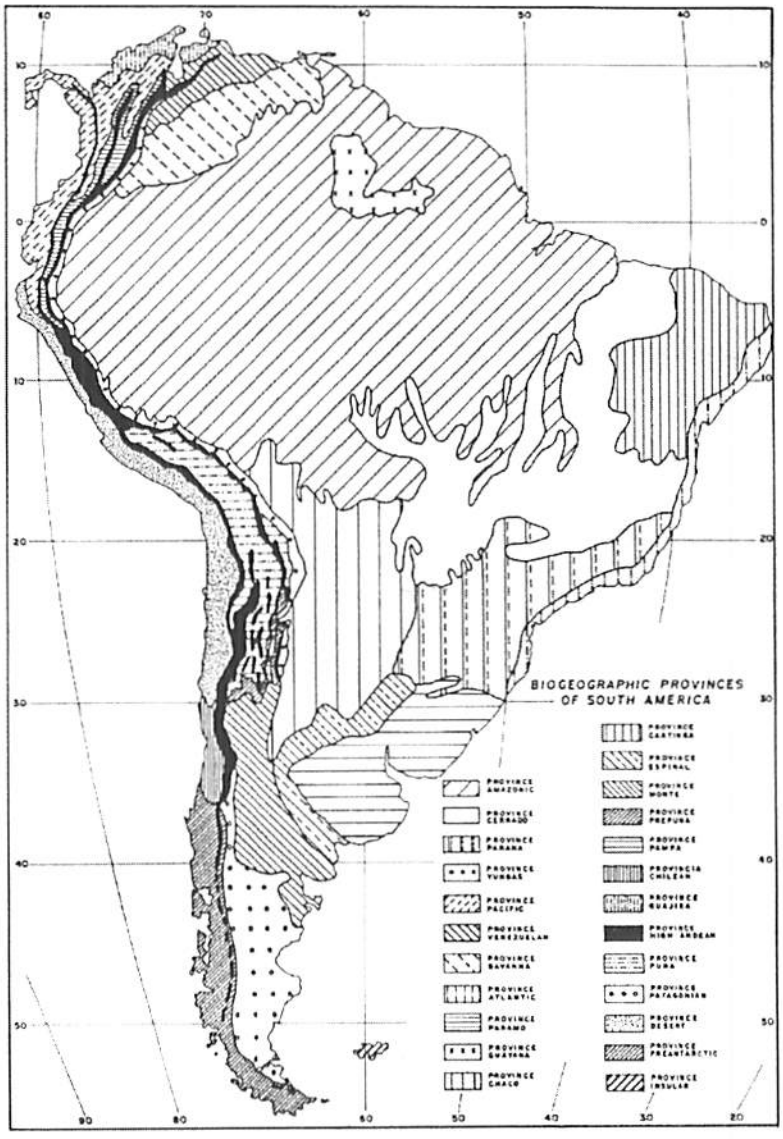

Figure 1. Biogeographic provinces of South America, according to Engler cartography and Mattick modifications. Adapted from Cabrera and Willink (1973).

Neotropical Region

Chaco Domain

- Caatinga Province
- Chaco Province (steppic shrublands in salty sites only)
- Monte Province
- Prepuna Province

Andean–Patagonian Domain

- High Andean Province
- Puna Province
- Desert Province (Coquimbo District)
- Central Chile Province
- Patagonian Province

Antarctic Region

Antarctic Domain

- Sub-Antarctic Province

Common to all arid and semi-arid environments is the threat of desertification due to the following: historical overgrazing; wood extraction for mining and domestic fuel; nutrient depletion; erosion due to indiscriminate soil plowing for seasonal crops; and, more recently, to salt accumulation in some irrigated areas.

Since shrubs are the climax vegetation, and most shrubs undergo successive stages, their reintroduction or replacement by similar species is the best way to control degradation or to recover rangeland productivity. Table 1 lists the names of some woody species, along with their forage values, which have been studied in South America. This strategy warrants particular attention in the Mediterranean-type ecosystems of arid and semi-arid Chile. Therefore, this paper deals with the research undertaken in the Chile IV Region, as well as with development programs based on results from that area.

Table 1. Woody palatable species studied in South America, including trees, shrubs and succulents.

Species, subspecies, variety, type	Family	Species, subspecies, variety, type	Family
A. caven	Fabaceae	*A. mucronata*	Chenopodiaceae
A. cyanophylla	Fabaceae	*A. paludosa*	Chenopodiaceae
A. saligna	Fabaceae	*A. polycarpa*	Chenopodiaceae
A. pendula	Fabaceae	*A. repanda*	Chenopodiaceae
A. piauhiensis‡	Fabaceae	*A. rhagodioides*	Chenopodiaceae
A. cantholippia punensis	Verbenaceae	*A. semibaccata*	Chenopodiaceae
Adesmia aphylla	Fabaceae	*A. undulata*	Chenopodiaceae
A. arborea	Fabaceae	*A. vesicaria*	Chenopodiaceae
A. argentea	Fabaceae	*Baccharis boliviensis*	Asteraceae
A. dichotoma	Fabaceae	*B. incarum*	Asteraceae
A. echinus	Fabaceae	*B. juncea*	Asteraceae
A. hystrix	Fabaceae	*B. paniculata*	Asteraceae
A. melanocaulos	Fabaceae	*Balbisia peduncularis*	Ledocarpaceae
A. odonttophylla	Fabaceae	*B. stitchkinii*	Ledocarpaceae
A. sentis	Fabaceae	*Balsamocarpon brevifolium*	Fabaceae
Anisomeria littoralis	Phytolaccaceae	*Bauhinia cheilantha*‡	Fabaceae
Anthyllis cytisoides	Fabaceae	*B. forticata*§	Fabaceae
Aristotelia chilensis	Elaeocarpaceae	*Boumelia sertorum*§	Sapotaceae
Artemisia herba-alba	Asteraceae	*Brachyclados lycioides*†	Asteraceae
Atriplex atacamensis	Chenopodiaceae	*Bridgesia incisaefolia*	Sapindaceae
A. bumburyana	Chenopodiaceae	*Bulnesia chilensis*	Zygophylaceae
A. canescens	Chenopodiaceae	*Caesalpinia angulicaulis*	Fabaceae
A. cinerea	Chenopodiaceae	*C. aphylla*	Fabaceae
A. clivicola	Chenopodiaceae	*C. ferrea* var *cearensis*§	Fabaceae
A. coquimbana	Chenopodiaceae	*C. microphtla*‡	Fabaceae
A. cordobensis	Chenopodiaceae	*C. pyramidalis*§	Fabaceae
A. costellata	Chenopodiaceae	*C. spinosa*	Fabaceae
A. deserticola	Chenopodiaceae	*Calliandra chilensis*	Mimosaceae
A. glauca	Chenopodiaceae	*C. depauperata*‡	Mimosaceae
A. halimus	Chenopodiaceae	*Capparis emarginata*†	Capparaceae
A. hastulata	Chenopodiaceae	*C. flexuosa*	Capparaceae
A. holocarpa	Chenopodiaceae	*Cassia cericea*‡	Fabaceae
A. imbricata	Chenopodiaceae	*C. fistula*§	Fabaceae
A. lampa	Chenopodiaceae	*C. stutii*‡	Fabaceae
A. lentiformis	Chenopodiaceae	*Cajanus flavus*‡	Fabaceae
A. leuca	Chenopodiaceae	*Cereus jamaracu*	Cactaceae
A. lindleyi	Chenopodiaceae	*Chacaya trinervis*	Rhamnaceae
Chamaesytisus mollis†	Fabaceae	*Maytenus boaria*	Celastraceae
C. proliferus subsp. *palmensis*	Fabaceae	*Mimosa arenosa*	Mimosaceae
Chenopodium paniculatum	Chenopodiaceae	*M. caesalpiniaefolia*‡	Fabaceae
Chloroleucum foliolosum	Fabaceae	*M. tenuiflora*§	Fabaceae
Chuquiraga ulicina	Asteraceae	*M. verrucosa*	Fabaceae
Clitoria ternatea‡	Fabaceae	*Monttea chilensis*	Scrhophulariaceae
Cnidosculus phyllacanthus†	Euphorbiace	*Muehlenbeckia hastulata*	Polygonaceae
Colutea atlantica†	Fabaceae	*Ophryosporus triangularis*	Asteraceae
C. histryx†	Fabaceae	*Opuntia ficus-indica*	Cactaceae
Cordia leucocephalla	Boraginaceae	*Oxalis gigantea*	Oxalidaceae
C. onconcaly§	Boraginaceae	*Parastrephia lepidophylla*	Asteraceae

Continued

Species, subspecies, variety, type	Family	Species, subspecies, variety, type	Family
Cratylia mollis	Fabaceae	*P. lucida*	Asteraceae
Croton conduplicatus	Euphorbiaceae	*P. quadrangularis*	Asteraceae
C. sonderianus	Euphorbiaceae	*Parkinsonia aculeata*[§]	Fabaceae
Cyclolepis genistoides[†]	Asteraceae	*Pilocereus pachycladus*	Cactacea
Desmanthus virgatus[‡]	Fabaceae	*Piptadenia macrocarpa*[§]	Fabaceae
Dinemagonum maculigerum	Malpighiaceae	*Pithecolobium policephalum*[§]	Fabaceae
Dinemandra sp.	Malpighiaceae	*Prosopidastrum globosum*[†]	Fabaceae
Ephedra andina	Ephedraceae	*Prosopis alba*	Fabaceae
E. breana	Ephedraceae	*P. chilensis*	Fabaceae
E. multiflora	Ephedraceae	*P. flexuosa*	Fabaceae
E. ochreata[†]	Ehedraceae	*P. juliflora*[‡]	Fabaceae
Euphorbia lactiflua	Euphorbiaceae	*P. strombulifera*	Fabaceae
Fabiana densa	Solanaceae	*P. tamarugo*	Fabaceae
F. squomata	Solanaceae	*P. cuneifolia forma tipia*	Asteraceae
Flourensia thurifera	Asteraceae	*P. pungens*	Asteraceae
Geoffroea decorticans	Fabaceae	*Salix humboldtiana* var. *fastigiata*	Salicaceae
Gutierrezia taltalensis	Asteraceae	*Senecio graveolens*	Asteraceae
Haplopappus rigidus	Asteraceae	*Spondia tuberosa*	Anacardiaceae
Indigofera ereta[‡]	Fabaceae	*Tabebuia spongiosa*	Bignoniaceae
Leucaena leucocephala[‡]	Fabaceae	*Talguenea quinquenervia*	Rhamnaceae
Lycium chilense	Solanaceae	*Tamarix* spp.[†]	Tamaricaceae
Bromelia laciniosa	Bromeliaceae	*Tarasa operculata*	Malvaceae
Maireana brevifolia	Chenopodiaceae	*Tessaria absinthioides*	Asteraceae
M. enchilaenoides	Chenopodiaceae	*Trevoa trinervis*	Rhamnaceae
Manihot pseudoglazio	Euphorbiaceae	*Ziziphus joazeiro*	Rhamnaceae

Sources of information: Lailhacar (1984, 1986, 1990, 1992); Carlos Passera[†], IADIZA, Argentina (personal communication, 1996); Silva et al. (1984)[‡]; and Sanford (1961)[§].

When undisturbed, the Chile IV Region rangelands are dominated by a low and open shrub formation known as *matorral*, associated with succulents (Cactaceae and Bromeliaceae), whose densities depend on exposure. As moisture is available in the upper soil horizon from early winter to mid-spring, a seasonal stratum of annual grasses and forbs provides enough forage to enhance milk and meat production.

Native perennial grass species, such as *Briza*, *Bromus*, *Chusquea*, *Danthonia*, *Deschampsia*, *Deyeuxia*, *Festuca*, *Hordeum*, *Melica*, *Nassella*, *Piptochaetium*, *Poa*, and *Stipa*, which originally dominated the herbaceous stratum, were displaced by exotic annuals when Spanish settlers introduced their own livestock species and grazing systems. This change in botanical composition highlighted the contrast in forage availability between the seasons.

The benefits range managers can obtain from rangelands include the transformation of their palatable phytomass into animal products such as wool, hair, meat, milk, leather, and game. Efforts are therefore oriented toward increasing primary production and attenuating seasonal fodder deficiencies. Several strategies have been tested, discussed below.

First, the recovery of the perennial herbaceous stratum was studied by testing perennial grasses and forbs under local range conditions. Although a few species were successful when sown under favorable soil and climate conditions, these tended to be overgrazed by livestock and rodents, as they kept on producing green fodder when local annuals were dry. In addition, their reseeding capacities were greatly reduced due to the aggressiveness of the annuals.

The second step was to improve both yield and forage quality of the annual stratum by introducing annual legumes to correct protein deficiencies and favor grass species through soil N fixation. But once more, results were locally unsuccessful, since commercial annuals could not stand the drought, and it became clear that a long-term program was required to select or improve native germplasm.

Meanwhile, the importance of native browse resources to palliate summer/fall fodder deficiencies was noted, and the first collection of native and introduced woody species was tested. At first, emphasis was put on legumes of genera *Acacia, Adesmia, Caesalpinia, Gourliea, and Prosopis* because of their protein content. However, since range degradation requires fast solutions, saltbushes (*Atriplex* spp.) were preferred, as they display the following features:

- Vast distribution in arid environments.
- High tolerance to dryness and salinity.
- Easy propagation and field establishment.
- High growth rates once transplanted in the field.
- High fodder production.
- Fodder rich and seasonally stable in protein and carotene.
- High resistance to plague and disease.
- Satisfactory recovery after browsing.
- Long life span.

However, they do have a few inconveniences:

- Seedling susceptibility to competition.
- Energy-deficient fodder.
- Excess ash and salt contents.
- Detrimental litter effect with associated annuals in some species only.

Research Performed

Many studies have been carried out, primarily with *Atriplex repanda* and secondarily with *Atriplex nummularia*. Specific research topics are discussed below.

Seed Germination

The low germination rate of *A. repanda* seed, which normally does not exceed 1–2%, has attracted much attention since the early 1970s. Intrinsic germination factors, such as embryo maturity, fruit bracts, and testa physico-chemical properties, and their modification through various treatments, were studied. So were extrinsic factors such as time, light, temperature, soil characteristics, previous plant management, and other environmental aspects. The effectiveness of various physical and chemical seed treatments to induce germination was also evaluated. Most research on germination was undertaken by Profs. Fernández, Johnston, and Olivares at the University of Chile.

Agamic propagation

Although not used extensively, obtaining new plants from cuttings to preserve genetic identity has been successful in experimental plantations. Because of differences in initial root growth, plants obtained from cuttings require a longer establishment period in the field. Growth differences, however, disappear after a few years. About 90% successful root induction may be reached in *A nummularia* and *A. repanda* when cuttings are obtained from early to mid-spring, and consist of young twigs for *A. repanda* (Peña 1979).

More sophisticated methods, based upon the microculture of tissues from selected accessions, are being tested on different saltbush species by Silva and Cabello.

Plant density

The optimal number of shrubs per hectare depends upon the growth habit of the species and accession, the climate and soil characteristics of the site, and the objective of the plantation.

A density of 400 shrubs/ha is most often used for experimental purposes, since it prevents shrub competition. In productive plantations, densities may vary from 625 to 2,500 plants/ha, depending on soil fertility and moisture. Densities should be lower as soil conditions improve.

Plantations of 3–5 year old *A. repanda* in semi-arid central Chile produced the largest individual fodder yields when densities varied from 700 to 3,300 plants/ha.

Establishment system

Direct field seedings have been extensively used in Chile with creeping saltbush (*A. semibaccata*), but little information is available in relation to typical woody saltbushes. In an experimental plot, *A. repanda* was sown directly and, although a satisfactory stand was obtained after a few years, low germination and growth rates suggest the need for longer rest periods before browsing initiation.

With traditional plantations, either productive or experimental, young specimens (15–25 cm high) grown in nurseries are transplanted in late fall and early winter. Holes are dug along the lowest regions of contoured furrows, which help increase water infiltration and reduce competition from annuals. Transplanting is performed after an effective rainfall.

Natural reseeding is not a good way to regenerate productive plantations, since it is hard to regulate density. Besides, highly palatable young plants require a long rest period before browsing begins. The best reseeding stands often occur in dry years, when competition from resident annuals is less intense.

Production

A considerable number of experiments has been conducted to determine either total aerial biomass or partial forage and firewood yields per individual shrub or hectare. Many of these studies, however, dealt with young plantations, where plants had not reached full maturity.

Yield

Total forage phytomass from a 42-month-old plantation of *A. repanda* (Fig. 2) varied from 1 to 5 tonne DM/ha as bush densities increased from 700 to 18,500 in semi-arid central Chile (Gastó and Caviedes 1976). In arid northern Chile, a five-year-old plantation containing 35 accessions of the same species, at a density of 400 shrubs/ha, yielded from 1.1 to 2.7 tonne/ha, depending on the accession (Padilla 1986). On average, the latter produced 1.770 and 4.215 tonne/ha of total aerial biomass and forage fraction, respectively (Lailhacar and Padilla 1987).

In an *A. repanda* plantation of 400 shrubs/ha, Di Marco (1973) found that forage yield varied from 850 kg FM/ha in October, when growth begins, to 2,000 kg in January. The same author found that forage biomass did not exceed 30% total phytomass in winter, but reached 70–75% in summer.

Variability in forage yield is attributed to species, accession, climate, soil, and management strategy (Table 2). Low yields in productive plantations of *A. repanda* confirm the species' susceptibility to overgrazing because of its excessive palatability to livestock and rodents. For this reason, this saltbush species is not being planted.

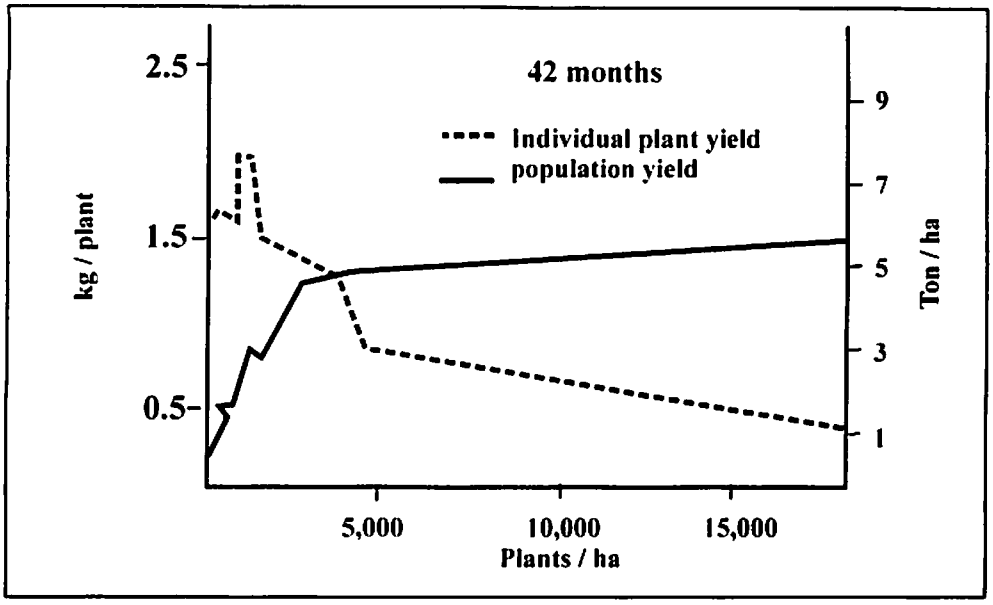

Figure 2. Effect of plantation densities on yield per *A. repanda* shrub and per hectare. Adapted from Gastó and Caviedes (1976).

Table 2. Yield of dry matter per mean shrub for total aerial phytomass, total forage phytomass, and their constituents.

	Source	TAP	TFP	LP	FFP	Region/ season
			(DM kg/shrub)			
A. nummularia						
TPH	1		1.086			IV/Win.
TPH	2		0.998			IV/Fall
Above 25 cm high	3		2.594			RM/Fall
Above 25 cm high	3		0.777			IV/Fall
Above 25 cm high	3		0.612			IV/Fall
A. repanda						
TPH	1		0.075			IV/Win.
TPH	2		0.073			IV/Fall
TPH 17 accessions	4	11.000	4.300			IV/Fall
TPH 18 accessions	4	10.100	4.000			IV/Fall
TPH > accession	5	15.500	6.800	6.200		IV/Fall
TPH < accession	5	6.000	3.300	2.500		IV/Fall
1 cm-section stem	6		1.700	0.390	0.650	RM/Sum. LD
1 cm-section stem	6		0.290	0.050	0.110	RM/Sum. HD

TAP = total aerial phytomass; TFP = total forage phytomass; LP = leaf phytomass; FFP = flowers and fruits phytomass; LD = low density; HD = high density; and TPH = total plant harvest.

Sources: 1. Gutiérrez (1990); 2. Correa (1992); 3. Garcia (1993); 4. Padilla (1986); 5. Lailhacar et Padilla (1987); and 6. Gastó and Caviedes (1976).

Wood production

Although the main benefit obtained from saltbushes is the succulent green fodder, rich in protein, once the herbaceous stratum has dried, wood may be an important source of fuel for isolated or low-income human populations living in arid rangelands.

Depending on environmental conditions and previous management, some saltbush species, such as *A. nummularia*, *A. halimus*, *A. lentiformis*, and *A. canescens*, may reach a considerable size at maturity. This excessive plant height may prevent sheep and goats from consuming all the fodder produced. Other species displaying a decumbent habit may have an excessive development in terms of diameter. These include: *A. deserticola*, *A. atacamensis*, *A. acanthocarpa*, and *A. undulata* (Lailhacar et al. 1996). In the latter species, diameter growth does not affect animal access to forage, but reduces herbage yield because of shrub interference. Since herbaceous forage is an important nutritional complement of saltbush fodder, its productivity should be favored.

The best way to correct excessive growth in height or diameter is to cut shrubs back to 25–50 cm above the ground to stimulate regrowth. This technique was tested and is being extensively used for *A. nummularia* in Chile.

Table 3. Dry firewood yield, caloric capacity, and tolerance to cutting in different saltbush species and accessions.

Species	Accession	Firewood yield (kg/shrub)	Caloric capacity (Kcal/kg wood)	Survival (%)
A. acanthocarpa	CU 600	3.61	4.362	37.5
	CU 601	7.90	4.406	37.5
A. atacamensis	CU 616	4.99	4.593	75.0
	CU 637	15.35	4.840	62.5
	CU 656	4.17	4.579	87.5
A. canescens	CU 610	10.24	4.663	100.0
	CU 687	14.42	4.639	100.0
A. clivicola	CU 602	0.88	4.623	37.5
	CU 670	1.37	4.410	12.5
A. deserticola	CU 604	7.18	4.821	50.0
	CU 651	2.26	4.542	37.5
	CU 657	4.49	4.421	37.5
A. glauca	CU 618	0.15	4.402	100.0
A. halimus	CU 688	6.72	4.586	100.0
	CU 689	12.42	4.552	100.0
	CU 690	30.61	4.472	100.0
A. lentiformis	CU 624	7.28	4.828	100.0
A. mucronata	CU 642	0.35	3.842	75.0
A. nummularia	CU 607	52.17	4.540	75.0
	CU 693	67.61	4.523	75.0
A. undulata	CU 634	17.42	4.340	87.5

Adapted from Rivera (1996).

Table 3 and Figure 3 compare firewood yield and quality for some saltbush species and accessions and provide information on their survival percentages after cutting (Rivera 1996). Despite extreme drought during the experimental period, the most productive species, such as *A. nummularia* and *A. halimus*, had satisfactory survival rates. The low variation in energetic quality suggests that selection for wood production should be based on recovery aptitude after cutting and firewood yield rather than caloric capacity.

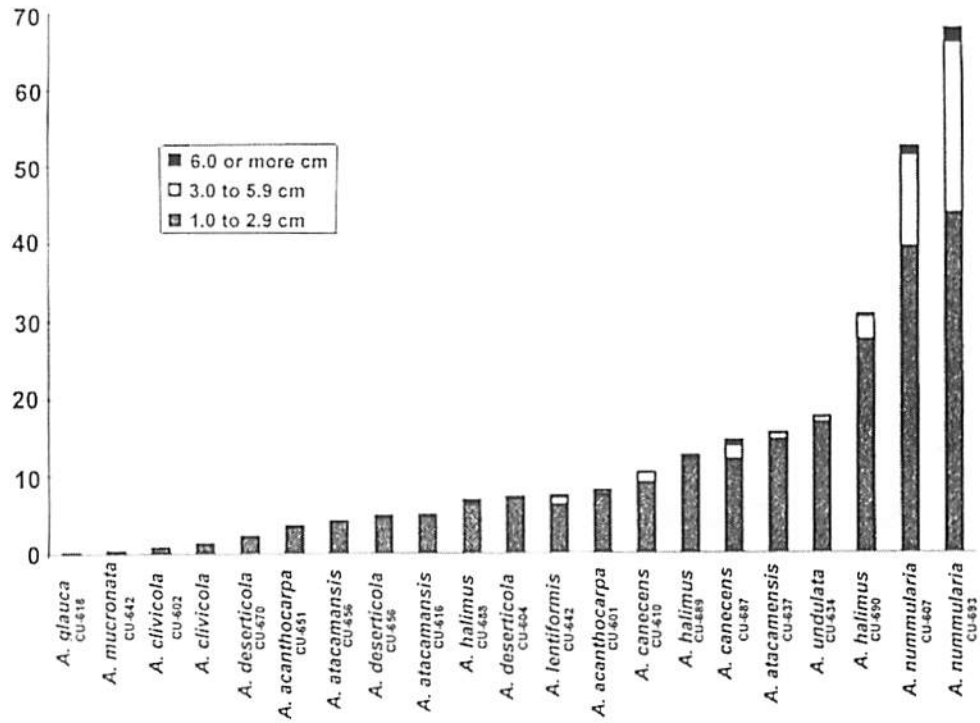

Figure 3. Proportions of wood yield for each diameter class in relation to total wood production for 21 accessions.

Equations to Predict Yield

The use of regression equations to predict fodder and firewood yields by means of allometric variables such as shrub height, canopy diameter, and their products, has been highly successful in Chile. Although this procedure needs to be validated each time it is used, because of yield differences due to saltbush age and phenology, previous management, and variations in total rainfall and rain distribution, it rapidly provides accurate yield information for the short term and prevents plant

destruction. The best parameters, or the most accurate equation models, depend mainly on plant age and growth habit (Table 4).

Table 4. Equations to predict yield of forage phytomass per shrub by means of allometric variables and their coefficients of determination.

Species and sample type	Source	Allometric variable†	Equation	r^2 or R^2
A. nummularia				
Fresh matter	1	MD (m)	$y = 851.9x^{1.5}$	0.69
Dry matter	2	MD H (m)	$y = e^{5.7} + x^{1.2}$	0.95
Dry matter	1	MD (m)	$y = 281x^{1.7}$	0.77
Dry matter	3	EA (cm)	$y = -273.8 + 0.08x$	0.96
A. repanda				
Dry matter	3	EA (cm)	$y = -2.9 + 0.01x$	0.91
Dry matter	4	P (cm)	$y = -3{,}005.5 + 11.7x$	0.66
Dry matter	4	P (cm)	$y = -4{,}795.9 + 15.1x$	0.79

† MD = mean diameter; H = height; EA = Elliptical area; and P = perimeter.
Sources: 1. Garcia (1993); 2. Correa (1992); 3. Gutiérrez (1990); and 4. Padilla (1986).

Since firewood yield is less variable and less dependent on rainfall than fodder, equations to predict wood are more accurate and stable (Table 5).

Table 5. Selected equations to estimate wood yield (kg) of dry matter for each accession and their coefficients of determination (r^2 or R^2).

Species	Accession	Equation		
		Model	Equation statement†	r^2 or R^2
A. acanthocarpa	CU 600	Linear	$y = +0.125+0.313Vol$	0.94
	CU 601	Geometric	$y = +0.184Vol^{1.260}$	0.84
A. atacamensis	CU 616	Geometric	$y = +0.113Vol^{1.222}$	0.88
	CU 637	Exponential	$y = +1.946e^{0.061Co}$	0.73
	CU 656	Exponential	$y = +0.082e^{0.703D_1}$	0.86
A. canescens	CU 610	Geometric	$y = +0.687D_1^{1.791}$	0.59
	CU 687	Linear	$y = -0.872+0.402Vol$	0.99
A. clivicola	CU 602	Linear	$y = -1.553+2.861H$	0.38
	CU 670	Exponential	$y = +0.191e^{0.259Vol}$	0.89
A. deserticola	CU 604	Geometric	$y = +0.017Vol^{1.624}$	0.93
	CU 651	Geometric	$y = +0.028D_1^{2.882}$	0.67
	CU 657	Linear	$y = -2.076+0.226Vol$	0.60
A. glauca	CU 618	Exponential	$y = +0.004e^{1.118D2}$	0.61
A. halimus	CU 688	Exponential	$y = +2.494e^{0.037Vol}$	0.77
	CU 689	Geometric	$y = +0.963D_1^{1.471}$	0.91
	CU 690	Exponential	$y = +3.939e^{0.364D2}$	0.77
A. lentiformis	CU 624	Geometric	$y = +0.914Vol^{0.837}$	0.78
A. mucronata	CU 642	Linear	$y = -0.060+0.095Vol$	0.94
A. nummularia	CU 607	Linear	$y = +2.549+1.126Vol$	0.90
	CU 693	Exponential	$y = +10.991e^{0.649H}$	0.80
A. undulata	CU 634	Geometric	$y = +0.108Vol^{1.369}$	0.94

† Allometric parameter selected: DI = north–south parameter; D2 = east–west parameter; H = height; Co = cover; Vol = volume.

Soil–plant relations

Before adult saltbush specimens were available in extensive plantations, studies to define their soil requirements were conducted in greenhouses. Seedlings were grown in pots with different soils whose variables had been analyzed previously. Through multiple regression analysis, yield was related to soil variables. In California, both *A. polycarpa* and *A. repanda* were positively related to P and N content (Lailhacar 1976), while in Chile, the latter species was related to N only (Gargano 1978).

Similar studies on plantations related soil variables to forage yield or nutritive characteristics in mature specimens of *Atriplex nummularia* and *A. repanda*. Soil variables succeeded in explaining up to 80% of shrub responses. While $Na^{+}SO_4^{-}$ and Cl^{-} concentrations in the shallow soil layer were positively related to yield in the first species ($R^2 = 0.89$), organic matter, pH, NH_4PT+PT, and deeper soil profiles were positively related to the second ($R^2 = 0.82$) (Correa 1992). Results for forage quality were not as accurate.

Field Fertilization

Although soil characteristics should be considered when deciding where to plant saltbushes, field fertilization is not encouraged due to its excessive cost and weak response under arid rangeland conditions.

Using the pressure-relative water deficit technique, Silva is studying internal water relations, seasonal as well as inter-annual variations of maximum and minimum water potential, osmotic pressure, and tissue elasticity in five saltbush species and eight accessions. Plant behavior for water relations and physiological fundamentals is highly specific, and for *A. halimus* may even vary among accessions. Maximum water potential varies from -1.4 to -2.8 MPa, while minimum water potential varies from -2.9 to -4.1 MPa. Most germplasm studied succeeded in adjusting its tissue-osmotic potential, despite the drought. In *A. canescens* and *A. atacamensis*, the osmotic potential at maximal turgescence was -4 MPa. The highest cell-wall elasticity was measured in *A. nummularia*.

Water–Plant Relations

In terms of transpiration efficiency (CO_2 fixed per unit of water transpired), the same author found levels within the range proper to C4 plants, although results varied among species. The highest ratio, 7.7 µMol CO_2 per mMol water, was measured in *A. atacamensis* in spring, and the lowest (2.2) in *A. canescens*. During the dry season these values decreased, due to water stress and stomata closure.

Effect of Saltbush on Soil

Field studies with mature shrubs of *A. nummularia* and *A. repanda* at low stocking rates have shown that litter deposition is much higher in the first species because of its abundant leaf production and lower palatability (Gutierrez 1990). In *A. nummularia*, mean litter cover was 23 and 78% at opposite radial transects beginning at the trunk, while in *A. repanda* it varied from 12 to 19%. Variation within each species was due to wind effect. Although both species induce a significant increase in soil pH, the litter produced by oldman saltbush has a larger effect on pH, due to its thickness and NaCl content.

After 12–15 years, *A. repanda* shrubs significantly affect all soil chemical variables. Particularly important among the favorable features are the N, P, and K increments (Lailhacar et al. 1989). Among the undesirable features are Cl^-, Na^+, and EC, because of their relationship to salinity.

Effect of Saltbush on the Herbaceous Stratum

Olivares and Gastó (1981) observed a decrease in herbaceous phytomass associated with a young *A. repanda* plantation as densities were increased up to 800 shrubs/ha. However, adult saltbushes favored a larger herbaceous phytomass and cover close to the canopy. This is due to their effect on soil fertility, to temperature, and to water balance. In the Southern Atacama Desert, where shrubs contribute to the accumulation of soil particles transported by wind, Lailhacar (1986) demonstrated the positive effect of *A. deserticola* on the density of ephemeral seedlings. Lailhacar et al. (1989) also measured the positive residual effect of *A. repanda* on soil fertility and its herbaceous response, even after shrubs had been removed and the soil plowed.

Nutritive Value

The main merit of saltbush fodder consists of its high N concentration and stability during the annual cycle.

As shown in Table 6, many studies have established the nutritive value of different *Atriplex* species; however, only Silva and Pereira (1976) refer to their amino acid composition. These authors conclude that both *A. nummularia* and *A. repanda* have satisfactory proportions of amino acids in their fodder, except for methionine, which just reaches the lowest level required.

Table 6. Mean nutritive values obtained from native and introduced saltbush species in Chile.

Species	Ash (%)	NaCl (%)	OMD (%)	BE (Mcal/kg)	CW (%)	CP (%)	Ca/P (%)
A. acanthocarpa	28.8		56.6			18.4	
A. atacamensis	31.7		60.4	3.2	30.0	16.4	
A. canescens	19.1		58.6			18.1	
A. cinerea	28.2		57.4			20.3	
A. clivicola	27.6		54.1	3.3	31.8	12.8	
A. costellata	24.8		59.8	3.3	34.8	17.8	
A. deserticola	31.0		65.6	3.2	31.4	13.8	
A. glauca	19.3		54.0			18.4	
A. halimus	29.3		59.6			20.8	
A. imbricata	19.8		54.9	3.8	42.3	11.5	
A. mucronata	28.9		56.4	2.9	41.6	10.7	
A. nummularia	26.0	9.5	61.6		38.8	11.5	6.8
A. repanda	18.8	4.1	59.3	3.6	32.6	16.8	10.0
A. rhagodiodes	22.8		60.6			18.4	
A. undulata	23.6		50.2			17.0	

OMD = organic matter *in vitro* digestibility; BE = brut energy; CW = cell wall; CP = crude protein.

Source: Correa (1992); Garcia (1993); Gutiérrez (1990); Lailhacar (1986, 1990, and 1992); Lailhacar and Padilla (1987); Lailhacar et al. (1993); Padilla (1986).

Di Marco (1973) observed that sheep fed on *A. repanda* associated with resident annuals consumed a ratio of 15% protein, 13% lignin, and 21% cellulose. When only saltbush fodder was available, concentrations were 20, 7, and 13%, respectively. The seasonal mean variations of some nutritive parameters in 35 accessions of *A. repanda* studied by Padilla (1986) are shown on (Table 7).

Table 7. Mean seasonal variations in the percentages of crude protein, *in vitro* digestibility of organic matter, and ash in the forage of 35 accessions of *A. repanda*.

Nutritive variable	Sampling term			
	March (%)	June (%)	September (%)	December (%)
Crude protein	14.9	20.9	26.5	16.9
OM digestibility	47.1	63.3	74.9	53.4
Ash	13.4	15.6	17.8	14.9

Adapted from Padilla (1986).

Although the protein content of *A. repanda* shows a strong decrease during the dry period—summer and fall—when its fodder is principally required, the level is still enough to maintain ratios in sheep and goats. The increasing percentages of protein in June warrant a satisfactory input for ewes in advanced stages of pregnancy.

In a similar study in Chile, Lailhacar et al. (1993) used the same variables and experimental terms to compare 13 saltbush species and 25 accessions, native and introduced. Except for *A. cinerea* and one accession of *A. nummularia*, which had

uniform percentages of crude protein throughout the year, all species showed a tendency similar to *A. repanda* in Table 7. *Atriplex glauca* was the only species to exceed *A. repanda* in crude protein in September (27.7%). Differences among accessions belonging to the same species were notorious, particularly in *A. canescens*.

The highest seasonal variations in OM digestibility were detected in *A. repanda*, *A. acanthocarpa*, and *A. undulata*. The highest ash percentages were found in *A. halimus*, *A. deserticola*, *A. acanthocarpa*, and *A. cinerea* (above 27%), while the lowest were in *A. repanda*, *A. canescens*, *A. glauca*, and *A. imbricata*.

Consumption and Palatability

Saltbush consumption by livestock does not necessarily depend on the content of traditional nutritive variables. Garcia, Lailhacar, and Azócar (unpublished data), who are looking for chemical indicators of animal preference, validated a set of equations to estimate goat consumption as a function of twig and stem diameter in 11 species and 21 accessions of *Atriplex* during an eight day trial. They observed that, excluding *A. repanda*, the most consumed species were *A. undulata* and *A. clivicola*, while *A. deserticola* and *A. lentiformis* were not browsed.

Table 8. Amount of fodder dry matter from saltbush species and accessions consumed by goats (unpublished data).

Species	Accession	Consumed forage (g of accumulated DM)			
		2 days	4 days	6 days	8 days
Atriplex acanthocarpa	CU 600	0.00	0.00	0.00	1.05
	CU 601	0.00	6.82	12.18	16.73
Atriplex atacamensis	CU 616	1.57	14.70	14.70	17.29
	CU 637	1.45	11.71	63.04	75.88
	CU 656	0.00	4.81	4.81	18.38
A. canescens	CU 610	0.00	10.77	67.65	107.61
	CU 687	0.00	26.11	53.75	54.05
A. clivicola	CU 602	0.00	0.00	95.92	118.16
	CU 670	0.22	2.19	28.99	38.56
A. deserticola	CU 604	0.00	0.00	0.00	0.00
	CU 651	0.00	0.00	0.00	0.00
	CU 657	0.00	0.00	0.00	16.00
A. glauca	CU 618	21.88	28.51	28.51	46.45
A. halimus	CU 688	0.0	0.00	2.33	4.65
	CU 689	0.00	0.95	2.12	2.12
	CU 690	0.00	2.00	3.22	11.39
A. lentiformis	CU 624	0.00	0.00	0.00	0.00
A. mucronata	CU 642	44.98	44.98	48.25	48.25
A. nummularia	CU 607	3.89	29.55	36.67	62.31
	CU 693	37.73	39.73	55.95	69.57
A. undulata	CU 634	71.64	182.29	184.56	184.56

The amount of dry matter consumed in each accession (Table 8) was related to the percentage of favorable variables, such as crude protein and enzymatic digestibility, and to unfavorable ones such as percentage of ash, oxalates, tannins, and NaCl (Table 9). At the end of the trial, the percentage of crude protein was positively related to forage consumption, while percentages of tannin and NaCl were negatively related.

Olivares and Gastó (1981) found that a plantation of *A. repanda* (400 shrubs/ha) in semi-arid central Chile provided 4.3 tonnes of total forage dry matter. However, sheep only consumed 2.6 tonnes. As sheep always eat the shallowest forage available on the shrub, the initial intake consists mainly of fruit, but as time goes on, leaves and finally twigs and stems will successively dominant their diet.

Table 9. Content of protein (Prot), ash (Ash), oxalales (Oxal), tannins (Tann.), NaCl, and enzymatic digestibility (ED) in forage samples of different *Atriplex* species and accessions (unpublished data).

Species	Accession	Prot (%)	Ash (%)	Oxal (%)	Tann (%)	Na Cl (%)	ED (%)
Atriplex acanthocarpa	CU 600	6.30	19.5	0.94	1.93	10.2	48.5
	CU 601	6.40	18.8	1.51	1.86	9.0	45.2
Atriplex atacamensis	CU 616	5.55	14.3	1.03	1.26	9.3	33.3
	CU 637	5.70	13.5	0.62	1.79	6.3	42.7
	CU 656	5.55	14.0	0.82	2.28	7.0	38.0
A. canescens	CU 610	6.15	12.0	1.04	2.41	1.5	48.4
	CU 687	6.90	7.0	0.92	1.29	0.6	31.5
A. clivicola	CU 602	8.10	12.0	1.66	1.98	5.2	47.4
	CU 670	6.00	12.8	0.91	2.20	5.0	39.0
A. deserticola	CU 604	6.25	21.5	1.40	2.20	9.4	45.2
	CU 651	6.15	17.0	1.04	3.20	8.6	47.0
	CU 657	7.70	16.0	0.80	2.39	9.0	47.7
A. glauca	CU 618	6.20	14.0	1.47	1.57	6.3	49.0
A. halimus	CU 688	6.70	16.0	1.04	2.39	9.0	37.2
	CU 689	5.95	11.0	1.35	2.24	7.3	26.2
	CU 690	5.20	15.5	1.04	1.80	8.6	30.8
A. lentiformis	CU 624	7.80	14.5	1.20	2.10	8.9	44.5
A. mucronata	CU 642	7.25	15.2	1.03	1.49	5.4	48.2
A. nummularia	CU 607	9.30	19.5	1.36	1.37	8.9	56.3
	CU 693	8.50	17.5	1.36	1.88	10.9	47.5
A. undulata	CU 634	7.10	12.5	1.04	2.06	7.5	37.0

Animal Production Using Saltbushes

As shown in Figure 4, Concha (1975) obtained higher weight gains when lambs were fed on rangeland reinforced with *A. repanda* than on pure herbaceous range. Mean lamb weights were 41.06 kg in the first case, but only 34.25 kg in the second.

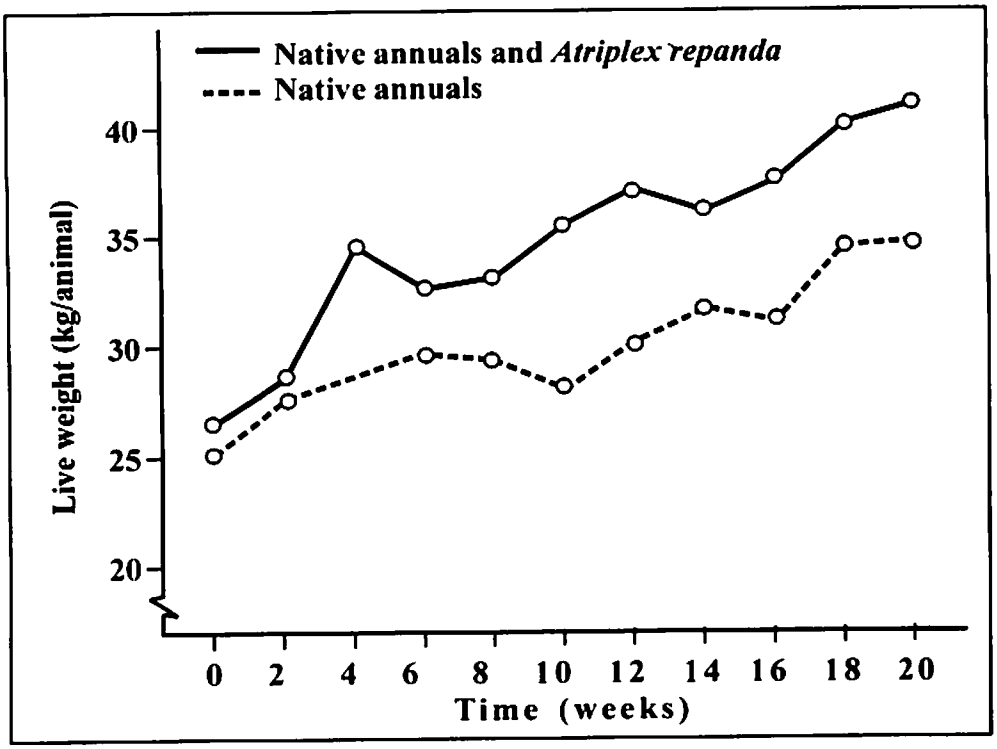

Figure 4. Weight gains in lambs fed on a pure annual-type rangeland vs annual-type rangeland planted with *A. repanda*. Adapted from Concha (1975).

The carotene that saltbush forage provides when most herbaceous species are dry contributes to the stimulation of ovulation in ewes. Olivares and Gastó (1981) found lambing concentration and twin lambing from 11.7 to 32.3% when mating occurred in areas planted with *A. repanda.*

Saltbush Management

In order to define the best browsing terms for *A. repanda* on a physiological basis, Pagliaricci et al. (1984) and Olivares et al. (1986, 1989) determined the organs where total-non-structural carbohydrates are seasonally stored. While roots provide carbohydrates during florescence, young green stems and twigs do so at both vegetative growth and fructification. Therefore, to protect carbohydrates stored in stems and favor satisfactory regrowth in the spring, fall browsing should not be intensive. Flowering is the best browsing term during the growth stage. According to Olivares et al. (1989), defoliation may alter the phenological stages of *A. repanda.*

As for cutting to reduce shrub size or to harvest firewood, Garcia (1983) concludes that shrubs should be cut 25 cm above the soil for *A. nummularia*. Shrub survival was significantly affected when cut at soil level. Higher cutting reduced wood yield and made browsing difficult. The same author points out that early winter is the best time to cut *A. nummularia* shrubs without reducing their rate of regrowth.

Shrub Selection

Germplasm selection depends mainly on the user's objectives; however, the following should also be considered:

- Selection for high palatability is not advisable for extensive plantations, unless saltbushes are to be harvested for soiling.
- Due to the previous point, plantations of saltbush mixtures are difficult to manage, unless all species have similar palatability. When vegetation diversity is required for shed, windbreak, or other purposes, it is better to plant other woody species associated with saltbushes.
- Dry matter yield is more important than protein concentration in the forage, since most species have similar N contents, while yield may vary.
- Selection for alternative firewood production should favor wood yield rather than caloric value.
- Since litter produced by some *Atriplex* species may interfere with herbage production and cause a spotted salinity pattern in the soil, such species should be discarded, unless litter accumulation can be controlled through adequate browsing or soiling practices.
- Carbohydrate-storage dynamics are important when selecting the best germplasm, depending on use and defoliation intensity.

Saltbush and Animal Production

Saltbush plantations are not expected to increase milk, meat, or wool yields during the productive season. This is the job of herbaceous species. The role of saltbush is to provide green and succulent fodder, rich in protein, during the dry season, to prevent or reduce animal and weight losses. However, this is not always what goats and sheep herders expect from their plantations, and continuous or long-term grazing has often caused total or partial stand losses.

In spite of the current four year drought, the drastic diminution of tranhumance to Andean meadows, and rangeland mismanagement, *Atriplex nummularia* plantations keep on growing in the Chile IV region (Soto 1995):

1975–1979	=	5,898 ha
1980–1984	=	21,621 ha
1985–1989	=	10,351 ha
1990–1994	=	9,765 ha
Total	=	47,635 ha

This sustained increase, however, is due largely to a government subsidy to stimulate afforestation. When 75% of transplanted shrubs are established, the State reimburses total plantation expenses.

Besides forage production, saltbushes, like any other shrub species, may play other roles in ecosystem dynamics. Although some of these roles have already been mentioned, they are summarized below.

First, low woody vegetation is the climax expression of most Mediterranean-type ecosystems—matorral, chaparral, garrigue, quenopodlands, etc. Thus, its presence should not be considered an indicator of degradation, as would be the case for other types of biomass, such the bush encroachment in mismanaged grassland formations.

Second, the presence of polystratified vegetation is a good warrantee of efficient use of nutrients and water resources in the soil and of energy resources above it. Even though the resulting larger biomass might not be palatable, it may play many important roles in terms of livestock, wildlife, or ecosystem equilibrium.

Among these roles are:

- The nutrient pumping effect performed by lignified roots in favor of shallow-rooted herbaceous species.
- Protection from low temperatures and dehydration of herbaceous species.
- Protection from overgrazing of reproductive organs—flowers, fruits, and seed—in herbaceaous species.
- Provision of shade for livestock and wildlife. The adequate distribution of woody elements in the field favors uniform grazing.
- Windbreak for soil and livestock.
- Recreation and landscaping.
- Increased vegetation diversity, which favors ecosystem equilibrium as well as increased productive alternatives.

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Discussion: International Experience with Fodder Shrubs

Chair: G. Gintzburger (ICARDA)

Rapporteur: A. Nefzaoui (Tunisia)

M. Ismaili (Morocco): Do you think that alley cropping with *Atriplex nummularia* and a cereal is sustainable in terms of nitrogen and phosphorus nutrition, since *Atriplex* and cereals are highly demanding of N and P?

Answer by H.N. Le Houérou (France): It may be so, but we do not have enough experience in this field to form an educated opinion. It may well be that increased organic matter and more stable soil structure will compensate. So far I have not seen the shrub having a depressive effect on the crop, but it may be different in the long term.

H.S. Oushy (Egypt): Why hasn't *Atriplex canescens* been widely incorporated into range plant communities in WANA? Are you in favor of *Atriplex canescens* or not?

Answer by H.N. Le Houérou (France): Yes, I am in favor of *Atriplex canescens*. However, suitable ecotypes should be identified for each ecological site in WANA.

C. Malcolm (Australia): What is the reaction of the land users? Will they use shrub plantations without financial help? If not, what criteria does the government use to give financial or other help?

Answer by V. Papanastasis (Greece): In southern Europe, land users will not plant fodder shrubs without some kind of financial support. Donating free seedlings is one type of support. The government benefits from the reduction of imports needed to supplement animals with high-quality feed.

M. Elmzouri (Morocco): 1) Total biomass production in the maquis ecosystem is low; is it possible that yield per plant is low but yield per hectare is higher? 2) Does the effect of prescribed burning favor soil erosion after the burning, because the soil is bare?

Answer by V. Papanastasis (Greece): 1) Yes, but I was speaking about edible biomass and grazing capaciy, and these are lower in maquis than in garrigue. 2) In semi-arid and sub-humid areas, prescribed burning is not dangerous, but I have no experience about its effects in arid zones.

P. Masson (France): What are the potential uses of *Chamaecytisus palmensis*, which seems productive, drought-resistant, and has good re-growth capacity after cutting?

Answer by V. Papanastasis (Greece): I think that the limiting factor is winter cold. But we do not have enough experience or information about this in southern Europe.

Hassan M. Elshaer (Egypt): 1) How do you define the arid and semi-arid zones? 2) Shouldn't shrubs as animal fodder be tested for degradation of crude protein and crude fiber components, and anti-nutritional factors, i.e. *saponines*, *tannin*, etc.?

Answer by V. Papanastasis (Greece): 1) According to the classification proposed by H.N. Le Houérou, semi-arid areas receive more than 400 mm annual rainfall, while arid areas receive less than that. 2) Yes, and some of the cultivated fodder trees and shrubs in southern Europe have low degradability of crude protein and crude fiber components (e.g. *Atriplex nummularia*).

T. Daoudi (Farmer, Morocco): Do shrub plantations affect negatively the stand of native species? If so, do they affect meat and milk quality of grazing animals, and is there any soil effect?

Answer by S. Lailhacar (Chile): Interaction with native and naturalized herbaceous species is now being studied. This effect depends mainly on the species and its management. Most saltbushes, however, favor and protect annual growth and reseeding. We only use shrubs during the dry season. They are not important in terms of production, the latter is the role of the herbaceous stratum.

B. Boulanouar (Morocco): We have to be cautious not to over-interpret the laboratory data to predict the feeding value of shrubs, but must rather emphasize the use of shrubs with other diet components, and consider expected production from these diets.

Answer by S. Lailhacar (Chile): I agree with your opinion. This is why we are studying the effects of secondary products such as NaCl, tannins, and oxalates, and are trying to analyze the effects of saponin over time.

E. Thomson (ICARDA): 1) Would it be more appropriate to express wood production per hectare, rather than per plant, given that different species need different densities? 2) What is the extent of the transfer of shrub technology to farmers, and how have they accepted it?

Answer by S. Lailhacar (Chile): 1) You are right. Experiments were performed with a 400 plant density for all species; this is the reason why data were provided per shrub. In productive plantations, however, density depends upon species and

accession. 2) Much technology is still under experimentation and has not been transferred. However, we have already succeeded in planting 47,000 ha with shrubs (mainly *A. nummularia*), and most plantations are well managed in spite of three difficult years of drought.

V. Papanastasis (Greece): Under your conditions in Chile, would it be more economical to control grazing and thus favor the growth of spontaneous woody species, including woody legumes, instead of planting saltbushes?

Answer by S. Lailhacar (Chile): I do not think so, as we do not have many palatable species among our native shrub species, although I agree about the convenience of favoring our native plants. We are already studying them. As a short-term solution, introducing shrubs such as *Atriplex* spp. is quite satisfactory.

K. Tadros (Jordan): 1) What parameters are used in estimating production of fodder shrubs, using non-destructive methods? 2) The slide from Brazil showed good stands of *Atriplex nummularia*, but clear bare soil between rows. What about native vegetation, is it grazed or cleaned, or does this imply (if grazed) something about the palatability of *A. nummularia*?

Answer by Lailhacar (Chile): 1) Shrub diameters and height. 2) You are right, but the Brazilians had removed all associated species just before I visited the experimental plot. It would have been useful to maintain some areas with local vegetation to check for differences.

E.B. Labiad (Farmer, Morocco): 1) Do the effects of shrub planting have an impact on understory (herbaceous) productivity? 2) What would be the effect of such a change on animal production?

Answer by S. Lailhacar (Chile): 1) Yes, it does, but this depends on the saltbush species and its management. Generally speaking, herbaceous species are favored because of nutrient recycling and protection from high temperatures, etc. 2) As far as herbaceous species are concerned, the effect is favorable. The problem occurs when some species, particularly *A. nummularia*, are under-grazed and litter accumulation interferes with the growth of annuals.

P. Masson (France): Do you have any information on the water table level after planting shrubs?

Answer by C. Malcolm (Australia): There is a paper on this subject in the *Journal of Hydrology* 45: 313–319 (1980), and on the use of water by forage shrubs. Groundwater levels were not recorded. There are also reports by farmers who have planted large areas (100–300 ha) of shrubs on areas with shallow saline groundwater. Observations show that groundwater was lowered on the order of one

meter. I am not aware of scientific studies on water table lowering due to shrub planting.

S. Lailhacar (Chile): What is your opinion of the effect of saltbush use on wool quality (contamination by weeds/goodrones).

Answer by C. Malcolm (Australia): Farmers report that the wool from sheep grazing shrubs is cleaner than wool from sheep grazing annual pastures, which usually has more dust and rubbish. Farmers also report that under their management (supplementing the shrubs when needed), there is little or no contamination of the wool. Mr. Lloyd gave figures to show that sheep grazing shrubs for about three months gave a higher wool return per head than sheep receiving supplementary feeding on annual pasture and stubble.

E. Thomson (ICARDA): Is there any possibility of salt-affected land being returned eventually to wheat/cereal or other crop production, as the result of grazing salt-tolerant shrubs?

Answer by C. Malcolm (Australia): I know of one farmer who grew *Mairiana brevifolia* on saline land, and after many years, plowed in the shrubs and grew barley. He reported a yield increase of at least four fold. But he believed the land had the potential to become salty again and returned to *M. brevifolia*, which he valued highly for his sheep. In general, I do not believe halophyte shrubs planted on salt-affected areas will return the land to wheat production. The possibility of alley cropping has not been studied. It is necessary to plant perennial species and change cropping practices on recharge areas that cause shallow water tables and result in the return of salinity.

H.S. Oushy (Egypt): What do you think is the best way for us to start, in order to get a wide range of germplasm tested and selected under WANA condition?

Answer by C. Malcolm (Australia): To get a really good germplasm collection, it is necessary to arrange plant exploration/collection missions, and the full passport data for the accessions should be recorded. There is a need to search for the original good species that have been largely eliminated from heavily used ranges, to multiply them, and to include them in selection programs. I also suggest cooperating with IPGRI and with Australia directly.

K. Tadros (Jordan): Talking about palatability of shrubs, in a study on the effect of intensity of grazing on *Atriplex nummularia* in Jordan, I noticed in one plot that some shrubs were grazed heavily while others were not touched. I analyzed samples of both for saponin and found no difference. Please comment more on this palatability issue.

Answer by H.N. Le Houérou (France): So far, no correlation has been found between palatability and biochemical traits. The saponin hypothesis may be wrong; we need more research.

A. Abdelguerfi (Algeria): 1) Vous n'avez rien dit sur le Frène (*Fraxinus* spp.) ; n'est-il pas très utilizé en Europe? 2) Ne faut-il pas rechercher des arbres et des arbustes à double fin (fourrage et utilization humaine) comme, par exemple l'Arganier au Maroc. Un tel choix (espèces médicinales, aromatiques, alimentaires, et en même temps fourragères) permettra le maintien des arbres et des arbustes dans les régions où la pression, animale and humaine, est forte.

Answer by V. Papanastasis (Greece): 1) *Fraxinus* spp. are very good for animals but slow growing and therefore not a priority in southern Europe. 2) Yes, I consider other uses of fodder shrubs and trees very important, but I did not have time to discuss them in my presentation.

P. Masson (France): Ne faudrait-il pas être moins catégorique sur la séparation des espèces d'arbustes. Si la gestion commune est possible, on peut peut-être imaginer des associations à bénéfices réciproques.

Answer by H.N Le Houérou (France): Pas d'objection s'il n'y a pas de conflit de gestion ; mais le plus souvent il y a conflit de gestion et d'écologie entre espèces d'arbustes. Mais il est naturellement désirable d'avoir plusieurs espèces mais dans des champs différents, sur des sols différents.

A. Abdelguerfi (Algeria): Il me semble que vous privilégiez les espèces à port rampant. Dans nos régions, la pression de pâturage est très importante, les espèces à port dressé semblent plus résistantes.

Answer by S. Lailhacar (Chile): Pas necéssairement. Autant les espèces à excès de hauteur comme celles à excès de diamètre doivent être coupées. Dans le cas des dernières, l'excès de croissance en diamètre empêche la croissance des herbacées indispensables pour équilibrer le régime alimentaire du troupeau.

B. Boulanouar (Morocco): Is there any long-term effect of planting *Atriplex* on soil fertility (organic matter, nitrogen) and salinity, with specific differences between cut-and-carry and direct use?

Answer by G. C. de Kock (South Africa): In South Africa, no significant difference between Na, Cl, and sodium absorption ration (SAR) for saltbushes and the natural range after 100 years was observed. Cut-and-carry systems reduce the Na, Cl, and SAR after 10 years under this system.

E. Correal (Spain): Could you give more details of your work on selection of oldman saltbush (*Atriplex nummularia*) for cold-tolerance (temperatures down to -10/-11°C)? What was the altitude?

Answer by G. de Kock (South Africa): Field selection was at an altitude of 1,500 m, during the winter. Day temperature was 18–20°C. Night temperature was -8 to -10°C.

H.N. Le Houérou (France): Could G. de Kock explain to us how *Agave americana* (American aloe) is managed and used in South Africa? In North Africa, it is known and used as an ornamental hedge, not as fodder.

Answer by G. de Kock (South Africa): Transplant *Agave americana* from root suckers 500 mm height. Plant 2 m apart in rows 3–10 m apart. Plant on the contour. Harvest before flowering. Remove the top spike and thorns on the edge of the leaf. Cut leaves in slices of 25–30 mm. Feed to sheep and cattle. Add 1% feed lime to prevent acidose.

M. Bounejmate (ICARDA): Several speakers stressed the differences between WANA countries and other parts of the world. Could you tell us how and in which areas WANA and other parts of the world could join efforts for mutual benefit?

Answer by H.N. Le Houérou (France): Use better-adapted plants from other regions for more cold-tolerance (*Atriplex canescens*, *Opuntia robusta*, *O. fusicaulis*, etc.). Use establishment techniques that are cheaper: direct seeding, bare-root transplanting, pre-germinated seeds, and pelleted seed that bring down the cost of establishment by 50–70%.

Answer by G. de Kock (South Africa): Select the species best-adapted to your conditions. Use soil and climate criteria so that you get seed of good quality of the species required. Use the most cost-effective seed technique proven under local conditions. Consider pelleted seed to lower the cost of establishment.

M. Tazi, Morocco: I would like to ask G. de Kock how much rainfall you are getting in areas where direct seeding is practiced, with seed treated before seeding.

Answer by G. de Kock (South Africa): Direct seeding is practical with summer rainfall of 220–320 mm in normal years, and winter rainfall of 140–250 mm. Length of the rainy season is also important.

National Experience with Fodder Shrubs

A Study on the Syrian Steppe and Forage Shrubs

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Introduction

The steppe is a large expanse with an average annual rainfall of no more than 200 mm. Since ancient times, pastures have been a part of life throughout most of the Arabian Peninsula, and, at its northern reaches, the Syrian steppe. Rangelands, on which weeds and fodder shrubs grow spontaneously, are the main source of animal feed. Such pasture provides free feed to about 60% of the sheep in Syria, some 10.5 million head in 1994.

The steppe land is owned by the State. Norms and customs, however, have established some rights of use for villages and tribes on certain areas. Common grazing, without any regulations, limitations, or management of the vegetation cover, has been the custom in the steppe. Sheep move from one place to another, grazing various kinds of fodder plants at will. This overgrazing has resulted in the extinction of many desirable plants, and the dominance of less-palatable plants. Such pastures are no longer able to satisfy the needs of sheep for fodder. This situation has been aggravated by the random cultivation of vast areas, which once made up the best pastures, by woodcutting, and by the random opening of roads. This has resulted in the destruction of a large part of the vegetative cover in the steppe, leaving the soil vulnerable to erosion and other desertification factors. Rainfall crops are not economically feasible, because of low rainfall that fluctuates from year to another, as well as the low fertility.

To maintain such rangelands, which exist under drought conditions, extensive effort and time are needed to overcome the factors that led to the degradation, develop them, protect livestock, and increase productivity. It is imperative to pay more attention to the people living in the steppe: about 600,000 nomads and sheep owners.

Environment and Topography

The average altitude of the steppe is 400 m asl, lower in the valleys and higher in the mountains. Lands include undulating valleys, rolling areas with many depressions, low hills, and high mountains. The land profile is characterized by local topographies, including dry depressions covered with thick precipitates carried over from the neighboring low hills. Aggregate soils appear on the

periphery of such depressions, where rainwater from the hills gathers to form temporary lakes that soon evaporate.

Area

The steppe makes up about 58% of the total area of Syria, some 10.2 million out of 18.5 million ha, distributed as follows:

- Steppe of Damascus Province: 81% of the province; 14% of the steppe.
- Steppe of Homs Province: 90% of the province; 35% of the steppe.
- Steppe of Aleppo Province: 12% of the province; 0.5% of the steppe.
- Steppe of Hama Province: 27% of the province; 2% of the steppe.
- Steppe of Raqa Province: 73% of the province; 13% of the steppe.
- Steppe of Hasakeh province: 10% of the province; 2% of the steppe.
- Steppe of Deir Ezzor Province: 96% of the province; 30% of the steppe.
- Steppe of Dara Province: 16% of the province; 3% of the steppe.

Rainfall

The Syrian steppe lies in stability zone 5, with rainfall less than 200 mm/year. The rainy season starts in October and ends in May. Rainfall in the steppe fluctuates over time and space, and is affected by the mild Mediterranean climate, which is characterized by low winter rainfall. This makes rain-dependent crops and pastures vulnerable to atmospheric and land droughts. In general, rainfall decreases from the northwest to the southeast. There are two types of rainfall: (i) low but well-distributed rains that help annual plants with surface roots to grow; and (ii) high daily rains that occur once or twice a year or only in some years, which help trees and fodder shrubs to be established.

Temperature

Temperature increases towards the southeast. The maximum absolute temperature ranges between 38 and 45°C, and minimum absolute temperature between 8.6 and 11.5°C. Solar energy is one of the most important alternative sources of energy available in the Arab steppes (due of course to its abundance). It is a constant and clean alternative to fuelwood. This is important, since nomads burn shrubs (branches and roots) for domestic use, and woodcutting is one of the causes of rangeland degradation.

Relative Humidity

Humidity is low and does not exceed 50%. It drops to 10% when the hot *khamaseen* winds blow. Humidity is more stable in the high-altitude areas and decreases gradually southward. Relative humidity undergoes daily changes, with maximum and minimum values before sunset and after midday, respectively.

Wind

Western, southern, and eastern winds dominate the steppe in winter, while southeastern winds dominate in summer. The most severe winds, with an annual average of wind speed of 4.2 m/s, blow around Palmyra, followed by Tanf, and Bu-Kamal. These winds severely damage the soil, causing extensive soil erosion. Wind speed increases during the summer and reaches its highest monthly rate, 5.7 m/s, in July. The lowest rate, 1.2 m/s, is in November. Winds are the main cause of desertification, especially in cultivated areas. The vegetation cover disappears completely in summer, making it easy for wind erosion to occur.

Soil

The soils of the Syrian steppe are mostly loamy with a poor structure. They are generally high in calcium carbonate, and are often gypsiferous. They are poor in nitrogen, phosphorus, and organic materials.

Farming Systems and Land Use

Legislative Decree No. 140 of 1997 was enacted to regulate the use of the steppe, amending Law No. 13 of 1973 on the use of non-irrigated steppe lands. The law prohibits acquiring rights on steppe lands after the date of its enactment, and maintains the rights of individuals claimed before it. The law also invests the Minister of Agriculture and Agrarian Reform with the authority to regulate land use exempted from these provisions. The rest of the steppe was dedicated to grazing, pasture projects, animal breeding, and forestation projects. Cooperatives were to be established to improve pastures and sheep breeding.

However, regulation of the steppe has not yet been put into effect. The growing of certain crops is allowed sometimes and prohibited at others. No specific control of the location or extent of land used for cultivation has been implemented. This has meant the break-up of wide areas of the steppe and contributed to contravention and random cultivation.

In 1978, the Higher Agricultural Council, the Ministry of Agriculture and Agrarian Reform undertook the regulation of the use of non-irrigated lands. Decision No. 96 allowed the cultivation of wheat and barley on lands exempted from the provisions

of the Steppe Protection Law (lands owned by individuals or the State and used by individuals under official documents issued before 1963). Under Decision No. 591 of 1988, population centers in the steppe were defined and distributed over the nine provinces associated with the steppe. Most of the people living in these centers are sedentary, semi-sedentary, or work in both agriculture and livestock breeding. There are 130 population centers, and 534 sites (Tabe 1).

Table 1. Distribution of the population centers.

Province	No. of centers	No. of Sites
Sweda	2	-
Dara	3	-
Rural Damascus	18	8
Homs	36	30
Hama	14	90
Aleppo	13	132
Raqa	30	65
Deir Ezzor	10	90
Hasakeh	4	119

The above-mentioned legislation regulates the use of the steppe based upon the permits issued by the Ministry of Agriculture and Agrarian Reform in collaboration with the concerned departments. They agreed to establish population centers to define the locations to be used, prevent transgressions and random cultivation, and punish those who contravene the law by confiscating their machinery and tools.

In 1992, the Higher Agricultural Council issued Decision No. 17. This decision prohibited the cultivation of non-irrigated steppe lands, regulated the use of the irrigated lands by the Ministry of Agriculture, and aimed at the gradual conversion of rainfed lands, the use of which was restricted to growing fodder shrubs over five years, starting in 1992/93.

Agricultural intensification and crop structures were defined in the agricultural plan 1994/95, outlined under Decision No. 13 of 1994. The rate of intensification in the steppe reached 20% of allowed areas, with 20% grown to barley and 2% to wheat.

Under Decision No. 11 of 1995, rainfed agriculture was prohibited in the steppe as from 1995/96. This was followed by Decision No. 27, which regulated the use of wells in the steppe. Licensed wells may be used for two years only, and permits are not renewable. Non-permitted wells are absolutely prohibited.

Improvement Projects and Rehabilitation

The Syrian steppe has a harsh, dry, and desert climate that affects adversely the structure of the vegetation cover and reduces its density. As a result of random and

early grazing, and various aspects of human activities, pastures do not produce the quantities of green fodder per unit area which should be produced. Such ranges often continue this weak production unless scientific methods are adopted to increase their productivity.

The most feasible ways to maintain the vegetation cover and improve its productivity are: (i) protecting and regulating grazing by adopting an appropriate crop rotation; (ii) adopting a regular grazing schedule rather than free and common grazing; and (iii) defining appropriate stocking rates.

The absolute prohibition of cultivation in the rainfed areas of the steppe is necessary to end the degradation of the vegetation cover as well as desert encroachment. Cultivation of the steppe with cereal crops, particularly in fertile areas, completely destroys the natural vegetation cover, which is considered an important source of free feed. It takes a long time for it to be restored.

Provision of supplemental feed to animals during critical periods of the year (summer, when pastures are dry due to rainfall retention and high temperatures, and harsh winters) is also important. Supplemental feed includes hay, silage, cereal straw, seed cake, and beet waste.

Rehabilitation of the natural vegetation and development of the degraded lands through pasture plantation is a quick way to complement the protection and regulation of these dry and semi-dry areas. The Ministry of Agriculture, represented by the Directorate of the Steppe, Pastures, and Sheep, has launched a wide-scale program to develop the productivity of the degraded rangelands by planting drought-tolerant pasture seedlings adapted to steppe conditions, or through artificial broadcasting of local and introduced species of fodder shrubs .

Salsola vermiculata

This is one of the most important fodder shrubs in Syria in terms of regenerating the steppe. Under Syrian conditions, its height ranges between 35 and 110 cm. It is salinity and drought tolerant. It is of high value as a pasture species across seasons, and is palatable to sheep and camels. It is self-regenerating if rainfall reaches about 200 mm/year. It dominates on shallow clay and calcic non-saline soils. It is found in Hamad and the mountains of the steppe. The Steppe Directorate grows it to improve the rangelands.

Atriplex halimus

This fodder shrub is used as a supplemental feed, particularly in autumn. Its height ranges between 70 and 250 cm. It is gray and highly resistant to drought and

salinity. It is palatable to sheep, camels, and goats. It is grown to develop the Syrian steppe.

Atriplex leucoclada

This shrub plant grows 30–100 cm high. It is palatable and rich in protein. It is drought resistant and all grazing animals like it.

Atriplex canescens

This fodder shrub grows 70–130 cm high. It is salinity and drought resistant, and has high nutritional value. It is palatable to sheep across all seasons. It dominates in the sandy areas.

Atriplex nummularia

This shrub is drought resistant, but not sufficiently cold resistant (it does not tolerate -4°C). It is not frost tolerant. It is palatable to sheep to a lesser degree than *Atriplex canescens*.

Atriplex polycarpa

This shrub is highly palatable throughout the year, and rich in nutritional requirements. It is drought tolerant and dominant in saline lands, dry valleys, and slopes.

Tamarix tetrandra

This tree ranges between 1.5 and 5 m high. It is found in highly saline and wet soils.

Haloxylon persicum

This tree grows to a height of 1–5 m. It is drought resistant and used to protect the soil from erosion and to fix sand dunes.

Nurseries to produce pasture seedlings were established in 1974. This activity was limited to *Atriplex nummularia*, which was grown over an area of 100 ha in farmers' fields in Aleppo Province. The low temperatures of 1979, which reached -10°C, killed large numbers of this shrub. Consequently, farmers refrained from cultivating fodder shrubs. As a result, the Ministry of Agriculture and Agrarian Reform introduced local varieties, such as *Atriplex halimus*, *Atriplex leucoclada*, and *Salsola vermiculata*, into its programs to develop the steppe.

In 1975–1976, the Syrian Ministry of Agriculture and Agrarian Reform and FAO agreed to implement various joint projects, including a project to improve pastures and provide fodder. Previous projects depended on developing old pasture policies within an integrated project to improve the Syrian steppe. This project's aim was to encourage the growing of *A. nummularia* by the private sector. The Ministry contracted with farmers to grow a specific area of fodder shrubs, planted 3 × 3 m apart, and cultivated by deep harrow. Seedlings were to be watered after planting. The farmers agreed to protect the shrubs from grazing for at least 2 years.

The Ministry agreed to: (i) provide free shrub seedlings pruned three weeks before transfer from the nursery; (ii) provide technical supervision for planting; (iii) provide cash funds (SL 45/ha, half of which was paid after the completion of planting, and half upon the second inspection in late summer); (iv) irrigate the shrubs in summer, 4–5 times (if sufficient rain fell the number of irrigations was reduced); (v) provide nutritional requirements for each hectare cultivated; and (vi) benefit farmers with a loan of SL 150/ha, free of interest, to be repaid in three installments. This project ran from 1976/77 to 1980/81. Contracts were made with farmers for the plantation of fodder shrubs. For example, 230 ha were planted in the steppe of Aleppo province.

Following is a summary of the measures taken for the improvement and development of the natural vegetation through the planting of pasture and fodder shrubs.

Establishment of Pasture Seed Multiplication Centers

These centers provide seed for the production of pasture seedlings for nurseries, and carry out the artificial sowing of pasture reserves. There are seven centers, namely: Qaser Hir Gharbi; Mafraq Sawana, Homs; Sieb Center, Hama; Maragha, Aleppo; Kahtaniya, Raqa; Furat, Deir Ezzor; and Shadadi, Hasakeh. As a result of establishing considerable areas of pasture reserves, seed is provided from the centers and reserves spread across the steppe. The amount of seed collected increased from 19.7 tonnes in 1985 to 55 tonnes in 1995. In 1996, a plan was developed to collect 60 tonnes of seed during November and December.

Establishment of Pasture Nurseries

This aims at providing locally adapted, drought-tolerant species of pasture seedlings to be used to improve the vegetative cover in the degraded areas of the steppe. Thirteen nurseries have been established, spread throughout the provinces as follows:

Sweda	1
Rural Damascus	1
Homs	4
Hama	2
Aleppo	1
Raqa	1
Deir Ezzor	1
Hasakeh	2

The number of seedlings produced increased from 5 million in 1986 to 7 million in 1990 and 9 million in 1995. They were provided, free of charge, to both the private and public sectors. However, recipients did not plant all the seedlings allocated to them—some 50% were left unused. We planted these seedlings in reserves, which, given the available capabilities, proved to be a burden.

Salsola vermiculata, *Atriplex halimus*, *Atriplex leucoclada*, and *Atriplex canescens* were the main seedlings produced in the nurseries.

Establishment of Reserves

This aims at the following:

- Regeneration of extinct species.
- Improvement and development of the natural vegetation cover by introducing local pasture species adapted to steppe conditions. This also increases the diversity and productivity of the pasture.
- Finding a source of seed for local species adapted to the dry conditions of the steppe.
- Fixation of the soil to stop erosion.
- Provision of a part of the supplemental feed required during drought.
- Rehabilitation of wildlife in the steppe.
- Creation of jobs for the inhabitants of the steppe to generate additional income.
- Control of desertification.

Planting seedlings produced in nurseries is costly and time-consuming. However, if this method is accompanied with sound and scientific grazing policies, it is economic in the long term.

Pasture are planted by three sectors (public, joint, and private). The steppe directorate produces seedlings in nurseries, and provides them to the joint and private sectors free of charge. Most of these seedlings are grown within the state-

owned reserves and the sheep center reserves. Other people refrain from such planting on the pretext that costs will increase and they will be unable to protect the plantations from sheep grazing.

Results are encouraging in terms of rehabilitation of the vegetation cover, and the provision of a part of the fodder reserve for sheep during drought. The number of reserves grew to 28 in 1995:

Sweda	2
Rural Damascus	1
Homs	4
Hama	4
Aleppo	4
Raqa	4
Deir Ezzor	5
Hasakeh	4

The total area planted with pasture shrubs by direct sowing in the above reserves is 125,000 ha.

Shrubs are planted (400 seedlings/ha) in the reserves at the start of the rainy season. They are given an establishment irrigation, and sometimes a summer irrigation, and protected for three years. Sheep may be allowed in under strictly controlled conditions.

Since protection is a basic element for the rehabilitation of the degraded vegetative cover, and in order to improve the largest area possible, the number of seedlings per hectare was reduced to about 200 during the 1996/97 season.

In 1995, the Ministry of Agriculture and Agrarian Reform (Steppe Directorate) developed a plan for the use of pasture reserves by contracting with neighboring sheep breeders to maintain the shrubs. Two periods were set during which sheep are allowed onto the reserves, namely:

- November–December
- March–April

The stocking rate is 3 head/ha, at a fee of SL 25 for two months. This plan was developed as a preliminary experiment and can be modified as needed in the future. Some 20,560 ha were used during March–April 1995, representing 59,930 head and 92 tenants.

The areas grown in the reserves grew from 32,000 ha in 1990 to 111,000 ha in 1995. These reserves represent a large bank of pasture seed.

Special mention of the natural reserve for the development of pastures and the rehabilitation of wildlife at Talila (Palmyra) must be made. This reserve was established in 1991 over an area of 22,000 ha and aims to:

- Maintain wildlife and protect it from extinction.
- Return extinct animals, such as the gazelle, to the area and introduce new ones, such as the ostrich.
- Maintain the natural plants and give them a chance for regeneration.
- Spread public awareness of the importance of the environment and the need to protect it.
- Establish parks to protect wildlife for scientific and touristic purposes.

The reserve was surrounded by a ditch and a barrage of soil. Some utilities were built for the animals, which were received from various Arab countries and bred in the reserve.

To maintain the local environment, restore the biological balance to the steppe, and create a nice landscape for the highways, four green oases on the Damascus–Palmyra–Deir Ezzor highway were also established and planted to fruit and forest trees:

- Al-Baytama oasis, rural Damascus: 50 ha, 16,450 seedlings planted, including 10,600 olive trees (the remainder are forest trees).
- Mafraq Al-Suwaniya oasis, Homs: 75 ha, 15,000 seedlings planted, including 11,500 olive trees (the remainder are pistachio, palm, and cypress).
- Al-Shola oasis, Deir Ezzor: 36 ha, 17,920 seedlings planted, including 7,400 olive trees.
- Kabakh oasis, Deir Ezzor.

The general situation in these oases is good, and the seedlings are growing well. The olive trees have entered the fruit stage at Al-Batma and Mafraq Al-Suwana. Seedlings are irrigated from artesian wells dug within the oases.

Method and Cost of Planting Fodder Shrubs

Most of the steppe lands are owned by the state. Maintaining and developing the vegetative cover of such lands depends on the provision of an environmental regime, and on maintaining the natural production cycle while orienting it to achieve maximum productivity without depleting resources.

Degradation of natural resources in the steppe prompted the official department concerned (Ministry of Agriculture) to focus on developing all steppe resources (both natural and animal). Introducing fodder shrubs is one of these efforts. Planting these shrubs is a preliminary step to using the vegetation cover and improving natural rangelands to provide green fodder to animals.

The Ministry of Agriculture formulates yearly plans to develop the steppe lands. Nine million shrub seedlings are planted every year on a total area of 20,380 ha, in addition to the yearly plan for direct sowing (2,260 ha).

Methods Applied

Bag seedlings

The land is reclaimed and sown. In November, with the first rains, seedlings are planted 5 m apart in rows spaced 5 m apart, and given one irrigation. From past experience, we know that the approximate cost of planting of 400 seedlings per hectare is as follows:

Sowing	SL 750
Transportation, loading, and handling/ha	350
Planting/ha	200
One irrigation	800
Seedlings (400)	700
Total cost	SL 2,800

A tractor rather than a bulldozer could be used between rows. This method, however, is not feasible due to the surface profile in some sites. Hole digging is also time consuming.

Direct sowing

In this method the land is lightly scarified by a cultivator. Seed is sown at a rate of 15–20 kg/ha at the beginning of the rainy season. Shrubs will be ready for grazing in 3–4 years. Good results have been obtained with a mechanical seeder. However, a tractor of at least 150 HP is needed, since the seeder is large and heavy.

The cost of planting one hectare by direct sowing is:

Sowing/ha by cultivator	SL 300
Collecting 15 kg seed/ha	SL 100
Seed transportation and planting	SL 100

Comparing the planting costs of one hectare of seedlings with one hectare of direct sowing, we see that the cost of the seedlings is six times higher. Though the cost of direct sowing is low, and seed can be sown over large areas with less effort and less time, its success depends on a good rainy season, especially right after sowing. Direct sowing should be adopted, particularly in good seasons, provided that emerging seedlings are well protected from grazing sheep.

Other annual plans include:

- Production of seedlings.
- Collection of pasture seed.
- Sand-fixing projects.
- Establishment of natural and pasture reserves to develop further projects.
- Protection of livestock in the steppe, including veterinary treatment and vaccinations.
- Establishment of sheep breeding centers.
- Collaboration in scientific research with Arab and international organizations.
- Development of appropriate measures to protect the lands in the steppe from trespass and cultivation.

Current Research

Collaboration among the Ministry of Agriculture and Agrarian Reform (Steppe Directorate), ICARDA, and other organizations, such as ACSAD and the Remote Sensing Organization, is ongoing in various fields.

A pilot project across Syria, called the Stocking Rates Projects, was established in Maragha, Aleppo Province, in collaboration with ICARDA and ACSAD. It aims to:

- Assess the productivity of pastures.
- Estimate the economic return from the pasture improvement process.
- Assess the impact of grazing at three stocking rates, and other activities.

Collaboration is taking place between the Steppe Directorate and ICARDA to conduct socioeconomic studies in the Syrian steppe and train personnel from the Steppe Directorate to conduct such studies in the future.

Rangeland management of the Aleppo steppe in the Maragha, Atami, Ein Zarka, and Ebesan reserves through the use of modern technologies is implemented by the Ministry of Agriculture (Steppe Directorate) in collaboration with the Remote Sensing Organization and ICARDA, with the involvement of local inhabitants.

Research is underway on the use of remote sensing in mapping, including data on soil and vegetation cover, water resources, water use, and use of natural resources, as well as the adoption of modern technologies to seed degraded rangelands.

We are looking forward to further collaboration in scientific research and to focusing on new projects with clearly identified objectives and appropriate sources of funding.

Fodder Shrubs in Jordan

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Abstract

The land area of Jordan is about 8.93 million ha. Rangelands (100–200 mm rainfall) constitute about 91% of this area. Rangeland soils are yellow and gray desert soils, with typical steppe and desert vegetation. There are many institutions engaged in research and development of rangelands, concerned mainly with fodder shrubs. Institutions, such as the Forests and Range Department and the National Centre for Agricultural Research And Technology Transfer (NCARTT), implement various programs and projects. Vegetation production in Jordan is estimated at about 40 kg/ha dry matter for desert rangelands and 100 kg/ha for steppe rangelands. Protecting rangelands for three years resulted in increasing their production five fold or more. Planting fodder shrubs would increase their productivity even more. Fodder shrub production in the wadis of the Jordanian Hamad comprised about 57% of total vegetation in 1981 (a poor year) and 69% in 1982 (a good, rainy year). Forage production of some developed range reserves in the steppe was estimated at about 6 to 20 fold that of open rangelands. In spring 1992, native fodder shrub production at Lajjoun was about 60 kg/ha, and production of planted *Atriplex* was about 270 kg/ha. In autumn 1992, native fodder shrub production was about 46 kg/ha, and production of planted *Atriplex* was about 322 kg/ha. Fodder shrubs, as well as other range plants, may be divided into three categories, according to their palatability to grazing animals: high, medium, and low.

Background

The land area of Jordan may be divided into five agro-climatic regions (Table 1). Rangelands in the semi-desert region (<200 mm average annual rainfall) constitute about 91% of the land, or about 8.1 million ha. About 5.9 million ha of this total receive less than 50 mm of average annual rainfall, while only about 1.0 million receive 100–200 mm average annual rainfall.

The rainfall in these areas is irregular and unevenly distributed. These lands are in a general state of degradation due to harsh environmental conditions and human misuse factors, such as overgrazing, cultivation, and uprooting of fodder shrubs and other range plants for fuel wood.

Table 1. Land area of Jordan according to agro-climatic region.

Region	Average annual rainfall (mm)	Area (million ha)	Total area (%)
Semi-desert	<200	8.08	90.5
Arid	200–350	0.51	5.7
Semi-arid	350–500	0.19	2.1
Semi-humid	>500	0.10	1.1
Water area	-	0.05	0.6
Total	-	8.93	100.0

Source: Water Authority, National Water Master Plan.

There are four main soil types in Jordan:

- Red Mediterranean soil occurs in the Mediterranean sub-humid and semi-arid areas, with rainfall greater than 350 mm on the plateaux.
- Yellow Mediterranean soil is found in the cool portions of the Mediterranean arid zone, with rainfall of 250–350 mm. This soil occupies a narrow zone along the border of the cultivated highlands and the steppe.
- Yellow soil occurs in the steppe. The surface layer contains the many roots of steppe vegetation.
- Gray desert soil occurs in the Saharan climate of eastern Jordan, and covers more than 50% of the territory.

The native vegetation in Jordan may be divided into four types:

- Forests. They are spread over the sub-humid and semi-arid zones. The shrub stratum comprises *Arbutus andrachne*, *Calycotome villosa*, *Pistacia palaestina*, *Smilax aspera*, etc. The herbaceous stratum is rich in good palatable species.
- Mediterranean scrub and dwarf shrub communities. The retrogression of the Mediterranean forest gives place first to a Mediterranean scrub, then to a dwarf shrub and grass community. The characteristic and dominant plant of the Mediterranean scrub is the invading and unpalatable *Poterium spinosum*. It is accompanied by *Thymus capitatus*, *Teucrium polium*, *Ballota undulata*, *Ononis natrix*, *Ononis leiosperma*, *Origanum syriacum*, and a number of good palatable grasses. Quite often, this plant community grows on skeletal soils where *Varthemia iphionoides*, *Gypsoplila rokejeka*, *Noaea mucronata*, *Anchusa strigosa*, *Urigena maritima*, *Ferula communis*, and *Astragalus bethleneticus*, all unpalatable, compete with the overgrazed good species. In the south, where rainfall is more erratic, the *Ononis natrix* association is found on deep soils, mixed with vigorous stands of *Artemisia herba-alba*. This type constitutes a transition to steppe vegetation.
- Steppe vegetation. This is the climax vegetation of the arid zone. In the northeast, *Artemisia herba-alba* dominates in pockets of deep colluvial soils

wherever wheat fields have not encroached on the range. *Salsola vermiculata*, a palatable and perennial species, is also abundant and even dominant. *Anabasis aphylla* and *Haloxylon articulatum* are too often the sole perennials that remain after plowing. In the south, an *Artemisia herba-alba* and *Anabasis articulata* association marks the transition to the desert vegetation.

- Desert vegetation. This covers about three quarters of Jordan and is related to the Saharan climate. The most widespread community in the Jordanian desert is an *Anabasis articulata* association. It exists where the rainfall is below 100 mm. The very clear stands of *Anabasis articulata* and *Haloxylon articulatum* are enriched by valuable species, such as *Salsola vermiculata*. The wadi bottoms and fans possess a richer vegetation of *Retama raetam*, *Achillea fragrantissima*, *Atriplex halimus*, *Artemisia herba-alba*, and a good number of palatable grasses. In the south, the semi-desert vegetation of the sand dunes offers a fairly high number of good perennial species as *Echiochilon fruticosum*, *Retama raetam*, and *Artemisia monosperma*. Further to the south, where rainfall is less than 100 mm, the grasses are mainly *Aristida* and *Stipa* spp. The vegetation, concentrated in the wadi bottoms, is *Haloxylon salicornicum* and *Artemisia judaica*. *Acacia* trees are sometimes scattered in the wadi fans. The perennial grass cover is mainly *Aristida obtusa* and *panicum turgidum*. The saxaoul tree, *Haloxylon persicum*, thrives on the desert sand dunes and sand plains of Wadi Araba and Wadi Rum. In the very hot valley of the Wadi Araba, tropical species, including *Acacia tortilis* and *A. raddiana*, are found.

Rangelands Divisions

Steppe Rangelands

This region, covering about 1 million ha, is located between marginal areas and desert rangelands. Average annual rainfall is between 100–200 m. It includes two areas distinguished by vegetation type. Range shrubs cover an area of about 0.6 million ha, and extend in a narrow belt from Ras El-Naqab in the south to Mafraq in the north. Native vegetation is dominated by shrubs, mainly *Artemisia herba-alba* and *Salsola vermiculata*. The range grass area is about 0.4 million ha, and extends along the Syrian borders from Mafraq in the west to the Iraqi borders in the east. Native vegetation is dominated by grasses, mainly *Poa sinaica* and *Stipa* spp., with many shrubs and annuals.

Desert Rangeland

This is an area of about 7.0 million ha to the east of the steppe rangelands. Average annual rainfall is less than 100 mm. Range plants (mainly *Artemisia herba-alba*,

Achilla fragrantissima, and *Poa simaica*) spread in the wadi bottoms and depressions. Other areas are dominated by the unpalatable *Anabasis aphylla*.

Mountainous Rangeland

This area receives more than 200 mm of average annual rainfall, and covers an area of about 45,000 ha. It is divided into scattered small pieces of land. Excellent fodder species, such as *Phalaris tuberosa*, *Poa bulbosa*, *Dactytis glomerata*, and *Hordeum* spp., grow in these areas. Native forests (40,000 ha) may provide some grazing in spring and summer.

Institutions Engaged in Range Activities

Various institutions in Jordan engage in range research and development activities. These include establishment of range reserves, introduction fodder shrub protection, use of range plants, and establishment of national reserves. The most important institutions are discussed below.

The National Center for Agricultural Research and Technology Transfer

Research activities at NCARTT are carried out through a number of research programs. One of these is the low-rainfall area/rangelands research program. The main objectives are to increase productivity of rangelands and suggest proper use for sustainable production.

Forest and Range Department, Ministry of Agriculture

This department is responsible for development activities concerning forests and range, especially planning, control, monitoring, and evaluation. Field work is the responsibility of the regional agricultural directorates. There is a forest and range division in each directorate.

The Jordan Cooperative Organization

Starting in 1980, the JCO has had the responsibility of implementing the World Food Program (WFP) range management project. Farmers and cooperatives are given incentives to establish and manage range reserves assigned to the cooperatives, plant fodder shrubs, establish water cisterns and ponds, and use these reserves.

Projects Department, Ministry of Agriculture

There were two projects concerned with rangelands within the framework of the Project Department. Al-Hamad Project conducted the studies, and the Arab Center for Studies of Arid Lands and Dry Areas (ACSAD) carried them out. Four countries had land within the project area: Jordan, Syria, Iraq, and Saudi Arabia. The project aimed at improving rangelands, animal production, water resources, and the socioeconomics of the local inhabitants. The Zarqa River Catchment Project, begun in 1987, focused on the project's lower catchment. It aimed to develop privately owned agricultural lands, forests, and rangelands, and to protect the Zarqa River banks from erosion to reduce sedimentation of the King Talal dam and increase its life span. It ended in 1996.

The Higher Council for Science and Technology

In cooperation with the Royal Geographic Society (RGS) of the United Kingdom, HCST established the Badia Research and Development Program in 1993. The objectives were: (i) to conserve and improve the management of the principal resources of Badia including land, water, range, and animal production; and (ii) to enhance the returns on future investments in the area through the optimal allocation of resources.

Royal Society for Conservation of Nature

The RSCN was established in 1976. Its main objectives and concerns included increasing public awareness towards the environment, control and organization of hunting, and the establishment of natural reserves and national parks.

Faculties of Agriculture, Jordan Universities

Faculties of Agriculture at some Jordan Universities teach courses in range management. In 1996/1997, the Faculty of Agriculture at the Jordan University for Science and Technology began a forest and range program leading to a BSc in the field.

Fodder Shrub Projects

There are a number of programs and projects that have been or are still being implemented in Jordan related to the improvement of the natural vegetation cover, rehabilitation, and improvement of rangelands. Some of these programs and projects are local to Jordan, and some are regional, involving countries besides Jordan. Objectives and achievements of such range programs and projects are discussed below.

Range Development Project of the Ministry of Agriculture

This project implements the annual plan for range development of the Forests and Range Department of the Ministry of Agriculture. About 23 range reserves have been established to date and distributed throughout the range areas in Jordan. The total area of these reserves is about 62,200 ha. About 13,400 ha have been planted to fodder shrubs. A new range reserve is being established at Rwaished. The annual Forests and Range Department plan includes preparation and plantation of about 2,000 ha with seedlings of fodder shrubs, mainly *Atriplex halimus* and *Atriplex nummularia* and direct seeding of fodder shrub seeds such as *Salsola vermiculata*, *Atriplex leucoclada*, and *Atriplex halimus*.

Range Development Project of the Jordan Cooperative Organization

The cooperatives have established nine range reserves since 1980. The total area of these reserves is about 11,000 ha, of which 6,400 ha have been planted to fodder shrubs. It is the responsibility of range cooperative members to protect reserves, plant them to fodder shrubs, and use them for their own flocks under the supervision of the JCO.

Low Rainfall Areas/Rangelands Research Program

This is a program of the NCARTT. It covers a number of projects and activities with various concerns:

- Designing, testing, and implementing direct seeding of fodder shrubs (1989–1991).
- Conducting an inventory of range resources. This was carried out at six range reserves: Rajib, Khanasri, Surra, Sabha, Nikhel, and Fujij (1989–1990).
- Grazing trials. These are carried out at the Rajib and Ma'een range reserves.
- Establishment of *Atriplex* seedlings at different times of the year (1991).
- Effect of cutting on production of *Atriplex nummularia* shrubs (1990–1991). Cutting 85% off the height of *Atriplex* shrubs led to about 40% mortality. Cutting only 15% off the height gave new green growth but was out of reach of sheep. Cutting 50% gave better new growth and was within the reach of animals.
- Adaptability trials of some fodder shrubs (1990). This experiment included studying adaptability and palatability of five *Atriplex* species: *Atriplex undulata*, *Atriplex lentiformis*, *Atriplex amnicola*, *Atriplex canescens*, and *Atriplex halimus*. Results show that *Atriplex undulata* is the best in terms of establishment rate and palatability, followed by *Atriplex halimus*.

- Effect of heavy grazing on *Salsola vermiculata* seedlings (1990). Seedlings of *Salsola vermiculata* were not affected by heavy grazing in spring.
- Effect of resting the range on the recovery of *Atriplex* shrubs (1991). Resting the range was effective in the recovery of heavily grazed *Atriplex* shrubs.
- Adaptability trials of range plants (1993–). This study of the adaptation of a number of range shrubs is implemented in six range reserves (Rajib, Khanasri, Eira, Ma'een, Lajjoun, and Fujij). Results show that *Atriplex halimus* has a higher rate of establishment, followed by *Atriplex nummularia*, *Acacia cyanophylla*, and *Prosopis* spp.
- Effect of phosphorus fertilization on range production (1991–1995). This experiment was carried out in a number of range reserves (Khanasri, Khaldia, etc.). Results confirmed the positive effect of phosphorus on increasing vegetative production of rangelands and enhancing growth of legume plants.
- Survey and monitoring of range resources (1995–1997). This project collected basic information on range resources regarding vegetation species, composition, and production.
- Establishment of a range research station (1995–1997). Range reserves are opened periodically to grazing, so a range research station was needed to better control studies and experiments that could be extended to other rangelands. About 50 ha was chosen and fenced at Khaldia as a range research station. Experiments, begun in 1995/1996, include plantation of four fodder shrub species: *Atriplex nummularia*, *A. halimus*, *Acacia cyanopylla*, and *Prosopis* spp. Further experiments are planned at Khaldia.
- Production and use of multipurpose fodder shrubs and trees in West Asia, North Africa, and the Sahel. A research proposal on the establishment and production of fodder shrubs in Jordan was submitted to ICARDA as part of the above-mentioned project. Three activities of the proposal were accepted for financing: (i) review of research and development activities on fodder shrubs in Jordan; (ii) effect of seedling density on survival and production of fodder shrubs; and (iii) establishment of fodder shrubs by direct seeding.

Establishment of Natural Reserves: Royal Society for Conservation of Nature

The RSCN has prepared plans and studies to establish 12 natural reserves, involving the climatic and environmental areas of Jordan and the wildlife distribution (plants and animals). Seven natural reserves have been established to date.

Badia Research and Development Program: Higher Council for Science and Technology

The HCST established this program in cooperation with the Royal Geographic Society of the United Kingdom. A number of research proposals have been suggested. Some studies have been implemented, on topics such as review of the vegetation cover, establishment of Al-Hashad range reserve, and demographic and socioeconomic factors in the program area.

The Hamad Project-Ministry of Agriculture

The Arab Center for Studies of Arid Lands and Dry Areas, in cooperation with four Arab countries (Jordan, Syria, Iraq, and Saudi Arabia), prepared a project to develop the Hamad (which is shared among these countries). Objectives of this project are to improve the range, animal production, water resources, and socioeconomic conditions of the inhabitants. A number of artesian wells and water-collecting ponds were established. The Rwashed Range Reserve is being established by the Forests and Range Department.

Zarqa River Catchment Project: Ministry of Agriculture

The project objectives are to develop agricultural lands, forests, and rangelands, and to protect the banks of the Zarqa River from erosion. The project area is about 82,500 ha. About 12,500 ha of this area are government rangelands and about 5,000 are private rangelands. About 4,600 ha have been protected and planted to fodder shrubs to date.

Increasing Productivity in the Arid and Semi-arid Areas Affected by Desertification

The Faculty of Agriculture of the University of Jordan implemented the first phase (1985–1989) of this project (Muwaqqar Project) in cooperation with the European Economic Committee (EEC). Three dams were constructed to collect water runoff. Their total capacity is about 80,000 m^3. A number of studies and experiments on fruit trees and fodder shrubs were carried out. The second phase of the project (1995–1998) was implemented in cooperation with the NCARTT and the EEC. This project included plantation of fodder shrubs in barley fields and water harvesting techniques for fruit trees and fodder shrubs.

Vegetation Production of Fodder Shrubs

Most of the studies concerning vegetation production on the rangelands of Jordan estimate total dry matter production. Few of these studies consider separation of vegetation production into grasses, forbs, and shrubs.

ACSAD and the Arab Organization for Agricultural Development (AOAD) estimate vegetative production in Jordan at about 40 kg DM/ha for the desert rangelands (<100 mm average annual rainfall) and at about 100 kg DM/ha for the steppe rangelands (100–200 mm average annual rainfall). The Forests and Range Department estimates natural vegetation production in the forests and marginal lands in high rainfall areas at about 300 kg DM/ha (Table 2).

Table 2. Vegetation production of rangelands.

Range Areas	Rainfall (mm)	Area (ha)	Productivity (kg/ha)	Total production (tonnes DM)
Desert rangelands	<100	7,100,000	40	284,000
Steppe rangelands	100–200	1,000,000	100	100,000
Mountain rangelands	>200	45,000	300	13,500
Forests	>200	40,000	300	12,000
Total				409,500

Source: Tadros et al. (1994).

The Ministry of Agriculture estimates that protecting rangelands for three years increases their production five fold or more. Planting fodder shrubs would increase their productivity even more.

Tadros (1983), who studied vegetation production at 21 sites in the Jordanian Hamad, noted that in a poor rainy year, fodder shrub production made up about 57% of total vegetation production (200 of 348 kg DM/ha). In an average rainy year, this was about 69% (443 of 646 kg DM/ha). These figures show the importance of fodder shrubs as a source of feed on the rangelands. *Artemisia herba-alba* is the main fodder shrub in the Jordan Hamad.

In some developed reserves in the steppe rangelands, NCARTT staff found that forage production was increased 6–20 fold compared to production in the open ranges (Table 3).

Table 3. Vegetation production at some developed range reserves (dry matter).

Range Reserve	Rainfall (mm)	Area (dunum)	Productivity (kg/ha)	Year of estimation
Rajib Range Reserve	100–200	20,000	2,000	1987
Khanasri	100–200	4,545	850	1988
Lajjoun Range Reserve	100–200	11,000	640	1988
Eira Range Reserve	100–200	20,000	1,380	1991

Source: NCARTT annual reports (1988–1991).

Tadros (1993) studied rangeland resources under different management alternatives in the Lajjoun area. He found that total vegetation production at the Lajjoun range reserve, in spring 1992, was about 910 kg/ha dry forage, compared to 650, 680, and 240 kg/ha dry forage for the cooperative reserve, the new governmental reserve, and the open range, respectively. Vegetation production of native fodder shrubs was about 60 kg/ha, and that of planted *Atriplex* about 270 kg/ha. In autumn 1992, total vegetation production at Lajjoun was about 680 kg/ha dry forage, compared to 450, 610, and 51 kg/ha for the other sites, respectively. Vegetation production of native shrubs was about 46 kg/ha, and that of planted *Atriplex* was about 322 kg/ha.

Main Fodder Shrubs

Fodder shrubs in the arid range areas in Jordan, as well as other range plants, can be divided, according to palatability, into three major categories.

Highly Palatable Fodder Shrubs

Fodder shrubs in this category are called "decreasers," as they are preferred by grazing animals and are usually subject to grazing pressures. These fodder shrubs need good management to give sustained production. Examples include *Salsola vermiculata*, *Atriplex halimus*, and *Colutea istria*.

Salsola vermiculata

This species belongs to the Chenopodiaceae family. It is one of the best fodder shrubs for arid areas. It is highly palatable and subject to heavy grazing during summer and autumn. It is also subject to cutting and uprooting for fuel wood. It regenerates from seed, which ripens in late autumn. Seed starts to loose viability after a few months and should not be stored longer than that.

Atriplex halimus

This species reaches a height of more than two meters. It keeps its leaves year round. It is drought resistant, adapted to the arid and desert areas, and tolerates salinity up to 30 ppm. *Atriplex halimus*, as well as *Atriplex nummularia*, has good nutritive value. Its digestible protein content reaches 12% of dry matter. Seed ripens in November and December. Shrubs regenerate directly from seed.

Colutea istria

This is a palatable legume shrub. It is adapted to high elevations (Shaubak) and grows in poor soils. This fodder shrub may reach a height of 3 m. Its habitat extends from Turkey and Syria southward to Jordan and Sinai. Its seed ripens in

mid-summer. Seed should be germinated in the nursery and seedlings transplanted to their permanent location.

Moderately Palatable Fodder Shrubs

Fodder shrubs in this category are called "increasers," because they increase, to a certain extent, alongside grazing pressures. With continuous heavy grazing, they start to decrease. These fodder shrubs are less palatable than those in the first category. They should be protected and managed but are not worth transplanting or reseeding. Examples of these fodder shrubs are: *Artemisia herba-alba* and *Haloxylon articulatum.*

Artemisia herba-alba

This fodder shrub belongs to the Compositeae family. It reaches a height of only 50–60 cm. It is widespread in the Middle East and North Africa and dominates most range plant associations. *Artemisia herba-alba* is an aromatic plant, containing volatile oils that reduce its palatability to grazing animals. It is mainly grazed in early spring and late autumn, when the concentration of volatile oils is low. When it is dry, volatile oils are also low. Millions of *Artemisia herba-alba* shrubs are cut or uprooted in arid areas every year for fuel wood.

Haloxylon articulatum

This shrub belongs to the Chenopodiaceae family. It is less palatable than *Artemisia herba-alba.* It produces palatable fruit in autumn. Grazing animals eat its fruit and twigs. This shrub is second in importance for fuel wood in the arid areas after *Artemisia herba-alba.*

Unpalatable Fodder Shrubs

Fodder shrubs under this category are of limited value for grazing. They have the potential to increase and invade the range when other plants are over grazed, so they are called "invaders." These shrubs and plants should be monitored and kept under control. Examples of these shrubs are *Anabasis aphylla* and *Peganum harmala.*

Anabasis aphylla

This shrub belongs to the Chenopodiaceae family. It spreads on plowed rangelands. It's presence is an indicator of the misuse of rangelands by man. It contains alkaloids, so it is not palatable. Sheep may graze very small amounts when they are hungry.

Peganum harmala

This shrub grows in rangeland depressions and on rangeland subjected to erosion. It is another example of misuse of rangelands by man. It contains harmalin, which affects the nervous system of animals.

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Moroccan Experience with Fodder Shrub Research and Development

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Abstract

Rangeland in Morocco covers more than 20 million ha in the semi-arid zones and mountains. This area increases to 60 million ha if we include the arid zones. More than 80% of the rangeland receives less than 250 mm rainfall annually. Rainfall in these zones is characterized by intra- and inter-annual variability in terms of quantity and distribution. This variability results in large fluctuations in forage resources in pastoral zones. Soils generally have very low potential and are vulnerable to water and wind erosion. This situation is made worse by the actions of man (cropping and overgrazing).

The contribution of rangelands to the feed balance is decreasing, which indicates that the rangelands of Morocco are being degraded. It is estimated that 81% of the total rangeland area is moderately degraded, and 12.5% severely degraded. Many rangeland development projects for shrubs have been implemented to restore degraded areas and improve rangeland productivity. The most widely used species is *Atriplex nummularia*, which is very palatable and rich in nitrogen. It has been planted on more than 40,000 ha of mostly communal rangelands. Usually, planted areas are those for which there are conflicts among users. Where proper management is insured, the impact on livestock production is significant, but this has not always been the case. Technical, social, institutional, and policy studies are necessary to investigate the effect of the interacting factors on the realization of successful rangeland improvement projects. Institutional and policy aspects are being tackled by the AFESD/IFAD/IFPRI/ICARDA crop/livestock integration project, which brings together researchers from different institutions. Technical aspects (management, species, etc.) are also being investigated. The CGIAR System-wide Livestock Initiative (SLI) shrub project will reinforce the efforts made in this area.

Introduction

Fodder shrubs are used for several purposes: (i) to reduce grazing pressure on degraded areas where plant cover is poor; (ii) as a standing fodder crop to buffer seasonal fluctuations that occur in arid and semi-arid Mediterranean areas; (iii) as a protein supplement for livestock on poor native rangelands or those consuming low quality roughage; (iv) as a forage source on arid and salt-affected areas; (v) as a

source of fuel for low-income farmers; (vi) as a means of soil erosion control; and (vii) as an emergency feed during drought years. In a recent literature review, Arif et al. (1994) extol the virtues of *Atriplex* as a forage for arid and semi-arid areas of Morocco.

Shrubs can be used at the farm level for alley cropping. In this system, annual crops, such as barley, are grown in alleys formed by hedgerows of shrubs, such as *Atriplex* spp. This system provides on-farm forage during critical periods, a protein-rich supplement for cereal stubble grazing, straw feeding during summer and fall, and improves grain yield (wind-shield effect).

In Morocco, during the growing season (January–May), animals graze on fallow lands (marginal for cereal production, or left untilled for a season). Following the harvest (early June), sheep usually graze on cereal stubble until the start of the rainy season (October or November). This period coincides with the mating and gestating periods. When cereal stubble is exhausted, straw is widely used for pregnant and lactating ewes until the fallow grazing land is available (about January). Except for the growing season (spring), sheep suffer nitrogen deficiency throughout the year. Outmani et al. (1991) conclude that the most logical approach to improving the economic potential of sheep production in the rainfed cereal-producing areas of Morocco is the adoption of a strategy of supplementation with a feed high in nitrogen (N) and, later in gestation, both N and energy. This improves nutrition and thus flock productivity.

The increasing human population of Morocco, which has doubled in less than 30 years (FAO 1987), has aggravated the feed shortage. This has led to falling crop yields, forcing crop farmers into fragile lands and grazing areas. This has resulted in widespread soil erosion.

Self-sufficient systems that produce sustainable high yields of crops with low inputs of fossil energy are required. Trees and shrubs need to be integrated into the farming systems.

Research on shrubs has focused on agronomic studies to quantify primary productivity and adaptability, ignoring their productivity and persistence under grazing. The "agronomistic" approach to screening germplasm has sometimes promoted the recommendation of species that are unpalatable or unable to withstand grazing.

This paper will: (i) describe the physical environment and the Moroccan shrub planting operation implemented by the government (with emphasis on *Atriplex*); (ii) discuss this experience in the light of available the literature pertaining to the biology, the primary and secondary production, the use, and the economics of forage shrub plantations; (iii) outline some of the constraints facing shrub

plantings; and (iv) conclude with some highlights on shrub research and development perspectives.

Physical Environment

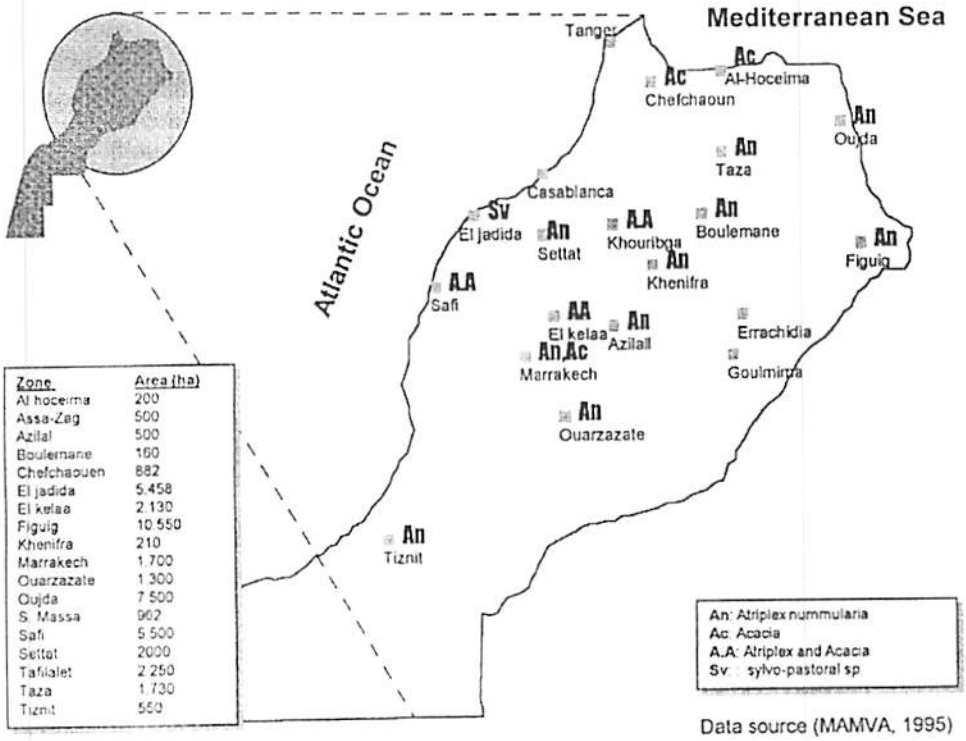
Morocco is located in the northwestern corner of Africa. The climate is predominantly semi-arid to arid. However, rainfall is relatively higher than in the other North African countries. The total land area is about 710,850 km^2. Arable land covers about 8 million ha, half of which is located in areas with less than 400 mm annual rainfall. The dominant agricultural system is cereal crops cultivated in rotation with fallow. The remaining half of the cultivated land area, where climatic conditions are more favorable, is mainly cultivated to cereals, food legumes, forages, and fruit crops.

Rangelands cover over 20 million ha in the semi-arid zone and mountains. This increases to 60 million ha if we include the arid zones. The forest covers about 5 million ha. More than 80% of the rangeland receives less than 250 mm rain/year. Rainfall in this zone is characterized by intra- and inter-annual variability in terms of quantity and distribution. This variability results in large fluctuations of forage resources in pastoral zones.

Soils generally have very low potential. They are shallow, calcareous, stony, salty, poor in organic matter, and sloping. They are thus very vulnerable to water and wind erosion. This situation is worsened by the actions of man (cropping and overgrazing). Rangeland development projects, such as PDPEO (Oriental) and MAC (Central Middle Atlas), must consider natural resource conservation in their strategies. The contribution of rangeland to the 1989–1992 national feed balance averaged 36.3% per year. This proportion is 5% lower than for 1980–1983, which may indicate that rangelands in Morocco are being degraded. In the Utah-IAV Hassan II study (1994), the authors estimated that 81% of the total rangeland is moderately degraded (about 70 FU/ha) and 12.5% severely degraded (about 50 FU/ha).

Shrub Planting Program

Since the mid 1980s, a program of forage shrub planting has been implemented in several pastoral zones of Morocco (Fig. 1). By the end of 1993, an area of 45,508 ha had been planted, with 2,776 ha still to go. Yearly hectareage, as reported in Table 1, varied from year to year (MAMVA 1995).



Zone	Area (ha)
Al hoceima	200
Assa-Zag	500
Azilal	500
Boulemane	160
Chefchaouen	882
El jadida	5.458
El kelaa	2.130
Figuig	10.550
Khenifra	210
Marrakech	1.700
Ouarzazate	1.300
Oujda	7.500
S. Massa	962
Safi	5.500
Settat	2000
Tafilalet	2.250
Taza	1.730
Tiznit	550

Figure 1. The main shrub plantations in Morocco.

Table 1. Yearly hectareage planted to fodder shrubs in Morocco.

Year	Area planted	Plantation density
1983	200	750
1984	60	1,000
1985	1,262	1,000
1986	1,962	1,000
1987	2,410	1,000
1988	7,901	1,000
1989	7,074	850
1990	5,223	950
1991	7,145	850
1992	3,601	1,000
1993	8,670	750
Total	45,508	750–1,000

Plantation Location

Initially, plantations were limited in space and served to demonstrate forage shrub use to livestock owners, informing them about the role of these shrubs in rangeland

rehabilitation. After 1987, and benefiting from the knowledge gained on shrubs, the program grew more ambitious, with more resources allocated through various development projects. Among these projects were the Projet de Development Pastoral et de l'Elevage dans l'Oriental (PDPEO) in northeast Morocco and the Abda Project in southwest Morocco. Eighty percent of the plantings took place in two major ecological zones: (i) the high plateaux and the Moulouya valley in northeast Morocco; and (ii) the North Atlantic plains and plateaux (Khouribga, Marakech, El Kelaa, Settat, and Safi Provinces). The remaining 20% are scattered in Chefchaoun, Al Houceima, Errachidia, Ouarzazate, Assa Zag, Agadir, and Tiznit Provinces (MAMVA 1995). The Water, Forest, and Soil Conservation Administration (Administration des Eaux et Forêts et de la Conservation des sols) has planted approximately 6,000 ha (MAMVA 1995) in the latter area.

Since the early 1970s, the Ministry of Agriculture and Agrarian Reform has identified and delineated pastoral perimeters (périmetres d'amélioration pastorale), within which improvements are undertaken with public funding. Typically, rangelands are under communal ownership (parcours collectifs), and therefore the consensus of the local community has been an important criterion in identifying plantation sites. Local populations agreed to start plantations on problematic and/or extremely degraded sites in the arid and semi-arid rangelands.

Species Planted

Atriplex nummularia is the most planted species in range revegetation programs (Tazi et al. 1992; Alaoui et al. 1992; ORMVAO 1992; ORMVAT 1992). MAMVA (1995) found that *Atriplex nummularia* is planted on 61% of the total area, followed by a mixture of *Atriplex-Acacia* (17%) and other sylvo-pastoral species (14%). This species has been successfully established under a variety of moisture and salinity conditions (Fig. 1).

Baumann-Matthaus (1990) compared leguminous (*Acacia* spp.) and non-leguminous (*Atriplex* spp.) shrubs in northeastern Morocco and found that the former had the lower rate of survival. He also found that leguminous species needed more moisture and deeper soils than *Atriplex* spp.

Other adaptation trials, conducted by Baumann-Matthaus and Jaritz (1994) in northeastern Morocco (Oriental) on 20 *Atriplex* species, showed that establishment success and persistence were higher for *A. vesicaria*, *A. halimus*, and *A. paludosa* than for *A. nummularia*. The authors suggest that *A. vesicaria* and *A. paludosa* are more productive and persistent than *A. nummularia*. They also note that although *A. halimus* had less edible biomass than *A. nummularia*, the former offers better soil protection and is more drought tolerant. Baumann-Matthaus (1990) states that losses as high as 30% can be expected in a dry year.

Establishment Method and Planting Density

Establishment methods commonly used in Morocco are: (i) pit planting (planting in equidistant pits surrounded by impluviums), used mostly in flat terrain; and (ii) furrow planting along topographical contours, the most common technique. The advantage of the latter technique resides in its ability to capture rainwater, which will benefit both native vegetation and shrubs. In research conducted during a drought year (1994/95) with 140 mm rainfall, Arif (unpublished) studied the effect of elaborate techniques to improve the water status in order to enhance establishment and vigor of transplanted *Atriplex* seedlings. No improvement in establishment. Work conducted by Baumann-Matthaus and Jaritz (1994) in northeastern Morocco suggests that seeding gives lower establishment performance than planting. Favorable rainfall conditions (good distribution of spring rain and some summer showers) are critical for establishment by seeding. For further details on technical aspects of establishment, refer to Arif et al. (1994).

Direct seeding has been referred to as an unsuccessful technique for *Atriplex* spp. establishment. Better results were obtained on humid soils with pre-soaked seed, with the survival rate improved by 60–70% (Le Houérou 1992). Field observations on several plantations in Morocco have shown that *Atriplex* has self-regenerated from seed. This finding should be a stimulus for research to investigate the feasibility of *Atriplex* seeding to reduce the cost of establishment.

When *Atriplex* spp. planting began, the average plant density was around 1,000 plants/ha. In plantings undertaken after 1990, density was lowered to 500–850 plants/ha. This density reduction was justified by the reduction of establishment cost for larger areas and by an unwillingness to jeopardize the growth of the herbaceous vegetation (MAMVA 1995). Recent work, conducted over three years in semi-arid Morocco by Arif and Chriyaa (1995), confirms that a shrub spacing of 2 x 5 m (1,000 plants/ha) gives optimal biomass production and plant vigor.

If the objective of the plantation is to provide protein during the dry season, then total shrub biomass can be increased with higher shrub density. However, if the plantation is to be used during the spring to graze herbaceous vegetation, shrub density should be decreased to obtain more biomass from the annual vegetation. It is therefore imperative that studies be conducted on the relationship between shrub density and total biomass from both shrub and herbaceous vegetation per unit area. This will obviously vary with soil and rainfall conditions.

Primary Production

The data available on forage shrub production levels in Morocco vary due to: (i) heterogeneity of planted material and plantation age; (ii) differences in sampling method, year, and date; (iii) differences in environmental condition; and (iv)

differences in the importance of the herbaceous vegetation. Baumann-Matthaus and Jaritz (1994) conducted adaptation trials in northeastern Morocco and found that yearly browse production averaged 920 kg DM/ha (at 1,000 plants/ha).

Production varied from 406 to 2,140 kg DM/ha depending on the species studied. *Atriplex vesicaria*, *A. semibaccata*, *A. nummularia*, and *A. paludosa* scored the highest levels of production. In the same trial, *A. nummularia* produced an average of 374 g DM/plant per year and varied from 36 to 1,100 g DM/plant, depending on the site and the age of the plantation. Hammoudi et al. (1994) found that forage production from a two-year-old *Atriplex* plantation was 625 and 1,125 kg DM/ha under 150 and 200 mm rainfall, respectively. Edible biomass of *Atriplex nummularia* varied from 200 to 1,500 kg/ha per year.

Plantation Use

The most reliable information on plantation use is found in the PDPEO project of northeastern Morocco. Plantations are grazed after being enclosed for 18–24 months. Organizational aspects of grazing are under the control of pastoral cooperatives, which record beneficiary and herd inventories, stocking rate, and grazing duration. In return, the beneficiaries pay grazing fees to the cooperative, which are meant to be used for the operating cost of the cooperative and the maintenance of the pastoral infrastructure. The PDPEO project has the most intricate pastoral population organization in Morocco. Fees of DH 1–2/head per grazing season are not enough to make the cooperative financially self-sustaining. A greater burden may be put on the users by a new law (33/94, Article 25), according to which the government must recover 30% of the initial investment from cooperatives or 40% from individual farmers.

The Water, Forestry, and Soil Conservation Administration has a concomitant program of shrub planting aimed essentially at soil and water conservation. This program is funded by the National Forestry Fund. This administration enforces strict controls on protecting plantations from grazing. If the plantation is on communal land, grazing fees are half what they would be on government-owned land. However, in both cases, 50% of the proceeds are given back to the local communities.

Grazing in northeastern Morocco takes place during two periods: fall grazing (October–December), generally preferred by small livestock owners; and spring grazing, generally preferred by large livestock owners (Hammoudi et al. 1994).

Some forestry plantations of *Atriplex* spp. that are protected for a long period, such as those established mainly to control soil erosion, may not be grazed enough. This causes early aging of the plantations, which become woody with reduced browsing biomass production. In such situations, pruning will stimulate new shoots and

leaves and boost fodder production. Le Houérou (1986) found that regeneration of old wood plantations should be done by periodic cutting (every 2–3 years) to increase browse production and palatability. According to the same author, the recommended cutting height is species-dependent. In semi-arid Morocco, Arif and Chriyaa (1995) recommend a cutting height no lower than 60 cm.

One way of using plantations is to cut and carry fodder to animals as a protein supplement. This method ensures plantation persistence but can be too costly for the farmer. Other fodder species, like *Opuntia.* (e.g. *Opuntia ficus indicus*), which are planted on thousands of hectares in North African countries, are traditionally cut and chopped before feeding to livestock during the dry season. In the absence of mechanization, and because of the low tolerance of cactus to direct grazing, this technique will likely continue.

At the farm level, a strategy involving *Atriplex* that integrates other farm forage resources is suggested. This strategy calls for a combined use of *Atriplex* with cereal stubble during the summer, with cereal straw during winter, and with herbaceous vegetation during the spring. Chriyaa (1994), as will be discussed later, reported a positive sheep response when straw was supplemented with *Atriplex* leaves. Applied research that tests the feasibility and the animal performance of other options for *Atriplex* use is a must. Likewise, in arid and semi-arid areas where overgrazing is a common problem, the performance of shrub plantations under rotational grazing systems should be investigated.

Nutritive Value

It is generally accepted that fodder shrubs are rich in protein and minerals, but deficient in energy (Cook 1972; Le Houérou 1980; Welch 1989). Laboratory analysis of 12 shrub species grown on an experimental station near Murcia (Spain) reveals that Chenopodiaceae species usually contain more minerals (ash), less fiber, and more protein than leguminous species (Correal 1993). However, interpretation of chemical analysis for the evaluation of feeding value of browse remains a field of controversy (Cook 1972; Le Houérou 1980; Welch 1989). Estimating diet quality of animals grazing *Atriplex* plantations is further complicated by the fact that grazing animals consume twigs as well as leaves in an undetermined proportion. In this regard, the use of oesophageal or rumen-fistulated animals gives a more representative estimate of the diet actually consumed.

Crude protein levels in *Atriplex nummularia*, studied by Zafati (1993), show that crude protein, although relatively high all year, is highest in spring and declines through the summer and fall. For this reason, *Atriplex* plantations could be used strategically as a stable source of fodder protein during periods of scarcity, such as late summer and fall. However, not all the nitrogen present in the plant is

digestible. Indeed, Silva-Colomer et al. (1986) report digestibility coefficients of 45 and 77% for fiber and protein, respectively. Chriyaa (1994) reports that only 7 and 74% of the total crude protein was rumen digested in *Acacia cyanophylla* and *Atriplex nummularia* foliage, respectively.

The high crude protein content of *Atriplex* leaves, up to 200 g/kg DM (Wilson, 1966), can be misleading, because up to 60% of this fraction can be non-protein nitrogen (Yaron et al. 1985; cited by Benjamin et al. 1992). This is not always used by ruminants unless readily available energy is present in the rumen. Hassan and Abdel-Aziz (1979) found that sheep eating *Atriplex nummularia* leaves had a negative nitrogen balance, which became positive when their diets were supplemented with barley grain. Benjamin et al. (1992) studied the nitrogen balance in sheep consuming *Atriplex* alone, and with 200, 300, and 400 g of tapioca meal per day. The amount of nitrogen retained varied from 3 to 4.5 g/day, which is equivalent to 19–34 g of CP daily, barely enough for maintenance (NRC 1985). Chriyaa (1994) found that the nitrogen balance increased from 0.6 to 3 and then to 7 g/d as he fed sheep straw alone, straw supplemented with *Acacia cyanophylla*, and straw supplemented with *Atriplex nummularia*, respectively.

Other authors (Ueckert et al. 1988; cited by Arif et al. 1994) found that older animals may use nitrogen in *Atriplex* more efficiently than younger animals. Based on nitrogen-balance studies, the same authors speculate that young animals have to adapt to eating saltbush. Protein quality might be another limiting factor. Khalil et al. (1986) found that methionine and cysteine are the most limiting amino acids in almost all *Atriplex* species.

Fiber content, as expressed by NDF, was lowest in the spring and increased steadily throughout the rest of the year. Digestibility was high from November to April but declined from May to October and averaged 61.3% OM (65% DM) (Correal 1993). *Atriplex nummularia* ranked highest in digestibility among several *Atriplex* species (72% DM on average).

Interestingly, Arthun et al. (1992) found that digestibility and intake of shrubs varied in opposite directions, suggesting that digestibility is of little importance as an indicator of diet quality, especially when the diet is a mixture of shrub and herbaceous species. Similar results were reported by Wilson (1977) with a diet based solely on shrubs. Le Houérou et al. (1983) found that the intake of *Atriplex halimus* offered alone could reach 90 g DM $kg^{-0.75}$. However, an adaptation period is needed for animals consuming shrub foliage.

Le Houérou (1992) found that the feeding value of *Atriplex* varied from 0.35 to 0.45 feed units/kg DM, which is enough to maintain a sheep consuming 1.2 to 1.5 kg/day of fresh feed. A Lower feeding value, 0.16 feed units/kg DM, was reported by Zafati (1993).

Depending on the growing conditions, the ash content of *Atriplex* can be as low as 200 g/kg DM when irrigated with tap water, and as high as 300–400 g/kg DM under saline conditions (Pasternack et al. 1986). Chriyaa (1994) found ash content in *Atriplex nummularia* foliage to be 313 g/kg DM, compared to 126 g/kg DM in *Acacia cynophylla* foliage. This same ash content is the cause of high water consumption (4.4 L/ewe per day, with a maximum of 8.2 L/ewe per day). Penned sheep run on a diet based on straw and *Atriplex* foliage consumed 3–5 times more water than sheep fed wheat straw alone (Chriyaa 1993; unpublished data). Because of its high ash content, the gross energy content of *Atriplex* DM is low compared to that of herbaceous species. In general, the apparent digestibility of *Atriplex* species has been expressed in the literature on a DM basis. This can be misleading because the ash content may include a high proportion of soluble salts of no energy value to the animal.

Feed Quality

The concept of fodder quality is a relative one. Indeed, the quality of a feed depends on supplemental resources to produce efficient production. For example, straw is poor-quality roughage, but when fed with a protein or non-protein nitrogen supplement, it can maintain good animal performance (Abidin and Kempton 1981; Zorrilla-Rios et al. 1989; Zorrilla-Rios et al. 1991; Boulanouar 1994). Furthermore, the quality of a feed depends on its role in the feeding system. In the case of *Atriplex*, one needs to know if it will be used as a supplement or as basal feed. We think that one strategic use of *Atriplex* is as a source of fermentable N and minerals to help the rumen make efficient use of crop residues and grazed natural pasture. We therefore argue that the comparison made by several authors based on UF (feed unit) is unfair to *Atriplex*, as it favors energy instead of nitrogen.

Foraging Behavior

When shrub planting began, livestock owners were skeptical about the benefits of *Atriplex* in improving animal production. Tremendous efforts were undertaken by extension staff to gain the interest of livestock owners.

Conflicting observations have been reported on *Atriplex* palatability in different situations in Morocco. Field observations have shown that when livestock is first introduced to a plantation, it will consume the herbaceous vegetation. Once the native vegetation is running low, animals will turn to *Atriplex*.

Some Moroccan farmers, referring to their experience with the native *Atriplex halimus*, declared that *Atriplex* consumption caused physiological discomfort and weight and wool losses. These adverse effects were denied by field observation (Hammoudi et al. 1994). These discrepancies may arise from differences in

quantity and quality of available forage at the time of grazing. The nutritional history of the animal influences its reaction to *Atriplex*. An animal coming off a good diet requires time to adapt to the new forage. Le Houérou et al. (1983) found that, after an adaptation period of 3–4 months, intake increased 1.5–4 times over intake in the first week.

Generally, animal preference for forage shrubs is low when other forage resources are available. Wilson (1966) found a daily intake of 0.8 kg DM for *Atriplex nummularia*. Kebdani (1993) found that herbaceous vegetation dominated the diet (85% in March, declining in May to a minimum in June). Messaoudi (1988) found that *Atriplex nummularia* contributed 1.9 and 9.6% in June and August, respectively, while the contribution of herbaceous vegetation decreased from 33 to 3% during the same period. Working with sheep and goats, Saadani (1988) found that the contribution of *Atriplex nummularia* to the diet increased from 2 to 19% in sheep and 2 to 6% in goats between April and September. Sheep are the biggest users of *Atriplex* plantations in Morocco. They seem to prefer leaves, while goats, camels, and cattle consume twigs and even stems, jeopardizing the success of the plantation (Hammoudi et al. 1994).

In an arid region of Morocco (Ouarzazate), Kebdani (1993) stocked a three-year-old *Atriplex nummularia* plantation with 2 sheep/ha for 135 days. At this low stocking rate, sheep selected herbaceous vegetation over shrubs. *Atriplex* made up only 7% of the diet in spring and 20% in summer.

Animal Performance

Animal performance was measured during a 42-day grazing period in spring (mid February to early April) on an *Atriplex nummularia* plantation in northeastern Morocco. Wethers sampled from different sized flocks gained 96 g/head per day. During fall grazing (mid September to mid October), performance, measured on a different sample of wethers with similar starting weights, was only 60 g/head per day. Wethers from control herds (kept on natural rangelands) gained 20 g/head per day. No diarrhea or wool loss occurred during either period (Anonymous 1995a). The low performance during fall grazing was likely due to the low availability of herbaceous vegetation. In an arid area in southern Morocco, sheep grazing *Atriplex nummularia* plantations gained 8.5 kg liveweight between December and March, whereas animals grazing native range lost weight (ORMVAO 1992). In a study conducted from September to March in eastern Morocco, where three flocks of pregnant ewes grazed an *Atriplex nummularia* plantation and were supplemented with 0, 300, and 600 g/day of a concentrate feed, Sabor (1995) found that shrubs contributed 2.5% in September and increased to 29% in February.

Unsupplemented ewes produced 30 and 10.5 kg milk during the first and the last six weeks of lactation, respectively (Sabor 1995). Lambs of the same ewes gained 112 g/d during 13 weeks of lactation.

Chriyaa (1994) fed straw to five groups of sheep during the day, with one of four supplements offered *ad libitum* at night. Supplements were alfalfa hay, *Atriplex nummularia* foliage, *Acacia cyanophylla* foliage, and *Medicago* pods. After a 15-week growth trial, only lambs supplemented with *A. nummularia* maintained or gained weight (290 g). Straw intake was increased by 40%.

In another study, conducted in Ouarzazate (ORMVAO 1992), three sheep flocks were fed diets based on *Atriplex nummularia* and barley grain. The first flock received *Atriplex nummularia ad libitum*. The other two groups received 50 and 25% of the first group's intake, respectively. The three groups received 200, 400, and 600 g of barley grain, respectively. The study revealed no difference in animal gain among diets. The average daily gain was 90 g/day. Meat quality, based on slaughtered animals, was similar regardless of treatment. The report pointed out that direct grazing may not use the full potential of *Atriplex*, and suggested that a cut-and-carry feeding system would optimize use.

In a large-scale experiment in Libya, Le Houérou (1987) used three *Atriplex* spp. (*A. canescens*, *A. halimus*, and *A. nummularia*), three *Acacia* spp. (*A. ligulata*, *A. salicina*, and *A. victoriae*), cacti (*Opuntia ficus indicus*), and *Artemisia herba-alba* in rations consisting of single species or in combination. The author concluded that ewes maintained their weight on *A. nummularia* and *A. canescens*, and gained 25–43 g/day when cacti were added to the ration.

Under stall feeding, ewes ingested 1–2 kg DM/day of *Atriplex nummularia* over 4–5 weeks. This diet maintained liveweight and body condition in dry sheep, and increased it when barley straw was added (Correal 1993). The same author found that under field conditions, productive ewes grazing an *A. halimus* plantation maintained liveweight but lost body condition. This may indicate that the *Atriplex* diet was energy deficient, and ewes had to mobilize fat reserves. Moreover, some weight stabilization or gain may be associated with gut fill (accumulation of feed in the reticulo-rumen and high water intake). Correal (1993) maintained a year-long stocking rate of 3.3 ewes/ha (or 150 kg liveweight/ha) to achieve 50 kg lamb/ha production on an *Atriplex* plantation.

Based on several feeding trials, Correal (1993) concludes that the feeding value of oldman saltbush is not limited by intake. Sheep can cover their maintenance needs with this forage, especially when they become familiar with it.

Anti-nutritional Factors

Tannins, characterized by strong protein-binding properties, have been reported to be a defense mechanism of plants against herbivores (McLeod 1974; Rhoades and Cates 1976). Zucker (1983) reports that hydrolyzable tannins depress the enzyme activity of herbivores, while condensed tannins protect plant cell walls against microbial and fungal penetration. High tannin levels may lower intake by depressing protein and fiber digestion (Tagari et al. 1965) and decreasing plant palatability (Arnold et al. 1980) and ruminal nutrient absorption (McLeod 1974). Boutouba (1989) found that tannins and phenolics increase fecal N, but compensate for this by reducing urinary N.

Anti-nutritional factors have evolved to deter feeding by herbivores, the deterrent level being around 20 g tannins/kg DM (Van Soest 1982). Chriyaa (1994) found that concentrations of condensed tannins were 11 and 0.07 g/kg DM in air-dried *Acacia* and *Atriplex* foliage, respectively. The author inferred that high tannin content in *Acacia* was responsible for the low nitrogen digestibility found in the same study.

The evaluation and use of fodder shrubs are full of difficulties, not least of which is problem of determining the role of anti-nutritional factors. In this regard, several questions should be answered: (i) does the fodder shrub contain anti-nutritional factors; (ii) how can research evaluate them early in the selection process; (iii) which particular anti-nutrients are involved; (iv) are the anti-nutrients acting at the microbial level or on the host animal; and (v) are the anti-nutrients secondary plant compounds or are they the products of their breakdown? When these questions are resolved, we must investigate how best to ameliorate the effects of the anti-nutrients, or how to put them to nutritional advantage (e.g. using naturally occurring tannins to limit the breakdown of complex proteins in the rumen). Wilting or drying before feeding as a technique to alleviate the problem is worth investigating.

Anti-nutritive factors are often associated with leguminous shrubs or trees rather than Gramineae. The recent interest in fodder trees has stimulated research on simple ways to identify anti-nutritive factors. Khazaal and Orskov (1993) used the simple yet effective *in vitro* gas production technique to identify microbial anti-nutritive factors. The difference in gas evolution with and without a compound with complex anti-nutritive tannins provides a measure of the extent to which fermentation is inhibited. When the technology is available, Near Infra Red Spectrophotometry can be calibrated to predict feed value and has been correlated with the results of chemical tests.

Animals can develop mechanisms by which they select certain parts of the plant or develop microbial populations capable of minimizing anti-nutritive factors, such as

the microbial destruction of mimosine (Jones 1981) and some tannins from tanniferous plants (Brooker et al. 1993). This may explain the increased adaptation to *Atriplex* over time.

Economics

In 1990, the cost of establishing 1,100 shrubs/ha varied between DH 2,570 and 3,370 (DH 286 = US$ 374) (Alaoui et al. 1992; cited by Arif et al. 1994). In a more recent report (MAMVA 1995), the average cost of establishment was DH 3.7 per plant, with a regional variation between DH 2 and 4 per plant, which corresponds to DH 1,700–5,900 per ha. Hammoudi et al. (1995) reports a production and establishment cost of DH 3 and 3.5 per plant for 1,000 and 500 plants, respectively.

Baumann-Matthaus and Jaritz (1994) review the economical merit of *Atriplex* plantation (1,000 plants/ha; established at DH 3,000–4,000 per ha; life span of 10 years, with 8 years of exploitation, conservative estimate) based on production data and cost of establishment in northeastern Morocco. Using the coefficient of 0.28 UF/kg DM (El Hamrouni et Sarson 1974), the authors calculated the cost (plantation maintenance not included) of DH 1.21 and 1.62 per UF based on a production of 1,100 kg DM/ha (optimistic production level).

In another evaluation study, conducted by ORMVA in Ouarzazate in 1984 (MAMVA 1995), the cost of producing and establishing plants was DH 1,756 per ha. Since a feed unit of barley costs DH 1.5, the authors were not impressed with the economics of planting *Atriplex* merely as a feed source. In northeast Morocco, deferring grazing for two years produced a much cheaper result, with a calculated cost of DH 0.5 per feed unit (Anonymous 1995b). Perhaps we should consider other benefits from shrub planting, such as protection and rehabilitation of degraded environments, rather than focusing on the micro-economic aspects. Other benefits, such as fuel wood and employment created by plant establishment, might be factored into the cost/benefit equation. The search for less-expensive methods (seeding, propagation, etc.) to establish plantations should be a research priority.

Social and Institutional Considerations

Inter- and intra-tribal conflicts are a major hindrance in the choice of plantation site and hectareage to be planted. A rational plan for use, in terms of timing, rest period, and stocking rate, has not always been followed. Some livestock owners have expressed their interest in grazing plantations earlier in the spring in order to use herbaceous vegetation. Moreover, livestock owners remain apathetic to a participatory approach to rangeland improvement investment on communal land. Many local communities, uncertain about the planting goals, fear to lose land ownership if they allow the government to establish plantations. Social,

institutional, and policy studies should investigate the effect of these different factors on the realization of rangeland improvement projects.

When a researcher is pleased with a shrub, why is it not always taken up by the farmer? In a world where disciplinary interest, institutional mandates, and professional recognition are the order of the day, there may not be the time or willingness to answer this pseudo-philosophical question. This issue is complicated by the question of who carries out what type of research or development.

Several questions should be asked about investment in rangeland improvement. Who is going to invest in what is often considered a high risk investment? If the government is going to continue to do so, to what extent and under what conditions is this investment going to be recovered? Finally, what is the measure of rangeland improvement: ecological, agricultural, social, or political? The answer to the last question will help identify the institutional responsibilities for rangeland preservation and sustainability. In our opinion, there is a need for an integration of efforts across institutions to tackle the development of these vast areas.

Research Orientations

To fill information gaps in forage shrub (mostly *Atriplex*) establishment, production, and use, the MAMVA Livestock Directorate contracted a number of studies with the Institut National de la Recherche Agronomique (INRA) and the Institut Agronomique et Vétérinaire Hassan II (IAV). We recommend the topics discussed below as the priority research agenda:

Genetic Resources

Germplasm collection is time and resource consuming. If we spend the time surveying everything before we get around to feeding an animal, then in many situations the animal never gets fed. Often the money runs out, or the interested scientists are promoted and become administrators! Research needs to concentrate on fewer promising species with an early evaluation of production and persistence under grazing, with the emphasis on livestock use. An important principle to remember is that ecological adaptation is not synonymous with productivity, or *vice versa*. *Atriplex canescens* offers interesting ecological features, as it is cold resistant, but ranks low to medium in palatability when compared with other *Atriplex* spp. Early evaluation under animal use (cafeteria trials) is the only way to address these issues. The use of indigenous knowledge about agronomic factors and animal grazing can be very helpful in identifying useful species as fodder.

Use

Development and testing of shrub-use schemes that complement other forage resources (natural and planted), and possibly crops (alley cropping), make up a high-priority research area. Cut-and-carry, as opposed to free grazing, needs to be addressed in these situations.

In arid and semi-arid Mediterranean areas, where overgrazing is a common problem, the study of shrub performance under a grazing–rest rotation associated with supplementation is a very relevant research topic.

Nutritive Value

There is a need to standardize methodologies used to evaluate the biomass and nutritive value of shrubs. This will help identify to what extent these shrubs meet the requirements for ruminant maintenance and growth, and what supplements are needed to correct possible deficiencies.

The use of more recent developments with *in vitro* gas production measured solely or in combination with *in vivo* measurements offers great potential. Likewise, the prediction of feeding value based on equations developed by NIRS technology has potential.

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Fodder Shrubs and Trees in Pakistan

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Physical Environment

Pakistan is situated between 24 and 37° N latitude and between 61 and 75° E longitude. The total area of the country is 796,095 km^2 (79.6 million ha). Pakistan is a land of great attitudinal variation. It has a vast coastal belt in the south and southwest, and high mountain peaks, such as K2 (8,611 m) and Nanga Parbat (8,126 m) in the north. The Indus basin river system is the world's largest contiguous irrigation system. The country is characterized by a continental climate, which is arid and semi-arid with two distinct seasons, summer and winter. There is an extreme variation in temperature, which depends upon topography. Although the country is in the monsoon region, it is arid, except for the southern slopes of the Himalayas and the sub-mountainous tract, where annual rainfall varies between 760 and 1,270 mm. Balochistan is the driest part of the country, with annual rainfall varying from 50 to 250 mm. The monsoon (July to September) provides the major portion of the rain in most parts of the country. The mean annual temperature is 27°C, the mean maximum temperature 31°C, and the mean minimum temperature 16°C. There are winter rains in November and December, which are limited in quantity but more widespread than the summer rains. June and January are the hottest and coldest months of the year, respectively.

The soils of the Indus basin are mostly alluvial soils, with smaller amounts of loess soils. The alluvial material is mostly calcareous silt loam. The organic content of these soils is 0.5–0.8% to a depth of 75–100 cm. The pH usually ranges from 8 to 9 (Sheikh 1993). The major problems in Indus basin soils are waterlogging and salinity. The deserts of Thal, Cholistan, and Thar extend over an area of 12 million ha. Most of the this area comprises dune lands, consisting of ridges of sand, drifted and piled by the wind (Sheikh 1993). The inter-ridge valleys have sandy loam soils which support a good vegetation cover.

Agricultural Systems

The agricultural production systems in Pakistan involve the production of crops, livestock, forestry, and rangelands.

Crop Production

Out of the country's total cultivated area (20.6 million ha), 75% is irrigated and 25% is *barani* (rainfed). The total cropped area amounts to 18.25 million ha, of

which food grains occupy 65%, cash crops 20%, pulses 8%, oilseeds 3%, and fruits, vegetables, and fodder 4% (PARC 1994). Cropping patterns have changed over time. The area under cultivation to major crops like wheat and rice has increased 10% since the 1950s. The area under cash crops, like sugar cane, cotton, fruits, and vegetables, has also increased (PARC 1994).

Livestock Production

Livestock is an important component of the farming system in most parts of the country. Livestock is the source of: (i) savings and capital for rural people, contributing to basic family food requirements; (ii) crop nutrients, draft, and transport for the poor; and (iii) wool and leather (PARC 1994). The livestock sector contributes 30% to the total agricultural share of the GDP.

According to the Pakistan Economic Survey report (1988/89), the livestock population has substantially increased over the last 45 years. This increase has been the greatest for sheep and goats, which registered a 4–5 fold increase in population. The buffalo population rose from 6.3 million head in 1955/56 to 14.3 million in 1988/89. The cattle population showed a similar trend. The poultry sector has flourished during the past decade or so, with 128.7 million birds in 1986, compared to 44.9 million in 1976 (PARC 1994). Over 90% of households have 30 sheep or goats. The large flocks of both sheep and goats are in the range areas of Balochistan, Sind, and the northwestern frontier provinces.

Forestry and Rangelands

The area under forests in Pakistan is only 5.2% (4.58 million ha). The total share of the forestry sector in the overall GDP was only 0.3% in 1990/91 (PARC 1994). Forest resources have been subjected to continuous depletion due to population pressures and the demand for fodder and fuel. The lack of policy initiatives and reforestation programs, and widespread illegal commercial logging, have also caused serious damage to this sector.

About 60–65% of the country is categorized as rangeland. These rangelands provide about 60% of the total feed requirement for sheep and goats, 40% for horses, donkeys, and camels, and 5% for cattle and buffalo. They also serve as a production base for livestock, which provide meat and milk for human consumption and products such as hides, skins, wool, bones, and manure. Rangelands also provide fuel, building materials, medicinal plants, and a habitat for wildlife. In the north and northwestern parts of the country, rangelands constitute about 40% of the watersheds, which drain into a number of big dams, such as Tarbela and Mangla.

Rangeland Ecological Zones

The rangelands of Pakistan can be divided into five major ecological zones, summarized below.

Sub-alpine, Temperate Zone

This zone lies between 2,000 m altitude and the snow line in Azad Jammu, the Swat and Kaghan valleys, and northern areas. Average annual rainfall is more than 1,000 mm. Snowfall varies from 1 to 5 meters. The climate is characterized by a short growing season and long cold winters. The vegetation is generally composed of slow-growing perennials and herbaceous and shrubby plants. Much of the landscape of alpine pastures is rugged and broken, with rocky snow-capped peaks (Mohammad 1989). These areas provide excellent forage for livestock grazing during the summer.

Sub-tropical Humid Zone

The sub-tropical humid zone is represented by Chir pine, but kail forests also occur on the higher slopes in northern Pakistan and Azad Kashmir. The altitude varies from 1,000 to 2,000 m. Ecologically, the area can be divided into moist temperate and sub-tropical humid zones. The humid zone (wet temperate areas) receives plenty of snow during winter. Most of the areas within this zone receive huge amounts of rains (>1,000 mm) during the monsoon season (July–September). Forestry, cropping, and livestock grazing are the major land uses (Mohammad 1989). Winters are very cold, with snowfall up to 1 m. These areas are grazed during the summer growing season (Mohammad and Naz 1985).

Sub-tropical Sub-humid Zone

This zone covers the Pothwar tract and the salt range. Rainfall varies from 500 to 1,000 mm per year. The Pothwar plateau consists of a large tract of 1.5 million ha, covering the Islamabad, Rawalpindi, Chakwal, Jhelum, and Attock districts. It lies between the Jhelum and Indus rivers. The altitude varies from 300 to 1,550 m. Ecologically, the area is located in the sub-tropical, semi-arid to sub-humid zones (Mohammad 1989). The climate ranges from temperate in the northeast to sub-tropical semi-arid in the southwest. Annual rainfall varies from 250 mm in the southern parts of the salt range to over 1,500 mm at Islamabad. The soils of the region are developed from wind- and water-transported material consisting of loess, old alluvial deposits, mountain wash, and recent stream-valley deposits. Livestock grazing is the most important component of the farming community. The zone has high potential for range reseeding and fodder tree/shrub plantation.

Arid, Semi-arid Desert Plains

Thal, Cholistan, Dera Gahzi Khan, and Tharparkar are the major range areas in this zone. Rainfall is erratic and ranges from 100 to 200 mm, most of which is received during the summer monsoon season. The vegetation of these areas consists of xerophytic trees, shrubs, and grasses. Sheikh (1986) describes the vegetation of Cholistan as sand dune and desert scrub, and the vegetation of Tharparkar as tropical thorn desert. The total area of the Cholistan and Tharparkar ranges is about 5.4 million ha. The Kohistan rangelands are located in the lower parts of Sind province and cover an area of about 2.3 million ha. These rangelands are characterized by strong winds and high humidity during the summer monsoon season. The soils of these areas are saline, alkaline, and gypsiferous (Mohammad 1989).

Mediterranean Zone

The highlands of Balochistan Province, including the Quetta and Kalat Divisions, are located in this zone. It has an arid or semi-arid climate. Annual precipitation varies from 50 mm in the west to over 400 mm in the east. The rainfall distribution pattern is erratic, with extremely low and high temperatures (Kidd et al. 1988). Physically, the area consists of an extensive plateau of rough terrain divided into basins by mountains. Most of Balochistan south of 30° N is classified as hot subtropical desert, where rainfall varies from 50 to 150 mm and the principal land use is grazing with some agriculture. The high altitude areas of northern and eastern (highland) Balochistan, with an altitude of 1,000–3,000 m, are climatically classified as semi-arid continental Mediterranean (Rees et al. 1988).

Important Native and Exotic Fodder Shrub/Tree Species

The geographical setting of Pakistan is characterized by a number of diverse ecological and climatic regions. It has wet and dry temperate regions and sub-tropical humid and sub-humid regions in the northern and northwestern parts of the country, and tropical arid (sandy and non-sandy), Mediterranean, and sub-mountain zones in the southern and southwestern parts of the country. These distinct zones are characterized by a variety of fodder tree/shrub species which provide much-needed forage/browse for the large number of livestock being reared in Pakistan. The main characteristics and the distribution of important native and exotic fodder trees/shrubs in Pakistan are summarized in Table 1.

Table 1. Distribution of important native and exotic fodder trees/shrubs species.

Ecological zone	Main areas	Fodder trees/shrubs	
		Native	Exotic
Sub-alpine and temperate	Azad Kashmir, Neelum and Jhelum valleys, Murree hills, Swat, Kaghan	*Amorpha fruiticosa* *Indigofera gerardiana* *Prunus padus* *Fraxinus excelsior* *Aesculus indica* *Alnus nepalensis* *Celtis australis* *Quercus dilatata*	
Sub-tropical humid	Abbottabad-Mansehra Murree hills, Muzaff arabad	*Amorpha fruiticosa* *Grewia oppositifolia* *Prunus* spp. *Robinia pseudoacacia*	
Sub-tropical sub-humid	Pothwar, Murree foothills, Haripur, Mirpur, Kotli and Bhimber (AJK)	*Acacia modesta* *Olea cuspidata* *Tecoma undulata* *Ziziphus mauritiana* *Z. nummularia*	*Acacia aneura* *Leucaena leucocephala* *Ceratonia siliqua* *Robinia psuedo-acacia* *Sesbania sesban*
Arid and semi -arid desert plains	Thal, Tharparkar DG Khan, Cholistan	*Acacia nilotica* *A. modesta* *A. senegal* *Prosopis cineraria* *Tecoma undulata* *Ziziphus mauritiana* *Z. nummularia* *Indigofera oblongifolia*	*Atriplex amnicola* *A. nummularia* *Opuntia ficus-indica* *Acacia aneura* *A. tortilis*
Mediterranean	Quetta and Kalat Divisions	*Pistacia khinjuk* *Prunus ebumea* *Fraxinus excelsior* *Olea ferruginea* *Caragana ambigua* *Astragalus stocksii* *Artemisia herba-alba*	*Atriplex canescens* *A. lentiformis* *Salsola vermiculata* *Gleditsia triacanthos*

Acacia modesta (phulai)

This is a medium-sized legume tree native to many parts of Pakistan, including the Salt and Sulaiman Ranges. It is also found extensively in sub-Himalayan tracts (<1,400 m) and as far as the Balochistan Mediterranean zone. It grows in areas with annual rainfall between 380 and 1,270 mm and temperatures from below 0 to 45°C (Mohammad 1989). It grows best on limestone and in the scrub forest zone of Pakistan. Its main propagation is through natural regeneration. However, extensive plantation of *Acacia modesta* has been carried out in the Thal desert range, the Pothwar scrub range, as well as the Loralai district in Mediterranean Balochistan. Large-scale irrigated plantations have been established in the Changa Manga forest. Phulai is considered one of the most valuable native fodder trees in

Pakistan, because of its palatability and nutritious fodder value, and is grazed by all classes of livestock (Mohammad 1989).

Acacia nilotica (babul, kikar)

Babul trees are native to the Indus plains of the Sind and Punjab Provinces, the Pothwar plateau, and the Sulaiman foothills. It is a moderate to large tree with a spreading crown and feathery foliage (Mohammad 1989). It also has a large ecological amplitude and grows in areas with 400–800 mm annual rainfall, with temperatures as high as 50°C. In the drier parts of the country, plantations of this species have been established under irrigation for forage, fuel, and ornamental purposes (Sheikh 1989). In the riverain forests of Sind, broadcast seeding has resulted in good growth. In Pothwar, direct sowing in pits, contour ridges, and furrows has resulted in good success (Mohammad 1989). Babul is known for its good-quality fodder from leaf pods. Ghori (1957) reports an annual pod yield of 4.2 t/ha from the riverain forest of Sind.

Acacia senegal (khor)

This is found extensively in the dry rocky hills of Punjab, Sind, and Balochistan (Khan 1965). It is a small to medium-sized legume tree that grows to a height of 13 m. It grows in sub-desert conditions in areas with rainfall as low as 200 mm (Mohammad 1989). In the Tharparkar desert, the species grows at temperatures of -4 to 48°C. The foliage is rich in protein and considered an important feed for livestock, especially during the rainy season and early winter (NAS 1983). The pods are numerous and are willingly consumed by goats and cattle. It grows through natural regeneration under very dry conditions, but nursery-grown seedlings are being planted in Tharparkar desert ranges by the Sind Arid Zone Development Authority (SAZDA) for forage as well as sand dune fixation (IUCN 1992).

Acacia tortilis (jangli babul)

This tree is native to the northeastern African desert, the Middle East, and southern Arabia (Mohammad 1989). It is a small thorny legume tree, 4–20 m high. This plant has been established successfully in arid and semi-arid areas and the desert ranges of Thal and Dhabeji by using moisture-conservation techniques. Some plants have been established in the desert ranges using pitcher irrigation techniques (Sheikh 1986). It grows well under extreme dry conditions and is considered a valuable addition to the fodder tree, adapted to the desert conditions of Pakistan, where annual rainfall is 200–300 mm and temperatures rise to 50°C. However, it is susceptible to frost and cannot be planted at high elevations with cold winters (Sheikh 1986). It can be propagated by seed, but nursery-grown seedlings are more

successful. Plantations have been established in Tharparkar for forage and sand dune stabilization (IUCN 1992). The leaves and pods are very nutritious and are fed to cattle, sheep, goats, and camels.

Atriplex canescens (fourwing saltbush)

This is a saltbush native to the west-central great plains of the United States, northern Mexico, and Canada. It is a medium-sized shrub that reaches a height of 1.5–2 meters. The shrub is considered valuable fodder for sheep and goats and is planted on a large scale in arid, semi-arid, and Mediterranean parts of the world. In Pakistan, fourwing saltbush was first introduced into Mediterranean Balochistan during the mid 1960s, when a few shrubs were planted near the Maslakh range by the Forest Department. Research on establishment and forage value of fourwing saltbush was started by the Arid Zone Research Institute (AZRI) during the early 1980s under the USAID financed project on Management of Agricultural Research and Technology (MART), implemented by ICARDA. As a result of research and extension efforts made by AZRI, fourwing saltbush is now being planted as a fodder shrub in highland Balochistan by the Government and NGOs. It has a great potential, if planted on a large scale, to establish forage reserves and rehabilitate denuded watersheds (Mirza 1995).

Atriplex lentiformis (quail saltbush)

This is a large shrub from the southwestern United States that is well-adapted in the Mediterranean highlands of Balochistan. It grows in areas with annual rainfall of 250–300 mm and resists temperatures as low as -15°C. Research conducted at the Arid Zone Research Institute, Quetta, shows that the species is preferred by goats and sheep and can be established successfully in the cold and dry conditions of highland Balochistan by using moisture-conservation techniques (Mirza 1995). The species has a fast growth rate compared to fourwing saltbush and old man saltbush. This, along with its larger leaf size, makes it a popular choice for the farmers and other agencies establishing nurseries and fodder reserves on a large scale in Mediterranean Balochistan. This species has the potential to grow under the saline conditions of the arid tropical parts of the country with warm winters (Abdullah et al. 1993).

Atriplex nummularia (old man saltbush)

This shrub is native to Australia and adapts well to the drier parts of the world because of its great resistance to drought. It is an erect shrub, up to 2 m high, and grows well in the arid and semi-arid parts of the Punjab and Balochistan provinces. It is also well-adapted to the saline conditions of the Indus plains. In highland Balochistan, it grows well in areas with 200–250 mm annual rainfall. It can resist

temperatures as low as -10°C, but dries at the top at temperatures below -10°C. The shrub produces considerable fodder, especially in the dry season, and has the potential for cultivation in arid tropical and Mediterranean environments using moisture-conservation techniques.

Caragana ambigua (makhi, haji pit)

This is a thorny medium-sized leguminous shrub abundant in the high altitude areas of northern mountains and Balochistan. The shrub grows naturally in areas with low annual rainfall (200–250 mm). Propagation through seed has been carried out in protected areas of highland Balochistan. The shrub produces a good amount of fodder that is browsed by sheep and goats, especially during summer and early winter. *Caragana* has the potential to be propagated through seed in degraded areas for forage and watershed management purposes.

Celtis australis (European hackberry, tagho, kharik)

This tree is found in the Himalayas and in the Sulaiman and Salt ranges of Pakistan at an altitude up to 2,500 m (Mohammad 1989). It is often planted in northern areas for good quality fodder for cattle and sheep/goats. Tagho flowers from March to May. Its trunk is short and grows quickly (Khan 1965).

Elaegnus angustifolia (Russian olive)

This tree is native to southern Europe, Central Asia, and the Himalayas. It is a medium-sized deciduous tree with leaves that are grayish on the upper surface (Khan 1965). It is widely planted in the northern areas and Balochistan as a fodder and fruit tree. Leaves are used as hay during winter, and its fruit berries are edible (Mohammad 1989). The tree is widely planted in highland Balochistan around water ponds, channels, and orchards for shade as well as fodder.

Fraxinus xanthoxyloides (shang, Ziarat ash)

This is a shrub or small deciduous tree, 3–7.5 m tall. It is native to the sub-continent, including Pakistan, Afghanistan, and India. In Pakistan, it is widely found in the Gilgit Agency, Chitral, Dir, Swat, Hazara, Kurrum, and Balochistan (Sheikh 1993). It prefers arid and semi-arid conditions, cool temperates, a Mediterranean climate with a temperature range of -20 to 35°C, and elevations between 1,000 and 2,500 m (Sheikh 1993). It grows from seed as well as by vegetative means. The growth rate is very slow, but the tree is considered valuable for forestation projects and watershed management. The leaves can be used for

fodder for sheep and goats. Natural stands of *Fraxinus* are lopped by farmers as a nutritious fodder for their animals.

Gleditsia triacanthos (honey locust, dozakh)

This is a medium-sized to large thorny legume tree, native to the USA, which has been successfully planted in Africa and Australia and is well adapted to the dry arid conditions of Pakistan. The tree is frost-hardy and famous for its nutritious browse and straight, crescent-shaped pods, 40–50 cm long (Gohl 1981). Small-scale plantations have been established by the Forest Department in parts of the sub-tropical sub-humid and Mediterranean zones. Seed of *Gleditsia* obtained from Aleppo, Syria was planted in nurseries in Quetta, Balochistan, and the seedlings established in field conditions with occasional watering. It has a fast growth rate and good potential for promotion on large areas throughout highland Balochistan as a fodder tree.

Leucaena leucocephala (ipil-ipil)

This semi-evergreen shrub or tree is native to Central America and has been introduced into tropical countries like Australia, the Philippines, Pakistan, and India (Mohammad 1989). It has feathery leaves and large pods. There are more than 100 varieties of ipil-ipil in the world (NAS 1977). It is widely adapted, and large plantations of this fast-growing legume shrub/tree have been established in Pakistan, mainly for fodder. It can grow up to altitudes of 1,000 m and survives in high temperatures (45°C). It requires extensive rainfall (600–1,700 mm), but is frost susceptible. In dry areas, such as Sind Province, it has been grown under irrigation (Mohammad 1989). Large-scale plantations have been established by range development projects in the semi-arid sub-humid Pothwar tract, including Islamabad and the Pabbi tract near Kharian.

Ipil-ipil has been identified as an excellent species for establishing fodder plantations in the northwest frontier, and in Punjab and Sind provinces. The leaves and pods are very nutritious and palatable. Extensive research on uses of this species for range improvement and as a feed for cattle and small ruminants has been carried out. Dry matter yield of 20–30 t/ha can be obtained by planting at one meter spacing (Mohammad 1989). It is also being grown for fuel and ornamental purposes along roadsides in Punjab, NWFP, and Sind provinces.

Morus alba (mulberry, tut)

This tree is native to China, Central Asia, and the Himalayan region. It is a medium-sized deciduous tree found extensively throughout Pakistan. It is also extensively cultivated for shade, fodder, fruit, and fuel wood in almost all parts of

Pakistan. It can grow on the plains and up to an elevation of 3,200 m. The tree can be easily established through seed or stem cuttings. Mulberry leaves make good-quality fodder, which is fed as green fodder as well as hay during winter (Mohammad 1989). It can also withstand low temperatures and grows well in the arid highlands of Balochistan with at least three years of supplemental irrigation. It is planted by farmers as a farm forestry tree.

Olea ferruginea (kau)

This is a medium-sized evergreen tree that grows on the foothills of the Himalayas, the Pothwar scrub ranges, the Salt and Sulaiman Ranges, and the Quetta-Pishin and Zhob districts of Balochistan. It grows at an altitude of 500–2,000 m, with an annual rainfall of 500–1,200 mm, and prefers limestone rocky soils (Mohammad 1989). The leaves are lopped for fodder and fed to cattle, sheep, and goats, especially during winter months. There are large tracts of *Olea* trees in the northwestern parts of Balochistan province, protected by the local communities and used for fodder and wood.

Opuntia ficus-indica (spineless cactus)

Cactus fodder is generally considered low-protein, bulk foodstuff used as emergency or supplemental feed during periods of extreme drought (Le Houérou 1989). Spineless cactus was first introduced in the arid tropical rangelands of Sind at Dhabeji, where a large plantation was established in the early 1980s. It is relished by sheep and cattle and is highly recommended for large-scale plantation in the Kohistan rangelands (tropical arid thorn sub-mountain zone). This zone is characterized by hot summers (45°C) with 150–200 mm annual rainfall and very high humidity (up to 80% during the monsoon season).

Pistacia khinjuk (shinae, wild pistachio)

This tree is native to the Mediterranean rangelands of Balochistan. It grows to elevations of 2,500–3,000 m in areas with annual rainfall of 150–300 mm. It has the capability to grow in dry and harsh climates and can withstand temperatures below 0°C. The growth rate of this species is very slow; seedlings grow at a rate of 8 cm/year. Nursery-grown seedlings planted in Ziarat, Balochistan had a 50% survival rate due to biotic and abiotic stresses (Sheikh 1993). Its main uses are fruit, fodder, and fuel. In some areas the trees are lopped to provide fodder for sheep and goats. The Balochistan Forest Department has made sporadic efforts to establish stands of shinae through nursery-grown seedlings and direct seeding in national parks. It is known to have come back in the community as a result of long-term protection from grazing (Sheikh 1993).

Prosopis cineraria (jand)

This tree is native to Pakistan, India, Afghanistan, Iran, and Arabia (NAS 1983). It grows in the tropical desert rangelands of Thal, Cholistan, and Tharparkar, in the lowlands of Balochistan, and in the Pothwar plateau (Mohammad 1984). It is a medium-sized thorny tree, 10–18 m high, with an open crown. It grows in areas with high temperatures (up to 50°C) and annual rainfall between 75 and 850 mm. It is widely distributed in the plains of Punjab and Sind, where the annual rainfall is less than 300 mm (Sheikh 1986). Direct seeding of jand in mixtures with perennial grasses (*Cenchrus ciliaris*) has been carried out successfully in the Thal desert ranges. However, natural re-generation is confined to moist depressions and along stream channels (Mohammad 1987).

Jand is considered by the local desert range pastoralists as one of the most valuable fodder and fuel trees. It is generally lopped for fodder and pods. The leaves and pods are relished by sheep and goats. Dry matter yield of 60 kg/tree from leaves and pods has been reported in India (Singh 1982). Although sporadic efforts are being made to establish stands of *Prosopis cineraria*, great potential exists for establishing fodder banks in the desert ranges of Pakistan.

Quercus species (oak)

Quercus dilatata, *Q. semi-carpifolia*, *Q. incana*, and *Q. ilex* are widely distributed in the moist temperate and sub-tropical humid zones across the Himalayan and Trans-himalayan grazing lands of northern Pakistan. They grow at altitudes between 1,300 and 2,600 meters, with annual rainfall of 1,000–1,800 mm. The shoots and leaves are extensively lopped for fodder for sheep and goats throughout the Himalayan grazing lands (Mohammad 1989). Local peoples attach great importance to the oak trees and protect the forests.

Robinia pseudoacacia (black locust)

Robinia is native to the North American continent. It is a fast-growing deciduous legume tree which is extensively grown in Pakistan for range and watershed management (Mohammad 1989). It grows well at altitudes of 1,000–2,000 m receiving 700–1,500 mm annual rainfall in a relatively cool climate. It is a multi-purpose tree, cultivated in Pakistan for hedges, fuel, ornamental uses, and erosion control (Mohammad 1989). It provides nutritious fodder for sheep, goats, and cattle, with leaves lopped and fed to livestock as green fodder and hay. *Robinia* has wide climatic adaptation and can be cultivated in the highland areas of Balochistan under cold and dry environmental conditions. However, planting in dry areas requires supplemental irrigation for up to four years.

Salsola vermiculata

This shrub, native to the Mediterranean environments of Syria and Jordan, has been introduced into Mediterranean highland Balochistan. It is a small to medium-sized perennial shrub with fine leaves and a profusely branched stem. A few seeds were brought from ICARDA, Aleppo, Syria and raised under field conditions at AZRI, Quetta. Initial results are very encouraging. It has been successfully grown under an annual rainfall of 200–250 mm with sub-zero temperatures in winter. Stands two to three years old have spread through natural regeneration. It is thus preferred by farmers and agencies involved in fodder shrub plantation and watershed management in highland Balochistan. Because of its propagation potential through direct seeding, there is a need for further testing under various ecological and climatic conditions.

Sesbania sesban (sesban)

This is an exotic medium-sized fodder tree, native to parts of Africa but now well-adapted to tropical Africa and tropical Asia. It is adapted to the sub-tropical humid and sub-humid areas of Pakistan in Punjab and the Northwest Frontier Provinces (Khan 1965). Sesban grows at altitudes of 300–500 m in Pakistan with annual rainfall of 300–1,000 mm. It grows well under a wide range of soil and climatic conditions at temperatures of 10–45°C. It is a multi-purpose tree. Because it is a legume, it is planted in the plains as a green manure and used for inter-cropping as part of an agroforestry system. It also provides good-quality fodder for livestock.

Ziziphus mauritiana (ber)

This tree is native to Pakistan, India, and Nepal. It grows up to elevations of 1,800 m in Pakistan (Khan 1965). It is widely distributed in the tropical arid lands of the Indus plains and the Balochistan lowlands. It has wide ecological amplitude, growing at temperatures from -5 to 50°C and rainfall as low as 150 mm. It is a small to moderately sized deciduous tree with a spreading crown and sweet berries. It reaches a height of 10 m and can easily be planted by seed. It makes a nutritious forage for browsing goats. The branches and leaves are also lopped for fodder for cattle, sheep, and camels. Although the tree is considered very valuable for fodder, its propagation in the country is limited to natural regeneration. As with *Prosopis cineraria*, great potential exists for large-scale plantation of this tree for forage and fuel in the arid and semi-arid ranges of Pakistan.

Ziziphus nummularia (mallah, ber)

This is a medium-sized prickly shrub with sweet small round fruits, native to the sub-tropical sub-humid and arid tropical zones of Pakistan. The small leaves are

dark green and velvety on top (Gohl 1981). These shrubs provide valuable fodder for camels and goats. The species is highly valued in desert-like areas. It is usually stored for winter use by beating dried cut branches and gathering leaves into heaps. There is abundant natural regeneration of these shrubs in arid and semi-arid parts of the country. No planned plantation has been carried out.

Previous Development Projects

Fodder shrubs and trees are being planted as part of the range improvement activities of various projects implemented by the Range Management Divisions of the Forest Department, the Pakistan Forest Institute, various institutes of the Pakistan Agricultural Research Council, and NGOs involved in natural resource management. However, very few development projects for planting fodder shrubs/trees have been undertaken in Pakistan. Generally speaking, most plantation of multi-purpose trees/shrubs is carried out by farmers on their own land as part of agroforestry practices. This not only provides the farmer with income from wood and timber but also with valuable fodder for stock during drought and lean periods. Recently, some NGOs have shown interest in large-scale plantations, mainly for biodiversity and environmental conservation. These include the National Rural Support Porgramme, the Sarhad and Balochistan Rural Support Programmes, the Agha Khan Rural Support Programme, the Sind Arid Zone Development Authority, universities, banks, and private sector agencies.

In addition, there are a number of international agencies and bilateral donor countries, such as FAO/UNDP, the World Bank, the Asian Development Bank, ICARDA, the Swiss Development Cooperation, the Italian Government, CIDA, JICA, the Swedish Government, and USAID, which operate in Pakistan for the overall development and management of natural resources (PARC 1994).

A few of the large-scale projects involved in the plantation of fodder trees/shrubs are highlighted below.

Productivity Enhancement Program

The Productivity Enhancement Program (PEP) of the Pakistan Agricultural Research Council (PARC), entitled Out-reach Project on Utilization of Salt-affected Soils, was started by the Range Section of AZRI in 1993 and ended in 1995.

Location. Project activities were confined to various areas of Mediterranean highland Balochistan, including Quetta, Kanak, Mastung, Panjpai, Kovak, Kalat, Pishin, Muslim Bagh, Qilla Saifullah, Sanjavi, and Loralai.

Project activities. Through the integrated efforts of AZRI and the provincial line departments, as well as NGOs, a total of 1,700,000 seedlings of fourwing saltbush (*Atriplex canescens*) and quail saltbush (*Atriplex lentiformis*) were planted on approximately 170 acres of marginal land in highland Balochistan. The initiation of the saltbush planting campaign under the PEP project encouraged NGOs and provincial forest and livestock departments to continue collaborating with AZRI in seedling production and planting on the marginal lands of highland Balochistan and high altitude areas in other provinces.

Impact of the project. As a result of the introduction of fourwing saltbush as a promising shrub for forage as well as fuel, the Balochistan Forest Department is initiating a project titled the Range/Watershed Rehabilitation Programme, under the World Bank's Natural Resource Management project. With the technical assistance of AZRI, BFD planted large areas with *Atriplex* seedlings for forage and fuel as well as for watershed management at Maslakh, Killa Saifullah, Loralai, Ziarat, and Zhob. The Balochistan Forest Department established a nursery of fourwing saltbush seedlings in AZRI fields during July–August, 1995, which has the capacity of holding 200,000 seedlings. Another nursery of 200,000 seedlings was established at Loralai.

Large-scale plantation of saltbush was begun by the Integrated Range/Livestock Development and Watershed Planning and Management projects, implemented by FAO/UNDP and the Balochistan Forest Department in highland Balochistan. Large areas near Quetta (Karak, Aghbarg, and Nohesar) and Loralai will be planted with *Atriplex* and other promising fodder shrubs using water harvesting techniques. At Karak and Aghbarg, about 120,000 seedlings were planted on watershed areas. The FAO Watershed Planning and Management Project established two nurseries, at Zangi Lora and AZRI, Quetta, each with the capacity of producing about 200,000 seedlings.

Evaluation of the research and extension work done so far by AZRI on fourwing saltbush propagation and use suggests that it should not be seen as a means to reverse advancing range degradation. Instead, we emphasize that saltbush is suitable for growing on lands that are marginal for crop production, with deep soil and less competition from existing vegetation. Hence, the technology should be used to establish forage reserves on land owned by farmers, which has the advantage of being under the control of the farmer. These forage reserves should be used in lean periods as a supplement to natural grazing instead of for revegetating degraded rangelands.

Pabbi Range Management Project, Kharian

The Pabbi Range, an area of more than 10,000 acres, is located in the sub-tropical sub-humid Pothwar scrub forest zone in Punjab Province near Kharian. The

climate is sub-tropical monsoon with high temperatures of 40°C in June. Range improvement activities include grass reseeding of *Cenchrus ciliaris* and *Panicum antidotale*. Large areas are planted with fodder trees and shrubs using various moisture-conservation techniques. The major fodder tree/shrub species, planted on approximately 1,000 acres, is *Leucaena leucocephala* (ipil-ipil). This fast-growing leguminous fodder shrub/tree is well-adapted to the sub-tropical sub-humid zone and is grown on a large scale under rainfed conditions for fodder and fuel. The range management division of the Punjab Forest Department allows lopping for fodder and also issues permits for browsing on leaves and pods. Ipil-ipil is a very popular fodder shrub/tree, planted throughout the region by farmers on their lands.

Range Management Project Dagar Kotli (Thal desert)

Dagar Kotli is located in the Thal desert in central Punjab. It is categorized ecologically as a tropical plain (sandy). The rainfall varies from 133 mm in the south to 300 mm in the northeast. Range improvement activities involved mainly reseeding of large tracts with *Cenchrus ciliaris* and *Lasiurus sindicus* bunch grasses. Various fodder tree/shrub species were planted, using micro-catchment techniques for moisture conservation, for research and demonstration activities on approximately 700–800 acres in Dagar Kotli. Similarly, in Rakh Karluwala, about 2,000 acres were planted using drip irrigation. The main fodder tree/shrub species planted in the area include: *Acacia modesta*, *A. tortilis*, *A. nilotica*, *A. victoria*, *A. albida*, *Prosopis cineraria*, *Ziziphus mauritiana*, *Tecoma undulata*, and *Leucaena leucocephala*. The fodder is lopped during drought, and permits for grazing and browsing leaves and pods are issued by the project authorities.

Other Plantations of Fodder Trees/Shrubs

Large-scale plantation of fodder shrubs/trees has also been carried out by the Dhabeji Range Management project, Kohistan, Sind. The main species planted include: *Acacia nilotica*, *Tecoma undulata*, *Leucaena leucocephala*, *Prosopis cineraria*, and *Opuntia ficus indica* (spineless cactus).

The Sind Arid Zone Development Authority (SAZDA), in cooperation with the Swiss Development Cooperation (SDC), initiated large-scale plantations of fodder tree/shrubs in the Tharparkar Desert of Pakistan under the Range Management and Agroforestry Action Research in Thar and Nara Region, Sind. Large-scale plantation for sand dune fixation and fodder production is being carried out as part of the action program of range and agroforestry in the Thar and Nara regions of the Tharparkar Desert (IUCN 1992). The main fodder tree/shrub species include *Acacia nilotica*, *Acacia senegal*, *Atriplex halimus*, *Leucaena leucocephala*, *Prosopis cineraria*, *Tecoma undulata*, and *Ziziphus mauritiana*.

Shrubs as a Feed Source

In Pakistan, shrubs are used for various purposes, including fodder—either lopped or browsed—sand dune fixation, watershed management, medicinal, and fuel.

Trees and shrubs are an important source of livestock feed throughout Pakistan. They have certain advantages because of their productivity, palatability, and nutritional quality (Mohammad et al. 1986). According to the last census, conducted in 1986, Pakistan has a total of 91.07 million head of livestock (Goverment of Pakistan 1988). Out of this total, sheep and goats represent 56.6 million head. The majority of these small ruminants are raised in various parts of the country on ranges dominated by shrubs and trees. In northern temperate and sub-tropical humid and sub-humid zones, where enough moisture is received for tree growth, farmers traditionally plant a number of local and fast-growing exotic fodder trees to meet their fodder needs. Fodder tree leaves and twigs provide supplementary feed, particularly during critical times of the year when no other green forage is available (Sardar 1992). In the drier parts of the country, including the tropical arid, tropical sub-mountain, and Mediterranean zones, rainfall is scanty and erratic. This poses problems for the establishment and growth of trees, and pastoralists depend primarily on the use of naturally growing fodder trees and dwarf shrubs.

Rangelands are the major feed source for 90–95% of sheep and goats, with about 60–70% of the feeding requirements met from grazing, particularly in the winter (Mohammad 1989). These ranges, in their present form, do not meet the year-long forage requirements of animals, as most of the vegetation is dormant during the winter. Small ruminants are generally confronted with severe nutritional deficits during this period of food scarcity, which exacerbates disease and health problems (Akbar et al. 1990). In this period, fodder shrubs play an important role in meeting part of the nutritional requirement. As the foliage of most shrub and some tree species remains green and nutritious during fall and winter, tree leaves and twigs are frequently lopped and fed to the animals during extreme drought and cold. Small ruminants and camels readily browse on shrub foliage, which constitutes the major part of their diet during fall and winter.

The local pastoral communities in arid and semi-arid zones attach great importance to fodder trees and shrubs. They maintain large stands of fodder trees in the dry zones to be used as emergency fodder during drought. Although shrubs are cut/uprooted for domestic fuel use, the locals selectively remove undesirable species and leave enough stock of desirable ones for seed setting and future growth. The planting of fodder tree and shrubs has also been carried out by government departments as part of range improvement and development projects in different parts of the country. In some places, where large plantations of fodder trees have been established, farmers are allowed to graze, cut, and carry fodder for

their animals, for nominal fees, during winter and drought. One such example is the large plantation of *Leucaena leucocephala* (ipil-ipil) in the sub-humid Pothwar tract near Kharian, where lopping and grazing of fodder leaves and pods earn the Forest Department an attractive revenue. Forest departments also issue permits for grazing and lopping naturally growing fodder trees and shrubs from protected forests during periods of extreme drought.

Recently, some NGOs established small-scale fodder reserves or banks of trees and shrubs with community participation. Some communities protect and use these reserves through farmer-managed associations. Such work has been initiated throughout the country, mainly by the National and Provincial Rural Support Programmes, and the Agha Khan Rural Support Porgramme in the north. Various projects on range/livestock improvement, feed resources, and watershed management, assisted by FAO/UNDP, the World Bank, and the Asian Development Bank, are also engaged in community-assisted plantations of fodder trees and shrubs for use as supplementary feed for their livestock. In highland Balochistan, fast-growing *Atriplex* species are becoming popular among farmers, through demonstration and farmer training, as a source of fodder and fuel.

Implementation of fodder shrub/tree plantation and management by the NGOs with community participation is a new concept,. The lessons learned so far show that an integrated approach must be used, because people living in fragile environments are not only threatened by ecological degradation but face problems with education, health care, communication, fuel, drinking water, etc. Therefore, other incentives are required to effectively achieve the objectives of fodder shrub plantation (Nawaz 1996).

Cost of Establishment

Although fodder trees/shrubs have been planted in different parts of the country for a long time, the economics of these activities has generally not been clear. In a very few cases, the cost of planting the shrubs/trees can be estimated, because most activities consist of research and demonstration under various projects. The cost of nursery-grown seedlings was calculated at PR 2 per plant. Similarly, the cost of planting and initial watering is estimated at PR 2 per plant. Therefore, planting 1,000 seedlings/ha costs about PR 4,000, or US$ 133. The cost of transportation and maintenance, however, is not known.

Cost estimates were prepared for the plantation of *Atriplex* as a fodder species in highland Balochistan under the Productivity Enhancement Programme. According to 1994 estimates, nursery raising, and planting costs of *Atriplex* seedlings (2,500 seedlings/ha) were PR 3,000, or US$ 100 per ha (Mirza 1995). The cost of land preparation (hand-dug holes/contour ridges) was estimated at PR 3,500 or US$ 117

per ha. The cost of transportation and maintenance of plantations was not calculated.

Fodder tree/shrub plantations under agroforestry systems cost only the price of the seedlings, which is about PR 2 per plant. Therefore, 1 ha (1,000 plants/ha) costs only PR 2,000, or US$ 57, if the household does the planting.

Literature Review

Pakistan Forest Institute (PFI)

The Pakistan Forest Institute, a pioneering institute, has been engaged in research on fodder trees and shrubs since the 1950s. The first documentary account of the status of fodder trees and shrubs of Pakistan was published in 1965 by A.H. Khan. It highlighted the distribution and characteristics of fodder trees and shrubs and provided the base for later research. Khan (1958) gives an account of *Acacia* species in Pakistan. The range management wing of the PFI at Peshawar initiated research on the establishment and use of local and exotic fodder tree/shrub species in various ecological range zones. Much focus was given to selection and adaptation trials of promising species in sub-tropical sub-humid and arid/semi-arid parts of the country. Khan conducted a number of trials on dry afforestation techniques for various local and exotic fodder trees/shrubs in the Thal desert ranges (Khan 1968). Later, Sheikh and Shah, from the PFI, initiated a comprehensive research program for the development of afforestation techniques in all major ecological range zones of the country, with particular reference to the arid zones (Sheikh 1981, 1986; Sheikh et al. 1982, 1984; Sheikh and Khan 1982; Rehman et al. 1988; and Shah 1990). Rafi (1965) describes the vegetation, including fodder trees and shrubs, in the Maslakh Range near Quetta, Balochistan.

Sheikh (1985) summarizes the results of germination and survival of a number of fodder trees and shrubs in the juniper forests of Balochistan. Qureshi and Ahmed (1973) give an account of the diseases of *Acacia modesta*, an important fodder tree in the sub-tropical region in the country. Hussain (1989) presented a model for determining the biomass of various fodder trees in arid areas. Sardar Mohammad Rafique, Range Management Officer of the PFI, conducted experiments on different planting techniques for survival and performance of fodder trees in the Peshawar valley. He also estimated the biomass of various fodder trees. (Sardar 1992a, b). Siddiqui et al. (1993) provide a comprehensive account on dryland afforestation, in which they summarize the results of long-term experiments on the establishment of different tree and shrub species in the country. Hafeez (1991) describes the production and management potential of *Prosopis cineraria*, an important fodder tree of the arid desert rangelands in Pakistan. Siddiqui (1995)

gives an account of tree planting for sustainable use of natural resources with special reference to the problem of salinity.

Pakistan Agricultural Research Council

Research on native and exotic fodder shrubs and trees was also conducted at the Rangeland Research Institute (RRI), AZRI, and its stations at Bahawalpur and Umerkot, and PARC, Islamabad. The National Forage and Pasture Research Programme of PARC conducted research on various fodder species at its provincial research units at NARC, Thal, PFI, Azad Kashmir, Mastung, and Dhabeji. A number of trials were conducted on the adaptability of fodder trees and shrubs for the sub-tropical sub-humid Pothwar ranges. These trials tested *Leucaena leucocephala, Ceratonia siliqua, Robinia pseudo-acacia, Acacia modesta, A. aneura, Olea cuspidata*, and other promising species (Mohammad and Naz 1985; PARC 1983, 1986; and Mohammad 1987). Several review articles on the production and management of fodder trees and shrubs in other parts of the country have also been published (Mohammad et al. 1985, 1986, 1988; Mohammad and Butt 1992; Akbar 1995; Afzal et al. 1993; Mirza et al. 1994; Maqsood and Butt 1994; Rafiq 1991; Ashraf 1991; Khan 1992). The use of fodder trees/shrubs for agroforestry systems in Pakistan is discussed by Joyia and Ajmal Khan (1994) and Khan et al. (1996).

Research conducted at AZRI, Quetta shows that among shrubs, *Atriplex* species are the most suitable for fodder reserves in arid highland Mediterranean Balochistan. Various research trials have been conducted on the establishment, management, and feeding of saltbush in highland Balochistan (Aro et al. 1988; Afzal et al. 1992; Mirza et al. 1996; Mirza 1995; Atiq-ur-Rehman et al. 1988, 1990a, b; Jasra and Afzal 1993; Rasool et al. 1995).

Other Agencies/Departments

Research on the role of halophytic shrubs in saline agriculture and the feeding value of various saltbush species as forage for livestock has been conducted by the Soil and Animal Science departments of the University of Agriculture and Nuclear Institute of Agriculture and Biology at Faisalabad (Qureshi et al. 1993; Nawaz et al. 1993; Aslam et al. 1993; Hussain and Gul 1993; Hanjra and Rasool 1993; Nawaz and Hanjra 1993; Mahmood et al. 1993). Abdullah et al. (1993) determined the forage potential of saltbush species in the Cholistan desert. Rashid et al. (1993) tested various *Atriplex* species under saline conditions in the Peshawar Valley.

Research on the provenance trials for *Atriplex* species in Pakistan was conducted at the department of Botany, University of Karachi (Ahmed and Ismail 1993; Ismail et al. 1993). The Agha Khan Rural Support Programme (AKRSP), an NGO based

in the north of Pakistan, reviewed important fodder species in that area. The International Union of Conservation of Natural Resources (IUCN) published a report on the feasibility of fodder shrubs and trees for the arid and tropical ranges of the Tharparkar Desert (IUCN 1992). Sheikh (1989) prepared a note on the production, management, and use of *Acacia nilotica* in Pakistan for the FAO Regional Wood Energy Development Programme in Asia.

Current Research

Research on fodder trees and shrubs in Pakistan has always been a priority, because 65–70% of the total land area is arid and semi-arid lands, and livestock enterprises, particularly with small ruminants, contribute significantly to the national economy. Currently, with the augmentation of environmental and conservation issues, research on trees and shrubs is gaining momentum. The rapid expansion of NGOs in the country, and their interest in natural resource management and conservation, has encouraged the scientists involved in tree and shrub research to devote more efforts to this area. There is substantial awareness among the policy makers, government departments, and NGOs to focus on research programs involving trees and shrubs in various parts of the country. A separate Ministry for Environment and Forestry at the federal level was recently created to undertake coordinated programs in the relevant disciplines. A National Conservation Strategy has been developed according to internationally approved guidelines. Legislation for increasing tree and shrub cover, putting more emphasis on research in these disciplines, has been laid out by the NSC.

Current research on fodder trees and shrubs addresses both basic and adaptive aspects, including screening, adaptation and evaluation trials, means of propagation, and uses (fodder, fuel, soil enrichment, agroforestry, sand dune stabilization, watershed management, hedgerow plantation, role of shrubs in saline agriculture, etc.). A gradual shift from on-station to on-farm is taking place in research involving trees and shrubs, so that farmers and communities are involved in all phases of evaluation and testing.

The main institutes involved in research on fodder shrubs in Pakistan are:

- Pakistan Forest Institute, Peshawar. Range management as well as watershed management.
- Pakistan Agricultural Research Council, Islamabad.
- Rangeland Research Institute, Islamabad. National Forage and Pasture Research program, with units at Dagar Kotli (Thal), Mastung (Balochistan), Dhabeji (Sind) and Muzaffarabad (AJK). Agroforestry research program.
- Arid Zone Research Institute, Quetta. Research stations at Bahawalpur (Cholistan), Umerkot (Tharparkar), and D.I. Khan (NWFP).

- Karakorum Agricultural Research Institute for Northern Areas. Research units at Gilgit and Skardu.
- Provincial Forest Departments. Range and watershed management branches; Gatwala Forestry Research Institute at Faisalabad.
- University of Agriculture, Faisalabad. Range, forest, and watershed department, soil and animal science departments.
- Barani (rainfed) Agricultural, Rawalpindi.
- University of Karachi. Botany department.
- Islamia University, Bahawalpur. Cholistan Institute of Desert Studies.
- NWFP Agricultural University, Peshawar. Department of soil science.
- Nuclear Institute of Agriculture and Biology, Faisalabad.
- Agha Khan Rural Support Program for Northern Areas. Forestry and range sections.
- Sind Arid Zone Development Authority. Action programs on range and agroforestry in the Thar and Nara regions.

Synthesis

Sporadic efforts aimed at planting fodder trees and shrubs have been carried out in almost all parts of the country, especially in arid and semi-arid areas, by government departments as well as NGOs. No consistent effort has so far been made to launch a carefully organized campaign of promoting fodder trees/shrubs. Such an effort needs to be supported by a solid information base encompassing ecology, grazing management, and, most importantly, farmer perceptions. Farmer participation in fodder tree/shrub plantation will ensure the success of such plantations and their sustained use in the long run. The activities of the various agencies and NGOs must be coordinated to devise development programs that affect the overall feed supply from fodder trees and shrubs in the country. Establishment of a Shrub Sciences Laboratory at the federal level is considered a necessary step for undertaking comprehensive research on shrubs.

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Potential of Saltbush (*Atriplex* spp.) as a Fodder Shrub for the Arid Lands of Iran

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Abstract

There are some 20 species of saltbush among the halophytic flora of Iran. These species range from thin herbaceous forbs to woody shrubs and bushes. In the past, some exotic species were introduced to the country, of which three perennial woody species of *Atriplex canescens* (Pursh.) Nutt., *A. halimus*, Boiss., and *A. nummularia* Lindl. were used to rehabilitate degraded rangelands in the arid areas of the country. *Atriplex canescens* was the dominant species. Over the years, thousands of hectares have been planted with this fodder shrub to provide feed for grazing animals and as a means of sand dune fixation in areas prone to wind erosion, sometimes with less than 150 mm rain/year. Although *A. canescens* provides a reasonable amount of good-quality fodder for animals, and performs satisfactorily on marginal lands of dry areas, its main shortcoming is its lack of self-regeneration by seed. The plant must be propagated by transplanted seedlings, which are costly and time consuming. This paper reviews the current knowledge and analyzes the scatter data available on the propagation, maintenance, and fodder potential of these shrubs, with particular reference to *A. canescens*. Although there is not much information based on scientific findings, Iran does have extensive experience with the establishment and maintenance of these shrubs. Other uses of saltbushes, such as dune stabilization and amenities, are discussed.

Key words: saltbushes, fodder shrubs, halophytes, Iran.

Introduction

The area of salt-affected lands in Iran is 245,000 km^2, which is 15% of the country (Pazira 1991). Halophytes, some 354 species, constitute 5.7% of the country's flora (Le Houérou 1992). Of the various halophytic and salt-tolerant species (73 genera and 26 families of flowering plants in Iran), 53% belong to the Chenopodiaceae family (Akhani and Ghorbani 1993). Other important families are Boraginaceae, Caryophyllaceae, Poaceae, Tamaricaceae, and Zygophyllaceae. Halophytes are used mainly as feed for sheep, goats, and camels. They may be used as supplementary or emergency feed during unfavorable conditions. These species are used for other purposes, such as erosion control, sand dune stabilization, salt land reclamation, rehabilitation of degraded land, wildlife and game management, and amenities. Other potential uses, e.g. as a coloring agent for dried fruits, gum, detergent, ornamental and medicinal herbs, have also been discussed (Koocheki

1996; Koocheki and Mohalati 1994). This paper emphasizes the potential value of saltbushes, the predominant introduced species in the country.

Saltbushes in Iran

There are some 400 known *Atriplex* species in the world, and, according to Le Houérou (1992), 20 of them are found in Iran. Other reports (Akhani and Ghorbanli 1993) indicate fewer species in the country. The nature and distribution of *Atriplex* species in Iran was reviewed by the above mentioned authors. An extract of their work is presented in Table 1. Of the 23 species listed, only three (*Atriplex griffithi* Moq., *A. leucoclada* Boiss, and *A. verrucifera* Bieb.) can be regarded as fodder shrubs. *A. griffithi* is a small shrub from the saline steppes of Iran. Although scientific work on this species is lacking, personal observations and scatter findings indicate promising results. Regeneration of *A. griffithi* by seed was found to be 3–5%. *A. verrucifera* is a dwarf shrub on saline sandy steppes, and *A. leucoclada* is a prostrate biannual native species that may spread over several square meters and produce up to 20 kg of dry matter per shrub. This shrub has fair grazing value and is easy to establish by seed.

Table 1. Distribution of native and naturalized *Atriplex* spp. in Iran.

Species and subsp.	Bio. type	Le Houérou	Akhani and Ghorbanli
Atriplex belangeri De Dieter	An	+	-
Atriplex chanicovii Bunge	An	+	-
Atriplex crassifolia De Decter	An	+	-
Atriplex crispa De Dieter	An	+	-
Atriplex dimorphostegia kar and kir	An	+	+
Atriplex flabellatum Bunge	An	+	+
Atriplex griffithi Mog.	Sh	+	+
Atriplex hortensis L. sub. aucheri leded.	An	+	-
Atriplex incisa M. Beib.	An	+	-
Atriplex leucoclada Boiss	An	+	-
Atriplex subsp. turcomanica (Mog.) Allen	Sh	+	+
Atriplex moneta bunge	An	+	+
Atriplex multicolor Allen	An++		
Atriplex patula L.	An	+	-
Atriplex Persica Boiss	An	+	-
Atriplex prostrata D.C.S.I (*A. hastata agg.*)	An	+	-
Atriplex rosea L. subsp. foliosa	An	+	-
Atriplex serpylifolia Buage	An	+	-
Atriplex thunbergiaefolia Boiss	An	+	-
Atriplex tatarica L.S.I.	An	+	+
Atriplex verrucifera Bieb	Sh	+	-
Atriplex micranta C.A. Mey.	An	-	+
Atriplex nitens schkuer	An	-	+
Atriplex hastata L.	An	-	+

An = annual; Sh = shrub.
Source: Le Houérou (1992); Akhani and Ghorbanli (1993).

Le Houérou (1992, 1993) recommend 13 exotic and native species and subspecies for range rehabilitation and fodder production in the Mediterranean basin, of which *Atriplex canescens* (Pursh.) Nutt., *A. lentiformis* (Wats.) Hall and Clen, *A. nummularia* Lindl., and *A. halimus* Boiss are the most promising under the climatic conditions of Iran. The most widespread exotic species used in Iran is *A. canescens*, a shrub native to North America. An estimated 40,000 ha were under this species in 1970 (Nemati 1986). With the fast rate of expansion during the last two decades, this figure is presumed to have tripled by now. Two morphological types are distinguished for *A. canescens* (Le Houérou 1992): the narrow-leaf type (*A. canescens* subsp. *linearis*) and the broad-leaf type (*A. canescens* subsp. *canescens*). Production by the narrow-leaf type is considerably greater than the broad leaf, but the latter is more palatable to sheep and is very cold tolerant, withstanding -20°C and below. This is one of the reasons for the preference of this subspecies in the dry areas of Iran. The cold tolerance of the other introduced species is reported to be lower (Le Houérou 1993; Sarafraz Ardakani 1991).

Plant Establishment and Management

Saltbushes are characterized by low seed germination and hence difficulty of establishment (Nemati 1977; Price et al. 1989; Le Houérou 1993). Therefore, transplanting has proved to be the most promising and satisfactory method of revegetation (Nemati 1977; Nemati 1986; Le Houérou 1992). This is achieved by growing nursery seedlings in polyethylene bags and planting them in the field. For this purpose, polyethylene bags (diameter 10 cm, height 20 cm) are filled with a mixture of three parts soil, one part fine sand, and one part animal manure. A few soaked seeds are placed in each bag. After germination, the seedlings are thinned and one is left to grow to the desired size. The bags are then transferred to specific sites for plantation. Maximum survival of *A. canescens* transplants occurrs in September–November plantings (Nemati 1986). The best survival rate occurs when transplants are 20–30 cm high. However, this method is tedious and costly. The average cost in 1980 was US$ 0.50 per seedling, i.e. US$ 250–1,250 per ha (Le Houérou 1992). A total investment of US$ 200 per ha over 10 years was reported for an *Atriplex* plantation in Iran (Tork Nejad and Koocheki 1996), with a net annual profit of US$ 200 per hectare. A yearly net income of US$ 114 per ha was reported elsewhere for saltbushes under 150–250 mm rainfall (Le Houérou 1986). Seed may also be sown in small plots. Bare-root transplants are also used.

Atriplex canescens seedlings are planted 1,500–2,500 plants/ha, usually in rows spaced 1–2 × 4–6 m apart (Nemati 1977; Le Houérou 1992). To establish a stand of 1,000 shrubs/ha, the amount of seed required for nursery-grown seedlings is 500 g/ha. Direct sowing may be possible, but seed may need to be dewinged and soaked, or pregerminated. Hand sowing of treated seed requires 5 kg seed/ha for a density of 1,000 shrubs/ha (Le Houérou 1993). Seedlings should not be kept for

more than four months; keeping them longer runs the risk of cutting the roots, with a subsequent high rate of die-off (Le Houérou 1992).

Cutting back every second or third year is recommended (Le Houérou 1986; Le Houérou 1992). Since the life span of leaves is about nine months, rest periods exceeding that are a waste in terms of forage use. Piper et al. (1978) found that vigor and productive capacity of fourwing saltbush is usually reduced by year-long grazing. One season of rest every 3–4 years is needed. Plants rested for 1, 2, 3, or more years produce progressively more flower stalks and less leader growth (Price et al 1989). It is clear that the proper sequence and length of rest are needed to maintain the plant in its most productive vegetative state.

Dry Matter Production

Dry matter production for different species of saltbush may vary from 2,000 to 10,000 kg/ha, depending on species, climate, and other factors (Le Houérou 1984; Le Houérou 1993; O'Leary 1985). A dry matter yield of 0.8–1.2 kg/plant was reported for *A. canescens* subsp. *linearis* in an area with 150–250 mm rainfall (Le Houérou 1986). Under seawater irrigation, an annual dry matter yield of 17,000 kg/ha was recorded (Glenn and O'Leary 1985). Dry matter (leaves and twigs) yields of 0.1–2.0 kg/shrub per year, i.e. 100–400 to 1,000–4,000 kg/ha per year, were found at densities of 1,000–2,000 shrubs/ha (Kernick 1986; Le Houérou 1986). Scatter data indicate forage dry matter yield of 1.5–2.0 kg/shrub for *A. canescens* under Iranian conditions. A rain-use efficiency of 8 kg DM/mm of rain was recorded by Le Houérou (1984). A mean dry matter yield of 1,500 kg/ha seems to be obtainable in the saltbush plantations of Iran (Tork Nejad and Koocheki 1996).

Feed Value

The feed value of *Atriplex* spp. is a controversial issue, and research findings indicate that saltbush forage possesses rather low energy (Le Houérou 1984; Le Houérou 1992). The high salt content of halophytes also constrains their use (Koocheki and Mohalati 1994). Sheep on a pure *Atriplex* diet may consume 100–200% more water than sheep on non-saline feed (Le Houérou 1986). However, there are ways to overcome these problems, such as blending these shrubs with other components in prepared feed mixes (Swinyle et al. 1994). The high nitrogen content of these species, as high as 2.5–3.5% of dry matter, is also important (Le Houérou 1992). A value of 21% soluble proteins on a dry matter basis was reported for *A. griffithii* (Joshi and Anjaiah 1987). Digestibility of this nitrogen is 65%, but only 55% of the digestible nitrogen is retained (Le Houérou 1992). Digestibility of dry matter and organic matter of saltbushes is reported to be reasonably high. Values of 78% digestible dry matter for leaves and 57% for the total herbage were

reported (Wilson 1994). Warren et al. (1990) recorded dry matter intake of 400–800 g/day for four species of saltbush.

In a preliminary trial (Koocheki, unpublished), the nutritive value of six introduced *Atriplex* species from different sites was evaluated. Average values of 68% digestible dry matter, 62% digestible organic matter, and 49% digestible organic matter in dry matter (D-value) were found for these species (Table 2). There was a negative correlation between crude fiber and digestibility, but this was not true for crude protein or digestibility. This finding has also been reported elsewhere (Koocheki and Mohalati 1994). *Atriplex nummularia* showed the highest digestibility values and *A. halimus* the lowest. Ash content varied between 18 and 25%, crude fiber between 17 and 30%, and crude protein between 19.73 and 26.16%, which seems rather uneven among species. Digestibility indices reported here are not much different from those reported elsewhere (Le Houérou 1986; Le Houérou, 1992; Wilson 1994). However, much higher values of ash and crude fiber have been reported for some of these species (Watson 1990; O'Leary 1985). Higher levels of organic matter digestibility for other halophytic species under the same conditions have been reported (Koocheki and Mohalati 1994).

Table 2. Nutritive value of some *Atriplex* species.

Species	Ash %†	CF %†	DDM %	OMD %	CP %†
A. halimus	24.8C	33.1A	59.6B	53.5A	19.7C
A. deserticola	30.0A	27.6A	67.1AB	57.8A	22.8ABC
A. lentiformis	24.8C	27.2AB	67.6AB	63.1A	21.8BC
A. glauca	25.9BC	27.3AB	69.8AB	65.1AB	22.0BC
A. nudulata	30.1A	24.0B	68.1AB	60.1A	26.1A
A. nummularia	28.5AB	25.7B	77.8A	68.8A	23.5AB
CV (%)	5.50	12.75	10.37	14.37	7.91
Sx	0.8691	2.026	4.096	5.097	1.037

CF = crude fiber; DDM = digestible dry matter; OMD = organic matter digestibility; and CP = crude protein.
Each value is the average of three replications; mean separation by DMRT at 5%.
† Primary data is transformed by mean of ArcSin x.
Source: Koocheki (unpublished data).

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Economic Aspects of Fourwing Saltbush (*Atriplex canescens*) in Iran

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Abstract

Lack of sufficient feed is the major constraint to the livestock industry in Iran. The total forage available in the country is equivalent to about 26 million TDN, insufficient to feed the 116 million animals in the country. Almost 60 million animals are entirely dependent on the rangelands to meet their feed requirements. Degradation of the rangelands in the dry areas, due to heavy population of livestock, and hence over-use, has caused serious social and economic problems. However, the introduction to these areas of exotic species of fodder shrubs, such as *Atriplex* spp., has been significant. *Atriplex canescens*, a shrub native to North America, has been planted on vast areas over the last 40 years. This paper evaluates the economics of this fodder shrub with regard to forage and hence meat production. A mean dry matter yield of 1,500 kg/ha was reported. This is equivalent to a feeding value of 1,000 kg barley and a production value of 100 kg meat. Therefore, based on international prices of barely and meat, net annual income from one hectare of *Atriplex* plantation can be as high as $200. Total investment per hectare over a 10 year period was calculated at $200.

Key words: economics, fourwing saltbush, Iran.

Introduction

Fourwing saltbush has been used as a fodder shrub in the degraded rangelands of Iran for more than three decades. This species is a native plant of North America, introduced to Iran for rangeland rehabilitation and sand dune fixation. It is estimated that from 1963 to 1995 more than 326,200 ha were planted to this species, at a rate of more than 1,000 ha/year (Mosavi Eghdam 1987). However, with an average stand longevity of 10 years, an estimated 100,000 ha exist at any given time (Ashraghi 1996).

The most important climatic factors for establishment of this species are the amount and distribution of rainfall and the minimum temperature. *Atriplex* species have been planted in areas with wide-ranging precipitation: 50–400 mm/year (Ashragi 1996). However, most are planted in areas with 150–230 mm rainfall. This species can withstand temperatures as low as -10 to -15°C (Mosavi Eghdam 1987) and salinity up to 80 dsm/m. However, 20–30 dsm/m is predominant (Eskandari 1995).

A dry matter yield of 2,885 kg/ha (plant density 1,000 plants/ha) was found in Khuzistan province, and 1,800 kg/ha (density 300 plants/ha) in Yazd province, which has a harsh environment (Sarafraz Ardakani 1991). A mean annual dry matter yield of 1,500 kg/ha seems to be optimum.

Economic Value of Fourwing Saltbush

A nation-wide survey was carred out to evaluate the economics of saltbush plantation and determine average costs and benefits. Total cost included two main activities: seedling production and on-site seedling establishment. Total cost of bagged seedlings, including polyethylene bag, seed, animal manure, fine sand, and labor, was US$ 50 per ha. The cost of protection and other activities required from the second year was calculated at US$ 100. Therefore, a total of US$ 200 is required for establishment and management of one hectare of saltbush. Although a stand may last up to 15 years, an average of 10 years is considered optimum. Therefore, total cost per hectare is calculated at US$ 20 per year.

Total annual dry matter yield was estimated at 1,500 kg/ha. This is equivalent to 1,000 kg barley, which, if consumed properly, could produce 100 kg meat/ha (Mckell 1989). Therefore, on the basis of international prices for barley (US$ 200 per 1,000 kg) and meat (US$ 2 per kg), annual revenues of US$ 200 per ha could be attained. In other words, the total cost for one hectare over a 10 year period could be met in the first year. Similar results have been reported elsewhere (Le Houérou 1986; Le Houérou 1992).

It has been estimated (Mosavi Eghdam 1987; Ashragi 1996) that a total area of 4×10^6 ha of degraded land in Iran could be brought under saltbush plantation. Although this may appear to be an exaggeration, based on the present evaluation, the total costs and benefits are as follows:

$$4 \times 10^6 \times \$200 = \$800 \times 10^6 \text{ cost for 10 years}$$

$$4 \times 10^6 \times \$200 \times 10 = \$800 \times 10^7 \text{ benefit for 10 years}$$

In other words, the ratio of cost to benefit is 1:10, which is economically justified.

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Utilisations des Arbres et Arbustes Fourragers en Zone Sahélienne du Sénégal

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Résumé

Le Sahel constitue une région géographique à formations végétales ouvertes avec des arbres et des arbustes. Les conditions climatiques et édaphiques y maintiennent une végétation ligneuse plus ou moins stable. Dans ce travail, il a été question de dégager le rôle joué par ces arbres et arbustes dans la vie quotidienne des populations et la reconstitution de l'équilibre écologique dans cette région nord du Sénégal. Cette étude a permis de montrer qu'ils fournissent une part importante du fourrage pour le bétail, interviennent dans l'alimentation des populations rurales et sont très utilisés dans la lutte contre l'érosion et dans la pharmacopée. Ils constituent également une source d'énergie considérable, servent beaucoup dans l'habitat, et représentent une composante essentielle du patrimoine culturel. Fort de ces utilisations multiples, et conscient de la dégradation qui affecte cette zone, des mesures de réhabilitation ont été suggérées dans une perspective de rétablissement des fonctions indispensables du couvert ligneux pérenne.

Mots-clés : utilisation, ligneux, fourrage, Sahel, Sénégal.

Abstract

The Sahel represents a geographical region with vegetation characterized by scattered trees and shrubs. Climatic and edaphic conditions permit the growth of more or less stable ligneous vegetation. This paper deals with the role of trees and shrubs in the everyday life of populations and the restoration of ecological equilibrium in northern Senegal. This study establishes their role as fodder for livestock, food for populations, in combating erosion, and their use in the pharmacopoeia. Also, they produce fuel, material for home building, and are a main component of the cultural patrimony. Restoration measures have been suggested to retrieve the essential functions of the perennial ligneous vegetation in the region in terms of their multiple uses and simultaneous degradation.

Key words: utilization, woody plants, fodder, Sahel, Senegal.

Introduction

Au Sénégal, les systèmes sylvo-pastoraux jouent un rôle essentiel, notamment dans l'alimentation du bétail. Dans ces périmètres, les arbres et arbustes fourragers

constituent des réserves sur pied qui sont très utilisées, surtout pendant la saison sèche qui dure 8 à 9 mois, pendant que la strate herbacée est quasiment absente.

Ils sont généralement adaptés aux conditions du milieu et à la pâture ; ce qui leur assure une certaine pérennité. Le plus souvent aussi, ils sont d'usage multiple et ont en particulier, une grande valeur alimentaire (Le Houérou 1980 ; Miehe 1994).

Cependant, le phénomène de l'aridification qui s'est installé depuis les années 1970 (Grouzis et Albergel 1989) et qui se traduit par une pluviométrie déficitaire et très mal répartie dans le temps et dans l'espace, entrave significativement la production pastorale et fourragère. Ainsi, une stratégie d'amélioration de ces parcours s'impose, si l'on veut y maintenir une activité socio-économique durable.

Les programmes de reboisement développés dans le passé ont connu des échecs du fait d'un matériel végétal inadapté aux conditions écologiques du milieu. Plus récemment (1992–1996), un programme pluri-institutionnel européen STD III, Contrat TS3*CT92-0047, "Réhabilitation des terres dégradées au nord et au sud du Sahara. Utilisation des légumineuses pérennes et des micro-organismes associés pour le rétablissement de formations pluristrates" qui a regroupé des partenaires du Sénégal (ISRA/URA-Forêt), de la Tunisie (IRA), de l'Italie (Université de Viterbo) et de la France (ORSTOM et CNRS), cherche à assurer le relais avec l'utilisation surtout de légumineuses indigènes.

Le présent travail se propose de dégager les principaux usages des arbres et arbustes fourragers dans la région nord semi-aride du Sénégal. Les informations fournies ici proviennent de l'expérience des auteurs, ont été recueillies auprès d'agro-pasteurs, et secondairement, d'une revue bibliographique d'auteurs ayant travaillé dans la zone.

Utilisation du Fourrage Ligneux

L'intérêt nutritionnel des arbres et arbustes fourragers, exprimé de façon intuitive par les éleveurs, a été mis en évidence par des travaux de recherche (Von Maydell 1983 ; Miehe 1994 ; Daget et Godron 1995). Ils constituent un important fourrage d'appoint pendant la morte saison, après que l'herbe sèche de la saison pluvieuse précédente ait été raclée.

Le tableau 1 donne une liste des principales espèces rencontrées dans la zone d'étude. Parmi ces espèces fourragères, on peut distinguer:

- Celles qui favorisent la production de lait: *Grewia bicolor*, *Acacia raddiana*, *Acacia albida* et *Adansonia digitata.*
- Celles qui favorisent l'engraissement: *Acacia raddiana*, *Acacia albida*, *Acacia senegal.*

- Celles qui, même si elles sont consommées, sont peu appétées par le bétail, et donc ne sont broutées qu'occasionnellement (disette) : *Boscia senegalensis*, *Combretum glutinosum*, *Dichrostachys cinerea*, *Leptadenia pyrotechnica*, *Sclerocarya birrea*, et *Ziziphus mucronata*.

Table 1. Principales espèces rencontrées dans la zone d'étude, les organes végétaux consommés et les bénéficiaires préferentiels.

Espèce	Organe consommé	Bénéficiaire préférentiel
Acacia ataxacantha DC	fl ; F	ch ; pr
Acacia nilotica var. adansonii (Guill. et Perrott.) O. Ktze.	fl	ch ; pr
Acacia nilotica var. tomentosa (Benth.) A.F. Hill.	fl ; F	b ; ch ; pr
Acacia senegal (L.) Willd.	fl ; F	ch ; pr
Acacia seyal Del.	fl ; F	b ; pr
Acacia tortilis (Forssk.) Hayne *subsp. raddiana* (Savi) Brenan ou *Acacia raddiana* Savi	fl ; F	b ; ch ; pr
Adansonia digitata L.	fl	ch ; pr
Balanites aegyptiaca (L.) Del.	fl ; F	b ; ch ; pr
Bauhinia rufescens Lam.	fl ; F	ch ; pr
Boscia senegalensis (Pers.) Lam ex Poir.	fl ; F	pr
Cadaba farinosa Forssk.	fl ; F	b ; pr
Combretum aculeatum Vent.	fl ; F	b ; pr
Combretum glutinosum Perrott. ex DC	fl	b ; pr
Combretum micranthum G. Don	fl	b ; pr
Commiphora africana (A. Rich.) Engl.	fl	ch ; pr
Dichrostachys cinerea (L.) Wight et Arn.	fl ; F	b ; ch ; pr
Diospyros mespiliformis Hochst	fl ; F	b ; pr
Entada africana Guill. et Perrott.	fl ; F	b
Faidherbia albida (Del.) A. Chev.	fl ; F	ch ; pr
Feretia apodanthera Del.	fl	b ; pr
Grewia bicolor Juss.	fl	b ; pr
Guiera senegalensis J. F. Gmel.	fl ; fr	pr ; ch
Lannea acida A. Rich.	fl ; F	b ; pr
Leptadenia pyrotechnica (Forssk.) Decne.	fl	ch ; pr
Maerua angolensis DC	fl ; fr	b ; pr
Maerua crassifolia Forssk.	fl ; fr	b ; pr
Piliostigma reticulatum (DC.) Hochst.	fl ; F	b ; pr
Prosopis africana (Guill., Perrott. et Rich.) Taub.	fl ; F	b ; pr
Pterocarpus lucens Lepr. Ex Guill. et Perrott.	fl ; F	b ; ch ; pr
Salvadora persica L.	fl ; fr	b ; ch ; pr
Sclerocarya birrea (A. Rich.) Hochst.	fl ; F	b ; pr
Tamarindus indica L.	fl	pr
Ziziphus mauritiana Lam.	fl ; F	ch ; pr
Ziziphus mucronata Willd.	fl ; F	b ; ch ; pr

Feuilles (fl), fleurs (fr), fruits (F), bourgeons (b), rameaux (r), ainsi que les bénéficiaires préférentiels [chameaux (ch), bovins (b), petits ruminants (pr).

Dans cette zone, on rencontre des arbustes particulièrement toxiques pour le bétail : *Adenium obesum* (Forssk.) Roem. et Schult. et *Calotropis procera* (Ait.) Ait. F. qui constituent souvent des peuplements très denses.

Rôle dans l'Économie

Ces arbustes fourragers, notamment le groupe *Acacia*, peuvent jouer un rôle économique important dans ces zones déshéritées grâce à la production de gomme arabique (Giffard 1966). *Acacia senegal* et *Acacia laeta* fournissent une gomme dite de premier choix, *Acacia seyal, Acacia raddiana, Acacia albida* donnent une gomme dite de second choix. Jusqu'aux années quatre vingt, cette production situait le Sénégal parmi les premiers pays exportateurs de gomme.

Rôle dans les Systèmes de Production Agroforestiers

Les ligneux fourragers constituent l'élément stable de la végétation en zone sahélienne. Ils développent un ensemble de réponses d'ordre morphologique, anatomique et physiologique (Diouf 1996) qui leur permettent de se maintenir en période de contrainte.

Par leur enracinement profond ils jouent un rôle déterminant dans la fixation des sols, et donc dans la lutte contre l'érosion éolienne. Comme plantes de couverture, ces ligneux améliorent la production de phytomasse herbacée, ainsi que le bilan minéral des pâturages (Akpo 1993). On peut citer ici : *Acacia albida, Acacia senegal, Acacia seyal, Acacia raddiana, Acacia nilotica* (les 2 variétés), *Combretum micranthum, Adansonia digitata,* et *Bauhinia rufescens.*

Ils contribuent également, les légumineuses notamment (genre *Acacia*), au relèvement du niveau de fertilité des sols par l'intermédiaire de la fixation biologique de l'azote atmosphérique.

Rôle dans la Production de Denrées de Consommation

Dans cette région, les ligneux fournissent également des produits utilisables (feuilles, fleurs, fruits) par l'homme dans son alimentation. On peut distinguer par ordre décroissant d'utilité : *Ziziphus mauritiana, Adansonia digitata, Combretum micranthum, Balanites aegyptiaca, Tamarindus indica, Annona senegalensis, Acacia nilotica var. tomentosa, Sterculia setigera, Bauhinia rufescens, Acacia senegal, Acacia seyal, Boscia senegalensis, Cadaba farinosa, Combretum aculeatum, Dichrostachys cinerea, Grewia bicolor, Leptadenia pyrotechnica, Maerua crassifolia, Pterocarpus lucens, Prosopis africana, Salvadora persica,* et *Sclerocarya birrea.*

Rôle de Combustible

En milieu rural comme dans la production nationale, les ligneux servent beaucoup comme combustible précieux (bois de chauffe et charbon de bois): *Acacia*

raddiana, Acacia laeta, Acacia nilotica, Acacia seyal, Acacia senegal, Balanites aegyptiaca, Combretum glutinosum, Prosopis africana, Prosopis lucens, et *Sclerocarya birrea.*

Faute de disposer de bois mort, les populations s'adonnent souvent à des pratiques comme la coupe pour couvrir leurs besoins énergétiques, et participent de fait à la dégradation de ces systèmes sylvo-pastoraux.

Utilisation en Pharmacopée

Selon les informations disponibles, certaines de ces espèces jouent un rôle très important dans la médecine indigène. Elles sont utilisées pour le traitement des maladies, à la fois chez l'homme et chez les animaux. On peut distinguer : *Adansonia digitata, Adenium obesum, Acacia nilotica, Annona senegalensis, Calotropis procera, Combretum glutinosum, Combretum aculeatum, Combretum micranthum, Commiphora africana, Dichrostachys cinerea, Guiera senegalensis, Prosopis africana, Sclerocarya birrea, Sterculia setigera, Tamarindus indica*, et *Ziziphus mauritiana.*

Autres Usages

A un degré moindre, les arbustes sont utilisés dans divers autres domaines :

- Dans la culture (pratiques traditionnelles) : *Adansonia digitata, Acacia albida, Tamarindus indica*, et *Sterculia setigera.*
- Dans la construction de haies et d'enclos : tous les épineux.
- Dans la construction des habitations : ce sont essentiellement des espèces à bois dur : *Balanites aegyptiaca, Acacia nilotica, Acacia seyal, Tamarindus indica, Combretum glutinosum, Prosopis africana*, et *Sclerocarya birrea.*

Conclusion

Au regard des informations recueillies sur les multiples usages des arbres et arbustes fourragers, il est important de souligner la place prépondérante de ces ligneux sahéliens dans les activités socio-économiques du milieu paysan. Le fourrage ligneux montre une certaine stabilité par rapport à la sécheresse et à la pression du bétail. D'autre part, la disponibilité du fourrage et sa valeur alimentaire de plus en plus grande au cours de l'aridification, devraient encourager la recherche de moyens appropriés pour une gestion efficace de ces systèmes sylvo-pastoraux.

En outre, des études sur la dynamique des peuplements ont montré une prédominance de quelques espèces particulièrement résistantes à l'aridité. Dans cette région nord du Sénégal, c'est le cas de *Balanites aegyptiaca*, *Boscia senegalensis* et des espèces du genre *Acacia* citées plus haut.

Du fait que les mises en défens posent des problèmes de vulgarisation à grande échelle, il serait donc tout à fait indiqué, de promouvoir leur réintroduction dans cette zone très dégradée ; opération qui serait précédée d'une étude sur leurs réponses aux facteurs écologiques. D'un autre point de vue, l'introduction d'espèces fourragères exotiques en plantations artificielles dont la phase expérimentale aura été réalisée au préalable, permettrait de réhabiliter de façon durable ces pâturages sahéliens.

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Research on Fodder Shrubs and their Management in the Rangelands of East Anatolia

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Abstract

Although grassland is a fundamental part of livestock production in East Anatolia in Turkey, rapid degradation has taken place for decades, due to traditional misuse of natural resources. Under existing laws, collective rights for the use of ranges are assigned to permanent residents of villages, along with the right to ensure sustainable use of these resources. However, no significant measurements of range use were ever taken, and as a result, some ranges have completely lost their plant cover as a result of severe degradation. Range management research, regional and country-wide, has concentrated on herbaceous plants to the exclusion of shrub vegetation, which is a major contributor to range production and soil and water conservation. Methods to rehabilitate both first and second class ranges have been developed, but are not successful on third class ranges. Work has been initiated in East Anatolia on the positive characteristics of shrubs in range improvement. A project to collect, evaluate, and test native and exotic shrubs will play a significant role in strengthening shrub research both in the region and the country.

Introduction

The rangelands of Turkey are very important, since they constitute one of the largest renewable natural resources in the country. Livestock production is still widely dependent on rangelands, which provide animal feed for six months a year, especially in Central and Eastern Anatolia. But the increasing demand for food grains has led to a rapid expansion of rainfed cereal cropping, and, as a result, a large proportion of the rangelands has been used for cropping, particularly in the central highlands and transition zones. Economic crops are usually harvested for only 3–4 years, which leads to the abandonment of many areas, while the soil, stripped of its original vegetation, is open to erosion hazards and invasion by unpalatable plants. This has meant a serious net loss of valuable genetic resources as well as total grazing area (Tosun 1996). The present stocking rate on the rangelands of Turkey is far in excess of the carrying capacity, in some cases as much as 3–5 times higher. Among the agro-ecological zones in the country, East Anatolia is the most important with respect to genetic diversity and range management. The region contains nearly half the total productive meadow and rangeland in the country, with more than half the land (8 million ha) classified as

pasture and range. The region consists of a mountainous plateau with a complex topography, which varies from wide level valleys surrounded by rolling hills to narrow valleys below precipitous rocky mountains, reflecting the variable geology. The region has an extreme continental climate with a very cold winter lasting 4–6 months with heavy snow cover and a very hot and dry summer. Winter temperatures range from an average minimum of -5.7°C in January to an average maximum of 22°C in August.

Native Shrubs

Mountain ranges with annual rainfall above 500 mm, usually well distributed, generally exhibit a close herbaceous cover of natural perennial grasses, legumes, and herbs, especially in alpine ranges. But heavy grazing may lead to an invasion of spiny, shrubby vegetation. The grassland vegetation is rich and diverse, with a wealth of grass and legume species. East Anatolia is the point of origin of many legume species. In recent vegetation studies on the Eastern Anatolia rangelands, 476 species belonging to 47 families were identified (Zengin and Güncan 1996). However, some of the rangeland is seriously overused; perennial grasses and legumes are at best still present, but ground cover is low and annual grasses and unpalatable species dominate. Signs of active soil erosion, both gully and surface, are widespread, notably on the lower slopes near the villages. Depending upon altitude, slope, and direction, the density of forage and shrub species on the rangelands varies widely. The primary native shrub species are: *Astragalus microcephalus*, *A. aureus*, *A. lineatus*, *A. gummifer*, *Atraphaxis spinosa*, *A. grandiflora*, *Atriplex nitens*, *A. laevis*, *Berberis nummularia*, *B. vulgaris*, *B. crategina*, *Caragana grandiflora*, *Celtis glabrata*, *Cerasus mahalep*, *C. incana*, *Cistus salviifolius*, *Crataegus pentagyna*, *C. monogyna*, *Colutea armena*, *Cotinus coggygria*, *Cotoneaster integerrimus*, *C. nummularia*, *Elaeagnus angustifolia*, *Genista albida*, *Haloxylon persicum*, *Hypericum androsoemum*, *Hippophae rhamnoides*, *Juniperus oxycedrus*, *J. nana*, *Kochia prostrata*, *Lonicera iberica*, *Malva sylvestris*, *Paliurus aculatus*, *Prunus spinosa*, *Pyrus salicifolia*, *Rosa canina*, *R. dumalis*, *R. montana*, *Salsola canescens*, *Sorbus kusnetzorii*, and *Tamarix smyrnensis*.

Shrub Research

Although the native shrub vegetation constitutes a large proportion of animal grazing and has economical importance as a feed source, particularly in steppe and coastal zones, very little is known about its characteristics. A traditional management system has been practiced for centuries, without any significant change. Shrub management has never been a priority in research programs at the

national level. Even the former Pasture Rangeland Institute produced only sporadic and incomplete research results.

Fodder shrubs are sparse over most of the East Anatolia ranges, except for spiny *Astragalus* spp., which are widespread on overgrazed hills. In some areas with oak and poplar woodlands, farmers, facing supplementary feed shortages, graze or prune oak and poplar leaves and branches to sustain their sheep during the winter. In dry years, when the winter roughage runs out, farmers dig up spiny *Astragalus* from the rangelands to feed their animals. Spiny milkvetch is commonly used as kindling for *tezek* (dried cow dung used as fuel) fires in rural areas where there is no wood available. Spiny *Astragalus* species, which make an excellent surface cover against erosion and also fix nitrogen in the soil, cover degraded ranges on the south-facing slopes, where the threat of erosion is severe. Hence, use of both these shrubs is very important for the rangelands. Village communities are well aware of this fact, and many have established control measures against the misuse of shrub vegetation.

Since there has been no research on fodder shrubs in East Anatolia, the contribution of shrubs to animal diets during the grazing period is totally unknown. Many collections of herbaceous forage crops have been made, and a large amount of local germplasm is under evaluation in the gene banks. But for shrub species, only small-scale collections and evaluation work have been carried out by the East Anatolia Agricultural Research Institute (EAARI). Nearly 40% of central and 20% of eastern Anatolian ranges, equal to about 5 million ha, have been denuded or invaded by unpalatable and poisonous species. High runoff water from these eroded lands threatens cultivated lands, roads, and settlements in the lower areas. The state suffers from such disasters almost every year, some of which are reported worldwide. Although there is a general awareness at all levels, including the government, that many problems related to inefficient livestock production and severe land deterioration stem from improper use or abuse of grazing lands, the Government of Turkey does not currently have a clear sustainable rangeland management policy. If the current rate of degradation continues, most rangelands will be destroyed as economic resources and classified as third class ranges, incapable of economic rehabilitation.

The Ministries of Agriculture and Forestry are mandated to improve rangelands and control erosion, and reasonable financing is allocated for these activities every year. However, as a result of inappropriate management and improvement techniques, they cannot effect significant improvement. A good amount of research has been conducted to investigate appropriate rehabilitation techniques for first and second class rangelands in the region, but these methods are not effective on eroded third class ranges. Since the establishment of a sustainable vegetation with herbaceous plants alone has not been successful, native and exotic shrubs present another alternative. Moreover, a sharp decline occurs both in quantity and quality

of herbaceous forages in the rangelands of East Anatolian at the end of July. To some extent, fodder shrubs can fill this feed gap by providing green material in autumn when feed becomes scarce on the rangelands. In addition to their feeding value, adopted shrub species are likely to play a pioneering role in the natural establishment of annual and perennial forages by conserving at least some part of soil and water on deteriorated rangelands. Hence, their contribution to soil and water conservation may be much higher than their value as a feed source in the rangelands.

With this in mind, a project to collect and evaluate native and exotic fodder shrubs for the rehabilitation of third class ranges in the region is being prepared. It is hoped that this joint research with EAARI, the Rural Service Research Institute, and the Forestry Research Institute will play a formative role in comprehensive fodder shrub research in the future. We would also like to invite ICARDA to join hands with us.

The future research program is likely to focus on ecological adaptation, natural regeneration, erosion control, production potential and persistence, animal intake, grazing resistance, nutritive value, and alternative uses (food, fuel) of shrub species. Despite the lack of national experience and the prevalence of extreme climatic conditions, environmental concerns and the potential benefits of shrub research makes it very attractive for researchers and donors. Local farmers are eager to cooperate to improve unproductive rangelands, and with large-scale projects, rapid expansion of appropriate techniques can be expected.

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Les Arbustes Fourragers Autochtones et Introduits dans les Parcours du Maroc Oriental

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Résumé

Les parcours du Maroc Oriental s'étendent sur une superficie d'environ 5 millions d'hectares. Le plateau de l'Oriental est caractérisé par un climat aride dans le nord et pré-saharien dans le sud, avec un sol limono-sableux dans le Nord et sableux dans le Sud. Le climat est marqué par l'importance des variations thermiques mensuelles et annuelles, la faiblesse des précipitations et leur irrégularité, ainsi que des vents secs et violents. Le couvert végétal traduit la rigueur du climat. Il est essentiellement steppique et caractérisé par la dominance d'espèces xérophytes d'une faible hauteur et recouvrant le sol de façon discontinue. Les espèces dominantes sont représentées par : *Stipa tenacissima, Artemisia herba-alba, Salsola vermiculata, Noaea mucronata, Haloxylon scoparium, Atriplex halimus*, ainsi que plusieurs plantes annuelles. Le développement végétal des plantes vivaces s'étale entre les dernières semaines du printemps et l'automne. Quant aux espèces annuelles, leur abondance est limitée au printemps et dépend des conditions climatiques.

L'élevage constitue malgré toutes les contraintes édapho-climatiques, l'activité socio-économique la plus adaptée à la région et autour de laquelle sont tissées les relations sociales. Cet élevage est de type steppique sur parcours. Le Projet de Développement Pastoral et de l'Élevage dans l'Oriental (PDPEO) couvre une superficie de 3,2 millions ha qui supporte environ 1 million d'ovins, 300 mille caprins, 12 mille bovins et 1000 camélidés. Cette superficie couvre environ 70% des besoins des animaux en année normale.

Intérêt Pastoral des Arbustes Fourragers

L'intérêt des arbustes fourragers réside essentiellement dans l'alimentation animale. Ils présentent les caractéristiques suivantes :

- Sur le plan nutritif, les arbustes sont connus par leur apport en protéines, en vitamines mais également en éléments minéraux qui, le plus souvent, font défaut chez les espèces herbacées durant la période sèche, et parfois même pendant la saison froide. Les arbustes fourragers et présentent un fourrage vert et de bonne qualité durant toute l'année, constituant ainsi des réserves fourragères sur pied.

- Sur le plan écologique, ils contribuent à:
    - La création de microclimats favorisant l'établissement des herbacées autochtones.
    - A la réduction des phénomènes d'érosion éolienne et hydrique.
    - A la réhabilitation des zones érodées, à la fixation des dunes et à la protection contre l'ensablement.

Par ailleurs, ils procurent un gîte pour la faune sauvage contribuant ainsi à sa reconstitution, et également du bois de chauffe pour les nomades.

Les Principaux Arbustes Fourragers Autochtones dans la Zone

Artemisia herba-alba

L'armoise blanche est l'espèce la plus représentative de la flore des parcours du Maroc Oriental. Elle couvre environ 1,250 millions ha et constitue l'aliment de base des troupeaux de la région, pendant une bonne partie de l'année. Elle fournit aux animaux un fourrage vert largement consommé, d'une valeur énergétique assez riche en éléments azotés et minéraux. En outre, l'armoise blanche est une source d'énergie (bois de chauffage) et d'huiles essentielles utilizées en parfumerie et comme agent antiseptique. Du point de vue écologique, l'armoise joue un rôle important dans la conservation des sols contre l'érosion éolienne et hydrique.

Salsola vermiculata

Cette espèce est très répandue dans les bas fonds, les Oueds et les zones d'épandage. La dominance de cette espèce est un indicateur d'un bon parcours. *Salsola vermiculata* est un fourrage de très bonne qualité et elle est très appétable et très riche en protéines. Durant les années 70 et 80, cette espèce a connu une régression, en raison :

- D'une exploitation abusive.
- De l'extension des labours, surtout dans les bas fonds et les zones d'épandage.
- Du prélèvement et de l'arrachage à des fins domestiques.

Noaea mucronata

Elle est cantonnée dans les sols limono-argileux et constitue l'espèce épineuse la plus répandue dans la zone. Elle connaît une extension continue d'une année à l'autre en raison d'une mauvaise gestion et de l'exploitation abusive des parcours.

L'abandon de l'élevage des camélidés dans la zone a également favorisé l'extension de cette espèce. *Noaea mucronata* est une espèce très peu appétable et elle n'est consommée par les petits ruminants qu'au printemps au moment de sa croissance. Du point de vue écologique, cette espèce contribue à la réduction des phénomènes de l'érosion hydrique et éolienne.

Haloxylon scoparium

Cette espèce végète sur les sols sableux dans la zone à climat pré-saharien. Elle est peu appétable et elle contribue à la production du bois de chauffe et dans la conservation du sol contre l'érosion hydrique et éolienne.

Atriplex halimus

C'est une espèce halophyte répandue dans la zone pré-saharienne, surtout dans les zones d'épandage et dans les sites salés. Elle est utilizée par les petits ruminants au printemps et pour la pratique de la cure salée. Elle est consommée par les dromadaires durant toute l'année.

Helianthemum lipii

Après sa dégradation durant les deux dernières décennies, *Helianthemum lipii* s'est régénéré par la technique de mise en repos préconisé par le PDPEO comme technique d'amélioration pastorale. C'est une espèce très appétable. Elle favorise la production des truffes du désert. Durant les trois dernières années, une activité de cueillette des truffes s'est développée, créant ainsi une importante source de revenus pour les petits éleveurs et les sans-emploi. Cette activité a permis à certains éleveurs de s'acquitter en partie ou en totalité de leur dettes auprès de la Caisse Nationale de Crédit Agricole (CNCA) ou auprès des commerçants locaux, voire même d'augmenter leur troupeau.

Les Arbustes Fourragers Introduits (*Atriplex nummularia*)

Durant les deux dernières décennies, les parcours de l'Oriental ont connu une forte dégradation, en raison de la sévérité des conditions climatiques et de l'anthropisation croissante. Cette dernière s'est traduite par :

- Le défrichement et la mise en culture : C'est là un fléau très grave ; chaque année, de nouvelles surfaces sont soustraites au pâturage et sont destinées à la culture céréalière pluviale épisodique dont les rendements sont dérisoires et aléatoires, alors que la proportion des terrains nus et dénudés s'agrandit.

- Le prélèvement et l'arrachage du bois de chauffage. Les nomades procèdent à des arrachages et à des prélèvements massifs des ligneux pour des usages domestiques. Les principales espèces ligneuses utilizées sont : L'armoise, *Salsola vermiculata, Noaea mucronata, Haloxylon scoparium.*
- L'exploitation abusive et anarchique des parcours.

Cette dégradation conduit à des conséquences néfastes sur les parcours et sur l'environnement :

- Une diminution de la production des parcours et l'apparition des plantes peu ou non appétables et toxiques (*Noaea mucronata, Peganum harmala*) et la disparition des plantes de bonne qualité fourragère.
- Une augmentation du coût de la supplémentation animale.
- La disparition de certains animaux sauvages (gazelles, outardes).
- La désertification et l'exposition du sol à l'érosion éolienne et hydrique.

Cette situation, fort préjudiciable aux conditions de vie des populations et à l'économie de la région, appelle à une meilleure gestion des parcours pour limiter leur dégradation et améliorer leur productivité afin d'assurer un mode de vie décent aux éleveurs. Dans ce sens, et dans le cadre d'une politique d'aménagement et d'enrichissement de la flore des parcours de l'Oriental, le Ministère de l'Agriculture (MAMVA) dans le cadre du Projet USAID a introduit, à titre d'essai, la plantation des arbustes fourragers (*Atriplex nummularia*) dans les terrains les plus dégradées, voire même dénudés.

Objectifs de l'Introduction des Arbustes Fourragers

L'introduction des arbustes fourragers dans la zone de l'Oriental vise:

- La conservation des eaux et des sols: Grâce à leur adaptation édapho-climatique, les *Atriplex* sont utilizés également dans le but de fixer les sols et de lutter contre l'érosion, d'atténuer le phénomène de l'ensablement et d'améliorer le bilan hydrique des sols par le biais des techniques de préparation des sols (ados).
- La production des réserves fourragères sur pied: Les parcours de l'Oriental sont caractérisés par une irrégularité pluviométrique et une exploitation abusive par les ayants-droit. Ceci a un impact néfaste sur la capacité des parcours à subvenir aux besoins des animaux durant toute l'année.

Pour remédier à cette situation, le MAMVA a accordé en plus des apports en aliments concentrés, une attention particulière à la création des réserves sur pieds. Les réserves pourront être utilizées en période de disette.

Réalisation des plantations d'*Atriplex nummularia* dans l'Oriental

L'introduction de cet arbuste dans l'Oriental a débuté en 1985, mais les grandes superficies n'ont été réalisées qu'à partir de 1988. La superficie plantée avant 1990 est de 7000 ha. Vu l'adaptation de cet arbuste dans la région et les résultats atteints, la plantation d'*Atriplex* a été poursuivie dans le cadre du projet PDPEO. La superficie plantée dans le cadre de ce projet est d'environ 4860 ha. Les aires plantées ont permis une production supplémentaire de 100 à 150 UF/ha, sans compter la strate herbacée, et la production d'environ 4 tonnes de bois par hectare.

Exploitation d'*Atriplex nummularia*

Depuis 1991, une superficie d'environ 4000 ha d'*Atriplex nummularia* connaît une exploitation annuelle en automne et en hiver. La plantation d'*Atriplex* a suscité, au début du projet, plusieurs controverses parmi les éleveurs. Toutefois actuellement, plusieurs utilizateurs témoignent de son intérêt nutritionnel (maintien du poids en période de soudure et absence de perturbations physiologiques).

La Participation des Éleveurs dans la Gestion des Aires Plantées par l'*Atriplex*

Pour une gestion rationnelle des parcours et la conservation des ressources naturelles, la direction du projet PDPEO a organisé les éleveurs dans des coopératives pastorales qui :

- Décident des programmes d'exploitation des aires plantées d'*Atriplex*.
- Assurent le gardiennage des plantations.
- Collectent les redevances de pacage et délivrent aux bénéficiaires des cartes de pâturage.

Conclusions

Les arbustes fourragers ont de remarquables aptitudes de résistance et de tolérance aux conditions des zones arides. Ces aptitudes font de ces arbustes un matériel de choix pour l'enrichissement de la flore et la protection du sol dans ces zones. Aussi les arbustes ont une valeur nutritive adéquate qu'ils maintiennent à des niveaux acceptables même à des stades avancés de leur développement.

L'intérêt que présentent les arbustes fourragers dans l'alimentation du cheptel n'est plus à démontrer, leur extension sur de grandes superficies reste liée aux conditions suivantes :

- La diversification du matériel biologique à travers la collecte, la multiplication et le développement de programmes de recherche sur les écotypes locaux.
- La mise en œuvre de programmes de recherche sur les techniques de plantation (densité optimale, semis direct, coupe).
- La participation des populations concernées dans le gardiennage, et l'entretien des sites plantés.
- La mise en œuvre du schéma d'exploitation des sites plantés en liaison avec les autres disponibilités alimentaires.
- La sensibilisation des éleveurs sur l'intérêt des arbustes fourragers.

Algerian Experience with Fodder Shrub Plantation

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Abstract

The legal status of the rangelands and their access are two vital issues for rangeland rehabilitation and re-establishment in the Algerian steppe. National experience with fodder shrub plantation has been dominated by two development approaches. The state controlled-approach, undertaken from the 1960s to the early 1990s, was implemented through the Association of Pastoral Livestock Development (ADEP), the Cooperative of Agrarian Revolution Pastoral Livestock (CEPRA), the Green Barrier program, and the Steppe Program (1985/89). The organizational structures and traditions of the local population were not incorporated into programs that were essentially imposed upon the steppe from the state, using models from other countries. Management was nonexistent. This approach led to the following: (i) a 75% decrease in forage production on the rangelands since 1978; (ii) a 100% increase in the cereal crop area from 1,100,000 ha in 1968 to 2,200,000 ha in 1993; and (iii) the capitalization of technological packages. The participatory approach started on a small scale in 1992. It is based on the principle of active participation by the indigenous population during all stages—conception, implementation, and evaluation—of a rangelands project. Pastoral communities and the state agree to proceed according to local tradition. This experience, which is still in its early stages, has already reached the double objective of: (i) decreasing the cost of state investment by 55%; and (ii) sensitizing local populations to the importance of rangelands, and of the need to replace activities that degrade the land with those that result in revegetating and restoring it. Restored rangelands have increased from 20 ha, planted by 10 beneficiaries in 1992/93, to 12,000 ha, planted by 8,146 beneficiaries in 1995/96. These experiences show that using indigenous knowledge, local organizational structures, and traditional rules is fundamental to successful rangeland development.

Key words: legal status, access mode, command approach, participatory approach.

Résumé

Le statut juridique des parcours et leur mode d'accès sont deux facteurs déterminants dans l'approche de réhabilitation et de restauration de la steppe algérienne. A ce titre, l'expérience nationale dans la plantation fourragère arbustive a été dominée par deux approches de développement. L'une volontariste de l'Etat,

à grande échelle, basée sur l'application de schémas d'aménagement systématiques et empruntés, mise en place des ADEP, en 1969, CEPRA, en 1975, le Barrage Vert, en 1971, et le Programme Steppe 1985/89, sans l'observation des modèles de gestion et d'exploitation qui les sous-tendent ni des formes d'organisations et des traditions des populations locales. Les effets ont été pour l'essentiel : (i) une réduction de la production fourragère des parcours de 75% depuis 1978 ; (ii) l'extension dramatique de la sole céréalière de 100% qui était de 1100000 ha en 1968 à 2200000 ha en 1993 ; et (iii) une capitalisation dans l'application de paquets technologiques. L'autre participative, conduite depuis 1992 à échelle réduite au niveau de l'exploitation individuelle, basée sur les principes de l'implication active des populations dans la conception, l'application et l'évaluation des programmes de revégétation, la contractualisation des relations, communautés et Etat, et du respect des droits coutumiers d'usage et des traditions locales. Cette expérience, qui est encore à ses débuts, a permis d'atteindre le double objectif de : (i) réduire le coût de l'investissement de l'Etat de 55% ; et (ii) conscientiser les populations pastorales à l'intérêt de la ressource naturelle des parcours par une mutation des mentalités d'une tendance de défrichement à une tendance de revégétation et de restauration des parcours : de 20 Ha plantés par 10 Bénéficiaires en 1992/93 à 112000 Ha plantés par 8146 Bénéficiaires en 1995/96. Ce double acquis d'expérience en terme d'approche de développement conforte la nécessité de l'observation des formes d'organisation traditionnelle et des droits coutumiers d'usage, préliminaire fondamental dans le développement de l'espace pastoral. Il est, aussi, générateur de perspectives nouvelles dans la réhabilitation de la fonction écologique et économique des parcours.

Mots-clés: statut juridique, mode d'accès, approche volontariste, approche participative.

Introduction

The rangelands, an essential natural resource of Algeria, represent 14% of the country's area and 78% of its agricultural land. Their legal status and access, founded on a traditional social organization, are two important issues of rangeland development.

Originally, the rangelands were owned collectively by the tribes. This ownership status has undergone several changes over the last hundred years. They became common lands in 1863, and further changes took place throughout the colonial period. Post-colonial rangeland development has followed a similar pattern, changing from total governmental control (1963–1990) to withdrawal and dismissal in the early 1990s. This inconsistency complicated the transfer of technology necessary for rangeland conservation and rehabilitation.

However, in 1992, the High Commission for Development of the Steppe (HCDS), a public institution, launched a shrub plantation program based on the active participation of local collectives and pastoral communities. Field trials on shrub plantations were carried out to develop a base of knowledge upon which to build a rangeland rehabilitation program, and develop the economic and ecological resources of the rangelands.

Changing Methods of Approach

Post-colonial experiences with rangeland development programs in general, and with fodder shrub plantations in particular, followed the dictates of external agricultural development policies. Rangeland development from 1963 to 1990 followed a policy of collectivization of agriculture. The rangelands, a common resource, were considered the responsibility of the state. This perception went against the pastoral culture and traditions.

This state-controlled approach was based on borrowed management and development schemes. It was implemented on the 200 ADEPs and CEPRAs established on 431,315 ha (14% of the rangelands). The remaining 86% of the area, which is used by the tribes, was not touched by any of the development programs. In 1971, the Green Barrier, a biological protection belt against desertification, increased the marginalization of the pastoral communities. The rangelands involved were planted with forest species, detrimental to the needs of local users. This experience made the users hostile toward any kind of technology suggested by the state. Technology transfer packages were limited to state projects, managed by government representatives, without consultation with local users, who remained on the margins of the state-run programs. The 1985–1989 Steppe Development Program, through its "referential projects," introduced new techniques of rangeland reclamation through fodder shrub plantation with species such as *Acacia* and *Atriplex*.

In 1992, change came when the national economy was liberalized. Tenure reorganization resulted in the renewal of pastoral traditions, and the recognition of customary rangeland rights. This fundamental change altered HCDS development programs, which can now be based on the reconciliation of rangelands development and traditional pastoral culture.

The participatory approach is built upon the following principles:

- There must be an active partnership between local users and developers in the conception and implementation of rangeland programs.
- The responsibilities of each partner must be clearly defined.

- There must be respect for rangeland uses, pastoral traditions, and specific local features.

The intention of this policy is to:

- Insure continuous and regular communication between the development agent and the development receiver.
- Benefit from the pastoral communities' experience and knowledge.
- Allow a progressive adoption of technology transfer.

This approach is essential to assure the participation of pastoral communities in efforts to introduce the fodder shrub plantations necessary for their survival.

Comparison of the Two Approaches

State Control

This policy resulted in the following problems:

- **Refusal of technology packages imposed by the state.** Because rangeland reclamation was associated by the pastoral communities with forestry plantation, fodder shrub plantations did not extend beyond the boundaries of the state projects and the Green Barrier space.

- **The worsening of the pastoral crisis.** Irrational exploitation of the rangelands based on a "who uses the most profits the most" logic resulted in decreases of 25% in rangeland area since 1974 and 75% in fodder production capacity. After 1978, inappropriate governmental incentive measures contributed to the refusal of private investment in fodder shrub plantations. Legal reform of the rangelands deeply deformed the relationship between government regulations and tribal traditions. Two indicators characterize the importance of this problem:

    - The degradation of the rangeland resulted in yield decreases from 150 FU/ha to 50 FU/ha.
    - The increase of the cereal crop area in the steppe zone from 1,100,000 ha in 1968 to 2,200,000 ha in 1993 added to the deterioration of rangeland vegetation.

- **The capitalization of technology packages.** This allowed a better appreciation of the economic opportunities of shrub plantations and rangeland reclamation techniques. However, transfer to local populations failed because of inadequate subsidies, making the packages too expensive for the people for

they were intended to help, because the pay-off period was too long (Table 1; Fig. 1).

Table 1. Effect of subsidies on the pay-off period of technology packages.

Technique	1991 cost (DA/ha)	Estimated production (FU 91)	Cost of sub-sidized barley (DA/kg) 1	Barley real cost (DA/kg) 2	Pay-off period (year) 1	Pay-off period (year) 2
Ripped strips	20,400	1,264	2.73	7	6	3
Furrow plantation	19,890	750	2.73	7	10	4
Reseeding	17,000	3,536	2.73	7	2	1
Steppe strips	10,000	85.	1.13	3	104	40
Transplanted	210,000	470	2.73	7	17	7

Data is from the Thlijene perimeter, Tebessa *Wilaya*.

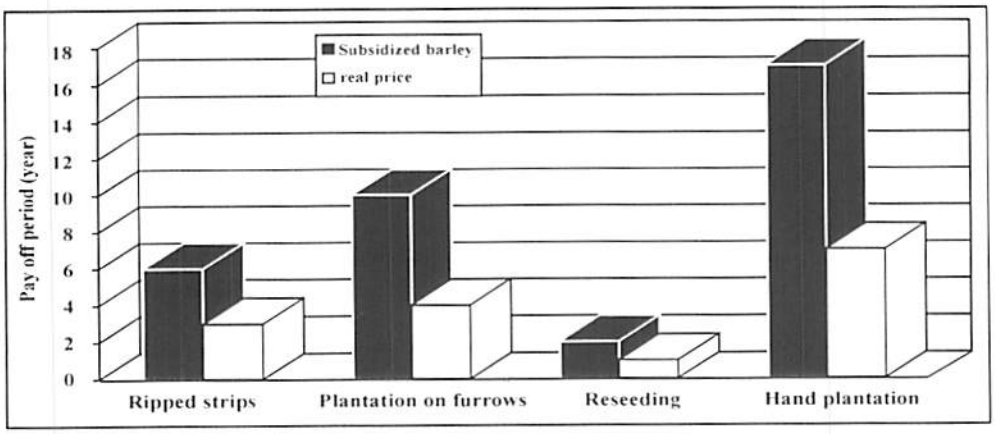

Figure 1. Effect of subsidized barley price on the investment pay-off period for technology packages in rangelands reclamation.

Participatory Approach

As described above, shared responsibility between the state and the pastoral communities, based on a contract, was implemented in 1992/93. This kind of partnership has already had the following effects:

- **State investment savings.** The cost of fodder shrub plantation decreased by 52% per hectare for hand planting by the collectives, and by 77% for private farmers, compared to plantation carried out by companies (Table 2, Fig. 2).

Table 2. Comparative costs of fodder shrub plantation (1994/95).

	Individual	Collective		Companies
		Mechanized	Hand	
DA/ha	10,041	13,975	20,530	42,960
Savings (%)	77	67	52	-

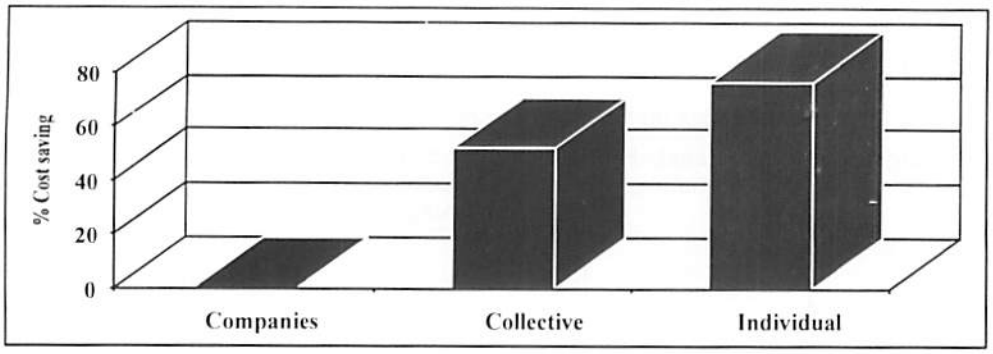

Figure 2. Comparison of different approaches to fodder shrub plantation in terms of state investment cost.

- **Progressive behavioral and philosophical changes.** Pastoral communities have realized the dangers of destroying rangeland vegetation, and are now participating in fodder shrub plantation. This fact is corroborated by the increase of the area planted on private lands with fodder shrubs species such as: *Atriplex halimus*, *A. canescens*, *A. nummularia*, *A. leucoclada*, *and A. semibaccata*, *Acacia cyanophylla*, *A. eburnea*, *Medicago arborea*, *Gleditsia triacanthos*, *Elaeagnus angustifolia*, *Retama raetam*, and *Opuntia ficus indica*. The number of beneficiaries increased from 10 to 8,146 between 1992/93 and 1996, nationally, and from 10 to 1,349 in the eastern region (Table 3).

Figure 3. Number of beneficiaries of fodder shrub plantation in the eastern region.

Table 3. Evolution of eastern region beneficiaries by number and area.

Season	Area (ha)					Area	Mean area/
	0–5	5–10	10–20	>20	Total season	(ha)	beneficiary
1992/1993	10				10	20	2.00
1993/1994	249				249	500	2.01
1994/1995	275	19	2		296	1,522	5.14
1995/1996	770	17	5	2	794	2,396	3.02
Total	1,304	36	7	2	1,349	4,438	3.30
Percentage	96.67	2.67	0.51	0.15	100		

Conclusion

Technology transfer, a vital part of rangeland development, must take into account the cultural heritage of the people to whom it is directed. This lesson, exemplified by the Algerian experience, is of great importance in rangeland reclamation and re-establishment. By working within the organizational structures of the traditional communities, local social and administrative communities take responsibility for the development of their territories.

It is important to recognize the limitations of state policy. Over three decades, government development programs affected less than 14% of the rangelands located on state projects and reached only about 1,385 CEPRA laborers, representing only 0.85% of the pastoral community. By comparison, a three-year trial using the participartory approach has been implemented in 99 locales, representing 32% of the administrative bodies, with a real participation of 6.5% of the pastoral community.

The fear of political instability remains a major concern. Past policy changes are still very much alive in the memory of local users. Table 3, which shows that 96% of plantations are only 0–5 ha, and mostly planted with *Opuntia* species, illustrates the fear of the private sector to invest in rangeland reclamation. Thus, technology transfer will not be efficient until the communities are sure of their long-term investment.

As with any farming population, the pastoral communities are conservative and view change with apprehension. Respect for pastoral traditions is fundamental to effective technology transfer.

A new land tenure system for the rangelands remains to be designed and implemented. This important undertaking will determine the future of rangeland resources and, consequently, the whole process of private and collective investment in fodder shrub plantation. Implementers of such a system should take a balanced approach that is acceptable to the pastoral communities, will promote private investments in rangeland restoration through fodder shrub plantation, and integrate rangelands resources into the national economy.

Tunisian Experience with Fodder Shrubs

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Introduction

The Tunisian climate is characterized by extreme irregularity in time and space (rainy and dry years, high thermal amplitude, and a long dry season). Drought is a permanent phenomenon. The key problems of the arid and semi-arid zones are summarized as follows (Oram 1995):

- Increasing degradation of the rangelands in the steppe and consequent declines in the feed supply for ruminants.
- Increasing numbers of small ruminants, especially sheep, despite widespread indications of the declining productivity of natural grazing.
- Uncertainty about grazing rights on the range, arising from changes in the traditional tribal regulation mechanisms as a result of range privatization and sedentarization of migratory peoples.
- Demographic changes and increasing population pressures on natural resources, both directly through competition of people for land and water, and indirectly through rising demand for meat and other animal products.
- Limited availability of technology for improving sustainable range productivity. This is due to the lack of support for range research, inexperience with management of range flora, and a "reservation-type" approach by government officials rather than a participatory approach to establishing and using forage shrub plantations.

Experience with fodder shrubs started in the early 1940s, and even earlier in some countries, with varying degrees of failure and limited success. Impact is difficult to assess, since monitoring and evaluation processes are generally lacking.

According to a recent survey, rangelands cover some 5,413,000 ha, including 970,000 ha of forest and forest pasture, 743,000 ha of *Stipa tenacissima*-based steppe, 2,500,000 ha of communal and state rangelands, and 1,200,000 ha of private rangelands.

Physical Environment

Climatic and Bioclimatic Characteristics

Tunisia is characterized by:

- Extremely irregular rainfall, both in space and time.
- Less abundant rainfall during the cold season.
- Fluctuation between rainy and dry years.
- Rainstorms of high intensity, which can exceed 100 mm/h for short (five minute) periods.
- Uneven rainfall (as much as 50% of one year's rainfall, and more than 100% of the inter-year average, can fall in 24 hours).
- High thermal amplitude (diurnal, monthly, yearly) of 25–35°C.
- Potential evapotranspiration of 900–1,200 mm/year in the central and southern parts of the country.
- A very long dry season of 8–12 months/year.
- Strong winds blow for 50–80 days/year, and hot dry winds, originating in the desert (sirocco), blow for 25–75 days/year.
- A negative moisture balance that varies from 600 to 1,100 mm/year in the central and southern parts of the country.

Tunisian bioclimates are generally classified as humid and sub-humid, semi-arid and arid. The humid and sub-humid bioclimates (>650 mm/year precipitation) represent only about 10% of the country. However, the semi-arid bioclimate (450–650 mm/year precipitation) covers approximately 32,800 km^2, about 20% of the country. The remaining 70% (114,800 km^2) is divided into arid and desertic (<100 mm/year precipitation). Thus, almost three-fourths of the country is characterized by an arid and desertic bioclimate.

Soils

The prominent characteristics of the soils in central and meridian Tunisia are:

- Expansion of quaternary crusts and encrusts with calcareous and gypseous textures that fossilize the erosion glacis.
- Expansion of salty soils.
- Evolution of recent sediments to brown desertic soils with calcareous or calcareous-gypseous deep horizons.

The major soil formations in central and southern Tunisia are:

- Sandy: 15%.
- Silt: 13%.
- Clayey: 10%.
- Gypseous: 20%.
- Limestone: 20%.
- Halmorphic: 15%.
- Divers: 7%.

The main edaphic characteristics of these soils are:

- Low level of organic matter.
- High level of limestone or gypsum.
- Fine to coarse texture.
- Occasional high level of salts.
- Soils are sensitive to hydric and aeolian erosion due to the lack of sufficient vegetation cover.
- Edaphic aridity 5–7 month/year.

Geomorphologic and Edaphic Characteristics

The geomorphologic forms most frequently planted to shrubs are: the glacis, the plains, the riverbeds, and the depressions. Figure 1 shows the different geomorphologic units where sylvo-pastoral plantations have been undertaken.

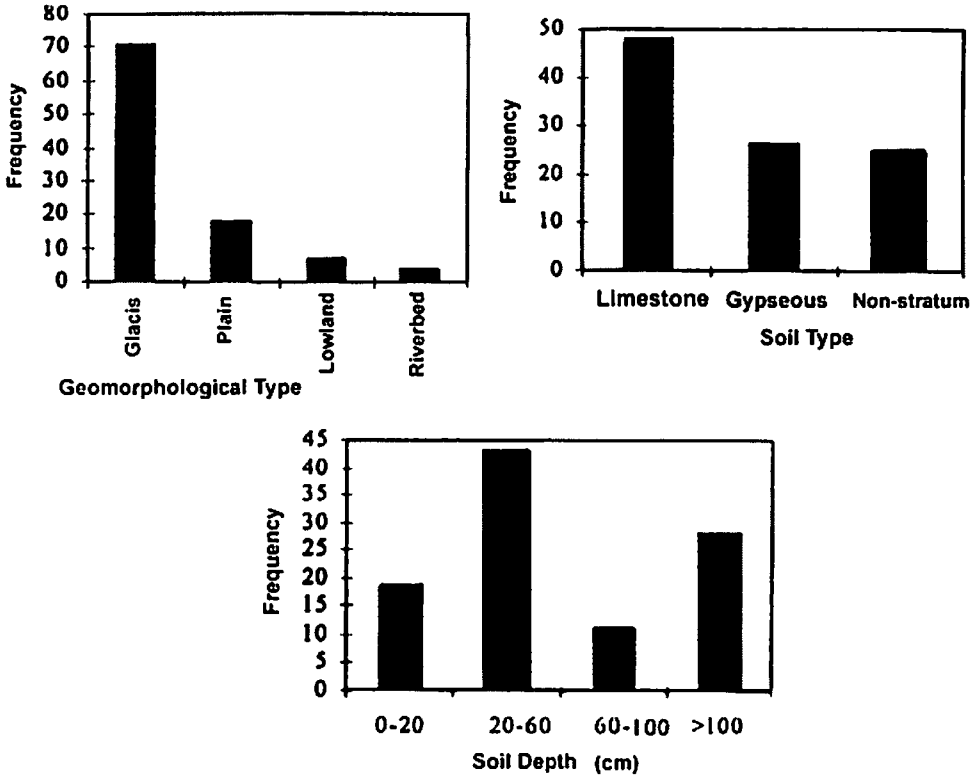

Figure 1. Frequency of shrub plantations according to geomorphologic characteristics of soil (a), soil type (b), and soil depth (c)

Some 70.3% of shrub plantation is carried out on the glacis. About 78% of the planted areas have low biological potential (glacis and depressions are more or less salty). This is linked to the ownership status of rangelands. Indeed, government ranges, where most shrubs have been planted, represent only 6.5%. In most cases, government ranges are mountains and hills. Farmers, when they do accept shrub establishment, allocate marginal land with low productive potential for shrub plantations.

Shrubs are generally planted on two types of substrate: limestone and gypseous, represent 47.9 and 27.1% of plantations, respectively. Soils without identifying substrate are not frequent, and are called non-stratum soils.

The arable land is generally sandy. Plantations undertaken on other soil textures are rare. Deep profiles are frequently of fine texture. River bed soils are either alluvial or colluvial. Plantations on sandy-gypseous textures, or those on outcrop crusts and encrusts, are well represented. Soil depth varies according to slope:

- 0–20 cm: shallow soils.

- 20–60 cm: medium to shallow soils.
- 60–100 cm: deep soils.
- >100 cm: very deep soils.

Figure 1 categorizes plantations according soil depth. Some 61.3% of plantations are established on medium to shallow soils (<60 cm). Plantations on glacis are characterized by deep to very deep soils (60–150 cm), and that of riverbeds by very deep soils (>150 cm). Erosion, mineral, and halomorph soils are well represented. Their organic matter levels are very low (<3%).

Major Production Systems

Tunisian agriculture is characterized by six production systems. Although these systems function differently, they share many common problems:

- An important and persistent anthropogenic pressure.
- The intensification of productive agricultural systems at the expense of natural range ecosystems.
- The dividing up and appropriation of land, leading to the parceling of land ownership.
- The transition from traditional production systems to a sedentary system, which has not been integrated into the economy.
- The incompatibility between the social structure and the technical requirements of productive systems.

The major agricultural production systems in Tunisia are summarized below.

- **Forest systems.** The government oversees several natural forests in the north of the country (Ghar Dimaou, El Feija, Ain Draham, Tabarka, Nefza, and Sejnan). Although they are relatively protected, they are more or less exposed to anthropic perturbations and are experiencing regression with regard to biodiversity, production, and area. Such regression has transformed several zones into pastoral systems.

- **Pastoral systems.** Pastoral systems result from the regression of forest systems. They are characterized by animal production (sheep and cattle), with enclaves reserved for cereal production in the north of the country. In the center and south of the country, these systems are used as reserves for drought.

- **Cereal-based agro-pastoral systems.** These systems are found mainly in the regions of El Kef, Siliana, Jendouba, Beja, Zaghouan, and Kasserine. In these systems, cereal production is expanding and even taking over the biologically unproductive lands (crusts and encrusts). Animal production, largely based on

forests and shrubs, is a major activity in these systems. Production susceptible to water deficit during dry seasons is not well-developed.

- **Rainfed mixed farming systems.** These systems are quite developed in the center of Tunisia (Kairouan, Sousse, Sidi Bouzid, Sfax, and Gafsa). They are characterized by a diversity of agricultural activities (cereal, fruit tree, and animal). Expansion of cereal and tree production is the major characteristic of these systems. Livestock production is directly related to rainfall. Indeed, herd size increases considerably in rainy years and faces an important reduction in dry years. These systems are progressively being converted into irrigated systems.

- **Agro-pastoral systems.** These production systems are based on sheep production and occasional cereal production. They are located in the south of the country (Sidi Bouzid, Kasserine, Gafsa, Gabes, Medenine, Tataouine, and outside the oases of Djerid and Nefzaoua). The steppe, which constitutes the major animal feed resource, is regressing, due to the expansion of cereal and fruit tree production. These systems are moving into the dry, mixed-farming systems in the regions of Jefara, l'Ouara, and Dhahar (Gabes, Medenine, and Tataouine), and into irrigated systems in the high plains of Kasserine, Sidi Bouzid, and Gafsa.

- **Oasis systems.** The oases are located in the regions of Nefzaoua, Djerid, and Gabes. They are characterized by:

    - An intensive cropping system with three levels (palm tree, fruit, and vegetables).
    - The intensification of palm tree farming (Degelet Nour) in the regions of Nefzaoua and Djerid.
    - The over-exploitation of non-renewable hydric resources from the deep aquifers.
    - The secondary salinity of soil.
    - The reduction of organic mineralization between animals and plant production due to the competition for water between date trees and forage production.
    - Animal production relegated to secondary importance and pushed to the peripheral steppe, which is poor in palatable pasture species. The development of dry farming in the steppe greatly decreases production capacity.

National Strategy for Rangeland Improvement

Evolution of Rangelands: Conflicting Statistics

Data on rangelands gathered from various sources (Ministry of Agriculture, Ministry of Regional Development, etc.) are conflicting. This is often because the definitions of chott, sahara, forest, and other non-arable lands make it hard to identify rangelands.

According to Sarniguet et al. (1995), rangelands decreased 13–24% between 1971 and 1992, corresponding to a loss of about 29,000 ha/year (Table 1).

Table 1. Eco-regional distribution of rangelands, forest, and pasture (000 ha).

Region		Total	Humid	Sub-humid	Semi-arid	Arid	Desertic
North							
	East	103.2	34.5	38.6	30.1	-	-
	West	352.8	54.6	40.8	257.3	-	-
	Total	456.0	89.1	79.4	287.4	-	-
Center							
	East	145.8	-	-	-	145.8	-
	West	808.5	-	-	60.3	748.2	-
	Total	954.2	-	-	60.3	893.9	-
South		2579.8	-	-	-	897.5	1682.3
Total		3990.0	89.2	79.4	347.7	1791.4	1682.3
Percent		100.0	2.0	2.0	9.0	45.0	42.0

Source: Saringuet et al. (1995).

Attempts to adopt management practices that sustain rather than degrade the productivity and quality of the rangelands go back to the 1950s and beyond. Prominent among the practices advocated by rangeland specialists (often expatriates) have been:

- Reseeding with "improved" drought-tolerant grasses.
- Resting a part of the land each year to allow regeneration of desirable species after a period of grazing, and to increase the seed bank in the soil.

Despite some promising early results from reseeding with introduced species, there has been little lasting success. This is partly due to recommendations presented after too short a trial period in areas of very high climatic variability. Consequently, range reseeding has fallen from grace.

An alternative approach now coming into favor is the plantation of various introduced and native shrubs, including *Acacia* spp., *Atriplex* spp., spineless cactus, etc. This approach shows some promise, especially if seeding, rather than planting individual bushes, proves successful.

All these technologies seem unlikely to have any impact if there is no grazing discipline. In fact, technologies for improving rangeland productivity exist, but are doomed to failure if the resource is common property.

Rangeland Improvement: Extensive Investment, But...

From 1956 to 1989, some 272,000 ha were planted with shrubs, mainly spineless cactus, *Acacia* spp., and *Atriplex* spp. (Table 2). Most (80%) rangeland improvement activities were carried out in arid and semi-arid areas.

...The Strategy May be Risky

The current strategy of rangeland improvement started in 1990 and aims to: (i) plant some 600,000 ha of shrubs (200,000 ha on private farms); and (ii) use other rehabilitation techniques (reseeding, fertilizing, etc.) on another 2.2 million ha (Fig. 2). Three departments of the Ministry of Agriculture are in charge of this strategy, namely the Forestry Department (common lands), the Livestock and Pasture Office (Private lands), and the Water and Soil Directorate (CES).

Table 2: Area (000 ha) of rangeland improvement (1956–1989).

Operators	Shrub plantation	Other techniques	Total
Forestry Department	53.60	1.40	55.00
Direction Générale des Forêts; Water and Soil Preservation (Direction de CES)	11.20	9.80	21.00
Livestock and Pasture Office (OEP)	24.25	18.97	43.20
Word Feed Program (PAM) Project	177.20	-	177.20
Development of Central Tunisia Office	2.65	-	2.65
OPPI Souassi	3.80	-	3.80
Sylvo-pastoral Development of NW Office	-	4.65	4.65
OPPI Kef	0.10	-	0.10
Total	272.80	34.80	307.60

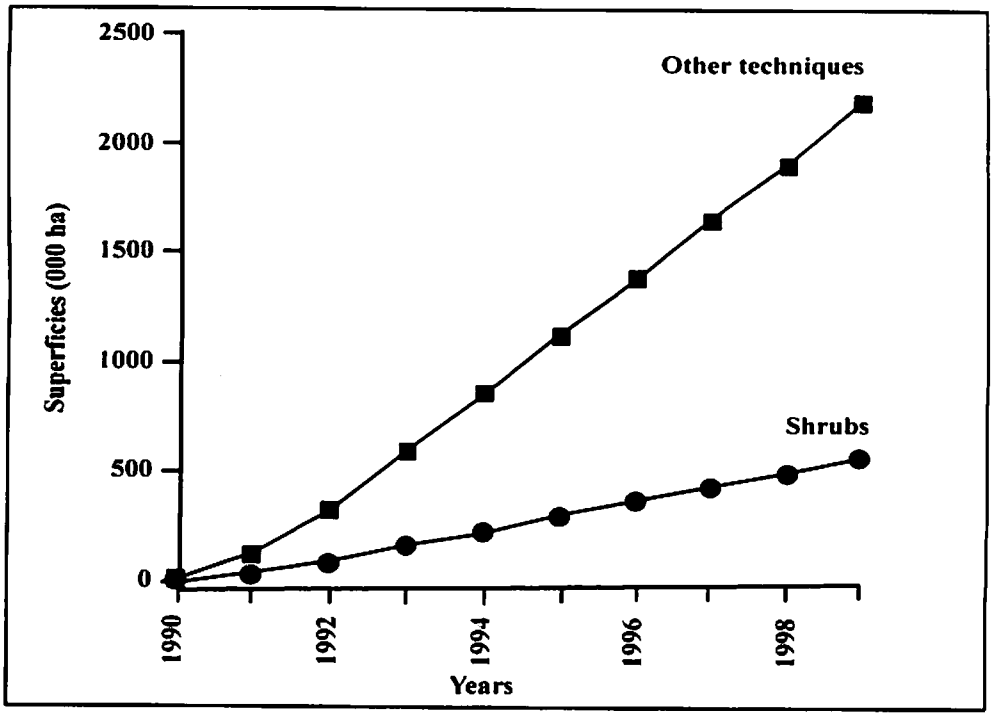

Figure 2. Objectives of the national strategy for rangeland improvement (to be achieved by the year 2000).

Spineless cactus is widespread today in arid and semi-arid areas. The OEP established some 43,000 ha of cactus between 1990 and 1993, all on private land. But questions remain. What are the risks of such monoculture? What is left of the plantations of the 1960s? One positive effect of this strategy is shrub plantation on private lands implemented by the Livestock and Pasture Authority (OEP). During 1990–1995, some 50,000 ha were planted with shrubs, mainly cactus (Table 3).

Table 3: Area (ha) of shrubs established by the Pasture and Livestock Office on private farms (1990–1995).

Zone	Spineless cactus	Other fodder shrubs[†]
Northeast	1,669	1,623
Northwest	2,772	1,449
Central-east	9,674	1,495
Central-west	33,099	528
South	2,712	2,265
Total	49,926	7,360

[†] Main shrub species were: *Acacia cyanophylla* Lindl., *Atriplex nummularia*, and *Medicago arborea*.

Establishment Costs

Establishment costs for a plantation of spineless cactus and shrubs (*Acacia cyanophylla*, *Atriplex* spp.), estimated by the Pasture and Livestock Office in 1994, are given in Table 4.

Table 4: Estimated costs of shrub establishment (Tunisian dinar/ha).

Item	Cactus	Other shrubs
Plowing (tractor, 1.5 hours)	27	27
Plant shopping	80	50
Plant transport	60	40
Labor (for planting)	100	125
Plant replacement	12	30
Labor (for replacement)	25	25
Irrigation	-	300
Safeguard (60 days)	300	300
Subsidies (3 first years)	150	150
Total	754	1,047

Current Management

One of the problems hindering the success of shrub plantations is management. Numerous questions arise when considering the use of introduced shrubs. How should they be used by the animal (cut-and-carry vs grazing)? How frequently can they be grazed? What stocking rate can the shrubland support? For how long can shrublands be grazed without permanent damage? Should plants be completely defoliated, or would they recover better if only partly defoliated? In the absence of a concrete management strategy, continuous grazing is the prevailing system in the Tunisian rangelands. Lands are exploited to the maximum of their potential, with no compensatory input. Unfortunately, little effort has been devoted to defining convenient strategies of management for introduced shrubs.

Once planted on communal, state, or private rangelands, shrubs have to be protected for at least three years before they are grazed. Subsidies, such as feed (concentrates, hay, and alfalfa pellets) are given to farmers to replace outputs of the improved rangelands during the maintenance period. After three years, the shrubs should be used as recommended. Under the Tunisian climate, shrubs are used after 2–5 years, depending on the zone (north or south) and rainfall. Shrubs are used according to the field experience of farmers and technicians. No adequate seasonal or annual calendars have been recommended to farmers.

Acacia cyanophylla trees are grazed every two years. Plants are grazed one year and browsed the next. Leftover branches and leaves are cut and distributed to the animals.

Cactus plantations are never grazed directly. Cut-and-carry is the common practice. Using this technique, the loss of feed is virtually nil, as is the risk of over-use. But the grazing layer of herbage remains unavailable to the stock.

Saltbushes (*Atriplex* spp.) are grazed during the summer. Plants are rarely cut for regeneration.

Shrubs are used in different ways, depending on the user. On private rangelands, shrubs are relatively well-managed. Their use is confined to the farmer's need to meet seasonal animal feed demands, following technical recommendations. Nevertheless, these shrubs are subject to overuse during dry years, and, consequently, plants barely survive. The use of established plants on communal rangelands under forestry control is dictated by forestry technicians. Plants can be used relatively quickly (three years after establishment). However, the use of rangelands by farmer flocks, whether or not the rangelands have been rehabilitated, is allowed only during dry years. To use improved and/or protected rangelands, farmers have to pay a fixed fee (0.3–0.4 Tunisian dinars). Most protected forests and communal rangelands are not grazed for many years. Such a practice leads to early aging of shrub plants, which become woody and less productive in terms of browsing. Periodic cutting favors the growth of new shoots and leaves, which results in an increase in fodder production.

Research Highlights

In Tunisia, fodder shrubs are frequently used to improve the production of rangelands and to create forage reserves that can be used in periods of drought. A range of exotic species, such as cacti, *Acacia*, *Prosopis*, *Parkinsonia*, and *Atriplex*, are the most commonly used. Native species, *Atriplex halimus*, *Ceratonia siliqua*, *Pistacia atlantica*, *Periploca laevigata*, *Rhus tripartitum*, *Calligonum comosum*, etc., are increasingly being introduced to replace low-resistance exotic species in arid areas. Native species are studied less than exotics in terms of resistance to ecological conditions, production, and mode of use.

The study of fodder shrubs in Tunisia involves:

- Problems of germination and installation.
- Resistance and response to ecological conditions.
- Evaluation of biomass yield.
- Techniques for use.

These topics concern several species, particularly the exotic ones, such as *Acacia cyanophylla* (syn. *A. saligna*), *Prosopis juliflora*, and *Parkinson aculeata*.

Exotics do not have the problem of germination that native species have. Their germination rate is about 90%, vs only 10–20% for native species, (although this can be improved by techniques such as scarification and sulfuric acid treatment). This problem is also encountered in the field. Indeed, transplanting exotic species is more successful than transplanting native species. The installation rate of exotics varies between 70 and 100%, according to edaphic conditions. That of native species rarely exceeds 60% under the most favorable conditions.

There is diversity in interspecies behavior in terms of response to ecological conditions and stress resistance. This suggests the need to adapt different strategies for each species to overcome the effects of ecological constraints. Native species are characterized by a high resistance to water stress. Their minimum hydric potential is very low (up to -6 Mpa for *Ceratonia siliqua*) and they are less dependent upon edaphic conditons. Exotic species are less resistant to water stress, require better soil quality, and have a higher minimum hydric potential. Thus, *Acacia saligna*, *Propopis juliflora*, and *Parkinsonia aculeata* have a minimum hydric potential of -2, -2.8, and -2.7, respectively. This difference shows that native species are more tolerant to hydric stress and are therefore more resistant to the ecological conditions of Tunisia.

However, native species are less productive than exotics. According to edaphic conditions and species, the biomass production of some exotic species is as follow:

- *Acacia saligna*: 2,000–5,000 kg DM/ha.
- *Atriplex nummularia*: 2,000–9,000 kg DM/ha.
- *Opuntia ficus indica*: 2,000–9,000 kg DM/ha.
- *Prosopis juliflora*: 200–2,000 kg DM/ha.
- *Parkinsonia aculeata*: 250–1,500 kg DM/ha.

The last two species are known for producing pods rather than leaves.

There are two main types of exploitation:

- Direct grazing by the herd.
- Indirect use by cutting (cut and carry).

The first technique implies that the leaves must be within reach of the animals (1–1.5 m high). This results in damage that can threaten the regeneration of species such as *Opuntia ficus indica*.

Indirect exploitation requires knowledge of the different phenologic stages for each species in order to determine the optimum time of cutting. Thus, *Acacia saligna* has to be used in autumn (October through early January), which allows it to escape summer drought and winter cold. The mild temperatures during October

and early November are beneficial for growth. The optimum age of exploitation for this species is the fourth year after planting. At this age, 70% of production is represented by the edible fraction (leaves, pods, and soft branches).

The history of research related to fodder shrubs reveals a focus on mainly vegetative aspects (ecology, etc.). However, the tendency in the last decade has been to focus more attention on plant and animal interactions. Indeed, the effect of fodder shrubs on animal productivity and the behavior of browsed shrublands are being increasingly investigated. The main research activities on fodder shrubs in Tunisia are summarized below.

Before 1950

Cordier (1947) reviewed research carried out in Tunisia on the potential use of some native and exotic shrubs (*Atriplex* spp., cactus, *Medicago arborea*, etc.) in livestock feeding. Analysis of these shrubs and their impact on ruminant (mainly sheep) productivity were discussed.

1950–70

Le Houérou carried out extensive work on environmental factors (climate, geology, soil, runoff, and erosion) and their relationship to plant cover during this time. A list of the steppe vegetation of Tunisia in that period was created (Le Houérou 1969).

1970–80

Amino acid and mineral profiles of some local and exotic ecotypes of *Atriplex*, *Acacia*, and cactus were determined at INRAT by Wehren (1976).

Since 1990

Studies on shrub ecology

Environmental constraints and responses of some exotic shrubs established in pre-Saharan Tunisia were studied in an IRA research program developed by Zaafouri and his collaborators. Results indicate that, in the low arid zone of Tunisia, three exotic species, *Acacia saligna* (syn. *Acacia cyanophylla* Lindl.), *Prosopis juliflora*, and *Parkinsonia aculeata*, are weakly dependent on edaphic condition. The development of these species is related to rainy-year frequency and periodic watering during the first year. Their production depends on chemical and physical characteristics.

Studies on the use of shrubs in livestock feeding

Research on the use of fodder trees and shrubs in livestock feeding and rangeland management is actively undertaken by the animal nutrition laboratory of INRAT. The research and development contract established between INRAT and the Pasture and Livestock Office since 1990 has resulted in some 25 experiments in this field. Four topics are being investigated:

- Identification and nutritive characterization of range species. The seasonal variation in the nutritive value of about 20 native and exotic shrubs and trees abundant in the arid and semi-arid rangelands was studied (Ben Salem et al. 1996). The palatability of these range species was measured on sheep, goat, and dromedaries (Nefzaoui et al. 1993; Ben Salem et al. 1994). These studies identified some species that have high nutritive value and may play an important role in livestock feeding in harsh conditions (*Atriplex*, spineless cactus, etc.). The potential use of some species is limited due to their low nutritive value.
- *Acacia cyanophylla* Lindl. as a fodder resource. It has been shown that *Acacia* has low nutritive value. It is less suitable as a protein supplement than might be expected from its crude protein content. Owing to its tannins, *Acacia* negatively affects the digestive use of dietary ingredients (Ben Salem and Nefzaoui 1993; Ben Salem et al. 1997a). Because *Acacia* generates substantial amounts of biomass, attempts are being made to circumvent the negative effects its tannins and thus improve its nutritive value. Field drying was found to increase dry matter intake by sheep without any change in digestive use (Ben Salem et al. 1997b). The nitrogen and/or energy supply of *Acacia*-based diets was found to improve the nutritive value of the whole ration without affecting digestion (Ben Salem et al. 1995). Finally, the use of precipitants, such as polyethylene glycol, proved to be a successful alternative for improving the nutritive value of *Acacia* foliage (Ben Salem et al. 1996). PEG may be incorporated in a concentrate, in drinking water, or in feed blocks (Ben Salem et al. submitted). In all situations, the use of this reagent significantly increases the digestive use of *A. cyanophylla*.
- The use of these range species may alleviate the cost of livestock feeding and reduce concentrated feed imports. In addition to their forage potential, *Atriplex* and cacti may be used for soil fixation and other purposes (i.e., fruit production for cactus).
- Rangeland management. Now that we are familiar with almost all fodder trees and shrubs abundant in arid and semi-arid zones, we must propose a management strategy for users of native and improved shrublands. The effect of stocking rate and exploitation frequency on animal and shrubland productivity will be the subject of future research in our laboratory.

Recent Research and Development Projects

Projects at Institut des Régions Arides (IRA), Médenine include:

- Rangelands Project in the South (Projet Parcours Sud 69/001), FAO/UNDP/ORSTOM.
- Livestock Project (Projet Elevage) Tun 84/013, 1984–1990, FAO/UNDP/Qatar.
- Degraded Lands Rehabilitation in Arid Areas (Projet Réhabilitation des Terres Dégradées en Tunisie Aride) STD1 and STD2, 1986–1991, EEC/CEFE France/ORSTOM.
- South and North Sahara Degraded Lands Rehabilitation Project (Projet Réhabilitation des Terres Dégradées au Nord et au Sud du Sahara, STD3), 1993–1995, EEC/CEFE/ORSTOM/Sénégal.
- Preservation of the Rangeland Resources of the Steppe (Sauvegarde des Ressources Pastorales Steppiques), 1992–1995, University of Gent, Belgium.
- Natural Environment Evolution and Population Dynamics (Evolution des Milieux Naturels et Dynamique des Populations), ORSTOM/Université de Provence/ISP Tabarka/ESA Mograne.
- Pastoral Systems of the Maghreb (Systèmes Pastoraux Maghrébins), 1988–1994, Canada (CRDI).
- Training-Research for the Arid Zones Development Project (Projet Formation Recherche sur le Développement des Zones Arides), 1995–1997, IAM/CIHEAM/Coopération Française.

The main topics investigated by the IRA were:

- Rangeland potentiality and productivity.
- Analysis of some pastoral systems of arid and pre-Saharan zones.
- Plant dynamics and sand mobility in the Jeffara.
- Livestock behavior on rangelands (animal requirements, rangeland productivity, supplementation).
- Phytoecological studies of saline and gypsiferous areas.
- Methodologies of rangeland improvement (rehabilitation of degraded rangelands, rational grazing techniques, and flock management).

Projects at the Institut National de Génie Rural et des Forêts (INGREF, formerly INRF) include:

- FAO Project. A research program on the rehabilitation of some forest and pastoral species. A seed bank was created for the following species: *Acacia*

tortilis, *Pistacia atlantica*, *Calligonum arich*, *Calligonum comosum*, *Calligonum azel*, *Ceratonia siliqua*, *Rhus tripartitum*, *Juniperus phoenicea*, and *Periploca laevigata*. Most of these species are adapted to arid conditions.

Projects at the Institut National de la Recherche Agronomique de Tunisie (INRAT) include:

- Experimentation and Demonstration Project in Arboriculture, Livestock and Pasture (Projet d'Expérimentation et de Démonstration en Arboriculture, Elevage et Pâturages) (PEDAEP) FAO TUN-17, 1967–1972. This project is located in Central Tunisia (Oueslatia, Sidi Bouzid) and implemented by INRAT. Areas of research are:
    - Improving degraded rangelands by using simple techniques (phosphorus fertilization, rotational grazing, scarifying, and destruction of non-palatable species).
    - Supplementing sheep grazing on improved rangelands with hay and olive leaves during late pregnancy.
- The Development of Integrated Crop–Livestock Production in WANA (Mashreq/Maghreb Project). This project is sponsored by AFESD and IFAD, coordinated by ICARDA and IFPRI, and implemented by the NARS (Iraq, Jordan, Syria, Lebanon, Libya, Tunisia, Algeria, and Morocco).
- Production and Utilization of Multi-purpose Fodder Shrubs and Trees in West Asia, North Africa, and the Sahel Project. This project was recently submitted and financed by the CGIAR System-wide Livestock Initiative. It will be conducted jointly by ICARDA, ICRISAT, ILRI, and the NARS (Pakistan, Syria, Jordan, Tunisia, Morocco, Mali, Senegal, Burkina Faso, and Niger). The project has the following purpose:
    - To enhance livestock production and natural resource management through the introduction of fodder shrubs and trees into production systems in the dry land eco-systems of WANA and the Sahel.

Recent projects related to management and rehabilitation of rangelands in arid and semi-arid regions include:

- World Food Program (Programme Alimentaire Mondial; PAM): project 482 and project TUN 71/525, aimed at the establishment of very large-scale fodder reserves (cacti, *Atriplex* spp., and *Acacia* spp.) to overcome feed shortage during drought years.
- Development of the Central Tunisia Project (Projet de Développement de la Tunisie Centrale avec le Sous Projet Parcours), 1982–1989)=. This project is financed by USAID (US$ 9.2 million) and covers seven governorates (Kairouan, Kasserine, Sidi Bouzid, Gafsa, Siliana, South Kef, and Zaghouan).

This large project aimed to improve some 20,000 ha of rangelands using several techniques, such as shrub plantation, deferred grazing, fertilizing, etc.

- Agricultural Development of the Province of Mahdia (Développement Agricole des Délégations Intérieures de Mahdia), 1986–1990. This project, created in 1985 and financed by BAD (TD 28 million), was conducted by the Office de Mise en Valeur de Souassi. Among its activities the project improved some 5,650 ha of rangeland.
- Development of Small and Medium-sized farms of Sidi Bouzid (Développement des Petites et Moyennes Exploitations de Sidi Bouzid), 1986–1990. Financed by IFAD (TD 7.6 million) and conducted by OMV Sidi Bouzid, this project aimed to improve rangelands through shrub (*Acacia*, cacti) plantation.
- Struggle against Desertification Pilot Project (Projet Pilote de lutte Contre la Désertification), 1983–1986. Financed by Sweden, this project established 165 ha of shrubs.
- Regional Project of Range Management (Projet Régional d'Aménagement des Parcours) (RAB/84/025, RAB/90/001). Financed by the UNDP, this project aimed to improve the rangeland management of WANA countries (Algeria, Tunisia, Morocco, Iraq, Jordan, and Syria). Its activities were mainly related to the establishment of networks (exchange of information) and training. The main outputs of the project were:
    - A seed network with IPGRI.
    - Some 2,000 tittles were collected and stored (on microfiche) at the National Center of Agricultural Documentation, Tunis.
    - Training of 60 technicians.
- UNDP Project TUN 86/002/A/01/99: Mapping of Pastoral Resources of South Tunisia (500,000 ha in 5 years).
- World Food Program Project to Support Professional Agricultural Associations in the Center and the South (Projet Aide du PAM aux Coopératives et Groupements d'Agriculteurs lÉgalement Constitués dans le Centre et le Sud) (Projet No. 482 and 2.518). The main objectives of the project were:
    - Relief of pressures placed on natural rangelands by shrub plantation (cactus, *Acacia cyanophylla*).
    - Natural resource rehabilitation and preservation (soil and water conservation).
    - Replacement of production systems through fruit tree plantation. Some 791 groups and 80,000 individuals were involved.

  Project outputs were:
    - Establishment of 160,000 ha of cactus.

  - Improvement of 6,615 ha of rangelands.
  - Establishment of 8,480 ha of irrigated forage crops.
- Forest Development Project (Projet de Développement Forestier), 1988–1995. Sponsored by the World Bank (US$ 20 million) and implemented by the Forestry Department (Direction Générale des Forêts), this project included in its program the improvement of 3,400 ha of pasture and the inventory of forest and pasture resources using satellite photos. This inventory is intended to improve rangelands classification and expose misconceptions about the forest and rangeland sector.

The impact of these projects on the sector is difficult to assess, since there is generally no monitoring or evaluation. Nevertheless, the national economical development plans indicate the following results:

- Vth Plan (1977–1981): 140,000 ha planted with shrubs.
- VIth Plan (1982–1986): 158,100 ha planted with shrubs and 58,700 ha of rangeland improved.
- VIIth Plan (1987–1991): 172,000 ha planted with shrubs and 689,000 ha of rangeland placed under management.

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Discussion: National Experience

Chairs: Ben Dia (Tunisia); M. Bounejmate (ICARDA)

Rapporteurs: M. Neffati (Tunisia); S. Hamadeh (Lebanon)

C. Malcolm (Australia): You identified the narrow range of germplasm and the high cost of establishment as problems, but you did not in clude them in your list of research priorities. Why? I believe they are important priorities in many countries.

Answer by A. Chriyaa (Morocco): Yes, I agree with you. They are priorities. I did not mention them because they are being investigated. We have arboretums in different locations of the country. They include more than 30 ecotypes and species.

Karim Nawaz (Pakistan): How have you calculated cost? Give us the details, i.e. the cost of the plant, planting, watering, and transport. Have you included the salary of the staff?

Answer by Chriyaa (Morocco): Cost includes plant production, all labor for plantation, irrigation, and the salary/wage of all personnel involved up to production.

Salem Bouzid (Tunisia): I would like to ask about the cost of planting fodder shrubs. What is involved in the calculation of the cost and what are the techniques adopted in Morocco for soil preparation?

Answer by Chriyaa (Morocco): Plowing plus seedlings plus irrigation plus a guard for protection. Direct seeding is being investigated, but results are not very promising; more work has to be conducted.

Hamdy Oushy (Egypt): In Jordan, what are the conditions for reseeding *Atriplex* spp. and *Salsola vermiculata*? What is the success rate?

Answer by K. Tadros (Jordan): Fodder shrubs (such as *A. leucoclada* and *S. vermiculata*) are established by direct seeding by making contour furrows or terraces perpendicular to the slope inside protected range reserves. Seed is broadcast in these furrows and terraces, and soil is moved to give the seed some cover. The success rate is being investigated.

L. Mayer (GTZ-CRDA/DASPI/Project, Tunisia): A major reason for choosing *Atriplex nummularia* over *Atriplex halimus* in Morocco was said to be the higher palatability of *A. nummularia*. In your palatability list, *A. halimus* is in the first category. How does this relate to the situation in Morocco?

Answer by K. Tadros (Jordan): I mentioned examples of native fodder shrubs in Jordan. I was not comparing *Atriplex halimus* with *A. nummularia*. There are

different ecotypes of each species of *Atriplex* that may be related to heterogeneity of germplasm. There is a lot of controversy about the palatability of these species, whether it depends on animal or season, etc. This is an open question and a research topic.

M. Tazi (Morocco): You were talking about testing the effect of heavy grazing on *Salsola vermiculata* seedlings. I would like to know if the seedlings are from native stands, or from direct seeding, or from transplantation? If they were from direct seeding, what was the percentage of establishment of the stand?

Answer by K. Tadros (Jordan): The *Salsola vermiculata* seedlings studied in our experiments are from a native stand inside the Khanaseri range reserve (North Jordan).

C. Malcolm (Australia): Did testing the *Atriplex nummularia* plantation result in new young plants being established? If not, is it an unsustainable system? Does *Atriplex leucoclada* establish new replacement plants under appropriate management?

Answer by K. Tadros (Jordan): Fodder shrubs are part of the story, i.e. part of the feed available to animals. *Atriplex nummularia* is an evergreen perennial fodder shrub that may last for many years, if well managed. Other fodder shrubs and grasses complement *Atriplex*. Under favorable conditions, it may regenerate. *Atriplex leucoclada*, which seems more drought-tolerant, regenerates from seed at lower amounts of rainfall, and is expected to replace other plants.

E. Thomson (ICARDA): Would range scientists at the meeting like to comment on the value of making comparisons between grazed and protected areas? Areas are often protected for several years, but the amount of biomass removed by the animals is never measured and rarely estimated. Therefore, I think the potential for improvement is exaggerated.

Answer by K. Tadros (Jordan): I agree, but I think we are measuring the potential production that rangelands can produce.

H.N. Le Houérou (France): Les chiffres fournis montrent une croissance linéaire de *Atriplex nummularia*, en MS/ha, avec la densité des plantations. Mais il y a un grand risque de mortalité en année sèche pour les hautes densités (>2000 pieds/ha). Ce risque est d'autant plus grand que la texture du sol est plus fine et que la pluviosité annuelle est plus faible.

M. Ben Diaf (Farmer, Tunisia): Avez-vous fait des travaux de recherche sur les *Acacia*? quels résultats?

Answer by Chryaa (Morocco): C'est une plante fixatrice d'azote du sol et un arbuste fourrager. Elle contient certaines substances non désirées.

El Bachir Labiad (Farmer, Morocco): Pouvez-vous nous donner des indications sur la valeur nutritive de chaque arbuste à chaque période de développement, l'adaptation des arbustes australiens aux conditions du Maroc, l'alimentation supplémentaire à moindre coût à donner à des animaux pâturant des arbustes fourragers en relation avec la production du lait, de la viande et de la laine.

Answer by M. Tazi (Morocco): In Morocco, we are looking for shrubs and trees that can be used directly, not for cut-and-carry. Many research projects are carried out on the palatability of different shrub species. Local germplasm research should be carried out and can be recommended by the workshop.

Acherkouk M. (Morocco): Avez-vous comparé l'appétibilité de *Salsola vermiculata* et de *A. halimus*?

Answer by K. Tadros (Jordan): In many reports, *Salsola vermiculata* is mentioned as an excellent range plant. My observation in Jordan is that it is eaten to the roots, compared with many other fodder shrubs, such as *Atriplex*. Actually, I did not compare experimentally these two species, but field observations confirm this.

A. Benchaabane (Morocco): Y-a-t-il en Tunisie une réflexion sur l'aspect juridique pour intégrer les usagers des plantations d'arbustes sur des terrains de statuts fonciers différents (privé, domanial, collectif)?

Answer by Fatine Elleuch (Tunisia): Les aspects juridiques en Tunisie sont assez développés. En matière d'intégration des usagers dans la gestion des plantations d'arbustes, des tentatives ont été réalisées afin de créer des associations d'intérêt collectif. Les associations peuvent participer à la prise de décision en matière d'amélioration pastorale, de gestion et d'entretien des plantations. Pour les terrains collectifs et domaniaux, la soumission au régime forestier permet d'obtenir l'adhésion des bénéficiaires aux projets réalisés et surtout de définir une convention entre le ministère de l'Agriculture et les bénéficiaires. Cette convention détermine le mode de gestion des parcours améliorés.

A. Abdelguerfi (Algeria): Lors du 4ème séminaire du Réseau parcours Euro-Afrique qui s'est tenu à Gabes en octobre 1996, nous avons beaucoup parlé de la privatisation du foncier et les conséquences sur les parcours et la conduite des troupeaux. Au niveau des textes législatifs, il y a une confusion (voulue ou non) entre « mise en culture » et « mise en valeur »; ceci provoque le défrichement et la mise en culture des parcours avec toutes les conséquences que cela peut avoir au niveau des régions semi-arides et arides du point de vue dégradation, érosion génétique et autres.

Finalement, ne pensez-vous pas que les méthodes anciennes ou traditionnelles étaient bien adaptées aux régions marginales? Les arbres et les arbustes fourragers ne sont-ils pas uniquement un moyen pour accéder à la propriété foncière et donc à la mise en culture des parcours?.

Answer by F. Elleuch (Tunisia): En Tunisie, la privatisation ne concerne que les terrains collectifs ayant une vocation agricole. Les terrains à vocation pastorale ne sont pas privatisables et, par conséquent, restent collectifs. L'objectif de cette législation est de ne pas surexploiter les parcours généralement pauvres et dégradés. Par contre, la plantation d'arbres fruitiers sur des terrains collectifs peut être un moyen afin de s'approprier le terrain, donc devenir privé.

T. Ngaido (ICARDA): During the 1930s in Tunisia, farmers received freehold contracts where they were obliged to plant cactus on one third of a field. The policies of the 1960s and 1970s tended to provide financial incentives for farmers to grow cactus. Presently, the privatization process is mitigated and faces many constraints, as in Sidi Bouzid, where the M&M policy and property-rights team are working, and most of the collective lands are individualized but not privatized.

T. Ngaido (ICARDA): In Syria, what will be the outcome of the policy that forbids barley cultivation in the range, when 70–80% of the 600,000 people living there depend on agriculture for their survival? There is a project funded by IFAD and Arab funds to work on the rangelands. Barley cultivation did not prove economical; in the past seven years, barley production has decreased. We think that the development of shrubs may enhance the living conditions of people leaving in the range.

M. Acherkouk (Morocco): 1) To what extent do Syrian farmers and agro-pastoralists accept and use fodder shrubs? 2) What about their participation in such programs?

Answer by N. Murad (Syria): 1) Some farmers are presently accepting fodder shrubs through range cooperatives and farmers' associations (growing and cultivating forages in Badia). But we must admit that there are a few who object to these fodder shrubs plantations. 2) The government decree prohibiting the planting of barley on Badia lands is recent. Time, in addition to financial support and credit to the Badia people, may bring a solution to these problems.

L. Karroumi (Farmer, Morocco): 1) How are the 12 protected areas established in Syria run, individually or collectively? 2) Is there any coordination between farmers and the authorities aimed at improving the range and pastures?

Answer by N. Murad (Syria), G. Gintzburger (ICARDA), and A. Osman (ICARDA): 1) These areas are under government control. Some of them (for example, the Maragha plantation in the Aleppo steppe, 150 km southeast of

Aleppo) are currently leased for a short time (one or two months a year, during the critical time in early spring and before the autumn rains) to individual agro-pastoralists under strict control in terms of number of animals and period of access. 2) Yes, current research is aimed at selecting and developing better shrubs in terms of leaf percentage (less woody type), with proven acceptability by the local sheep, and higher palatability. Individual *Atriplex* plants are being identified. Seed collection and propagation by cuttings is being attempted by ICARDA in collaboration with the Steppe Directorate. Range reseeding using native species is being attempted and combined with water harvesting by micro-catchment. This is now being carried out inside the government-protected zone and will hopefully be tested with the support of agro-pastoral communities.

E.B. Labiad (Farmer, Morocco): What are the incentives given to farmers and pastoralists to plant shrubs in Syria?

Answer by N. Murad (Syria): Free seedlings from the government nurseries. Free water for irrigation and for sheep. Subsidized feed through cooperatives. Credit system.

H.N. Le Houérou (France): Je voudrais signaler ici la législation tunisienne sur la plantation d'arbustes fourragers qui offre 50% comme subvention et 50% sous forme de prêt à faible taux d'intérêt. Qu'en-est il de la réalité?

Answer by A. Nefzaoui (Tunisia): Les bénéficiaires ont manifesté une réticence vis-à-vis des prêts pour l'installation des arbustes fourragers compte tenu de leur endettement ou de la non-accession aux crédits. Aussi, les crédits sont plus recherchés pour les plantations agricoles (fruitières). Actuellement, l'Etat supporte la plus large proportion des coûts d'installation d'arbustes notamment sur les parcours forestiers and communaux.

E.B. Labiad (Farmer, Morocco): 1) Quelle est la longévité des plantations de cactus? 2) Peut-on envisager des association cactus/*Atriplex*.

Answer by S. Ashawed (Tunisia): 1) La longévité des cactus comme les autres espèces arbustifs est fonction du milieu où ils sont introduits. Une abondante littérature est disponible en Afrique du Nord. A noter aussi que les modes d'utilization sont déterminants; l'exploitation directe est totalement déconseillée. D'une manière générale, les plantations peuvent durer plus de 25 ans. 2) Déconseillée en association avec d'autre arbustes fourragers, car le pâturage direct peut détruire le cactus.

A. Chriyaa (Morocco): Pourquoi toujours l'*Acacia Cyanophylla*? Quel en est l'objectif? On a tendance à oublier le coût et les bénéfices associés à la protection de l'environnement lors du calcul du prix de revient des plantations. En attendant

de trouver des méthodes moins coûteuses, il faut continuer dans cette voie, car nous ne savons pas le coût futur de ne rien entreprendre.

Answer by A. Nefzaoui (Tunisia): L'introduction de *l'Acacia* en Tunisie remonte aux années 60. Elle a été introduite au début essentiellement pour la lutte contre l'érosion. Mais actuellement on a tendance à l'utilizer de plus en plus comme plante fourragère. Les programmes récents de recherche menés à l'échelle mondiale ont montré sa faible valeur alimentaire. Faut-il continuer la plantation de cette espèce ou la remplacer par une autre? Nous sommes conscients de ce problème, les recherches continuent dans ce sens pour trouver la meilleure solution. Il nous faut d'en trouver les moyens d'améliorer la valeur alimentaire. On cherche aussi d'autres espèces prometteuses.

V. Papanastasis (Greece): Have you done any work expanding deciduous fodder trees and shrubs such as *Amorpha frucitosa* and *Robinia pseudoacacia* in the sub-humid and semi-arid areas? We have promoted only fodder trees such as *Robinia* and *Leucena*, but no fodder shrubs yet. These two species are very fast growing legumes.

Answer by A. Nefzaoui (Tunisia): No, these species have not been tested yet. We understand that their ecology could limit their use in arid zones.

K. Tadros (Jordan): *Atriplex lentiformis* and *A. amnicola* were introduced to Pakistan. Comparing four *Atriplex* species in Jordan, I found that *A. lentiformis* is the least eaten by sheep. Seedlings of *A. amnicola* died the first year due to frost damage.

Answer by S. Mirza (Pakistan): The ecology and the sheep are certainly different between these two countries.

M. Tazi (Morocco): Why are you introducing *Atriplex* species, when you have, in Kazakstan and Uzbekistan just next-door to Pakistan, drought-tolerant species such as *Kochia*, *Salsola*, *Eurotia*, etc.?

Answer by S. Mirza (Pakistan): I do not have knowledge of fodder trees/shrubs in the Central Asian zone. I will discuss this with the Central Asian delegation and investigate the possibility of exchanging/obtaining germplasm.

G. Gintzburger (ICARDA): After Tazi's comment on the potential of germplasm from Central Asia, I would like to ask our colleagues from Kazakstan and Uzbekistan if there are native *Atriplex* in Central Asia, and if so, you do use them.

Answer by S. Abduraimov (Kazakhstan): There are some native forms of *Atriplex* in Central Asia. Native *Atriplex* are not palatable in our conditions; we don't use them in practice.

T. Daoudi (Farmer, Morocco): 1) Should we plant *Atriplex* and other shrubs on bare soil or on rangeland, where there is some native vegetation? 2) Could we use *Atriplex* and halophyte species to take out the salt from halophyte soil with high salinity?

Answer by S. Mirza (Pakistan): 1) We only plant *Atriplex* on degraded land, marginal for crop cultivation. 2) Yes, we can use *Atriplex* species, but we need to irrigate these plants with fresh water. However, I very much doubt that we would be able to extract salt in large quantities from the soil using *Atriplex* plantation.

C. Malcolm (Australia): *Atriplex lentiformis* occurs in a wide range of conditions; is there an opportunity for us to seek other genotypes for properties, such as cold-tolerance and palatability?

Answer by S. Mirza (Pakistan): Hopefully. I will share my knowledge with C. Malcolm and investigate the possibility of obtaining seed of other ecotypes of *A. lentiformis* for use in Pakistan.

Farmers and NGO Experience

Agro-pastoral Community Experiences with Fodder Shrubs in Syria*

A.R. El-Fikiki (Eneza Tribe)[1], F.A. Ibn Nuri (Abraz Tribe)[2] and A.M. Ibn Jassim (Bou Kurdi Tribe)[1]

[1]*Sheep breeder, Aleppo Steppe, Syria*

[2]*Head of the Jub Ahmad Almash'el Cooperative for Sheep Breeding and Range Amelioration, Aleppo Province*

Mr. Abd El-Hadi Ramadan El-Fikiki: Personal Experiences with Shrub Plantations

When the Syrian Government issued a law asking farmers benefiting from State land in the steppe below 200 mm to put 20% of this land into shrubs, with seedlings provided for free, many sheep owners tried to implement the idea. Many failed, but in 1987, I was successful with my first attempt at planting 80 ha with equal shares of three shrub species: *Atriplex halimus*, *Atriplex canescens*, and *Salsola vermiculata*. In my part of the steppe in Hama Province, we were fortunate to receive good rains at the right time that year. We got about 250 mm of rain, which is 100 mm above average for our area, which is called Shahhatyeh. I think 95% of the seedlings, planted at about 400 plants/ha, survived to become mature plants on our gypsum soils.

In 1988/89 I planted another 20 ha using seedlings, and this was successful too. Then, in 1989/90, I tried direct seeding of 10 ha, broadcasting *Salsola* seed after a light cultivation with a duck's-foot cultivator. But this did not succeed, due to low rainfall. I have since added new areas of seedlings to my plantations, and now have 150 ha of improved rangeland.

I started grazing my plantations after three years of growth, for periods of four or five months, beginning September to early November, and continuing through January. In this period, before lambing, my sheep depend entirely on grazing the shrubs and native plants on my plantations. I start supplementary feeding only at lambing.

Prior to the recent government ban on barley below 200 mm, I sowed 300 ha of barley each year on one piece of land. I still think it can be a good idea to grow barley in limited areas to supplement sheep diets. If sheep graze shrubs alone in the summer, without such supplementation, their fertility can be reduced. Over the nine years I have been growing shrubs, I was only able to harvest a barley crop in two of those years. Based on this experience, I agree with the government's plan to

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* Information collected and translated from arabic by Mr. Faik Bahhadi (ICARDA, livestock scientist).

replace barley with shrubs in the Syrian steppe. But good management by farmers is needed to keep the shrubs alive and productive.

We should graze shrubs first when they are two years old to avoid woody growth. With woody growth, a large part of the green matter is not accessible to sheep, because it is either inside the plant or too high for sheep to reach. It is also clear that we should be planting only those shrub species, such as *Salsola vermiculata* and *Atriplex halimus*, that can reseed themselves under our environment. I have observed an increase in plant populations with these species from seed falling from the shrubs I planted.

Mr Faysal Al-Ahmad Ibn Nuri: Personal Experience with Shrub Plantations and Sheep

I have long practical experience with fodder shrubs, and now own 1,100 head of sheep. Management of my sheep includes using the traditional winter/spring rangelands. Sheep are moved to the cropped areas for summer/autumn grazing of residues (mainly cereal stubble), and then returned to the range.

My immediate family has traditional use rights on 600 ha in a place called Ja'ar (in southeastern Aleppo Province). This involves rights for grazing, and, until 1994, when it was prohibited, barley cultivation. My larger family (Abraz tribe) once had traditional control of 40,000 ha. Government plantations or reservations now occupy some 14,300 hectares of this land: 2,000 ha at Adamy; 3,800 ha at Ain Zarka; 5,000 ha at Obeisan; 700 out of 13,500 ha at Abu Al Fayad; and 2,800 out of 6,500 ha at Maragha.

I was obliged to plant 12 hectares of *Atriplex* in 1987. The seedlings survived for two years, but were lost due to lack of irrigation and protection when we moved our sheep to the cropping areas. The new shrub plantation at Ain Zarka has had a negative effect on my family by further decreasing our traditional range area, forcing our traditional winter camps to move 20 km to the east, and increasing our winter feed costs by more than 50%.

In April 1995, I leased 900 ha for one month of grazing on the government plantation at Maragha. It was a dry year and grazing inside the plantation was good at first and milk production increased. Toward the end of the month, however, milk production fell back, as the green grasses turned yellow. Grazing off-take on the plantation was made up of 30% *Atriplex*, 20% other shrubs (*shih*, *Artemisia herba-alba*; *surr*, *Noeae mucronata*; *roteh*, *Salsola vermiculata*; and *gaysoom*, *Achillea fragrantissima*), and 50% grasses. Because of the salty soils inside the plantation, and the consequent increase in salt intake, I had to offer one meal of fodder to the sheep every day to avoid unhealthy conditions, such as dizziness. I also had to transport double the amount of water, as each sheep drank over 9 L/day.

I did not personally lease any government pasture in 1996. The main reason was that we are not allowed to erect our tents or offer water to our sheep on the parcels we leased. We are only allowed to camp and rest our sheep over-night outside the government plantation. We can offer water to our sheep only on the main roads of the plantation. These rules mean my sheep would have to do a lot of extra walking, not less than 6 km extra each day. This results in loss of weight, loss of health in new mothers, and loss of small lambs. If we were allowed to camp and water our sheep inside the leased plantation parcels, which would cause no harm, I would lease again.

I have some comments on establishing shrub plantations:

- Separate the good rangelands from the bad as a basis for management. When government plantations are established, alternative grazing areas should be provided to the people.
- Protect the good ranges from fuel cutting by supplying the herders with cheap fuel and by severe laws which forbid shrub cutting. In my opinion, fuel cutting is the only operation affecting the vegetation in the steppe; simply prohibiting it will let the vegetation renew itself.
- We don't need to establish reserves on good lands; natural reserves are better than artificial—let us not destroy them with bulldozers. In addition, protecting good lands is less costly than establishing plantations.
- When we establish a reserve on bad lands, we should grow a mixture of shrubs; we have to imitate nature if we want to provide good pastures for the sheep. Man can't survive by feeding himself bread only.
- *Atriplex* can be planted everywhere in the steppe, but it thrives in soils that have white stones underneath; these seem to work to feed moisture to the shrubs.
- In my opinion, barley cultivation is sustainable and unharmful in the right places—depressions and wadis. If the season is good, we harvest and use the stubble and fallen grain to feed our animals. If the season is poor, we use the unharvested barley to feed our sheep. Nothing can substitute for barley in providing good nutrition to sheep. From 1962 until recently, we had leasing contracts with the government that allowed us to plant limited areas of barley for sheep.
- When the wadis flow, we cultivate. Wadis are not like the rest of the steppe lands; we consider them as our irrigated lands.

In summary, I think good rangelands should be managed better, and all shrub-cutting prohibited. Poor rangelands, which have been denuded of vegetation or have salty soils, could be the targets for shrub plantation. Land suited to sustainable forage cultivation (i.e., barley in the wadis and depressions) should be used in this

way. Blanket rules that ignore topography, soil, and vegetation potential may result in low efficiency compared to rules that respect the diversity of natural resources.

Mr Ahmed El Mohamed Ibn Jassim, Sheep Breeder: Personal Experience with Shrub Plantations and Barley

I have long experience with barley cultivation, fodder-shrub planting, and sheep production in the steppe of the eastern parts of Aleppo Province, where my larger family (Bou Kurdi) is based. There, in our winter camp, called Neyfet Al Adam, my immediate family, with 500 sheep, has traditional land use rights for 800 ha in two parcels. One of these (500 ha) is only for grazing. Two-thirds of the other 300 ha were used for barley cultivation and grazing from 1961 until the barely prohibition in 1994.

In 1983, I planted 15 ha of *Atriplex*, but, since I was unable to irrigate or look after it properly, it failed to survive. In 1983, a partner and I planted 25 ha of *Atriplex canescens*. This time, we irrigated the seedlings twice, directly after transplanting and 15 days later. We protected this plantation from grazing for two years. We allowed our sheep to graze the area only when the *Atriplex* plants were about 50 cm tall. I have noticed that if hungry sheep are allowed to graze *Atriplex* or unharvested barley, they will stop eating after about 1.5 hours. They will be hungry again some two hours after grazing *Atriplex*, but 10 hours after grazing barley.

Barley is a basic component of our livestock system. If the year is good, we harvest it and store the grain and straw for winter feeding, and then graze the stubble. If the year is poor, the barley plants provide an important source of grazing. Barley is the king of feeds; it is the best and healthiest for sheep. Grazing of unharvested barley in summer during the mating season increases conception rates and, for some ewes, the incidence of two lambings in a year. We usually graze 1,000 sheep—half mine and half my partner's—on our 25 ha *Atriplex* plantation for two months, starting in September or October. Because the area is so small, we limit this grazing to about two hours a day. I guess the *Atriplex* itself provides about 15% of what the sheep take from the plantation, the rest comes from grasses growing among the shrubs.

Through my experience with shrubs and sheep, I can say *Atriplex* has an "acid"[1] taste, and sheep eat it to get "acids" for their bodies. But sheep cannot survive on *Atriplex* alone; if there are no grasses as well, sheep must be fed one supplementary meal a day (wheat bran and straw, for example).

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[1] The concept of "acidity" is common among the Bedouins of the Syrian Steppe. They use the following terms to characterize the vegetation: *murr* = bitter; *hamed* = sour or acid; *dassemm* = fatty or rich; *helu* = sweet; *mahej* = salty and bitter; and *maleh* = salty (after Faik Bahhady, personal communication).

Atriplex can be a supplementary source for salt in sheep, as can other plants of the same kind. Further, there is a shrub in the steppe called *shnan* (*Anabasis syriaca*). If sheep eat it while grazing *Atriplex*, they will be all right; if they do not eat *Atriplex*, however, sheep can be killed by grazing *shnan*.

On the question of the practical economics of shrub production, if herders are not allowed to produce barley side by side with shrubs, but are obliged to plant shrubs alone and protect them for four years before grazing, and if there is no financial support in the meantime, they will go out of the sheep business, because they will have to sell all their animals. There must be an alternative to barley cultivation that will decrease the high costs of feeding during the period of protection, until herders can develop their own pastures.

It will be better to establish *Salsola vermiculata* plantations rather than *Atriplex*. Sheep like *Salsola*, and their milk and weight increase with it. Any new reserves should be established in cooperation with the traditional users—with the realization that the steppe is owned by people—or plantations will fail in the future. The local people can be effective in managing their rangelands, controlling access, and controlling animal numbers if they are allowed to do so. We are sure of this.

People's Participation in Range Management: Ma'in Range, Jordan

J. Mohamed
Queen Alia Fund for Social Development, Jordan

Introduction

The Ma'in range is located southwest of Madaba, on the road to the Ma'in hot springs. The land is state property, with an average rainfall of 150 mm around Humra, and higher in the mountains. It is characterized by extreme slopes and hard topography towards Humra. It is one of eight cooperative range sites, and has the largest area, about 83,330 ha, of which about 4,000 ha have been improved by shrub plantation.

Rangeland and Forage Development Project

Since 1980, the World Food Program has provided assistance in the form of funds used for range improvement, fodder production, and fattening of lambs. These activities were under project WFD2422 "Rangeland and Forage Development," which began in 1981 and aimed to provide technical assistance from the UNDP/FAO under projects JOR/70/010, JOR/87/007, and the RAB/84/025 management program.

The main objectives of this development can be summarized as follows:

- Objectives related to social concerns: improving economical and social status; supply of community needs (education, health, water, electricity, and other important services); improving social relations among participants, sheep owners, and administrative groups; keeping the environment clean from pollution, such as plastic bags; and working to increase income and range carrying capacity through livestock production development.
- Objectives related to production: for livestock, improving range and flock productivity; and, for other agricultural resources, improving cereals, fruit trees, veterinary services, extension, marketing of products, and increasing milk life.
- Objectives related to land: improving environmental factors related to water and mineral cycles; stopping further desertification and erosion; establishing dams, water cisterns, and other water-harvesting methods; and promoting shallow cultivation of the soil, direct seeding, and transplanting of fodder shrubs.

There were 55 flocks before the project started in 1980, consisting of 4,800 head (excluding nomadic flocks). The RAB/84/025 survey in 1987 and 1988 showed a high increase in numbers: more than 14,000 sheep and goats owned by two groups of herd-owners. Lambing percentage had risen from 61 to 80%. Lamb fattening increases meat production, which results in higher revenues. Regulations restrict not only grazing, but promote health care, vaccination, and supply of feed.

Ma'in hasn't faced any major obstacles to rangeland development. This is due to effective extension, which has gradually increased the people's acceptance of development. Some groups (nomads), who rarely accept such intrusions, have begun to cooperate and become involved in the system.

Rainfall varies from year to year. Water is necessary to increase soil moisture and allow for good establishment of transplants. Runoff water is harvested and stored in ground cisterns. Phase three of the project included the construction of earth dams to collect water from the valleys.

Lamb fattening using concentrates and green forage were two topics investigated in phase one, along with low-interest farmer loans. Profit per lamb in the early 1980s was a little more than JD 5 per lamb. It is now JD 10–15 per lamb (JCO fattening stations 1992; personal communication, small feedlot enterprises in Jordan).

Forage production in rainfed areas has encouraged sheep owners and farmers to produce forages for winter feeding. The government has adopted a policy of subsidizing prices for forages to expand national production and minimize feed import.

Ma'in and other cooperative ranges have proved that range development and management of resources can be carried out in a sustainable manner. Negotiating with the beneficiaries, respecting their rights, and involving them in all stages of project planning are essential. Ecologically, the project aimed to improve range productivity through a survey of plant cover, soil conservation methods, and water conservation. This project should be used as an example for further development of arid and semi-arid rangelands in Jordan and the region.

The project strategy was to develop and manage all activities with the participation of the beneficiaries, setting simple regulations for range use, time and period of grazing, carrying capacity, and stocking rates. The project received technical advice from concerned partners in development (JCO, MOA, FAO, and the agro-pastoral community). It was able to increase range productivity from 42 to 125 FU/ha (Natural Resources in Main Pilot Area 1987) and increase the stocking rate for 2–4 months/year from 2,500 head in 1983 to 14,000 in 1989 and 20,000 in 1993. The goal was not only to increase rangeland productivity, but also to improve range cover and plant species. This began as a result of the 1987 survey.

Abu Setta, Abu Rmelah, and others were able to recognize and identify more than 260 plant species.

A detailed survey and study of targeted areas is a first step toward realistic development without challenges from the traditional users. Special care should be taken to improve resource use on the one hand and conditions on the other. Emphasis should be given to expanding the sowing of native plant seed. This requires further trials and experiments on the possibility of replacing the costly operation of transplanting fodder shrub seedlings. Protection of the rangelands has resulted in a high increase in productivity and in new plants, especially high-quality grasses and shrubs such as *Atriplex leucoclada*, *Salsola vermiculata*, *Stipa* spp., *Plantago* spp., *Medicago* spp., *Dactylis glomerata*, and other plants.

The Queen Alia Fund for Social Development

The Queen Alia Fund for Social Development (QAF) was founded in 1977. It is a non-profit, non-governmental, social development organization, governed by a board of trustees and headed by HRH Princes Basma Bint Talal, the only sister of His Majesty King Hussein. QAF was the first Jordanian organization to achieve development by directly involving the underprivileged in attempts to improve their lives and become economically independent productive members of the community. It remains the only organization of its kind with a presence in communities through its network of social community development centers.

QAF's work ranges from the establishment of community development centers across Jordan to the training of trainers in areas as diverse as pre-school education and agricultural development, to vocational training and income-generating activities for women. The goal is sustainable development: helping people to help themselves, rather than rely on charity.

QAF projects focus on education, awareness, training, and leadership development at the grassroots level. This gives people the means, skills, and knowledge to use what is naturally available in their environment for household food production, improving family living conditions, and generating income. To make sure that the benefits will reach all sectors of society equally, it is QAF policy to involve as many people as possible in development.

A major component of QAF's approach to community development is education and training in agricultural techniques to help individuals and groups establish projects that help them generate income, cut down expenses on food, and contribute to the greening of the village and environment. Agricultural projects also further the role of women in development. Women committees organize agricultural activities for local women, offering income opportunities in and around

the home. The revolving loan project offers needy families soft loans to establish and expand agricultural and food production projects.

Ma'in Rangeland before Development

Ma'in is a part of the range located between the western mountains and the Jordan Valley. It is an open area for grazing with no restrictions or rules as are found in other rangelands in the country. Plant cover density is moderate, and even in good rainy years it shows good growth and coverage. Rainfall is 200–250 mm/year. Areas at lower elevations around Humra are heavily populated in winter months by Bedouin shepherds and other groups, which results in deterioration, exacerbated by warm weather and availability of water.

Ecological Factors

Elevation varies from 100 m below sea level to more than 800 m above. The climate is Mediterranean. Rainfall varies; the hills receive more than 200 mm/year, while Humra receives less than 150 mm. Water resources are mainly springs, many of which are dry in summer. Water is used for animal drinking and, in very limited areas, for irrigation of some fruit trees and vegetables.

Range Condition

Before development, the area was nearly bare ground. Only on the hillsides was there some plant cover, which was heavily grazed. Following is a list of these plants.

Perennials	Annuals
Artemisia herba-alba	*Anthemis* spp.
Gymnocarpos decander	*Onobrychis* spp.
Helianthemum vesicarium	*Erucaria hispanica*
Gundelia tournefortii	*Plantago coronopus*
Noaea mucronata,	*Astragalus hamosus*
Dactylis glomerata	*Stipa capensis*
Sarcopoterium spinosissimum	*Aegilops Kotschyi*
Teucrium polium	*Bromus scoparium*
Poa bulbosa	*Plantago ovata*
Retama raetam	*Medicago laciniata*
Salsola vermiculata	

These plants indicate that the potential of the land is as follows:

- Remaining desirable plants indicate the possibility of regeneration and setting of seed for new plants.
- The history of the area and reports by older persons indicate that the area was once very rich with different plants.

Table 1. Plant cover before and after the project.

Before the project	After the project	Undesirable plants
Artemisia herba-alba	*Stipa lagascae*	*Carlina hispanica*
Gymnocarpos decander	*Trifolium cuisii*	*Asphodelus aestivus*
Helianthemum vesicarium	*Orozopsis* spp.	*Ballota undulata*
Gundelia tournefortii	*Phalaris minor*	*Fagonia mollis*
Retama raetam	*Medicago* spp.	*Ononis natrix*
Noaea mucronata	*Atriplex* spp.	*Peganum harmala*
Stipa capensis	*Dactylis glomerata*	*Varthemia iphionoides*
Onobrychis spp.	*Poa bulbosa*	*Alhagi maurorum*
Teucrium polium	*Avena sterilis*	
Cutandia dichtoma	*Salsola vermiculata*	
Astragalus craetageus	*Stipa capensis*	

Livestock

At the beginning of the project, the cooperative flock comprised 4,000 sheep and 800 goats, with low productivity (Table 2).

Table 2. Sheep and goat production in the Ma'in area before the project.

	Semi-extensive		Nomadic	
	Sheep	Goat	Sheep	Goat
Cooperative flock	4,000	800	2,200	2,300
No. of productive animals	3,200	640	1,540	1,610
Lambings/year	2,400	512	1,010	1296
Milk yield/ewe/doe (kg)	55	65	50	65
Twinning (%)	3	5	2	4
Average ownership	73	32	110	115
No. of sheep owners	55	-	20	-
Shepherding	Family and non-family		Family only	
Milking	Family, adult females		Female family members	
Shearing	Males, family, and non-family		Mainly family	
Feeding supplement	All winter and part of autumn		Rare feedings, minimum quantities in winter	

Socioeconomic Aspects

Beneficiaries can be divided into the following groups:

- Members who own sheep and goats live in Ma'in town. This group owns permanent houses, and their standard of living is good. They have additional income sources.
- Members who have agricultural lands but do not own livestock. They are settled and participate in some cooperative activities to receive the food ration from the WFP.
- The poor and unemployed with small holdings. Their benefit was receiving food from direct work.
- The nomadic Bedouins are sheep and goat herders who plant some crops. More than 90% of them are migratory; some participated in the project. Their management practices are nomadic to semi-intensive, with very little use of technology, except for ownership of some water cisterns, pick-ups, and permanent sheds for protection of animals in winter.

Various institutions contributed in different ways, such as financing food rations, seedlings, and machinery for soil reclamation and extension.

Development Approach

In 1980, the government of Jordan signed an agreement with the World Food Program to begin the Food for Work project. Objectives were as follows:

- Establish a number of cooperative range sites in arid and semi-arid zones.
- Help farmers fatten their lambs by providing easy seasonal loans, accompanied by efficient and constructive extension.
- Introduce a cereal/vetch mixture in rainfed areas to improve forage production for farmers and sheep owners. In the second phase of the project, other activities were added, such as water harvesting and construction of groundwater cisterns.

The purpose of the project was to counter decreasing rangeland productivity and its negative social and economic effects on livestock raisers.

In the early 1990s, the Jordanian Government started a national program for range development. This program examined and evaluated methods for improving and developing the rangelands. Most of the work concentrated on the range reserves, which were fenced and planted with different fodder shrubs, mainly *Atriplex halimus* and *A. nummularia*, without direct participation of community members (except as wage workers). This system failed to convince people, especially sheep-owners, of its positive impact on the future.

The cooperative system has the following principles: respect for tribal rights, participation of involved peoples in development, minimizing development costs

of planting fodder shrubs, establishment of a fund generated from grazing fees, and establishment of a sustainable management system.

Achievements of Development

Social Organization

After development, changes were seen within the cooperative and with individual members. The new system of grazing is based on equal rights for all. Members participate in the lamb fattening and vetch/cereal programs to improve and increase their income, standard of life, and family nutrition. Social services are provided, such as schools, health centers, telephone, post office, roads, electricity, water, and others.

The QAF is a pioneering NGO in rural areas. It complements government actions and services with its Social Development Centers (SDC), which serve as a focal point for social activities, organizing women groups, raising awareness of rangeland problems, and other important matters. The center includes a kindergarten for children, training facilities, and income-generating activities through rehabilitation, training, and loans. In the field of agricultural, the QAF has introduced a number of activities, such as home gardening. It has established a sheep station with 220 head to help poor families. Management is shared and poor families receive a ewe, which creates an income-generating activity. A processing unit for diary products was set up in the QAF center, run by a group of women and for their benefit. The QAF will continue to support and encourage communities to become self-sufficient in a sustainable way, by improving the standard of living, nutrition, and especially the role of women in development. But, working with the target population in the rangelands is costly and risky due to their distribution over a relatively large geographic area. Help from donors is needed to overcome these higher costs and risks.

The role of grassroots institutions and local and foreign NGOs includes:

- Creating awareness of problems.
- Financing.
- Training and extensicn.
- Disbursing loans.
- Organizing.
- Cooperating and coordinating among groups and institutions.

Range Improvement and Fodder Shrub Use

Rangelands have long been a feed source for small ruminants in Jordan, estimated at 30% in 1991. This importance is one of the reasons for rangeland development.

The Ma'in range site was established in 1980, as a result of the following actions:

- Protection of the area by the cooperative for three years to plant and rehabilitate the site.
- Plantation of fodder shrub seedlings (*Atriplex nummularia*, *A. halimas*, *A. cyanophyla*, and *A. canescens*) on leveled areas and deep soils.
- Broadcasting local native seed of *A. leucoclada* and *Salsola vermiculata*, necessary because of weak natural self-germination.
- Scarification of soil strips between planted shrubs to improve the germination and growth of medics and grasses.

As a result of the protection and rehabilitation of 4,800 ha in the Ma'in rangelands, sheep numbers increased to about 32,000 head. This is an eight-fold increase over the establishment level. Other factors, such as feed subsidies, played a role in this increase.

Management

Management is the soul of rangeland development and sustainability. Without it, failure is certain, especially in a traditional system that allows sheep owners free and unrestricted access. Participating institutions and cooperative members agreed upon a clear and practical system, which includes the following:

- Allocation of the site based on traditional grazing.
- Tribal grazing rights respected through the involvement of the cooperative.
- Water resources put under restricted use, mainly for sheep and supplementary irrigation of planted shrubs.
- Prohibition of land sale or use for other purposes.
- Target groups have the right to keep out foreign flocks.

The system allows grazing in two periods, one in spring and one in autumn. The spring grazing grants access to sheep and goats to annual grasses and forbs when green. The autumn grazing uses dry grasses and planted fodder shrubs. This simple system give the shrubs the opportunity to regenerate after grazing and to benefit from the winter rains.

Grazing is usually organized by the community, which prepares a list of sheep owners and flock numbers, evaluates range productivity, and establishes the

grazing period. Fees, based on the cost of .5 kg barley, are collected before grazing. Fees are kept by the community (cooperative) to cover related activities. Results are summarized in Table 3 (1987) and in Table 4 (1988).

Table 3. Estimated range productivity in the Ma'in pilot area (1987).

Item	Unit	After improvement	Open areas (unprotected)	Total	Remarks
Total area	ha	4,507	15,355	19,862	22,500 total pilot area
Production	kg DM	2,426,600	6,948,200	9,374,800	
Unit production	ha	538.6	453	472	
Production	FU/ha	162	135	141.5	

Table 4. Estimated range productivity in the Ma'in pilot area (1988†).

Item	Unit	Free grazing	Cont. range	Total
Total area	Ha	3,502	4,827	8,330
Production (consumable)	FU	34,3400	1,136,200	1,487,930
Unit production (consumable)	FU	98	235	178

Source: Dr. Soud El Abadi and others: 1989 RAB/84/025 Programming and Planning of Natural Resources in the Ma'in Perimeter.

† This was a particularly good year.

This management system was later adopted by RAB/84/025 for rotational grazing by dividing the area to 10 blocks. This facilitated detailed monitoring and a realistic evaluation of grazing capacity. Animals move from block to block according to the grazing plan. Table 5 summarizes the project's impact on sheep owners from the cooperative in 1989 and 1990.

Table 5. Grazing impact on sheep and goat owners (beneficiaries).

Year	No. of grazing animals	Grazing days	Season	Animal/day	Daily grazing value (JD)	Total value (JD)
1989	12,860	30	Spring	385,800	0.06	23,148
1989	7,980	20	Autumn	159,600	0.06	9,576
1990	7,287	24	Autumn	174,888	0.07	12,242
Total	28,127	74		748,415		44,966

Rangeland Rehabilitation through Plantation of Fodder Shrubs in Kanak Valley, Balochistan, Pakistan: Community Participation

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Background

Pakistan is one of five countries participating in the Food and Agriculture Organization/Government of Italy Inter-regional Project for Participatory Upland Conservation and Development Project (GCP/INT/542/ITA[1]). Field activities in each country are implemented through a national sub-project. In Pakistan, the national sub-project is located in the Kanak Valley (Mastung District, Balochistan), where activities have been implemented in cooperation with local communities—village associations, women's associations, special interest and users groups—since October 1992.

Project Area

The Kanak Valley covers an area of 40,000 ha, at altitudes of 1,750 to 1,880 m asl. Average rainfall is 200 mm, received mostly during winter. The valley has an estimated resident population of 20,000 inhabitants, living in 40 villages. In addition, many transhumant nomads pass through the valley twice a year. The inhabitants belong to the Brahui ethnic group of the Baloch tribes.

Main Problems of the Project Area

In highland Balochistan (>1,000 m elevation), rainfall is erratic and received mainly during winter, when most native plants are dormant. Local communities (farmers, the landless, nomads, and sedentary peoples) face several problems, including land degradation. Uplands degradation in the area is due to many factors. First, overgrazing and low carrying capacity have resulted in poor physical and natural conditions. Second, substantive increases in animal and human populations have resulted from recent settlements by neighboring tribes and Afghan refugees.

Use of grasses and bushes for grazing and fuel is open to all. Over-exploitation of these resources has resulted in degradation of the uplands on two levels: (i) the area under productive use, i.e. vegetation for grazing and fuel wood, has decreased; and (ii) the quantity per unit production has declined.

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[1] The other countries are Bolivia in Latin America, Nepal in Asia, and Burundi and Tunisia in Africa.

Information collected through participatory rural appraisal in the valley shows that Kanak faces many development problems, such as:

- Continued lowering of the water table (over a 30 year period, a drop from 50 to 200 feet below ground level).
- Very low and erratic rainfall, resulting in extremely variable agricultural yields and low production levels from rainfed agriculture.
- Extreme shortage of fuel wood and fodder from the upper watershed (non-agricultural) areas, which comprise 90% of the valley.
- Lack of education and health-care facilities.

Present Use of Natural Resources in the Valley

The Kanak Valley uplands have great potential for the improvement of natural resources, because of their unique characteristics. Fan areas, known 40–50 years ago as watershed areas, have been meeting most of the fodder and all of the fuel demands of the local and transhumant population in the area. The semi-nomadic lifestyle includes: fodder for livestock, runoff for rainfed fields, medicinal plants for domestic use and market, fuel wood, and hunting, mostly in the catchment areas. *Karezes* (wells) were dug in catchment areas, especially mother wells, because of the closeness of the first aquifer to the surface. Local shrubs and grasses are not only used by animals, but are an important source of fuel. Steppe shrubs are the main vegetation in the uplands of the valley, and include: *Artemisia herba-alba*, *Haloxylon griffithii*, *Sophora mollis*, *Daphne mucronata*, *Astragalus stocksii*, etc. The perennial bunch grasses, *Chrysopogon aucheri*, *Pennisetum orientale*, and *Cymbopogon jwarancusa*, have been over-used and are present in areas with low grazing pressures. These bushes and grasses help infiltrate runoff water and snowfall. Livestock grazing in these uplands comes mostly from the sedentary flocks of the Kanak Valley, but bands of nomadic herds also pass by for a few days of intensive grazing twice a year. Livestock feed in the valley is supplemented by wheat straw and stubble after the harvest of cereals. Autumn and winter are the main periods of fodder shortage, when almost all the vegetation dries up and animals loose weight and suffer from diseases.

Land Ownership

Most of the land in the valley is owned by a clan or sub-clan of the tribe. Arrangements for sharing and use vary. Uncultivated land is still usually governed by the traditional land tenure system and is used as common property. *Kareze* (local well) villages have clearer ownership, especially in terms of water rights. With irrigated orchards, individual rights are very clear and are registered with the revenue department. The rights of ownership in rainfed fields are clear, and

input/output arrangements are also transparent in terms of investment and harvest. Ownership of uplands, e.g. *khushkaba* (rainfed) lands, and lands under irrigation, is often not as clear as for the other two categories. Even in the case of clear ownership, boundaries are vague and land is not further demarcated among families or individuals. Moreover, regardless of ownership, the use of the uplands is free to everyone for grazing and fuel wood collection. This makes it extremely difficult to start development activities in the uplands.

Project Strategy

The project has sought to adopt a participatory approach to upland conservation and development. To do this, it was necessary for staff to undergo training before activities could start. In addition, it was recognized that to institutionalize the participatory approach within the Forestry Department, the department itself would require orientation, as well as practical experience in implementing its procedures.

The primary emphasis of the project is the management of natural resources (e.g. soil, water, and vegetation) in the uplands, in order to decrease runoff and increase infiltration from rainwater and snowfall, and to provide fodder and fuel wood.

For effective management, good-quality information is needed prior to planning and implementation. It is important to understand existing conditions to avoid mishaps during implementation. Information gathered through villagers not only helps us to understand the situation better, but leads to a partnership between the villagers and the forest department for better long-term management. Therefore, participatory rural appraisal tools are used to gather information, make decisions, plan, implement, monitor, and evaluate (including self-evaluation).

Participatory Rural Appraisal Tools

In addition to observations, various participatory rural appraisal tools are used to collect information. The community makes a social map of the village, indicating tribes, occupation, households, population, social/tribal structure, homogeneity among villagers, and important locations. A time-line exercise is used to follow major and minor changes as they occur in and around the village. Discussion is directed towards the degradation of natural resources, drying of the *karezes*, lowering of the water table in the area, vegetation, fodder, fuel wood supply, changes in cropping patterns, occupational changes in the villages, and past and current economic dependency on the uplands. After these exercises, the data collected are compiled by male and female teams and discussed with technical staff. At the next meeting, this information is presented to the community for further clarification and cross checking, and modifications are made if needed.

A transect walk is made to identify the different micro and macro zones of the land around the village. Cropping patterns are discussed in detail at this stage. The periods of use of different land parcels, their potential, and problems faced are discussed in the light of indigenous knowledge and experience. Identification of areas (orchards, *khushkaba*, uplands, and lands under limited use) where project intervention can be started occurs at this stage. A seasonal calendar helps to determine the availability of fuel wood and fodder from the uplands or fallow lands, the supply of fodder and fuel from outside the valley, and the quantity and time of year in which it is supplied.

Selection of villages

Preliminary data about villages is collected from the union council office, and the councilors of these local bodies are contacted. An initial survey is made by the foresters and group promoters, and villages with high potential are recommended. Special attention is paid to villages with uplands, clear ownership rights, and the willingness to develop their uplands. Local men must support women's development activities in their village.

Dialogue with community

The staff introduces the project to a full assembly of residents. This process takes place at the same time on different sites and includes both male and female members.

Establishment of local organization

For successful and sustainable uplands development and management, formal involvement of the local population is a prerequisite. Experience shows that local organizations are very successful in carrying out these activities. In the past, such organizations formulated, managed, and repaired the *karezes*. Now, villagers form a village association (VA), with each tribe, sub-tribe, and occupation represented. Special focus is on the establishment of women's associations at the same time. Village associations start saving regularly to meet the financial needs of the community for natural resource management, etc. The village association makes the decisions at all stages of planning, implementation, monitoring, and evaluation. Members not only take an active part in decision making, but also contribute their local knowledge of uplands development and conservation. Women at this stage have much to contribute, based on their experience and knowledge: they know the best bushes and plants for fuel based on heat value and good burning, the medicinal plants for domestic use and for market, etc.

Village upland use map

The villagers prepare an upland use map. The land use map helps identify different zones, type of soil, crop areas, orchards, input-output shares and arrangements,

fallow/barren land use, and ownership. This map is discussed with women to ensure their contribution and involvement.

Village upland use plan

According to various estimates, about 5.6% of the land in the Kanak Valley is used for rainfed agriculture, 2.1% for irrigated orchards, 1.1% for vegetable production, and the remaining 91.2% for grazing (considered rangelands). Development activities in the irrigated and rainfed lands are directly concerned with better management of natural resources in the uplands.

In light of the experience gained in the first phase of the project, it is apparent that people understand to some extent the problem of the lowering water table, as well as fodder and fuel wood shortages. The question then was, how to address this problem through community participation. It was decided to put more emphasis on natural resources development during the PRA process. In the new villages, more attention was paid to land use maps and problems of natural resources degradation. The land use plan must make clear the benefits and costs to the community in quantitative and qualitative terms. In arid areas, where benefits accrue over a long time, and are not visible or tangible, this is not easy. Until and unless benefits/outputs are partially or fully balanced, the community may never participate completely. At this stage, villagers may not have a clear picture of the development process, so the project must help to identify the activities to be undertaken.

Valuable experience was gained from the first phase of the project with regards to priority areas and different methodologies. Currently, the participatory approach is applied in a variety of ways for information collection, problem identification, and activity implementation. The implementation plan for the development of the uplands, for the purposes of groundwater recharge and fodder and fuel wood production, is made and agreed upon by all members of the community and the project. This includes appointment by the community of a guard (*chowkidar*) to protect the uplands.

Women have a very low literacy rate and do not have access to the decision-making process for the management of natural resources. This despite the fact that, in the project area, experience shows women to be major actors. Firewood cutting and collection is the responsibility of women. Normally, plants are uprooted instead of cut above the stem; therefore, women need to be trained to cut these plants so that they will continue to sprout. Their involvement in conservation and natural resources development should increase substantially.

Integrated Approach to Fodder Shrub Plantation

The Arid Zone Research Institute (AZRI) in Quetta is the focal point for the supply of and technical support for fodder shrubs and trees. Therefore, AZRI experiments and demonstrations have been used by project personnel as a training ground for the villagers of Kanak Valley. Various *Atriplex* species (*A. canescens* and *A. lentiformis*) have been chosen and introduced in the uplands as exotic species for fodder and fuel wood. These *Atriplex* species are fast growing, compared to native shrubs, and provide nutritious fodder in late summer and winter, as well as a much-needed fuel wood source for local communities.

Village Participation

In the beginning, villagers were reluctant to accept the idea of upland development due to various concerns:

- The fear that the project would usurp the area under plantation.
- The fear that trees would be planted by the project instead of shrubs and grasses.
- The non-availability of shrubs that can survive under rainfed conditions.
- The fear that animals might not like to eat such shrubs.
- The length of time before shrubs can be cut for fuel wood or grazed.

To clarify these fears, the project organized several study tours for the villagers. Firstly, they were taken to AZRI in Quetta, where they observed:

- The saltbush nursery.
- Young and old plants.
- An experiment on sheep grazing saltbush at AZRI, where sheep were fed with saltbush forage and its seed.
- Discussion with AZRI scientists about different aspects of saltbush plantation and use.
- Training about the nursery, plantation, and use of saltbush.

Secondly, villagers visited demonstration saltbush plantations in different areas of highland Balochistan. As a result of these visits, upland sites were chosen in one village, Lehri, as a model. Initially, 10 ha of land was selected. Villagers took an interest in the various activities, such as surveying the site, making ridges, planting, watering, and, most importantly, protecting the newly established stands. Before work began in the area, soil coverage was only 5%, with only 20 species of plants.

A second piece of land (100 ha) adjacent to first was selected by the villagers for plantation the following year. This time, besides saltbushes, other species, like *Tamarix* and *Glycirrihza haloxylon*, were tried to rehabilitate the degraded areas.

Plantation is done in blocks to be used as forage reserves and only the remaining area is protected. It is expected that after protection, many native species will regenerate. Some pieces of land were seeded with a variety of native bushes, such as *Artemisia*, *Haloxylon*, wild almond, etc., to observe their regeneration. In 1995, three more villages developed upland use plans for shrub plantation. This occurred after they saw the plantation in the model village and discussed the establishment of nurseries and plantations with the original villagers. At present, 238 ha are involved with various range improvement activities, including large-scale plantation of fodder shrubs.

Impact and Lessons Learned

The results of saltbush plantation are very encouraging. During three years, water was supplied only twice, during summer drought. The survival rate of the plants was more than 70% in arid conditions such as upland Balochistan.

The growth rate of the plants is quite satisfactory. Saltbush has no thorns and villagers can cut it easily for fuel wood and fodder. People like it and their animals browse it, especially during the winter when other fodder species are dormant or not available. Villagers are protecting the shrub plantations and are now ready to replace the dead plants. The furrows made for saltbush plantation are easy for villagers to replicate on their own.

Villagers demanded a decrease in spacing to create a thicker block of plants as a forage reserve. Although some illegal grazing was done by the villagers in the beginning, the saltbush plants survived and resprouted the following spring.

In conclusion, the following lessons have been learned:

- No matter how effectively communities are mobilized and involved, sound technical packages play an important role to start and sustain the activities.
- Technical packages must be compatible with local knowledge. The initial inventory of plants should include multipurpose uses of native flora.
- Fodder shrub plantation became a priority with villagers to implement upland land use plans through community participation.
- The areas under shrub plantation in the four villages are protected by the community without the need for fencing. This follows the example in Balochistan, where traditional social pressures are strong enough to prevent illicit grazing.

- Normally, nomads are blamed for grazing and destroying the plantation, but in Kanak Valley, experience shows that nomads respect the rules. However, sometimes members of the community violate the rules.
- Villagers have started to establish their own nurseries of saltbush for future plantation programs.
- With limited-scale plantations, villagers participate fully without payment. But with large-scale plantations, the project/department should offer incentives.
- To avoid dependency of plants available only from AZRI, farmers in the area should be encouraged to establish nurseries and the project should obtain plants from these nurseries.

The concept of fodder shrub plantation and management in Kanak Valley is becoming popular among members of the farming community, as they participated fully in the plantation and utilization programs.

The Arid Zone Research Institute, Quetta, is cooperating fully by supplying saltbush seed/seedlings and providing technical know-how. A number of training courses on nurseries and establishing fodder shrub reserves have been organized by AZRI for the farmers of the valley

Although plantation of fodder shrubs has been carried out in the valley, proper management plans have not yet been established. For sustainable use of fodder shrubs in the uplands, a management plan covering the details of fodder availability and the number of animals to be grazed or fed is needed.

Saltbush Propagation: Seed Handling from Picking to Planting

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Introduction

In the Karoo region of South Africa, periodic and regular droughts are a scourge that have caused steady and inexorable desert encroachment. This unstable climate, coupled with ineffective farming practices, has caused the climax vegetation of the region to disappear and damaged the pioneer vegetation to such an extent that total denudation has occurred in many places. As a result, desert encroachment has occurred, stemming mainly from the drier west and the Kalahari region to the northwest.

Rainfall in the region, which occurs mainly in summer, varies between 100 and 300 mm/year, but the reliability factor is <50%. Temperature varies from –9°C on winter nights to 45°C in midsummer. Given the severe frost that occurs in winter and the sizzling heat in summer, coupled with erratic rains, the area is extremely sensitive to any significant grazing pressure. Long periods of rest after grazing are indicated, and various rotational grazing systems have been developed which, when carried out, have proved successful.

This area is exclusively devoted to small stock farming, and sheep and goats have played their role in causing damage to the natural pasture, the *veld*, as it is known in the area. The farmers of the region are faced with the economic pressures of the day, and, as a result, enhancement of the natural veld was conceived as the only long-term and viable solution. Thanks to the efforts of Mr. G. de Kock and his ongoing research into most known, and some unknown, desert plants, it appears that oldman saltbush (*Atriplex nummularia*) is one of the most effective and successful species for veld enhancement. De Kock spent years breeding the most palatable cultivar with the highest leaf-to-stem ratio, stability within the cultivar, etc. Successful plantations of oldman saltbush have been achieved in many parts of South Africa, and indeed many parts of the world, using the de Kock cultivar. These plantations have proved their worth in the severest conditions.

Propagation

Our role has been to develop processes to improve picking practices, storage, treatment, and preparation for planting in the modern context of improved germination rates. The mechanization of the system, with labor at a premium, commenced in the 1970s. During the ensuing 25 years, a series of machines

evolved, and affordable handling of seed was achieved for the farmer. It was important to sell the concept to the farmer, and in this context, the cost of establishment was a major factor.

Two main problems presented themselves:

- Devising a system whereby costs of propagation could be drastically reduced.
- Ensuring that a good and viable stand was achieved to ensure one-shot establishment.

Research was continued by de Kock, and at this stage the Botany Department of the University of Port Elizabeth, under the leadership of Prof. Guy Bate, also took an interest. It soon became clear that saltbush seed is uncommonly difficult to germinate evenly at a good percentage. Various systems of propagation have been tried: planting directly from raw seed; planting from slips; and transplanting seedlings from nurseries. None of these systems seemed totally satisfactory, accompanied as they were by high costs. This called for more research. The problem was examined in its entirety, and as the facts emerged, a *modus operandi* was established.

Picking

Picking the seed under controlled conditions is critical. Seed must be ripe, but not so ripe that it falls to the ground before it can be harvested.

The seed must be dry to ensure that storage is successful. It is desirable to conduct daily moisture testing so that management can decide whether it is safe to pick or not. At the same time, it is important to separate the seed taken from the extremity of the frond from the seed taken from the inner end of the frond. These two groups of seed do not ripen at the same time.

Picking is done by hand and seed is placed into adapted bags and weighed each evening. The pickers are paid by weight, but a careful watch is kept to ensure that quality work is done. The seed is sieved every morning to remove extraneous material (leaves, twigs, etc.). Frequent early morning dews delay the start of picking. An average picker can pick 40–50 kg/day (9 hrs), depending on the amount of seed a particular plantation is carrying.

Seed plantations are not grazed during the year at all, but are kept exclusively for seed production. The original plants in the seed plantations are derived from slips from selected parent plants with good growth and good leaf development, and from plants that obviously stand out as excellent material from which to propagate. It is vital to use only the de Kock cultivar. The location of the seed plantation is carefully selected to ensure that no cross breeding with other saltbush cultivars is

possible. To ensure good seed yield from relatively small areas, the slips are taken from female plants. A row of male slips is planted every tenth row.

Storage

The seed ripens in mid-summer, and is stored after picking in hessian bags to enable it to breathe. It should be stored in a dry place in such a way that control over rodents can be exercised. Mice love saltbush seed. Storage in the raw state should be as short as possible. The next stage in the seed treatment should be conducted within six months.

De-husking

After establishing that a large portion of the sprouting inhibitor was located in the husk (brachia), the question of removing the husks was addressed. R.M. Jones, in October, 1968, established that no significant improvement in germination was noted by leaching the seed in water for various periods. Further experiments by M. von Holdt, University of Port Elizabeth (UPE), in 1989, showed that complete removal of the bracteole along with the addition of growth regulators achieves excellent germination results. Clearly, all of the inhibitor could not be removed, but de-husking, in addition to removing most of the inhibitor, makes handling the pip easier due to uniformity of size, mass, etc. The possibility of mechanizing the subsequent handling of seed then became the focus. Various mechanical attempts to de-husk were made. A number of small mills were developed, but in each case either the cleaning process was ineffective and too much unopened seed was lost, or, if the cleaning process was more aggressive, too much pip material was damaged. Eventually, an alternative hydro-mechanical technology was developed, and, after a number of years of research and development, a machine was fabricated that was effective about 95% of the time. This particular apparatus has a capacity of 1 kg of de-husked seed (pips) per day and requires two operators. After the de-husking process is complete, the pips are dried rapidly by a specially designed fan heater. At this stage, the pips and the husks are still mixed. After drying, the material is winnowed again via a very specialized wind tunnel where the husks are separated from the pips. This machine is capable of sorting the pips according to mass or size. This sorting is done to accommodate the modern vacuum seeders that are used in the nursery. G. Bate, from UPE, showed in 1993 that the pips could be categorized after de-husking into three groups: (i) small hard seed; (ii) larger and softer seed; and (iii) dark (almost black) seed. All three categories have different germination percentages and germination rates. The larger and softer the seed, the faster it germinated.

The small and darker seed took longer to germinate, but in the end gave a better percentage. Experiments done at UPE showed that the application of a growth

hormone could dramatically improve the germination percentage. Seed that had been de-husked by the hydro-mechanical process responded to the growth hormones instantly, whereas seed that had been cleaned mechanically remained relatively unchanged. It became clear that the hydro-mechanical system was the most successful; the straight mechanical systems simply did not deliver the performance required. By sorting the seed after cleaning and drying, a more uniform result was obtained. After grading, the seed is ready for treatment with fungicide and vacuum packaging.

Prior to packing, germination tests are carried out to determine ultimate germinability. These tests are done in a laboratory and the results are presented, along with the seed, to the client. When propagation via a nursery is undertaken, good germination (above 85%) results. The seed is planted under ideal germinating conditions, and when the plant is 120 mm high, the seedling can be transplanted. This is a very effective system of propagation, with the slowness of the process and, of course, the cost, the only drawbacks. Transplanting can be done by hand or by machine. With hand planting, soil preparation is important, as the plant must be placed in the hole and closed up quickly. The costs are high, and in summer, when temperatures are in the 40s, planting can only be done early in the morning and late in the afternoon. After planting, the seedlings require water (1 liter each). If no rain follows, another irrigation with 1 liter is necessary.

For this reason, in the Karoo, most of the planting is done towards the end of summer, when the very high temperatures are past and it is more likely that rain will occur. When transplanting is done by machine, the soil should be carefully examined. Most planting machines require a well-prepared seedbed with few clods. If the terrain is rough, the machine's effectiveness will be reduced. Mechanical planters usually require three operators and can plant 6–8 ha/day.

Pelleting

The high cost of transplanting becomes a problem when large areas are involved. Direct drilling is the best alternative, but the pips are too small for a regular drilling machine to handle.

An accurate precision planter is needed to achieve a spacing of about 1 m in the row. Rather than developing a special planter, it made sense to provide the customer with seed that could be planted using a normal maize planter, which is a well-designed machine already in common use. This meant pelleting the saltbush seed to a size that standard machinery could handle. As an additional benefit, more than one pip could be placed in the pellet, thereby ensuring that, if the eventual stand in the field was not 100%, at least seed germinability would not have been the main factor. The recipe for the pellet can be varied, and research has been done

on additives (fertilizer, growth regulators, fungicide, super-absorbents, wetting agents, etc.).

Natural clay with the various additives proved the most effective basis for the pellet. A cylinder 5 mm in diameter and 5 mm long was chosen as the best size. All standard planters handle this pellet with ease. A pelleting machine that can produce 40,000 pellets/day was developed. Larger models could easily be produced if required. The pellets are dried immediately and then baked to reduce moisture levels to 13% within 30 minutes. The pellets are sorted to eliminate malformations, and then packed for storage and marketing. With a density of 3,000–4,000 plants/ha, one pelleting machine with a standard capacity can plant 10 ha/day. As previously mentioned, larger models could easily be manufactured if necessary. The size and shape of the pellet can also be varied to suit requirements. Some planters need a slight modification to enable them to achieve a 1 m spacing in the row.

Soil Preparation

Soil preparation for direct drilling is the same as for field crops, except that the rows are much further apart. With a row spacing of 3 m, and 1 m in the row, a stand of 3,000 plants/ha is achieved. The first step in soil-breaking normally involves using a single line ripper (sub-soiler) to a maximum depth: about 800 mm. Two or three passes are made over the same area. The second step is to use a small leveler blade to make a furrow over the same area. This assists in water harvesting when it rains and ensures that all runoff from the intervening area will end up in the furrow—which is tantamount to an irrigation. The laying out of the rows should be done on a contour of 1 in 1,250. The furrow will thus be flat enough to prevent water runoff, but will allow water to spread out so the entire row will benefit. After the furrow is made, a final pass with the ripper is made. The soil is then ready for the planter. The leveler blade also has the effect of removing excess organic matter, ensuring that the planter has a good tilth to work in.

Timing

Correct timing of planting is vital. The seed will germinate much faster if planted during warm weather, which means at the onset of spring or summer.

Equally important is the advent of the rainy season. Although the seed can lie in the ground for long periods, waiting for rain, it is always better if the seed is planted in damp soil during a period when rain is likely. Planting depth must be shallow, no more than 5 mm. As the soil dries rapidly at that depth, it is important that rain has already fallen, and wet the profile to a greater depth. Capillary action will greatly assist in keeping the top section of the soil damp for a longer period.

General

Because of the extremely low cost of planting with pellets, as described above, and the ease with which one man on a tractor can do the job, it is feasible to replant and to keep on replanting (if insufficient rains fall to sustain germination) until a satisfactory stand is achieved. The fact that two or more pips can be placed in the pellet is key to achieving the desired stand. The shelf life of pelleted seed has not yet been established, but a period in excess of one year has already shown virtually no decrease in viability. The major attractions of this planting system are its simplicity and low cost. The cost of transplanting seedlings compares with the cost of direct drilling is shown in Table 1:

Table 1: Comparing the costs of transplanting and direct drilling of *Atriplex*.

Planting from nursery	($)	Direct drilling	($)
Soil preparation: deep rip; draw a contour furrow; rip again; 1.5 days/ha	67	Soil preparation: same	67
Fertilizer: apply 2:3:2 @ 400 kg/ha	23	Fertilizer: same	23
Plants: rate of 3,000/ha @ 2.25	67	Seed pellets: 3,000/ha @ 1.83	55
Labor to plant: 1 day for 16 workers @ $7/day	112	Labor: 2 tractor hrs. @ $11/hr	22
Transport: from nursery and general handling	7	Handling	0
Water: via tanker or pipeline, to establish: 2 applications	23	Water:	
		1) planted in the rainy season	0
		2) irrigated to establish (2×)	23
Total/ha	299	Total/ha	190

Direct drilling results in a savings of at least $109/ha, equivalent to 36%. If no irrigation is applied, as is usually the case, the savings is $132/ha, a savings of 44%. This is less than half the cost of using transplants.

A vital factor emerged from the laboratory tests done at UPE during the early 1990s. The survival rate of different categories of seed, and of de-husked seed, varied considerably. Tests showed that de-husked seedlings, although they took longer to germinate, survived up to 25% better than the control. De-husking, and subsequent grading, improved germination and resulted in far better survival in the field. The case for de-husking using the hydro-mechanical method was strengthened by this factor, and has proved itself in the field. Research is continuing at de Kock's Institute and at the University of Port Elizabeth.

I am deeply indebted to both Institutions for their unstinting help and enthusiasm in our search for answers to the handling of this most complex plant.

Profitable Saltland Farming: An Australian Farmer's Experience

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Abstract

The farming system in southwestern Australia is based on cropping and merino sheep. Salinity is an increasing problem due to rising groundwater levels. Significant areas have been planted to salt-tolerant shrubs and grasses such as *Atriplex amnicola*, *A. undulata*, *A. nummularia*, *A. lentiformis*, *A. semibaccata*, *Acacia saligna*, *Maireana brevifolia*, and *Puccinellia* spp. Direct seeding is done in late winter in rows 2.5 m apart, using a niche seeder and vermiculite mulch. Grazing commences in autumn, 6 to 8 months after seeding. In subsequent years, grazing is from late spring to early winter, combining saltbushes with dry grasses and stubble. There is no reluctance of sheep to eating saltbush, but they also require adequate dry cellulose material. Fresh water is essential and is pumped to saline areas from an earth tank. The stocking rate improves when saltbush is grazed, with cleaner wool per head, a higher price per kilogram, and higher gross income per sheep. The capital cost of seeding is recouped in less than three years. Other benefits are erosion control, increased wildlife, lower groundwater levels, improved cover of annuals, improved aesthetics, and improved farm value. Land-care organizations are an important factor in salt-land re-vegetation, with emphasis placed on farm planning, sustainability, and agronomy. The local Land Conservation District promotes land-care by carryring out trials on trees and saltbushes, monitoring groundwater levels, farm planing, field trips, and distributing awards.

Key words: saltbush grazing, saltbush establishment, *Atriplex amnicola*, *Atriplex undulata*, *Atriplex nummularia*, *Atriplex lentiformis*, *Atriplex semibaccata*, *Maireana brevifolia*, land-care.

Introduction

I live and farm in southwestern Australia. The climate is Mediterranean, with a hot, generally dry, summer and a cool wet winter. Average rainfall is 325 mm/year, with approximately 80% (260 mm) occurring in the winter growing season (May to October). Summer rainfall is irregular, usually taking the form of thunderstorms, and varies greatly in amount and time. Average maximum and minimum temperatures are: summer maximum 31.5°C, minimum 14.5°C; and winter maximum 16°C, minimum 6°C. Farming systems are based on cropping (wheat, barley, oat, grain legumes, and canola) and grazing sheep for wool production. The

sheep pastures consist of annual clovers (*Trifolium* spp.), medics (*Medicago* spp.), and annual grasses.

My farm has an area of 2,160 ha, of which 1,100 ha are arable and suitable for cropping, 700 ha are saline, and suitable for grazing only, and 360 ha are left as native natural vegetation, rocky outcrops or salt lakes. I crop approximately 600 ha each year to barley, oat, lupin, and canola, and graze sheep on the remainder.

Salinity problems are increasing. Part of the district where I live was first cleared for farming in 1922, but since then the rising water table has caused a considerable area to become saline. This has occurred in the lower valley floors, as a result of clearing the natural trees and shrubs for agriculture.

My farm was originally cleared of natural vegetation between 1960 and 1968. By 1975, some of the lower areas started to show signs of salinity. By 1985, these areas were extensive (700 ha), and there was a need to get production from them to remain viable. In some places the groundwater, with a salinity of 5,000 mS/m or more, is within 1 meter of the soil surface in summer and within 250 mm of the soil surface in winter. Where this occurs, there is little or no herbage growing. These are the areas on which I have planted saltbush (*Atriplex* spp.).

These saline areas are mainly shallow duplex soils with 100–200 mm of sand over clay. Generally, the pH is neutral to slightly alkaline (6.5–7.5).

Patches of Mediterranean barley grass (*Hordeum geniculatum*) are usually the only ground cover. It has been several years since successful crops have been grown on these areas.

Shrub Selection

In 1989, I planted some saltbush seedlings (*Atriplex* spp.), and after viewing some work done by another farmer, I tried 17 ha of direct seeding. This was a great success and encouraged me to buy a niche seeder, specially designed for direct seeding saltbush. Since then I have seeded over 350 ha on my property and a further 200 ha for neighbors. The varieties I have used are *Atriplex amnicola*, *A. undulata*, *A. nummularia*, *A. lentiformis*, *A. semibaccata*, *Maireana brevifolia*, *Acacia saligna*, and *Puccinellia* spp. Below, I detail some of my experiences with these plants.

Atriplex amnicola

This variety appears to be well suited to this area, as it grows well and recovers well from grazing. It is also very palatable. However, it is difficult to establish by direct seeding.

Atriplex undulata

This variety is extremely easy to establish by direct seeding. It is very palatable and well suited to the area. Growth and recovery from grazing are not quite as good as *A. amnicola*, but it is still a very good all-round variety. It is the main variety in the seed mix.

Atriplex nummularia

This variety, a native to the area, is a taller, slower growing saltbush. It appears to be not as prolific or palatable as either *A. amnicola* or *A. undulata*. Its tall growth (up to 1.5 m) provides shelter from cold winds for sheep after shearing in late autumn. I feel it is a useful variety to have in the seed mix. The de Kock selection of *A. nummularia* appears to be well suited to the slightly less saline areas.

Atriplex lentiformis

This variety is very tall (up to 3 m) with rapid growth. It needs to be grazed heavily and early to keep it in check. If it is not grazed heavily, it becomes rampant and tends to break off at the base. While it is palatable, its requirement for more frequent grazing may create problems with grazing system management. I have reduced *A. lentiformis* in the seed mix over the last few years.

Atriplex semibaccata

This is another variety which is native to this area. It is a prostrate variety that is extremely palatable and a prolific seeder. The seed germinates readily each year, with several hundred seedlings from each plant. It is a very useful variety to have in the seed mix.

Maireana brevifolia

This variety is also native to this area, and grows well on well-drained soils with a higher clay content. It is extremely palatable, but does not recover from grazing as quickly as some of the other varieties. It seeds prolifically and germinates readily from seed. As it volunteers readily, there is generally no need to have any *M. brevifolia* in the seed mix.

Acacia saligna

This salt-tolerant tree grows well and provides food and shelter. However, it is not well suited to my grazing system, which commences in the autumn (see below). If

it can be protected from grazing for 18 months to 2 years it is a very useful plant. I now only plant *A. saligna* in areas which will not be grazed for at least 2 years.

Puccinellia spp.

This salt-tolerant, perennial grass appears to be a little out of its environment. It would seem to require slightly higher rainfall and soil of higher sand content. I still use a small amount in the seed mix, as it does provide some balance to the saltbush in the feed ration.

Seeding

The seed mixture is sown using a niche seeder. The machine rips a furrow about 200 mm deep and has two opposing discs, which construct a mound over the ripped furrow. A niche wheel follows to form a flat V-shaped niche on top of the mound, into which a small amount of seed is placed at regular intervals. The metering mechanism is controlled by the niche wheel, and deposits the seed every 2 m. Vermiculite, a mulch material that keeps the seed moist, is placed on top of the seed. The sides of the niche slope gently toward the center to harvest rainfall. In addition to watering the seed, this washes the excess salt away from the seed, allowing it to germinate in relatively salt-free soil.

Seeding is carried out in August (towards the end of winter). Prior to seeding, the area is grazed heavily and sprayed with 800 mL/ha of glyphosate (450g/L) to kill grasses.

The seeding rate is such that there are approximately 50 viable seeds in each placement. This normally means about 300–350 g/km of travel. My rows are placed 2.5 m apart, giving 4 km/ha. In ideal conditions, most of this seed will germinate. However, due to the harsh conditions of early summer on delicate seedlings, only a few survive to maturity.

Grazing Management

Generally, the recommended method of grazing is to leave the newly planted shrubs for 18–20 months before light grazing. Grazing begins at the end of autumn, when the traditional annual pasture and stubble (crop residues) are at their lowest nutritional level. I depart from this recommended method of grazing in a number of ways.

Early Grazing

I start grazing the newly planted shrubs about 6–8 months after seeding (early autumn). Timing depends on the amount of growth during that first summer, which, in turn, depends on the amount of summer rainfall. The sheep enjoy eating the young fresh shoots, and it also helps to keep the bushes compact. This, in turn, encourages a better growth pattern of new shoots. Where *Atriplex lentiformis* is present, it keeps the shrubs down to a level that the sheep can reach. Previously, delayed grazing allowed the *A. lentiformis* shrubs to reach heights up to 3 m.

Spring Grazing

Again, I depart from the recommended method by commencing grazing (in the second and subsequent years) in the late spring. This is done as soon as the annual pastures dry off (generally late October). From my observations, it appears that the saltbush is more palatable and nutritious, due to a lower salt level in the new shoots. Once the cereal crops have been harvested in November and December, the sheep are grazed on the stubble, and the saltbush is allowed to regenerate. When the grain in the stubble is exhausted, the sheep return to the saltbush, and graze the shrubs along with the stubble. This provides the sheep with a reasonably nutritious diet throughout the summer/autumn, when the traditional annual pastures have low nutritional levels.

With this early start to grazing, together with grazing throughout the summer/autumn, *Acacia saligna* will not survive. At eight months, the plants are usually less than 900 mm high, and are readily eaten by the sheep. Grasses are encouraged, and along with Mediterranean barley grass (*Hordeum geniculatum*) and *Puccinellia* spp., annual ryegrass (*Lolium rigidum*) provides most of the dry cellulose material needed to supplement the saltbush. Cereal hay is kept on hand to supplement the saltbush shrubs if necessary. I have noticed that the sheep will scour and lose weight rapidly if insufficient dry cellulose material is available. Water use by the shrubs has lowered the saline water table, and as a result, annuals such as capeweed (*Arctotheca calendula*) and clover (*Trifolium* spp.) are returning naturally.

Successful salt-land pasture grazing management depends upon fresh water. My supply comes from a large excavated earth tank with a storage capacity of 38,000 m^3. This water is pumped around the property into tanks and troughs. At the moment, all the troughs are located at the edges of the saltbush paddocks, but plans to re-route the pipeline through the center of the paddocks to allow for central watering points are in hand. Another requirement to obtain maximum benefit from the saltbush is to have paddock sizes that can be grazed in about 15 days. In my situation, this means a paddock size of 40–50 ha.

I have not experienced any difficulty in getting sheep to eat the saltbush. In fact, the sheep will cluster around each bush as they enter the paddock to feed. As mentioned before, I have been planting saltbush in rows 2.5 m apart, while leaving a wider space (3.5 m) every five rows, to allow for vehicle movement. Consideration is now being given to changing this. Next year, I will plant three rows of saltbush as close as possible (about 1.5 m), leave a space of about 8–10 m, then plant another three rows of saltbush, etc. This will produce an alley effect, allowing the saltbush shrubs to use the saline groundwater and draw it down. It also allows other fodder species to be grown in the areas between the rows of saltbush. These could include some mildly salt-tolerant clovers (*Trifolium* spp. especially *Trifolium balansae*) and grasses grown to improve production. In time, there may also be some opportunity to grow some barley or other cereals.

Economic Analysis

The sheep I run are merinos, bred mainly for wool, but with some of the young wethers sold as "shippers" and transported live to West Asia and North Africa. The wool fiber diameter is 22 microns, and grown sheep usually produce more than 6.5 kg of wool per head. The flock of 4,000 sheep is self-replacing, with surplus sheep sold for meat. In our area, sheep are run as an adjunct to the main industry of cropping. I concentrate more on sheep because of the large proportion of my farm that has become saline. This means that I have to obtain more production from my farm to remain viable.

As wool production is the primary aspect of my sheep enterprise, I will focus on the economics of wool to determine whether the planting of saltbush shrubs on the salt-land has been economic.

During the summer/autumn of 1993/94 (November 1993 to April 1994), I grazed a number of sheep on a 30 ha paddock of saltbush. The mob size varied, as did the time each mob spent in the paddock. The area was grazed until all leaf material was eaten, and then, when the sheep were taken out, allowed to re-generate. Stocking rate, calculated on a year-round basis, equates to 5.2 dry sheep equivalents per hectare (DSE/ha).

In another paddock, which is about 60% saline with a natural annual pasture but no saltbush, I grazed mobs of varying sizes for varying lengths of time. Stocking rate, calculated on a year-round basis for this paddock, is only 3.0 DSE/ha, a difference of 2.2 DSE/ha. With adult sheep producing an average of 6.5 kg of wool each, and long-term value of wool estimated at A$ 4.00 per kg, the extra gross income per hectare for the salt-land shrub area is A$ 57.20. The operational cost of running sheep is estimated at A$ 4.50 per head, leaving a gross margin of A$ 47.30 per ha.

The cost of direct seeding of saltbush varies due to the cost of seed and the hire or contract charges for the niche seeding machine. I have calculated the cost on my property at A$ 30.00 per km, or A$ 120.00 per ha. Thus, the total capital cost of seeding is recovered in less than three years. Although no additional costs of fencing or watering points have been included, neither has the additional savings when seed is harvested from existing stands of saltbush.

In 1995/96, I compared two mobs of ewes. Both mobs were grazed together for the first nine months of the year. One mob (A) was then grazed on salt-land shrub pasture for the final three months, while the other mob (B) was grazed on stables and annual pasture with a lupin grain supplement. Mob A had no supplement during the final three months on the saltbush shrubs.

The two mobs were shorn at the end of the twelve months, with interesting results. Mob A produced slightly less greasy wool, but of a higher clean scoured yield, and therefore a higher price per kilogram. This higher price was more than enough to compensate for the lower greasy fleece weight. Mob A cut 6.5 kg wool at 64.8% yield and sold for A$ 3.75 per kg, a total of A$ 24.38 per head. Mob B cut 6.9 kg wool at 58.9% yield and sold for A$ 3.42 per kg, a total of A$ 23.60 per head. When the cost of the supplementary lupin feeding of mob B is taken into account, the difference is even greater in favor of the ewes in mob A, which grazed the salt-land shrub pastures during the last three months.

Other Benefits

As well as the economic benefits referred to above, there are many other benefits to the re-vegetation of these saline areas:

- Erosion control. Due to the re-vegetation, there is decreased erosion. The shrubs provide an effective windbreak to control wind erosion, and the annual grasses assist in controlling water erosion.
- Wildlife. There is an increase in the native wildlife in the re-vegetated areas. A few small birds and animals, as well as kangaroos, now inhabit the area.
- Lower groundwater levels and improved cover of annuals. Monitoring of the bores on my farm indicates a lowering of the groundwater levels in areas where shrubs are planted, compared to other areas of the farm. This has led to a return of some of the annual pasture species, improving productivity and assisting in erosion control.
- Aesthetics and improved resale value. With the bare saline areas covered and productive, there are significant aesthetic benefits, as well as improved resale value. On one section of the property, which I purchased in 1978, the vendor actually deducted A$ 2.50 from the purchase price for each hectare of saline

land! Nearly 200 people have visited the farm in the last six years, and are impressed with the aesthetics and wildlife.

Land care

An important aspect of agriculture in Western Australia is land-care organization. The whole rural community comes together to encourage land management practices that do not degrade the land, but improve it for future generations. To assist in fulfilling this objective, the government has established a legislative framework to allow for the formation of Land Conservation Districts (LCDs).

These LCDs are usually centered on a local government or community area. They are often divided into smaller units based on individual catchments of 5–15 farmers. The aim is to promote sustainable agriculture within the district or catchment by managing projects that show farmers ways of preventing land degradation. This can include advice on surface water control, drainage, groundwater monitoring, re-vegetation strategies, and other land conservation measures.

The LCDs are managed by a committee of local people, mainly farmers and other interested people. This committee (LCDC) organizes projects, conducts field days, and arranges for scientists and researchers to be involved. While there is significant support for the LCDs from the government and its agencies, the drive and impetus come from the local community and farmers.

In the past few years, there has been an increased emphasis on planning and agronomy on farms. This encourages farmers to recognize the links between land care, planning, and agronomy. For instance, farmers previously used earthworks (banks and drains), together with a tree planting program, as a means of controlling groundwater. Now, farmers are encouraged to plan their farms to take advantage of natural features and grow higher-yielding, higher-water-use crops to produce the same effect. Perennial pastures are also being used to good effect. The government provides advice to groups within the LCDs to assist them to meet these goals.

I belong to the Newdegate LCD, and in 1995 I was elected Chairman. We have a committee of 15 people, and meet once a month to discuss issues relating to land care. All members of the committee except one are farmers. The non-farmer is a coordinator, funded partly by a government grant, and partly from local sources. She helps to organize speakers for field days, set up trials and demonstrations, and develop a school land-care program for the area.

As an encouragement to the farmers in the local community, the Newdegate LCDC organizes various functions and field days. Our program includes the following activities:

- Land-care signs. In an endeavor to encourage interest in land care among school children, a competition was held in the local school. The children were asked to design signs depicting land care, to be erected on the five roads leading into Newdegate. Almost all the children, between 6 and 12 years old, entered the competition. These five signs are now a talking point in the district, and it has certainly raised the awareness of land-care among the children.
- Trees and saltbush. A number of sites in the LCD have been planted as trials and demonstrations of various trees and saltbushes suited to the area. At these sites, planting has been by direct seeding and with seedlings. Again, this has created interest as people compare the results on field days.
- Rising groundwater tables. One of the major, if not *the* major problem in the LCD is the increase in salinity. The cause of this is the rising groundwater table brought about by the clearing of natural vegetation. A large number of bores has been placed in the LCD to monitor groundwater levels. This monitoring will show what effect re-vegetation is having on groundwater levels. There is also considerable interest in drainage, banks, and contours to assist in the control of surface water flow.
- Farm planning workshops. All the farmers in the LCD have had the opportunity to prepare physical farm plans to assist in the management of their properties. These plans include all the physical features, such as soil types, salt areas, lakes, remnant vegetation, rocky outcrops, etc. Farmers are encouraged to farm each property to its best advantage, and in a sustainable way, using the land-care principles embodied in the farm plan.
- Land-care Achiever Award. The LCDC realizes the need to recognize the efforts that farmers have put into land care on their own property, and the need to promote these people and their achievements to the wider community. To this end, The LCDC has instituted an award for the "Newdegate Land-care Achiever of the Year." Farmers, community members, and groups are encouraged to nominate for this award. The award is presented annually at the Newdegate machinery Field Days, which attracts more than 15,000 people each year.
- Field trips. Another way the LCDC encourages farmers to improve their farming practices is to organize field trips to visit farmers who have achieved success in integrating land-care practices into their everyday farming operation. This is usually done once or twice a year, when a bus is hired. Visits are made to farms both inside and outside the local LCD area.

Conclusion

A large area of Western Australia is either saline or in danger of becoming saline. Many farmers are starting to realize the extent of the problem, and are searching

for ways, firstly, to deal with the saline areas, and secondly, to try to slow down, or stop, the spread of salinity. Some of the farmers in already saline areas have achieved considerable success in growing salt-tolerant shrubs and grasses. Their efforts have increased production and started to rehabilitate the areas.

Much more needs to be done! There needs to be more research into types and varieties of plants suited to saline areas. Suitability of plants to soil type, climate, etc., needs more research. Grazing management research is vital if the full potential of the saline shrublands is to be realized. What is the response to fertilizers on these saline areas? What are the best animals to graze these areas? These and many other questions are being asked. It is groups like the LCDs and a small number of individual farmers that are trying to find the answers.

Acknowledgment

It is with great appreciation that I acknowledge the financial support I have received from the Crawford Fund and the organizers of this workshop. Thank you very much.

"Un Arbre pour Chaque Citoyen:" Résultats d'un Essai Mené par une ONG pour la Reconstitution du Couvert Végétal dans le Sud Tunisien

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Résumé

Créée en 1991, l'Association des Jeunes de Zammour: *AJZ* (Béni Khedache-Médenine) a pour principales missions :

- La reconstitution du patrimoine culturel de la région.
- La sensibilisation des jeunes aux avantages de la conservation de la nature et leur incitation à la réalisation de travaux d'intérêt collectif.
- L'organisation d'excursions et la création de relations de coopération avec les associations et comités nationaux similaires.

Plusieurs activités ont été menées dans le cadre de cette association. Les résultats de l'une des activités menées par l'AJZ et ayant pour objectif la reconstitution du couvert végétal et la lutte contre la désertification dans la région de Béni Khedache (sud-est tunisien) constituent l'objet de cette contribution. Ayant démarré depuis 1992 sous l'égide "d'un arbre pour chaque citoyen," cette activité a permis la plantation de 7300 arbres par des adhérents volontaires de l'association. Les espèces plantées appartiennent à des catégories différentes : espèces forestières, ornementales et arbustes fourragers. Le taux de réussite de ces plantations varie de 60 à 80%, selon les sites de plantation et les conditions climatiques de l'année d'installation.

Objectifs

- La conservation des eaux et des sols, la lutte contre la désertification et la bonification du paysage.
- L'augmentation du potentiel productif des écosystèmes en zone aride (amélioration de la valeur des terres à pâturage, développement de l'apiculture, production de bois).
- La sensibilisation des citoyens et particulièrement les jeunes aux avantages du reboisement et de la conservation de la nature.

Réalisations

Ayant touché près de 300 familles, ce programme a permis la plantation de 7300 arbres et arbustes au cours des 5 dernières années. Parmi les espèces plantées on peut citer : *Eucalyptus* spp., *Cupressus horizontalis, Pinus halepensis. Acacia cyanophylla, Casuarina glauca*, et *Ceratonia siliqua.*

Les plants sont distribués gratuitement aux différents adhérents qui s'occupent eux-mêmes de l'opération de plantation. Les travaux d'entretien (irrigation, binage) sont, en partie, réalisés par l'association.

Afin d'encourager une participation plus efficace des citoyens, des prix d'une valeur symbolique, ont été alloués aux trois premiers volontaires ayant réalisé les plus forts taux de réussite au niveau de l'installation des espèces plantées.

Ce travaux sont réalisés dans la chaîne montagneuse des Matmata au sud-est tunisien ; Région de Béni Khedache (Altitude: 400 à 700 m ; Pluviométrie : 150–200 mm) et dans la Vallée de Zammour (plein coeur des Matmata). Ces plantations sont faites dans les cours des habitations à des fins d'agrémentation et pour l'ombrage. La réussite des plantations nécessite des irrigations fréquentes en phase d'installation.

La plantation d'arbres et d'arbustes en plein parcours s'est traduite, entre autre, par un développement de l'apiculture.

La consolidation des ouvrages de conservation des eaux et des sols constitue l'une des préoccupations des agriculteurs de la région de Zammour en raison de l'importance de l'érosion hydrique dans cette zone montagneuse. La plantation d'arbustes fourragers constitue le meilleur gage pour minimiser les risques de destruction de ces ouvrages.

Technology Transfer of Fodder Shrubs: A Synthesis

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Abstract

Fodder shrubs have recently been introduced to arid and semi-arid zones throughout the world. Their adoption by local populations was not effective until the 1980s, when social awareness of rangeland degradation and its contribution to desertification became a reality. Rangeland rehabilitation and reclamation policies in the arid and semi-arid zones have been dominated by two underlying premises:

- Rangelands are common resources, and thus investment in them is the obligation and duty of the state. This premise is prevalent in developing countries, and has led to the circumscription of technology transfer through shrub plantation to a few state projects. This has negatively influenced the improvement and preservation of rangelands and their integration into the economic structure of these zones. State-subsidized range improvement operations were planned and carried out without the involvement of the concerned agro-pastoral communities.
- Rangelands are a renewable natural resource that belongs to the people. Consequently, their rehabilitation and preservation are the duty of society in general, and the pastoral communities in particular. This premise acknowledges the contribution and participation of the communities in rangeland development. It is based on the principle of shared responsibility between the state and the community.

Success depends on viable agricultural policies, communication networks, education, and sensitivity to local populations. These factors dictate the future of technology transfer and, ultimately the sustainability of the fragile rangeland ecosystem.

Résumé

Les plantations arbustives fourragères sont une introduction récente dans les zones arides et semi-arides. Comme en témoigne les différentes expériences des pays, leur adoption par les populations n'a été effective que durant les années 1980. Ce transfert de technologie a coincidé avec la prise de conscience, de plus en plus grandissante, de la société du phénomène de la dégradation des parcours et de son incidence sur la désertification. Cette vision de restauration des zones arides et semi-arides a été dominée par deux perceptions distinctes de la société :

- La première perception considère que les parcours sont une ressource commune et partant leur restauration est une obligation de l'Etat. Cette option est caractéristique de plusieurs expériences nationales et dont son impact a été un confinement des plantations aux projets de l'Etat et a influencé toute la politique de transfert de technologie pour améliorer les conditions de production de cette ressource vitale à l'économie des zones arides et semi-arides. Cette perception a été sous-tendue par des mesures d'accompagnement renforçant la présence de l'Etat et non pas la conscientisation des populations par le respect de leur culture, valeur et objectif.
- La seconde perception considère que les parcours sont une ressource de génération et partant leur réhabilitation et conservation sont une obligation de la société. Elle privilégie la contribution et la participation des populations à son développement.

Elle a eu des résultats très encourageants dans l'adoption technologique de la plantation fourragère arbustive. Et elle rassemble les éléments essentiels des sociétés pastorales, culture, traditions, expériences et savoir faire. Elle priorise l'attitude de responsabilisation mutuelle nécessaire à la créativité et à l'initiative.

Introduction

Technology transfer to local users is the final step of research, extension, and development system. This report summarizes a selection of national experiences with technology transfer of native and exotic fodder shrubs plantation in the arid and semi-arid zones of WANA, South Africa, Greece, and South Australia. The effectiveness of their adoption by the local populations is analyzed.

National Experiences

South African Experience

From G. Louw: Practical Cost Saving Methods for Planting Oldman Saltbush (*Atriplex nummularia*).

Objective

Identifying establishment costs for the expansion of oldman saltbush (*Atriplex nummularia*) plantations along the west coast of South Africa.

Historical review

The development and propagation of fodder shrub plantations, especially *Atriplex nummularia*, on a large scale, was inhibited by the high cost of establishment. This

was overcome by a simple, practical, and economical method of seedling production, transplantation, and irrigation:

- The cost of seedling production was reduced by opting for production in seedbeds instead of plastic bags.
- Transplantation was mechanized by using a planter with a capacity of 2,500 seedlings/hour, requiring only three laborers.
- Irrigation fees were decreased by good soil preparation, which increased the water-holding capacity, and by choosing the right time for transplanting (after a good rain).

When correctly applied, these methods have a success rate of 95%. The reduction of cost establishment has increased the number of plants to 2,000,000 since 1991, which translates to a carrying capacity of 1,273,810 sheep days per year.

Conclusion and suggestions

To motivate farmers to plant fodder shrubs (*Atriplex nummularia*) the investment cost must be lowered However, the success of the plantation itself relies on good soil and climate conditions, which are not always available in the arid and semi-arid rangelands of WANA. Because of these poor conditions, seedlings have to be produced in pots or plastic bags.

Algerian Experience

From N. Redjel and J. Boukheloua: Algerian Experience with Fodder Shrub Plantation.

Objective

To review the effect of development approach on technology transfer and its adoption by local populations.

Historical review and result

Technology transfer has followed two contrasting approaches:

State-controlled approach. This consisted in implementing a reclamation and rehabilitation scheme characterized by a "technocratic" vision, wherein the state imposed its development policy without consideration of the cultural heritage and traditions of the pastoral communities. This resulted in the rejection of shrub plantation by local populations. The following ensued:

- Technology transfer was confined within the limits of state projects only.

- Destruction of the rangelands in favor of crop cereal encroachment led to the 100% increase in the cereal area, the decrease of pastoral area by 25%, and the decrease of grazing capacity by 75%.
- Background knowledge with regard to technology transfer packages was improved.

Participatory approach. Starting in 1992, this approach began to correct the mistakes of the past. It was built upon the principles of respecting the knowledge of pastoral communities, their cultural heritage, and traditions. Although this new development environment in Algeria is still young, it has already achieved what the first could not in more than 30 years:

- The rehabilitation of 12,000 ha (shrub plantation) by the pastoral communities themselves.
- The cost of fodder shrub plantation decreased by 52% per hectare for hand planting by the collectives, and by 77% for private farmers, compared to plantation carried out by companies.
- Shared responsibility for rangeland reclamation and development matters between the state and the pastoral communities.

Conclusion and suggestions

The limitations of state control of rangeland development have been confirmed. Thirty years of such a policy resulted in the following:

- Only 14% of the rangeland was involved in reclamation and rehabilitation projects. Success was ephemeral and not sustainable.
- Only 0.85% of the pastoral population was passively involved in these projects.

The participatory approach replaced a paternalistic vision of development by one based on the involvement of the pastoral communities. In three years this led to:

- An adoption of the technology in more than 32% of local communities.
- An active involvement of 6.5% of the pastoral population.

This success must be supported by a rangelands policy based on pastoral customs and traditions on the one hand and the sustainability of ecosystem on the other.

The Australian Experience

M.J. Lloyd

From M.J. Lloyd: Profitable Saltland Farming: An Australian Farmer's Experience.

Objective

To use fodder shrub plantation to reclaim land lost to increases in soil salinity and a rising groundwater table.

Historical review and results

To combat problems of a rising groundwater table and increasing soil salinity caused by the clearing of the natural vegetation during the 1960s, a reseeding trial with *Atriplex* spp. was started in 1989 on a 17 ha plot. Since then, this area has been increased to 350 ha, seeded with five species of *Atriplex* plus *Acacia saligna, Maireana brevifolia, and Puccinellia* spp. *Atriplex undulata* and *A. semi baccata* were very palatable and recovered quickly after grazing, while *A. nummularia* and *A. lentiformis* required heavy grazing to keep them in check and therefore required different grazing management.

Two grazing periods were tried:

- Early grazing: starting 6–8 months after early autumn seeding, depending on vegetation growth rate and the amount of summer rainfall.
- Spring grazing: starting 18–20 months after seeding.

The late spring grazing is best suited for two reasons. At this time, the salt content of new shoots is low, which makes the saltbushes more nutritious, and allows summer regeneration while the sheep are grazing on stubble.

From the ecological point of view, this practice is of great importance for salt-land reclamation. It helps restore the ecosystem by lowering both the groundwater table and salinity levels, and thus increases the capacity of economical salt-land farming.

Conclusion and suggestions

Shrub plantations were found to be an effective method of salt-land reclamation. However, its implementation must be based on local parameters.

The soil and climate conditions, the species to be planted, and the reclamation and the grazing skill management are key elements to the success or the failure of the enterprise.

E.C. Lefroy

From E.C. Lefroy: Experience with the Adoption of the Fodder Shrub Tagasaste (*Chamaecytisus proliferus)* in the Mediterranean Climate Zone of Southern Australia.

Objective

To review the commercial experience and research history of tagasaste since its introduction to Australia from the Canary Islands in 1879.

Historical review and results

Despite many advocates of the widespread use of tagasaste, a shrub species, its adoption by local users did not begin until the 1980s. Acceptance followed the discovery of a viable grazing system and its incorporation into cropping systems in a widely spaced agroforestry program.

Research into the use of tagasaste shows that:

- For wool production, the carrying capacity of degraded deep sandy soil can increase six fold in the 350–600 mm rainfall zone.
- For beef production, daily liveweight gains reached 600 g/head per day for steers and 1 kg/head per day for calves.

Commercial experience, based on whole-farm economic modeling using MIDAS, suggests that planting 10% of the arable area of a farm to tagasaste represents an economically robust substitute for supplementary feeding during summer and autumn drought.

The main constraints to limited adoption are:

- The need for mechanical cutting of the shrubs to keep new growth within the reach of browsing sheep.
- The transition cost from wool production to cattle production.

Conclusion and suggestions

Despite its early introduction and economic and environmental advantages, it took more than a century for local farmers to start planting tagasaste. Interest was boosted by research demonstrating its large-scale efficiency when used in sand-plain and salt-soil farming systems. This fact must be considered in any technology transfer in terms of local environmental, economical, and social characteristics.

The Iranian Experience

From A. Koocheki: Potential of Oldman Saltbush (*Atriplex* spp.) as a Fodder Shrub for the Arid Lands of Iran.

Objective

Analysis of the introduction, propagation, and use of saltbushes in Iran, with special reference to *Atriplex canescens*, based on a literature review.

Historical review and results

Before 1970, fodder shrub plantation in Iran involved some 40,000 ha. This figure may have tripled by now. The use of shrub plantation was motivated by the potential for:

- Providing feed for grazing animals.
- Sand dune fixation.
- Rangeland reclamation.
- Improving farming systems for marginal lands in dry areas.

The main shortcoming of saltbushes, especially *A. canescens*, is their lack of self-regeneration by seed, making plant propagation through seedlings grown in nurseries necessary. However, that process is costly and time consuming. The dry matter yield for different species of saltbushes ranged from 2,000 to 10,000 kg/ha, and engendered a net annual profit of about US$ 200 per ha against a total investment of US$ 200 per ha over ten years.

Conclusion and suggestions

In terms of the area planted with *Atriplex canescens*, Iran could be one of the leading countries in adopting saltbush plantation for rangeland reclamation and sand dune fixation. However, most of the current knowledge is based on observation. Scientific research is yet to be carried out, especially on grazing and feeding management systems that would ensure the preservation of the plantations with adequate feeding values.

The Turkish Experience

From L. Tahtacioglu: Research on Fodder Shrubs and their Management in the Rangelands of Eastern Anatolia.

Objective

To collect, evaluate, and test native and exotic shrubs to strengthen the background knowledge of shrubs in the region and the country.

Historical review and results

The rangelands in Eastern Anatolia are of major importance to livestock production. Although they are grassland-type ranges, their misuse has led to severe degradation. This has resulted in a serious loss of valuable genetic resources and the appearance of new, unpalatable spiny species. Range management research has not included shrubs, despite their contribution to range production and soil and water conservation.

Rangelands, especially third class ranges, must be rehabilitated through shrub plantations that supplement grass production, increase feeding capacity, and reduce erosion hazards and resource depletion.

Conclusion and suggestions

The collection, evaluation, and testing of native and exotic shrubs provides the basic knowledge for a better and efficient technology transfer to local users through plantation and adoption.

Technology Transfer

In general, the analysis of the national experiences on shrubs plantation shows the following:

- There is a long period between the introduction of shrub plantation and its adoption by local users. This is best illustrated by the Australian experience with tagasaste species.
- The use of shrub plantations is indicated by ecological criteria such as rangeland degradation, the need for sand dune fixation, salt-land rehabilitation, etc.
- Rangeland degradation can often be overcome by simple, practical, and economical methods of seedling production, transplantation, and irrigation
- The local population must play a role in decision making.
- Research should proceed plantation, rather than follow it.

Problems of Technology Transfer

Analysis of these papers identifies three types of problems facing technology transfer:

Agricultural policies

Development policies define the orientation towards achieving goals and choosing the technology packages. Poorly designed policies can result in the following:

- Governments decide technology issues without consulting local users, and without regard to indigenous knowledge and realities. Technology packages are put together by analogy using research activities carried out in different environmental and social conditions.
- Macro-economical policies, such as the pricing, subsidies, and agricultural strategies, have inhibited technology adoption and the involvement of pastoral communities in fodder shrub plantations. The pastoral communities have been discouraged by the misapplication of inappropriate measures. Barley and concentrated feed price subsidies and the indemnification of cereal crop growers for drought and hail damage in arid and semi-arid-zones are two examples of faulty economic policy.

Communication

To be reliable and consistent, technology transfer should follow a logical path from the researchers and developers to the users. A top–down communication, based on a paternalistic state control of development, stifles motivation and innovation. This results in a passive or refractory attitude and increases the gap between the interests of the rangeland user and the state.

Education

This fundamental element of development needs to receive more attention. We must find ways to relieve the ignorance of the introduced technologies and their continued mismanagement.

Discussion: Farmer and NGO Forum

Chair: A. Gharbaoui (Morocco)

Rapporteur: A. Souissi (Tunisia)

A. Zammouri (NGO, Tunisia): 1) What are the environmental and economic added value of shrub plantations compared to natural rangeland? 2) How can we benefit from research results, keeping in mind the high cost of shrub plantation and the uncertainty of success? 3) Several projects are supporting shrub plantations. What is the future of these plantations after the projects are terminated? 4) After two decades, methodologies are not uniform, and several non-technical problems remain unsolved. How can we convince farmers? 5) As an NGO, we request that development projects not be restricted to land belonging to the forestry domain. It would be better to include private land and to work with NGOs.

L. Karroumi (Morocco): L'avenir des arbustes dépendra du statut juridique des parcours. Actuellement, les arbustes sont installés sur du collectif: l'éleveur bénéficie d'herbe gratuite et n'investit pas. Si on privatise, le collectif sera mis en culture et l'arbuste sera condamné.

Comment: H.S. Oushy (Egypt): In Syria, forage research should include the ley-farming system or an integrated system between barley and fodder shrubs. In Egypt, the situation is completely different: the environment is more arid, and water-harvesting systems should be implemented to support fodder shrub plantation.

K. Nesheiwat (Jordan): Property rights and land tenure systems cause many problems for the adoption and expansion of fodder shrub plantations in the arid zones. We identify three categories of country:

- South Africa and Australia, where land-tenure problems are clear and solved.
- Morocco and Tunisia, which support privatization of the rangeland.
- Jordan, Pakistan, Syria, and Egypt, where shrub plantation faces failure after failure because property rights in low-rainfall areas are not clear and are subject to continuous argument.

M. Ali Jamil (Jordan): How can we achieve the participation of the local users through direct investment and, at the same time, try to achieve sustainable development, especially when we know the deserts are expanding onto the cultivable lands? We hope that the private sector and the cooperatives will take the leading role, accompanied by adequate extension and applied research.

A. Abdelguerfi (Algeria): Les agriculteurs tiennent au maintien de la culture de l'orge dans les régions arides et semi-arides. Il existe même des adages ou des proverbes mettant en évidence l'importance de l'orge en vert et en grain dans l'alimentation du cheptel. Cependant si, avant l'orge était localisée dans les bas fonds (les dayas), avec la mécanisation, l'orge est sortie de son terroir et a été pratiquée dans les zones inadéquates avec destruction des parcours.

A mon avis, il sera judicieux de maintenir l'orge dans les bas-fonds et introduire les arbres et les arbustes pour améliorer la production des parcours. L'agriculteur utilizera de façon complémentaire l'orge et les arbustes. Cette approche permettre une mise en confiance de l'agriculture et une gestion meilleure des parcours améliorés.

M. Tazi (Morocco): Since this meeting is unique because of the participation of farmers, I would like to see some original ideas coming from it. We might, for example, establish a fodder shrubs network for WANA and the Mediterranean region.

T. Daoudi (Farmer, Morocco): Nous aimerions que vous nous aidiez à développer les points suivants:

- Une augmentation des superficies plantées par des espèces qui ne détruisent pas la végétation spontanée et ayant une grande longévité.
- Des techniques de travail du sol qui amélioreraient l'infiltration de l'eau de pluie.
- Des techniques de rétention d'eau dans les zones à pente élevée.

Martine Rochon (Eleveur, France): La maîtrise du foncier est pour un éleveur un point très important car seule une maîtrise à long terme peut permettre une valorisation de son travail. La gestion d'un troupeau passe par une sécurité "relative" concernant le territoire de pacage. Si la propriété privée n'est pas possible, une gestion collective, associée à une politique des terres, avec compensation financière pour les propriétaires, doit être envisagée, soit en faisant ressortir des problèmes de sécurité en faveur de tous ; ex.: lutte contre les incendies de forêts et de parcours dans le sud de la France, soit dans un but de respect et d'entretien du "milieu naturel" et du patrimoine national. Une prise de conscience politique doit émerger et nous soutenir.

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