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in

Ferchichi A. (comp.), Ferchichi A. (collab.).
Réhabilitation des pâturages et des parcours en milieux méditerranéens

Zaragoza : CIHEAM
Cahiers Options Méditerranéennes; n. 62

2004
pages 267-283

Partnership for understanding land use/cover change and reviving overgrazed rangeland in Mediterranean areas: ICARDA's experience

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RESUME – *"Partenariat pour comprendre les changements d'utilisation des terres/couvert du sol et pour la régénération des parcours surpâturés dans les zones méditerranéennes : l'expérience de l'ICARDA". Les parcours méditerranéens, qui contribuent au revenu des populations les plus pauvres, ont atteint un degré alarmant de dégradation, nécessitant par conséquent une action rapide. Il y a eu une réduction drastique de la capacité des parcours comme source alimentaire pour le bétail et pour assurer un revenu durable aux bergers. La régénération des parcours épuisés et surpâturés de la région méditerranéenne est une préoccupation incontournable pour l'International Center for Agricultural Research in the Dry Areas (ICARDA). L'ICARDA a développé un solide partenariat avec des instituts et universités de recherche agronomique en Afrique du Nord. Il a également promu la participation dans de nombreux projets, d'un grand nombre d'interlocuteurs tels que ONG, secteur privé, services de vulgarisation, agriculteurs et autres usagers finaux, décideurs, centres internationaux de recherche, et bailleurs de fonds. En outre, des technologies, mécanismes, et processus ont été mis au point et testés dans le contexte de plusieurs projets. En matière de méthodologie d'investigation, le développement de l'approche communautaire permettant de passer de la recherche au développement a été une véritable percée. Elle a été développée dans le contexte du Projet Mashreq/Maghreb. L'approche communautaire facilite l'intégration de la recherche dans les politiques, le droit foncier, et l'environnement institutionnel et socio-économique, de façon à aborder les problématiques sous une perspective technique, socio-économique, culturelle, institutionnelle et sous l'angle des politiques. Fondé sur les résultats de la recherche, un "Plan d'Action Négocié" est mis au point après validation par toutes les parties prenantes. Dans un deuxième temps, le "Plan d'Action Négocié" est évalué et ensuite développé en "Plan de Développement Communautaire". Plusieurs études ont été entreprises pour comprendre les changements qui ont lieu concernant les pratiques d'utilisation des terres et de couvert du sol. L'histoire récente est marquée par une nette intensification de l'utilisation des terres cultivées et des zones steppiques. L'introduction de la mécanisation, qui s'est généralisée au cours des années 60 et 70, a permis une expansion considérable des cultures au détriment des steppes, et l'habitude de mettre en jachère les champs d'orge a été peu à peu abandonnée. Les résultats d'une étude de cas au Maroc indiquent que de façon générale le couvert végétal non cultivé a diminué entre 1988 et 2000, parallèlement à un grand accroissement des zones cultivées. En Syrie, l'intensification de l'agriculture et du pastoralisme a profondément modifié les conditions d'exploitation des ressources agropastorales. L'ICARDA et ses partenaires ont développé plusieurs technologies pour l'Amélioration et la Gestion Durable des Parcours en Zones Arides. Parmi celles-ci : (i) l'amélioration des terres marginales en utilisant des quantités et types appropriés de fertilisants phosphatés, le réensemencement avec des légumineuses natives des pâturages, et la mise en défens temporaire des pâturages pendant la floraison et la formation des graines ; (ii) le développement de technologies à faible coût pour le réensemencement des parcours ; (iii) l'utilisation de blocs alimentaires comme stratégie de supplémentation ; (iv) la technologie des cactus ; et (v) les cultures en allées. Nous montrons également comment encourager d'autres possibilités de revenu associées à travers la différenciation des produits et l'établissement de critères et normes de qualité (labels) ; la promotion de produits animaux autochtones et artisanaux, tels que le fromage, la laine et le cuir, et en particulier le développement de produits du terroir liés au travail des femmes ; ainsi que la promotion de plantes et arbres médicinaux, culinaires et aromatiques. En collaboration avec l'International Food and Policy Research Institute (IFPRI), des recherches ont été menées sur les politiques et les aspects institutionnels. Parmi celles-ci : (i) l'analyse de l'impact et du rôle des politiques du gouvernement par rapport à la production végétale et animale dans les zones à faible pluviométrie, et plus spécialement leur effet sur les incitations économiques pour une utilisation durable des ressources en terres et en pâturages et pour la lutte contre la pauvreté ; et (ii) l'analyse des aspects liés au droit foncier, ainsi que le rôle et l'efficacité des institutions locales pour réguler l'utilisation des parcours. Des stages et ateliers de formation se sont tenus pour consolider les compétences nationales. Les agriculteurs, chercheurs du pays, techniciens, agents de développement, décideurs et ONG ont bénéficié de ces activités de formation formelles et informelles, de ces ateliers, sorties de terrain, et démonstrations en extérieur*

Mots-clés *: Degradation, approche comunautaire, recherche integrée, technologies, politiques.*

Introduction

Fight against desertification in North Africa is an inevitable concern for the international Center for Agricultural Research in the Dry Areas (ICARDA). The area threatened with desertification in North Africa is estimated at about 121 million ha. Studies show that the economic and social consequences of desertification represent the most serious problem affecting the development of North African countries. These studies also confirm the preponderant role of desertification in aggravating global warming (UMA, 1999).

North Africa is characterized by fragile zones generally subject to desertification hazards caused by both natural factors such as climatic variability and land characteristics, and human factors such as over-exploitation of natural resources that lead to the deterioration of the land, loss of biodiversity and extension of desertification phenomena.

The climate and its component in these countries, which lie within the arid and semiarid zones, represent the most important factor in the repartition of the vegetation cover, the intensity of soil erosion, and the development of the desertification phenomena. Climate variability and particularly recurrent drought have a disastrous effect resulting in decreased land productivity, natural resources degradation, deterioration of standard of living of rural people, and rural exodus.

North African rangelands contribute to the living of the poorest population. They provide a large proportion of the feed requirements of livestock grazing and are an important source of domestic milk and proteins. Wood harvest is an important source of fuel for isolated or low-income human populations (Le Houérou, 1991). Rangelands are also a source of biodiversity including medicinal and herbal plants that enhance health care and rural well-being. In general, throughout the region, the degradation of the rangelands has reached an alarming degree, calling for prompt action. The capacity of rangelands as a feed source for livestock and ensuring the sustainable livelihood of herders has been drastically reduced due to the combination of various factors, including degradation due to overgrazing and expansion of cultivation.

The progressive degradation of the rangelands may be attributed to population pressure as traditional systems for managing the land, and the biodiversity it supports, are abandoned. Demographic and economic pressures have led to the widespread use of erosion-promoting cropping practices that are having detrimental effects on the environment and have generated serious problems associated with declining soil fertility and inadequate feed supply for livestock. To meet increasing demands for food and feed, farmers are using non-sustainable rotations such as cereal monoculture and there is an obvious expansion of rainfed crops (barley mainly) onto the best range in the 150-250 mm zone (Fig. 1). As a consequence, the area available for grazing is becoming smaller and the capacity of rangelands as a feed source for livestock and ensuring the sustainable livelihood of herders has been drastically reduced with more animals grazing fewer hectares. The degradation of the rangelands has reached an alarming degree, calling for prompt action.

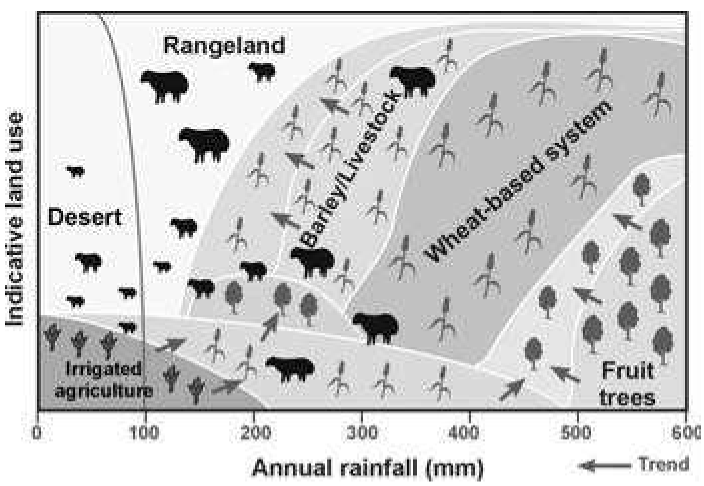

Fig. 1. Changes occurring in land use in North Africa and West Asia.

In the face of the great changes are occurring in land-use patterns that are causing desertification in North Africa, ICARDA, Arab Maghreb Union (AMU), national institutions, development agencies, farmers and NGOs are joining efforts to develop options and introduce practices for the sustainable conservation and use of natural resources for combating desertification and enhancing livelihoods. The present paper highlights some of the achievements to revive overgrazed land in North Africa.

Understanding the changes occurring in land-use patterns

Changes suffered by rangelands in North Africa

A study was undertaken in the Aïn Béni Mathar rural community in Morocco to assess the changes occurring in land-use patterns. The study was undertaken within the context of the "Sustainable Management of the Agro-Pastoral Resource Base in the Oujda Region (Morocco): A Regional Approach" Project funded by the Swiss Agency for Development and Cooperation (SDC), and jointly implemented by ICARDA and INRA Oujda (Morocco).

The Aïn Béni Mathar rural community is located northeast of the High-Plateaux. It covers 168 000 ha and has a population of 7300 inhabitants. Rangelands occupy 95% of the total area. Average annual rainfall is 180 mm/year, and very variable.

A participatory approach involving livestock owners' participation was combined with geographic information systems and remote sensing technologies. The different rangelands, as recognized by herders, were identified and mapped. Also, the extent of cultivation in each rangeland was monitored.

The comparison between 1988 and 2000 rangeland condition (Mahyou *et al.*, 2001; Fig. 2) showed that natural resources degradation is progressing, in particular:

- The *Stipa tenacissima* steppe in good condition decreased from 22,457 ha to 15,929 ha.
- Degraded *Stipa tenacissima* steppe increased from 54,149 ha to 56,188 ha.
- Overall degraded area increased from 53,541 ha to 72,228 ha, an increase due to the clearing of *Stipa tenacissima* and *Artemisia herba-alba* steppes.
- Degraded *Artemisia herba-alba* steppe decreased from 5,674 ha to 1,354 ha, mainly due to cultivation of these steppes.
- Irrigated area decreased from 1,818 ha to 1,617 ha.

The overall state of the non-cultivated vegetation cover has diminished between the two dates. The major increases in extent of cultivation occurred in the northern sector of the study area. More favorable conditions for agricultural production exist there due to a slightly higher rainfall regime and lower salinity of the predominant soil in the area.

To study changes that occurred in pastoral practices in the rural commune of Aïn Béni Mathar, semi-structured interviews were conducted with livestock owners. Workshops were organized to discuss land use and flock management. Important changes were observed in the pastoral system at Aïn Béni Mathar during the last decades. Traditional management used to be based on tribal organization and on the grazing of large areas to meet animal feed needs.

Currently, these systems are disappearing and are replaced with agropastoral systems characterized by intensification of livestock production and degradation of natural resources. There are new forms of pastoralists organization, of which pastoral cooperatives are the most common. There is less and less transhumance and rangelands are not used rationally. The best rangeland sites are converted to cropping areas. Smallholders are becoming more and more sedentary and contribute greatly to rangeland degradation. Pastoralists explain rangeland degradation according to their flock size: for smallholders it is rangeland cultivation; pastoralists with large flocks attribute rangeland degradation to the continuous grazing of the same site.

Livestock remains the principal source of income in the region. Clandestine flock mouvements from Algeria combined with the low rangeland productivity is obliging patoralists to adopt new strategies of livestock management. More and more farmers are raising the Algerian breed Ouled Djellal. The number of animals per livestock owner is decreasing. The use of supplementation is increasing. The decline in rangeland productivity, the high price of concentrate feed, and market competition have obliged many pastoralists to abandon livestock production resulting in rural exodus.

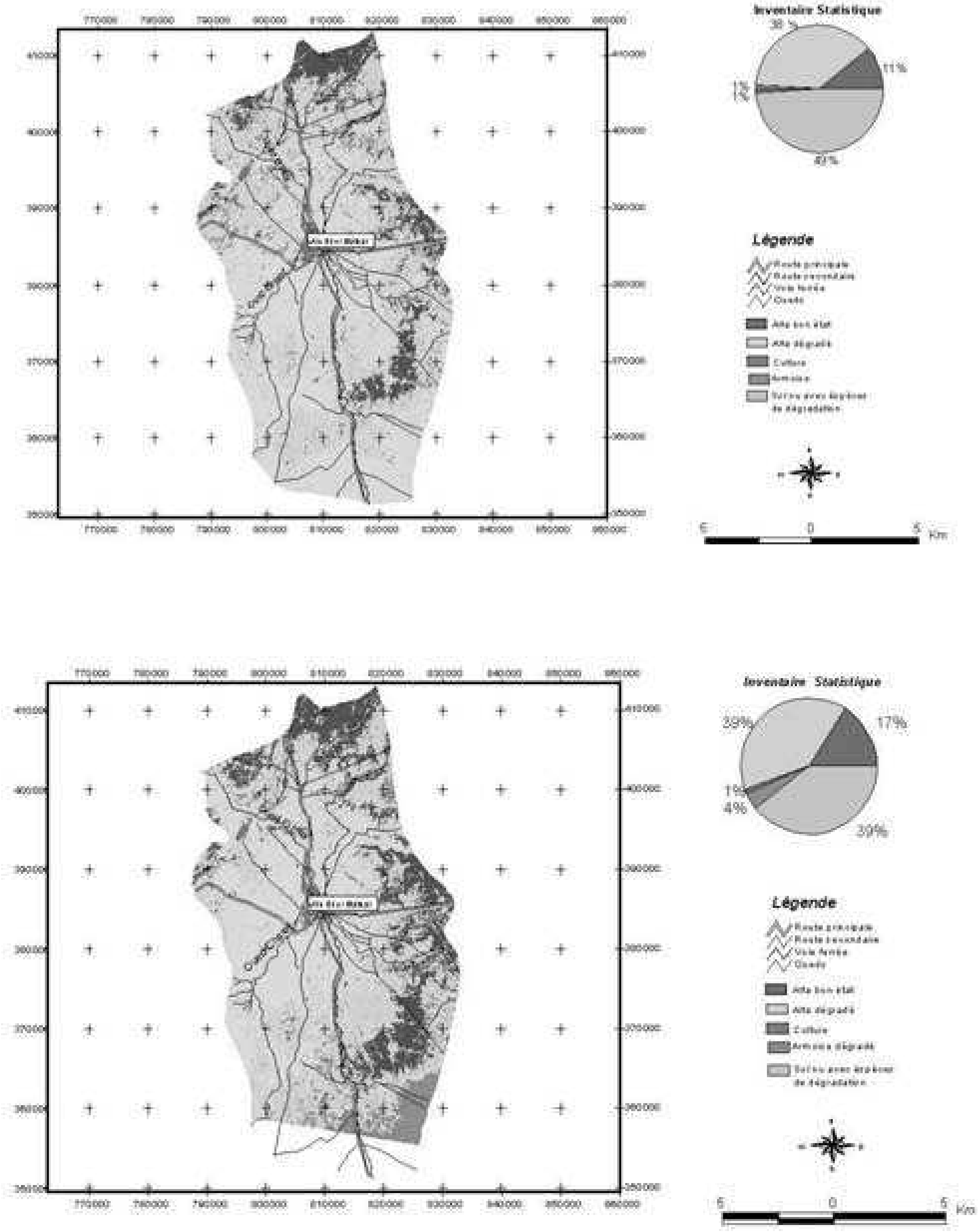

Fig. 2. Land use of the Aïn Béni Mathar rural community in March 1988 (top) and in March 2000 (down).

In Tunisia rangelands are also degrading since the 1960s (Azaiez, 2001). The profound socioeconomic changes, which resulted in a sedentary mode of living of pastoralists, have upset the management systems of the pastoral resources: clearing, overgrazing, and deforestation. Comparison of the state of rangelands between 1978 and 1999 showed (Fig. 3):

- A decrease in the steppe area of about 9.6%;
- A decrease in soil cover in all ecological system;
- A decrease or disappearance of palatable pastoral species;
- Changes in the physiognomy of pastoral species.

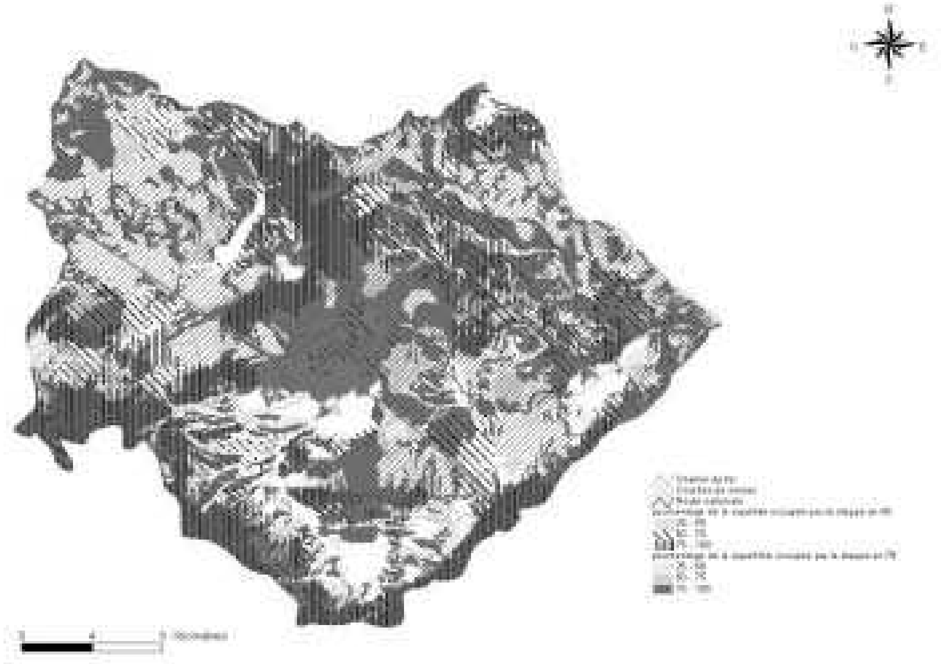

Fig. 3. Steppe degradation in Tunisia between 1978 and 1999.

Change in biological diversity

North Africa harbors a rich flora with a high number of endemics. The different soil, climate and management systems across these countries interact to provide a wide range of ecological situations resulting in a diverse flora (Sauvage, 1975). Several indigenous species could be used to restore degraded pastoral ecosystems and to combat desertification. *Acacia raddiana* is one of the few trees that grow in arid zones of in Tunisia and that needs more attention considering its strategic role. In addition to protecting land from erosion and providing feed for livestock, the tree has also several medicinal uses. In southern Morocco, the endemic Argan tree (*Argania spinosa*) plays important ecological, economic and health roles. Other target species in the region include *Stipa tenassissima, Artemisia campestris, Periploca laevigata, Matricaria chamomilla, Rosmarinus officinalis, Capparis spinosa, Ruta chalenpensis*, *Rhanterium suaveolens*, *Stipa lagascae*, *Cenchrus ciliaris, Plantago albicans* and *Thymus hirtus*.

Species and ecotypes have developed adaptive strategies to cope with prevailing conditions and several useful agronomic characters are associated with local germplasm. Adaptive features include summer dormancy in perennial grasses. One of the striking aspects of the climate is the low summer rainfall coinciding with a period of high temperatures. Dormancy enables plants to grow during the winter and survive the summer. In a Mediterranean environment, plant survival during the summer was 97% for Moroccan families of *Dactylis glomerata* compared to 59% for the purely European families (Knight 1966). Hardseededness is another important feature developed by annuals legumes to cope with the erratic Moroccan climate. For example, Moroccan strains of *Trifolium subterraneum* (Gladstones *et al*., 1981) and annual *Medicago* species (Crawford, 1985) are a source of hardseededness.

However, the continuous and accelerating over-exploitation of these native plants in their natural habitats, combined with the increasing demand for such plants, have led to destruction of the natural stocks in the wild. Many of them are endangered and some are threatened with extinction. The vegetation of the Mediterranean-type arid environments characterized by the predominance of shrubs is rapidly becoming shrubless steppe. The perennial vegetation has been almost totally destroyed by overgrazing and firewood collection, leaving the soil exposed. For example, the North African *Stippa tenacissima* steppes occupied some 12 million ha at the end of the nineteenth century and have now receded by about 50% owing to overexploitation, repeated burning for grazing, and clearing for cultivation; in Tunisia, the area of *Stippa tenacissima* steppe has reduced by an average of 10 000 hectares per year since the beginning of this century (Le Houérou, 1986). In the North African steppe, invaders such as *Noaea mucronata, Anabasis aphylla* and *Peganum harmala* are replacing *Artemisia herba-alba* (Berkat, 1986 ; Yessef, 1992).

There is an increasing evidence of genetic erosion and degradation of native perennial grass species in Morocco. The importance of conserving the genetic resources of these species has not been given the attention it deserves: genetic diversity is far from being adequately sampled and preserved. Increased cultivation, more intensive grazing, erosion, and climate change appear to be the factors contributing to the loss of Moroccan turfgrass biodiversity. During recent fieldwork, extensive rangeland areas in all of the geographical areas of Morocco were found to be overgrazed. Perennial grass species could only be collected in protected areas between cropping or horticultural paddocks and along roadside verges or reserves (Cunningham *et al.,* 1994). The sampling of only 22 accessions of *Phalaris aquatica* –with only one of these coming from the Rif mountains– is clear evidence of severe genetic erosion of this species, which was previously reported to be abundant in higher-rainfall regions of Morocco, especially in the Rif mountains. In eastern Morocco, evidence from the field suggests an irreversible degradation of *Stipa tenacissima* steppes into shrub steppes. At a time when breeders are placing more and more emphasis on low-maintenance, low-input grasses, it is frustrating –to say the least– to watch species rich in these traits disappear. Further collection and preservation are crucial if access to these precious genetic resources is to be maintained.

Developing methodologies

A real breakthrough in research methodology was the development of the community approach that helps getting from research to development. It was developed within the context of the Mashreq/Maghreb Project, coordinated by ICARDA and IFPRI and jointly implemented with eight countries in North Africa and West Asia. This approach enhances participation of a wide range of stakeholders to the generation and adoption of appropriate technologies and accompanying policy and institutional measures.

With the community approach, the adaptive research has shifted from with individual farmers to testing and evaluating combinations (or packages) of associated technologies at the community level. Significant efforts are devoted to characterizing the selected communities, and identifying key constraints and problems, as a basis for developing community action plans. Characterization of the selected communities is based on data collected from rapid rural appraisals, household surveys, secondary information, and informal discussions with community members. Characterization of communities involves mapping of resources and other descriptors. Community participatory mapping, in which community members draw their territory and resources, allows the community to express their own perceptions of their environment and land use.

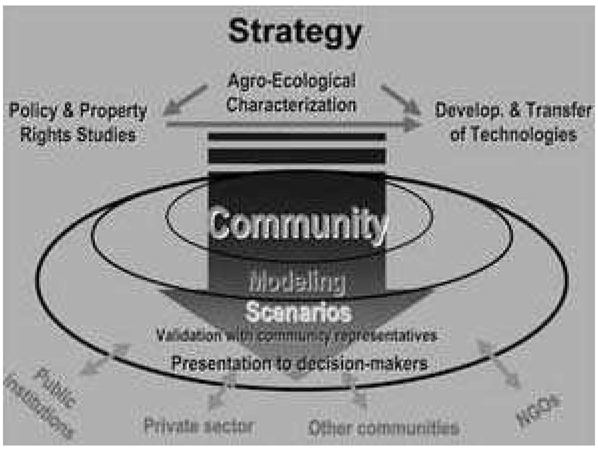

Fig. 4. Strategy and steps to implement the Community Approach.

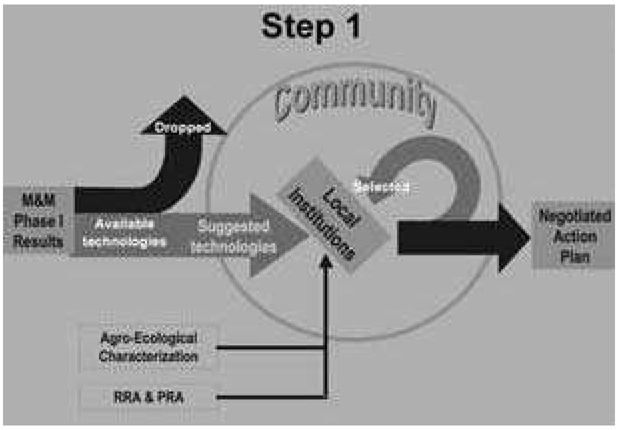

Fig. 4 (cont.). Strategy and steps to implement the Community Approach.

Initial meetings are held with communities to explain and discuss the project's activities and the available technologies. Based on the detailed characterization of the community, and the community members' own priorities, action plans for adaptive research and technology testing are developed. In some cases the project has assisted communities in establishing informal or formal organizations that will facilitate and support the uptake of new technologies or management strategies. For instance, in Lebanon, the project has assisted the communities in establishing specialized cooperatives for livestock producers.

Multidisciplinary and multi-institutional teams, decision-makers, end-users are involved. "Community teams" are established, consisting of project researchers, and community representatives, as well as representatives of local extension services, agricultural authorities, NGOs and other institutions. The community approach also facilitates the integration of research on policy, property rights, and the institutional and socioeconomic environment, so that issues are addressed from a technical, socioeconomic, cultural, and institutional and policy perspective. Based on research results, a "Negotiated Action Plan" is developed after validation by all stakeholders. In a second step, the "Negotiated Action Plan" is evaluated and then developed into a "Community Development plan". The strategy and steps to implement the community approach are shown in Figure 4.

Promoting native annual legumes to improve marginal land

Marginal lands are non-arable land within the cereal zone. They are normally characterized by steep terrain and stony or shallow soil, and are generally used as grazing land for flocks of sheep or goats. These lands vary greatly in terms of total rainfall, soil depth and soil fertility, abundance of stones, and presence and distribution of plant species. Most often, they are held under common property or open access. Marginal lands constitute a large proportion of the land surface in North Africa.

Degradation of marginal lands in the region is very common. Originally most marginal lands in the region supported perennial plants and shrubs. However, during the past few decades these lands have become denuded of perennials. The main causes are the increased populations of people and livestock, which leads to overgrazing, uprooting of shrubs and trees for fuel. As a result, annual plants and unpalatable spiny herbs and shrubs have replaced the original perennial species.

North Africa is an area rich in the genetic resources and is the center of origin and primary diversity of pasture and forage legumes: Vetch (*Vicia* spp.), *Lathyrus* spp., annual medics (*Medicago* spp.) and *Trifolium* spp., along with other lesser known genera. These native legumes can be used to improve marginal lands.

The international Center for Agricultural Research in the Dry Areas (ICARDA) has conducted several experiments to improve marginal lands. Trials, including a large one at Tel Hadya that lasted 12 years (Osman *et al.*, 1994), were conducted with the national programs at sites in Syria, Lebanon and Jordan, and investigated how best to rehabilitate these lands. Results showed that degradation of marginal lands can be reversed using appropriate amounts of phosphate fertilizers, re-seeding with native legumes, and deferred grazing during flowering and seed set.

Where legumes are a part of rangeland vegetation, and soil phosphate is limiting production, the application of phosphate fertilizer has potential for resource rehabilitation. As soil deficiency in phosphate widespread in the region, the effect of improving soil phosphorus on growth and productivity of native pasture legumes is profound. In Syria, at ICARDA's Tel Hadya research station where more than 40 legumes are a part of rangeland vegetation, annual applications of phosphorus, even as low as 25 kg P_2O_5/ha, alleviated the deficiency in soil P and resulted in improved pasture production, even in dry years (Osman *et al.,* 1991). When the trial began in 1983-84, the composition of legumes in spring vegetation ranged from 26 to 32%. Superphosphate application every year increased this percentage overall, but the response in an individual year was strongly affected by the seasonal rainfall (Table 1). By 1991 the P fertilizer had enhanced available soil phosphorus to 20.8 and 40.1 mg P/kg under the 25 and 60 kg P_2O_5/ha application rates, compared to only 6.5 mg P/kg under the control.

Table 1. Effect of 3 phosphate fertilizer treatments on cumulative yield of herbage (kg/ha dry weight) near end of April 1988 and 1989 (derived from Osman *et al.,* 1991), and proportion (%) of legumes in April biomass for 1988 (Osman *et al.*, 1989) and 1989 (Osman *et al.*, 1990). [precipitation 1987-88: 499mm; 1988-89: 224mm]

Parameter and year	Fertilizer treatment (kg P_2O_5/ha)		
	0	25	60
Yield in April			
1988	2150	3770	4500
1989	580	1165	1645
% legumes			
1988	48.5	51.5	48.7
1989	17	34	46

Where the seed bank is insufficient, over-seeding with indigenous pasture legume species is necessary. That was the case on communally-owned marginal lands in the barley/livestock zone of north Syria. In a series of experiments at El Bab district (Fig. 5), introduction of annual legumes significantly increased productivity (Ghassali *et al.*, 1999). There were more than 3,000 legume seeds/m^2 in the seeded treatment compared with less than 2,000 in the unseeded treatment. The number of medic and clover seedlings also increased significantly while the number of *Trigonella* seedlings decreased significantly. Biomass production increased in the final two years. Most successful species were *Trifolium. campestre, T. tomentosum, T. speciosum,* and *Medicago rigidula.*

Based on results from the region, species that are the most adapted to grazing and are recommended for reseeding degraded marginal lands include: *Trifolium angustifolium, T. campestre, T. haussknechtii, T. lappaceum, T. pilulare, T. purpureum, T. resupinatum, T. scabrum, T. speciosum, T. stellatum, T. tomentosum, Medicago rigidula, M. noeana, and M. rotata*.

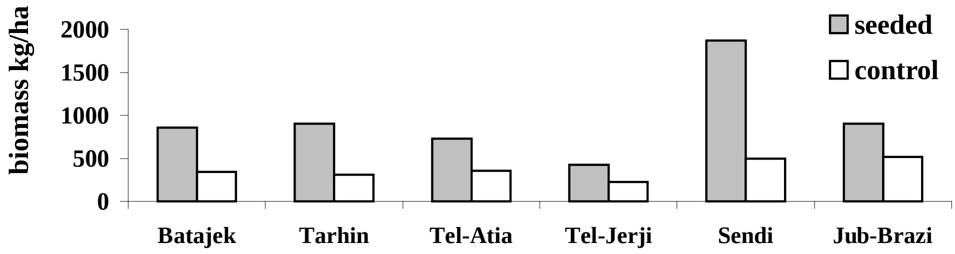

Fig. 5. Total biomass at different sites in the El-Bab area of north Syria, May 1997.

Grazing management must also be improved if the productivity of marginal lands is to be improved. To allow legume regeneration, particular attention should be given to grazing during flowering and seed set. Results from Osman and Cocks (1992) showed that partial protection from grazing (for one or two months in late winter and spring) more than doubled the number of legume seeds in the seed bank compared with full protection and open grazing. This phenomenon could be a useful management tool to help build up the seed bank of native legumes, which is an essential step towards the improvement of productivity in these degraded pastures. In his research on the seed bank dynamic of the Mediterranean grassland in Tel Hadya, Syria, Russi *et al.* (1992) studied the ecological and agricultural importance of seed banks in native Mediterranean grassland, concluded that under the grazing pressure implemented in this study grasses species showed little carry-over of seeds from season to the next. By contrast, about 30% of the legume seed bank particularly of the small seeded species (*Trifolium campestre* and *Trifolium tomentosum*) was carried over to the next season.

Shrubs as an intercrop with barley and with other common crops

Due to human and animal population growth, cropping has expanded into low rainfall and on very fragile environments. Cultivation expanded to the detriment of rangeland resources, resulting in increased feed deficit and soil erosion. To reverse the situation, ICARDA and its partners tested the suitability of shrubs as an intercrop with barley as well as with other common crops. The combination of crops with wide-spaced hedgerows of drought-tolerant fodder shrubs is a feasible solution. Results suggest that intercropping crops with *Atriplex* could greatly increase crop and animal production at the same time helping to protect fragile soils from wind and water erosion.

In Morocco, encouraging results were achieved in on-station and on-farm testing of *Atriplex* in combination with a range of grain crops, including barley, oats, a barley-fodder pea mixture and an oats-vetch mixture. Total biomass (Table 2) and grain yields were higher in intercropping systems, as also were energy and crude protein yields, which increased by 11-93% and by 16-196% respectively (Table 3). Intercropping improved land-equivalent ratios to 1.20-1.46, suggesting that this technology will be particularly useful in areas where farm size is small.

Table 2. Average DM biomass yields of different forage alternatives under alley cropping as compared to those of monoculture barley and weedy fallow in Morocco

Forage alternatives	Dry Matter (t/ha)	Variation (%)
Barley	4.43	100
Weedy fallow	3.07	69
Barley + shrub	5.04	114
Oats + Shrub	8.04	181
Barley/peas + shrub	6.96	157
Oats/vetch + shrub	7.39	167
Annual medics + shrub	4.94	112

Table 3. Comparison of Energy and Crude Protein yields and Land Equivalent Ratio (LER) of different forage alternatives under alley-cropping to those of monoculture barley and weedy fallow in Morocco

Forage alternatives	Energy		Crude Protein		LER
	FU/ha	%	Kg/ha	%	
Barley	2746.6	100	443.0	100	-
Weedy fallow	1074.5	39	245.6	55	-
Barley + shrub	3060.2	111	515.4	116	1.46
Oats + Shrub	4996.8	182	968.6	219	1.20
Barley/peas + shrub	5303.4	193	1233.8	279	1.39
Oats/vetch + shrub	5148.1	187	1311.2	296	1.41
Annual medics + shrub	3089.4	112	1007.0	227	1.25

And the technology is taking off. Indeed a total of 6000 ha have been already established in alley cropping systems on private farms within the context of the Taourirt-Tafoghalt project. This was a result of collaboration between different research and development projects such as the System-wide Livestock Shrubs Project, the Mashreq/Maghreb Project, the Taourirt-Tafoghalt Project. A further 8000 ha are planned to be planted in the two next years.

In Syria, the indigenous saltbush (*Atriplex halimus*) is being tested for its suitability as an intercrop with barley, the region’s major feed as grain, straw and stubble. The study is being carried out in the 200-250 mm rainfall zone in Khanasser Valley, 70 km southeast of Aleppo in northwest Syria. Farmers’ fields, each 2 ha, have been planted with *Atriplex halimus* in rows 10 m apart, 500 shrubs/ha. By the time they are ready for grazing in the second year after planting, the shrubs occupy about 10% of the field, calculated from their canopy cover. Several farmers have participated in the study over the past 4 years. Preliminary results presented in Table 4 show that yield of both barley grain and straw is enhanced in the intercropped alleys, and this higher yield compensates almost exactly for the 10% reduction in cropping area. The proportional increase in barley yield for an intercropped field compared to the control field was negligible in the most favorable season of 2001, but up to 30-40% in low-rainfall years. The benefit to barley production from shrub hedgerows is possibly due to a microclimate effect in which wind velocity is ameliorated and soil-water retention enhanced.

Table 4. Production of barley and shrub foliage (kg/ha) and rate of sheep liveweight gain (g/head/day) on pure barley fields compared to fields with hedgerows of *Atriplex halimus* (means of 6 trials)

	Pure barley field	Barley between hedgerows	Alley field (10% shrub)	% Change on a field basis
Barley grain	428.8	502.5	452.3	5.48
Barley straw	688.5	738.0	664.2	-3.53
Total barley yield	1117.3	1240.5	1116.5	-0.07
Shrub foliage	-	-	342.2	
Shrub plus barley	1117.3	-	1458.7	30.6
Live weight gain	108.9		116.4	6.9

The combination of native forage shrub and a cereal crop restores an element of rangeland to sites whose ecological integrity may have been better served if they had been left in their original rangeland state. The shrub foliage production is a bonus from the alley farming, amounting to an average of 342 kg/ha of forage in the ICARDA trials. Sheep grazing intercropped barley stubble in summer have access to the protein-rich *Atriplex* leaves, and daily weight gain on shrub fields was almost 7% higher than on stands of barley stubble alone (Table 4). However, the best indication that shrub alley-cropping has promise on marginal lands in West Asia may not be the trial results themselves, but rather the fact that farmers who are no longer participating in the research study have nevertheless kept the *Atriplex* hedgerows intact.

Reseeding fodder shrubs to bring them back to the steppe

In West Asia, there are huge areas in need of revegetation as millions of hectares are degraded. But only a small area has been replanted with fodder shrubs. A major reason is the high cost of the traditional method of rangeland regeneration. In winter, the soil is opened with an 80-cm deep, tractor-drawn ripping implement, and planted with three-to six-month-old seedlings raised in open-air nurseries. Transplanted seedlings must receive 10 liters of water three times in each of their first two summers, and they must be protected from grazing. Dead shrubs must be replaced, which is expensive and time-consuming.

To remedy this situation, ICARDA and national agricultural research system partners are testing low-cost, low-labor methods for establishing native fodder shrubs to reduce costs and cover larger area. One such method is called pitting, which involves direct seeding in shallow pits dug to catch rain run-off and organic matter. Researchers have developed a simple pitting implement (See *Caravan* No. 3), a modified disc plough mounted on a two-wheeled trailer that can be pulled by a car or light utility vehicle. The technique is cheap and has proved effective in establishing *Artemisia herba-alba* and *Salsola vermiculata* on the Syrian steppe and in the drier soils of northwest Egypt. ICARDA has since joined with the Badia Project Directorate (funded by IFAD) in Syria to produce the pitting implement.

An experiment (Gintzburger, 1998) was established in October 1997 at Odame station in the Aleppo Steppe, 20 km South of Khanasser village. Three common techniques were tested and compared with a control with no treatment: (i) Traditional broadcasting on soil surface of seeds with no soil preparation; (ii) harrowing before seeding; and (iii) pitting. Plant material used includes: *Atriplex halimus*, *A. canescens*, *A. leucoclada*, *Artemisia herba-alba*, *Salsola vermiculata* and *Haloxylon aphyllum*. Emerging seedlings were counted in late April 1998 to evaluate the establishment of the species with the different treatments. Results (Table 5) indicate that in terms of the seeding treatments, the pitting is significantly more efficient in terms of seedling emergence than the other seeding techniques. Among the species, *Salsola vermiculata* gave the best emergence in terms of number of seedlings, followed by *Artemisia herba-alba*. The interaction is highly significant when combining pitting with *Salsola*, but not significant for the other interaction.

Table 5. Emerging seedlings (No.) under different treatments

Seeding treatment	Species	Mean	*Std. Errr*	*95% Confidence Interval* Lower Bound	Upper Bound
Harrowing	*Atriplex halimus*	.107	1.891	-3.728	3.942
	A. canescens	-4.848E-16	1.891	-3.835	3.835
	A. leucoclada	.307	1.891	-3.528	4.142
	Artemisia herba-alba	1.920	1.891	-1.915	5.755
	Salsola vermiculata	1.213	1.891	-2.622	5.048
	Haloxylon aphyllum	-4.193E-16	1.891	-3.835	3.835
Pitting	*A. Halimus*	2.667E-02	1.891	-3.808	3.862
	A. canescens	1.067	1.891	-2.768	4.902
	A. leucoclada	.133	1.891	-3.702	3.968
	Artemisia herba-alba	4.013	1.891	.178	7.848
	Salsola vermiculata	14.960	1.891	11.125	18.795
	Haloxylon aphyllum	4.119E-15	1.891	-3.835	3.835
Broadcast	*A. Halimus*	-4.441E-16	1.891	-3.835	3.835
	A. canescens	6.141E-16	1.891	-3.835	3.835
	A. leucoclada	1.333E-02	1.891	-3.822	3.848
	Artemisia herba-alba	.427	1.891	-3.408	4.262
	Salsola vermiculata	.213	1.891	-3.622	4.048
	Haloxylon aphyllum	-1.520E-15	1.891	-3.835	3.835

Direct seeding may prove useless if not supported by appropriate range management measures carried out by the agro-pastoral communities and supported by government authorities. The plants being used are resilient to overgrazing but it may still take at least 10 years to reestablish a proper and valuable range cover. Controlled spring grazing would allow collection of the biomass from the annuals and not touch the perennials. Let's be careful when we deal with this and environment!

Potential germplasm for rangeland rehabilitation

A great number of range taxa thrive in the steppe of North Africa as well as in other similar environments. These represent a gold mine with huge potential to reverse land degradation in fragile arid and semi-arid environments in West Asia as well as in other parts of the world. Key species include *Artemisia herba-alba, Atriplex halimus, Haloxylon aphyllum, Haloxylon persicum*, *Kochia prostrata, Periploca laevigata* and *Salsola vermiculata,.*

These genetic resources remain largely unused for research and development both in the countries themselves and by the international community at large. However this unique source of novel genes and diversity of both crop and range species are under extreme threat of erosion. To this end, ICARDA increased its cooperation with NARS and international organizations interested in helping to conserve valuable and unique range plant germplasm.

For example, ICARDA and national research institutions in Morocco undertook a mission to assess rangeland biodiversity and collect native rangeland species. The collection covered 43 sites over an area of 2200 km and rainfall zones of 180 to 500 mm. Samples were collected at intervals of 10-15 km along the collection route. Over 385 accessions of at least 60 species were collected. *Stipa* spp. was most frequent (51 accessions of four species); *Artemisia* spp. was also found frequently; other species collected were *Helianthemum* spp., *Herniaria* spp., *Paronychia argentea*, *Schismus barbatus*, and *Thymus* spp. In areas where there was protection from grazing, vetch and medic species were collected.

A great number of range varieties and genuses are now saved. The gathered material is conserved at ICARDA either *in-situ*, as a living collection (Table 6) or *ex-situ* as a collection of seeds held in a cold storage facility. Importantly, source of germplasm was made available for national agricultural research systems in West Asia, Central Asia, and North Africa. Also, seed were provided to development projects in several countries for rangeland rehabilitation. For example, ICARDA provided the Marsa Matrouh Project, funded by the World Bank, with enough seed to the direct reseeding of 300 ha.

Table 6. A selection from the list of perennial species growing in the ICARDA germplasm nursery

Species	Source of germplasm	Species	Source of germplasm
Artemisia herba-alba	Spain, Syria, etc.	*Melica ciliata*	Turkmenistan
Atriplex canescens	U.S.A.	*Melica persica*	Turkmenistan
Atriplex cordobensis	Bolivia	*Onobrychis aurantiaca*	Syria
Atriplex glauca	Australia	*Onobrychis ptolemaica*	Syria
Atriplex halimus	Jordan, Tunisia	*Onobrychis sativa*	Turkey
Atriplex leucoclada	Jordan, Syria	*Opuntia ficus-indica*	Tunisia
Atriplex nitens	Uzbekistan	*Panicum turgidum*	Sudan
Atriplex nummularia	Australia	*Paronychia argentea*	Morocco
Climacoptera lanata	Uzbekistan	*Periploca laevigata*	Tunisia
Colutea gracilis	Turkmenistan	*Plantago albicans*	Syria
Colutea istria	Jordan	*Plantago psyllium*	Morocco
Coronilla glauca	France	*Plantago lanceolata*	Turkmenistan
Dactylis glomerata	Turkmenistan	*Salsola inermis*	Jordan
Ceratoides ewersmanniana	Uzbekistan	*Salsola orientalis*	Uzbekistan
Festuca elatior	Morocco	*Salsola paletzkiana*	Uzbekistan
Haloxylon aphyllum	Uzbekistan	*Salsola vermiculata*	Syria, Jordan
Haloxylon persicum	Syria	*Stipa caspia*	Turkmenistan
Kochia prostrata	Uzbekistan	*Stipa parviflora*	Morocco
Medicago arborea	Spain	*Thymus leucotrichus*	Morocco
Medicago citrina	Spain	*Zygophyllum atriplicoides*	Turkmenistan

Establishing fodder reserves on private farms

Drought is a recurring shock for the cropping and livestock systems of West Asia, and an inherent feature of the climate. In such erratic environment, plantation of fodder reserves could play a strategic role in time of shortage. Shrub and tree plantations should be used as strategic resources to complement natural shrublands in the form of browsing or feeding reserves. The remarkable tolerance of shrubs and trees to drought and their ability to accumulate green fodder over several seasons, or even several years, allows for the building up of fodder reserves that can be used in time of shortage, and so constitute a true *"drought insurance"* for livestock.

Fodder reserves can be of two types: browsing fodder reserves and feeding fodder reserves (Papanastasis, 2000). In the first case, shrubs and trees are planted in dense spacing in specific areas of a private farm for direct browsing by livestock. These reserves must be established on good soil so that they yield as much as possible and fenced. Animals graze only during the critical periods. For feeding fodder reserves, shrubs and trees are also be planted in dense spacing but for indirect feeding. Fodder shrubs or trees are cut and brought green to the animals in the barn. Species that can be used include *Acacia saligna, Atriplex halimus, Atriplex nummularia, Ceratonia siliqua, Medicago arborea* and *Opuntia ficus indica* var*. inermis.*

Fodder reserves can play a critical role in dry years. The example of Mr. Hassan A. Istaytyyah, a farmer from Lebanon, is illustrative. The farmer introduced *Atriplex halimus* as forage-shrub hedgerows in intercropping with vegetables and cereals. In normal rainy years, sheep flock graze the Atriplex and crop residues whenever the vegetable crop has reached the end of production. But during the drought years of 98-2000, the fodder reserves proved an invaluable resource. By cutting the bush at a height of 30 cm from ground and carrying the harvested fodder to the sheep in the barn, the farmer was able to sustain his flock on green feed till the late spring after which vegetable crop residues were available.

Spinless cactus : A strategic fodder for arid zones

Spineless cactus (*Opuntia ficus indica* var*. inermis*) is a multipurpose plant that fits well in crop–livestock systems in dry areas. In North Africa, spineless cactus is used as a feed source for animals in the desert margin and covers about 200,000 hectares. In West Asia, attempts have been made to introduce spineless cactus and results are encouraging. Jordan now has a project on the promotion of cactus production, and communities in Syria have also started cactus plantation.

Spineless cactus is well adapted to harsh conditions, helps in stabilizing sand dunes and controlling soil erosion particularly on sloping land. Benefits of these plant species include high biomass yield, evergreen habit, drought resistance, and salinity tolerance. Terminal and subterminal pads of spineless cactus have low crude protein (20 to 50 g/kg DM) and low crude fiber (80 to 150 g/kg DM) contents. However, they have high water (800 to 900 g/kg fresh weight) and ash (150 to 250 g/kg DM) contents. They are rich in readily available carbohydrates and vitamin A, but need to be supplemented with nitrogen.

Spineless cactus is very appropriate for supplementing poor quality diets. The intake of straw increases significantly with the increase of the amount of cactus in the diet (Nefzaoui *et al.*, 1993). Other trials show that cactus is a good supplement to ammonia or urea-treated straw, since it provides the necessary soluble carbohydrates for the efficient use of the non-protein nitrogen in the rumen.

Another advantage is that cactus help to overcome the need for watering animals–300 g DM of cactus in sheep diet to avoid watering (Ben Salem *et al*., 1996). In another experiment (Bensalem and Nefzaoui, 2001), sheep supplemented with cactus drunk less water than those receiving barley (Table 7). Drinking water consumption increased substantially when atriplex was associated to barley as supplements. Regarding water content of feeds, total water intake was higher in atriplex-containing diets [(B+A) and (C+A)] than B and C-diets. Energy and N sheep requirements may be matched by using cactus based-diets supplemented with *Atriplex* sp. (*halimus*, *nummularia*). It is possible to provide almost normal performances by feeding animals with diets containing limited amounts of hay and barley grain, and cactus and *Atriplex ad-libitum*. It is recommended to use such diets in dry years (Nefzaoui *et al*., 1996).

Table 7. Water intake (kg/d) of acacia-based diets supplemented with barley, cactus and atriplex

	B	C	B+A	C+A	SE	(B *v.* C)	(-A *v.* +A)
From drinking	1.2[b]	0.6[c]	2.8[a]	0.8[bc]	0.2	***	***
From feeds	0.6[c]	2.1[b]	1.7[b]	4.4[a]	0.2	***	***
Total	1.8[c]	2.7[b]	4.5[a]	5.2[a]	0.2	**	***

[a,b,c,d]means with different superscripts are significantly different (P<0.05).

**P<0.01, ***P<0.001,

[1]B: barley, C: cactus, B+A: barley and atriplex, C+A: cactus and atriplex. [2](B *v.* C): mean effect of barley supply as compared to the mean effect cactus supply, (+A *v.* -A) mean effect of diets supplemented with atriplex (+A) as compared to the mean effect of diets without atriplex (-A).

The feed blocks technology

Shortage of feed resources is one of the principal limiting factors affecting small ruminants productivity in the semi-arid areas of West Asia and North Africa (WANA). This shortage leads to an increasing pressure on rangelands and therefore to a rapid deterioration of the natural feeding sink in many areas of WANA. Furthermore frequent occurrence of drought in many countries of WANA results in widening the gap between feed supply and feed demand for sheep. On the other hand, considerable amount of crop residues and agro-industrial by-products (pulp of date, tomato and beet, brewer grain, wheat and rice bran, olive cake, molasses and poultry waste) is available. But these by-products are not efficiently utilized in small ruminant feeding. ICARDA and the national agricultural research systems, through the Mashreq/Maghreb (MM) Project, have been working side by side to make use of available by-products by reviving the feed block technology. The introduction of feed blocks technology, in addition to being an important contribution to small-ruminants production, is a good example of how ICARDA encourages the transfer of technology between a country and another. The feed block technology is simple and does not require sophisticated equipment. Manufacturing and handling of feed blocks is also easy and can be done at the farm levels using the family labor.

The feed blocks may contain different formulas with different levels of urea, binders and wide range of agro-industrial by-products, which are available locally. For instance, in Iraq, date pulp, rice bran, poultry waste are the main agro-by-products used whereas tomato and beet pulp and olive cake are used in Tunisia, olive cake and brewery grain in Jordan and molasses in Morocco.

Livestock owners have readily accepted feed blocks and the technology has rapidly spread through the countries involved in the MM project. It has been a major success in the region and has developed into a feed industry in Iraq where a large research effort is being invested in improving and adapting the technology to the semi-arid conditions of the country. Other countries, Jordan, Tunisia, Morocco have developed community feed blocks units. As a spillover, countries other those participating in the MM project have shown clear interest in the technology. Among those Saudi Arabia, Egypt, Eritrea and Turkey can be cited.

The feed blocks technology has wider benefits in addition to providing a valuable source of feed. It provides an alternative, relatively cheap source of feed, it relieves pressure on natural grazing resources, helping to combat degradation of rangelands and the loss of biodiversity from overgrazing.

Concluding remarks

The technologies described in this paper can contribute to restore good range condition. But alone they are not enough to reverse degradation, to allow maintenance of species diversity, and overcome feed shortage. Development of feed resources outside rangelands and policy are also important to achieve impact.

Development of feed resources outside rangeland

Rangelands in West Asia used to provide more than 60% of the diet for small ruminants. Now, that has fallen to as little as less than 10%. Livestock populations have generally increased over the past two decades due to rising economic demand, and rangelands cannot meet the need of growing livestock populations. Development of feed resources outside rangelands is as important as improving rangeland productivity and management.

Potential area to improve feed availability outside rangeland include:

- Growing more fodder in cropping areas;
- Transformation of by-products into cheap feeds to reduce costs of production: storage, feed blocks, straw treatment, weeding.
- More linkage of rangeland to cropping areas: arrangements between herders and farmers, growing fodder in the marginal rainfed areas, incentives for growing fodder in marginal areas.

Improved range management: not only a question of technology but also of policy

There are sufficient technical solutions to improve rangelands. However, experience shows that unless they are included within an institutional set up providing the required policy related to grazing rights, empowerment of herders, and better access to marketing, these technical options are not likely to be adopted.

We may be better-informed about the status and dynamics of semi-arid rangelands in dry areas, but we are still unable to reverse the decline in resource condition that has continued throughout the last half of the twentieth century, except in relatively small areas that have been placed under strict government control, such as in range reserves planted to forage shrubs. When it comes to better management of rangelands in general, appropriate technology is generally not among the limiting factors. Technologies such as those for describing resource condition, for rehabilitating vegetation using perennial species, and for more sustainable grazing management, are either currently available or readily adapted to specific situations. Their value in an applied context, however, depends on solving other constraints or land-use issues that impinge directly on rangeland management.

Two policy issues are of paramount importance to the future of rangelands. The first concerns the encroachment of crop cultivation into the best available grazing land, which incrementally and inexorably consumes natural forage resources. The predictable consequence for rangeland is an increase in grazing pressure and likely overgrazing on the remaining range resources, irrespective of livestock numbers. The predictable consequence for cultivated fields is soil erosion and lower crop yields, because the prerogative to cultivate virgin rangeland makes sustainable farming practices less relevant. A further consequence for the landscape as a whole is decline in biodiversity, an obvious feature of both farming and overgrazing. This problem of unrestricted cultivation on rangelands is being tackled in Syria through policy initiatives articulated in legislation, but regulation of cropping in the semi-arid zone is only one of two critical policy issues.

The second is concerned with grazing rights and land tenure for communal rangeland property. A common problem in the region is weak control over areas of rangeland by the people who are the primary users of those lands. Some form of pastoral cooperative is the contemporary substitute for the traditional tribal authority that could prevent flocks from outside the community from trespassing onto prime grazing land, but these cooperatives are often ineffective. Central governments are reluctant to assign sufficient responsibility to pastoral communities to allow them to exercise full land tenure privileges. Without effective local control over range resources, there is little incentive for pastoral communities to accept management recommendations or technological interventions that increase resource productivity, because intruders will compete for the benefit. Ultimately the implementation of any form of improved range management, outside government-protected areas, will depend on the ability to control land use, which calls for a powerful land-tenure policy for non-cultivated rangelands.

There is a need for a comprehensive approach to rangeland management which encompasses the farming sector as well as the livestock sector, with priority given to the establishment of policies which enable technological interventions to succeed. The responsibility of CG centers, NARS and other research groups in the region is not only to develop the technological packages that could be successful in a suitable policy and regulatory environment, but also to understand the socioeconomic context from which suitable policies will emerge, and in which those packages will be implemented.

Conclusions

In the face of the challenges facing rangelands and livestock producers in North Africa, combining of forces, sharing of the research findings and experience, and communication with end-users, are absolutely essential. To this end, ICARDA, Arab Maghreb Union, national institutions, development agencies, farmers and NGOs are joining efforts to add value to the ambitious programs launched by governments for the sustainable development of rangelands in the region.

ICARDA's achievements and experience combined with its involvement in the UNCCD and its commitment to fight desertification offer the hope and the scientific base of holding back the desert in arid environments. ICARDA has developed mature partnership with national agricultural research institutes and universities in North Africa. It has also involved in several projects a wide range of stakeholders including NGOs, the private sector, extension services, farmers and other end-users, policy-makers, international research centres, and donors. In addition, technologies, mechanisms, and processes were developed and tested within the context of several projects.

This set the ground for the empowerment of local communities for achieving a sustainable agriculture in dry areas. Local communities can better face the challenges of low rainfall areas: low productivity, land degradation, drought, desertification, high risk and uncertainty.

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