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### **Presenter Information**

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# Participatory management of rangeland hydrology – a new socio-ecological technology to effectively adapt to and mitigate climate change: case from Morocco

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**Key words:** Rangeland; arid zones; climate change; water management; pastoralism

## Abstract

Morocco's drylands cover over 90% of the land area; low and irregular rainfall and high potential evaporation contribute to extremely high-water deficits. These phenomena have greatly impacted rangeland hydrology and nomadic and transhumant pastoralism. To adapt to this predominant water deficit, the inhabitants of these areas have developed two forms of lifestyles, which include household and livestock mobility: (i) a pendulum movement for seasonal transhumance between the mountains and their bordering plains; and (ii) random nomadic mobility regulated by the sporadic frequency of rains and thus water availability. In both cases, this mobility is controlled by the degree of development of the routes, but it derives also from participatory governance of water access to livestock. For example, pastoral communities first use routes with ephemeral waters, while saving perennial or semi-perennial water sources for long lasting drought periods. To mitigate water scarcity, nomads and transhumants often reduce herd size, and switch temporarily to complementary activities such as trade, crafts, wage labor, and engagement in public services. The conservative practices of rangeland and water management have progressively declined following regional and global trends of sedentarism, urban extension, and the emergence of new activities such as intensive irrigation, industry, and tourism. Faced with this situation, various development organizations aim for the recovery of local traditional conservation and participatory water management practices. Rainwater harvesting as well as hydraulic facilities, storage and tank services for isolated populations are being implemented at several points along nomadic routes. Besides, new schooling opportunities have opened employment options and additional income from farming activities. In this context, transdisciplinary monitoring of rangeland development through remote sensing in addition to biophysical and socio-economic indicators have been installed. In this work, we present an integrated analysis of hydrological management systems of Moroccan drylands in relation to pastoral adaptation to climate change.

## Introduction

Morocco is one of the semi-arid countries with a significant pastoral vocation. The agro-sylvo-pastoral, pastoral and oasis lands cover more than 90% of Moroccan territory (Ministry of Agriculture, 2015). These lands offer an important land support dedicated to extensive livestock farming which play a major role in the income generation for peasant society and in the functioning of the rural economy. Its production is about 1/3 of added-value in agricultural sector, contributing to 30% of jobs in the sector. More importantly, it represents a source of income for 80% of rural households (Qarro et al, 2010).

Most of the rangelands (97%) (oasis 7 %) are located in arid and semi-arid environments where the chances of success of rain-fed cereal crops are closely related to the frequency of droughts (Araba and Boughalmi 2016; Reed and Dougill 2002). The North Africa drylands will face increasing temperatures with climate change and experience disruptions to their hydrological cycles with a pronounced tendency of reduction of precipitation exacerbating water scarcity and social conflicts over water allocation (Hssaisoune et al. 2020; Thomas, 2008).

Over centuries and decades, pastoralism in arid areas has been considered a crucial economic activity and a method of land use. Under these conditions, the possession of small flock becomes a strategic way of ensuring the subsistence of human communities especially in the context of climate variability. In addition to the characterization of the socio-ecological frameworks for the land use of Moroccan pastoral territories, the main objective is to re-examine the traditional pastoral activities and management of water resources in the light of technological innovation to better mitigate and adapt to climate change and variability.

## **Methods and Study Site**

The methodology used in this work focused on transdisciplinary, multidisciplinary, collective action. We applied literature reviews, field observations, and included experiences from researchers from different disciplines. A special focus was made on research that was carried out with the objective to tackle sustainable development by safeguarding and conserving the fragile pastoralist ecosystems. In this study, we are referring to: i) studies on the exploration and development of water supply systems for rural populations and their livestock, ii) establishment of National Parks and Biosphere Reserves for the conservation and rehabilitation of declining ecosystems, and iii) delimitation and characterization of pastoral and agro-sylvo-pastoral zones. We performed a reviewing of accessible documents such as reports of inedited studies and publication of different research results that constitute an added value to this paper (Ahlafi 1999; FAO 2006; Neggar 2018; Qaro et al. 2010). The choice of Moroccan drylands was justified for several reasons : i) decreasing trends of production capacities in arid and semi-arid ecosystems; ii) the degradation of old legacy systems of governance of scarcity resources under effect of extensive migration caused by youngsters, producing a break in the line of expertise transmission between different generations; iii) different actors and partners' interests in aiming at reconciliation between development and the safeguarding the equilibrium of arid and semi-arid ecosystems; iv) the socio-economic importance of pastoralist environments which constitute the veritable in-situ laboratories for participatory observation and analysis of the socio-ecological systems in the light of extensive use of rangelands, as well as the monitoring of the mitigation aspects and especially the adaptation of climate change effects.

## **Results and discussion**

### ***Pastoral area and socio-ecological framework of exploitation***

The pastoral lands cover more than 87% of national territory which corresponds to more than 71 million Ha. Forest and scrubland (matorral) areas constitute only 10%; while land classified as rangeland and uncultivated land covers more than 55 million Ha, this is 90% of the pastoral area. These grazing lands, without the forest rangeland, consist mainly of steppes at the rate of 94%, the rest concerns land covered with *alfa* formations (*Stipa tenacissima*).

Ecologically, most of the potential of rangelands extends in the areas with extreme edaphoclimatic conditions, with water shortage due to a high frequency of seasonal and interannual drought periods (Qarro et al. 2010):

- ❖ Saharan rangelands: mainly cover the provinces of southern Morocco with an area of around 50 million ha, more than 4/5 of national rangelands. The hyperaridity of the environment contributes to the reduction of the rates of floristic richness and recovery of vegetation, and to the regression of water resources. The possibilities of using the rangelands can only be sporadic during irregular rainfall events;

- ❖ Pre-Saharan rangelands: located further north where the more favorable bioclimatic conditions allow the development of steppe plant formations dominated by Saharan strains. This area is a modest extension of 10% of all rangelands, but it remains strategic for the maintenance of pastoral activity through its forage supply of perennial xerophyte shrubs and its potential for livestock watering;
- ❖ Eastern rangelands: these are steppe lands representing 8% of the total rangelands. These lands are dominated by a plant formation of alfa representing a species adapted to arid or semi-arid bioclimatic conditions.

### ***Socio-ecological systems of rangelands and water governance***

Human presence in drylands has only become possible through the shaping of ingenious socio-ecological systems based on adaptive mobilization and management of natural resources. In the case of nomads and transhumants, livestock's watering needs control the movements of the herds and households between water points. Historically, pastoral activity has been practiced without any significant hydraulic development. The most widely used surface waters are those of isolated ponds (Dayat, Graara) and receding ponds of wadis (Gueltas), while groundwater is limited to resurgences of underflows of wadis (Aayn). More often than not, to quench their thirst, livestock use the same water resources as is used by wild animals.

When the mobilization of greater volumes of water becomes unavoidable to increase the duration of grazing of pastures, the communities pass by collective hydraulic installations mainly of using and storage. The most adopted technique is the digging of wells (Bir, Hassi) for the extraction of water from the shallow aquifers generally attached to infra-flows of permeable alluvium. In pre-Saharan areas where the potential of underground resources becomes relatively important, pastoral communities may have the possibility of benefiting from groundwater springs (Ayn) and underground drains with accumulation basin (Khettaras and Charij). On the other hand, for surface water, the most frequent developments consist in collecting rainwater and runoff: reservoirs covered with impluvium (Notfias) and open excavations (Ghdir). The mobilization and use of water resources are subject to a rigorous and collective management system with the rights and obligations of individuals. Under climate change conditions, the groundwater extraction is the more reliable water resource. Moreover, during the last decades the government, through its different services, encourage the rain water harvesting especially by small dams (hill dams), in order to ensure drinking water for both local population and livestock. This last technique can play dual role, the first is surface water storage and the second is groundwater recharge.

### ***Rehabilitation attempts and experiences of stakeholder participation***

The pastoral areas in Morocco are more than ever subject to pronounced stresses due to overexploitation of rangelands combined with shortage of water (Del Barrio et al. 2016; Kouba et al. 2018). Hence, attempts to rehabilitate the pastoral socio-ecological framework are underway in these areas. They include various decisions, such as national rangeland development strategies; emergency drought response programs; the rangeland and livestock development projects; biodiversity conservation projects through transhumance in the High Atlas, projects to install national parks and biosphere reserves. Currently the ministry in charge has just launched a study of demarcation, inventory and characterization of the rangelands with the objective of creating pastoral and sylvo-pastoral spaces in the twelve regions of the country. The development and implementation processes of the various programs and projects have provided precious opportunities for adopting horizontal approaches favoring the principles of consultation and citizen participation as well as all stakeholders. These new approaches, which put those concerned at the center of the development process, have been successful in improving the living environment of pastoralists, and in supporting their activity by installing more efficient hydraulic equipment, but without being able to curb the trend of disappearance of nomadic and transhumant lifestyles.

### **Conclusion**

Even though the water supply systems used for livestock may appear to have poor to moderate yields. The traditional pastoralist socio-ecological systems are recognized by their high capacity to adapt to the fragility and irregularities of local water potential. For the community of scientists engaged in the processes of finding the best practices facing mitigation and adaptation to the effects of climate change, the traditional pastoral systems developed in the past by nomadic and transhumant societies in arid and semi-arid environments turn out to have a vital interest. However, these traditional pastoral systems seem to be in a phase of regression marked by increasing loss of local expertise and traditional knowledge, which has been caused by an increasingly intense sedentarization. Complex factors have contributed to the trend of spatial fixation and intensification of this former mobile pastoral activity. Besides of important ecological characteristics, the factors of change in these pastoral systems have economic, social and political dimensions. We cite in this context, the closing of international borders for various pretexts, increasing urbanization and the desire of pastoralists to improve the standard of living, growth of population and food needs and the shift towards intensification of breeding.

In synthesis, currently all development action of arid and semi-arid pastoral areas, carried out by the State and pastoral partnerships, is mainly oriented towards pastoral hydraulics with the objective of improving the water supply. Such actions only facilitate the fixation of nomadic and transhumant societies, which ends in the exhaustion of the regeneration capacities of pastures, the loss of a highly functioning adaptive pastoralist system and consequently jeopardizing food security.

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