FAO-KSA Technical Cooperation Programme
Strengthening MoEWA's Capacity to implement its
Sustainable Rural Agricultural Development Programme
(2019-2025)

Rangeland Rehabilitation Guideline

2022

Food and Agriculture Organization of the United Nations

Riyadh, Kingdom of Saudi Arabia

NRM/051/2022/4

1. Contents

List of figures

List of tables

1. Background

Sustainable management of natural resources in the Kingdom of Saudi Arabia (KSA) faces many constraints associated with the arid climatic conditions, vast and varied landscapes, breakdown of traditional and indigenous natural resources management systems, inadequate capacity, and dispersed data and information among other challenges. The development of the environment sector, therefore, requires a holistic and comprehensive approach, one which will take into consideration institutional capacity development, efficient management processes and systems, innovative practices and technologies, development of resource value, and improved collaboration and coordination among sector actors.

Within this context, sustainable management of natural resources forms part of the flagship programme of the Sustainable Rural Agricultural Development Program jointly formulated by the Food and Agriculture Organization of the United Nations (FAO) and the Ministry of Environment, Water and Agriculture (MoEWA) within the context of the Saudi Vision 2030.

The FAO technical cooperation in the Kingdom of Saudi Arabia is providing support to MoEWA in implementing this flagship programme through the project "Strengthening MoEWA's Capacity to Implement the Sustainable Rural Agricultural Development Programme (SRADP, 2019-2025)". This project is consistent with the national development goals, fits within the Saudi Vision 2030, and contributes directly to the achievement of the objectives of the National Agriculture Strategy, the National Environment Strategy, and all Saudi development goals. The project further supports fully the achievement of the Sustainable Development Goal (SGDs) within the KSA. The project is being implemented by FAO through direct implementation modalities in full collaboration and partnership with the MoEWA Under-secretariats for Agriculture, Environment and Livestock and the relevant government centers and agencies.

SRADP constitutes nine components covering rain-fed cereals, subtropical fruits, rose, fisheries, arabica coffee, beekeeping and honey, and livestock besides natural resource management and enhancing value addition from smallholdings and rural activities. The project aims to achieve six outcomes that cut across several areas including development of innovative technologies and practices, institutional and capacity development, and development of information and knowledge products.

The NRM component of the SRADP aims to improve sustainable conservation and management of environmental and natural resources to rehabilitate vital ecosystems, improve and diversify income and living standards of rural communities and small-scale producers, strengthened food security and social stability and build the capacity of relevant institutions and organizations at different levels.

As part of the SRADP, the natural resources component specifically focuses on the domains of rangelands, forests, national parks, and combating desertification and biodiversity conservation and responds to development needs in these four areas as identified and defined in the relevant policies, strategies, and initiatives.

2. Introduction

Rangelands are very important ecologically, economically, and socially. They provide a range of ecological services, including nutrient cycling, pollutant filtering, and biodiversity preservation. They also serve as a resource base for livestock production – a key source of income and livelihood. Additionally, they hold special cultural and heritage value for pastoral and agro-pastoral communities.

Much of the arid rangelands are of low fertility soils and poor plant cover. Over time, various human activities have altered the natural vegetation cover, which mainly comprises very sparse steppe species.

During the last few decades, complex political, social, and environmental factors and management practices have degraded large areas of rangeland, this calls into question rangelands' long-term sustainability under current usage practices. The major causes of rangeland degradation, habitat change, and biodiversity loss are conversion of natural ecosystems to farmland, exploitation through selective grazing, fuel wood removal, charcoal production, and livestock overgrazing. Disturbances caused by these activities and, by climate change, influence ecosystem dynamics, structure, and composition. On the other hand, rangelands rehabilitation and management are facing several challenges and constraints, the main are:

- The protection can be efficient only if the vegetation cover keeps its resilience and the key range species are rarefied and do not disappear. Long-term protection may lead to the aging of the plants and the extension of the crust. Short-term protection (rest) is acceptable by the pastoral communities.

- Most of the plant species used in the rehabilitation operations are of low palatability. This may be due to the lack of the seeds. A seed production system should be established by the newly created National Center for Vegetation Cover and Combating Desertification and will resolve this problem.

- Some of the reasons for the continuing rangelands deterioration and the lack of achieving any progress on their rehabilitation and sustainable management are represented in the lack of effective application of rangeland and forestry law and its regulations. This needs an integrated monitoring system to enhance the application of rangeland and forest law, to reduce abuses and stop offending activities to protect and develop rangeland. The creation of the Environmental police may overcome this problem.

- Communication and coordination between the various institutions servicing and supporting grasslands in rangeland regions have been weak, with pastoral communities rarely being consulted when projects are first formulated. As a result, most past efforts directed to the development of these spaces have been mostly technical with no consideration for social aspects such as tribal rules and land tenure. Nowadays, as decentralization and local empowerment gain momentum, community participation can no longer be ignored.

- Rangeland ecosystems in the dry areas including Saudi Arabia are sensitive to changes in climate. Climate change increases the negative impacts of drought on rangeland vegetation. These impacts include low levels of emergence of annual species, changes in phenology and the timing of reproduction, reduced biodiversity, low levels of plant cover, and a decline in productive capacity in pastoral systems (Ouled Belgacem and Louhaichi, 2013). Climatic changes could also lead to a shortage of water resources, widespread land degradation, and increased desertification. These threats would negatively impact rangeland biodiversity, the life cycle of plants, and crop/livestock productivity. Overall, climate change may greatly reduce the resilience of rangeland ecosystems.

The present guideline is produced within the framework of the SRADP Component 9 “Strengthening MoEWA’s capacity in sustainable management of rangelands, forests and natural resources to support rural livelihood” and more specifically the subcomponent “sustainable rangeland management” which aims at presenting the concepts and the main techniques of rehabilitation that can be adopted by the Rangeland Department of the established National Center for Vegetation Cover Development and Combating Desertification, to improve the pastoral productivity in the selected rangeland sites in common agreement with all stakeholders including the pastoral communities, the end users. This guideline can further assist MoEWA, private sector actors, contractors, and the public generally to gain additional information about recommended procedures in the vegetation rehabilitation process and effective environmental management. Furthermore, the kinds of people for whom this guideline is designed, range from natural resource managers and planners and those engaged in policy development to research workers, teachers and students.

This guideline arises out of a need to provide clear direction to the efforts of the National Center for Vegetation Cover and Combating Desertification (NCVC) of Saudi Arabia in planning and implementation of rangelands rehabilitation and revegetation activities associated with the implementation of the Rangelands initiative under NTP 2020 of Vision 2030, the Rangeland Strategy and Saudi Green Initiative (SGI). Under the rangeland initiative, 300,000 hectares of rangelands are planned to be rehabilitated before 2030.

3. Concepts and approaches

3.1. Rangelands

Rangelands, also called Ranges, are any extensive area of land that is occupied by native herbaceous or shrubby vegetation which is grazed by domestic or wild herbivores. The vegetation of ranges may include tallgrass and shortgrass prairies, desert grasslands and shrublands, woodlands, savannas, chaparrals, steppes, and pseudo-steppes. Rangelands cover more than one-third of the earth's land surface area. These important landscapes provide a wide variety of ecosystem goods and services, such as the maintenance of biodiversity and carbon storage compared with other production land uses. Rangelands are most used as natural ecosystems to produce domestic grazing livestock and contribute to the economy, social traditions and resilience of many communities and support the livelihood of at least one billion people worldwide. However, these systems are potentially at threat from overgrazing, land clearing or cultivation and climate change. Rangelands are distinguished from pasturelands because they grow primarily native vegetation, rather than plants established by humans. Rangelands are also managed principally with practices such as managed livestock grazing and prescribed fire rather than more intensive agricultural practices of seeding, irrigation, and the use of fertilizers.

The present conditions of the rangelands are the result of a protracted evolution of plants and animals, which has also been influenced by human activities for thousands of years. Unfortunately, the impact of humans and their livestock became excessive and negative in the second half of the twentieth century. The removal of vegetation for wood and overgrazing are the main causes of the deterioration. Certain improvements have been made in some of the rangelands, but these do not make up for the serious conditions that have developed in more extensive areas.

Over 26% of Earth's land is now pasture or grazing land. This area increases to over 70% when only agricultural land is considered. These percentages are predominantly composed of rangelands, plus pastures and other types of grazing land. The area occupied by grazing land is in dynamic equilibrium with that of agricultural land and forests. More than 220 million hectares of forest became pasture in the thirty years between 1970 and 2000; this area, added to that of the previously existing rangeland, has brought the level of grazing land up to the present 3423 billion ha. Most of the new pastures emerged from the native forests of Africa, Asia, and America, and only a small part from the noncultivation of unproductive land. The abandonment of cropland has favored the new diffusion of pastures and rangelands, in some parts of Europe because of economic diversification, and in parts of Africa after population dispersal caused by both AIDS and war. In the same period, grazing lands have been lost because of acidification or salinization in Australia, and in Africa through desertification.

On the other hand, the number of livestock has increased by 600 million heads (equivalent to ~250 million livestock units (LU)) over the last thirty years of the twentieth century; the total number is at present ~3,300 million heads, half of which graze in the rangelands. This number is too high when compared to the area of pasture, thus ~30% of the total world production of cereals and pulses is necessarily used to feed some of these animals. Some of the livestock are housed in stables, but the rangelands sustain most of the domestic livestock and are also home to the largest number of wild grazers and browsers. Excessive exploitation, due both to direct human intervention and to the unduly high number of animals, has frequently resulted in moderate to severe degradation in the quality and productivity of this ecosystem.

Traditionally, the principal parameter taken into consideration when estimating the value of a rangeland was its production of forage; however, its vegetation also contributes in other ways to the economy of the local population.

Animal products and by-products, firewood and timber, medicinal plants, wild fruits, and honey—these are all part of rangeland-based economies. Moreover, some new industries have already identified the economic importance of native forage: small legumes produce estrogens for the pharmaceutical industry, while other species can absorb the heavy and toxic metals produced by industrial activities and mining; genes are being collected to improve certain characteristics of the crops. This biodiversity will presumably be valorized in the future.

Rangelands also play a significant role in ecological stability on a global scale, and their importance also comprises landscape diversity over large territories. Biodiversity, landscape diversity, and economic differentiation interact and will influence future changes in pastoral economies.

There are numerous reasons behind the degradation of rangelands in many parts of the world. Normally direct human intervention is the principal cause of degradation, which is then further exacerbated by the excessive number of livestock (Table 1).

Table 1: Causes of degradation due to bad management and the negative effects on the rangeland

	Cause	Effect
(a)	Excessive stocking rate	Excessive intake; reduction of vegetation cover; diffusion of unpalatable and toxic-poisonous species; reduction of the seed bank in the soil
(b)	Wood collection and tree cutting	Reduced vegetation cover; decreased seasonal availability of forage; deterioration in microclimate, also for herbaceous pasture
(c)	Absence of rotation of the grazing sectors	Continuous removal of tissues and nutrients from the plants; management difficulties (weed mowing, manure distribution)
(d)	Excessive frequency of pastoral fires	Extinction of or damage to the perennial species, destruction of annuals, destruction of unburied seeds; nutrient leaching; soil erosion
(e)	Lack of improvements to sustain productivity and biodiversity (sowing, fertilization, weed control)	Vegetation productivity lower than optimal; reduced soil fertility; invasion of alien species
(f)	Use of unsuitable animal breeds or non-selected genotypes	Animal productivity lower than optimal (temperate breeds introduced in the tropics); low meat transformation rate (native animals not bred)
(g)	Absence of handling facilities	Damage to the soil by trampling; reduced animal productivity; diffusion of animal disease; increased number of animal deaths
(h)	Lack of differentiation of the vegetation resources	Sensitivity to seasonal and annual variations of climate; diffusion of phyto-pathologies; excessive specialization of produce

Rangeland systems are vulnerable to climate change (Ouled Belgacem and Louhaich, 2013). Rangelands vegetation dynamics, and in consequence livestock production, are highly sensitive to climate—mean climate trends, but also and importantly climate. High interannual climate variability creates large fluctuations in forage supply, and thus represents a challenge for herd management. Increases in intra-annual climate variability may also affect livestock production, although studies establishing relationships between climate seasonality and livestock dynamics and productivity are scarce and often limited to the analysis of drought and flood events. Studies focused on vegetation have however found that changes in seasonal climate patterns can have either positive or negative impacts on above-ground biomass and forage quality, depending on the nature of the change and the agroecological context (Godde et al., 2020).

Rangelands are also threatened by climate change-driven woody plant encroachment. In addition to altering rangelands ecosystems services, these dynamics impact ruminant production systems since woody forage is harder to physically access for cattle and sheep and less palatable, digestible, and nutritious than herbaceous plants.

Rangelands are the dominant land use in Saudi Arabia. They suffer since the last century from severe degradation due to profound socioeconomic changes. Traditional grazing systems (transhumance and nomadism) which had historically allowed for grazing deferment and control of grazing livestock were abandoned. Human disturbances, such as overgrazing and firewood harvesting, are the main activities that reduce natural plant communities in the rangelands. Furthermore, the interaction between human disturbances and climatic factors modifies the structure of natural ecosystems (Ouled Belgacem et al., 2008).

3.2. General model of rangeland ecosystem degradation

Depending on the stage of degradation reached, several techniques have been developed and practiced in different countries of the MENA region to enhance the ecosystem resilience of rangeland in the face of disturbance and stress factors and improve its productivity. Figure 1 presents the general model describing the ecosystem degradation process to help decide when restoration, rehabilitation, or reallocation should be the preferred response. The latter two pathways are suggested when one or more “thresholds of irreversibility” have been crossed in the course of ecosystem degradation, and when “passive” restoration to a presumed pre-disturbing condition is deemed impossible.

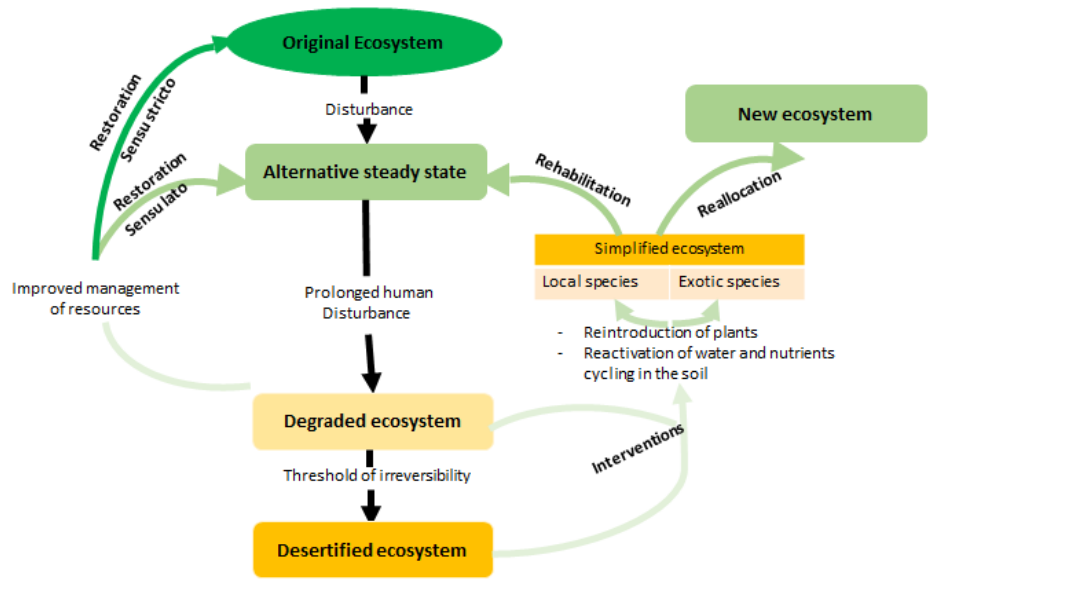

Figure 1: General model of rangeland ecosystem degradation and the 3 potential options of its development (Aronson et al., 1993, adapted)

3.2.1. Threshold of degradation

The threshold of irreversibility is the separation point between restoration and rehabilitation (Figure 1). Restoration techniques may be used and promote successful outputs once this threshold is not reached. However, only rehabilitation techniques are generally applied once having passed through a state, when most ecosystems apparently cannot cross back without interventions designed to correct the specific changes that led to the threshold being crossed (Aronson et al., 1993; Visser et al., 2010). Practically, this state is not easily detected or quantified, for example, reconstitution of seed banks might be needed, or the restocking of soil fertility that promote higher plant establishment and growth.

The major objectives of restoration and rehabilitation are, at the ecosystem level, both to maintain or increase primary or secondary productivity and to enhance biodiversity and stability and, at the landscape level, to facilitate reintegration when they have been severely fragmented.

3.2.2. Restoration

To face the degradation of the plant cover, it is necessary to take adequate measures to relieve human pressure and promote the auto-regeneration of the vegetation. In areas where degradation has not reached the threshold of irreversibility, natural vegetation can be regenerated, very often, by simple protection or by improving the soil fertility conditions. If the degradation of the rangeland ecosystem has not entirely suppressed the possibility of its resilience, the ecosystem can, following the removal of disturbance factors return to its structure, its biodiversity and therefore its equilibrium stage. However, if the level of soil fertility does not allow a rapid return of this equilibrium, the induced improvement of soil fertility by fertilizer application accelerates the process of plant cover restoration. It has been shown that the ecological equilibrium stage is often marked by the dominance of grasses as well as other highly palatable species which have been rarefied under different constraints and disturbances (Ouled Belgacem et al., 2008).

The Society for Ecological Restoration (SER) defines restoration as "the intentional alteration of a site to establish a defined indigenous, historic ecosystem" (Aronson et al., 1993). The UICN adopted the following definition of ecological restoration: "*Ecosystem Restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (SER, 2004)***"** The goal of this process is to emulate the structure, functioning, diversity, and dynamics of the specified ecosystem. It seeks to put back exactly what existed in the ecosystem before the disturbance.

3.2.3. Rehabilitation

In situations where rangeland degradation reaches the threshold of irreversibility, seeds are lacking in the soil and the reconstitution of the ecosystem by a simple restoration is no longer possible, the rehabilitation by reintroduction of the range species having disappeared and/or improving the soil conditions (scarification, water harvesting techniques, etc.) become the only alternative to improve the productivity of the rangeland ecosystem to be comparable to the initially existing one.

Rehabilitation seeks to repair damaged or blocked ecosystem functions, with the primary goal of raising ecosystem productivity by putting back most of what existed in the ecosystem prior to the disturbance (Aronson et al., 1993). It aims at increasing the productivity of the degraded ecosystem, to which it is applied, by repairing as quickly as possible its altered functions (destroyed, diminished, or blocked). It is a question of restoring the structure and the level of functioning by taking as a model (reference ecosystem) a stable and autonomous alternative state of the pre-existing ecosystem.

3.2.4. Reallocation

Reallocation happens when part of a landscape, in any state, is assigned a new use that does not necessarily bear an intrinsic relationship with the pre-disturbance ecosystem's structure or functioning. For simplicity's sake, reallocation pathways in figure 1 are indicated only after various stages of ecosystem degradation have taken place and one or more thresholds of irreversibility have been crossed. It can occur in the case of a slightly disturbed ecosystem or even an undisturbed (pre-disturbed) one. Problems arise when reallocated sites sprawl over landscapes in an anarchic fashion.

In contrast with restoration and rehabilitation, reallocation assumes a permanent managerial role for people and normally requires ongoing subsidies in the form of energy, water, and fertilizers. The huge plantations of the fodder shrubs in the MENA region, such as Atriplex, Acacia, and Opuntia spp., are examples of reallocation.

4. Techniques of Rehabilitation

Some of the main rehabilitation techniques that can be used in Saudi Arabia are presented below. The choice of techniques depends on the condition of the rangeland to be rehabilitated. This, therefore, requires a characterization of the target rangeland (Annex 1).

4.1. Water harvesting

Water is an important resource in arid and semi-arid rangelands, but often it is wasted or allowed to erode the landscape. One way to address this is through simple, cost-effective water harvesting techniques (WHT) that can be easily adopted by pastoral and agro-pastoral communities. This practice has been used for thousands of years in arid and semi-arid regions of the world to supplement scarce water resources. In general, the interventions are used to increase soil moisture content, vegetation cover, and productivity and can improve the productivity of rainwater, and maintain productive and sustainable agro-pastoral systems in marginal environments (Van Wesemael *et al*., 1998). WHT can also control soil erosion and reduce the impact of drought. Experience of the last two decades provides increasing evidence that WHT can mitigate the effects of increasing rainfall variability.

4.1.1. Soil scarification

The degradation hazard of some species may be insensitive to a decrease in vegetation cover if the site is flat. Whereas further deterioration of vegetation leads to reducing litter accumulation on soil surfaces, disruption of nutrient cycles, the formation of soil crusts, disruption of nutrient cycles that retard or impede germination on microsites, and altered species composition (Archer, 1989). Given these circumstances, the availability of microsites should be developed to serve as useful factors for changes in the vegetation cover.
The recommended soil treatment is scarification, scratching or disturbance of the soil surface to permit deeper water penetration and provide microsites for seedling establishment.
The severe depletion of the soil's seed bank following many years of continuous grazing makes soil scarification alone insufficient to establish and maintain rangeland. To not limit rangeland regeneration, seeding desired species may be required. Scarification of the soil surface to enhance seeding success is frequently advocated as a mechanism to create a favorable microsite and retain soil moisture for the germination and survival of seedlings.

Scarification is intended to overcome the drawbacks associated with the presence of a hard crust on the soil surface that causes poor penetration of rainwater and difficulties in germination. Its beneficial effects, both on the production of annuals and on the value of perennial plants, have been demonstrated in many arid areas, especially in xeric soils.

The objective of scarification is to improve the water balance of the soil through the destruction of the surface crust which promotes infiltration of water and consequently helps to bury seeds and facilitate germination. Its effect depends on many factors including the type of soil, the stock of seeds in the soil, the date of intervention, and the tolerance of the plants to this practice among others.

The role of anti-erosive structures consists, among other things, in protecting pastures against water erosion (runoff) thanks to the construction of small structures to stop gullies such as banks, dry stone cords and the consolidation of ravines by dry stones and gabions.

However, water and soil conservation works must be considered with caution in line with its objectives and locations. In fact, in arid and desert areas, most of the fodder supply comes from around the sites corresponding to depressions and wadis benefiting from runoff. Any intervention causing an alteration of this balance risks causing a drop in overall production, especially if through water harvesting, the water would be retained in places with poor-quality soils. On the other hand, it would be wise to focus on controlling and using part of the floodwaters from the wadis before they flow into non-productive places like the sebkhas.

Scarification should be applied to sandy loam soils covered with crust. It might be established in alternating bands with others that are not scarified. Scarification must be carried out using light tools with teeth mounted on flexible springs to ensure very superficial scraping work and above all to prevent the loosening of native woody vegetation. The Chisel seeder would be the most suitable tool. In stony places with a compacted surface horizon and therefore not very sensitive to wind erosion, it is recommended to carry out picking using a plow. Lines which can be of varying lengths should be spaced ten to twenty meters apart (depending on the density of the remaining vegetation and the degree of the slope) and laid out perpendicular to the slope.

4.1.2. Rainwater harvesting

In arid environments, rainfall is one of the most limiting factors associated with the failure and success of rangeland management projects. Rainwater harvesting practices are usually combined with shrub plantation and direct seeding and protection from grazing for successful rangeland rehabilitation. Therefore, rainwater harvesting techniques are considered a part of the solution aimed at improving arid rangeland productivity. Rainwater harvesting systems can be constructed in several ways that are easy, versatile, and adaptable to a wide range of conditions. They can be used anywhere in rural areas, and local people can easily be trained to install them. This lowers costs and promotes greater community engagement, ownership, and sustainability.
Rangeland managers strive to create sufficient catchments on the soil's surface to provide enough water to meet the needs of the vegetation recovering by planting and seeding.
The amount of water collected from such watersheds is dependent on the size of the area, the constructed catchment, the intensity of the precipitation, and soil permeability.
Bunds. For small areas, using semi-circular bunds and V-shaped micro catchments are an appropriate practice for the rehabilitation of degraded rangeland.

Figure 2 : Semi-circular bunds and V-Shape micro catchments for shrubs in Bsita, Aljouf region (Photo credit: Mbarak Al Sharari)

The sizes of semi-circular bunds vary from small structures (2 m) to very large structures (30 m). Bunds are constructed by digging out soil from within the area to be enclosed and supporting it up to form the bund. They are easy to construct and reduce soil erosion and catch water to insure good storage for the shrubs. The bunds should be established along a contour line in a matched arrangement so that water, will be caught and collected by those two main tips. Semi-circular bunds are suitable on gentle slope areas. One or two shallow holes are dug in the lowest part to help concentrate moisture; in these holes, the seedlings are placed. While V-shaped micro catchments are well suited for hand construction, they cannot easily be mechanized. These micro catchments are mainly used for growing trees or shrubs in arid and semi-arid areas.

Contour bunds. For large areas, contour bunds are suited for rainwater harvesting. They are suitable on the sloping ground of low rainfall areas where runoff can be impounded by constructing bunds all along the contour of equal elevation. Contour bunds may be continuous contour furrows or Intermittent contours.

- **Contour furrows.** Contour furrows are small soil banks that run along a contour. A furrow should be established next to each bank on the upper side of the slope. The distance between the ridges varies depending on the rainfall and the slope. Contour furrows aim to concentrate moisture into the ridge and furrow area where the plants are placed by trapping runoff water from the catchment area. This also reduces the erosion risk. To maximize the runoff between the two ridges, the catchment area should be left uncultivated and clear of vegetation.

- **Intermittent contours.** To prevent the destruction of the contour bunds, intermittent contours are very useful for erosion control. Contour bunds are a mechanical method that makes them efficient for large scale rehabilitation. The optimal distance between two contours depends upon the slope of the area, where steeper grounds require less distance.

4.2. Direct seeding

The restoration of large areas can be expensive, although more modest efforts are often practical and can be effective if implemented well. Low-cost options, such as direct seeding or natural regeneration, are cost-effective in returning degraded ecosystems to productive levels.

Direct seeding involves sowing seeds directly into their final growing position, rather than transplanting seedlings. Direct seeding is ideal for small or large areas where the terrain and cost of transplanting seedlings prevent natural regeneration or planting. It is an age-old practice that has regained favor because of the high costs associated with alternative methods of planting and transporting seedlings from nurseries for transplanting. Direct seeding reduces the time and labor required, increasing resource efficiency.

4.2.1. Improving the impact of direct seeding in drylands

The limited success of direct seeding in drylands is mainly caused by drought, and seed mortality due to heat and predation by birds or insects. Outcomes can be improved through better site selection and ground preparation as extensive areas of barren rocky hills are characteristic of many degraded dryland ecosystems. Drilling and pitting seeds also enhance the success of direct seeding.

4.2.2. Enhancing emergence and seedling establishment

The efficiency of direct seeding can be enhanced by seed pretreatment methods. These can break dormancy and overcome field stress factors. Seed pretreatment also speeds up germination and enhances seed survival. Pretreatments include mechanical and hand scarification, soaking in hot water, or treating with acid. To optimize direct seeding benefits, low-cost direct seeding could be combined with transplanting seedlings, which is more expensive, but more reliable.

4.2.3. Choosing species for direct seeding

The success of direct seeding varies with species, field conditions, and plant and seed characteristics. Direct seeding is better for rehabilitation projects with a strong biodiversity element, as multiple species are far easier to handle this way. In the dry areas, it is recommended to target the lowlands and micro-depressions receiving a supplement of rainwater by runoff. This will increase the chance of the seeding operation.

4.2.4. Methods of direct seeding

The most common method of direct seeding is hand broadcasting. However, this must be combined with soil scarification or the use of a seed drill to improve emergence and survival, especially in terrain dominated by hard soil and rocky outcrops. Seed drilling makes much better use of limited seed supplies than hand broadcasting. A seed drill typically has disks that open a furrow, a seed metering device to place the seed in the furrow, and a set of disks or wheels to bury the seed.

Placing seeds in pits made by hand or machine in the soil improves emergence and survival because seeds are protected from wind and absorb moisture better. Seeding with an imprinter also improves seedling establishment and survival by creating soil micro catchments that collect water. Seeding depth is also a very important factor for emergence and seedling establishment. An appropriate depth is recommended to avoid the risk of seed at low depth drying up before germination and to avoid exhaustion of seedling reserves when seeds are placed too deep in the soil.

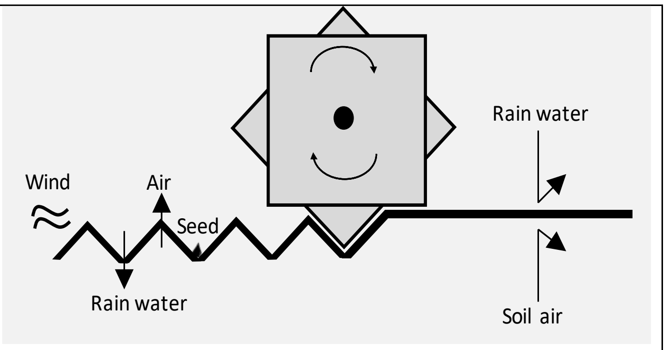

Figure 3: Soil scarification using a tractor. Effectiveness and pattern of direct seeding with an imprinter increase water harvesting and seed survival.

4.2.5. Advantages of direct seeding

The advantages of direct seeding include:

- It is cost-effective when compared with transplanting seedlings.
- Plants develop deep, strong root systems that help them establish quickly and tolerate drought and wind.
- The timing of the planting is more flexible, depending on the species being planted and seed treatments.
- It promotes vegetative growth in areas difficult to reach, such as hillsides.

4.2.6. Effective establishment and maintenance

The condition for effective establishment and maintenance in direct seeding include:

- Selection of sites and pre-sowing treatments are vital to the success of direct seeding.
- Direct seeding should be done at the beginning of the rainy season.
- The sowing rate should be adjusted based on seed viability not total seeds.
- A high seeding rate increases seed emergence and establishment.

4.2.7. Innovation in reseeding

Direct seeding is a cost-effective way of introducing species to a degraded ecosystem, as there are no nursery and seedling transplanting expenses. However, the micro-environment of the developing seedling is important. Consequently, selecting groups of species with similar habitat requirements at the establishment phase and introducing these to the site in stages will improve species performance and the rate of rehabilitation. Timing of seed sowing should also be considered, as well as methods to enhance seed emergence, such as seed pretreatment techniques.

A new approach is direct seed where pellets stuffed with fertilizers, pesticides (the seeds be coated with materials which will not disintegrate when in contact with moisture on the soil surface) are used in the pelleting process. This is used to enhance the seeding in the range grass seeds for aerial seeding in semi-arid regions. The pellets absorb sufficient moisture to cause emergence through the coat. This feature alone has been the main reason for many failures in aerial seeding projects. It might become an advantage in using this method in spreading the rehabilitation process over large areas of the rangelands.

4.3. Planting fodder shrubs

Shrub canopy reduces solar radiation and soil temperature, conserve moisture, and enrich the soil nutrient content. In providing ecosystem goods (especially forage for livestock and carbon sequestration), shrubs in arid zones boost poverty alleviation strategies and contribute to reducing food insecurity. The integration of shrubs through agroforestry has the potential to improve both the sustainability and profitability of utilizing a piece of land, thus improving the livelihoods of smallholder farmers.

4.3.1. Shrub planting benefits:

The benefits of planting shrubs include:

- Ability to valorize marginal water not usable for conventional crops,
- Facilitative effect for the establishment of understory vegetation,
- Supply of ecosystem services,
- Improvement of salt-affected soils by halophytic shrub species such as saltbush, and
- Feeding livestock during drought and source of firewood for farmers.

4.3.2. Species and site selection

Select shrubs well-adapted to the conditions of individual planting sites. The choice of species will depend on the annual rainfall rate, soil, topography, runoff, and water harvesting potential of the site, and the likelihood of environmental stresses such as drought, salinity, and cold. Species selection is also guided by rangeland development objectives, such as fodder production, wood production, dune fixation, or erosion control.

4.3.3. Ideal species for arid environments

In arid and semi-arid areas, common fodder shrubs include *Atriplex halimus* (Mediterranean saltbush), *A. leucoclada* (Orache), *A. nummularia* (old man saltbush), *Bassia prostrata* (desert bush), *Salsola vermiculata* (Mediterranean saltwort), and *Haloxylon aphyllum* (saxaul). Certain shrubs contain anti-nutritional factors (secondary chemical compounds or toxins), which reduce the overall digestibility and palatability of their forage quality. Care must be taken to select highly adaptable species to low rainfall and salt conditions of arid environments.

4.3.4. Challenges during shrub planting

The high cost related to the establishment and the maintenance of shrubs presents the main challenge for smallholder farmers with low incomes. Another common issue faced by most rehabilitation programs is the availability of suitable species for the target ecosystem at the right time. In most cases, supplementary irrigation is needed right after planting to secure good roots and soil contact. Alternative feed resources to supplement livestock are most often in high demand in dry areas. This increases the risk of predation on planted shrubs as young succulent seedlings are more preferred by animals than older and more mature plants.

4.3.5. Effective establishment and maintenance:

Effective establishment and maintenance of planted shrub require:

- Special care when transporting seedlings from the nursery to the planting site to reduce mortality
- Hardening of young seedlings by gradually introducing them to their new environment
- Avoiding browsing by livestock during the establishment phase
- Allowing enough recovery time after events of browsing/harvesting
- Replacing missing and/or dead seedlings in the following season
- Pruning shrubs every other year to induce regeneration of new growth.

4.3.6. Establishment and management

Shrubs can be established in degraded rangelands using seeds or transplants (young seedlings). In some shrub species, seed germinability is low and several techniques are used to aid seed germination, such as seed pretreatment through scarification, or soaking in hot water. To improve overall productivity once established, rotational browsing/grazing of the rangeland will aid in stimulating new growth and reducing soil erosion, depletion of soil nutrients, prevalence of weeds and invasive species, and more uniform soil fertility levels. Browsing shrubs is permissible after good establishment to avoid a reduction in survivability or growth.

4.3.7. Combining shrub planting with water harvesting techniques

On deep slopes, shrubs are planted into a prepared micro-catchment with water harvesting structures to harness surface runoff and enhance soil moisture conditions, thus creating a more favorable micro-environment for shrubs and native vegetation. Semi-circle structures and intermittent contours are simple and suitable water harvesting methods that can be implemented by small-scale farmers. Combining shrub planting and water harvesting techniques improves erosion control, forage quality and availability, and plant and animal biodiversity levels.

5. Sustainable rangeland management practices

5.1. Monitoring and assessment

Any rangeland rehabilitation and management activity should be preceded by an inventory, an assessment, and an appropriate mapping of the condition and use of the rangeland. To ensure that these lands can provide sustainable products for future generations, their ecological condition should be monitored against specific standards. Both short- and long-term monitoring are necessary – to account for the dynamic nature of plant community responses to climate and management strategies. Large rangeland areas can be rapidly mapped and monitored if appropriate technology such as GIS and remote sensing are used.

Once we have the full information on rangeland condition (Range species ecology, phenology, biomass, rangelands trends, current stocking rates, watering points location and water quality, active wind or water erosion sites, sand dunes movements, etc.), we are able to put in place appropriate management strategies. Such strategies include where, when, and with what kind of plants we should approach the range rehabilitation task. This must be in consultation and collaboration with the pastoral community.

5.2. Participatory approach

Sustainable rehabilitation of degraded rangelands that are dominated by collective and/or tribal use is a challenging task. The policy responses to this complex issue have been sectorial and fragmented. Previously, the "top‐down" approach, which puts forward technical solutions and neglects the social context, was the more common form of intervention. But in response to frequent failures of the top-down approach, international development turned during the 1970s towards ‘participatory development’ as an alternative approach. National governments have been slow to adopt this participatory approach, but recent experiences suggest that integrated and participatory approaches may lead to more sustainable rangeland resource management. This kind of development aims to organize people on a decentralized basis and to apply participatory tools to effectively empower local people (Nefzaoui et al., 2014).

5.3. Grazing management

Once rangeland is rehabilitated through combined practices such as soil scarification, rainwater harvesting, planting, and seeding, grazing management is an effective tool for the sustainable management of these harsh ecosystems. Grazing management is a tool to balance the capture of energy by plants, the harvest of that energy by animals, and the conversion of that energy into a product that is marketable. Timing of grazing and growth rate of plants after-grazing events are key factors in controlling the frequency, intensity and duration of grazing. These factors enhance soil stability, forage production, efficiency of forage use, and improve livestock production.

6. Conclusions

Both restoration and rehabilitation aim at maintaining or increasing primary or secondary productivity and enhancing biodiversity and stability and facilitating the reintegration of severely fragmented landscape. The difference lies in the fact that rehabilitation frequently requires the imposition of a "forced start" of a new ecosystem trajectory that combat the conditions for establishing irreversibility thresholds. However, restoration projects apply to ecosystems that still can't repair the negative effects of minor disturbances.

Reversing the trend of rangeland degradation, and sustainably increasing forage, requires better management. If management and rehabilitation are to be sustainable in the long term, they must also be conducted in a participatory manner. Using this approach, developments that improve the productivity of rangelands involve a set of policies to assure pastoral communities that they will benefit from the improvements made. Ownership, whether in legal terms or in practice, needs to be cultivated and respected so that pastoralists become guardians of their resource base, thus encouraging long-term sustainable management. Further research on land tenure arrangements is required to encourage best management practices throughout the rangelands. In KSA, the National Center for Vegetation Cover and Combating Desertification needs to clearly identify the rights and responsibilities of all rangeland users, including the pastoral communities. This can ensure that those with the right to manage land are aware of their management responsibilities.

7. Citations

Aronson, J., Floret, C., Le Floc'h, E., Ovalle, C., & Pontanier, R. (1993). Restoration and Rehabilitation of Degraded Ecosystems in Arid and Semi-Arid Lands. I. A View from the South. Restoration Ecology, 1, 8-17.

Attia W.,Tarhouni, M., Ouled Belgacem A., Gammar O., Khatteli H. 2013. Vegetation dynamics under variable conditions in the famous sandy steppe of southern Tunisia. African Journal of Ecology: 53: 16-24.

Le Floc'h, E., Neffati, M., Chaieb, M., Floret, C., Pontanier, R. 1999. Rehabilitation Experiment at Menzel Habib, Southern Tunisia. Arid Soil Research and Rehabilitation, 13(4): 357-368.

Ouled Belgacem A., Tarhouni, M., Louhaichi M. 2013. Effect of protection on plant community dynamics in the Mediterranean arid zone of southern Tunisia: a case study from Bouhedma national park. Land Degradation & Development, 24: 57–62.

Ouled Belgacem, A., Ben Salem H., Bouaicha A., El Mourid M. 2008. Communal rangeland rest in arid area, a tool for facing animal feed costs and drought mitigation: the case of Chenini Community, Southern Tunisia. Journal of Biological Sciences 8 (4): 822-825.

Visser M., Ouled Belgacem A., Neffati M. 2010. Reseeding Mediterranean dryland cereal fallows using *Stipa lagascae* R. & Sch.: influence of cutting regime during the establishment phase. Grass and forage Science, 65(1): 23-27.

Tollner, E.W., Calvert, G.V., Langdale, G. 1990. Animal trampling effects on soil physical properties of two Southeastern U.S. ultisols. Agriculture, Ecosystems & Environment, 33(1): 75-87.

Anderson, D., L.P. Hamilton, H.G. Reynolds, and R.R. Humphrey. 1957. *Reseeding Desert Grassland Ranges in Southern Arizona.* Tucson, AZ, USA: Arizona Agricultural Experiment Station Bulletin 249.

Bainbridge, D.A. 2007. Guide for Desert and Dryland Restoration: New Hope for Arid Lands. Island Press, Washington, DC.

Fischer, H., F. Huth, U. Hagemann, and S. Wagner. 2016. Developing restoration strategies for temperate forests using natural regeneration processes. Pages 103–164 *in* Restoration of Boreal and Temperate Forests, 2nd edition (J.A. Stanturf, ed.). CRC Press, Boca Raton, FL.

Godde, C.M., Boone, R., Ash, A.J., Waha, K., Sloat, L., Thornton, P.K., Herrero, M., 2020. Global rangeland production systems and livelihoods at threat under climate change and variability. *Environ. Res. Lett.* 15, 44021. https://doi.org/10.1088/1748-9326/ ab7395.

Lohrey, R.E. and E.P. Jones. 1983. Natural regeneration and direct seeding. Pages 183–193 *in* Proceedings of the Managed Slash Pine Ecosystem Symposium (E.L. Stone, ed.). University of Florida, School of Forest Resources, Gainesville, FL.

Mohammad, N. 1989. Rangeland Management in Pakistan. International Center for Integrated Mountain Development, Lalitpur, Nepal.

Munshower, F.F. 1994. Practical Handbook of Disturbed Land Revegetation. Lewis, Boca Raton, FL.

Uriarte, M. and R.L. Chazdon. 2016. Incorporating natural regeneration in forest landscape restoration in tropical regions: synthesis and key research gaps. *Biotropica* 48(6): 915–924.

- Ouled Belgacem A., Neffati M., Papanastasis V., Chaieb M. 2006. Effects of seed age and seeding depth on growth of *Stipa lagascae* R. & Sch. seedlings. *Journal of Arid Environments*. 65: 682-687.

Franzel, S., Carsan, S., Lukuyu, B., Sinja, J. and Wambugu, C., 2014. Fodder trees for improving livestock productivity and smallholder livelihoods in Africa. Current Opinion in Environmental Sustainability, 6, pp.98-103.

Louhaichi, M., Yigezu, A. Y., Werner, J., Dashtseren, L., El-Shater, T., and Ahmed, M. 2016. Financial incentives: Possible options for sustainable rangeland management? Journal of Environmental Management 180: 493-503. doi:10.1016/j.jenvman.2016.05.077

Louhaichi, M., Ziadat, F., Ates, S., and Zucca, C. 2016. Rangeland rehabilitation in the southern part of the Mediterranean basin. Options Méditerranéennes, Series A: Mediterranean 114: 415-418

Ouled Belgacem, A., and Louhaichi, M. 2013. The vulnerability of native rangeland plant species to global climate change in the West Asia and North African regions. Climatic Change 119: 451-463

Oweis, T.Y., 2016. Rainwater harvesting for restoring degraded dry agro-pastoral ecosystems: a conceptual review of opportunities and constraints in a changing climate. Environmental reviews, 25(2), pp.135-149.

Pardini A. 2008. Rangeland Management. *In: Biodiversity conservation and habitat management.* Vol. I–. UNESCO, ISBN: 978-1-84826-920-0. Pages: 236-260.

Standish, R.J. and Hulvey, K.B., 2014. Co-benefits of planting species mixes in carbon projects. Ecological management & restoration, 15(1), pp.26-29.

Vallentine, J. 1980. Range development and improvements, 2d edition. Brigham Young University Press, Provo, UT.

Annex 1. Site Characterization

General information on site:
Country: **Governorate:** **County:** **Site name:**
Area (ha): **GPS Coordinates:**
Elevation (m):

List of categories for data collection and review in the baseline.

	Categories/tools	Contents
1	**Acting social institutions**	•Type of institution (NGOs, CBOs, GDA…) •Effectiveness (services) •Presence of conflicts (within and outside)
2	**Maps, satellite images and photos**	• Maps: administrative boundaries, soil, terrain, land-use, vegetation, watersheds, agro-ecological zones, land use systems (LUS), roads etc • Aerial photographs • Time series satellite images (SPOT-NDVI) • Land use and water resources plans
3	**Climatic (including natural disasters) and meteorological records**	• Rainfall amounts and variability; temperature; humidity • Trends in rainfall and temperature over recent decades • Incidence and impacts of drought and flooding etc. • Information and studies on the impacts of climate change including likely future impacts on water resources.
4	**Water resources**	• Water resources records over the last decade (Sources: water boards / authorities) to show - water flow regimes in rivers - water storage capacity and water levels of lakes, dams and reservoirs - sedimentation load / rates • Incidence of water borne diseases and pollutants (Sources: health sector and water authorities) etc.
5	**Vegetation**	• Type of disturbance (past and present) • Vegetation structure (past and present) • Dominant plant communities • Key plant species (forage, erosion control, wildlife, herbal, and medicinal) • Percent cover • Biomass production • Diversity (richness, floristic composition…) • Soil seed bank and the ability for regeneration • Life form

		• Palatability index
6	**Soil**	1- Soil Observations • soil cover (protection) • soil colour and soil life (SOM content) • soil texture (erodibility) • soil structure (permeability, root penetrability and stability) • soil depth (plant rooting depth and nutrient and water availability) 2- Soil Measurements • pH (acidity and alkalinity) • slaking and dispersion (stability) • soil labile carbon content (often backed up by lab. analysis of total organic C) • salinity and sodicity • nutrient content (N, P, K and micronutrients) (optional lab tests)
7	**Edaphic factors (site, soil)**	• Slope gradient and slope aspect (direction) • Elevation (above sea level) • Topography features • Location of site within the watershed • Soil properties (texture, structure, depth, organic matter content, salinity, basic infiltration rate, runoff coefficient) • State of soil surface (crust, feces, litters, rock, gravel, etc.) • Type and indicators of soil erosion (wind, water, presence of rills and gullies) • Ground cover (vegetation, rocks, gravels, crusts, rock outcrop, litter…)
8	**Human Population (socioeconomic data)**	• Total population and recent trend(s); age, gender and ethnic minority distribution • Household and family composition information • Employment by sector; labour force; migration information; settlement patterns etc. • Poverty and food security etc. • Household income information; composition of income (i.e. contribution from farming and other activities) • Proportion of population below poverty line, % of food insecure, malnutrition etc. • Credit / loan availability, etc.

9	**Land use types**	• Size of land use types in the local assessment area and community territory; farm land and protected areas • Areas and proportions under different land use types (including forest and protected areas). • Land cover and land resources surveys, etc. • Type of ownership (private, communal, state) • Traditional users • Governance (mechanism, regulation)
10	**Farming system information**	• Existing agricultural plans, programmes and projects Crop and livestock and forestry systems information • Presence & extent of local and introduced practices for land management / land degradation control • Information on livestock numbers, distribution, ownership, actual and recommended stocking densities, management
11	**Pastoral Animal Production**	• Flock size per HH • Type of dominant livestock • Feed calendar (grazing and non-grazing feed resources) • Livestock watering resources • Subsidies (feedstuffs, veterinary services, watering) • Grazing practices (spatial and temporal mobility of flocks) • Role of women in the livestock production • Availability and adequacy of livestock supporting services (veterinary, marketing, shearing).
12	**Wild life**	• Wild life species (Birds, mammals) • Population density. • Endangered species
13	**Land tenure**	Information on land-holdings: ownership, size and distribution Type and prevalence of renting/leasehold arrangements Legal status of holdings (civil, cooperative, government arrangements, titles) etc.
14	**Institutions, policies, regulations, byelaws**	• Relating to land, agriculture, livestock, water resource, environment, rural development, technical sectors, extension • Relating to implementation of the multilateral environmental conventions (UNCCD, UNCBD, UNFCCC, Ramsar, etc.) • Access to services ((official/informal), private / public sector), application / effectiveness of

		regulations / policies, mandates / capacities of actors, etc. • Presence, roles and activity of NGOs, community based organizations in their implementation, etc.
15	**Basic infrastructure and investments**	• Road and market access; input supply • Schools; health centres; • Water points (wells, boreholes, piped / tap water); • Irrigation systems; reservoirs;
16	**Planning reports and Rangeland improvement and development activities**	• Land use planning; water resources planning; agriculture and forest management plans; livestock / environmental management; etc. • Water harvesting (micro- and macro-catchments) • Revegetation (direct seeding, seedlings) • Managed grazing • Training and extension