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EDITORIAL

DESERTIFICATION: HISTORY, CAUSES AND OPTIONS FOR ITS CONTROL

DUST BOWL

In 1939 John Steinbeck published his famous novel 'The Grapes of Wrath', which describes the fate of the Joad family who were forced to give up their lives as farmers in Oklahoma in the early 1930s. The reason for abandoning their agricultural activities was the economic crisis and the extended drought that hit the Great Plains. Along with the drought, strong winds swept the barren land and caused massive dust storms (Figure 1) in what is now known as the Dust Bowl. Steinbeck wrote:

> '*The wind grew stronger. The rain crust broke and the dust lifted up out of the fields and drove gray plumes into the air like sluggish smoke. The corn threshed the wind and made a dry, rushing sound. The finest dust did not settle back to earth now, but disappeared into the darkening sky*'.

Many people in the Great Plains gave up farming and moved to the west coast or northern cities. Hundreds of thousands of people migrated, all hoping to find jobs and a better life, but because of the sheer numbers many ended in extreme poverty (UNEP, 1997). This migration, which was the largest in American history, and the socio-economic impacts it had made conservation of soil and water resources a national priority. In 1935 the US Congress passed Public Law 74-46, which resulted in the establishment of the Soil Conservation Service (SCS). The SCS technical experts conducted scientific research to improve understanding of erosion processes and to develop effective conservation practices (USDA Natural Resources Conservation Service, 2015). This culminated in the important publication on soil conservation by H.H. Bennett (1939), the first director of the SCS (1935–1951). The SCS was probably the second institute where concerted research was conducted to understand the causes and impacts of soil erosion and to develop mitigation measures. Iceland founded a Soil Conservation Service already in 1907.

DESERTIFICATION

The Dust Bowl is an early example of the tragedy that can be caused by desertification. The term desertification was first introduced in 1949 by the French forester Aubréville, who used it to describe the expansion of desert-like conditions in non-desert areas (Aubréville, 1949). The desert-like conditions were characterized as non-productive or very low productive areas. Later on, during the Earth Summit at Rio de Janeiro in 1992, desertification was defined as 'land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors including climatic variations and human activities'. This definition was adopted in 1994 by the United Nations Convention to Combat Desertification (UNCCD).

The UNCCD definition specifies the climatic zones, in which desertification can occur. It assumes that the hyper arid or real desert zones are excluded and that desertification can only occur in the world's inhabitable drylands (UNEP, 1997). These drylands are characterized by an extended period of water shortage throughout the year. In general, soil moisture is limited because of the low rainfall and high evapotranspiration. Drylands are climatologically defined by the Aridity Index (AI), which is the ratio of annual average precipitation over annual average potential evapotranspiration. In the AI calculation, the evapotranspiration is calculated using the standard Penman equation (Le Houérou, 1996). The inhabitable drylands are defined as having an AI between 0·05 and 0·65 (UNEP, 1997), meaning that on average between 5% and 65% of the annual potential evapotranspiration is met by the annual rainfall.

Drylands cover approximately 40% of the terrestrial Earth surface (Figure 2) and are home to some 2 billion people, or 30% of the global population. Most of those people live in developing countries in Africa and Asia, where they largely depend on rainfed agriculture. The agriculture mainly consists of crop production by settled farming families, livestock keeping by pastoralists who move through large grazing zones or a combination of the two types of agriculture (mixed farming). In many developing countries in the dryland zone farming conditions are difficult because of low annual rainfall amounts, highly variable rainfall patterns, low soil fertility and poor socio-economic conditions that hinder necessary investments in agriculture. Desertification threatens the sustainability of land and is considered one of the most serious global environmental problems (Schreiber *et al*., 2012).

Estimates vary widely, but it is believed that between 10 and 20% of the drylands are already degraded (Millennium Ecosystem Assessment, 2005). This means that between 1 and 6% of the dryland population lives in desertified areas, and many more are threatened by desertification. According to the UNCCD the livelihoods of about one billion people in

Figure 1. A dust storm approaches Stratford, Texas, 18 April 1935. (Source: NOAA's National Weather Service Collection, George E. Marsh Album).

over 100 countries are at risk, and some 250 million people are directly affected by desertification. These people include many of the world's poorest, most marginalized and politically weak citizens (United Nations Convention to Combat Desertification, 2015). The main land degradation processes involved in desertification are wind erosion, water erosion (Figure 3), soil surface crusting, soil compaction, nutrient depletion, salinization, sodification and acidification.

CAUSES OF DESERTIFICATION

Despite the general awareness that desertification is a serious natural and human problem in the drylands, it is not so clear what actually causes this desertification (Helldén, 1991). It is usually not a single cause, but most often a combination of factors that may change over time and can vary spatially. Indirect factors include population density and growth, socio-economic drivers, policies and globalization. The direct factors that may cause desertification are land use, land management and climate-related processes (Millennium Ecosystem Assessment, 2005). An important reason for land degradation in drylands is the removal of natural vegetation cover. Dryland vegetation may consist of a combination of

Figure 3. Water erosion has removed the soil completely in an Olive field in northwest Syria.

grasses, herbs, shrubs and trees. This vegetation is important for maintenance of soil fertility through delivery of organic matter to soils, but it can also influence the energy and water balance of an area. Micro-climate modification by vegetation may conserve soil moisture by reducing soil evaporation, and it can help to protect soils against destructive forces of wind and rainfall.

There can be many reasons why vegetation cover has degraded in drylands. Traditionally, drought, overgrazing by livestock and exploitive use of vegetation have been blamed for dryland degradation (Dregne *et al*., 1991). Drought is an intrinsic feature of drylands and is typically a period of below average rainfall. This may occur within a year, but also multiple years may be dry, like the devastating Sahelian drought in the 1970s and 1980s. Drought does not result in desertification per se. The natural vegetation in drylands is adapted to drought and will normally recover after a drought period. Whether desertification will occur depends on the land use and management practices that either improve or weaken the ecosystem resilience.

Livestock grazing and use of natural vegetation by local populations are common practices in many drylands.

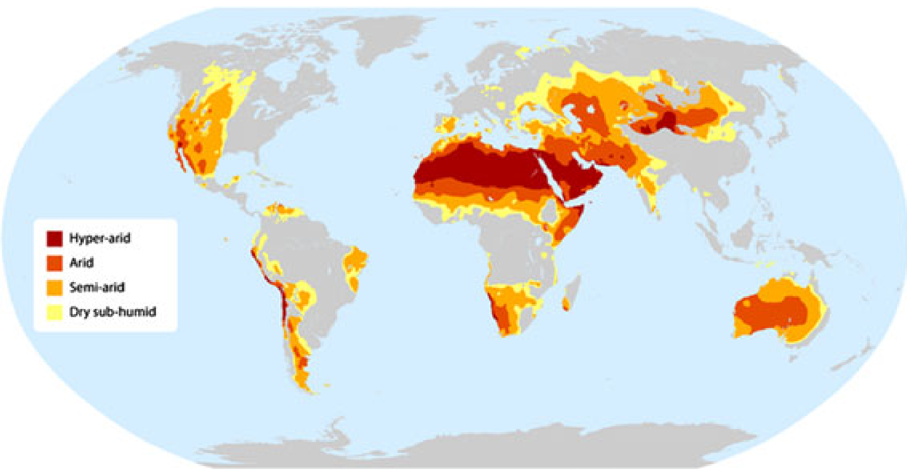

Figure 2. The world's drylands and subtypes. Reproduced with permission from the Food and Agricultural Organization (FAO). Source: http://www.fao.org/forestry/aridzone/39619/en/.

Grazing of the sparse resources is no problem as long as livestock numbers are relatively low. Livestock keeping can actually have a positive influence on sustainable use of soils, by redistributing soil nutrients across landscapes (Webb, 1998). However, if livestock numbers exceed the location-specific threshold for sustainable use of the land, desertification can become a serious problem.

Dryland communities have also been blamed for removal of woody vegetation, especially for the use of fuelwood and expansion of cropland. With increasing population numbers, the demand for fuelwood and crop land is also increasing. But the destruction of natural vegetation by local communities for household fuel consumption is more complicated than previously believed. Darkoh (1998) showed that the urban demand for especially charcoal is usually causing more vegetation destruction in rural areas than the local fuelwood consumption. Deforestation for creation of crop land is a continuing problem in many dryland zones, which may increase the vulnerability to desertification. Strategies such as the currently popular Farmer Managed Natural Regeneration that stimulate the integration of woody vegetation on agricultural land in the Sahel can help to reduce the vulnerability of crop land to land degradation processes, but how vegetation recovery affects important ecosystem services at the landscape scale remains to be studied (Sinare & Gordon, 2015).

CONTROL OF DESERTIFICATION

There is a suite of measures available to control land degradation in drylands (Morgan, 2005). These include field-scale wind erosion control measures such as soil roughening, ridging, mulching, use of cover crops and shelterbelts. For water erosion control measures like mulching, contour earth bunds, stone bunds (Figure 4), grass strips, contour strip cropping and terracing can be applied. Surface crusting can be prevented by adding organic matter to soils, usually in the form of an organic surface mulch. Nutrient depletion can be reduced by supplying the same amount of nutrients, either by manure or fertilizer, to soils as the amount of nutrients that is taken away with the harvested crop. Salinization and sodification are usually caused by adverse irrigation practices and need to be solved by improving irrigation water quality and drainage conditions. Problems of acidification can be controlled by adding lime to soils to increase the pH.

Despite the availability of these measures to reduce the impacts of desertification, there are many drylands where at best a minimal adoption of measures has been achieved. The problem is that most, if not all, measures require financial or labour investments, which in the poorer dryland zones is often problematic. For example, leaving post-harvest crop residues on the cropland has been promoted for wind erosion control in the Sahel. However, biomass yields are generally low ($<3\,\text{ton ha}^{-1}$), and the crop residue is also needed for other purposes (animal feed, fuel and fencing). This leaves very little material to be used as mulch in the field (Figure 5), which can actually stimulate wind erosion instead of reducing it (Sterk, 2000). Also, the implementation of contour earth bunds or stone bunds to control surface runoff and sediment transport is usually too large investments for individual farmers. Exploring new pathways and strategies for the control of land degradation processes in the Earth's drylands remains an urgent issue that deserves full scientific attention.

Figure 4. Semi-circular stone bund in an olive field in northwest Syria.

In their special issue on *Science for improving the monitoring and assessment of dryland degradation,* Winslow *et al.* (2011) identified a range of scientific methods for improved assessment of sustainable land management, but also pointed to their constrained use because of the lack of coordinated action at the science-policy interface. Drawing on the perspectives of different stakeholders, experiences on impacts and responses of land degradation in locations across the globe were collected in a second special issue on *Land management and policy responses to mitigate*

Figure 5. Low amount of crop residue (~$1\,\text{Mg ha}^{-1}$) protecting a young Pearl Millet crop in the Sahelian zone of Niger.

desertification and land degradation (Fleskens & Stringer, 2014). In order to increase adoption of effective land conservation strategies, these authors confirmed the need for multi-stakeholder partnerships that embed scientific insights in policy and practice, but they also highlighted the importance of multi-level analyses that take into account complex interconnections between local and global processes. This latter observation marks a change in perceptions and perspectives on desertification and the dynamics of drylands.

Technological advances integrating large datasets, and cultural shifts fostering data sharing and integration between multiple user groups, certainly open up opportunities for creative, innovative solutions (Browning *et al*., 2015). There is, however, still a long way to go before adequate adoption of desertification control will be achieved in many dryland areas, especially in the developing countries. Research on adoption of control measures might benefit from the long history and many tested approaches of soil and water conservation planning in the humid East African Highlands. Several studies have shown that participatory awareness creation of soil erosion problems is an important step towards adoption of measures (e.g. Okoba *et al*., 2007). In addition, *ex ante* financial cost–benefit analysis gives insight about the required investments and potential gains of adopted soil and water conservation measures (Tenge *et al*., 2007). Similar approaches could work for achieving better adoption of desertification control by resource-poor farmers in the drylands.

DESERLAND CONFERENCE

This special issue of *Land Degradation and Development* presents 11 case studies emanating from DESERTLAND – 1st Conference on Desertification and Land Degradation, that took place in Ghent, June 2013. The conference was organized on the occasion of the World Day to Combat Desertification (17 June), which had as its theme 'Don't let our future dry up'. A total of 134 participants from 35 countries came to the two-day meeting to present research results and discuss desertification issues. The main aim of this conference was to showcase locally designed and installed interventions that combat land degradation and to highlight their successes and failures, opportunities and challenges. It, furthermore, meant to offer an interactive environment for sharing experiences among all kinds of stakeholders, including scientists, policy makers and non-governmental organizations. Despite difficulties of communication between these different communities, stakeholder involvement is pivotal in improved decision-making and implementation of sustainable conservation technology.

Of the 11 papers, nine report about desertification issues from African dryland environments. Three studies were conducted in Burkina Faso. Kambiré *et al*. (2016) compared analytical and indigenous indicators of soil fertility in cotton-based production systems and showed that there is reasonable agreement between two types of fertility indicator. Carbon sequestration was studied for Jathropha curcas systems by Baumert *et al*. (2016). It was shown that growing Jathropha on degraded land can improve soil fertility and help to sequester significant amounts of carbon in soils. Finally, Leenders *et al*. (2016) modelled wind erosion reduction by scattered trees and shrubs and showed the good potential of this woody vegetation for wind erosion control. Two studies by the same lead author (Murethi *et al*., 2016a, 2016b) report on rangeland management and the benefits generated from rehabilitated rangelands in Kenya. It was shown that good management of rangelands improves the herbaceous quality and can have multiple benefits to the local communities. In Ethiopia, one study (Opolot *et al*., 2016) used a model to quantify the impacts of different rainwater harvesting techniques. A second Ethiopian study evaluated the effectiveness of a subsurface geomembrane for gully control in Tigray (Frankl *et al*., 2016). Two papers are from North Africa. De Boever *et al*. (2016) show that scattered Acacia trees in semi-arid Tunisia have a positive influence on soil physical properties below their canopies, and increase moisture availability. In Algeria, Houyou *et al*. (2016) measured extremely high soil losses by wind erosion on crop land that was recently converted from grasslands. Two papers are based on research in Asia. In Uzbekistan, it was investigated how trees can be used to rehabilitate irrigated cropland that has been degraded in the past (Dubovyk *et al*., 2016). Finally, Saygin *et al*. (2016) evaluated different aggregate stability measures for assessment of degradation potential of clay loam soils in central Turkey.

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