Annals of Arid Zone 50(1): 1-10, 2011

Coping with Climate Change and Risk Management Strategies for Sustainable Rangeland-based Systems in WANA Region

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Received: November 2009

Abstract: Livestock is still the main source of income of rural populations in the West Asian and North African (WANA) countries. However, many factors including climate change are threatening the production systems. There are considerable gaps in our knowledge of how climate change will affect livestock systems and the livelihoods of these populations. Management of the production risk caused by the fluctuation of feed availability is the main problem hampering the development of livestock production in the WANA region. To overcome this situation governments emphasize different interventions, mainly subsidies, which are costly and use resources that could otherwise be spent for development purposes. This paper reviews some technical, institutional and policy options to help developing drought mitigation strategies. These options were developed and or evaluated in NARS and ICARDA over a decade under the framework of the Mashreq/Maghreb project targeting better integration of crop and livestock, community development and the improvement of the livelihoods of agropastoral communities in 8 countries of WANA. 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, (iv) efficient animal feeding involving cost-effective alternative feeds like feed blocks and health monitoring, (v) the use of biotechnology as a potentially effective tool to breeding drought resistant forages and cereals and to biodiversity protection, (vi) development of early warning systems building on local knowledge, livelihood strategies and modern tools to forecast information on biophysical, economical, and markets environment to agropastoral communities. Success stories and difficulties faced when adopting these options are discussed.

Key words: Climate change, rangeland, livestock, drought mitigation grazing, ruminants.

Most rangelands in the dry areas of WANA stand on non-arable lands characterized by a low (<200 mm) and variable rainfall, shallow soils, rocks dominance, steep slopes, or a combination of these characteristics. These rangelands contribute significantly to the livelihoods of some of the poorest and vulnerable populations in the world primarily by providing grazing for livestock.

WANA's rangelands cover ca. 555 Mha, 90% of which are considered degraded dryland (Lal, 2002). Short and long-term climatic drought variability, which affects the availability of grazing resources and sometimes livestock drinking water supplies, associated to land use change, fuel wood collection and improper grazing practices (overgrazing and early grazing) are the main causes of rangeland degradation. In North Africa for example, the perennial biomass of the steppic vegetation has decreased from 1000-1500 kg DM ha^{-1} to 200-500 kg DM ha^{-1} in 50 years (Le Houérou, 2000). Depending on the year, these rangelands contribute nowadays between 10 to 25% to livestock needs, compared to 65 to 80% in 1960.

Small ruminant (SR) production is an important component of the agricultural sector in most of the arid WANA countries. During the last fifty years the region has been facing a substantial increase in SR population driven by more demands for animal products, mainly meat and milk. Adhesion of WANA countries to the world trade agreements put them at a comparative disadvantage for SR production as not being competitive at a global level. Investment in agricultural sector and particularly in low rainfall areas has been very low. Climate change exacerbated this unfavorable

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environment and led to more water scarcity and poverty, resulting in an increased risk and vulnerability of herders (Nefzaoui *et al*., 2008).

Small ruminant production systems in these areas are facing serious challenges to their sustainability (Alary and El Mourid, 2007) deriving from: (i) climatic constraints represented by the low and erratic rainfall and the high incidence of droughts, affecting the productivity of rangeland ecosystems and the livelihoods of the population; (ii) the desertification spiral, which accelerated during the droughts of the 1980s and the late 1990s, coupled with changes in livestock and range management practices; (iii) technical constraints underpinned by shortages in improved technologies to restore the ecological integrity, function and services of the degraded rangeland ecosystems, as well as the absence of monitoring and early warning systems; (iv) socio economic limitations, including the high poverty and vulnerability rates of the population, which are exacerbated by unstable feed and animal market conditions and limited diversification of income sources; and (v) institutional obstacles linked mainly to continued cross-lawful inefficiencies on issues dealing with land use, coupled with the inadequate capacity of local institutions for land use control and management, and weaknesses in the system of incentives for adoption of improved land management practices, and in the drought mitigation approaches (Alary and El Mourid, 2007; Nefzaoui *et al*., 2008).

The pastoral and agropastoral societies went through deep mutation during the last decades, which includes (Bourbouze, 2000):

- Dismantlement of traditional organizations (informal institutions/community-based organizations)
- Privatization of communal rangelands and the development of barley and tree cropping
- Regression of animal mobility with the sedentarization of the population. Only poor herders remain full transhumant
- Increasing demand for livestock products leading to an increasing pressure on rangelands and subsequent degradation
- Increasing reliance on supplemental feed.
- Mechanization (water and feed transport) that modified the management of rangeland
- Inequality between poor and rich herders (less opportunity to purchase feed, drought mitigation policies favor pastoralists with large flocks).

In the mid-20th century, the mobility pattern of the pastoralists was perfectly matched to 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 the degradation process (Sidahmed, 1996; Nefzaoui, 2002; 2004). Mechanization profoundly modified rangelands' management in the steppes of the WANA. Water, supplements and other services are brought by trucks to flocks. As a result, the family is settled close to cities to have access to education and health services, and only sheepherders move up with their flocks to target grazing areas (transhumance).

Production systems are intensifying and it is possible nowadays to find in the steppe a continuum between intensive fattening units that are developing in peri-urban areas and along the main transportation axes, mixed grazing-fattening systems and pure intensive systems where hand feeding is only used to provide feed supplements to animals. In addition and when terms of trade conditions are favorable, herders in WANA are switching from permanent livestock production to "opportunistic livestock production".

Off-farm income and immigration are playing an increasing role in pastoralists' economy, especially to young generation. The overall impact is not known, but migrants are reinvesting their earnings in livestock production and hold onto their right to access (and cropping) even during an extended absence. This fact is causing difficulties to the overall community management of rangelands. On the other hand, off-farm labor represents a complementary activity to livestock production and a risk management strategy and may actually improve community homogeneity and cohesion (Nefzaoui, 2002).

Inequality between poor and rich herders has been accentuated during the last decades due to several factors. The poorest herders, i.e. those with the smallest flock size are the ones affected most severely by rangeland degradation since they have less opportunity to purchase feed and rely mostly upon free range resources. Second, the drought mitigation policies have favored pastoralists with large flocks over those with small flocks since they

are more often organized into associations in order to benefit from these actions (Hazell *et al*., 2001).

Expected Impacts of Climate Change on Livestock and Rangelands

In smallholder crop-livestock and agro-pastoral and pastoral livestock systems that concern and sustain the livelihoods of about 1 billion people in the world have a much more limited environmental footprint compared with populations in developed countries. Livestock are particularly important for increasing the resilience of vulnerable poor people, subject to climatic, market and disease shocks through diversifying risk and increasing assets (Krishna *et al*., 2004).

Is pastoral climate change a problem? *Not per se,* because pastoralism is an adaptive strategy to a stressful environment. Pastoralists are the most capable to adapt to climate change, since pastoral livelihoods are shaped to deal with scarce and variable natural resources and climate change could conceivably lead to the extension of territories where pastoralism could show comparative advantages. A much greater threat is likely to be posed by the food:feed:fuel conflict providing reduced feed supplies.

There are many ways in which climate change may affect negatively livestock and livestock systems; they include water, feeds, biodiversity, and livestock (and human) health (Thornton and Herrero, 2008). There is quite a lot of information on some of these impacts and much less on others.

- Water: Coupled with population growth and economic development, climate change impacts will have a substantial effect on global water availability in the future
- Feeds: Changes in land use, primary productivity of rangelands, species composition and quality are expected to occur
- Biodiversity: Climate change will accelerate the loss of genetic and cultural diversity in agriculture already occurring as a result globalization (Ehrenfeld, 2005)
- Livestock health: Major impacts on vector-borne diseases: expansion of vector populations into cooler areas (higher altitude areas, such as malaria and livestock tick-borne diseases) or into more temperate zones (such as bluetongue disease in northern Europe). Helminth infections are greatly influenced by changes in temperature and humidity (Thornton and Herrero, 2008).

There are areas in which the impacts of changing climate and climate variability are fairly well understood at an aggregated level. But there are major gaps in our knowledge of the localized impacts, which seriously inhibit current pro-poor targeting of adaptation options.

Much greater threat is likely to be posed by the food:feed:fuel conflict leading to reduced feed supplies. This is debated daily in media and international fora. It is obvious that producing ethanol or biodiesel from biomass is not economically cost-effective and relies on government subsidies. An attractive alternative option would be gasification of fibrous biomass (Table 1) within an integrated livestock-based farming system (Preston and Leng, 2008).

Adaptation Strategies of Pastors to Climate Change

Changing environments may provide suitable conditions for the expansion of pastoralism, as the flexibility and mobility afforded by pastoralism may increasingly provide a means of providing security where other sedentary models fail. Pastoralists are the most capable to adapt to climate change, since pastoral livelihoods are shaped to deal with scarce and variable natural resources and to tackle difficult and uncertain agro-ecological conditions, and climate change could conceivably lead to the extension of territories where pastoralism could show comparative advantages (MacOpiyo *et al*., 2008).

Table 1. Inputs and outputs when 1 kg dry biomass of sugar cane bagasse is converted to make ethanol or reacted in a gasifier (Preston and Leng, 2008)

System	Ethanol	Gasification
Energy inputs	>8 MJ	Very little
Litres ethanol	0.18	
Gas		2.5 m^3
Kwh	0.40	0.83
Scale	Large	Localized
Carbon sequestered	None	100 g

Many possible adaptation options do exist, such as local institutions and empowerment, science and technology, and risk management to enhance system resilience. All these options aim at increasing the adaptive capacity of poor livestock keepers and agropastors. Given this range of

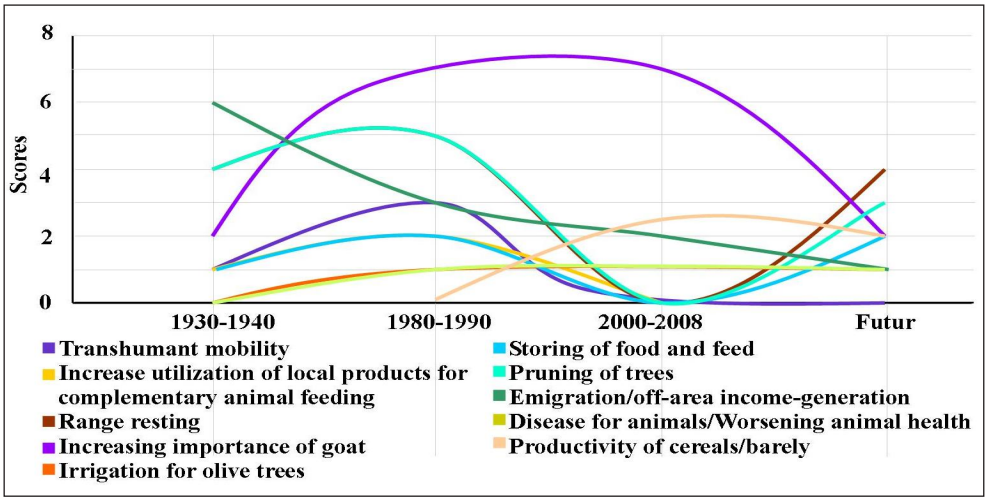

Fig. 1. Tendencies of major drought strategies in Chénini agropastoral community, Southern Tunisia (Sghaier et al., 2008).

options, there is a real need for methods and tools to assess what may be appropriate and where? This includes the collation of toolboxes of adaptation options and the identification of the domains where these may be relevant, at broad scales through the use of spatial analysis, and at more localized scales through more participatory, community-based approaches.

Most national and international climate change policy documents hardly recognize traditional and indigenous coping strategies. This needs to be rectified. Indeed, traditional and indigenous peoples "may have valuable lessons to offer about successful and unsuccessful adaptations, which could be vital in the context of climate change". Because of their long dependence on nature they've developed strategies to cope with climate change and extreme natural events, which still have as much relevance today as they did centuries ago.

How herders traditionally manage drought?

Agropastoral societies have developed their own strategies for coping with drought. 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 reason 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 grains, straw and forage as a reserve in good rainfall years;
- diversification among animal species (sheep, goats, cattle, camels, donkeys) and different breeds within species; and
- income diversification into non-agricultural occupations, particularly seasonal migration for off-farm employment in urban areas.

However, recent infrastructural and demographic changes (e.g. urbanization) have made such knowledge less effective.

In a recent study conducted within ICARDA Mashreq/Maghreb project in Chenini agropastoral community, Southern Tunisia, perception of drought and livelihood strategies to mitigate drought has been investigated using "sustainable livelihood approach" (Sghaier *et al.*, 2008). Main coping strategies for drought mitigation were: transhumant mobility, food and feed storage, increased utilization of local feed supplements (barley grain, wheat bran, olive cake, etc.), trees pruning, range resting, immigration, increasing importance of goat husbandry, which better adapt to harsh conditions than sheep, governmental subsidies for feed supplements, irrigation of olive trees, and reduced productivity

of cereals/barley (Fig. 1). This figure reflects the evolution of rural populations for drought and the evolution of tools considered to mitigate and or to cope with drought. While in the thirties, there was a self-reliance on drought coping mainly through transhumance, food and feed storage and goat husbandry, these options shifted in the last decades towards a significant reliance on government intervention mainly through subsidizing feeds and their transport to target areas (from the north to the south).

Institutions and empowerment of agropastors

There is no integration of indigenous knowledge into development planning, thus people are becoming more powerless. IUCN recommends that communities must be actively involved in policy making at all levels, from local to international. It is suggested that development agencies should use indicators extracted from local know-how of agropastors to prepare relief instead of just relying on satellite imagery.

Promoting community-based organizations and empowerment will support adaptation (Garforth, 2008):

- Help build strong institutions that can facilitate both collective and individual adaptation and respond to climate change and other external pressures, both short and long term;
- platforms for managing conflict over natural resources;
- create and intensify learning opportunities, to broaden the set of information and knowledge available to farmers and support local innovation: Livestock Field Schools are an example of how this can be done;
- support local innovation processes; and
- help livestock keepers identify opportunities, to enrich the set of options they have when making livelihood choices: re-thinking how advisory services are provided, particularly to small-scale, relatively poor livestock keepers, is an important ingredient.

Decision-makers and all research and development partners are increasingly aware that "the heart of the rangeland sustainable management" is linked to institutional issue. Indeed, in the past the situation of rangelands was relatively better not only because population pressure and demand for meat were lower, but also because the management of rangelands was more strictly controlled by traditional institutions (Jmaas in Morocco, Myaad in Tunisia) that enjoyed effective power. Numerous policy and institutional reforms have been carried out in several countries of the WANA. In most cases, policy and institutional reforms weakened pastoral institutions. These institutional reforms can be classified into three main approaches: state appropriation of rangeland resources, strengthening customary tribal claims, and privatization with titling (Ngaido and McCarthy, 2004).

Recent experience of communal rangeland management in South Tunisia (IFAD PRODESUD Project) is quite promising. The community-based organizations (GDAs) are built up on socio-territorial units that correspond to the traditional tribe boundaries. They are fully participating in the design and the implementation of their integrated local development. The approach used involves the real participation of agropastoral communities, in a new bottom-up mode, for the establishment of community development plan (CDP) that reflects the real issues and priority needs of the community. This is developed through the joint inputs of all stakeholders including community members, agricultural specialists, extension services, local administration and state representatives. Best-bet technologies for technical, institutional and policy issues are jointly identified for implementation, monitoring and evaluation. The community is represented by a formal community-based organization (CBO), directly elected by community members and fully recognized by government authorities as their equal partner for implementation of all actions set out in the jointly developed CDP. This includes such crucial issues as management of communal pasture and rangelands (20,000 ha of collective rangelands are put under rest and fully controlled by the communities), as well as the procurement of funds and necessary inputs and facilities, and the independent and transparent contact with all stakeholders and similar CBOs in the WANA region for exchange of relevant information and experiences (Nefzaoui *et al*., 2007).

Science and technology

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 have to succeed. The integration of new technologies into the research and technology transfer systems potentially offers many opportunities to further contribute to the development of climate change adaptation strategies. Such tools as geospatial information and spatial analysis tools, and other decision support tools will continuously play a crucial role in improving our understanding on how climate change will affect livelihoods of pastoral communities. Climate change also offers an opportunity to promote payment to pastoralists for environmental services, as in the case of some livestock keepers in Europe. These services could include watershed management, safeguarding biodiversity, landscape management and carbon sequestration (MacOpiyo *et al*., 2008).

NARS in collaboration with ICARDA have been working to develop several options to cope with vulnerability and climate variability. Options include: managing water scarcity, livestock nutrition and health, rangeland management and monitoring, integration of crops and livestock, and diversifying feed resources.

Managing the production risk caused by the variability of feed availability is the central issue in the SR production system in the WANA region.

Although solutions to major SR constraints resulted in some easing of the pressure caused by human needs for SR products, the consumption-production gap increases for most of the countries and imports are therefore increasing into the WANA region both in terms of feed and animal products. This trend is becoming alarming with the recent surge of cereal prices, and concentrate feeds, particularly barley. The future of SR production in the WANA region is uncertain. The WANA countries will witness an increasing budget load for SR production and import. Most countries will have to face an increased pressure on rangelands, which requires an innovative approach to their effective management and complementation with better use of local natural resources with an emphasis on water harvesting and better use of adapted indigenous plant species, such as cactus and fodder shrubs, and introduction of feed blocks using agricultural by-products and treated straw (Nefzaoui *et al*., 2008).

Desertification, increased drought frequency and duration, greenhouse emissions, and decreased livestock performances, justify the needs for a serious reflection on the readjustment and or the establishment of new feeding strategies targeting the improvement of animal production without detrimental effects on the environment. Therefore, the development objectives should move towards resource conservation and natural resource management while striving for greater agricultural production. Livestock is critical to the development of sustainable and environmentally sound production systems. The NARS developed and or approved the advantages of set technical options that are simple, inexpensive and efficient in improving livestock performances and help contribute to the environment protection. This could be achieved through targeted formulation of diets and or manipulation of rumen microflora (Ben Salem and Smith, 2008). Some promising cost-effective and environmentally friendly options those have been proved recently to be efficient in improving ruminant performances and health include the use of plants, plant extracts or natural compounds (e.g. tannins and saponins) as potential alternatives to growth promoters and antibiotics. Therefore, the incorporation of fodder shrubs in the diet would have positive effect on digestion and performances of small ruminants. More interestingly, shrub mixing based on the complementary role would stimulate digestion thus enhance productive and reproductive performances. Moreover, the development of simple and cost-effective techniques (e.g. feed blocks, pellets, and silage, Ben Salem and Nefzaoui, 2003) to valorize local feed resources (e.g. agroindustrial byproducts) could help smallholders in better managing livestock feeding throughout the year. 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 effects of tanniniferous (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 performances of ruminants should encourage the establishment of practical options for agronomical applications of plants containing these natural plant secondary compounds in grazing systems. These options offer promising solutions to reduce the use of chemicals in livestock production systems enhance livestock

Table 2. Productive, environmental and social benefits from some alternative options

Alternative options	Impact on the animal	Impact on the environment	Impact on farmers livelihoods
Feed blocks	– Improved digestion of low quality diets – 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 establishment of mechanized unit for making of FBs
AGIBs-based pellets	– Improved productive and reproductive performances of ruminants	– Decreased pollution with perishable AGIBs such as olive cake – Better quality manure	– Decreased use of conventional feedstuffs, increased animal performance and decreased feed cost result in higher income
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	– Complementarity between shrub species (nutrients and secondary compounds) increases feeding efficiency thus animal performances	– Combat desertification – Soil protection	– Reduced budget allocated for feedstuffs purchasing
Rangelands resting	– Increased feed intake and digestion – Increased productive and reproductive performances	– Reduces degradation risk – Protection of vegetative and animal biodiversity (domestic and wildlife animals)	– Reduced the feeding cost and increased performances resulting in increased income
Inclusion of small amount of tannin containing foliage in the diet	– Improved performances through increased rumen bypass protein	– Lesser discharge of polluting nutrients	– Increased performance results in increased income
Inclusion of medium amount of tannin containing foliage in the diet	– Decreased concentration of nematodes – Decreased CH_4 production – Increased performances – Protection of ruminants from bloat	– Lesser greenhouse gas contribution to global warming – Manure with higher level of N for crop production (Lower N excreted in urine and higher in the faeces)	– Increased performance and saving money allocated to the purchase of common anthelmintic products result in increased income
Saponins containing plant extracts	– Increased absorption of nutrients – Defaunation and increased microbial flow from rumen – Reduced CH_4 production – Improved performances	– Decreased methane emission from ruminant livestock	– Increased animal performance results in increased income

productivity and decrease emission of methane and discharge of nutrients to the environment. Another promising and sometimes sole option to increase production of livestock raised under harsher conditions is the rest technique. For example, the desert part of Tunisia (Tataouine region) is receiving on average 100 mm rain per year, but is home to important flocks of small ruminants and dromedaries raised on wide and degraded native and communal rangelands. Most of the above technical options cannot apply under these severe conditions. The rest technique, based on the principle of leaving in rest (without grazing) the rangeland to reconstitute its plant cover proved efficient in improving rangelands productivity. Applied in several types of natural environments at various ends (rangeland improvement, dune stabilization, national parks, etc.) this technique permitted spectacular results in the whole of arid and even desert Tunisia. Several works, however, showed that the effectiveness of this technique varies according to several factors, which determine the potential of regeneration of the treated area (rainfall, soil nature, level of degradation reached, period of validity of this technique, etc.).

Risk Management to Enhance System Resilience

Several tools are available for managing risk. Among these:

- Early warning and preparedness aim at improving regional capacities to monitor and analyze livestock related food and livelihood security information and to advocate for timely and appropriate responses
- Adoption and dissemination of new understandings in rangeland ecology and pastoral economics, climate change and recognition of the capacity of pastoralism to sustainably produce valuable goods in marginal lands
- Focus on need-oriented-technology and addressing the specific concerns raised by pastoral producers themselves
- Target human development to enhance the livelihoods of agropastoral communities
- Rangeland monitoring to adapt to climate change. This might include: rapid methods for rangelands quantification of carbon stocks / carbon sequestration and payment for environment services (PES) inductive policy; diversifying livestock and forage species for climate resilience; water harvesting and conservation techniques
- Markets and economic integration and income diversification might bring positive benefits of spreading risk
- Enabling pro-pastoral policies. Pastoral societies have a right to utilize local resources that sustain and protect their livestock. Enabling pastoralists to claim their rights and participate in decision- making at policy level is important because policies and institutions influence the ability of livestock owners to use their assets in support of their livelihoods. The principal governance issue has been, and continues to be, resource access and control. In most pastoral areas, community organizations and local non- governmental organizations are very important, especially where they are influential in advocating and influencing user rights to access of resources found in these communities (MacOpiyo *et al*., 2008)
- Most WANA governments view pastoral resources as state property, while the pastoral communities consider them as their territory. Poorly defined tenure rights often lead to conflicts and equity issues. Those who advocate devolution policies suggest that the success of range management depends on the extent to which pastoral communities are granted full control over access and use of the resources and on the assurance of benefiting from improvements (Ngaido and McCarthy, 2004)
- Drought relief programs. The high cost of droughts and the increasing vulnerability of agropastoral societies have led many governments in the region to intervene with various forms of drought assistance. However, many of these interventions are encouraging farming practices that could increase both the extent of future drought losses and the dependence of local people on government assistance. They are also costly to governments and use resources that could otherwise be spent for development purposes (Hazell, 2007).

Looking Ahead

Long-term vision action plans are needed to integrate research and development programs focusing on marginal areas. Wealth of knowledge is available today to build initiatives to help agropastoral communities to adapt and mitigate climate change impact; however, new research is needed with new paradigm.

This work should revolve around the development of collaborative learning processes to support the adaptation of livestock systems to better cope with the impacts of climate change. Farmers already have a wealth of indigenous knowledge on how to deal with climate variability and risk, but well-targeted capacity building efforts area needed to help farmers deal with changes in their systems that go beyond what they have experienced in the past. In sum, the livestock development issues raised by climate change are highly intertwined and complex; some of the possible impacts at broad scales are reasonably well-researched while others are not, and currently many of the agricultural and other impacts at local scales are simply not known. How these impacts may combine to affect household vulnerability, and how adaptive capacity may be most effectively increased, are critical issues that need considerable attention (Thornton and Herrero, 2008).

New science and tools will be based on:

- Biotechnology: Use of biotechnology tools in the development of species that are adapted to heat and drought stresses as well as to biotic stresses while maintaining higher productivity
- Modeling at local level: Elaborate climate models, which would allow better understanding of climate change impact at local level in order to improve forecasting climatic and metrological events, and to help communities to be better prepared
- Carbon sequestration is needed to increase the carbon stocks and sequestration by rangelands through increased vegetative plant cover; access the world carbon market (CDM clean development mechanisms) and investigate the institutionalization of payment for environment Services (PES)
- Insurance: Insuring against climatic risk is becoming a powerful tool for risk management that offer payback on indices on measurable objectives. The insurance would allow farmers to better manage risk and encourage investing in agropastoral activities.

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