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Appropriate Technologies for Drought Mitigation in Agropastoral Areas of North Africa

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Abstract: The North Africa region, comprising Morocco, Algeria, and Tunisia, has been identified as a hot spot for high vulnerability to climate change. ICARDA has established a strong partnership in dryland research jointly with national agricultural research systems (NARS) with a focus to reduce food insecurity and enhance sustainable livelihoods of farming communities. Agriculture in the region is marked by acute water scarcity and strong dependence on low, erratic and decreasing rainfall and a predominance of rainfed crop-livestock systems. High population growth rate coupled with low agricultural productivity led to widening food deficits that are met by increasing food imports. The pastoral and agropastoral systems in North Africa have been submitted to deep mutation that affects the mobility pattern of the flock, the feeding strategy which relies more on supplement feeds rather than natural grazing. Production systems are intensifying and it is now possible to find in the steppe a continuum between intensive fattening units that are developing in peri-urban areas and along the main transportation routes, mixed grazing-fattening systems, and purely intensive systems based on hand feeding only to provide feed supplements to animals. Agropastoral societies have developed their own strategies for coping with drought and climate fluctuation. ICARDA worked on two major themes to help pastoralists to adapt to these deep changes, namely matching small ruminant breeds to environment and developing efficient animal feeding techniques that lower the cost of production while using local products. Indeed, in North Africa 7 of the 16 sheep breeds of the arid regions are at high risk of disappearance, either because animals are totally replaced by exotic species or because they are crossbred with more productive breeds. On the other hand, many experiments have shown that efficient animal feeding using local alternative feeds like by-products processed as feed blocks, native or exotic shrubs (*Atriplex*) and trees (*Acacia*) allow significant reduction in feeding costs and reduce import of cereals.

Key Words: Drought, Shrubs, Small ruminants feeding, Soil and water conservation

1. Introduction

The dominant agricultural production systems in North Africa are based on livestock and crops, and livestock are the main source of income of rural populations. Sheep and goats make up the major livestock species in North Africa with 30 million and 10 million head, respectively (Iniguez *et al*., 2005a). Two critical trends prevail in the current production context: (i) The first trend involves a crisis in the feed supply reflecting water scarcity, exacerbated by the progressive decline of rangeland productivity due to overgrazing, cultivation encroachment, or the disruption of institutional arrangements for resource utilization. Moreover, very low ratio of cultivated forages prevails in the cropping systems. (ii) The second trend involves the expansion of market demand for livestock products leading to opportunities for productivity and income improvement.

Several factors including climate change threaten the sustainability of the production systems. Management of the production risk caused by the fluctuation of feed availability is the main problem hampering the development of livestock production in North Africa. Under the framework of research for development project, the Mashreq/Maghreb project, NARS and ICARDA developed over a decade sound technical, institutional and policy options targeting better crop/livestock integration, community development and improvement of the livelihoods of agropastoral communities in 8 countries (Algeria, Iraq, Jordan, Lebanon, Libya, Morocco, Syria and Tunisia). These options include (i) organization of local institutions to facilitate both collective and individual adaptation and response to climate change, (ii) an innovative approach to their sustainable improvement and management including institutional solutions for access to communal/collective rangelands, (iii) better use of local natural resources with an emphasis on water harvesting and appropriate use of adapted indigenous plant species, such as cactus and fodder shrubs, and (iv) efficient animal feeding involving cost-effective alternative feeds including feed blocks, and nutrition and health monitoring.

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2. The Pastoral and Agropastoral Systems in North Africa are in Transition

The pastoral and agropastoral societies in North Africa went through deep mutation during the past few decades. In the mid-20th century, the mobility pattern of the pastoralists was dictated by accessibility and availability of forage and water. With the mechanization of water transportation and the reliance on supplemental feed, animals can be kept continuously on the range, which disturbs the natural balance and intensifies range degradation (Nefzaoui, 2002, 2004). Mechanization profoundly modified rangeland management in the steppes of North Africa. Water, supplements and other services are brought by trucks to flocks. As a result, families settle close to cities for easier access to education, health, and other services, with only sheepherders moving flocks to target grazing areas (transhumance). Production systems are intensifying and it is now possible to find in the steppe a continuum between intensive fattening units that are developing in peri-urban areas and along the main transportation routes, mixed grazing-fattening systems, and purely intensive systems based on hand feeding only to provide feed supplements to animals.

Agropastoral societies have developed their own strategies for coping with drought and climate fluctuation. These strategies include (Hazell, 2007; Alary *et al*., 2007): mobile or transhumant grazing practices that reduce the risk of having insufficient forage in any location; feed storage during favorable years or seasons; reciprocal grazing arrangements with more distant communities for access to their resources in drought years; adjustment of flock sizes and stocking rates as the rainy season unfolds, to best match available grazing resources; keeping extra animals that can be easily sacrificed in drought conditions, either for food or cash; investment in water availability (wells, cisterns and water harvesting); diversification of crops and livestock (agropastoralism), especially in proximity to settlements, and storage of surplus grain, straw and forage as a reserve in good rainfall years; diversification among animal species (sheep, goats, cattle, camels, donkeys) and different breeds within species; income diversification into non-agricultural occupations, particularly seasonal migration for off-farm employment in urban areas.

However, recent infrastructural and demographic changes as a result of urbanization have made such strategies less effective. In a recent study conducted within the Mashreq/Maghreb project in Chenini agropastoral community, in Southern Tunisia, perception of drought and livelihood strategies to mitigate drought has been investigated using a "sustainable livelihood approach" (Nori *et al*., 2009). Results show in the thirties drought mitigation depended on strategies such as transhumance, food and feed storage and goat husbandry that could be implemented by individuals. These options gradually shifted towards a significant reliance on government intervention mainly through subsidizing feeds and facilitating feed transport from the North to Southern arid areas.

However, science and technology, including climatic adaptation and dissemination of new knowledge in rangeland ecology and a holistic understanding of pastoral resource management, are still lacking. Successful adaptation depends on the quality of both scientific and local knowledge, local social capital and willingness to act. Communities should have key roles in determining what adaptation strategies they support if these are to succeed.

3. Matching Small Ruminant Breeds to Environments

It is widely recognized that pastoralists and their communities play an important role in conserving domestic animal diversity. In North Africa seven of the sixteen sheep breeds of the arid regions are at high risk of disappearance (**Table 1**), either because animals are totally replaced by exotic species or because they are crossbred with more productive breeds.

Most of these local breeds (Table 1) are well adapted to harsh environments and their genetic makeup is attracting interest by many western countries that are preparing for the predicted effects of climate change. ICARDA has been documenting the status of the diversity and phenotypic characteristics of sheep and goat breeds in the West Asia and North Africa (WANA) region jointly with NARs partners. Many breeds are shared across the region and have important adaptive traits to dryland conditions (Iñiguez, 2005).

4. Efficient Animal Feeding Using Cost-Effective Alternative Feeds

Managing the production risk caused by the variability of feed availability is the central issue in the small ruminant (SR) production system in the WANA region. Desertification, increased drought frequency and duration, greenhouse emissions, and decreased livestock performance, justify the need for a bettter understanding of alternative feeding strategies for the improvement of animal production without detrimental effects on the environment. Moreover, the development of simple and cost-effective techniques such as feed blocks, pellets, and silage (Ben Salem and Nefzaoui, 2003) can add value to local feed resources (*e.g.* agroindustrial byproducts), while providing much needed seasonal livestock supplements for smallholders.

Table 1. Sheep breeds of non-sedentary (pastoral and semi-pastoral) production systems in North Africa (Dutilly-Diane, 2007).

Breeds	Average rainfall (mm)	Country*	Risk to genetic erosion	Primary purpose
Atlas Mountain breed	500 (mountain)	M	High	Meat + wool + skin
Barbarine	75-500	MATL	High/low	Meat, milk
Barki	150-300	EL	None	Meat, wool
Beni Guil	100-250	M	High	Meat, wool
Berber	450-500 (mountain)	A	High	Meat, milk
Boujaad	300	M	None	Meat, wool
D'man	100 (oasis)	MAT	High	Meat, manure
Farafra	100 (oasis)	E	None	Meat, wool
Hamra	200-250	A	High	Meat, fleece, milk
Ouled Djellal	200-500	AT	None	Meat, fleece, milk
Queue Fine de l'Ouest	200-400	T	None	Meat
Rembi	300	A	Moderate	Meat, fleece, milk
Sardi	300	M	None	Meat
Taadmit		A	Extreme	
Tergui-Sidaou	50	A	Low	Meat
Timahdite	500 (mountain)	M	None	Meat, wool

(*) A: Algeria, E: Egypt, L: Libya, M: Morocco, T: Tunisia.

Table 2. Productive, environmental and social benefits from some alternative feeding options (Nefzaoui *et al*., 2011).

Options	Impact on the animal	Impact on the environment	Impact on farmers livelihoods
Feed blocks (FB)	- Improved digestion of low quality diets and increased growth and milk production - Improved health conditions due to decreased parasitic load (use of medicated FBs)	- Decreased pollution with perishable AGIBs (olive cake, tomato pulp, etc.) - Decreased pressure on rangelands - Better quality manure	- Decreased feeding cost, increased animal performance and hence higher income - Diversification of farmers' income (sale of FBs) - Employment generation through mechanized unit for FBs making
Cactus (*Opuntia* spp.)	- Improved digestion of low quality forages - Improved animal performance	- Improved soil condition - Decreased pressure on primary resources (water and rangelands)	Added value cash crop (fruit and cladodes sale), and increased animal performance result in increased income
Shrub mixing	- Complementarities between shrub species (nutrients and secondary compounds) increased animal performances	- Combat desertification - Soil protection	Reduced budget allocated for feedstuffs purchasing
Rangeland resting	- Increased feed intake and digestion - Increased productive and reproductive performances	- reduces degradation risk - Protection of plant and animal biodiversity (domestic and wildlife animals)	- reduced feeding cost and increased performances resulting in increased income

The main benefits from these options for the animal, the environment and their impact on farmers' livelihoods are reported in **Table 2**. Overall the interesting results on the positive effect on animals of tannins (*e.g. in situ* protection of dietary proteins, defaunation, reduced emission of methane, anthelmintic activity) and/or saponin (*e.g.* increased absorption rate of nutrients, defaunation, decreased production of methane) containing forages to improve feed efficiency and to control gastrointestinal parasites, and thus improve the productive and reproductive performance of ruminants should promote plants rich in secondary compounds in grazing systems. These options offer promising solutions to reduce the use of chemicals in livestock production systems to enhance livestock productivity and to decrease emission of methane (Nefzaoui *et al*., 2011).

4.1. Feed Blocks (FBs) technology

Cold-processed feed blocks are made of a mixture of one or more agro-industrial by-products (*e.g.* olive cake, tomato pulp, etc.), a binder (*e.g.* quicklime, cement and clay), water and common salt, as well as urea with or without molasses. The technique of FB making is well described in the literature (*e.g.* Ben Salem and Nefzaoui, 2003; Ben Salem *et al*., 2005a). Some variations in the blocks include the incorporation of

Table 3. Compiled data on the potential use of feed blocks as alternative feed supplements for sheep and goats in the Mediterranean area (Ben Salem *et al.*, 2005a).

Basal diet	Supplement*	Animals	Growth rate (g/day)	Feeding cost variation	Country
Stubble grazing	Concentrate (250 g/d)	Lambs	95		Algeria
Stubble grazing	Conc. (150 g/d) + FB1	Lambs	136	-81%	Algeria
Wheat straw *ad lib*	Conc. (500 g/d)	Lambs	63		Tunisia
Wheat straw *ad lib*	Conc. (125 g/d) + FB2	Lambs	66	-11%	Tunisia
Acacia leaves	FB4	Lambs	14		Tunisia
Acacia leaves	FB5 enriched with PEG	Lambs	61		Tunisia
Rangeland grazing	Conc. (300 g/d)	Kids	25		Tunisia
Rangeland grazing	FB4	Kids	40		Tunisia

(*) FB1: wheat bran (10%), olive cake (40%), poultry litter (25%), bentonite (20%), salt (5%); FB2: wheat bran (25%), wheat flour (15%), olive cake (30%), rapeseed meal (10%), urea (4%), quicklime (8%), salt (5%), minerals (1%); FB4: wheat bran (28%), olive cake (38%), wheat flour (11%), quicklime (12%), salt (5%), minerals (1%), urea (5%); FB5: wheat bran (23%), olive cake (31.2%), wheat flour (9%), quicklime (9.9%), salt (4.1%), minerals (0.8%), urea (4.1%), PEG (18%).

polyethylene glycol as a tannin-inactivating agent, which has increased the utilization of tanniniferous browse foliage in ruminant feeding (Ben Salem *et al*., 2007). Mineral enriched FBs (*e.g.* phosphorus, copper, etc.) are distributed to animals to mitigate deficiency and improve reproduction in ruminants. Benefits from the integration of FBs in the diet of sheep and goats are reflected by data compiled in **Table 3**. It is clear that depending on the formula, FBs can partially or totally replace concentrate feeds, thus reducing feeding costs without detrimental effects on livestock performance.

4.2. Fodder Shrubs and Trees (FST) in the smallholders farming systems

Trees and shrubs are part of the Mediterranean ecosystem. They are present in most natural grazing lands of the North Africa region. Some species are high in essential nutrients and low in anti-nutritional factors (*e.g. Morus alba*), whereas some others are low in nutrients but high in secondary compounds (*e.g. Pistacia lentiscus*) while some shrubs are high in both nutrients and secondary compounds (*e.g. Acacia cyanophylla*, *Atriplex* spp.). Such characteristics enable the plants to withstand grazing and to provide ground for selective grazing. In arid and semi-arid North Africa regions where available forage species cannot grow without irrigation, FST could be used as feed supplements. Saltbushes (*Atriplex nummularia*, *Atriplex halimus* and *Salsola vermiculata*) are planted in dry zones in North Africa and have many advantages because of their wide adaptability to harsh agro-climatic conditions and ability to grow for a longer period. As trees require little care after establishment, the production cost is low (Nefzaoui *et al*., 2011).

4.3. Alley-cropping

This technique consists of cultivating herbaceous crops of both graminae and legumes species between rows of trees or shrub species. Among the reasons for the low adoption of pure shrubs planting are the technical design of plantation, mismanagement, and competition for land often dedicated to cereal crops. Alley cropping overcomes some of these disadvantages because it (1) improves soil; (2) increases crop yield; (3) reduces weeds and (4) improves animal performance. Properly managed alley-cropping allows diversification to benefit from several markets. It also promotes sustainability in both crop and livestock production. Benefits from the cactus-barley alley cropping system were evaluated in Tunisia (Alary *et al*., 2007; Shideed *et al*., 2007). Compared to barley alone, the total biomass (straw plus grain) of barley cultivated between the rows of spineless cactus increased from 4.24 to 6.65 tones/ha and the grain from 0.82 to 2.32 tones/ha. These results are due to the change of the micro-environment created by alley-cropping with cactus, which creates a beneficial 'wind breaking' role that reduces water loss and increases soil moisture. The barley crop stimulated an increase in the number of cactus cladodes and fruits, while the cactus increased the amount of root material contributing to the soil organic matter. The alley-cropping system with *Atriplex nummularia* proved efficient in the semi-arid regions of Morocco (annual rainfall 200-350 mm). Barley was cropped (seeding rate 160 kg/ha) between *Atriplex* (333 plants/ha) rows. Compared to farmers' mono-cropping system, dry matter consumable biomass yield of *Atriplex* was significantly higher in the alley-cropping system. The latter system was more profitable than mono-cropping. Indeed, Laamari *et al*. (2005) determined the net benefit from *Atriplex* monocropping and Barley-*Atriplex* alley cropping over 15 years. The cumulative net benefit was 732.18 \$/ha and 3,342.53 \$/ha, respectively. The economic and agronomic assessment of alley cropping shows that this technology is economically profitable. Therefore, it should be extended on a large scale in the agro-pastoral areas of the North Africa region.

Table 4. Effect of shrub mixed diets on sheep and goat growth (adapted from Nefzaoui *et al*., 2011).

Basal diet	Supplement	Animal	Daily gain (g)
Acacia (417 g/d)	Atriplex (345 g/d); Barley (280 g/d)	Lambs	54
Cactus (437 g/d)	Atriplex (310 g/d); Acacia (265 g/d)	Lambs	28
Cactus (499 g/d)	Straw (207 g/d); Atriplex (356 g/d)	Lambs	81
Atriplex grazing	Cactus (290 g/d)	Lambs	20
Native shrubland grazing	Cactus (100 g/d); Atriplex (100 g/d)	Kids	60

Acacia: *Acacia cyanophylla*; Cactus: *Opuntia ficus* indica f. inermis (cladodes); Atriplex: *Atriplex nummularia*. (2) Values between parentheses are daily dry matter intake.

4.4. Shrub mixing technique

Most Mediterranean fodder shrubs and trees are either low in essential nutrients (energy and/or digestible nitrogen) or high in some secondary compounds (*e.g. saponins, tannins, oxalates*). These characteristics explain the low nutritive value of these fodder resources and the low performance of animals. For example, *Acacia cyanophylla* foliage is high in condensed tannins but low in digestible nitrogen. *Atriplex* spp. are low in energy and true protein although they contain high levels of crude protein, fibre and oxalates. *Cactus cladodes* are considered an energy source and high in water but they are low in nitrogen and fibre. Moreover, they are remarkably high in oxalates. A wealth of information on the complementary nutritional role of these three shrub species and the benefit of shrub mixing diets for ruminants, mainly sheep and goats, are reported in the literature (Ben Salem *et al*., 2002, 2004, 2005b). This technique permits balancing the diet for nutrients and reducing the adverse effects of secondary compounds and excess of minerals including salt. The association *Cactus-Atriplex* is a typical example of shrub mixing benefits. The high salinity and the low energy content of atriplex foliage are overcome by cactus. Some examples of the effects of shrub mixed diets on sheep and goats performance are reported in **Table 4**. In summary, diversification of shrub plantations should be encouraged to improve livestock production in the dry areas of North Africa.

5. Conclusions

Small ruminant production is the main source of income in arid areas of North Africa. Water scarcity and frequent droughts exacerbated by climate change together with mutation of pastoral and agropastoral production systems are putting this asset at risk. Agropastoral and pastoral societies have developed their own strategies for coping with drought and climate fluctuation; however recent changes have made these strategies less effective. ICARDA developed alternative technologies and approaches to help reduce the effects of droughts, including: conservation and improvement of well adapted local breeds of small ruminants; development of feeding techniques and strategies based on the better use of local by-products and shrubs and trees and alley cropping system. These options reduce the feeding cost and imports of feeds.

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