DEVELOPMENT SCENARIOS FOR SEVERELY DEGRADED ARID HILLSIDES IN FUJAIRAH, UAE

M.A. Zoebisch[A] and E. DePauw[B]
[A] Asian Institute of Technology (AIT), Pathumthani, Thailand
[B] International Center for Agricultural Research in the Dry areas (ICARDA), Aleppo, Syria

Abstract
The objective of the study was to assess the restoration and development potential of dry hill range ecosystems. The study was carried out in the Ahfara area, which is representative for large parts of the Arabian Peninsula, and therefore has excellent potential to become a benchmark site for ecosystem restoration in the region. The natural vegetation is dominated by spiny trees and shrubs, which can survive the frequent prolonged drought periods. Inherent carrying capacity is low. Dominant land use is range grazing and sporadic oasis-type, small-scale irrigation farming of date palms and fodder grasses. Groundwater extraction is high and the water table has fallen considerably. The area has favorable restoration potential, but the limits to restoration are set by the climatic conditions and the groundwater availability. Restoration needs to be based on an improvement of rainwater interception to improve soil-moisture storage and encourage groundwater recharge. Four development scenarios, i.e. pathways, are proposed, which build on each other and which may be combined at any level of spatial extent and sophistication of activities. They range from a relatively simple enclosure (ecosystem restoration area) to a nature conservation center with various degrees of animal integration and national heritage conservation (desert museum and heritage center) that has potential for eco-tourism.

Additional Keywords: ecosystem restoration, rangeland, water conservation

Introduction
The dry coastal mountain ranges of the United Arab Emirates are a fragile range ecosystem. The traditional livelihood of the people in this area is based on livestock grazing (Al-Rowaily, 1999). Due to the climatic risks and increasing grazing pressure –that has led to significant overgrazing– the region's range resources have degraded significantly over the past decades. But there is also potential for rehabilitation. This potential may be achieved through applying two basic principles: (i) improvement of the overall rainfall infiltration and recharge of groundwater, and (ii) control of grazing of the rangelands, especially during the dry periods, to match the carrying capacity (Le Houérou, 2000). The main purpose of the study was the assessment of the restoration and development potential of the region with respect to its natural resources, and to develop scenarios for future use of the resources. Special emphasis is given to the conservation of the ecosystem versus its productive utilization. These scenarios were intended to provide the basis for high-level decision-making on the use and development of this ecosystem. The study did not intend to provide detailed project plans.

Materials and Methods
Study area
The study was conducted in Ahfara, a typical dry ecosystem area in the Emirate of Fuijairah, United Arab Emirates – UAE. The area is representative of the northeastern hill ranges of the UAE, the northeastern coastal mountains of Oman and large dry hill areas in Yemen and Saudi Arabia. The soils are generally highly permeable gravelly colluvium of low fertility and low water-holding capacity because of high (ie. 70-80%) gravel content. High average annual temperatures, high evaporation rates, and low highly erratic annual rainfall characterize the climate (Boer, 1997; Zahran, 1997). Agricultural land use is portrayed by localized small-scale irrigation farming using groundwater and widespread rangeland grazing with small ruminants –mainly goats– and a few camels. Prolonged drought periods (ie. >18 months without significant rainfall) are not uncommon, and over the last decade, groundwater tables have fallen significantly.

The climatic risk of land use is high. The most limiting factor to agricultural and rangeland productivity is water. More recently, the expansion of stone mining (quarries and stone crushing) in the area is of concern, with increased and uncontrolled traffic, noise and considerable dust emissions.

Data collection
The study is based on extensive vegetation and land-use surveys, and participatory appraisals of local land management and livelihood. The database was complemented by existing information on terrain, ecology, soils, climate and water resources.

Plate 1. Typical view of the study area

Results and Discussion

Main issues

Native feed resources – Fujairah Emirate has some 200 species of native plants, i.e., about 42 % of the native species reported from the entire UAE (Ferguson, 1998; ICARDA, 1999). For large parts of the year, the vegetation is dry. Annual species are rare, mainly due to overgrazing; only *Acacia* trees persist, whose leaves are only accessible to camels (Le Houérou, 1998). However, goats do eat the tree bark to complement their fiber-scarce diet of fodder grasses, and thus damage the trees. There are only a few undamaged (i.e., not debarked) trees in the area. The situation is better with increasing distance from Ahfara village. If the debarking of the Acacia trees by the goats continues, the damage of the trees will be irreversible and may result in the loss of many trees. Given the extremely low probability of summer rains, only perennial plants are a reliable source of vegetation. However, virtually all the perennial plants currently present in the area -with the exception of Acacia trees- are unpalatable to livestock.

Livestock keeping – We estimate the project area holds at least 3,000 small ruminants (>90 % goats) and a few camels and donkeys (200-300). Assuming that goats can graze within a radius of about 5 km from a permanent water source in the dry season, the present stocking rate would be in the range of 1 goat-equivalent per hectare, i.e., 20 kg live weight per hectare. The rangeland cannot support such high stocking densities, especially during prolonged droughts. Presently goats get virtually all their daily feed rations from irrigated green fodder (mostly Guinea grass) and concentrate feeds (bran, dry bread, and date byproducts). The animal keepers (with a mean flock size of approximately 100 goats) who do not own irrigated land have to buy feed from the farmers with irrigation in the village. Guinea grass is currently being sold for 1 AED per kg fresh grass, i.e., approximately 4 AED per kg dry matter. As a 20 kg goat needs 0.6 kg dry matter per day (about 3 % of the live weight) the cost of full feeding is 4 AED x 0.6 kg = 2.4 AED day^{-1}. The market value of a local goat is approximately 300 AED. This value is offset by 300/2.4 = 125 days of continuous full feeding. Thus feeding goats on purchased fodder during a long drought period is highly uneconomic.

Groundwater – Around Ahfara village, the groundwater table fell 2 m below the mother well of the local *falaj* system. The *falaj* (also called *qanat)* is a traditional underground well and tunnel system for water supply. The current water level in the *falaj* is around 15 m below ground. A number of farmers have had to reduce their irrigated area because of lack of water. Within the Ahfara area there is a significant gradient in water salinity depending on the distance to the sea and increasing depth (measured range 1.5 - 4.3 dS m^{-1}). With continued groundwater pumping above the recharge rate, water salinity will increase due to seawater intrusion.

Restoration options

The restoration and development potential of the area is closely linked to the general soil moisture and groundwater situation. Adequate soil moisture will enable annual range species to develop a full regenerative cycle, and thus ensure survival. Perennial species will improve their biomass production and develop reserves to survive drought stress. Improved groundwater conditions will make irrigation more sustainable and thus enable fodder production, especially during the dry season and extraordinary periods of drought when the rangelands cannot support the livestock population, and when the risk of degradation and desertification –caused by overgrazing– is high. This potential may be achieved through applying two basic principles: (i) improve the overall rainfall infiltration and recharge of groundwater, and (ii) control grazing of the rangelands, especially during the dry periods to match the carrying capacity.

Enhancement of infiltration – The terrain provides suitable basic conditions for rain infiltration. Inherent infiltration rates are favorable. With appropriate techniques, instantaneous infiltration can be increased substantially. On sites with deeper soil – usually on the lower, less steep sections of the hill slopes and in the flat valley bottoms, a large portion of the moisture will be retained in the soil profile. This moisture will improve the *in situ* plant development and plant growth on the rangeland. A smaller fraction of the water will penetrate the soil and enter the substratum to recharge the groundwater. On sites with shallow soils and a high content of large-size gravel, improved infiltration will directly increase deep percolation and groundwater recharge in the area. On these sites, the direct effects on plant development will be less pronounced.

Establishment of vegetation – The re-establishment of the vegetation (range plants) will basically be by natural regeneration, following the improvement of the soil-moisture situation. However, this process requires the exclusion of livestock during the rehabilitation period (ie. 2-5 years). Seeding (planting) useful and adapted species will speed up the restoration process on these sites. After establishment and evaluation of the carrying capacities (location-specific and seasonal) a range-use plan may be developed that ensures sustainable use of the range resources. This will include irrigated fodder production required to support the livestock population during periods of drought. At this juncture, the introduction of game may be considered, taking into account the competition with the local livestock.

Recommended water-conservation measures
Contour stone lines and small boulder bunds – To increase instantaneous infiltration, measures that improve localized surface roughness –and thus increase infiltration-opportunity time- are recommended. Contour stone lines and boulder bunds are recommended because of their simplicity, ease of construction, low maintenance requirements, and cost-effectiveness. These measures increase instantaneous infiltration and reduce surface runoff. This is particularly important for high-intensity rainfall events, which usually lead to short-term peak flows that escape to the sea through the *wadi* system. Contour stone lines and boulder bunds are particularly effective for soil-moisture and water-table replenishment. The construction materials are readily available in the area. Construction will be by hand.

Graded stormwater bunds and diversion channels – To intercept runoff at various stages along the slope –from the steep hillsides to the flatter gravel plains-, stormwater bunds and diversion channels of varying dimensions are recommended. These structures will intercept part of the runoff at pre-determined locations along the slope and facilitate infiltration. According to the locations (sites), the structures will be designed to provide short-term storage of overland flow for increased infiltration. The structures will be intermittently graded, so that any excess runoff that could destroy the structures will be discharged safely. The structures will be made from the locally available stones and soil with minimum interference in the landscape. Construction will be by hand.

Groundwater-recharge barriers – At the level of the *wadis*, recharge dams will intercept the *wadi* flow to provide groundwater recharge. In small *wadis* (*wadi* branches), the structure should be semi-pervious to reduce the risk of destruction by heavy spate flows. It is suggested to use gabions (stone cages, wire baskets) for this. Construction materials are the stones locally available. Construction will be by hand. For the main *wadi*, a major recharge dam is recommended. This dam should be designed after the other measures have been implemented and when their water-trapping efficiencies have been evaluated.

The need for more observations and studies
In order to fine-tune the design of the recommended rangeland restoration and conservation measures, systematic observations and basic studies are required for a period of 1-3 years. During this time, (i) the behavior of plants to be introduced will be studied, (ii) required moisture regimes for optimum re-establishment of various range species will be determined, and (iii) basic planning and modeling parameters relating to rainfall, runoff, infiltration, and deep percolation will be established, which are required for the design of the conservation measures.

Development Scenarios

On the basis of the identified restoration options and water-conservation measures, four different development scenarios have been developed. Each of these scenarios puts emphasis on different objectives. Public awareness creation, education and training will be integral components of each scenario.

Scenario 1: Ecosystem conservation area – This is essentially a permanent enclosure, with the aim to monitor range regeneration. In this area, studies will be made to describe and quantify local restoration processes in relation to the applied measures, particularly for rainfall-runoff relationships, water-harvesting techniques, vegetation recovery (indigenous and exotic species under different management regimes, and fodder-production strategies.

Scenario 2: Ecosystem conservation area with restricted range use – This is an enclosure with control of temporary livestock access. This area will be used to study the interaction of livestock and rangeland. The area will be managed as the area in Scenario 1, and when the vegetation has regenerated completely, small ruminants and camels will be allowed to graze in various regimes, according to the biomass production.

Scenario 3: Ecosystem conservation area with introduced wildlife – This is a permanent enclosure and wildlife park. This option will introduce wildlife according to the apparent carrying capacity of the restored rangelands and the irrigated fodder production utilizing the water resources gained from the groundwater-recharge measures in the catchment.

Scenario 4: Desert museum – This is a wildlife park and display of local traditions. This scenario combines a wildlife park with a living desert museum of the local life. It will be a living herbarium and displays of traditional life and indigenous knowledge that has mastered the survival of people and their culture under the harsh conditions of the area. This scenario opens the area to the eco-tourism industry and diversifies the economic use of the resources. It also contributes to education and heritage conservation.

Conclusions

It is assumed that the local population of Ahfara will support the planned conservation of the area, especially the livestock keepers who are dependent on the rangelands for most of the year. Therefore, the measures should be of direct (and indirect) benefit to these people. The planned measures will, to a large extent, result in improved recharge of the groundwater. Although the groundwater will not be directly available (accessible) in the grazing areas (for plants and livestock), it will indirectly help the protection of the area by providing irrigation water for the production of fodder crops, both indigenous and exotic, during the dry periods, and may help maintain *falaj* flows.

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