Sustainable Rangeland Management Toolkit for Resilient Pastoral Systems

International Union for Conservation of Nature

TABLE OF CONTENTS

CREDITS

This publication has been made possible in part by funding from GEF and the implementing agency for the HERD project UNEP.

Published by: IUCN, Gland, Switzerland in collaboration with IUCN ROWA

Produced by: IUCN Regional Office for West Asia

Cover photo(s): IUCN ROWA & ICARDA

Layout by: Nisreen Al Kabariti

Printed by: Doculand Print & Copy Center

IUCN Project team: Dr Hany El Shaer / Dr Laith Al Rahahleh / Amer Al Maadat / Emma Kool / Razan Baqain / Laila Annouri

LIST OF CONTRIBUTING AUTHORS

- Mounir Louhaichi (ICARDA, Tunisia)
- Jonathan DAVIES (IUCN, Kenya)
- Mouldi Gamoun (ICARDA, Tunisia)
- Sawsan Hassan (ICARDA, Jordan)
- Mahfouz Abu Zanat (University of Jordan, Jordan)
- Mohamed Neffati (IRA Medenine, Tunisia)
- Maher Tadros (JUST University, Jordan)
- Azaiez Ouled Belgacem (FAO, KSA)
- Toshpulot Rajabov (Samarkand University, Uzbekistan)
- Bora Masumbuko (IUCN, Kenya)
- Chris Magero (IUCN, Kenya)
- Claire Ogali (IUCN, Kenya)
- Slim Slim (ESAM, Tunisia)
- Mohamed Ahmed B. Abdallah (OSU, USA)
- Mohamed Souissi (Consultant, Tunisia)
- Mehdi Sebri (Office of Livestock and Pastures, Tunisia)

ACKNOWLEDGEMENTS

IUCN is a membership Union and home to numerous multi-national governments and active civil society originations. It thrives to harness the scientific knowledge and tools to address pressing human and environmental challenges while finding a balance and inclusive zone for both economic development and nature conservation. Land degradation and the associated loss of biodiversity and natural habitat productivity due to climate change and anthropogenic activities have become a serious global challenge that requires immediate action. Arid and semi-arid lands are home to millions of vulnerable and poor communities and their livelihoods are on edge of devastation, threatening not only the social integrity but its repercussions will be, sadly, felt elsewhere.

The HERD project – Healthy Ecosystems for Rangeland Development (HERD): sustainable rangeland management strategies and practices – is being fabricated through close collaboration of local and international partner organizations, stakeholders and actors, and multi-objective institutions to address land degradation in both Jordan and Egypt.

Participatory approaches and innervations were made based on the local needs and resources and through a well-designed approach. Globally, rangelands cover around 50% of the total land area of the world and between two-thirds and three-quarters of all drylands. Rangelands are the subsistence basis of several pastoral societies throughout the world – likely 200 to 500 million people globally. Managing rangelands sustainably is one of global relevance, especially for the rangelands located within drylands, the impact of the process of land degradation is particularly severe.

The sustainable management of rangelands is also closely related to the maintenance and renewal of cultural traditions, some of which have lasted centuries and have been the basis for a balanced approach to rights and responsibilities linked to tenure land rangelands. Understanding how these traditions transform and adapt, and supporting this process to favour sustainability, is vital for maintaining rangelands' productive under pastoral use.

This "Sustainable Rangelands Management Toolkit for Resilient Pastoral Systems", I am pleased to share, is a fruit of joint and tremendous efforts made by local and international experts to bring in the best available knowledge and tools for SRM in arid and semi-arid regions with the sincere hope it will bring positive changes and impacts both to local communities and natural habitats. It is in the IUCN-ROWA's best interest to disseminate the knowledge and skills gained throughout the HERD project to all possible beneficiaries including policymakers, active actors, and institutions involved directly in land degradation mitigation, and many more.

I am extremely grateful to the Global Environment Facility (GEF) for their kind financial support for this project. I also want to express my sincere gratitude to the United Nations Environment Programme (UNEP), the project's implementing agency, for its generous help and support in completing the project's activities in a timely and efficient manner. I am also thankful to the local partners in Jordan and Egypt for their efforts to make the project activities viable, feasible, and cost-effective to their utmost resources available. A big thanks and appreciation are also for the outstanding authors that brought this work to life.

Special thanks to the in-house staff, experts, and consultants at the IUCN-ROWA for the teamwork to bring this work to see light albeit going through the difficult time of the Covid-19 pandemic.

I wish you a pleasant time reading this report and I am looking forward to developing new and complementary initiatives that contribute to global efforts in tackling land degradation and biodiversity loss.

Dr. Hany AL Shaer
Regional Director

RATIONALE FOR GOOD PRACTICES FOR SUSTAINABLE RANGELAND MANAGEMENT

gef
UN environment programme
ICARDA Science for resilient livelihoods in dry areas
CGIAR Research Program on Livestock
CGIAR Livestock, Climate and System Resilience

RANGELANDS

1. Definitions

The term ‘rangelands’ can be used to describe an ecological or a social system.

In ecological terms, rangelands are “land on which the indigenous vegetation is predominantly grasses, grass-like plants, forbs[1] or shrubs that are grazed or have the potential to be grazed, and which is used as a natural ecosystem for the production of grazing livestock and wildlife” (Allen et al., 2011). As an ecological term, rangelands can include annual and perennial grasslands, shrub and dry woodlands, savannah, tundra, and desert.

In social terms, rangelands refer to the management unit of extensive livestock keepers. In this sense, rangelands can include a wider variety of ecosystems and other resource zones, such as forest, wetlands, and ecosystems that might be used only occasionally but may be critical for the survival of the whole system and the livelihoods it supports (Davies et al., 2015).

Figure 1. Common use grazing by sheep on an improved rangeland site in semi-arid Tunisia

2. Importance

World’s largest land cover: Rangelands are the world’s largest land cover, accounting for between 30 and 75% of the Earth’s land surface, depending on which definition is used (MEA 2005; Neely et al. 2009). The Rangelands Atlas, published in 2020, includes seven of fourteen biomes or rangeland types made up of terrestrial ecoregions as defined

[1] A forb or phorb is a herbaceous flowering plant that is not a graminoid (grass, sedge, or rush). The term is used in biology and in vegetation ecology, especially in relation to grasslands and understory.

by WWF, and estimates that rangelands occupy 54% of the global terrestrial surface[2]. Rangelands are found mainly in arid and semi-arid regions, but are also found in less dry regions. They are dominated by herbaceous vegetation and include important woody biomass.

Goods and services: Rangelands produce a wide variety of goods and services, including livestock forage, water, wildlife habitat, wood products, mineral resources, recreation space, and natural beauty. The people living in rangelands include pastoralists, agropastoralists, crop farmers and other groups who depend on natural resources for their livelihoods. Many rangeland societies are highly adapted to their environment and the cultures of the people living there are a part of our rich global heritage.

Terrestrial biodiversity: Rangelands are home to one-third of the world's terrestrial biodiversity and include numerous species, some of which are threatened. Rangelands store around one-third of all land-based carbon, with a large proportion below ground, including an unusually high proportion in the root-mass of rangeland plants. One-third of the world's major river basins extend into at least 50% of global rangelands. Due to the scarcity of water in rangelands, water ecosystem services are often of particularly high value (Davies et al., 2012; Davies et al., 2015).

Figure 2. Rangelands provide natural beauty and maintain biodiversity

3. Threats

Between one-quarter and one-third of the world's rangelands are considered degraded, with some regions more heavily affected than others. Rangelands are affected by conversion of land to uses such as crop farming, and by land degradation through over-exploitation, for example, from poorly managed grazing (Bai et al., 2008; Le et al., 2013).

2 https://www.rangelandsdata.org/atlas/

4. Drivers of change

Rangelands are increasingly affected by anthropogenic climate change. Drivers of rangeland degradation include a growing human population, increased investment that drives over-exploitation, unsustainable management practices, gaps in policy that undermine traditional management practices, the widespread misunderstanding of rangeland ecology, and the adaptations that rangeland communities have made to local conditions. These adaptations include complex communal land management systems and herd mobility that have evolved over centuries.

Figure 3. Access to clean drinking water is a basic necessity for grazing animals

5. Rangeland ecology and sustainable rangeland management

Rangeland ecology

Rangeland management depends on applying knowledge of rangeland ecology such as using grazing management and other interventions to stimulate growth of desired plant species and to inhibit growth of undesirable species. A good understanding of rangeland ecology is therefore necessary to manage rangelands sustainably.

For example, it is vital to understand the close relationship between grasses and grazers. Many grasses are highly adapted to the habits of grazing ungulates and thrive under the influence of grazing. These same grasses are out-competed by less well-adapted plants in the absence of grazing. Without grazing livestock, the existing ecological community will shift away from grasses toward increased woody vegetation.

Two major risks

The two major risks to rangeland ecosystems are over-grazing and under-grazing.

Over-grazing occurs when plants are exposed to intensive grazing for extended periods of time, or without sufficient recovery periods.

Over-grazing reduces the usefulness, productivity, and biodiversity of the land and is one cause of desertification and erosion.

Under-grazing means permitting the growth, quality or species composition of grazed vegetation to deteriorate significantly through the lack of, or through insufficient, grazing or management.

Both terms are poorly understood, and this confusion contributes to land degradation. The term over-grazing is usually taken to mean the intensity of animal grazing, most often associated with the number of animals or stocking density. In fact, it is the timing of grazing as much as the total stocking density that is most likely to determine the health of a rangeland area. The management response is critical. Reducing the number of animals can be detrimental if no consideration is given to the timing of grazing or to the beneficial role that animals play in rangeland health.

Sustainable land management: Definition

Sustainable Land Management has been defined as, "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" (UN Earth Summit, 1992). Sustainable rangeland management (SRM), in simple terms, is the management of rangelands to meet current human needs while ensuring their long-term productivity.

Human needs vary across rangelands, hence, different management objectives are needed. For example, rangelands may be managed mainly for livestock production, for wildlife protection, or to protect a watershed. Although management often focuses on one objective as primary, in many cases rangelands provide multiple benefits to society and sustainable management means ensuring an appropriate balance of ecosystem services.

Sustainable rangeland management: Practices

SRM plays a vital role in stopping, slowing, or reversing rangeland degradation and desertification and in rehabilitating degraded lands. SRM practices are often promoted to reverse land degradation and restore or rehabilitate degraded lands, are guided by the management objectives of the users, and recognizes that different users may have different views on sustainability, and therefore rangeland degradation can be subjective. Sustainable management has to consider the production of a wide range of services both now and in the future, and recognize that management practices influence this balance, sometimes promoting one service at the expense of others.

Improving and sustaining productivity

To maintain and improve rangelands productivity, it is important to understand how they respond to ongoing environmental changes and anthropogenic pressure. This knowledge can guide conservation and restoration efforts in dryland rangelands, as biotic factors can be actively managed at the local scale to increase ecosystem resilience to global changes (Safriel, 2009).

Addressing underlying drivers and pressures

Before addressing rangeland management practices, it is often necessary to first address the underlying drivers and pressures causing degradation. In particular, it is frequently necessary to address the decline in effective rangelands governance. In many countries, this requires a change in perceptions of pastoral herding practices, increased understanding of rangeland ecology, and an overall improvement in dialogue and trust between governments, other development actors, and rangeland pastoral communities. Above all, an increased recognition of the essential relationship between rangeland health and grazing management is urgently needed, together with the legitimization of herd mobility as a management tool.

Rangeland managers

The primary rangeland managers in most countries are livestock keepers, often called pastoralists. Many pastoralists have a deep knowledge of rangeland ecosystems and effective herd management practices. This indigenous knowledge is a valuable asset in rangeland restoration. Although pastoralists are usually blamed for rangeland degradation, they often face many constraints in applying their management knowledge. Restoring effective management practices therefore requires addressing these underlying causes and constraints. This includes strengthening the representation of pastoralists in policy and investment dialogues in many countries.

Figure 4. A pastoralist from Southern Tunisia

6. Toolkit objectives

Despite technical advances, the scale of rangeland rehabilitation intervention is still small and lacks a holistic approach. Most projects focus on a single SRM practice, ignoring the myriad possible interventions that would guarantee achieving the desired rehabilitation status. This toolkit brings together current state-of-the-art knowledge about SRM practices known to contribute to sustainable rangeland management.

Successfully applying these methods, tools, and approaches requires they be used together with improved rangeland assessment and monitoring and better data on rangeland ecosystem services. It also requires attention to policy gaps and failures, including legislation on communal tenure rights. Sustainable rangeland management ultimately requires a major increase in investment, which requires a deeper understanding of investment opportunities and the values of ecosystem goods and services.

Figure 5. Women herding a flock of sheep acros a sivopastoral site in Central Tunisia

FURTHER READING

Allen, V.G., Batello, C., Beretta, E.J., Hodgson, J., Kothmann, M., Li, X., McIvor, J., Milne, J., Morris, C., Peeters, A. and Sanderson, M. 2011. An international terminology for grazing lands and grazing animals (The Forage and Grazing Terminology Committee). Grass and Forage Science. 66: 2-28.

Bai, Z.G., Dent, D.L., Olsson, L. and Schaepman, M.E. 2008. Proxy global assessment of land degradation. Soil Use and Management. 24: 223-234.

Davies, J., Poulsen, L., Schulte-Herbrüggen, B., Mackinnon, K., Crawhall, N., Henwood, W.D., Dudley, N., Smith, J. and Gudka, M., 2012. Conserving Dryland Biodiversity. IUCN, Nairobi, xii, 84pp.

Davies, J., Ogali, C., Laban, P. and Metternicht, G. 2015. HOMING IN ON THE RANGE: Enabling Investments for Sustainable Land Management. Technical Brief 29/01/2015. Nairobi: IUCN and CEM. vi+23

Le, Q.B., Nkonya, E. and Mirzabaev, A. 2014. Biomass Productivity-Based Mapping of Global Land Degradation Hotspots. ZEF-Discussion Papers on Development Policy No. 193. Bonn, July 2014

MEA [Millennium Ecosystem Assessment], 2005. Ecosystems and human well-being: desertification synthesis. Millennium Ecosystem Assessment. Washington, DC: World Resources Institute, Washington, DC.

Neely, C., Bunning, S. and Wilkes, A. 2009. Review of evidence on drylands pastoral systems and climate change: implications and opportunities for mitigation and adaptation. FAO Land and Water Discussion Paper, 38pp.

Safriel, U. 2009. Deserts and Desertification: C hallenges b ut also opportunities. Land Degradation and Development: 20: 353-366.

United Nations Earth Summi. 1992. Agenda 21: the United Nations programme of Action from Rio. New York, USA.

IUCN

PARTICIPATORY RANGELAND MANAGEMENT PLANNING AT SCALE

gef

UN environment programme

ICARDA
Science for resilient livelihoods in dry areas

CGIAR RESEARCH PROGRAM ON Livestock

CGIAR Livestock, Climate and System Resilience

INTRODUCTION

Participatory approaches – such as Participatory Rural Appraisal (PRA) and Participatory Learning and Action (PLA) – are a collection of approaches used by development actors to incorporate the knowledge and opinions of rural people in the planning and management of development projects and programs. Participatory approaches are typically used to improve decision-making, foster ownership by local communities, and enhance accountability in development projects. Participatory approaches are a process of empowering communities, or groups within these communities, and are central to natural resource governance in development context.

Participatory Rangeland Management and Planning (PRMP) provides a framework for adapting participatory approaches to the unique context of rangelands. PRMP takes into consideration the spatial scale on which rangelands are managed, the diversity of stakeholders involved, and seasonal patterns of movement and resource use. The large scale on which rangeland landscapes are managed is a major challenge for coordination and necessitates participation on a similarly large geographic scale. PRMP provides the most effective framework of engagement considering the socioeconomic and natural resource dynamics.

Figure 1. Atriplex bush in Al Surra protected area

Principles of PRMP

Many participatory approaches exist and PRMP adheres to principles that are common to most of these approaches, including:

- **Multistakeholder engagement,** that recognizes contested claims and aspirations for a given rangeland landscape and ensures different socio-economic, ethnic and other groups are engaged in relevant dialogue
- **Continuous dialogue** in which stakeholders express their needs, wants, and interests and reach a consensus on future rangeland use and management that respects the values of all users
- **Inclusivity** in which all stakeholders are represented and engaged in the relevant dialogue, planning and implementation
- **Mobilizing local knowledge** and integrating or reconciling local knowledge with scientific knowledge to influence planning
- **Visioning** that builds on the current state of rangeland resource to provide a foundation for managing in future
- **Action orientation** with a focus on developing action plans that shape how agreed strategic interventions will be implemented
- **Learning,** using participatory tools to monitor and evaluate actions and to adapt management according to emerging lessons.

STEPS IN PARTICIPATORY RANGELAND MANAGEMENT PLANNING

Many participatory tools can be adapted for rangeland management planning. However, specific measures are recommended in each step of the participatory process to ensure the approach is aligned to the unique conditions of the rangelands. The following guidance is organized according to the 4 steps illustrated in the chart below, but can be adapted to other participatory planning frameworks.

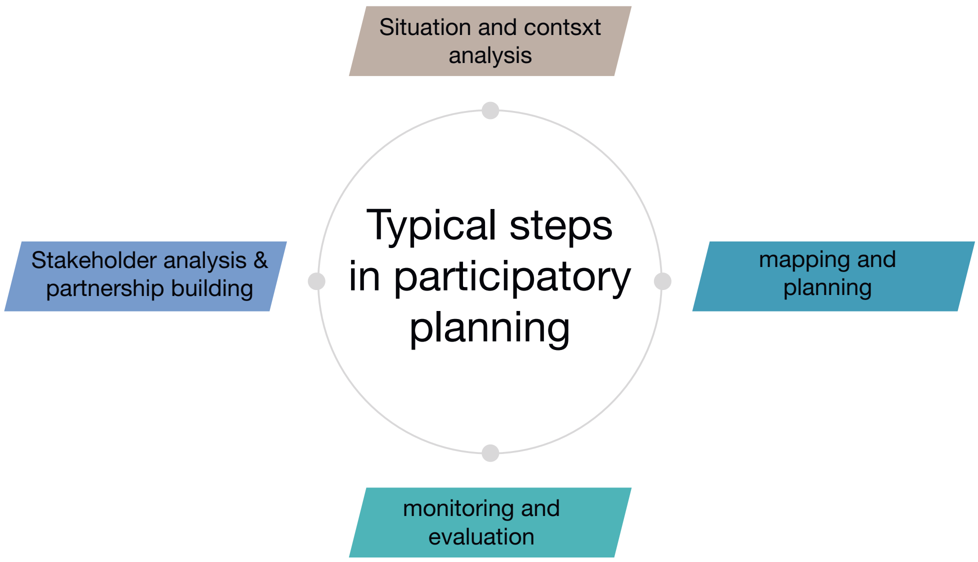


Figure 2. Restored rangelands in Al Surra protected area showing the contour lines for plantation and water harvesting

Step 1: Partnership building and stakeholder engagement

Rangelands are social-ecological systems, often with a great diversity of resource users and rights-holders. Sometimes these stakeholders are absent seasonally or for long periods. Rangelands often fall through institutional and policy gaps as there may be several institutions with overlapping responsibilities for rangelands. Important consideration for stakeholder analysis should therefore include:

1. Identification and analysis of all stakeholder groups involved in rangeland use and management, including communities (e.g. herders, crop farmers and others), women and youth as well as men, migrant labourers, and marginalized groups within pastoral societies, as well as relevant public institutions

2. Preliminary dialogue with stakeholders to agree on the challenge to be addressed and the scale of rangeland landscape for action.

In this step, the people and organizations with interests and influence over rangeland resource use and management are identified. Relevant questions to address include:

PRMP requires particular attention to include the **voice of marginalised groups**, including indigenous peoples, women and youth. Women have unique responsibilities over rangeland resources and unique knowledge on their sustainable use and management. However, women are largely marginalised in many rangeland societies. Extra effort and attention needs to be made to ensure fair and meaningful participation. It is common to separate groups of men and women while conducting participatory planning, although this is context specific and other measures may be needed to engage women of other groups.

The extent of stakeholder identification and analysis will vary depending on the time and financial resources available. Stakeholder identification should include a 'validation meeting' with the stakeholders and external partners to ensure that relevant groups have not been excluded and to identify differences of opinion between stakeholder groups over their perception of rights and responsibilities over natural resources. This is a sensitive process, requiring local knowledge and cultural sensitivity to draw out disagreements that are likely to require future negotiations.

Figure 3. Knowledge exchange in Al Surra protected area

Step 2: Situation and context analysis

In Step 2, the characteristics of the rangeland landscape can be clearly described to capture the spatial scale and the variety of resources and rights holders. Rangeland landscapes are often managed on a large scale and people and institutions introducing localized interventions must be aware of their impact on larger scales, for example on a communal tenure system or a river basin.

The situation analysis should include baseline studies to review relevant information to establish state and trends of rangeland health, policies and institutions. Large-scale assessment of rangeland can be accomplished through remote sensing. Step 2 allows the scale of landscape management to be determined, and guides planning under Step 3.

As part of the preparation activities, a baseline analysis is required to provide the context and the situation of the area where participatory mapping will be conducted. The baseline study describes the environmental and socio-economic conditions. This should combine information from both published and non-published literature. Information gathered should also cover the interconnectivity between the landscape at which planning is taking place in relation to the wider landscape. This will mainly depend on the target landscape for planning and the availability of money and time. Analysis of the baseline conditions could include biophysical conditions, socio-economic conditions, and the social and political context.

Additional data such as topographic maps, climate data, and indicators of land productivity are outputs for this process. This will involve collecting and organizing existing remote sensing imagery on the selected landscape to produce an overview map on the status of rangeland health, using the maps generated to assess and understand the baseline condition of rangeland resources at a landscape level before participatory mapping, and, if resources are available, engage the community to do ground verification of the information contained in landscape maps during participatory mapping (FAO and IUCN, 2015).

Figure 4. Display of topography in Hima Bani Hashem

Step 3: Mapping and planning

Natural resource mapping is the cornerstone of participatory approaches and it is vital for effective rangelands management. However, the mapping process needs to be approached with an open mind, to learn from the way stakeholders mentally map their landscapes, and to ensure that pre-determined notions of scale and boundaries do not restrict local knowledge and understanding.

Participatory tools have generally been developed for use at the village level, whereas a rangeland management unit may be many thousands of square kilometers, with rights shared by thousands of households. The stakeholders involved in participatory mapping must ensure clear accountability,and representation and differentiated rights and responsibilities must be accommodated across the entire landscape. This includes seasonal rights and responsibilities of some user communities as well as seasonally-differentiated gender roles. One solution is to involve well-informed and credible representatives of the key stakeholder groups, and ensure that they feedback on their involvement to the people they represent.

Participatory mapping can be improved by deliberately involving local community experts. This selection should consider the diversity expertise, knowledge, responsibility, rights and gender, including women and youths. The representatives should be conversant with their rangeland production system(s) and should be able to contribute to the mapping by sharing their experiences about the state, use and management and trends of their rangeland resources. They bring along important knowledge on the social, environmental and rangeland use dynamics.

Participatory mapping follows these steps:

1. **Mapping the current state of a rangeland:** Overlaying hand-drawn features on to a high-resolution map can help when digitizing information. Careful attention should be given to the complex spatial arrangements of rangeland governance.
2. **Mapping a future vision** (e.g. 10 years hence): This vision can also be overlaid on a high-resolution map to represent a group's consensus on a desirable scenario for the rangelands from an ecological, productive and local governance perspective. The future vision should be guided by a combination of local knowledge and scientific advice concerning the actual and the potential state of the rangelands. This step can be combined with information gathered earlier through a rangeland health assessment. The visioning map provides the basis for identifying indicators to assess change in rangeland health and for identifying the type of rangeland governance desired by the range-users.
3. **Developing an action plan:** Action planning should be made particularly sensitive to gender roles and responsibilities as well as seasonal resource rights. Action plans should the transformation pathway to move from the current status of the rangeland to the envisioned future, outlining the detail of responsibility, resources and how progress will be measured.

1. **Establishing steps to strengthen local resource governance**: Rangeland restoration requires significant effort to secure rangeland resource governance and land rights (particularly management rights). Participatory planning is an important preliminary step in understanding governance. The mapping exercise determines the rights and responsibilities of stakeholders over different rangeland resources. Steps for strengthening governance should be included as a sub-set of the Action Plan above, but a detailed discussion is needed to identify the acceptable measures for strengthening governance and rights. There should be clear description of what the best possible governance structure is expected to look like in the given context. Attention should be paid to the rights of women and other groups within society. Participants should consider the following questions[1]:

- Who are the rights holders over different resources (e.g. access rights, use rights, management rights, right of alienation etc.)?
- What different systems of rights influence rights over each resource (e.g. customary, formal legal, constitutional)?
- What measures – both formal and informal – can stakeholders take to strengthen their management rights over each resource?

Figure 5. Local community member involved in a participatory initiative

Step 4: Monitoring and evaluation

Step 4 enables adaptive rangeland management by tracking progress of actions, measuring the impact of those actions on rangeland health and socioeconomics, and responding to a dynamic setting. Participatory monitoring should include both field evaluation, such as monitoring changes in rangeland health, and evaluation of implementation of actions.

[1] Detailed guidance for strengthening governance can be found in the manual "Improving Governance of Pastoral Lands": http://www.fao.org/3/i5771e/i5771e.pdf

The participatory maps developed in Step 3 are used to recall the community's vision and plan of action developed earlier. Individual actions proposed under Step 3 should then be evaluated to reflect on progress, identify barriers and find solutions. Typical questions used during monitoring and evaluation meetings are:

- What was planned (maps and plans developed during the first planning exercises)?
- What was achieved (review maps and plans originally developed by communities)?
- What was not achieved?
- Why was intended change not achieved?
- What will be done to address this?
- What are the revised targets (e.g. for the next 6 months or 12 months)?

Regular annual stakeholder meetings should be held to discuss progress in management and changes in resource conditions taking into consideration the short-term and long-term variability and projected future dynamics. Stakeholder meetings are ideally conducted by a community organization, and can be part of their annual planning cycle. Those organizations can develop their capacity to play a coordinating role in rangeland management, sometimes acting as a hybrid institution that includes both customary leaders and non-customary leaders.

Monitoring and evaluating change in rangeland governance also requires evaluating changes in governance institutions, which is a sensitive task requiring careful analysis from community members. It can include monitoring policies, rules, and institutional arrangements and processes, as well as decisions made informally and implemented by the community. The effectiveness of the governance systems should be assessed in relation to resource use and management. One useful approach for evaluating governance changes is the 'most significant change' method, which focuses on identifying significant changes experienced by community members, through stakeholder stories and focus groups.

FURTHER READING

Davies, J., Herrera, P., Ruiz-Mirazo, J., Batello, C., Hannam, I., Mohamed-Katerere, J. and Nuesiri, E. 2016. Improving Governance of Pastoral Lands. FAO, Rome. http://www.fao.org/3/i5771e/i5771e.pdf

Davis, R. 2005. The ‘Most Significant Change’ (MSC) Technique: A Guide to Its Use. Research Gate. DOI: 10.13140/RG.2.1.4305.3606. https://www.researchgate.net/publication/275409002_The_'Most_Significant_Change'_MSC_Technique_A_Guide_to_Its_Use

Flintan, F., Ebro, A., Eba, B., Assefa, A., Getahun, Y., Reytar, K., Irwin, B., Yehualashet, H., Abdulahi, M., Gebreyohannes, Z.T., Awgichew, S. and Gudina, D. 2019. Review of participatory rangeland management (PRM) process and implementation. Rangelands Research Report 2. Nairobi, Kenya: ILRI. https://cgspace.cgiar.org/handle/10568/106017

Food and Agriculture Organization of the United Nations and International Union for Conservation of Nature. 2015. Participatory Assessment of Land Degradation and Sustainable Land Management in Grassland and Pastoral Systems. https://www.iucn.org/sites/dev/files/content/documents/praga_project_brochure.pdf

HIMA: A TRADITIONAL COMMUNAL RANGELAND MANAGEMENT SYSTEM

SUMMARY

Hima means ‘protected area’ in Arabic. Hima is a traditional approach to the conservation of natural resources and has been used in the Arabian Peninsula for more than 1,500 years. The hima system has a set of guiding principles, is participatory in nature, and uses community knowledge and practices in setting up and managing protected areas. Implementing a hima system requires consideration of the land tenure system in place, the biodiversity on the site, and the socioeconomic and cultural context of the community. The hima system is a proven governance approach that allows land users to implement actions that preserve natural resources, conserve ecosystems, restore biodiversity, and support local communities. Pastoralists from other regions often practice analogues to hima.

Figure 1. Al Surra protected area, managed by local community

Background

Access to a hima was forbidden by the individual or group that owned it. Later, its meaning evolved to signify a reserved pasture, a piece of land set aside seasonally to allow regeneration. The hima system is inclusive and designed to preserve and protect ecosystems for the sustainable use of resources by the people and for the people, while taking into account the social and cultural practices of the communities involved.

History: The fall of the Ottoman Empire at the end of the 1800s resulted in more control by smaller states that emerged in the region. During the twentieth century, political and socioeconomic changes in the Arab region led to the weakening of the hima system, exposing the environment to a multitude of anthropogenic transformations resulting in widespread degradation. Tribal land was nationalized and increased demand for export products led to the abuse of natural systems. Sustainable systems of land use and management declined and so did the diversity and health of habitats. Recent years have witnessed several campaigns to conserve nature and its resources, including a revival of the hima concept.

Benefits: The value of the hima approach lies in its ability to integrate food production with conservation goals. Protected areas often exclude local users and thereby miss out on important opportunities for tapping their local knowledge and the institutions that enable its use. The hima approach legitimizes Indigenous and Community Conserved Areas[1] as a way to achieve both sustainable land management and biodiversity conservation on land used primarily for food production. Healthy, productive rangelands offer a genuine win for agricultural production through livestock and biodiversity conservation. The hima model provides a key to unlock this potential by improving landscape connectivity and harnessing the role of domestic herbivores for ecosystem management. All six established IUCN Protected Area Categories could benefit from the hima approach, but in the context of rangeland restoration the main focus is on Category VI: Protected area with sustainable use of natural resources (Dudley et al. 2013).

Measures and steps to establish a hima

To be considered a hima, an area should:

1. be constituted by a legitimate governing authority,
2. be established to improve public welfare,
3. not cause undue hardship to local people and not deprive them of resources they need for their subsistence, and
4. realize more benefits for society than detriments.

1 https://portals.iucn.org/library/efiles/documents/PAG-011.pdf

One starting point for restoring rangelands and reviving hima is to address social rather than technological constraints. Reviving hima is therefore a process rather than an action and while it is highly cost-effective, it is also highly demanding of skills, particularly skills for negotiation, participation, and consensus building. Reviving hima requires extensive dialogue between communities, government, and other stakeholders to reach agreement over policies and shared governance of natural resources at local, national, and regional level.

Development of hima sites is typically carried out through participatory planning, beginning with a complete stakeholder analysis and identification of suitable sites. Given the sensitivity around resource rights, it is important that all stakeholder groups, and particularly women and marginalized groups, are involved in planning. Additional effort is often needed to build capacity of marginalized groups so they can participate on an equal footing with other community members. From the outset, the primary focus of the hima approach should be to empower local communities, identify and respond to their needs, and ensure their full ownership in the hima process and the actual hima site.

It is highly recommended to embed the development of a hima in wider landscape restoration planning, given the communal nature of rangeland resources and the potential for off-site impacts (both costs and benefits). Implementing livestock management plans on a hima site will mean periods of rest and recovery when livestock will need to be moved to other areas. Maintaining connectivity between the hima site and the rest of the landscape, and between multiple himas within the same landscape will facilitate effective herd management. Participatory planning at landscape level can also help mitigate conflict between groups of resource users and rights-holders.

Figure 2. Al Surra protected area landscape

Common steps in setting up a hima include:

01. Detailed stakeholder analysis and participatory planning at landscape scale.

02. Preparatory meetings with local authorities to ensure political support for the process.

03. Training on hima approaches, sustainable land management, community governance, and legal options for formalizing the hima.

04. Hima site identification within the landscape, including mapping and site visits.

05. Development of a hima management plan, including livestock management arrangements, environmental and biodiversity management considerations, land rehabilitation options, and a monitoring plan.

06. Development of associated incentives such as livelihoods development options for hima communities.

07. Agreements for legal documents, community practices or bylaws depending on the legal context and options to formalize the hima.

The following principles are recommended for the development of hima sites:

01. Strengthen land stewardship and communal tenure.

02. Strengthen scientific and economic evidence and local knowledge to provide systematic monitoring for quality assurance.

03. Create an enabling environment of policy and institutional support and address the cross-sectoral nature of hima.

04. Develop incentives and rewards for the multiple and diverse benefits of hima.

05. Build capacity and awareness in public institutions and communities, with a particular focus on the skills of participation, empowerment, and monitoring.

06. Strengthen community organizations for hima governance.

07. Ensure that hima management is aware of and sensitive to the socio-ecological landscape within which it is situated.

BENEFITS

Himas provide many overlapping benefits including improvements in livestock production, conservation of biodiversity, maintaining habitats and connectivity for fauna and flora, protecting hydrological cycles, capturing atmospheric carbon, and reinforcing local culture. Himas contribute to poverty reduction and economic growth as well as the protection of habitats and conservation of endangered species, and they have benefits to people outside their boundaries and to the world as a whole (The Amman Declaration, 2014).

The revival of himas has also been used to promote social justice and gender equality. The hima approach provides benefits in improving natural resource governance structures, empowerment of local communities, public participation, equitable resource use and sharing, preservation of indigenous knowledge, local customs and recognition of customary rights. Himas also play a role as seed banks and in halting and reversing desertification. An IUCN study using a Total Economic Value approach estimated the economic value of Jordanian rangelands managed as himas to be JOD 136 million or nearly USD 200 million (IUCN, ND).

Figure 3. sustainable grazing management in Hima Bani Hashem

FURTHER READING

International Union for the Conservation of Nature (IUCN). 2012. Al Hima: the possibilities are Endless. https://www.iucn.org/sites/dev/files/import/downloads/hima_case__1_.pdf

Dudley, N., Shadie, P. and Stolton, S. 2013. Guidelines for applying protected area management categories including IUCN WCPA best practice guidance on recognising protected areas and assigning management categories and governance types. Monograph Series No. 21. International Union for the Conservation of Nature.

International Union for the Conservation of Nature (IUCN). ND. Natural Resource Economic Valuations. Environmental Economic Valuation of the HIMA System. The Case of Zarqa River Basin, Jordan, ND. https://www.iucn.org/sites/dev/files/import/downloads/iucn_econmicvaluation_final.pdf

Kilani, H., Serhal, A. and Adb-ar-Rahman Llewellyn, O. 2007. Al-HIMA: A way of life. International Union for the Conservation of Nature and Natural Resources. https://www.iucn.org/node/21486

Securing rights and Restoring Range Lands for Improved Livelihoods in the Badia of the Zarqa River Basin, Jordan. Baseline study. https://www.iucn.org/sites/dev/files/import/downloads/baseline_study___securing_rights_and_restoring_land_for_improved_livlihoohs.pdf

The Amman Declaration on Innovating Hima. 2014. https://www.iucn.org/downloads/the_amman_declaration_on_innovating_hima_signed_by_hrh.pdf

WATER HARVESTING TECHNIQUES

BACKGROUND

Water scarcity is among the main problems to be faced by several countries around the world as demand for domestic, agricultural, industrial, and environmental uses continues to increase (Khanal et al., 2020). Socioeconomic development, technological innovation, and environmental degradation, particularly climate change, are further intensifying the pressure of global water shortages (Wu et al., 2020). Climate change is one of the main factors affecting the availability of water resources (Haque et al., 2015). Climate change is predicted to cause a high climatic variability in semi-arid environments, leading to an increase in the frequency of droughts and heavy rainfall events (IPCC, 2012). When there is a high rainfall event on steep land and on soils with poor infiltration rates, surface runoff is high. Runoff can be reduced by increasing surface storage and/or the soil infiltration rate. This global water crisis is projected to worsen due to population explosion and the higher food demand (De Fries and Rosenzweig, 2010). The growing population and the increasing demand for agricultural products are putting pressure on limited grazing and rangeland resources, especially in arid environments.

Figure 1. Mechanized constructed Vallerani contours for water harvesting planted with *Atriplex halimus* in Jordanian Badia

Many rangelands are found in arid and semi-arid lands where biomass production is constrained by moisture availability. Furthermore, when these lands are affected by land degradation, the soil moisture content often declines, due to reduced capacity to hold moisture as well as reduced capacity for water to infiltrate. Soil moisture scarcity occasioned by insufficient and unreliable rainfall is one of the most limiting factors to biomass production in rangeland ecosystems. This means that production is possible only when additional water is made available for cultivation. With water scarcity placing heavy pressure in many arid regions, alternative methods, such as soil and water conservation, are of paramount importance in recent decades. Water harvesting is one such technology and is based on the direct collection of rainwater, which can be stored for direct consumption or can be recharged into the groundwater (Khanal et al., 2020). Numerous countries have supported the implementation of such practice to overcome the water demand increase (Yannopoulos et al., 2019; Piemontese et al., 2020). Water harvesting can be carried out for multiple purposes, including to provide domestic water, water for livestock, and water to enable restoration. The most suitable water harvesting technology will depend on the purpose of harvesting as well as the biophysical properties of the location.

In addition to water scarcity, arid environments face challenges sustaining or raising production levels without effective management interventions. Water harvesting in rangelands can help increase the production of forage shrubs and herbs, followed by a more general improvement in soil fertility and may be the most feasible option for raising productivity for these large areas. Distribution of water is an important consideration when managing the access and use of rangeland sites. Water harvesting that accounts for forage use within and between different growing seasons can support livestock that contribute to maintaining and even improving rangeland resources (Pamo, 2004). Concentration of water resources has been strongly associated with the degradation of rangelands because animals tend to overgraze around watering holes.

COMPONENTS OF WATER HARVESTING STRUCTURES

The basic goal of water harvesting on rangelands is to intercept the flow of surface water. In arid areas, 70–80% of rainwater falling early in the rainy season is lost to runoff. Rainfall runoff washes away about 40% of the available nutrients in the form of organic matter. Thus, it is important to capture and preserve it through various manually constructed structures.

In arid areas, most rain falls occur during a short period, and sometimes even then only sparsely. Thus, the water must be collected when available. As water scarcity increases with increasing population, conserving and harvesting water is critical in arid environments. Degraded soils are characterized by ‘crustiness’, which slows down infiltration and prevents germinated seeds from emerging.

WATER HARVESTING TECHNIQUES

Applying manual techniques can be difficult in areas with shifting dunes, the type of soil, the volume of rainfall, construction costs, and topography. Important mechanical water harvesting techniques include terracing, which involves macro-catchment structures across large areas, and contour bunds or different forms of tillage. Manual water harvesting techniques are appropriate in village tree stands or around homesteads where a few open-ended micro-catchments provide shade and support trees of value.

There are three biophysical components in all water harvesting systems:

The catchment area that receives rainfall and channels runoff downstream. Catchments can vary in size.

The storage medium where rain runoff is stored temporarily before being used.

The Conveyance moves the water from the roof surface to the storage.

BENEFITS OF WATER HARVESTING TECHNIQUES

- Play a vital role in supporting the rural population in water-scarce areas.
- Facilitate vegetation production in areas that would otherwise lie fallow due to lack of water.
- Improve water availability for livestock. The water harvesting structure cistern is the best option for storing rainwater for livestock watering.
- Improve soil fertility as runoff water contains silt, manure, and organic

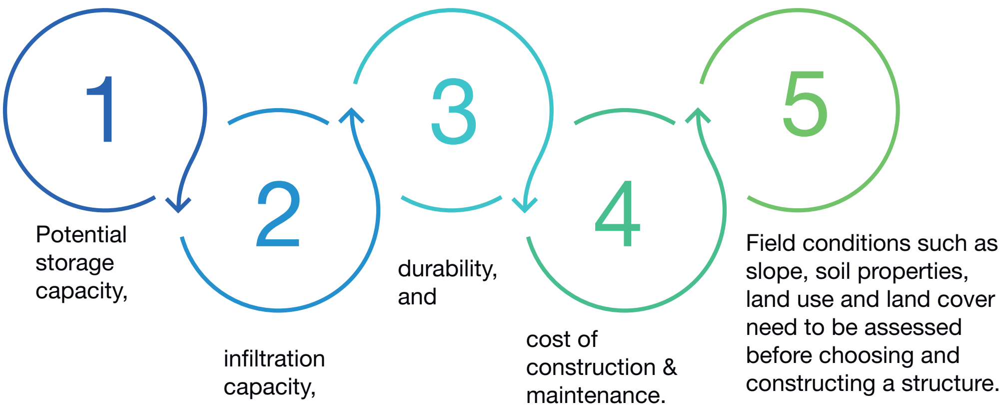
matter.
- Reduce soil erosion and siltation downstream.
- Enhance soil moisture and also prolong the wetting and softening of crusted soil surfaces, allowing seeds to germinate and emerge.
- Improve conditions for soil flora and fauna.
- Increase seedling survival for the most drought-sensitive species.
- Capture atmospheric carbon dioxide through increasing biomass production.
- Reduce the use of groundwater, which is a valuable water source and needs energy for its exploitation.
- Contribute to the recharge of groundwater tables.

TYPES OF WATER HARVESTING TECHNIQUES

A variety of surface structures have been used, but earthen dykes, berms, bunds, and dams are popular because of their simplicity, effectiveness, and relatively low cost of installation and maintenance.

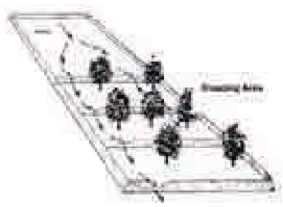
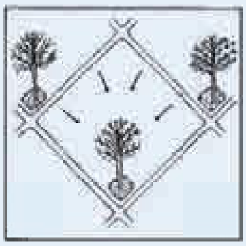
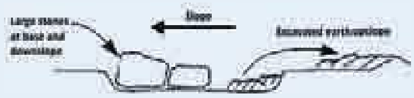
Choosing the right method

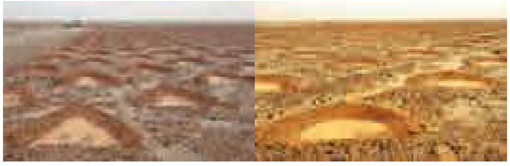
It is important to understand the

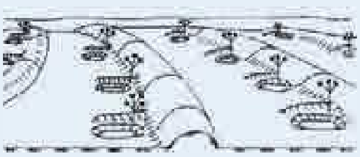


Commonly used structures and their characteristics are described in Table 1.

Table 1. Description of commonly water harvesting structures

Water harvesting structure	Characteristics
Meskats  Meskat micro catchment System (Ahmed, 2003).	Ideal for gentle slopes and low hills with 300 mm mean annual rainfall. Based on a catchment area of 500 m^2, supplying additional water to a series of downstream plots enclosed by small earth bunds (about 20 cm) and connected by spillways for discharging excess water. Meskat systems are often used for watering trees.
Nigarim  Nigarim micro catchment System for trees (Critchley et al., 2013).	Diamond-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each. Runoff is collected from within the basin and stored in the infiltration pit. Micro catchments are mainly used for growing trees or bushes. This technique is appropriate for small-scale tree planting in any area which has a moisture deficit. Besides harvesting water for the trees, it simultaneously conserves soil.
Trapezoidal bunds  Trapezoidal Bunds for crops (Critchley and Reij, 1989).	Trapezoidal shaped earth bunds capturing runoff from external catchment and overflowing around wingtips. This technique is used to enclose larger areas (up to 1 ha) and to impound larger quantities of runoff which is harvested from an external or "long slope" catchment.
Stone bunds  Photo: Critchely and Siegert, 1991.	Constructed with stones along the contours of slopes with a 2–5% gradient. Bund height should be 65 cm with a base width of 80–100 cm and a shallow trench on the upper side 15–30 cm deep to trap runoff and sediment.

Water harvesting structure	Characteristics
V-shaped and semi-circular bunds  Photo: Mounir Louhaichi	Made of soil or stone, diameter of 1–7 m and 50 cm high, tips are set on the contour line facing upslope. Slopes up to 20% in areas with rainfall as low as 100–150 mm per annum. Soils should be at least 1.5 m but preferably 2 m deep.
Earth basins  Photo: Duveskog et al., 2003	Designed to collect and hold rainfall as runoff water is channeled to the lowest point and stored in an infiltration pit. Usually 1–2 m long, with basins of up to 30 m. Ideal on deep soils (1.5–2 m), annual rainfall amounts of 150 mm and above on flat surfaces to slopes of 5%.
Check dam (gully plug)  Photo: Mounir Louhaichi	A check dam (also called gully plug) commonly constructed across a drainage ditch, swale, or channel having gentle slope to conserve stream flows and to conserve soil moisture. The harvested soil and organic matter act as a sand tank that quickly infiltrates stormwater flow, then slowly releases it to nearby plant roots.
Stone gabion  Photo: Mounir Louhaichi	Stone gabion is constructed manually to treat deep ravine heads, to reduce the speed of water flow downslope, to capture soil flowing downslope, and to also reduce the effects of runoff on the soil. They are manually constructed with attaching section of fencing to settle sediments. It is possible to keep soil moisture due to infiltration depending on the topography and amount of precipitation.
Open reservoir  Photo: Mounir Louhaichi	Natural or (hand) dug open reservoir to store water collected from elsewhere (Lasage and Verburg, 2015). The permeability of the pond can be reduced by using lining (concrete or plastic). Sizes vary from 30 m^3 (individual household use) to 20,000 m^3 (community use).

Water harvesting structure	Characteristics
Contour trenches  Photo: Mounir Louhaichi	A contour trench and pit are an excavated ditch/pit along a uniform level across the slope of land in the top portion of catchment to trap runoff water.
Cistern  Photo: Mounir Louhaichi	Cisterns: means of collecting rainwater for drinking water supply. This is a very old rainwater collection system in North Africa. It is designed with the objective of supplying the household with water for various domestic uses, including irrigation and watering of livestock in arid and semi-arid environments. The collection of rainwater by cisterns is done from an impluvium which must be clean, sanitary and impermeable. The rainwater storage tanks can be of various shapes and geometry, storing water collected from a surface plot, capacity 5 m^3 - 100 m^3 (Lasage and Verburg, 2015).
Jessour  Photos: Mounir Louhaichi	Consists of a dam, terrace, and catchment area. The dam is made of stones and can be up to 200 m in length in wide valleys. The height of the dam can vary between 0.5 and 5 m. Runoff water is collected up to a height of about 20 cm or more before it is discharged downstream via the spillway.
Contour earth bunds  FAO, 1991	Small ridges constructed downslope (1–25%), reinforced with vegetation or stones to stabilize and break long slopes into smaller, less steep slopes.
Water-spreading bunds  FAO, 1991	Spread water by slowing the flow of floodwater and distributing it over land to be cultivated, thus allowing it to infiltrate. Ideal on even topography or 1% slopes receiving 100–350 mm annual rainfall.

Water harvesting structure	Characteristics
Contour bunds using Vallerani machine  Photo: Mounir Louhaichi	Contour bunds are effective methods to conserve soil moisture in watershed for long duration. They slow down runoff and improve water infiltration in the soil. Contour bunds can be continuous or intermittent. A special tractor-pulled plow that automatically constructs water-harvesting catchments, ideally suited for large-scale reclamation work. There are two types of modified tractor plows: the 'train' and the 'dolphin'. Used in microbasins 4–5 m long, 0.4 m wide, and 0.4 m deep. Applicable on areas 100–600 mm and on slopes between 2–10%.
Hill reservoir  Photo: PAN-LCD, Tunisia	This practice is widespread in areas receiving an average annual rainfall greater than 250 mm in Tunisia. The hill reservoirs contain tens of thousands to 1 million m^3 of water collected from small catchment areas of a few hectares to a few km^2. The hill reservoirs built have a definite impact on the rural population by providing them with readily available water for their use. These reservoirs have also contributed to improving the environment, recharging the water table and protecting downstream infrastructure against flooding and siltation.

SUPPORTING MEASURES

The following factors should be considered during the planning phase:

- **Slope:** Water harvesting is not recommended for areas where slopes are greater than 5% due to uneven distribution of runoff and large, uneconomic investments in terms of machinery. Depending on the slope of the catchment area and the reason for water harvesting, mechanical water harvesting techniques are effective in upper catchments (slopes up to 25–40%)

- **Soils:** Soils should be deep to improve infiltration, with some level of fertility, while sandy soils should be avoided to reduce loss of water

- **Costs:** Cost of water harvesting structures should be balanced against their potential benefits. When combined with multipurpose trees, for several years the main benefits will be soil conservation effects and grass for fodder until the trees become productive. Manual water harvesting structures are labor-intensive, hence, labor costs are high. A general lack of awareness of appropriate practices and low levels of investment in knowledge dissemination contribute to limitations. The quantities of soil and stonework involved in construction directly affects the cost of its initiation and the labor investment needed.

Note: Once the structure is in place maintenance is required. Structures can be damaged by heavy storms soon after construction when the structures are not fully consolidated. Structures should be inspected after each significant rainfall and after grazing livestock in the area.

Effective establishment and maintenance

The selected water harvesting technique should:

1. In arid environments, a water harvesting structure/technique can be sustainable only if it fits the socioeconomic context of the area
2. Be applicable under physical conditions in the field
3. Be appropriate for the slope of the terrain, soil properties, geology, land use, and land cover
4. Be simple to design and control, and easily replicable
5. Begin at the top of the catchment or watershed, where the volume and velocity of water is lower, making it easier to manage and work downwards; and
6. Be cost-effective.

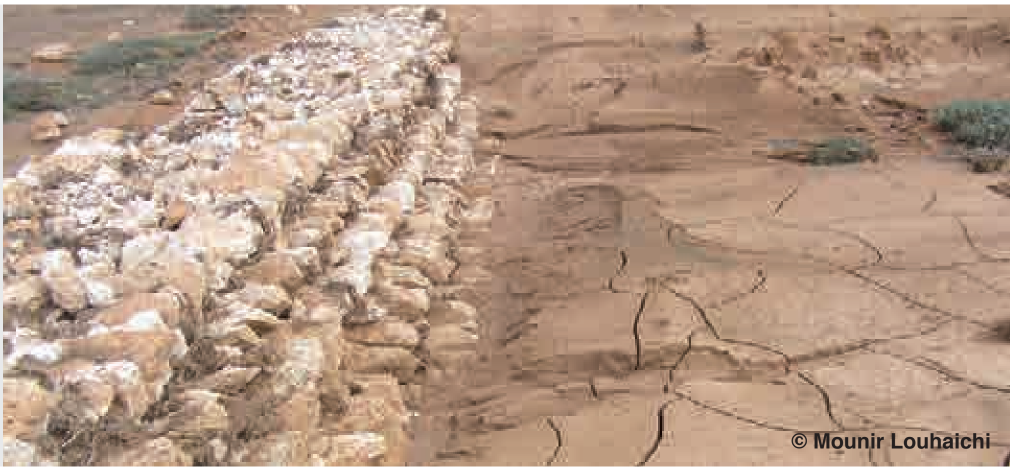


Figure 2. Stone wall to control water erosion in the landscape

SUMMARY

Water harvesting is used in greening projects to conserve rainwater, a precious commodity in arid regions. An effective water supply to the soil-vegetation complex will increase the likelihood that rangeland restoration projects will succeed. Determining which water harvesting techniques have the best performance and choosing which ones to promote and scale up requires consideration of biophysical, technical, and socioeconomic factors.

By increasing water retention and soil moisture, water harvesting techniques will affect important processes such as evaporation, transpiration, air humidity, air and soil temperature, soil microbial activity, soil organic matter build up, and decomposition. Raising awareness, promotion, and training will facilitate the adoption, adaptation, and spread of water harvesting practices among landowners. However, effective community participatory initiatives are still needed to promote the adoption of these techniques.

FURTHER READING

Ahmed, A.A. and Naggar, O.M. 2003. Rainwater Harvesting: Concepts and Techniques, Conference on WH and the Future Development in Sudan, Khartoum, 19-20 Aug., Sudan.

De Fries, R. and Rosenzweig, C. 2010. Toward a whole-landscape approach for sustainable land use in the tropics. Proceedings of the National Academy of Sciences. 107(46): 19627-19632.

FAO. 1991. Water harvesting (AGL/MISC/17/91). Gammoh, I.A. and Oweis, T.Y. 2011. Contour laser guiding for the mechanized Vallerani micro-catchment water-harvesting systems. Journal of Environmental Science and Engineering. 5: 1309-1316.

Haque, M.M., Rahman, A., Hagare, D., Kibria, G., and Karim, F. 2015. Estimation of catchment yield and associated uncertainties due to climate change in a mountainous catchment in Australia. Hydrological Processes. 29(19): 4339-4349.

IPCC. 2012. Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change [Field, C.B., Barros, V., Stocker, T.F. and Dahe, Q. (Eds.)], Cambridge University Press.

Khanal, G., Thapa, A., Devkota, N., and Paudel, U.R. 2020. A review on harvesting and harnessing rainwater: an alternative strategy to cope with drinking water scarcity. Water Supply. 20(8): 2951-2963.

Lasage, R. and Verburg, P.H. 2015. Evaluation of small-scale water harvesting techniques for semi-arid environments. Journal of Arid Environments. 118: 48-57.

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M.A. and Kijne, J. 2010. Improving agricultural water productivity: between optimism and caution. Agricultural Water Management. 97(4): 528-535.

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): 135-149.

Pamo, E.T. 2004. Water development strategy as a driving force for sustained rangeland management by local communities in sub-Saharan Africa. Environmental Monitoring and Assessment. 99(1-3): 211-221.

Piemontese, L., Castelli, G., Fetzer, I., Barron, J., Liniger, H., Harari, N., Bresci, E. and Jaramillo, F. 2020. Estimating the global potential of water harvesting from successful case studies. Global Environmental Change. 63: 102121.

Rango, A. and Havstad, K. 2011. Review of water-harvesting techniques to benefit forage growth and livestock on arid and semiarid rangelands. In: M. K. Jha (ed.). Water Conservation, IntechOpen, London. 10.5772/29857.

Vallejo, V.R., Bautista, S. and Cortina, J. 2000. Restoration for soil protection after disturbances. In: L. Trabaud (ed.). Life and Environment in the Mediterranean. WIT Press, Boston, MA.

Wu, W.Y., Lo, M.H., Wada, Y., Famiglietti, J.S., Reager, J.T., Yeh, P.J.F., Ducharne, A. and Yang, Z.L. 2020. Divergent effects of climate change on future groundwater availability in key mid-latitude aquifers. Nature Communications. 11(1): 1-9.

Yannopoulos, S., Giannopoulou, I. and Kaiafa-Saropoulou, M. 2019. Investigation of the current situation and prospects for the development of rainwater harvesting as a tool to confront water scarcity worldwide. Water. 11(10): 2168.

Yosef, B. and Asmamaw, D. 2015. Rainwater harvesting: An option for dry land agriculture in arid and semi-arid Ethiopia.International Journal of. Water Resources and Environmental Engineering. 7(2): 17-28.

SOIL SURFACE SCARIFICATION

gef
UN environment programme
ICARDA
Science for resilient livelihoods in dry areas
CGIAR RESEARCH PROGRAM ON Livestock
CGIAR Livestock, Climate and System Resilience

BACKGROUND

Crusted or capped soils are common in arid or semi-arid degraded rangelands, either occurring naturally or as a result of poor management. Without measures to improve soil conditions, rangeland rehabilitation efforts often result in unacceptably low seed germination and/or seedling performance. Success rates may be improved by human intervention, using methods such as soil surface scarification to promote physical and chemical processes within the soil that enhance plant survival and growth.

Figure 1. Soil surface scarification before rainy season (fall) to break soil crust

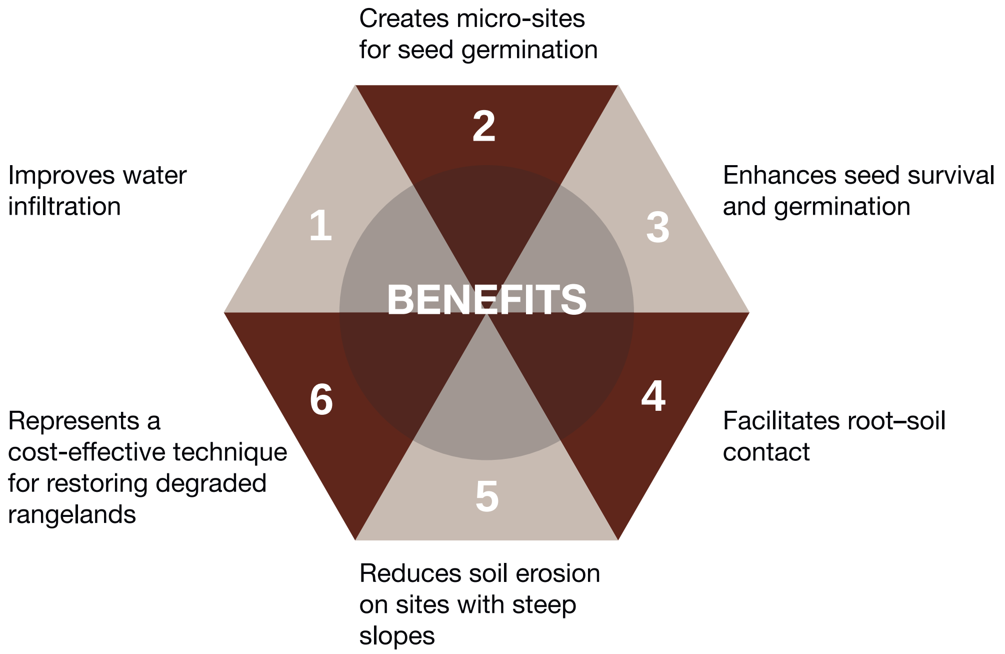
Purpose of soil surface scarification

Soil surface scarification breaks up the compacted/crusted surface soil to enhance ecosystem processes. Soil respiration is improved, water can penetrate faster, the germination and emergence of seeds are facilitated, and succession can move forward more quickly. Scarification is commonly used to ensure successful regeneration of vegetation either through natural rehabilitation or by direct seeding.

Figure 2. Positive impact of soil scarification on rangelands species germination (Spring season)

Procedure

Different soil surface treatments can be used to improve degraded rangelands, with surface disturbance being achieved either naturally or mechanically. These actions may have different impacts on mixed plant communities and may have a significant effect on biodiversity and rangeland structure.



Natural scarification (herd effect)

Ideally, soil surface scarification should be achieved naturally through the action of the hooves of grazing animals. In the past, this was facilitated by the behavior of grazing wildlife which, when chased by predators, would stampede and break up the soil surface. However, nowadays, with domestic livestock grazing calmly at a slow pace, the impact of the herd is negligible, especially when the soil surface is already capped or crusted. There are certain practices that can mimic predator-induced behavior such as the use of a mobile watering facility or additional feeding and/or mineral supplementation (for example, salt in a granular form).

Figure 3. Using a crust breaking machine (cultivator) in the Jordanian Badia

Mechanical scarification (machinery)

Mechanical scratching or plowing are the most common scarification techniques. The choice of field cultivator or ripper is based on how compacted the soil is, how hard the crusted layer is, and whether rocks are present. Usually, a tractor is fitted with a tool bar carrying tines, rippers, or other devices capable of disturbing the upper 5–10 cm of the crusty soil. Cultivators consist of a frame, tines with reversible shovels, and heavy-duty springs. The teeth work on the soil surface to loosen the soil without inversion.

Effective implementation

- Recommended for bare (denuded) and crusted soil
- Depending on the geographic location, scarification should be implemented in advance of the early fall rainfall (usually 1–2 weeks before the first rain is expected)
- If the soil seed bank is depleted, scarification should be combined with direct seeding
- Scarified areas should be protected to allow seeds to emerge and seedlings to establish
- The established plants should be lightly grazed initially, with moderate grazing permitted thereafter
- The drag chain harrow is a simple, quick and effective way to break crust while keeping the soil healthy and can help reduce the risk of erosion, while also helping with moisture retention
- Cautionary note—there could be limitations according to soil depth or the risk of wind erosion. Land managers should assess the overall conditions of the site (slope, soil texture, soil depth) to make sure tools used are appropriate.

SUMMARY

Soil surface scarification under arid climate conditions facilitates plant succession and enhances ecosystem health. Lightly breaking up the surface soil creates narrow furrows that trap moisture and improve seedbed conditions. This practice, if complemented by seeding, is a cost-effective technique for rehabilitating degraded rangelands.

Figure 4. Livestock grazing affects pasture productivity

FURTHER READING

Gauthier, M.M., Lambert, M.C. and Bédard, S. 2016. Effects of harvest gap size, soil scarification, and vegetation control on regeneration dynamics in Sugar Maple-Yellow Birch Stands. Forest Science. 62(2): 237-246.

Liu, Z. and Zhang, X. 2010. Steppe degradation and rehabilitation in Northern China. In: Ci, L. and Yang, X. (eds.). Desertification and its control in China. Higher Education Press. Springer, Berlin Heidelberg.

Louhaichi, M., Clifton, K. and Hassan, S. 2014. Direct seeding of Salsola vermiculata for rehabilitation of degraded arid and semi-arid Rangelands. Range Management and Agroforestry. 35(2): 182-187.

Savory, A. 1988. Holistic Resource Management. Washington, DC: Island Press.

DIRECT SEEDING

BACKGROUND

Rangeland degradation resulting from unsustainable human activities and climate change is a serious threat to natural resources in arid and semi-arid areas. Changes in rangelands use, and management practices are urgently required to slow down and even reverse degradation.

There are several solutions available to tackle rangeland degradation. One of the most rapid and cost-effective options is direct seeding, which involves sowing seeds directly into their final growing location rather than transplanting seedlings nurtured elsewhere.

Due to the low cost of direct seeding, large-scale degraded rangeland in many areas of the world can benefit from this practice. In choosing whether to restore rangelands with native or exotic species, we must choose suitable species based on their responses to specific site characteristics for the restoration project's success.

Figure 1. Mechanical seed drillers, rangeland improvement project in Kairouan, Central Tunisia

Direct seeding and its merits as a restoration option

Direct seeding is currently receiving much attention as a method of rangeland improvement. Direct seeding is suitable 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 due to 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, and preserving soil structure through reduced tillage. It is a method recommended in the lowlands and landscape depressions (Marab) that receive additional amounts of rainwater from runoff because the extra soil moisture improves seedling emergence and establishment. Furthermore, under intensifying climate change and increasing soil degradation rates, direct seeding without disturbing the soil (no-tillage) is becoming more appealing. Such practice helps the soil retain moisture and maintain more organisms that break down organic matter into vital nutrients, increasing the potential for nutrient recycling, leading to healthy soil.

Figure 2. Seedlings emergence in pits of Mediterranean saltwort *(Salsola vermiculata)*, Syrian Badia

Improving the impact of direct seeding

The limit on the success of direct seeding in drylands is due to drought, soil surface crusting and compaction, slow permeability, low available water capacity, and seed mortality due to heat and predation by birds or insects. Direct seeding is feasible on drylands if well-adapted species and recommended seeding methods are used. Outcomes can be improved through better site selection and ground preparation through drilling and pitting seeds to enhance germination and survival. Drills and pits can be created by hand or machine, and they contribute to protecting the seeds and improving moisture capture in arid areas.

Frequently, direct seeding is combined with soil scarification and improving water capture. Direct seeding following soil surface scarification will have an important effect on seedlings' establishment and survival. Furthermore, a rest period is needed to allow species to emerge and establish. The grazing should also be light during the first year or two to avoid plant being uprooted or compacted.

Enhancing seedling emergence and establishment

Seed pretreatment methods such as mechanical and chemical scarification or soaking seeds in hot water can also improve direct seeding efficiency by breaking dormancy and overcoming field stress factors. Seed pretreatment also speeds up seedling emergence and enhances seed survival. Sowing at the right time and the proper depth is critical to the success of direct seeding.

Choosing the best species for direct seeding

Choosing seed species depends on the restoration's objective and the biophysical and socio-economic condition of the target site and its community. In general, plants that grow naturally in the same habitat have the greatest chance of success. Exotic species such as fodder shrubs may also perform well under direct seeding once their ecological demands in the target site are met.

Figure 3. Rangeland rehabilitation using direct seeding of Mediterranean saltwort *(Salsola vermiculata)*, Jordanian Badia

Methods of direct seeding (pitting machine)

Given the nature of rangeland landscapes, the most common method of direct seeding is **hand broadcasting** - sprinkling the seeds by hand. It is the easiest and cheapest method, requiring less labor compared to seedling transplantation. In most cases, this intervention is usually combined first with seedbed preparation through light soil surface scarification. After broadcasting, the seeds should be covered to protect against birds and other predators.

Another direct seeding technique is **drilling** - dropping seeds at a fixed depth and covering them with soil. In this method, sowing tools are used for placing the seeds into the soil. Several options are available, such as mechanical seed drillers and pitting machines. The latter is towed by an ordinary two-wheel-drive pickup making it popular and achievable with small scale farmers. Small shallow 'pits' are scooped out by the action of inclined metal disks just before the rainy season. Seeds are placed in each pit either by hand or through a seed hopper mounted on top of the pitting machine. Seeds that germinate in the pits find favorable conditions for emergence and growth.

Along mountain slopes or where plowing and harrowing are difficult, **dibbling** is usually practiced. Dibbling entails making small holes in the ground for seeds using a pointed stick or a long piece of wood, then dropping seeds into the holes and covering them with soil, all by hand.

Some pastoral communities in West Asia have developed the practice of using livestock to distribute seeds. Seeds are harvested by hand and placed in a pouch that is punctured with holes and strung around the animal's neck. As the animal grazes the seeds shake loose and are widely distributed. This is an example of low cost local technology that partially replicates the role livestock play when they graze desired species and distribute seeds in their dung.

For remote and inaccessible sites, **aerial sowing** is an option. It is often used to spread seeds to large land areas that need vegetative cover after severe degradation that has depleted the soil seed bank.

Figure 4. Precision aerial seeding for rangeland rehabilitation using drone

Advantages of direct seeding:

- Rapid and cost-effective method for large-scale restoration of degraded rangeland
- Seeds are easier and cheaper to transport and store than seedlings
- Large areas can be covered with direct seeding because of its relatively low transport costs, while storage of seed is straightforward and cheaper than for seedlings
- Requires less time and labor than transplanting
- Plants develop deep, robust root systems that allow them to establish themselves quickly to withstand drought and wind, unlike transplanted seedlings
- Timing of seeding is more flexible depending on species, seed treatments, and rainy season
- Able to access rough and distant terrains through aerial seeding
- Promotes vegetative growth in less accessible areas, such as hillsides, rocky, and uneven terrain (Though more success can be achieved in lowlands)
- Better root growth in preparation for harsh conditions such as drought or overgrazing
- A higher level of seed germination in the years following the original sowing (depending on biophysical conditions).

A new approach in direct seeding is planting pellets stuffed with combinations of fertilizer nutrients and pesticides to enhance the establishment of vegetation cover by aerial seeding in semi-arid regions. The seeds are coated with materials that will not disintegrate when in contact with moisture on the soil surface, and the pellets absorb enough moisture to cause germination through the coat.

Figure 5. Mechanized direct-seeding using pitting machine, Syrian Badia

Another potential solution to land degradation is the use of biodegradable materials such as geotextiles that hold moisture, allowing seeds to germinate and establish roots even during low rainfall. This method can also control erosion and sediment.

Effective root establishment and seedling maintenance

- Selection of suitable sites and appropriate pre-sowing treatments is vital for successful direct seeding
- Always assess remnant vegetation, soil, risks, and opportunities along with the purpose of the revegetation
- A mixture of seeds (including shrubs and herbaceous species) can be sown simultaneously to increase the chance of at least one species establishing even in case of prolonged drought
- Sowing at the right time, generally at the beginning of the rainy season to ensure optimum soil moisture, increases success
- Sowing at the right depth for species seed size is vital to root establishment
- The sowing rate should be based on seed viability (not total seed) and adjusted density compared to the original and reference rangeland ecosystem. This ensures adequate seeding rates are met in case the seed germination rate was low
- For successful root establishment, seed quality should be checked first to estimate proper seeding density
- Certain species require pretreatment to break seed dormancy (mechanical or chemical treatment)
- If the seeds are too small, mixing them with sand makes a bulky mixture easier to handle
- Respect plant association and try to balance species composition accordingly to avoid plant competition over limited resources
- A high seeding rate increases overall seedling emergence and establishment
- Avoid incorporating the seed too deeply, especially in heavy soils (clay) or where soil surface sealing is a problem as the plants are less likely to establish themselves.

SUMMARY

Direct seeding is a fast and cost-effective method to revive rangeland vegetation. It is also well suited for a large-scale degraded environment due to its reduced costs (no need for nursery and seedling transplantation). However, the micro-environment of the developing seedling is an important factor. Therefore, selecting groups of species with similar habitat requirements at the establishment phase will improve species establishment and increase restoration success. Timing of sowing and using methods to enhance seed germination should be considered, such as seed pretreatment techniques and seeding depth.

Figure 6. Restored rangeland site in Almaty, Kazakhstan

FURTHER READING

Louhaichi, M., Clifton, K. and Hassan. S. 2014. Direct seeding of *Salsola vermiculata* for rehabilitation of degraded arid and semi-arid rangelands. Range Management and Agroforestry. 35(2): 182-187.

Louhaichi, M., Hassan, S., Missaoui, A.M., Ates, S., Petersen, S.L., Niane, A.A., Slim, S. and Ouled Belgacem, A. 2019. Impacts of bracteole removal and seeding rate on seedling emergence of halophyte shrubs: implications for rangeland rehabilitation in arid environments. The Rangelands Journal. 41: 33-41.

Matthew, J.R., Knudsen, A.D. Jacobs, J.S. and Mangold, J.M. 2019. Seeding Causes Long-Term increases in grass forage production in invaded rangelands. Rangeland Ecology & Management. 73: 329-333.

Palma, A.C. and Laurance, S.G.W. 2015. A review of the use of direct seeding and seedling plantings in restoration: what do we know and where should we go? Applied Vegetation Science. 18: 561-568.

Pellizzaro, K.F., Cordeiro, A.O.O., Alves, M., Ribeiro, F., Motta, C.P., Rezende, G.M., Silva, R.R.P. and Schmidt, I.B. 2017. "Cerrado" restoration by direct seeding: field establishment and initial growth of 75 trees, shrubs and grass species. Brazilian Journal of Botany. 40: 681-693.

SHRUB/TREE PLANTATION

BACKGROUND

The degradation of rangelands is induced by overgrazing, over-gathering of firewood, and conversion of the best rangelands into cropping land. Over-exploitation results in negative effects leading to soil erosion and the reduction of forage biomass for livestock. To alleviate the spread of rangeland degradation, planting shrubs provides a large amount of fodder for livestock, combats desertification, and plays a key role in natural resource conservation.

Figure 1. Rangeland rehabilitation using *Atriplex halimus*, Aleppo Badia, Syria

Importance of shrubs/trees

Shrubs/trees reduce 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 alley cropping has the potential to improve both the sustainability and profitability of utilizing a piece of land, thus improving the livelihoods of smallholder farmers.

Species and site selection

Select shrubs/trees well-adapted to conditions of individual planting sites. The choice of species will depend on the annual rainfall amount, soil, topography, runoff, 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.

Shrub/tree planting benefits:

01 Able to valorize marginal water not usable for conventional crops

02 Facilitative effect for establishment of understory vegetation

03 Supply of ecosystem services

04 Halophytic shrub species such as saltbush can improve salt affected soils

05 Excellent for feeding livestock during drought & a source of firewood for farmers

06 Trees provide shade for livestock.

Ideal species for arid environments

To ensure successful rangeland rehabilitation, the choice of species should be selected according to the site specificity while prioritizing native species. Extra caution should be always taken against the risk of invasive alien species. 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 vermiculat*a (Mediterranean saltwort), and *Haloxylon aphyllum* (saxaul). *Ceratonia siliqua* L. (carob tree), a long-living evergreen tree native to the Mediterranean, is commonly used to provide shade for livestock during hot summers. Certain shrubs/trees 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 suited to the low rainfall and salt conditions of arid environments.

Figure 2. Goats browsing *Atriplex halimus* planted in alley cropping in khanasra, Syria

Challenges during shrub/tree planting

The high cost related with the establishment and the maintenance of shrubs/trees presents the main challenge for smallholder farmers with low incomes. Another common issue faced by most shrub/tree planting programs is the availability of suitable species for the target ecosystem at the appropriate time. In most cases, supplementary irrigation is needed right after planting to secure strong 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 transplanted shrubs as animals prefer the young succulent seedlings to the older and more mature plants.

Establishment and management

Shrub/tree establishment and growth often suffer heavy plant losses due to intense lack of soil moisture.
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 reducing soil erosion, depletion of soil nutrients, prevalence of weeds/invasive species, and more uniform soil fertility levels. Before establishment, shrubs/trees should not be browsed as this reduces their growth and survival potential.

Combining shrub planting with water harvesting techniques

When seedlings are planted on steep slopes, water harvesting techniques, which enhance efficient use of soil moisture, should be implemented first. When combined with water harvesting techniques such as semicircle structures or intermittent contours, shrub planting improves erosion control, forage quality and availability, and plant and animal micro-habitat conditions.

Figure 3. Transplanting *Atriplex halimus* seedlings along contour lines, Aleppo Badia, Syria

Effective establishment and maintenance:

01 Select suitable sites for introduction of new shrubs

02 Transport seedlings to site of transplanting with extra care

03 Harden young seedlings by gradually introducing them to their new environment

04 Avoid browsing during the establishment phase

05 Allow enough recovery time after browsing/harvesting

06 Replace missing and/or dead seedlings during the following season

07 Prune trees and shrubs every other year to induce regeneration of new growth.

SUMMARY

Planting shrubs/trees is beneficial in reducing the effects of degradation such as soil erosion and also in creating microhabitats for vertebrate and invertebrate fauna. The establishment and management of shrubs/ trees requires that they receive a long enough period for them to recover lost biomass after a browsing and pruning event.

FURTHER READING

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: 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.

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): 135-149.

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

GRAZING MANAGEMENT

BACKGROUND

Grazing management is the process of grazing and browsing animals to accomplish a desired levels of livestock production coupled with maintaining quality wildlife habitat and ample recreational space. When managing grazing, both the plants and animals need to be considered. If the rangeland is grazed too intensively, particularly for sustained periods, both plant and animal production will be reduced. However, if the grazing pressure is too light forage use will be low, forage quality may decrease and animal production per unit area will be low.

Figure 1. Goats browsing *Rhanterium suaveolens*, southern Tunisia steppe

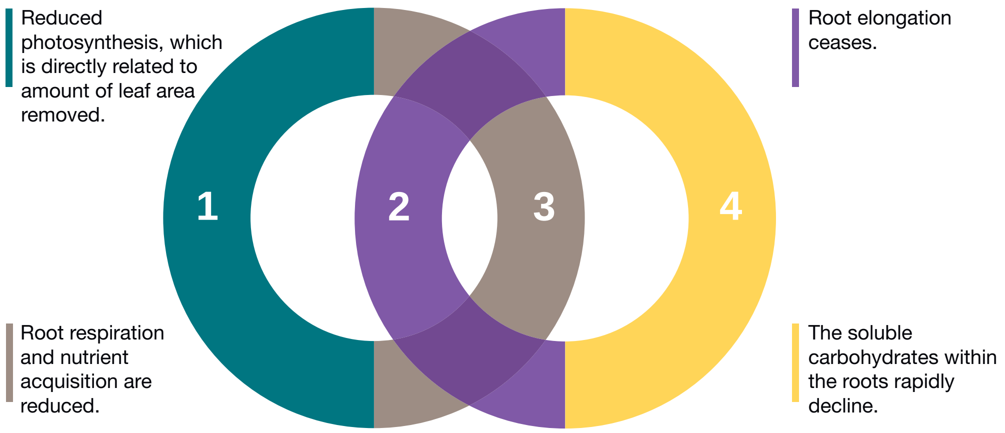
Principles of grazing management

The fundamental principle of grazing management is to control the frequency and severity of defoliation of individual plants. The principle factor controlling this is grazing pressure which is defined as the ratio of forage demand to forage available for any specified forage at any point of time. Grazing management is a tool to optimize the capture and use of energy in grazing systems that enables maximum quality forage production, optimum harvest and the conversion by animals of that energy into a marketable product by animals. Timing of grazing and maintaining plant vigor, especially after-grazing events, are key factors to consider in controlling frequency, intensity and duration of grazing. These factors influence soil stability, forage production, and efficiency of forage use, and therefore have a significant impact on livestock production.

Responses of plants to grazing

Grazing pressures can have both positive and negative impacts on plant species. Grazing management requires these impacts to be balanced in order to optimize productivity over time.

The immediate, adverse effects of grazing on plants include:



The following **benefits** can occur as a result of grazing:

- Enhances the abundance, vigor and productivity of the desirable plant species in which grazing triggers the potential for emerging new growth and thus conserves the species existence in the area
- Optimizes the use of forage produced without causing detrimental effects to soils where the new growth does not need any disturbance planting practices affecting the soil
- Maintains and enhances plant diversity in which plant species are endemic to the site and maintained annually
- Enhances livestock production were the fodder available supports the quantity and quality of livestock products
- Enhances soil conservation and reduces soil erosion where the rangeland vegetative cover causes root soil boundingthereby reducing the chances to detached soil particles
- Improves soil fertility due to the organic matter availability after long periods of grazing
- Improves watershed protection through water infiltration and percolation in the soil
- Enhances nutrient cycling within ecosystems.

Figure 2. A flock of sheep tend to graze and move across the pasture as one unified group

Key components of grazing management

The main components of grazing management include supply of forage, forage demand, degree of grazing use, and timing. The supply of forage depends on abundance, vigor, condition of the desirable plant species, and climate conditions. Forage demand is a function of the number of animals, forage intake by animal, which is correlated with metabolic body weight and number of grazing days, number of grazing days. Degree of use and timing of grazing are controlled by the grazing system (graze and rest periods), including the periodicity including periodicity and seasonality. Manipulation of these components is easier in a fixed area management and can be difficult to apply in communal grazing or transhumance systems, although seasonal herd movements in transhumance systems can provide similar grazing management benefits.

Timing and pressure of grazing is closely influenced by access to water. Grazing utility of land goes hand-in-hand with water provision and distribution within grazing blocks landscapes, but water is a leading factor in the degradation of pastures if it allows animals to remain too long in any one area. Water is often a challenge to consider especially areas where access to surface water including stream, rivers or lakes is not readily available.

When to graze?

Grazing optimization is often determined by the management objective of the production system. A land manager could be interested in maximizing sustainable yield from grazing and producing a valuable product for the market, promoting better ecosystem functioning by enhancing vegetation heterogeneity, or a range of objectives in between.

Determining when to graze relies on knowledge of plant species physiology abundance and quality as forage, site characteristics including soil fertility, animal types and classes and their forage requirement and economic and management factors. Many range forage plants are highly nutritious and palatable during the early growing period then they steadily decline in quality and quantity over time. Understanding the forage growth cycle of the key forage species is essential to determine the optimal timing and duration of grazing.

For profit maximization, a manager will consider enhancing enhancing the productivity of the more nutritious and palatable plant species more nutritious and palatable plant species. Intensive grazing during the early growing season using livestock that are less selective to grazing has the potential to achieve this objective since plant growth relatively rapid and the forage resources are homogenously green. This also works well because the less desirous plants do not disperse their seeds and propagate.

Higher biodiversity in supports a wider a wider variety of plant and animal species because they contain a structural complexity that provides niches and habitats for wildlife and and other flora and fauna. Maintaining heterogeneity in landscapes increases biodiversity, enhances ecosystem goods and services and provides long-term sustainability of ecosystems. This is particularly effective for the conservation of the functionality of large-scale ecological rangeland processes as in pastoral systems. In such a scenario, the grazing management would entail using different types and classes of livestock to graze on different environmental patches of the landscape to maintain heterogeneity.

Figure 3. Herd's mobility is used by pastoralists to cope with climate change

Effective grazing management

Timing is the most critical factor for effective grazing management. Effective timing allows a manager to gain the full benefits of grazing, as well as mitigate any risks associated with grazing during rest periods, which will put pressure on rangeland plants. Effective grazing managementshould consider the timing rather than the overall grazing pressure. If pastures are being actively managed, and grazing pressure is avoided during rest periods, then high grazing pressure can be supported for short periods during the appropriate phase in the growth cycle of the pasture. The following principles should be taken into consideration in grazing management planning:

1. Establish pasture areas for managed grazing and recovery periods

Controlled grazing requires discrete pasture areas to be identified and systematically grazed and rested according to seasonal demands and the characteristics of both the vegetation and the environment. On private lands this is commonly practiced through rotational grazing and dividing the land into paddocks. On communal lands, it requires a high degree of agreement and coordination to implement effectively. Grazing management on communal lands can be controlled controlled by limiting access to water. **Livestock with unlimited access to water resources can cause considerable degradation to the rangelands surrounding water points. Therefore, periodically excluding access to water point can be an an effective method to reduce the negative impact of livestock trampling and overgrazing around water points. This can be done by mobile water tanks in remote areas where rangeland vegetation is greater in terms of quantity and quality.**

2. Understand the growth characteristics of forage plants (species and communities) and how they respond to grazing

Most grasslands have coevolved with grazing animals (ungulates) and depend on specific actions of those animals to maintain ecological balance. Grazing management depends on careful timing, both in terms of how long and how often grazing occurs. Plants are overgrazed as a result of multiple, severe defoliation events without sufficient recovery periods between defoliations.

Effective management means allowing time for full plant recovery before re-grazing when grass growth and nutritional value are at their maximum. Plant growth follows a sigmoid curve, growing at a slower rate when young, then accelerating, before slowing again towards maturity. Nutrient value starts to decline with seeding, so the optimal grazing time – in terms of both biomass and nutritional value – is soon after maturity. Usually re-grazing should not be allowed until grass species have matured and reproduced.

Most grasslands consist of a community of valuable plants that mature at different rates, and and some may include both herbaceous and woody species. Timing, therefore, depends on a detailed local knowledge of both plant growth cycles and the desired combination of plant species for livestock production. The balance of plant species is determined by the livestock species (and the combination of species) as well as the livestock production objectives. Effective grazing management is therefore underscored by strong scientific knowledge, knowledge, and is effectively applied through the local the local knowledge of herders.

3. Establish grazing management plans

Grazing management plans are designed around periods of grazing and recovery of pasture areas. Plans are informed by the resting periods required for different plants, including the most desirable grasses and legumes. Decisions about moving animals from one pasture area to the next are based on the amount of forage available, size of the area, and the estimated seasonal growth rates. A key objective is to avoid repeated, severe defoliation of plants and allow for planned recovery periods.

Grazing management faces the challenge of seasonal forage availability, with seasons of abundance and seasons of scarcity. Many pastoralist societies move their herds over great distances between seasons to exploit pasture zones with different grazing characteristics. Managing grazing patterns withinthese different areas can be challenging, particularly when each grazing area has a different group of users. Grazing management plans therefore need to be adapted to the social arrangements around pasture use, and management planning is usually dependent on identifying zones where the users have the right and the ability to enforce grazing rules.

SUMMARY

Continuous grazing, the most common grazing system in the world, often results in overgrazing and an increase of less-desirable or invasive invasive plant species. When livestock graze without restriction, they eat the most palatable forage first. If these plants are frequently grazed without allowing time for their roots to recover and leaves to regrow, they will die. Plants not eaten by livestock – the less desirable species – will mature, reproduce and thrive. Thus, populations of undesirable plants increase, while preferred plants are eliminated, thereby reducing the forage quality. In many rangelands, such undesirable changes may have happened in the past and improved grazing management can be used to rehabilitate former ecological communities that are more economically useful. Changing from from continuous to controlled grazing management requires skillful decisions and close monitoring of its consequences. This can be challenging for many pastoral communities and requires significant effort to address underlying governance challenges.

FURTHER READING

Angassa, A. 2014. Effects of grazing intensity and bush encroachment on herbaceous species and rangeland condition in southern Ethiopia. Land Degradation & Development. 25(5): 438-451.

Heitschmidt, K.R. and Stuth, W.J. 1991. Grazing management: an ecological perspective. Timber Press, USA.

Lemus, R. 2015. Pasture management and grazing guide for livestock producers. Mississippi State University-Extension.

Savory, A. and Butterfield, J. 2016. Holistic management: a commonsense revolution to restore our environment. 3rd Edition, Island Press.

Undersander, D, Albert, B., Cosgrove, D., Johnson, D. and Peterson, P. 2002. Pastures for profit: a guide to rotational grazing. University of Wisconsin-Extension.

RANGELAND INVENTORYING, MONITORING AND ASSESSMENT (RIMA)

RANGELAND MANAGEMENT

Range management is a science that aims to ensure a sustained productivity of rangeland through improving the range resources attributes including soil, water, fauna and flora, in addition to other ecosystem services such as carbon sequestration and renewable energy.

Importance of rangeland inventorying, monitoring and assessment

Rangeland inventory is to collect, gather, analysis, and interpretate natural resources data to characterize the ecological site and provide potential information for planning or other purposes following certain procedures. Site inventory data describes site biophysical, hydrological, and ecological features in addition to vegetation and animal resources, habitat assessments for wildlife and other variables that are relevant to the required planning goals. This data allows for comparison with other study sites.

Rangeland monitoring is the gathering of the ecological information that describes changes in rangeland attributes status using systematic and repeatable methods, usually to evaluate the response to certain intervention at the rangelands site.

Data and results developed from repeated rangeland inventories can be used to produce the basis to compare responses and to support the site monitoring in order to assess the state of rangeland health according to specific indicators.

Figure 1. Measuring vegetation characteristics is essential in rangeland monitoring

Rangeland managers benefit from improved monitoring methods that provide rapid, accurate, cost-effective, and robust measures of rangeland health and ecological trend.

Rangeland assessment provides range lands manger and stakeholders with a communication tool regarding the status of ecosystem properties and processes on a site and how well they are functioning helping to develop clear adaptive restoration management.

- **Range condition** describes the current state of the vegetation compared with that of the climax or original vegetation for the range site. Range condition is used to measure deterioration or improvement in the plant community.
- **Range trend** defines the rate and direction of change in range condition.

Site description (background information)

Before taking measurements, detailed properties of a site and vegetation communities to be studied must be identified (Sheley et al., 2011). The toolkit has a separate section describing in greater details the information needed for developing the action plan based on site potentiality. In short, an ecological site description would include the following:

- Coordinates of the target site, area, plot locations and transect starting points (where required) using GPS should be recorded. Elevation above mean sea level may also be identified
- Vegetation communities should be identified, usually they are distinguished by the dominant species
- Soil type (sandy, silty, loamy, clay loam, limestone and sand dunes), in general rangeland soils are extremely diverse and different soil types may occur within the study site
- Geomorphology: refers to the nature of the terrain (plains, hills, mountains, wadis, etc.)
- Slope: usually expressed in percent or degrees
- Climate: is the average weather conditions for the region (humid, semi-arid, arid, desert, etc.)
- Meteorological data (rainfall, temperature, wind…) including their historical average and current average
- Tenure systems (private, communal, public, protected, etc.)
- Current state: natural reserve (park), rested (age of resting, implemented strategies, who supported the project), rotational grazing, continuously grazed, etc.)

- Grazing patterns: stable grazing systems, seasonal, transhumant grazing, etc.)
- Number of the main types of livestock (sheep, goats, cattle, camels or a mixed herd)
- Distribution of water points.

Stakeholder engagement: a key ingredient

Note: For a full description of this sub-section including stakeholder identification, please refer to the toolkit chapter on: Assessing rangeland and grassland ecosystem health.

Stakeholder engagement is particularly recommended at the following stages in rangeland assessment:

1. Identifying and mapping the target relevant indicators of rangeland condition and determining management objectives and uses of different landscape patches
2. Identifying landscape condition indicators according to both local and scientific knowledge based on agreed management objectives
3. Interpretation and validation of the landscape condition assessment results

Participatory indicator selection is usually combined with selection of pre-determined indicators, particularly when rangeland assessment needs to be carried out for comparison between different landscape managements (e.g., as part of a national methodology and monitoring system). While local indicators and scientific indicators often converge, they can also show differences in perceptions and understanding, and analysing how indicators diverge can be informative (Figure 2).

Figure 2. Capacity development of partners in rangeland management and evaluation

Typical scientific indicators can include the following:

- Changes to total vegetation cover (species density, bare ground, stony surface and rocky outcrops)
- Change in the balance of herbaceous and woody vegetation
- Change in total vegetation diversity
- Presence of palatable species and other economically important species
- Presence of invasive plants and undesirable species
- Change in diversity of wild animals, birds, insects and other native species
- Changes in topsoil properties (loosening, crusting, erosion)
- Loss of soil nutrients, including soil organic carbon
- Changes in seed stocks in the soil.

Methods of rangeland monitoring & assessment

There are numerous methods for monitoring and assessing rangelands. Some define the assessment process in terms of decreasing palatable species, increasing invasive plants; others on determining the quantitative values of the species in terms of dominance, abundance, and frequency; and on assessing rangeland conditions by determining vegetation cover, density, biomass, forage production, and plant diversity in each plant community to evaluate its status.

1. Rangeland monitoring and assessment using conventional field plot-based methods

Traditional field monitoring methods (e.g., transects or quadrats) can provide detailed information for assessing the health of rangelands. Cost, however, often limits monitoring locations to a few key areas or random plots that observe a small fraction of the land they are intended to represent. There are many indicators that use plot-based methods for qualitative and quantitative assessment of the rangeland's conditions including:

1.1. Vegetation cover

is the relative area covered by single plants, a group of individuals of a single species, or all species of plant community. It is expressed as a percentage of the total area of the plant community. Vegetation cover is estimated by the point intercept method. A metal pin or stake is inserted vertically next to the measuring tape at 50 cm intervals (100 points). The intersection at each point is recorded (vegetation, litter, stone, crust, wind veil; Figure 3). It is essential to replicate the sampling method by recording measurements from at least three transects laid out in either the spoke or parallel design. The layout of transects may vary depending on landscape-scale. Parallel transects must be evenly spaced.

Figure 3. Vegetation cover estimation using the point intercept method

1.2. Plant Density

is the number of individuals of each species per surface unit (m^2 or ha). Density provides a good ecological indicator of grazing intensity. As grazing pressure increases, the density of palatable species decreases, and the density of unpalatable species increases. When counting the number of annual plants, the count is made on a 1 m^2 quadrat (Figure 4). For perennial plants, the count is usually taken in a rectangle 50 m^2 aligned with the line intercept used to cover measurement (Figure 4). The number of replications needed is determined by the homogeneity of the area.

Figure 4. Frame of 1 m^2 for annual plants density and frame of 50 m^2 for perennials density measurements

1.3. Biomass production

is the total weight of plant mass per unit area at a given time. Measuring vegetation biomass is best done at the peak growth period. During favorable growth periods, the abundance of annual plants (generally therophytes) is high. A 1 m^2 quadrat is usually used for measuring their biomass. (Figure 5). Biomass should be clipped as close to the soil surface as possible. Weigh the harvested biomass with a balance or spring scale, in the field if possible, to get the fresh matter weight.

Figure 5. Clipping aboveground biomass rooted inside the frame as close to the soil surface as possible

Samples should then be dried for 48 hours at 60-65oC and weighed again to get the dry matter weight.

Biomass harvesting of perennial plants (shrubs and trees) can be harmful to rangeland health and livestock production. Since the measurement of biomass needs a number of replicate samples and some plants are rare or endangered, destructive methods are an issue of concern to researchers. Various non-destructive methods have been developed to conserve ecosystems. Among the best-known and most accepted methods for measuring the biomass of shrubs and trees is the reference unit method (Figure 6). The reference unit is consisting of a branch usually reflect 10-20% of the vegetation of an average sized plant in the sampled site. The number of reference units in other plants should be recorded and the estimate of biomass can be obtained by multiplying the number of reference unit tallies by the weight of the reference unit.

Figure 6. Method for estimating biomass production of shrubs using the reference unit

2. Rangeland monitoring and assessment using remote sensing

Given the extend of rangeland area, it is difficult to use conventional techniques to monitor and assess rangeland conditions. Remote sensing can offer a rapid method for effectively and efficiently covering large area and assessing rangeland vegetation cover with an acceptable level of error. Rapid advancements in sensor technologies and analytical techniques coupled with decreasing costs of remote-sensing products have resulted in myriad examples of the utility of remote sensing to quantitatively monitor rangelands in ways previously not possible.

2.1. Fine scale remote sensing: Satellite imagery

Several satellite sensors (e.g., AVHRR, Landsat, MODIS, SPOT, etc.) have now been operational long enough to provide a reliable record of change in rangeland ecosystems with global coverage free of charge (Figure 7). The data archive provides an opportunity to assess the long-term phenological changes. There is evidence that remote sensing may prove superior to conventional ground measurement methods for several reasons: (1) it facilitates extensive data collection by reducing the labor requirement for monitoring, (2) it reduces human bias by limiting the influence of human judgment, (3) it is more precise, and (4) it provides a permanent record of information.

Figure 7. Google earth imagery of an agroforestry area in Central Tunisia

2.2. Large scale remote sensing: Aerial photography (Drone)

The recent introduction of low cost small, unmanned aircraft systems (sUAS) to remote sensing has provided a significant improvement in the quantity and quality of high-resolution imagery (Gillan et al., 2020). Aerial photography and drone-based imagery in particular, can observe larger areas than field methods while retaining high enough spatial resolution to estimate many rangeland indicators of interest (Figure 8). However, the geographic extent of drone imagery products is often limited to a few hectares (for resolution ≤ 1 cm) due to image collection and processing constraints.

Figure 8. A landscape view taken by a drone of an improved site in the Jordanian Badia

2.3. Near earth remote sensing using digital vegetation charting technique

Digital cameras monitoring vegetation cover has an important role by filling the “gap of observations” between satellite monitoring and the conventional vegetation monitoring. In fact, digital vegetation charting technique (DVCT) is one of the most reliable technique for the monitoring of vegetation under different physiographic conditions (Louhaichi et al., 2018). It is less subjective and easy to use while providing high frequency and resolution data. The analysis of the color of images taken by high-resolution allow the detection of vegetation cover using software such as VegMeasure® to create meaningful classes through quantifying the red, green, and blue (RGB) color channels of each pixel (Louhaichi et al., 2019) (Figure 9). However, the low height pictures taken by the human makes this technique suitable to monitor the vegetation cover of annuals and small size shrubs but not the tall ones or trees.

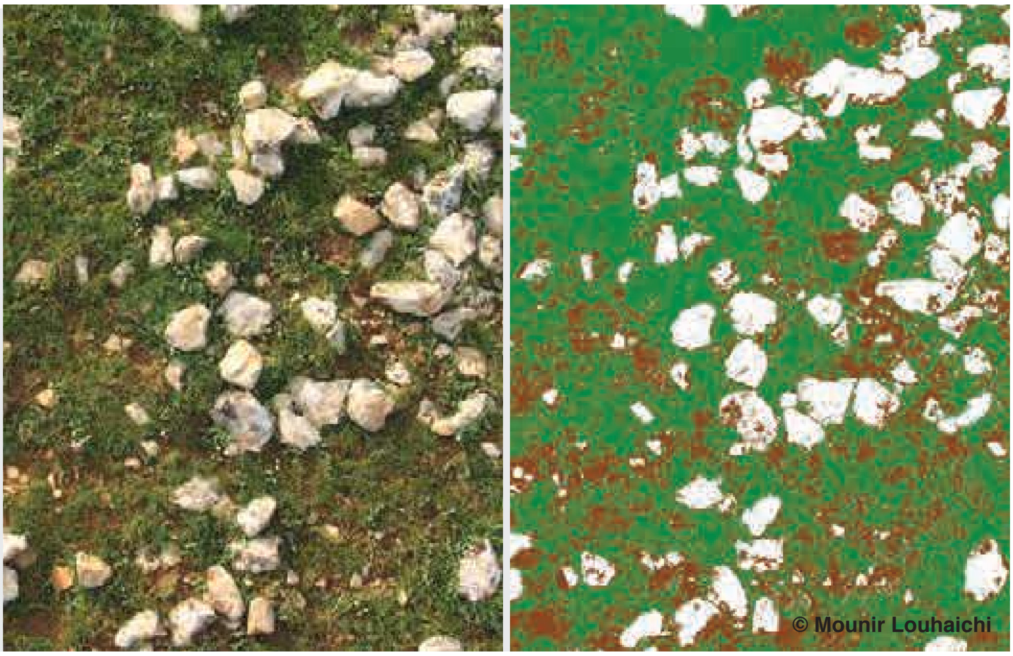


Figure 9. Original and processed images using VegMeasure software

FURTHER READING

Booth, D.T., Cox, S.E., Fifield, C., Phillips, M. and Williamson, N. 2005. Image analysis compared with other methods for measuring ground cover. Arid Land Research and Management. 19: 91-100.

Gillan, J.K., Karl, J.W. and van Leeuwen, W.J. 2020. Integrating drone imagery with existing rangeland monitoring programs. Environmental Monitoring and Assessment. 192: 269. https://doi.org/10.1007/s10661-020-8216-3

Louhaichi, M., Hassan, S., Clifton, K. and Johnson, D.E. 2018. A reliable and non-destructive method for estimating forage shrub cover and biomass in arid environments using digital vegetation charting technique. Agroforestry Systems. 92: 1341-1352. https://doi.org/10.1007/s10457-017-0079-4

Louhaichi, M., Hassan, S. and Johnson, D.E. 2019. VegMeasure: Image processing software for grassland vegetation monitoring. In Advances in Remote Sensing and Geo Informatics Applications; Springer: Berlin/Heidelberg, Germany, pp. 229-230.

Sheley, R., Mangold, J., Goodwin, K. and Marks, J. 2011. Revegetation guidelines for the Great Basin: Considering invasive weeds. ARS #168. USDA Agricultural Research Service. 52 pp.

Shibia, M.G., Rödera, A., Fava, F.P., Stellmes, M. and Hill, J. 2022. Integrating satellite images and topographic data for mapping seasonal grazing management units in pastoral landscapes of eastern Africa. Journal of Arid Environments. 197: 104661. https://doi.org/10.1016/j. jaridenv.2021.104661

IUCN

ASSESSING RANGELAND AND GRASSLAND ECOSYSTEM HEALTH

gef

UN environment programme

ICARDA
Science for resilient livelihoods in dry areas

CGIAR | RESEARCH PROGRAM ON Livestock

CGIAR | Livestock, Climate and System Resilience

PURPOSE

This chapter on "Assessing rangeland and grassland ecosystem health" addresses one of the most significant challenges of drylands: diagnosis of land and ecosystem degradation. It provides a series of principles and elements that can help ensure assessment of rangeland and grassland ecosystems is both scientifically correct and locally accepted. It addresses the challenge of defining baselines and reference points, which are in a state of natural flux in many drylands. It also addresses the fact that most drylands are semi-natural ecosystems, managed according to the economic and other objectives of local communities.

This chapter should inform project design and situation analysis and should be used to guide project baselines and monitoring. It will ensure that rangelands restoration and management plans can be implemented adaptively while demonstrating measurable progress against indicators that are both locally acceptable and scientifically robust

Key Action: ensure dryland restoration projects are established on an effective assessment of the drivers, pressures, state and trends of land degradation.

Figure 1. Hima Bani Hashem rangelands and ecosystem health

Why we need rangeland and grassland health assessment

A recent analysis based on WWF's terrestrial ecoregions estimates that 54% of all land is rangeland, including 100% of all drylands (ILRI et al., 2021). Rangelands include grasslands, shrublands, savannas, open woodlands, most desert, tundra (arctic and alpine), meadow, wetland, and riparian ecosystems. They support between 200 and 500 million livestock keepers, generating half of all red meat and a significant proportion of milk product, and providing valuable animal protein in many countries that suffer from malnutrition and food insecurity.

Thirty percent of rangelands and grasslands are estimated to be degraded worldwide, although the estimates range widely, depending on the methodologies and definition used. Some countries estimate that more than two thirds of their rangelands are degraded. Rangeland and grassland degradation create social, environmental and economic threats. They contribute to food and water insecurity, poverty, and vulnerability; create new risks of drought and flood; lead to biodiversity loss; and contribute to emission of greenhouse gas. Rangeland and grassland health assessment is therefore crucial for identifying land degradation and monitoring efforts to restore those lands and to address the associated social, environmental and economic risks.

Global assessments of rangeland degradation invariably use remote sensing data that gives an indication of biomass productivity, but provides little insight into the desirability of that biomass. The risk of misdiagnosis of rangeland degradation becomes more serious when these methodologies are used for assessment at the national and sub-national level. There are numerous examples of misdiagnosis of rangeland degradation or health that have led to harmful investments or missed opportunities. Historically, this is perhaps most notoriously manifested in the designation of such lands as ‘wastelands’: degraded and barren lands of no value that are waiting to be put to good use.

Figure 2. Hima Bani Hashem participatory rangelands assessment

Challenges to rangeland health assessment

Grasslands and savannahs are the most widespread biomes within rangelands. The composition, structure, productivity, and diversity of these ecosystems are governed by a combination of climate, geography, topography, geology, and soil. Many rangelands and grasslands are powerfully influenced by natural phenomena, such as herbivore pressure, fire and drought, that have created and sustained unique ecological communities.

The unique factors that create rangelands and grasslands also create challenges to objectively assessing their health. Foremost among these challenges is the non-equilibrium nature of drylands, which transition between stable states in response to different forces acting on multi annual and decadal time scales. For example, a savannah may rest in a grass-dominated state for many decades, then transition to a tree-dominated state, perhaps due to a drought-induced reduction in natural herbivory, only to transition back to grass-dominated decades later, perhaps due to fire or some other pressure. It is not feasible to determine which of these states is 'natural', since both are, and therefore it is challenging to agree on a baseline against which degradation or restoration processes can be evaluated.

A second challenge to rangeland and grassland health assessment is that, in most cases, they represent a semi-natural ecosystem: 84% of all rangelands globally are used for livestock production, most of it low-pressure and extensive. The healthy state of these lands can therefore be a subjective judgement based on the desired objectives of the managers. For example, an African grassland may be particularly desirable to a cattle herder but less desirable to a camel herder. The same land could transition to shrub-dominated, meeting the production objectives of the camel herders but viewed as degraded by the cattle herder. Wildlife managers face a similar challenge since most rangelands are highly heterogeneous, providing many different habitats that support different assemblages of species, some of which depend on grasslands and others on shrublands or woodlands.

Figure 3. Controlled sheep grazing in Hima Bani Hashem

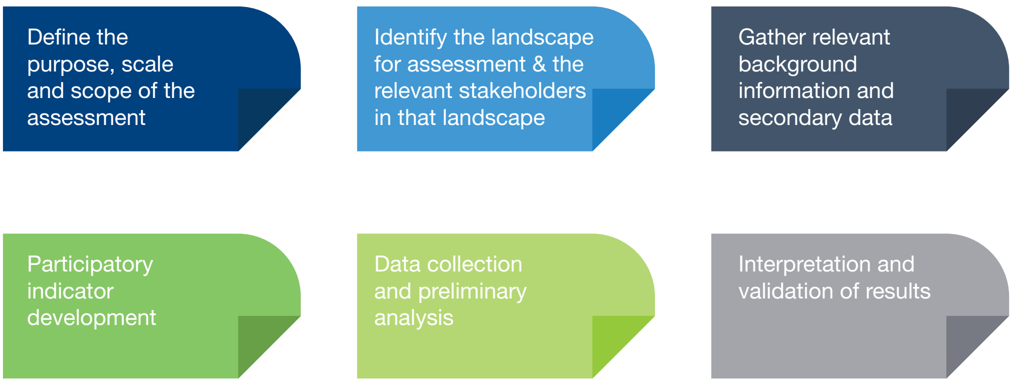
Definition of rangelands

Rangelands have been described as “land on which the indigenous vegetation (climax or sub-climax) is predominantly grasses, grass-like plants, forbs or shrubs that are grazed or have the potential to be grazed, and which is used as a natural ecosystem for the production of grazing livestock and wildlife” (Allen et al., 2011). Faber-Langendoen et al. (2012) place grasslands and rangelands into two natural formation classes: i) Shrubland and Grassland and ii) Desert & Semi-Desert.

However, other actors view rangelands as a socio-economic system, defined according to the rights and resources of the users rather than according to ecological criteria. In this view, rangelands can include a combination of pasture lands, woodlands, wetlands, oases, riparian zones, and other resource areas and habitat types. The diversity of resources that are implied in a typical rangeland system, as well as the disagreement over definition, creates an additional challenge to monitoring rangeland health.

Elements of effective rangeland health assessment

The following elements have proven to be required for effective assessment of rangeland health. These elements do not necessarily take place in the order listed.



Define the purpose, scale and scope of the assessment

Although scale and purpose may be determined in advance, for example during project development, there are important questions and uncertainties to clarify before launching a rangeland assessment. The purpose of the assessment should be clearly established, since the needs of different users are likely to be different. Restoration planning is often the responsibility of a public institution and the scale may be determined by institutional boundaries, while the indicators may be determined by the relative infrequency of monitoring. Restoration action is sometimes carried out by pastoralists and therefore the scale is influenced by their management system – often extending beyond administrative boundaries – while they may use a wide range of indicators to track short term changes in rangeland condition. While restoration action may require support to build the capacities of pastoral communities to assess rangeland health, restoration planning may require different actions to institutionalise assessment and monitoring, and to ensure indicator sets and methodologies are affordable, scalable and replicable.

A common problem with rangeland health assessment has been encountered at the preliminary stage of agreeing the goal of the assessment. Different actors require different information to support decision making and there is a tendency to address multiple assessment goals simultaneously, leading to collection of more information than may be required or manageable. This can overwhelm the assessors with information that is beyond their capacity to analyse and interpret. Heavy methodologies that incorporate large numbers of indicators may sometimes be useful for projects that are designed to deliver many results, but they are at risk of remaining within a project and not being institutionalised for long term use. In the PRAGA methodology (referenced at the end of this document) IUCN recommends focusing on the minimum number of indicators to strike a balance between cost-effectiveness (and capacity-effectiveness) and adequacy: indicators that are robust but feasible.

Figure 4. Participatory rangelands and grassland assessment in Egypt

Identify the landscape for assessment and the relevant stakeholders in that landscape

In many cases, the landscape for assessment has been determined before the assessment has been conceived. Nevertheless, it is important to verify the landscape and define the boundaries, for the sake of data analysis and also to ensure a thorough identification of stakeholders. Some groups may have a vested interested in disenfranchising other stakeholders and the stakeholder analysis should be through and independent. Although pastoralists are often marginalised within their country, other ethnic groups may be marginalised within a pastoral territory. Stakeholder analysis should examine gender roles and responsibilities in different rangeland communities and should ensure that the rangeland assessment is gender responsive.

Stakeholder analysis should examine public institutions and private business interests within the landscape. Rangelands frequently fall between multiple public sectors and decision making has implications for ministries of livestock, forests, wildlife, water and others. Meanwhile the assessment should be informed of the expectations of different business interests, including private landowners, mining concessions, conservation organisations and others.

Gather relevant background information

Background information, from secondary data sources and local informants, can be compiled to characterise the target landscape and to gather available environmental and socio-economic data. Background information is useful for identifying potential challenges of access to the field and consent to conduct assessment. Some physical constraints to access – such as the lack of roads or seasonal accessibility – can be addressed through careful planning, while barriers created by insecurity need to be taken seriously. Rangeland assessments can be undermined by access constraints, since access will determine how areas in a landscape are used and therefore what condition they are in.

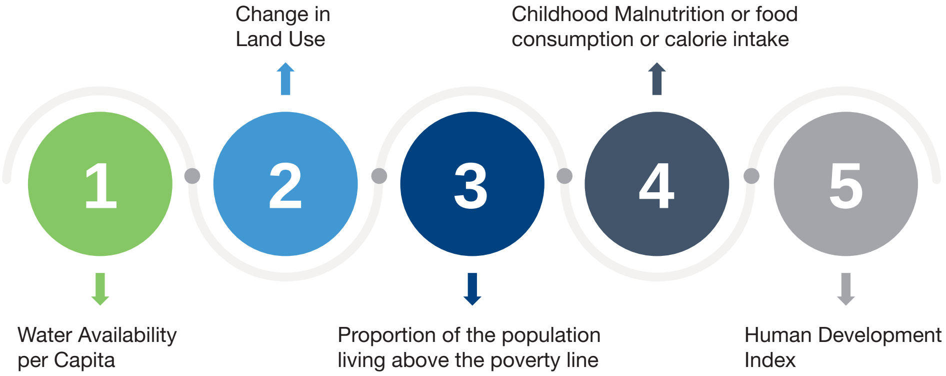
Figure 5. Participatory rangelands and grassland assessment in Egypt

A thorough understanding of local ownership and rights, including seasonal rights, should inform site selection. Bias at this stage of selection can be construed as recognising the rights of one claimant over another and it is important to avoid aggravating conflict. In some cases, Free, Prior, and Informed Consent (FPIC) may need to be sought before engaging in participatory assessment.

The following elements have been recommended by ICARDA and IUCN in the Rangeland Restoration Toolkit

- Coordinates of the target site (using GPS), plot locations, transect starting points, elevation above mean sea level may also be identified
- Vegetation communities distinguished by the dominant species
- Soil type (rangeland soils can be extremely diverse)
- Geomorphology (plains, hills, mountains, rivers, water pans, wadis etc.) Slope and tendency (e.g. north or south facing)
- Climate data and climate change projections
- Tenure systems (private, communal, public, protected, etc.) and current primary and secondary uses of different resource areas
- Grazing patterns (e.g. stable grazing systems, seasonal, transhumant grazing, etc.)
- Number of the main types of livestock (sheep, goats, camels or a mixed herd)
- Distribution of water points

Socio-economic data may be required to help interpret the rangeland health assessment and to interpret drivers, pressures, state, impact and responses to land degradation. In some cases, rangeland health assessment will be aligned with other national assessment and reporting mechanisms. For example, some countries have applied the 5 UNCCD Impact Indicators as the minimum-standard for cross-comparability between sites. These indicators have the added value of strengthening reporting on UNCCD commitments while being an established indicator set, and therefore a low cost option for ongoing impact monitoring.



Depending on the purpose of assessment, and the rangeland management system, economic data may also be gathered, including data on income and assets, and livestock production and health data. However, relating this to rangeland health assessments in most communal settings has proven to be challenging and not particularly informative.

Participatory indicator development

There are a number of stages of rangeland assessment where participation with stakeholder is required, although participation may not be required at all stages and may impose an unnecessary burden on rangeland users. Participation is particularly recommended at the following stages in rangeland health assessment:

1. Identifying and mapping the target landscape and determining management objectives and uses of different landscape patches

2. Identifying indicators according to both local and scientific knowledge according to the agreed management objectives

3. Interpretation and validation of the assessment results.

Although data collection in the field usually requires the participation of some key community representatives, both to provide local knowledge and to ensure security, participation of a meaningful number of community members in data collection is usually not feasible and can be an unwanted burden. Participatory approaches to indicator selection are not discussed in detail here, but can be reviewed in the PRAGA manual.

Participatory indicator selection is usually combined with selection of pre-determined indicators, particularly when rangeland assessment needs to be carried out for comparison between landscapes (e.g. as part of a national methodology and monitoring system). While local indicators and scientific indicators often converge, they can also show differences in perceptions and understanding, and analysing how indicators diverge can be informative.

Figure 6. A landscape view taken at one of HERD project Locations in Surra protected area

Typical scientific indicators can include the following:

- Changes to total vegetation cover (species density), bare ground, stony surface and rocky outcrops
- Change in the balance of herbaceous and woody vegetation
- Change in total vegetation diversity
- Presence of palatable species and other economically important species
- Presence of invasive plants and undesirable species
- Change in wild animals, birds, insects and other native species
- Changes to topsoil (loosening, crusting, erosion)
- Loss of soil nutrients, including soil organic carbon
- Changes in seed stocks in the soil.

Data collection and preliminary analysis

Data collection often begins during a participatory workshop, where rangeland stakeholders are asked to map their landscape in its current state, and map their vision of the landscape after a period of improvement. Rangeland maps should be developed at the appropriate scale, determined by the landscape that is established under the first element above. These maps can be drawn overlaid on a printed digital map, allowing features, plots, transects etc. to be digitised for future analysis.

Remote sensing data is often introduced after this mapping exercise, to cross-examine trends observed using satellite data and trends observed through local knowledge and experience. Remotely sensed maps are not usually introduced earlier as this can lead to confirmation bias from some stakeholders.

Site sampling is often best performed during these mapping workshops, and is often selected based on a locally-derived landscape classification. For example, local communities may differentiate different aridity zones, different seasonal grazing areas, or altitude zones. Sampling sites can be pre-selected in each of these zones to ensure adequate coverage.

The data collection team is often assembled to include representatives from key stakeholder groups and institutions, including community members. The numbers are typically limited by access to vehicles and other practical considerations. It is usually desirable to include a balance of local knowledge and technical (scientific) expertise as well.

Data is usually collected on data sheets, and increasingly makes use of mobile phone apps that allow geolocation and photographs in each sample site. This accelerates the data management and analysis as well as the consistency of responses between different groups that may be sampling different sites and locations.

Figure 7. Data collection and preliminary analysis with local community members and experts

Interpretation and validation of results

Most IUCN rangeland assessment use the DPSIR framework for analysis: drivers, pressures, state, impact and response. Underlying drivers of rangeland degradation – such as population growth and economic development – need to be understood to guide long term rangeland development planning. More attention is needed to reach agreement on the pressures that driver rangeland degradation, such as inappropriate crop and livestock production, of poor location of water resources, which can be contentious. The assessment can be used to develop consensus as far as possible, or to identify areas of disagreement that can be addressed through follow-on activities.

Results of rangeland assessment should also be interpreted through the prism of climate change, projecting likely trends and responses to climate change scenarios. This includes projected changes in water availability and severity of weather events. Climate analysis can also draw on secondary background information collected earlier in the assessment, including data and key informant perceptions of observable climate changes

Validation of the results of rangeland assessment is the third of the recommended stages where a participatory approach is recommended. It is important to feedback to stakeholders on the assessment findings, the implications for rangeland management, and recommended responses. Ideally this validation exercise is a step between assessment and action, enabling stakeholders to take ownership of the response measures. The validation exercise is also a critical opportunity to examine practical solutions for addressing rangeland degradation and develop support for collective action where necessary, for example through the development of community rangeland management plans.

FURTHER READING

Allen V.G., Batello, C., Berretta, E.J., Hodgson, J., Kothmann, M., Li, X., McIvor, J., Milne, J., Morris, C., Peeters A. and Sanderson, M. 2011. An international terminology for grazing lands and grazing animals. Grass and Forage Science. 66(1): 2-28. https://doi.org/10.1111/j.1365-2494.2010.00780.x

Faber-Langendoen, D., Keeler-Wolf, T., Meidinger, D., Josse, C.; Weakley, A., Tart, D.; Navarro, G., Hoagland, B., Ponomarenko, S., Saucier, J.P., Fults, G. and Helmer, E. 2012. Classification and description of world formation types. Part II (Description of formation types). Hierarchy Revisions Working Group, Federal Geographic Data Committee, FGDC Secretariat, U.S. Geological Survey and NatureServe, Reston, VA and Arlington, VA.

ILRI, IUCN, FAO, WWF, UNEP and ILC. 2021. Rangelands Atlas. Nairobi Kenya: ILRI

PRAGA: https://www.iucn.org/theme/ecosystem-management/our-work/global-drylands-initiative/gdi-projects/participatory-assessment-land-degradation-and-sustainable-land-management-grassland-and-pastoral-systems-praga/a-methodology

STEPS NEEDED FOR THE CHARACTERIZATION OF THE TARGET SITE

gef
UN environment programme
ICARDA
Science for resilient livelihoods in dry areas
CGIAR RESEARCH PROGRAM ON Livestock
CGIAR Livestock, Climate and System Resilience

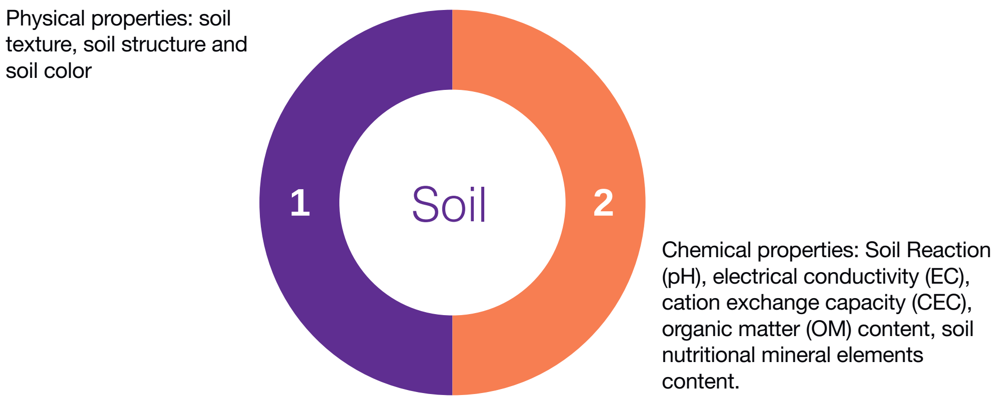
SHORT INTRODUCTION

Before deciding on the type of SRM practice(s) a thorough diagnostic is conducted for each selected site:

Administrative (localization)

- Site name, county, state, country
- Site coordinates and elevation
- Demographic data
- Human population, income, education, employment, and poverty statistics (census reports etc.)
- Identify key stakeholders.

BIOPHYSICAL



Vegetation

- Vegetation structure, vegetation cover, vegetation types and dominant plant communities and species.

Livestock

- Livestock type, livestock population, livestock breeds, average flock size, herd management practices, transhumance practices if any
- Indicate if the site is subjected to be grazed by flocks from outside the area
- Feed resources and feed calendar.

Water resources

- The spatial distribution, quantity and quality of natural and man-made ground and surface water sources, uses (domestic, livestock, irrigation, other) and changes in demand (surface and groundwater extraction e.g. irrigated area, number of extraction points (dams, boreholes, wells pump capacity etc.).

Climatic and meteorological records

- Average Long-term monthly rainfall data (last 25-30 years records)
- Last two years monthly rainfall data
- Long term average annual rainfall
- Long-term monthly temperature max and temperature min, precipitation and degree days
- Hottest month and coldest month
- Evaporation
- Soil temperature and moisture
- Solar radiation
- Storm reports
- Wind speed and direction.

PAST DISTURBANCES

- Seasonality and trends (flood frequency and severity, storms, strong winds and dust storm events (20 or ideally 30 years)
- Changes in intensity of management in croplands, grazing lands and forests/ woodlands, where possible, in relation to demographic changes and market forces, also their implications on land resources and livelihoods (e.g., human population density, livestock numbers / stocking density by type; cropping system, inputs use, crop, livestock and forestry productivity; land fragmentation, diversity of products for consumption and sale, access to markets etc.).

MAPS AND IMAGES

- Current and historical Maps, aerial photos, satellite images and photos.

POLICIES AND INSTITUTIONAL ARRANGEMENTS

- Land tenure arrangements and access rights, land availability / shortage, land policy, legislation and other relevant institutional issues (e.g., land use plans)
- Water allocations, access and costs, institutional rules and arrangements, water policy, legislation and other relevant institutional issues (e.g., water management plans)
- Energy sources, availability / shortages, access and costs, policies, legislation and other institutional issues including bioenergy
- Land and land use types
- Farming system information (including agricultural census /crop yield data)
- Economy and livelihood
- Institutions, policies, regulations, by–laws.

OTHER INFORMATION

- Relevant projects and NGOs located in the area

Site Characterization Questionnaire			
General information on site:			
Country:	Governorate:	County:	Site name:
Area (ha):	GPS Coordinates:	Elevation (m):	Rangeland type:

List of categories for data collection and review in the baseline survey:	
Categories	Content
***Institutions	• Type of institution (NGOs, CBOs, GDA…) • Government institutions • Effectiveness (services) • Presence of conflicts (within and outside)
**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
***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

**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.
***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
**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)
**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…)
**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.
**Land use types	• ***Size of land use types in the local assessment area and community territory; farmland 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)

**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
***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).
**Wildlife	• *Wildlife species (Birds, mammals) • **Population density • *Endangered species • *Soil biodiversity
***Land tenure	Information on land-holdings: ownership, size and distribution Type and prevalence of renting/lease-hold arrangements Legal status of holdings (civil, cooperative, government arrangements, titles) etc.
***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.
***Basic services, infrastructure and investments	• **Road and market access; input supply • *Schools; health centers • ***Water points (wells, boreholes, piped / tap water) • *Irrigation systems; reservoirs • **Extension services
Planning reports and Rangeland improvement and development activities * must have	• **Land use planning; water resources planning; agriculture and forest management plans; livestock / environmental management; etc. • **Water harvesting (micro- and macro-catch ments) • **Revegetation (direct seeding, seedlings) • **Managed grazing • *Training and extension

CASE STUDY OF SOUTHERN TUNISIA: (TATAOUINE)

BACKGROUND

Tunisia is blessed with large areas of native rangelands richly populated with excellent forage species allowing pastoralists to enjoy the benefits of extensive livestock production systems. Even where natural rangelands cannot provide sufficient livestock fodder requirements, they remain the only recourse available to herders and pastoralist, if only for a short time of each year.

However, over time, extensive areas have become degraded and now require urgent interventions to control or reduce grazing pressure to avoid further decline. There are many practices offering good results. Some are slow or ineffective because they fail to consider the root causes of degradation whether they are related to social conflicts or biophysical in nature such as previous disturbances. Whatever the cause, effective management is the key to sustainability and successful livestock production.

The most important aspect of rangeland management is to use the appropriate methods of restoration consistent with the status of a particular area and the goals and priorities of the restoration project. Well-known ecological sites, rangeland health, and monitoring data reflect responses of fundamental ecosystem processes and allow managers to select the most appropriate combination of practices and to adapt them to specific local conditions.

Figure 1. Goat resting on a near water point in southern Tunisia

For sustainable rangeland restoration, several steps should be considered including a clear description of the target site (Figure 1). Site characterization is an important technical element of adaptive rangeland management practice. The other technical elements are i) assessment, ii) monitoring and iii) making proper and timely decisions.

Site characterization includes compiling data to develop an understanding of the properties and characteristics of the location and the projects that could be implemented. The design of each target site is based on a characterization that includes:

Lessons learned from collected information and recommended best practices for a planned project should be reviewed to avoid known pitfalls. For example, what should be included in a detailed characterization of a degraded rangeland site? How successful have past initiatives been? with an assessment of the consequences of various actions. Once the site characterization is completed, objectives, goals, and performance measures can be developed and agreed upon among all concerned stakeholders.

This case study illustrates a site characterization and the effective use of practices aligned with Tunisian arid rangelands (Figures 2 and 3).

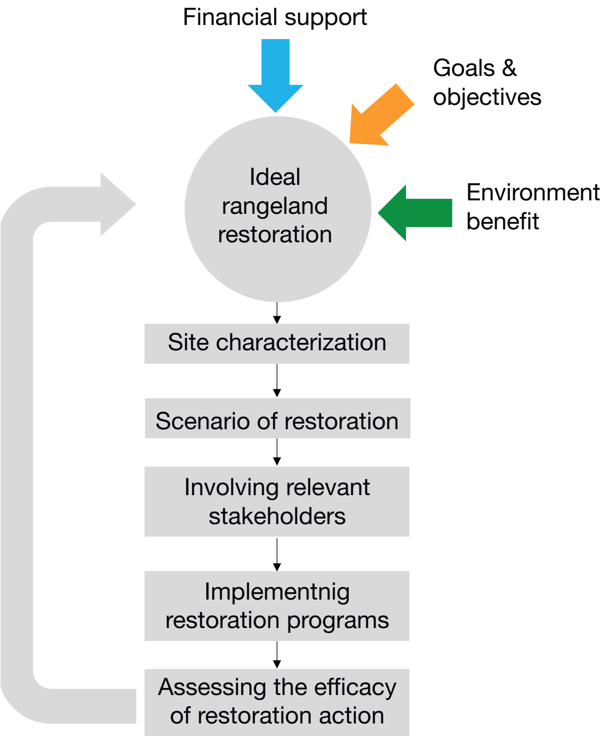


Figure 2. Components of effective rangeland restoration

Figure 3. Map of Tunisia showing the target site

A. SITE CHARACTERIZATION IN CHENENNI TATAOUINE, SOUTHERN TUNISIA

Collecting baseline information is the first step once the restoration project is approved. Detailed site characterization should be conducted by the project team and includes what is locally known about the site. Baseline data collection should cover some or all the topic listed below as appropriate.
Collecting baseline data in the field is expensive and time consuming. Some or even much of the required data may already be available in government ministries and departments, UN agencies operating in the region, local NGOs, and graduate student dissertations. A great deal of time and money can be spent duplicating the work of others, time and money better spent on implementation and action on the ground.

Institutions					
Type of institution	NGOs, CBOs, GDA, LMC				
Government institutions	Yes				
Effectiveness (services)					5
Presence of conflicts (within and outside)				4	

Maps, satellite images and photos	
**Maps: administrative boundaries, soil, terrain, land use, vegetation, watersheds, agro-ecological zones, roads etc.	Available
**Aerial photographs	NA
*Time series satellite images (SPOT-NDVI)	NA
*Water resources	Available

Climatic (including natural disasters) and meteorological records			
Rainfall amounts and variability, temperature, humidity	Rainfall: 100–120 mm/year (from Sept to May)	Temperature: ≥ 45 °C (summer), ≤ 5 °C (winter)	Humidity: 1,500 mm/year

**Trends in rainfall and temperature over recent decades	Rainfall Variable (between years)/ decreasing	Temperature Increasing
*Incidence and impacts of drought and flooding etc.	Very weak vegetation cover, soil erosion	
*Information and studies on the impacts of climate change including likely future impacts on rangeland vegetation	Source: 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.	

Water resources	
**Water resource records over the last decade Sources: water boards and authorities to show: • water flow regimes in rivers • water storage capacity and water levels of lakes, dams and reservoirs • sedimentation load and rates	- Water Association of Common Interest (AIC) in Chenenni. - SONEDE, CRDA
*Incidence of water borne diseases and pollutants Sources: health sector and water authorities	

Vegetation		
Type of disturbance (past and present)	Past: Arboriculture, cereals, grazing, uprooting, fire cooking, traditional practices and uses, wind and water erosion	Present: Arboriculture, cereals, grazing, wind and water erosion
Vegetation structure (past and present)	Past: Steppe of *Stipa tenacissima* and perennial shrubs	Present: contrasted, degraded *Stipa tenacissima,* scat-tered shrubs, bare ground and stones
Dominant plant communities	Disturbed and scattered *Stipa tenacissima, Artemisia herba-alba, Haloxylon schmittianum, Anthyllis henoniana, Gymnocarpos decander, Rhanterium suaveolens, Stipagrostis pungens* and *Retama raetam.*	
Key plant species (forage, erosion control, wildlife, herbal, and medicinal)	*Stipa tenacissima, Rhanterium suaveolens, Artemisia herba-alba, Anthyllis henoniana, Gymnocarpos decander, Rosmarinus officinalis, Thymbra capitata, Thymus algeriensis, Capparis spinosa* and *Moricandia suffruticosa*	
Percent cover	Perennial plant cover: 10–30%, can reach 30-40% during rainy season	
Biomass production	3,000 and 5,000 kg DM/ha to 6,000 and 9,000 kg DM/ha during rainy season	

Diversity (richness, floristic composition)	10 to 50 species during rainy season
Soil seed bank and the ability for regeneration	Poor
Endangered species	*Stipa tenacissima, Rosmarinus officinalis, Thymbra capitata, Thymus algeriensis, Capparis spinosa* and *Moricandia suffruticosa*
Life form	Chamaephytes, hemicryptophytes, nano-phanerophytes, geophytes and therophytes
Palatability index	From 0 to 5

Soil	
Soil Observations	
Soil cover (protection)	Degraded soil
Soil color and soil life (SOM content)	Low organic matter content
Soil texture (erodibility)	Sandy, skeletal, silty, gypsum, calcareous, sand dunes
Soil structure (permeability, root penetrability and stability)	Crust, rockets, and mostly wind veils and nebka
Soil depth (plant rooting depth and nutrient and water availability)	Shallow to deep (sandy) soils
Soil Measurements	
pH (acidity and alkalinity)	pH is greater than 7
Slaking and dispersion (stability)	Loose soil with low moisture content
Soil labile carbon content (often backed up by lab. analysis of total organic C)	1–2 kg OC m^{-2}
Salinity and sodicity	Generally sandy soils tend to be less saline. High salinity in Sabkha and gypsum soil
Nutrient content (N, P, K and micronutrients) (optional lab tests)	

Edaphic factors (site, soil)	
Slope gradient and slope aspect (direction)	• Steep irregular slopes eroded into ravines. • It can be an asset in the developing land located downstream which thus benefits from additional water supplies • The total absence of slopes (endorheic areas, sometimes flooded)
Elevation above sea level	Between 200 and 500 m
Topography features	Mountain and plain

Location of site within the watershed	Numerous mountainous watersheds
Soil properties (texture, structure, depth, organic matter content, salinity, basic infiltration rate, runoff coefficient)	• Sandy, skeletal, gypsum, silty, sand dunes • Shallow to deep (sandy) soils • Low organic matter • Low infiltration, high evaporation • Runoff on steep slopes is greater
State of soil surface (crust, feces, litters, rock, gravel, etc.)	• Crusted soil surface and litter accumulation in protected areas • Gravel and rock in mountains and hills • Feces of sheep, goats and camels, and wind veils in heavily grazed areas
Type and indicators of soil erosion (wind, water, presence of rills and gullies)	• Wind erosion: sand accumulation and rocky outcrop • Water erosion: presence of rills, gullies rocky outcrop
Ground cover (vegetation, rocks, gravels, crusts, rock outcrop, litter…)	• Sparse cover of vegetation in plains • Vegetation cover is relatively dense in catchments and depressions • Disruption of vegetation cover exposing bare ground of hills and highlands

Human population (socioeconomic data)	
Total population and recent trends: age, gender and ethnic minority distribution	Around 400 people The indigenous peoples are known as Berbers
Household and family composition information	150 families
Employment by sector; labor force, migration information, settlement patterns	The primary agricultural activities in the region are animal production, cereal crops and cultivation of olives, migration (inside and outside country), tourism
Poverty and food security	Low poverty with stable food security
Household income information; composition of income (i.e. contribution from farming and other activities)	14% of household heads active outside the region 90% of other household members of households active outside the region (70% in Tunis and 20% in France) Agricultural income contributes to the formation of overall family income with 28% The primary agricultural activities in the region are animal production, cereal crops and cultivation of olives
Proportion of population below poverty line % of food insecure, malnutrition	Low poverty, no malnutrition
*Credit availability	Money available mainly from those outside the region

Land-use types	
Size of land-use types in the local assessment area and community territory Farmland and protected areas	Tataouine: 1.5 million ha are rangeland 170,000 ha private land 530,000 ha communal 800,000 ha Dhahar rangeland

Areas and proportions under different land-use types (including forest and protected areas).	Agricultural land: 200,000 ha Rangeland: 1.5 million ha Protected areas in Tataouine: 8,250 ha
Land cover and land resources surveys	Agropastoral Development and LocalInitiatives Promotion Programme for theSouth-East project (PRODESUD)
Type of ownership (private, communal, state)	Private, communal
Traditional users	Pastoralists, Agro-pastoralists
Governance (mechanism, regulation)	CG, NGO

Farming system information	
• Existing agricultural plans, programs and projects • Crop and livestock and forestry systems information	PRODESUD project, National program (OEP, CRDA, DGF)
Presence and extent of local and introduced practices for land management and land degradation control	Resting rangeland (over 80.000 ha)
Information on livestock numbers, distribution, ownership, actual and recommended stocking densities, management	In Tataouine: Sheep 315,000, goats 80,000, camels 12,300

Pastoral animal production	
Flock size per household	In Chenenni, the average herd comprises of about 25 head There are big herds and Khlata ('mix' in Arabic) with payed shepherds
Type of dominant livestock	Small ruminants (sheep and goats) and camels
Feed calendar (grazing and non-grazing feed resources)	Dry season: complementation (barley grain and wheat bran + agricultural by-products) Rainy season: rangeland basis with limited supplementation (concentrate, barley)
Livestock watering resources	Watering points Rainwater tanks, cisterns
Subsidies (feedstuffs, veterinary services, watering)	Veterinary services
Grazing practices (spatial and temporal mobility of flocks)	Continuous grazing and transhumant
Role of women in the livestock production	Very active participation, mostly for small herds and agricultural practices
Availability and adequacy of livestock supporting services (veterinary, marketing, shearing)	Depending on to access to rangeland

Wildlife	
Wildlife species	Depending on rangeland health: rabbits gazelles, wolves, vulpes, foxes, reptiles, rodents, Outarde (a type of bustard), birds
Population density	Very low
Endangered species	Gazelles, rabbits, vulpes, foxes, Outarde houbara
Soil biodiversity	Low

Land tenure	
Information on land-holdings: • Ownership, size and distribution type • Prevalence of renting or leasehold arrangements • Legal status of holdings (civil, cooperative, government arrangements, titles)	• Communal rangelands exclusively for grazing • Private rangeland used for agriculture and grazing

Institutions, policies, regulations, byelaws	
Relating to land, agriculture, livestock, water resources, environment, rural development, technical sectors, extension	NGOs, CBOs, GDA, LMC
Relating to implementation of multilateral environmental conventions (UNCCD, UNCBD, UNFCCC, Ramsar, etc.)	Ramsar, IUCN
Access to services (official/informal), private-public sector), application. effectiveness of regulations, policies, mandates, capacities of actors	Available
Presence, roles and activity of NGOs, community-based organizations in their implementation	Available

Basic services, infrastructure and investments	
**Road and market access, input supply	Available
*Schools, health centers	Available
***Water points (wells, boreholes, piped tap water)	Available
*Irrigation systems; reservoirs	Not enough
**Extension services	Not enough

Planning reports and rangeland improvement and development activities	
**Land-use planning, water resources planning, agriculture and forest management plans, livestock and environmental management	PRODESUD project and Atlas of Tataouine
**Water harvesting (micro- and macro-catch-ments)	Traditional water harvesting techniques: jessour, tabia or ketra
Revegetation (direct seeding, seedlings)	Unsuccessful
**Managed grazing	Rest-rotation grazing
*Training and extension	Training was provided in rangeland assessment and forage plant identification

B. ADAPTIVE MANAGEMENT AND RESTORATION PRACTICES IN DEGRADED ARID AND SEMI-ARID RANGELANDS

Thresholds for control

Arid rangelands in Tunisia are known for their variety, with ecosystems such as steppes, mountains, hills, wadis and various types of soil. In their current state, arid rangelands may not meet pastoralist needs for managing livestock production, wildlife, or ecosystem health and the effects of grazing pressure vary depending on different systems (Figure 4). Some are able to maintain their functions despite continuous grazing, fluctuations in climate, and successive droughts (Figure 5).

Figure 4. Example of moderate to good rangeland condition

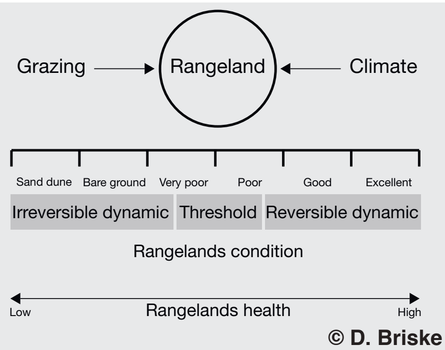


Figure 5. Examples of state and transition models of rangeland dynamics

Sometimes, rangelands are turned into unproductive bare ground and desert after the decline in plant cover (Figures 6 & 7). Grazing exclusion is the first required practice to prevent further degradation and retain minimum rangeland functions. In whatever state of rangeland degradation it may be, grazing exclusion, even temporary, is similar to first aid.

Figure 6. Desert encroachment in the arid rangelands of Tunisia

Figure 7. Increasing bare ground indicates very poor rangelands health

Rangelands below the threshold of irreversibility

Where the process of rangeland degradation has not yet reached the threshold of irreversibility, natural restoration by resting through grazing exclusion is possible. The restoration speed and success are usually a function of climate conditions and soil and vegetation types. Whenever climate conditions are favorable, rangelands can regenerate after a short resting period. Soil type plays a key role in regeneration. For example, sandy soils are more responsive to resting than limestone soils. When the rest period is long (3 to 5 years) and interspersed with a rainy year, short-term heavy grazing intensity is recommended (Figures 8 & 9).

Figure 8. Restored rangeland through short-term grazing exclusion

Figure 9. Healthy rangeland subjected to short-duration grazing

Rangelands above the threshold of irreversibility

Sometimes, rangeland degradation leads to crossing the threshold from productive ecosystems dominated by perennial species to bare ground with scattered unpalatable species that is difficult or impossible to reverse (Figures 6 & 7). Once this transition has occurred, a return to its original state will be difficult if not impossible without significant human intervention. There are many pathways to rangeland rehabilitation, each appropriate for a specific type of soil and success will vary from site to site.

When the soil is sandy or depressions

Direct seeding with superficial soil surface scarification can play an important role in arid rangeland rehabilitation in sandy soils and depressions. Native plants can be reintroduced through direct seeding, transplanting seedlings, or both (Figure 10). This management technique is recommended during the rainy season to guarantee seed emergence and plant growth.

Figure 10. Soil surface scarification, direct seeding and planting on sandy soils and landscape depressions

When the soil is crusted, stony and with slopes

When the ground is sloped, crusted and stony, all the variables that cause stormwater runoff can be mitigated with proven practices for conserving water and improving landscape management. Some of these practices double as effective landscape features. For example, micro-catchment water harvesting and dams are the common forms of water harvesting and erosion control for sloping land and give a pleasing order and symmetry to the landscape (Figure 11).

On milder slopes, semicircular bunds and Vallerani water harvesting structures can be built to slow the flow of runoff giving it time to infiltrate. These also form visually pleasing lines in the landscape and double as suitable beds for plants.

A micro-catchment water harvesting system is simply a ditch constructed along the contour of a slope. When water flows, the micro-catchment berm prevents it from continuing downhill. The water will then percolate into the ground, and any sediment that it may contain will be deposited in the base of the berm. Sometimes, seeding or transplanting forage shrubs in micro-catchment berms is recommended as a method of improving degraded rangelands.

Figure 11. Water harvesting techniques play a major role in restoring degraded watersheds

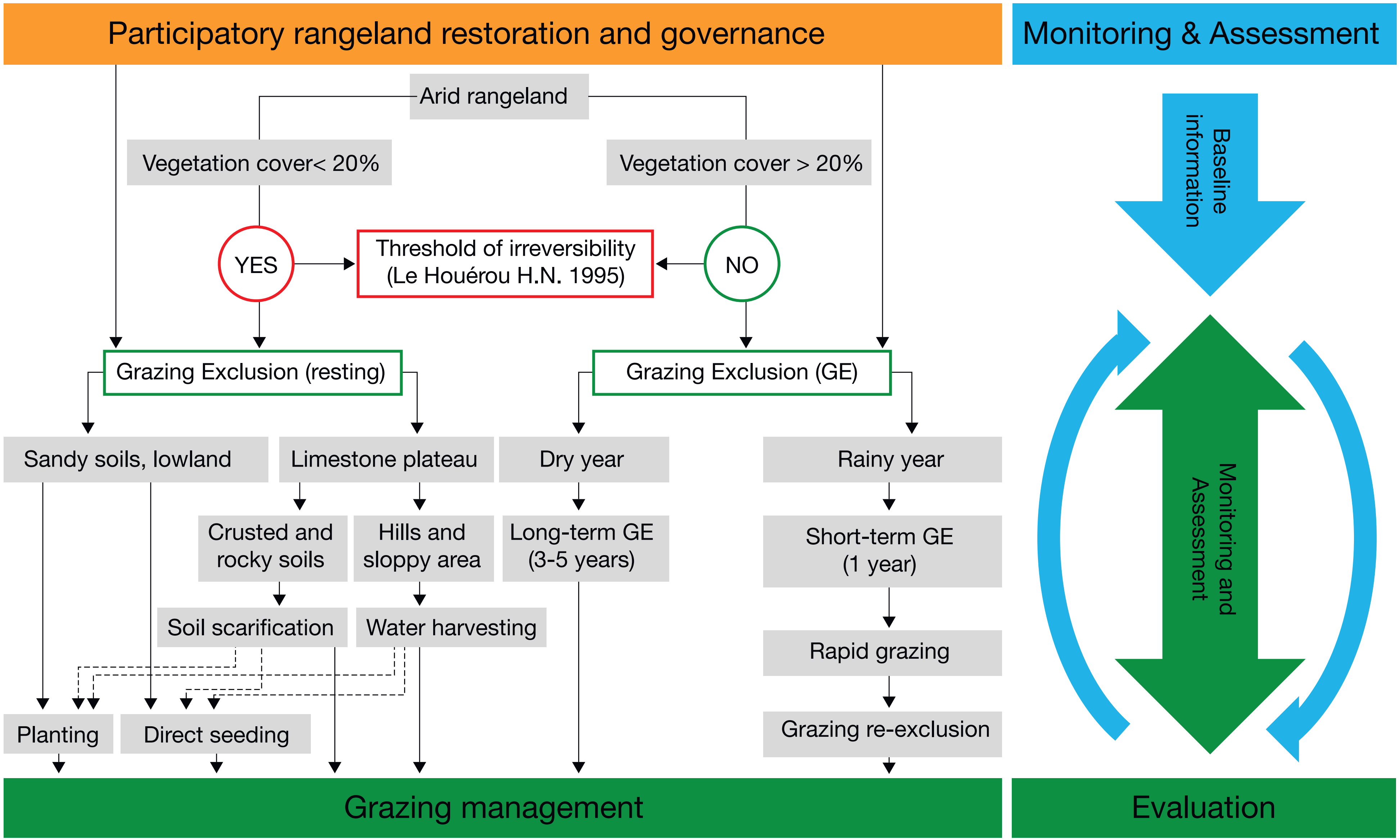


Figure 12. Reversible and irreversible rangeland dynamics and recommended management applications

FURTHER READING

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.

Gamoun, M., Tarhouni M., Ouled Belgacem A., Hanchi B. and Neffati M. 2011. Response of different arid rangelands to protection and drought. Arid Land Research and Management. 25: 372-378.

Le Houérou, H.N. 1995. The Sahara from the bioclimatic point of view–definition and limits. Annals of Arid Zone. 34: 1-16.

Louhaichi, M., Clifton, K. and Hassan, S. 2014. Direct seeding of Salsola vermiculata for rehabilitation of degraded arid and semi-arid rangelands. Range Management and Agroforestry. 35(2): 182-187.

Westoby M., Walker B. and Noy-Meir, I. 1989. Opportunistic management for rangelands not at equilibrium. Journal of Range Management. 42: 266-274.

CASE STUDY OF KARNABCHUL IN SOUTHWESTERN UZBEKISTAN

INTRODUCTION

he Karnabchul semi-desert in southwest Uzbekistan represents a typical Artemisia-dominated rangeland covering about 5,000 km^2. The elevation ranges between 280–500 m a.s.l. The climate is characterized by extreme daily and seasonal temperatures and high inter- and intra-annual precipitation variability. Mean annual precipitation is close to 200 mm and occurs during autumn, winter, and spring with almost no precipitation during the summer months. Winters are cold with an extreme minima of minus 16.8 °C with 74 days of frost and 10 days of snow cover. Summers are dry and hot with an extreme maxima of plus 47.7 °C in July.

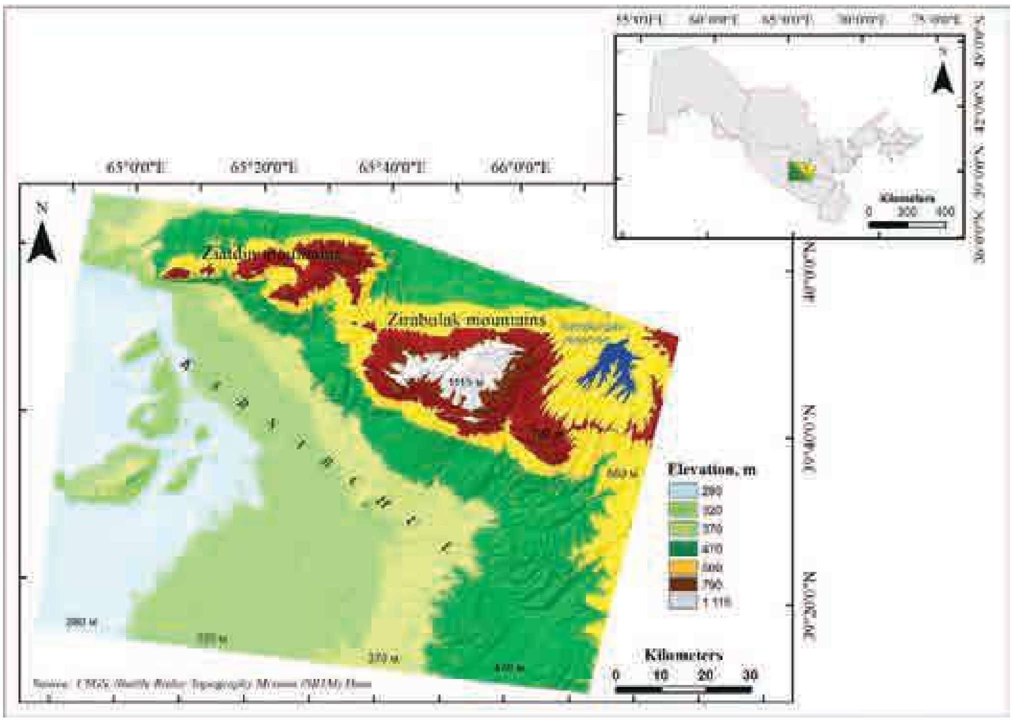
Historically, the Artemisia rangelands in Karnabchul were the primary grazing lands providing reliable feed resources for the sheep, goats, and cattle of the local population for centuries. The most critical factor affecting Artemisia rangelands is the high and mismanaged sheep and goat stocking rate, which is causing rampant desertification. The number of small ruminants has increased during the past 20–25 years. Due to the extensive development of livestock husbandry and human pressure, these valuable ecosystems are facing an increasing and detrimental anthropogenic stress. As a consequence, more 50% of Artemisia rangelands in Karnabchul have been significantly degraded through overgrazing and fuel wood harvesting. The vegetatoin is being replaced with weedy, poisonous plants such as *Peganum harmala* and unpalatable *Iris songarica.*

Figure 1. Pasture shelterbelts in Central Asia

Ecological monitoring and assessment of the current condition and historic degradation trends of Artemisia ecosystems is a major concern in Karnabchul to prevent further degradation and to undertake conservation and restoration measures. Thus, a site characterization of Karnabchul rangeland is the key to understanding the causes of degradation and developing appropriate conservation and restoration measures.

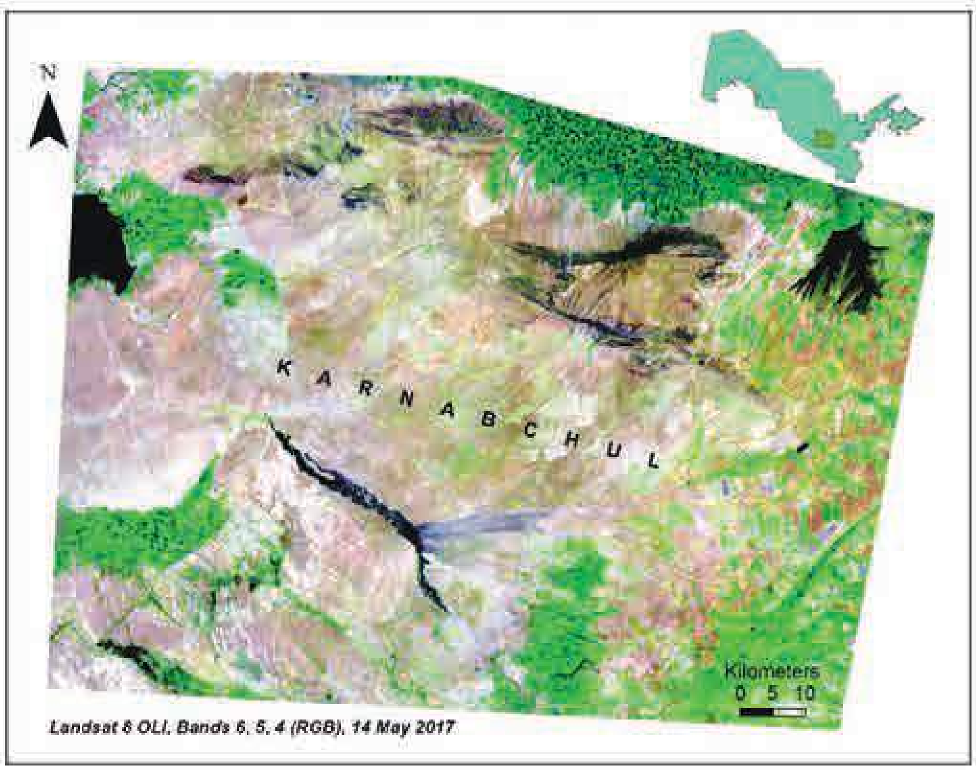
A. SITE CHARACTERIZATION IN KARNABCHUL IN SOUTHWESTERN UZBEKISTAN

Baseline information about the site is crucial for understanding the current situation and taking appropriate steps for restoration. The basic biophysical and socioeconomic data are displayed in Figures 2 to 6 and 2, and Tables 1–12.



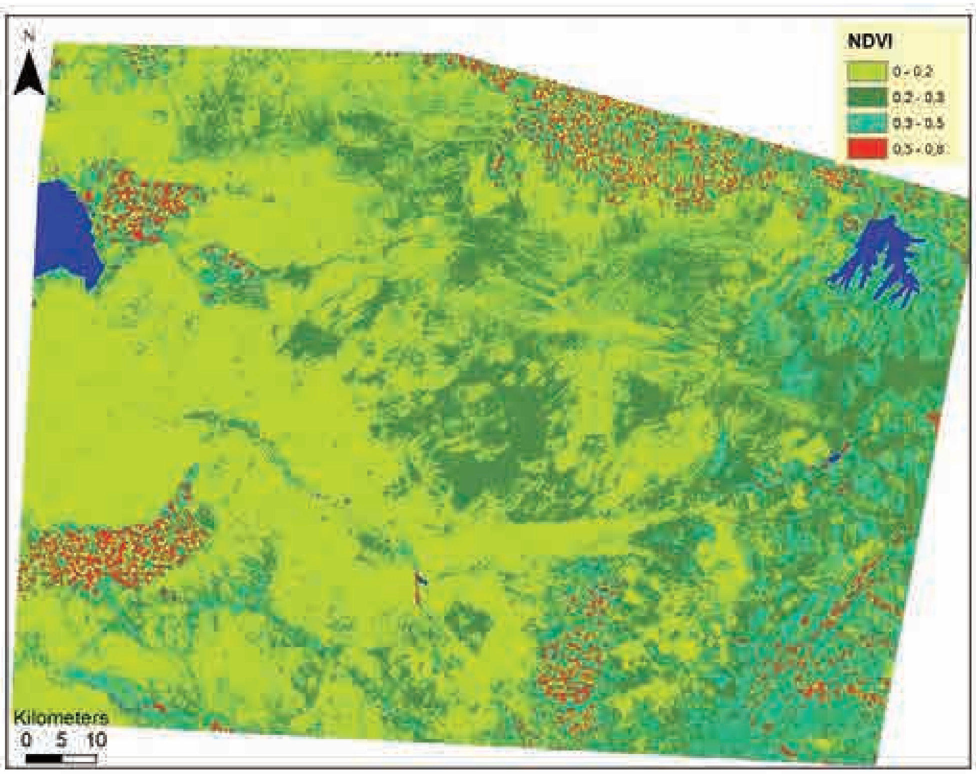
© Toshpulot Rajabov

Figure 2. Digital elevation model of Karnabchul site, Uzbekistan



© Toshpulot Rajabov

Figure 3. Satellite map of Karnabchul site, Uzbekistan



© Toshpulot Rajabov

Figure 4. NDVI map of Karnabchul site, Uzbekistan

Figure 5. General view of the landscape with healthy rangelands, Karnabchul site, Uzbekistan

Figure 6. General view of the landscape with degraded rangelands, Karnabchul site, Uzbekistan

Table 1. Climatic and meteorological records (including natural disasters).

Parameter	Observations		
Rainfall amounts and variability, temperature, humidity	MAP: 174.2 mm	MAT: 16.3 °C	Mean Air Humidity: 48.14 %
**Trends in rainfall and temperature over recent decades		Rainfall: No significant trend, but high annual fluctuations for the last 20–25 years	Temperature: Increase for 13% compared to 1947
*Incidence and impacts of drought and flooding etc.	Due to frequent droughts, degradation of range-land vegetation has been intensifying.		
*Information and studies on the impacts of climate change including likely future impacts on water resources.	The intensity of temperature increase is much higher than the global average (Uzhydromet, 2020)		

Table 2. Water resources

Parameter	Observations
**Water resources record over the last decade to show: • water flow regimes in rivers • water storage capacity and water levels of lakes, dams and reservoirs • sedimentation load and rates Sources: Water boards & authorities.	In rangeland areas, the decline of underground water and increase in salinity is common
*Incidence of water borne diseases and pollutants Sources: Health sector and water authorities.	Not available

Table 3. Vegetation

Parameter	Observations	
Type of disturbance (past and present)	Past: cropland conversion	Present: overgrazing, uprooting
Vegetation structure (past and present)	Past: Rangelands with pure domination *of Artemisia diffusa, A. turanica* and ephemeral-epemeroids	Present: Degraded rangelands with wide expansion of native invaders such as *Peganum harmala, Iris songarica*
Dominant plant communities	**In healthy rangelands:** Vegetation with pure domination of Artemisia species (*Artemisia diffusa, A. turanica*) and desired perennial and annual herbaceous plants such as *Carex pachystylis, Poa bulbosa, Astragalus filicaulis, A. campylorrhynchus, Koelpinia linearis, Alyssum desertorum* and others. **In degraded areas:** Vegetation with pure domination of *Peganum harmala, Iris songarica* with annual and perennial herbaceous species such as *Carex pachystylis, Poa bulbosa, Bromus tectorum, Astragalus filicaulis, Leptaleum filifolium, Hordeum leporinum, Minuartia meyerii, Holosteum umbellatum* and others.	
Key plant species (forage, erosion control, wildlife, herbal, and medicinal)	*Artemisia diffusa* *A. turanica* *A. sogdiana* *Carex pachystylis* *Poa bulbosa* *Astragalus filicaulis* *A. campylorrhynchus* *Koelpinia linearis* *Alyssum desertorum* *Strigosella africana* *S. grandiflora* *Ziziphora tenuior*	
Percent cover	Perennial plant cover: • 5–15% in degraded areas • 25–30% in healthy rangelands	

Biomass production	In healthy rangelands: from 250–350 kg DM/ha to 450–500 kg DM/ha In degraded rangelands: about 250–300 kg DM/ha only in spring season because of ephemeral-ephemeroidal species; in other season biomass is almost absent
Diversity (richness, floristic compositio)	25 to 30 species
Soil seed bank and ability for regeneration	Poor and very limited due to continuous overgrazing.
Endangered species	*Stipa hohenackeriana* *Tulipa turkestanica*
Life forms	Hemicryptophytes Geophytes Therophytes
Palatability index	From 0 to 6

Table 4: Soil

Parameter	Observations
Soil cover (protection)	Grey-brown and light sierozem soils
Soil color and soil life (SOM content)	Low organic matter content (<1.0%)
Soil texture (erodibility)	Loam, sandy, salty, gypsous
Soil structure (permeability, root penetrability and stability)	Soils with light and medium mechanical composition, compacted top soil
Soil depth (plant rooting depth and nutrient and water availability)	Shallow soils, main root system is accumulated at the depths of 0–40 cm
Soil Measurements	
pH (acidity and alkalinity)	pH ranges from 7.1 to 7.8
Slaking and dispersion (stability)	Loose soil with low moisture content
Soil labile carbon content (often backed up by lab. analysis of total organic C)	Not available
Salinity and sodicity	Generally soil salinization is low, soil dry residue 0.37–0.41 High salinity in salty soils.
Nutrient content (N, P, K and micronutrients) (optional lab tests)	**Averages for 0–40 soil horizon** N-NO_3 - 8.33 mg/kg N-NH_4 - 8.87 mg/kg P_2O_5 - 7.83 mg/kg K_2O - 156.06 mg/kg SOM - 0.62% EC - 225.6 цS/cm

Table 7. Land use types.	
Parameter	**Observations**
Areas and proportions under different land use types (including forest and protected areas)	50,000 ha agricultural lands, household plots, roads, infrastructure
Type of ownership (private, communal, state, etc.)	State owned land
Traditional users	Range farmers specialized in Karakul sheep breeding

Table 8. Farming system information.	
Parameter	**Observations**
• Existing agricultural plans, programs and projects • Crop and livestock and forestry systems information	Not available
Presence and extent of local and introduced practices for land management and land degradation control	
Information on livestock numbers, distribution, ownership, actual and recommended stocking densities, management	In Karnabchul region: • Sheep and goats 600,000 • Cattle 40,000

Table 9. Pastoral animal production.	
Parameter	**Observations**
Flock size per household	• In Karnabchul, the mean herd comprises approximately 50–70 head • There are big herds with 400–600 head
Type of dominant livestock	Small ruminants (sheep and goats) and cattle
Feed calendar (grazing and non-grazing feed resources)	Mostly rangeland-based if forage production is adequate in. Supplementary feed is provided during the winter seasons and in drought years during summer and autumn.
Livestock watering resources	• Watering wells • Transported water tanks, cisterns
Subsidies (feedstuffs, veterinary services, watering)	Some small subsidies provided by government to improve breeding activities
Grazing practices (spatial and temporal mobility of flocks)	Continuous and year-round grazing
Role of women in livestock production	Women participate in livestock production
Availability and adequacy of livestock supporting services (veterinary, marketing, shearing)	Limited

Table 10. Wildlife.	
Parameter	**Observations**
Wildlife species	Depending on rangeland health and distance from populated areas: rabbits, gazelles, wolves, foxes, reptiles, rodents, snakes, birds
Population density	Low to medium
Endangered species	Gazelles
Soil biodiversity	Low

Table 11. Land tenure.	
Parameter	**Observations**
Information on land-holdings: • Ownership, size and distribution • Type and prevalence of renting or leasehold arrangements • Legal status of holdings (civil, cooperative, government arrangements, titles, etc.)	Not available
Institutions, policies, regulations, by-laws	
Relating to land, agriculture, livestock, water resources, environment, rural development, technical sectors, extension	NGOs, Limited Liability Companies , agricultural clusters
Relating to implementation of the multilateral environmental conventions (UNCCD, UNCBD, UNFCCC, Ramsar, etc.)	There is a Shorsay lake with saline water extending 30 km in length and 3 km in width in Karnabchul which serves as an important area for bird migrations.
Access to services both official/informal and private-public sector, application and effectiveness of regulations, policies, mandates, capacities of actors	Not available
Presence, roles and activities of NGOs and community-based organizations	Not available

Table 12. Basic services, infrastructure and investments.	
Parameter	**Observations**
**Road and market access, input supply	Available
*Schools, health centers	Available
***Water points (wells, boreholes, piped and tap water)	Available (40% of watering wells are out of operation)
*Irrigation systems and reservoirs	Insufficient
**Extension services	Not available

Table 13. Planning reports and rangeland improvement and development activities.

Parameter	Observations
**Land use planning, water resources planning, agriculture and forest management plans, livestock and environmental management	No specific planning, year-round use of range-lands
**Water harvesting (micro- and macro-catchments)	Water harvesting is not practiced
Revegetation (direct seeding, seedlings)	Not undertaken
**Managed grazing	Rotational grazing is not applied, continuous misuse of rangelands
*Training and extension	Very limited awareness of adaptive rangeland management practices and methods

B. ADAPTIVE MANAGEMENT AND ECOLOGICAL RESTORATION PRACTICES IN SEMI-ARID RANGELANDS OF UZBEKISTAN

Introduction

A production-oriented management philosophy has dominated rangeland management across Uzbekistan for the last century. The focus on maximum livestock production with little or no consideration of ecological processes has led to severe deterioration of ecosystems. It is estimated that more than 60% of rangeland areas of the country are affected by degradation and more than 10 million ha of rangelands are severely degraded. In most cases, degraded rangelands are covered by noxious plants such as *Peganum harmala, Iris songarica, Phlomis thapsoides,* and *Sophora pachycarpa.* Expansion of these undesired species reduces the self-supporting and self-organizing ability of rangeland ecosystems. To date, few management approaches have investigated effective ways to eliminate noxious species from rangelands. As a consequence, biodiversity of rangeland ecosystems remain under threat and the well-being of local communities is weakened. The current situation in rangelands strongly indicates a need for development of effective and practical methods of sustainable rangeland management and restoration of degraded rangelands. Development of effective and scalable standards for ecological restoration of degraded rangelands are essential as vast areas of the country are subject to severe degradation.

Native rangelands and degradation

Native rangelands in Uzbekistan occupy about 50% of the total territory of the country. The Artemisia-dominated rangelands cover about 15 million ha, representing 65% of the total rangeland area (Salmanov, 1993). Throughout history, rangelands have served as the main source of wildlife, feed, fuelwood and medicinal herbs for thousands of pastoral communities. Currently, rangelands provide natural forage for about 20 million head of small ruminants and 95% of their total diet comes directly from natural vegetation. Over the last decades, rangeland vegetation has been subject to significant anthropogenic change due to mismanagement of resources. As a consequence, vast rangeland areas have been significantly degraded through overgrazing, fuelwood collection and cropland encroachment. Due to overgrazing and trampling, several million hectares of native rangelands have been invaded by unpalatable plants such as *Peganum harmala, Iris songarica, Phlomis thapsoides,* and *Sophora pachycarpa* (Figure 7).

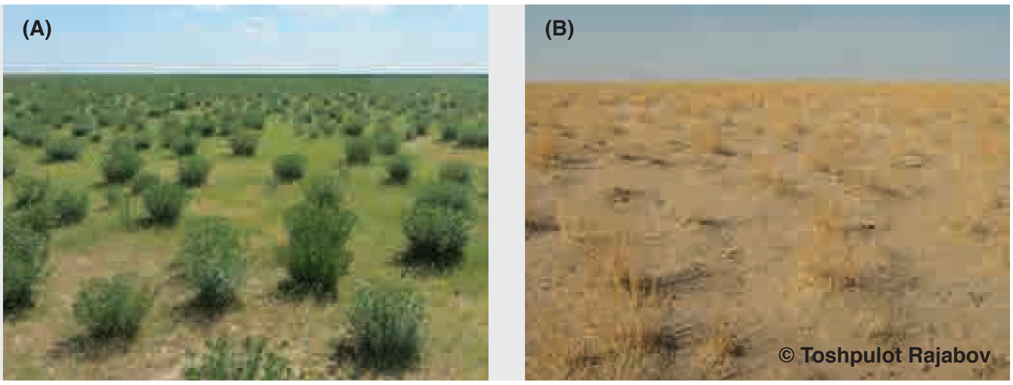


Figure 7. Degraded rangelands dominated by poisonous *Peganum harmala* in spring (A) and Degraded rangelands dominated by poisonous *Peganum harmala* in autumn (B)

At present, rangeland degradation covers large spatial and temporal scales. According to estimates, 50–70% of rangeland areas are affected by different levels of degradation. However, the exact spatial and temporal extent and the trend of this degradation is largely unknown due to the absence of a comprehensive framework for the assessment of rangeland conditions.

The Need for Participatory Rangeland Management

The most severe rangeland degradation in Uzbekistan occurs around settlements and villages and is largely due to mismanagement. This happens because of the weakness or absence of participatory governance systems (planning and management) in rangeland areas.

The lack of property rights also contributes to degradation as local users do not feel they are responsible for protecting or improving the rangelands (Christmann et al., 2014).

One of the potential ways to prevent further degradation processes in commonly used rangelands is developing the community-based frameworks in rangeland governance by involving multiple stakeholders and users. At the first stage, it is important to increase the awareness of local rangeland users. In governing and managing common rangelands. This is done through sequential phases of participatory rangeland management (PRM), which is not difficult to understand (Figure 8). PRM provides practical approaches and methods for adaptive rangeland management and ensures long-term sustainable use of vegetation resources and balances the rights and benefits of all stakeholders. The urgent implementation of PRM approaches is the highest importance for conservation of commonly used rangelands in Uzbekistan.

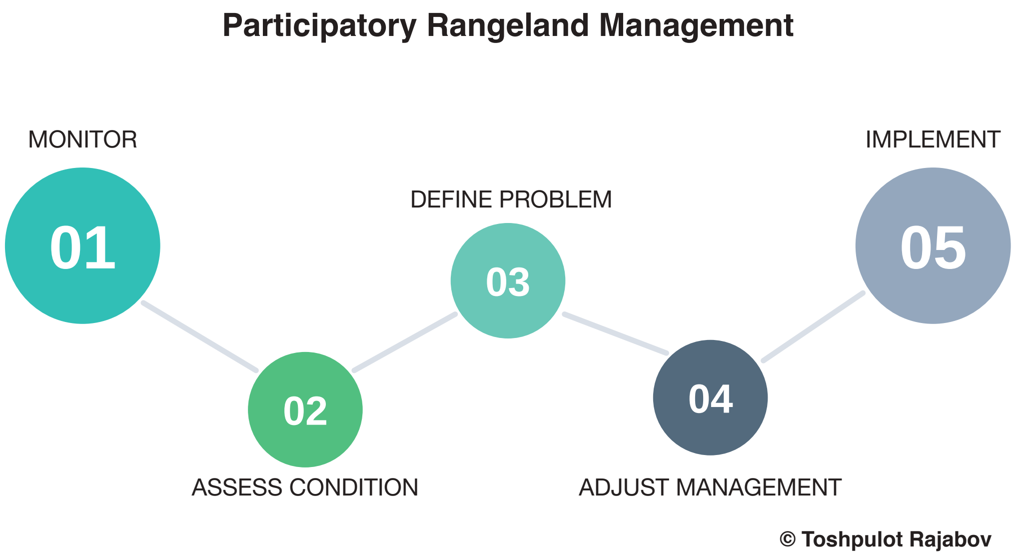


Figure 8. Basic sequential phases of Participatory Rangeland Management

Necessity for new approach and methods

Rangeland research has focused on optimizing livestock fodder production. Less attention has been given to the factors driving degradation or the interaction of ecosystem components such as vegetation response to grazing. Current research tends to focuses on applying novel conceptual frameworks, ecological methods and sophisticated tools such as GIS and Remote Sensing. At present, the application of such novel methods in Uzbekistan is limited.

Going forward, rangeland research should focus on applying rangeland health indicators, conceptual ecological models and threshold theories, which have been developed and widely applied in other rangeland-dominated countries. Current methods are easy to adapt can be used to organize existing knowledge into a conceptual framework (Briske et al., 2005). They are an effective tool for improving our understanding of the current state and dynamics of rangeland ecosystems.Applying these methods also allows for developing realistic strategies for better management of resources and can be effectively applied and scaled out in Uzbekistan.

Rangeland condition assessment

Any grazing plan requires data and information about the current state of vegetation, the amount of forage available, the extent of degradation and the indicators and criteria used to determine levels o of degradation. Ecological frameworks help planners develop adaptive grazing plans and ecologically and economically friendly restoration strategies. Thus, developing a fine-scale framework to assess rangeland conditions requires the application of methods such as the state and transition model, increaser/decreaser concepts, threshold theory and grazing gradient approaches. The latter help identify the gradual spatio-temporal vegetation changes in relation to focal points such as watering wells and livestock camps. Integration of other concepts and methods into the grazing gradient approach significantly improves our understanding of about the system's behavior.

In the Karnabchul in southwest of Uzbekistan, grazing-induced degradation is common in the native Artemisia-ephemeral rangeland. The vegetation state and its dynamics are complex due to unpredictable and unsystematic grazing practices. The situation is complicated by our lack of understanding of the current dynamics of the vegetation under increased grazing pressure. However, the application of grazing gradient methods integrated with other ecological concepts would allow planners to develop methods to assess the rangeland condition.

In the first stage, indicative properties of the vegetation under livestock grazing were studied and plant indicators of rangeland degradation were developed (Rajabov, 2021). These indicators included several increaser/decreaser species, density of *Poa bulbosa* and Carex pachystylis, appearance and density of perennial invasive species such as *Peganum harmala, Iris songarica, Phlomis thapsoides,* the density of *Artemisia* spp. and its mortality rate.

Based on these indicators and their quantitative changes along the grazing gradient, we defined criteria and thresholds for different levels of degradation. In addition, reversible and irreversible transitions of vegetation states were established. Most important, this framework allowed planners to differentiate healthy and degraded rangelands (Figure 9). Defining a healthy rangeland allows planners to develop the measures needed for an adaptive grazing plan. Assessing the available forage resources, defining the carrying capacity and developing rotational schemes are integral steps in the developing of adaptive rangeland management and its successful implementation.

Ecological restoration

The current situation in rangelands strongly indicates the need for effective and practical ecological restoration methods. The phytomeliorative methods of rangeland improvement were developed in the last century are no longer useful given global climate change and the penetration of market economics into rangeland communities. To date, experiments to restore degraded rangelands based on ecosystem capabilities have not been conducted in Uzbekistannor have there been research observations to monitor self-regeneration of ecologically important fodder plants such as *Artemisia* spp. which have sharply declined. Therefore, new rangeland improvement principles have to be refined and should be based on the ecological potential of the management unit, regardless of the specific ecosystem. These novel rangeland restoration methods can draw from current best practices and restoration strategies.

Grazing exclusion

Grazing exclusion is one of the first and most effective ways to restore native functions and services of rangeland ecosystems. Based on the level of alteration in species composition and their richness, the duration of grazing exclusion will be different.

Vegetation manipulation

Using the indicative properties of vegetation and quantitative criteria for condition assessment, various levels of rangeland degradation can be differentiated and a series of treatments implemented to promote desirable native species. Vegetation treatments can include mechanical control of noxious species and direct seeding of perennial semi-shrubs such as *Artemisia* spp. without tillage. In severely degraded rangelands with strong turf layers of *Poa bulbosa* and *Carex pachystylis*, limited tillage is recommended to break up the compacted turf layer for *Artemisia* to promote the growth of vegetation after direct seeding. When seeding, Native species must be used when seeding. Alien species are not recommended.

Treatments can be repeated based on the rate of restoration.

The restoration area must be protected as until it has returned to its native condition. As soon as evaluations suggest the restored area is healthy, adaptive grazing plans can be developed and implemented Figure 9).

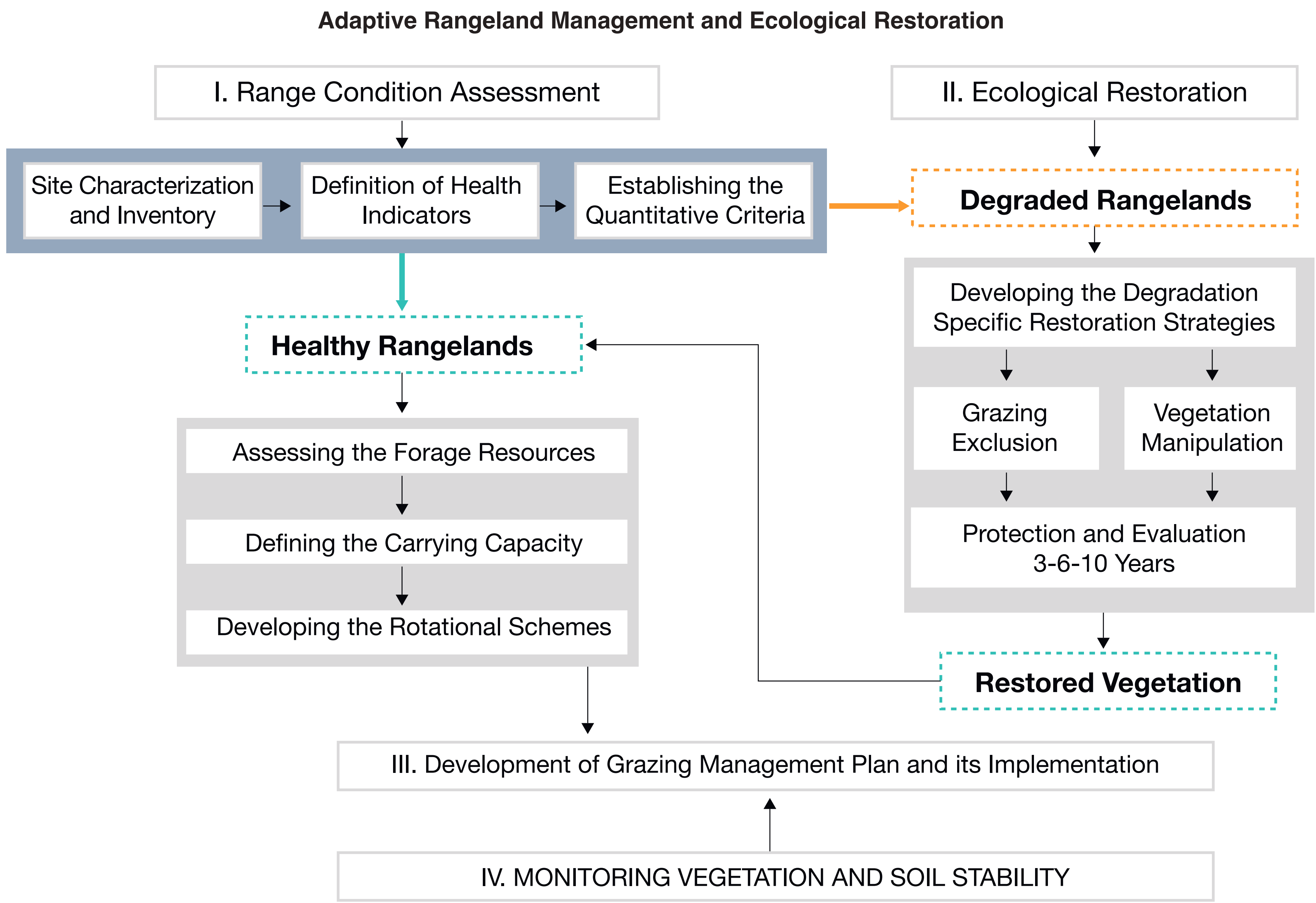


Figure 9. Framework for sustainable rangeland management and ecological restoration in the study area

FURTHER READING

Uzhydromet. 2020. Climate change tendencies in Uzbekistan: the intensity of temperature increase is higher than the global average (in Uzbek). http://meteo.uz/#/uz/news/2020-04-14-uzbekistonda-ik-lim-uzgarishi-tendenciyalari-kh-aroratning-kutarilish-suratlari-global-mik-yosdagi-urtacha-suratlardan-yuk-ori. Accessed May 14, 2022.

Briske, D.D., Fuhlendorf, S.D. and Smeins, F.E. 2005. State-and transition models, thresholds, and rangeland health: a synthesis of ecological concepts and perspectives. Rangeland Ecology and Management. 58: 1-10.

Christmann, S., Aw-Hassan, A., Rajabov, T. and Rabbimov, A. 2014. Collective Action for Common Rangelands Improvement: A Climate Change Adaptation Strategy in Uzbekistan. Journal of Society and Natural Resources. 28: 280-295.

Rajabov, T.F. 2021. Indicative properties of rangeland vegetation in the condition of livestock grazing (in Uzbek). Acta of National University of Uzbekistan. 3(1/1): 93-96.

Salmanov, N.S. 1993. Intra-annual changes of productivity of Artemisia-ephemeral rangelands of Uzbekistan under the impact of climatic factors and regimes of sheep grazing (in Russian). In Valiev, R.G. (Ed.). Technology of Karakul sheep breeding and arid fodder production. Uzbek Academy of Agricultural Sciences. Tashkent: pp. 72-85.

CASE STUDY OF THE JORDANIAN BADIA

INTRODUCTION

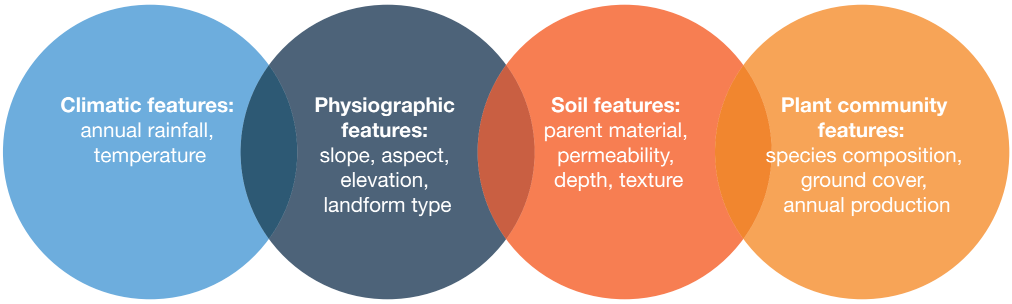
The Jordan Badia constitutes 80% of the Hashemite Kingdom of Jordan. The steppe rangelands of the Jordanian Badia are continuously being degraded, many indigenous plant species have disappeared, and their productivity has been halved over the last two decades. Productivity has fallen to a disturbingly low level–less than 40 kg DM/ha, which makes it difficult to predict a trend for the Badia rangelands.

With the rapid deterioration of rangelands and increasing climate change impacts, pressure grew on the government to resolve these problems. At the beginning of 2000, the government responded to this crisis with urgency. Their strategy comprised important measures such as rangeland management and restoration, for example, shrubs planting, direct seeding, rainwater harvesting and soil surface scarification. The strategy has been well received as it offers technical solutions. However, it remains challenging for pastoral communities to own the process. This change in behavior needs time to be fully embraced.

Figure 1. Contour water-harvesting micro-catchments consolidated with *Atriplex halimus*, Jordanian Badia

Based on recent as well as historical data, it is clear that the rangeland condition of the Hashemite Kingdom of Jordan is declining. Rangelands must be healthy, productive and diverse to meet the needs of rural communities and society today as well as those of future generations. Restoring and rehabilitating rangeland's health and ecological integrity will better support the social and economic needs of the population.

Climate condition, soil type, land use type, livestock, population density, distribution, and change, along with the demographics of the project area, are useful attributes for rangeland rehabilitation projects. These attributes also provide an understanding of how rangeland rehabilitation could affect the livelihoods of people living in the project area. They are called the Ecological Site Characteristics, include:



Site characterization reports also include information about what the site is best suited for, such as 1) wildlife and livestock uses, 2) hydrologic functions, 3) other products the site may produce. Using this information, land managers can evaluate the suitability of their land for various purposes, set realistic goals and better predict the outcomes of management practices.

Figure 2. Map of Jordan showing the extend of the Badia

A. SITE CHARACTERIZATION OF THE BADIA

Collecting baseline information is the first step once a restoration project is approved. Detailed site characterization should be conducted by the project team and includes what is locally known about the site. Baseline data collection should cover some or all topics listed below as appropriate.

Collecting baseline data in the field is expensive and time consuming. Some or even much of the required data may needed may already be available in government ministries and departments, UN agencies operating in the region, local NGOs, and master's theses and doctoral dissertations. A great deal of time and money can be spent duplicating the work of others, time and money better spent on implementation and action on the ground.

Institutions	
Type of institution (NGOs, CBOs, GDA…)	Clans, tribes, NGOs, CBOs, farmers' organizations, private citizens

Climatic (including natural disasters) and meteorological records			
Rainfall amounts and variability, temperature, humidity	Rainfall: less than 200 mm/year (October to April)	Temperatures range from 14-16°C in winter to 35-37°C in summer	Humidity: 58%
**Trends in rainfall and temperature over recent decades		Rainfall	Temperature
*Incidence and impacts of drought and flooding etc.			
*Information and studies on the impacts of climate change including likely future impacts on water resources	Louhaichi et al., 2019. Effects of Climate change and grazing practices on shrub communities of West Asian rangelands		

Water resources	
**Water resources records over the last decade Sources: water boards and authorities to show: • Water flow regimes in rivers • Water storage capacity and water levels of lakes, dams and reservoirs • Sedimentation load and rates	Ministry of Water and Irrigation
*Incidence of water borne diseases and pollutants Sources: health sector and water authorities) etc.	

Vegetation		
Type of disturbance (past and present)	Past: irrigated agriculture, grazing, wind and water erosion	Present: grazing, wind erosion
Vegetation structure (past and present)	Past: Chert Hammada, salt and mud flats, sand dune vegetation, shrubs on the basalt	Present: Poor vegetation cover and accelerated land degradation
Dominant plant communities	The vegetation is dominated by chamaeophytes, small shrubs and small annuals in the wadi beds and bushes such as *Artemisia herba-alba*, and *Anabasis syriaca*	
Key plant species (forage, erosion control, wildlife, herbal, and medicinal)	*Artemisia Judaica, Anabasis syriaca, Anabasis articulata, Haloxylon persicum, Retama raetam, Calligonum comosum,* and *Hammada scopiara*	
Percent cover	Vegetation cover is very sparse, with large areas of bare soil	
Forage production	35 FU/ha/year to 100 FU/ha/ in depressions and other favored sites	
Diversity (richness, floristic composition)	3 to 30 species during rainy season	
Soil seed bank and the ability for *regeneration*	Very poor	
Endangered species	*Salsola vermiculata, Achillea fragrantissima, Artemisia herba-alba, Achillea santolina, Artemisia judaica, Atriplex halimus, Traganum nudatum* and *Thymus bovei.*	
Life form	Chamaephytes, hemicryptophytes, and therophytes	
Palatability index	From 0 to 5	

Soil	
Soil Observations	
Soil cover (protection)	Degraded soil with very low vegetative cover mostly dominated by unpalatable invasive species such as *Anabasis syriaca*
Soil color and soil life (SOM content)	Low organic matter content
Soil texture (erodibility)	Sandy, skeletal, salty, silty, clay, basalt, sand dunes: Soils with aridic (i.e. dry) moisture regime, weak soil development, often enrichment of calcium carbonate and/or gypsum or other salts
Soil structure (permeability, root penetrability and stability)	Crust, rockets, and mostly wind veils
Soil depth (plant rooting depth and nutrient and water availability)	Decrease in soil depth

Edaphic factors (site, soil)	
Slope gradient and slope aspect (direction)	• Irregular slopes eroded into ravines • It can be an asset in the development of land located downstream that benefits from additional water supplies • The total absence of slopes (endorheic areas, sometimes flooded)
Elevation above sea level	Between 100 and 1500 m
Topography features	Mountain, plains and depression running from Wadis
Location of site within the watershed	Numerous watersheds
Soil properties (texture, structure, depth, organic matter content, salinity, basic infiltration rate, runoff coefficient)	• Sandy, rocky, salty, basalt, silty, sand dunes • Shallow to deep (sandy) soils • Low organic matter • Low infiltration, high evaporation • Runoff on steep slopes is greater
State of soil surface (crust, feces, litters, rock, gravel, etc.)	• Crusted soil surface and litter accumulation in protected areas • Gravel and rock in mountains and hills • Feces of sheep, goats and camels, and wind veils in heavily grazed areas
Type and indicators of soil erosion (wind, water, presence of rills and gullies)	• Wind erosion: sand accumulation and rocky outcrop • Water erosion: gullies rocky outcrop
Ground cover (vegetation, rocks, gravels, crusts, rock outcrop, litter…)	• Sparse cover of vegetation in plains • Vegetation concentrated in wadis and the mudflats • Disruption of vegetation cover exposing bare ground of hills and highlands

Human population (socioeconomic data)	
Total population and recent trends: age, gender and ethnic minority distribution	• Approximately 380,000, or 6.5% of the total population of the Kingdom (7.7 inhabitants per km^2) • 58,000 total man-made dwellings in the Badia
Household and family composition information	• 67,810 families • Family size was 5.6 person • Women comprise 37% of the Badia's population • Youth below 15 years of age compose 41% of Badia inhabitants
Employment by sector; labor force, migration information, settlement patterns	• Most people in the area depend, at least in part, on livestock for their livelihood • Small- and medium-scale farming • The labor force in the Jordan Badia stands at approximately 82,000
Poverty and food security	• The Badia as a whole suffers from approximately 21% illiteracy, and parts of the southern Badia peak at almost 28% • There are about 569 schools throughout the Badia, with approximately 90,000 students • The lack of housing infrastructure has adversely affected the search for qualified staff, such as physicians, nurses and teachers to come work in and help Badia communities • Poverty in the Badia is widespread, as the area contains 22 of Jordan's 30 pockets of poverty

Household income information; composition of income (i.e. contribution from farming and other activities)	• Limited income sources for the Badia inhabitants. • Families in Badia suffer from income deficit, which reached 12%, 26% and 3% in the northern, middle, and the southern Badia, respectively
Proportion of population below poverty line % of food insecure, malnutrition	Almost half (43%) of Northern Badia households are classified as food insecure, either moderately or severely
*Credit availability	
Land-use types	
Size of land-use types in the local assessment area and community territory Farmland and protected areas	Between 85% and 91% of Jordan's land area (73,000 km^2)
Areas and proportions under different land-use types (including forest and protected areas).	• As well as the large land area used for grazing, many parts of the Badia are cultivated through rainfed and irrigated agriculture • Vegetables constitute around 81% of total crops • Barley productivity
Land cover and land resources surveys	NA
Type of ownership (private, communal, state)	Mostly state land though private ownership does exist
Traditional users	Pastoralists, herders, private citizens
Governance (mechanism, regulation)	In most cases, absent but in recent years attempts by IUCN to revive the concept oh Hima
Farming system information	
• Existing agricultural plans, programs and projects • Crop and livestock and forestry systems information	• The Hashemite Fund for the Development of Jordan's Badia (HFDJB) is working on several projects that seek to rehabilitate rangeland areas of through the cultivation and provision of forage and fodder crops. • International Fund for Agricultural Development (IFAD) • The Arab Fund for Economic and Social Development (AFESD)
Presence and extent of local and introduced practices for land management and land degradation control	Rangeland rehabilitation: planting, seeding, water harvesting practices,
Information on livestock numbers, distribution, ownership, actual and recommended stocking densities, management	In Badia, sheep constitute the majority at approximately 85% of the livestock population (800,000 sheep)
Pastoral animal production	
Flock size per household	• One camel per family • Seven goats per family.
Type of dominant livestock	• Sheep and goats represent important sources of income through milk, meat, and wool production • Camels in the Badia was 6,848
Feed calendar (grazing and non-grazing feed resources)	• Animals graze on the rangeland, or open pasture • Farmers maintain their livestock with concentrated feeds throughout the entire year, even though their sheep are physically present on the rangeland

Livestock watering resources	To sustain their livestock, farmers have to fill a water tanker truck with water at the closest well on a daily basis, sometimes driving a round trip of up to 60 km
Subsidies (feedstuffs, veterinary services, watering)	For veterinary services, farmers usually use private clinics a significant financial cost
Grazing practices (spatial and temporal mobility of flocks)	Continuous grazing and transhumant
Role of women in the livestock production	Very active participation, mostly for small herds
Availability and adequacy of livestock supporting services (veterinary, marketing, shearing)	Depends on access to rangeland
Wildlife	
Wildlife species (birds, mammals)	Depending on rangeland gazelles, birds, rodents, Golden Jackal, Caracal, Ratal
Population density	Low
Endangered species	Gazelles, birds, rodents, Golden Jackal, Caracal, Ratal
Soil biodiversity	Low
Land tenure	
Information on land-holdings: • Ownership, size and distribution type • Prevalence of renting or leasehold arrangements • Legal status of holdings (civil, cooperative, government arrangements, titles)	• Private rangelands which are registered represent more than 800,000 titles • The state provides free access to all resources to land owned by the state ownedland • The state withdraws gradually from land ownership toward privatization
Institutions, policies, regulations, byelaws	
Relating to land, agriculture, livestock, water resources, environment, rural development, technical sectors, extension, grazing rights and strategy	• Government institutions, communities, civil society institutions, tribal institutions, International donors • Ministry of Agriculture. 2014. Updated Rangeland Strategy for Jordan
Planning reports and rangeland improvement and development activities	
**Land-use planning, water resources planning, agriculture and forest management plans, livestock and environmental management	
**Water harvesting (micro- and macro-catchments)	Water harvesting technologies in the agro-pastoral system especially at watershed scale
Revegetation (direct seeding, seedlings)	Successful: planting and seeding of *Atriplex halimus* and *Salsola vermiculata*
**Managed grazing	Rest-rotation grazing
*Training and extension	Training was provided in rangeland rehabilitation

B. IMPROVING RANGELAND CONDITIONS AND LOCAL LIVELIHOODS IN THE JORDANIAN BADIA

Rangeland restoration

The primary goal of restoration projects in the Badia rangelands is livestock production. However, the multiple-use of rangelands also includes soil and water conservation, especially in watersheds. For these rangeland improvements to be of real value, they must fit within a plan.

For example, in many areas of water shortage, water harvesting is necessary for strengthening efforts to ensure the success of any restoration program. Potential solutions to restore and rehabilitate degraded rangelands in Badia vary across locations, soil surface, degree of slope, and the degree of rangeland degradation.

When rangeland productivity does not exceed the degradation threshold

This degradation leads to slight degeneration of vegetation and soil surface erosion. These changes represent a light disturbance that allows vegetation to recover when intervening to rehabilitate. When the vegetation cover is higher than 20%, natural restoration of vegetation cover and soil characteristics will recover significantly (Gao et al., 2011).

Protecting rangelands from grazing disturbances can be efficient so that they can undergo natural recovery without human intervention. Grazing exclusion can be used to implement seasonally deferred grazing practices. During favorable climatic periods protection from grazing during the growth stage of vegetation have significant positive impact on rangeland health (Louhaichi et al., 2021).

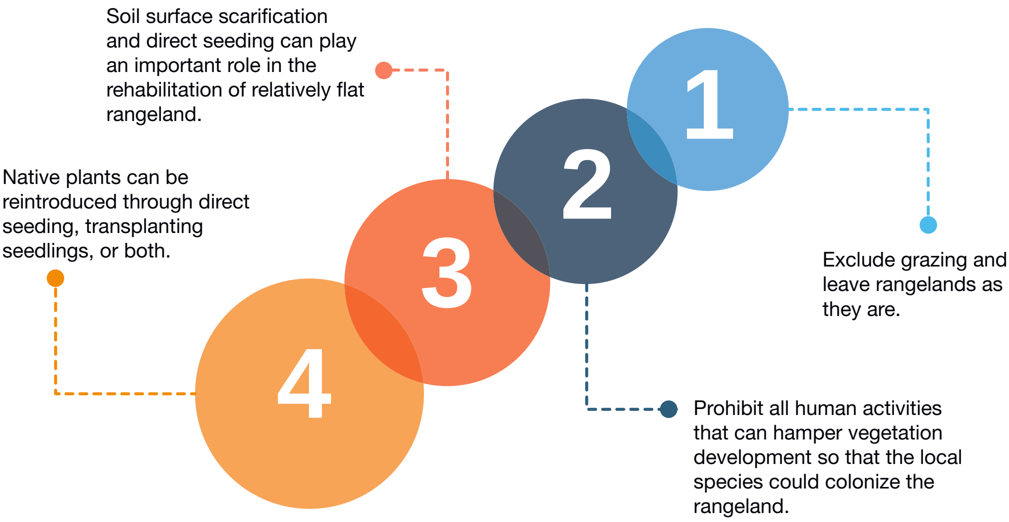
Figure 3. Rangeland natural regeneration in the hima site of Bani Hashem, Jordan

When rangeland productivity exceeds the degradation threshold

When overgrazing triggers practically denuded vast areas of rangeland will exacerbate directly the desertification processes, which consequently demanded urgent and prompt interventions to prevent damage to rangeland and livestock production rather than intervention after disastrous harms. There are several basic alternatives if we want these denuded rangelands to sustain a native or introduced forage species.

On relatively flat rangelands (<5% slope)

Instead of abandoning rangelands due to their advanced degradation status, there are certain actions which could reverse trend or at least slow it including:



Considerations

The degradation hazard of some species may be insensitive to a decrease in vegetation cover if the site is flat. Deterioration of vegetation leads to reduce litter accumulation on soil surfaces, disruption of nutrient cycles, 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 of 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 the rangeland. recurrent barley cultivation and 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 germination and seedlings survival.

Steep-sloped rangelands

Increased grazing pressure, often on steep slopes, results in rangeland degradation until abandoned once they became denuded which exacerbates the grazing pressure on other existing rangelands.

Figure 4. Overgrazing is a common problem leading to severe degradation of rangelands, Jordan

To ensure that the productive potential of rangeland and sustainability of livestock production is maintained in the long term, implementing adaptive rangeland management should be required.

1. **Rainwater harvesting:** In arid environments, rainfall is one of the most limiting factors associated with the failure and the 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 to 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 be easily trained to install them. This lowers costs and promotes community engagement, ownership, and sustainability.

   In arid areas, 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 depends on the size of the area, the constructed catchment, the intensity of the precipitation, and soil permeability.

2. **Bunds:** For small areas, using semi-circular bunds and V-shaped micro catchments are an appropriate practice for rehabilitation of degraded rangeland.

Figure 5. Semi-circular bunds and V-Shape micro catchments for shrub plantation

   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 slopes 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.

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

   • **Contour furrows are:** 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. The aim of contour furrows is 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 useful for erosion control. Contour bunds is a mechanical method which makes it efficient for large scale rehabilitation. The optimal distance between two contours depends upon the slope of the area, where steeper grounds require less distance.

Figure 6. Transplanted shrubs along intermittent contours in the Majidya site, Jordan

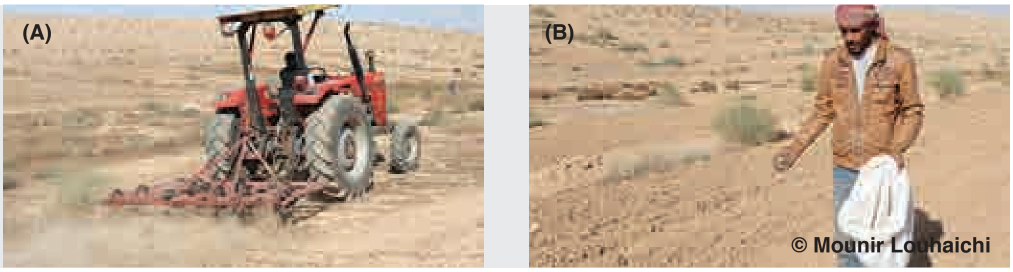


Figure 7. Mechanized soil surface scarification (A) and Hand sowing of *Salsola vermiculata* right after soil scarification (B)

Figure 8. Successful establishement of *Atriplex halimus* along contour lines in the Jordanian Badia

Rangeland governance

Rangelands governance is the process by which all stakeholders negotiate, make, and enforce binding decisions about rangelands resources management, use, and conservation. It could include public and local institutions, groups and associations, land tenure and infrastructure and other capital investments in the region and its implications.

Stakeholders' involvement

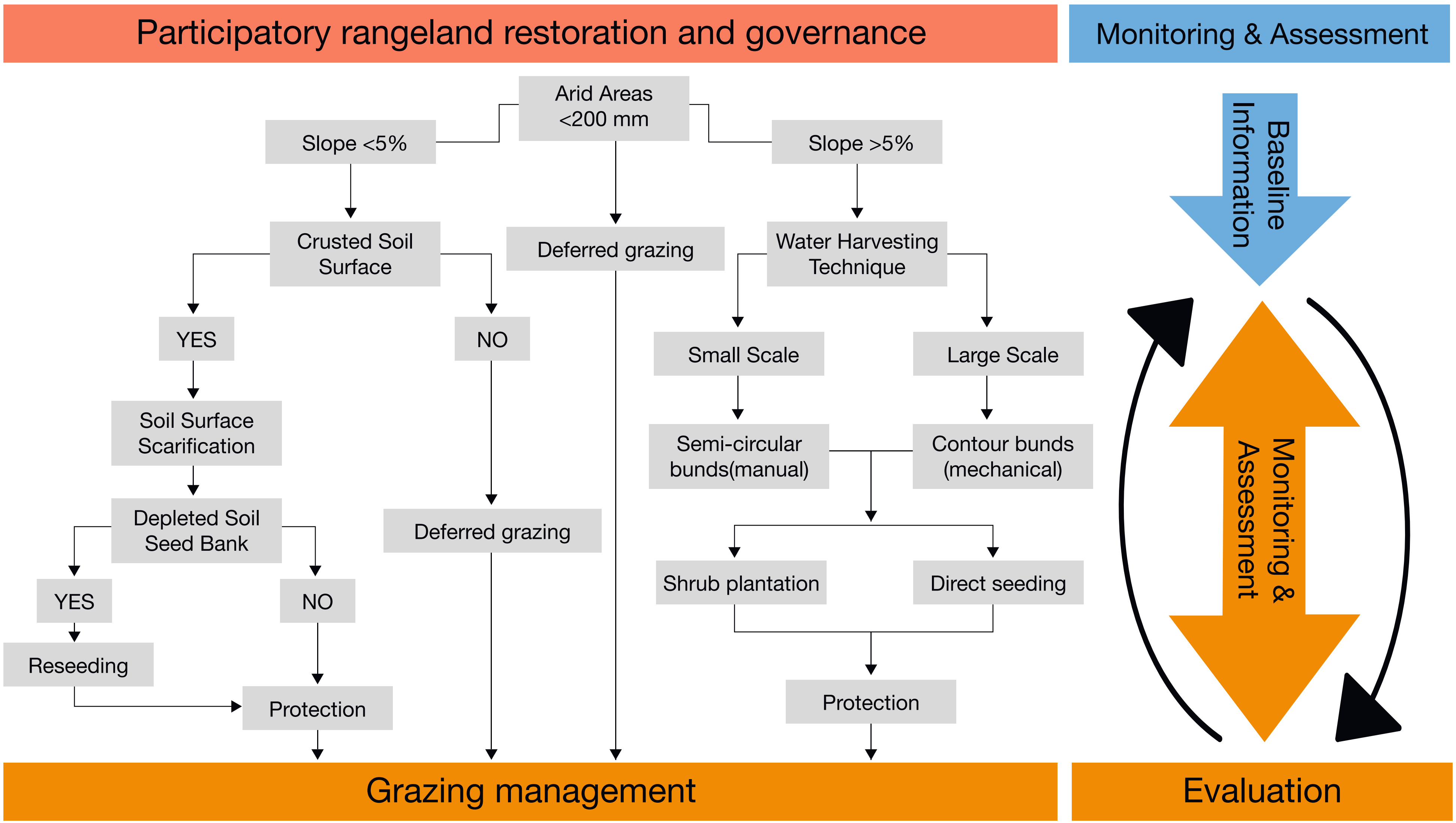
Rangeland management governance mechanisms, which include stakeholders, tackle rangeland-related issues and implicate other sectors that interact with rangelands. At the local level and to deal with governance processes, a rangeland council or association can be established where all stakeholders can consult on rangelands management issues.

The involvement of all stakeholders in rangeland assessment is one of the best practices in their management. This requires starting by identifying, mapping and evaluating the role of each stakeholder, its responsibility as well as the degree of implications on rangelands management activities. The analysis of social aspects and factors affecting rangeland management can be carried out by relying on social surveys, interviews, and rural appraisal methods. The involvement and cooperation between stakeholders should be both horizontal intra and inter communities and local authorities but also vertical between the local communities and the central institutions. The establishment of rangeland associations or councils at the local level is very useful for management consultation. These associations will play key roles in the implementation of support programs related to rangeland management originating from the central government.

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 sustainable management of these harsh ecosystems. Grazing management is a tool to balance the capture of energy by the plants, the harvest of that energy by animals, and the conversion of that energy into a marketable product. Timing of grazing and growth rate of plants after-grazing events are key factors in controlling frequency, intensity and duration of grazing. These factors enhance soil stability, forage production, efficiency of forage use, and improve livestock production.

Figure 9. Small ruminant grazing a rehabilitated site in Jordan



© Mounir Louhaichi

Figure 10. Scenario of planning and implementing a participatory and sustainable rangeland rehabilitation in Jordan

These rehabilitation practices make it viable for pastoralists to increase livestock production by increasing their herd sizes. They also increase the economic and environmental conditions, such as improving the food security status in drought years and reducing grazing pressure on the natural rangelands from the increased vegetation cover.

The management of the improved range sites, after the rest and rehabilitation, should considering the diversity of the environmental conditions of the range sites and limit to the minimum the change in the usual management methods. The following considerations are important:

- The sites will be subject to rest technique (including those to be rehabilitated) for two years to increase the chances of rehabilitating their stock in seeds and / or strains of the most important pastoral plants and those seriously affected by mismanagement

- In the third year, the rested areas will be open to grazing only once during the vegetative dormant season to enhance the cumulative forage units (FUs) and take advantage of the animal impact (burying seeds, improving the infiltration of rainwater, etc.).

From year 4, these areas will be opened twice a year: the first of short duration during the vegetative growth season (preferably at the beginning) but with a high animal stocking density; and the second during the dormant period of the main pastoral species but of longer duration (until almost total use of the annual grass cover). The duration of this second grazing period and the stocking density will depend on the fodder supply (carrying capacity), the availability of water for watering the herd and the size of the herds entitled to access the perimeter in question, but roughly, the animals can stay if the breeders wish, subject to the following conditions:

- Not to take more than 60% of the consumable biomass offered by perennials (all of the biomass offered by annuals can be consumed without risk of degradation); All animals using the site must leave it the same day and before the first fall rains (around End September at the latest)

- All animals using the site must leave it the same day and before the first fall rains (around End September at the latest)

- At the end of the dormant period, grazing will be excluded until the following spring and the cycle will begin once again.

Figure 11. Truck transporting water to the herd in the Jordanian Badia

Management of grazing animals

Among the problems that face rangeland manager is the non-uniform distribution of grazing animals on the surface area of rangelands resulting in some patches exploited more than others do. Therefore, a higher uniformity in the distribution animal on rangelands is preferred.
The animal species can highly influence the grazing management plan. The nature of the dominant vegetation cover will dictate the use of sheep if it is herbaceous. In case of shrubs, bushes, and spiny vegetation, goats and camels are more favorable. The management plan to improve the efficiency of rangelands will target the selection of animals that will adjust the species composition. In case of grazing by different animal species, it should be noted that even if camels and small ruminants have different preferences rangeland types, it is essential to avoid grazing by small ruminants before camels. Both types of animals must graze the range at the same time. Camels refuse, in fact, to graze after the small ruminants. Furthermore, grazing annual plants in spring, essential for camels, should be favored in case of mixed grazing. In contrast, small ruminants are not embarrassed to graze in the areas frequented by camels and even if grazing annual plants is preferable; their lack is not a determining factor.

Several accompanying measures may guarantee the uniform distribution of grazing animals on rangelands. A good distribution of watering points and shelters (shady areas) and services center (for concentrates and storage of food, veterinary treatments, …) may help in adapting and implementing a rotational grazing system.

FURTHER READING

Al-Tabini, R., Al-Khalidi, K. and Al-Shudiefat, M. 2012. Livestock, medicinal plants and rangeland viability in Jordan's Badia: through the lens of traditional and local knowledge. Pastoralism. 2: 4 https://doi.org/10.1186/2041-7136-2-4

Archer, S. 1989. Have southern Texas savannas been converted to woodlands in recent history? American Naturalist. 134: 545-561.

FAO. 1991. Workshop on Pastoral Communities in the Near East: Traditional Systems in Evolution, 1–5 December 1991. Amman, Jordan: FAO.

G a o , Y ., Zh o n g , B., Y u e , H ., Wu , B. a n d C a o , S . 2011. A Degradation Threshold for Irreversible Loss of Soil Productivity: A Long-Term Case Study in China. Journal of Applied Ecology. 48: 1145-1154.

Kherissat, F. and Al-Esawi, D. 2019. Checklist of Wadi Hassan flora, Northeastern Badia, Jordan. Plant Diversity. 41: 166-173.

Louhaichi, M., Gamoun, M. and Gouhis, F. 2021. Benefits of Short-Duration, High-Stocking Rate Opportunistic Grazing on Arid Rangelands During Favorable Conditions. Frontiers in Ecology and Evolution. 9. https://hdl. handle.net/20.500.11766/66517

Louhaichi, M., Ouled, B.A., Hassan, S. and Petersen, L.S. 2019. Effects of Climate change and grazing practices on shrub communities of West Asian rangelands. International Journal of Climate Change Strategies and Management. 11(5): 660-671. https://doi.org/10.1108/IJCCSM-02-2018-0017

Ministry of Agriculture. Updated Rangeland Strategy for Jordan. Available at https://www.iucn.org/sites/dev/files/import/downloads/english_strategy.pdf

Sankari, M. 1993. Maintenance and Development of the Rangeland in Arabic Countries. In: Workshop on Maintenance and Development of the Rangeland, its Role in Combating Desertification of the Arab World, ed. M.S. Radwan, 180–297. Jordan, FAO: Amman.

USAID. 2018. Property Rights and Resource Governance – Jordan. https://www.land-links.org/wp-content/uploads/2018/06/USAID_Land_Tenure_Profile_Jordan.pdf

GLOSSARY

SOURCE: Society for Range Management. 1998. Glossary of terms used in range management, fourth edition. Edited by the Glossary Update Task Group, Thomas E. Bedell, Chairman. Used with permission. https://globalrangelands.org/glossary/

Aspect: (1) The visual first impression of vegetation or a landscape at a particular time or as seen from a specific point. (2) The predominant direction of slope of the land. (3) The seasonal changes in the appearance of vegetation.

Biodegradable: Capable of being decomposed by natural processes.

Biomass: The total amount of living plants and animals above and below ground in an area at a given time.

Broadcast Seeding: Process of scattering seed on the surface of the soil prior to natural or artificial means of covering the seed with soil. cf. drill seeding

Browse: (n.) The part of shrubs, woody vines and trees available for animal consumption. (v.) To search for or consume browse.

Canopy Cover: The percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included. It may exceed 100%. Syn. crown cover.

Carrying Capacity: The average number of livestock and/or wildlife that may be sustained on a management unit compatible with management objectives for the unit. In addition to site characteristics, it is a function of management goals and management intensity. The amount of forage produced annually in a management unit is only one attribute used to determine carrying capacity. The forage also has to be available to the animals. On many rangelands, the carrying capacity may be less than forage production would indicate because parts of the management unit are inaccessible to grazing animals. In essence, forage is present but unavailable.

Climax: (1) The final or stable biotic community in a successional series; it is self-perpetuating and in equilibrium with the physical habitat.
Common Use: Grazing the current year's forage production by more than one kind of grazing animal either at the same time or at different seasons. cf. dual use.

Community (Plant Community): An assemblage of plants occurring together at any point in time, while denoting no particular successional status. A unit of vegetation.

Community Type: An aggregation of all plant communities with similar structure and floristic composition. A unit of vegetation within a classification with no particular successional status implied.

Competition (rangelands): The interaction between organisms as a result of the removal or reduction of a common, required resource from the environment. Resources may include water, nutrients, light, oxygen, carbon dioxide, food and shelter.

Continuous Grazing: The grazing of a specific unit by livestock throughout a year or for that part of the year during which grazing is feasible. The term is not necessarily synonymous with yearlong grazing, since seasonal grazing may be involved. A preferred term is continuous stocking.

Contour Furrow: A plowed or listed strip, commonly 8 to 18 inches deep and wide, made parallel to the horizontal contour for the purpose of water retention and reduction of soil erosion.

Controlled Burning: Syn. prescribed burning.

Cover: (1) The plant or plant parts, living or dead, on the surface of the ground. Vegetative cover or herbage cover is composed of living plants and litter cover of dead parts of plants. Syn. foliar cover (2) The area of ground covered by plants of one or more species. cf. basal area.

Decreaser: For a given plant community, those species that decrease in amount as a result of a specific abiotic/biotic influence or management practice.

Deferment: The delay of grazing to achieve a specific management objective. A strategy aimed at providing time for plant reproduction, establishment of new plants, restoration of plant vigor, a return to environmental conditions appropriate for grazing, or the accumulation of forage for later use. cf. deferred grazing, rotational deferred.

Desirable Plant Species: Species which contribute positively to the management objectives.

Drill Seeding: Planting seed directly into the soil with a drill in rows, cf. broadcast seeding.

Ecosystem: Organisms together with their abiotic environment, forming an interacting system, inhabiting an identifiable space.

Ecotone: A transition area of vegetation between two communities, having characteristics of both kinds of neighboring vegetation as well as characteristics of its own. Varies in width depending on site and climatic factors. cf. edge effect.

Ecotype: A genetically differentiated subpopulation (race) that is restricted or adapted to a specific habitat 1. most differences among ecotypes are observed only when different ecotypes are tested in a common environment, 2. ecotypes are generally subdivided into races, e.g., edaphic, climatic (termed cline), geographic (termed variety).

Edaphic: Refers to the soil.

Extensive Grazing Management: Grazing management that utilizes relatively large land areas per animal and a relatively low level of labor, resources, or capital. cf. intensive grazing management.

Fauna: The animal life of a region. A listing of animal species of a region.

Flora: (1) The plant species of an area. (2) A simple list of plant species or a taxonomic manual.

Forage (rangelands): (n.) Browse and herbage which is available and may provide food for grazing animals or be harvested for feeding. (v.) To search for or consume forage. cf. (v.) browse, graze.

Forage Production: The weight of forage that is produced within a designated period of time on a given area. The weight may be expressed as either green, air-dry, or oven-dry. The term may also be modified as to time of production such as annual, current year's, or seasonal forage production.

Forage Reserve: Standing forage specifically maintained for future or emergency use.

Forage Use Factor: An index to the grazing use that may be made for forage species that will maintain economically important forage species or to achieve other management objectives.

Forb: Any broad-leafed herbaceous plant other than those in the Poaceae, Cyperaceae and Juncaceae families. cf. legume.

Grassland: Land on which the vegetation is dominated by grasses, grass like plants, and/or forbs (cf. dominant). Lands not presently grassland that were originally or could become grassland through natural succession may be classified as potential natural grassland.

Grazing Capacity: The maximum stocking rate that will achieve a target level of animal performance, in a specified grazing method, based on total nutrient resources available, including harvested roughages and concentrates, that can be applied over a defined period without deterioration of the ecosystem. A description of the grazing capacity should include stocking rate, grazing method, targeted animal performance and nongrazed nutrient resources.

Grazing Distribution: Dispersion of livestock grazing within a management unit or area.

Grazing Management: The manipulation of animal grazing in pursuit of a defined objective.

Ground Cover: The percentage of material, other than bare ground, covering the land surface. It may include live and standing dead vegetation, litter, cobble, gravel, stones and bedrock. Ground cover plus bare ground would total 100 percent.

Growing Season: Period of active growth.

Gully: A furrow, channel or miniature valley, usually with steep sides through which water commonly flows during and immediately after rains or snow melt. cf. arroyo and coulee.

Habitat Type: The collective area which one plant association occupies or will come to occupy as succession advances. The habitat type is defined and described on the basis of the vegetation and its associated environment. The concept was developed by Rexford Daubenmire. Habitat type is similar in concept to ecological site. The difference depends mainly on how specifically plant associations are defined. Habitat type is often misused to refer to classification of vegetation or wildlife habitat rather than a land classification.

Half-Shrub: A perennial plant with a woody base whose annually produced stems die each year.

Hard Seed: A physiological condition of seed in which some viable seeds do not immediately absorb water or oxygen and germination is delayed when a favorable environment is provided. Non-synonymous with seed dormancy.

Hardpan: A hardened soil layer in the lower A or in the B horizon caused by cementation of soil particles with organic matter or with materials such as silica, sesquioxides, or calcium carbonate. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not crumble in water. cf. caliche.

Heavy Grazing: A comparative term which indicates that the stocking rate of a pasture is relatively greater than that of other pastures. Often erroneously used to mean overuse. cf. light and moderate grazing.

Herbaceous: 1. Non-woody plant growth. 2. A term often used to describe the flavors in wine or grapes which resemble leafy, or vegetative flavors.

Holistic Management: Holistic Management is a practical, goal-oriented approach to the management of the ecosystem including the human, financial and biological resources. Holistic Management entails the use of a management model which incorporates a holistic view of land, people and other resources. Holistic Management is now the correct name for the approach formerly called Holistic Resource Management.
https://www.iucn.org/theme/protected-areas/about/protected-area-categories

Increaser: For a given plant community, those species that increase in amount as a result of a specific abiotic/biotic influence or management practice.

Indicator Species: (1) Species that indicate the presence of certain environmental conditions, seral stages, or previous treatment. (2) One or more plant species selected to indicate a certain level of grazing use. cf. key species.

Indigenous knowledge: A body of knowledge built up. by a group of people through generations of living in close contact with. Nature.
Indigenous: Born, growing, or produced naturally (native) in an area, region, or country. Cf. endemic.

Infiltration rate: The rate of movement of water from the soil surface into soil.

Intensive Grazing Management: Grazing management that attempts to increase production or utilization per unit area or production per animal through a relative increase in stocking rates, forage utilization, labor, resources, or capital. Intensive grazing management is not synonymous with rotation grazing. Grazing management can be intensified by using any one or more of a number of grazing methods that use relatively more labor or capital resources. Cf. extensive grazing management.

Introduced Species: A species not a part of the original fauna or flora of the area in question. cf. native and resident species.

Invader: Plant species that were absent in undisturbed portions of the original vegetation of a specific range site and will invade or increase following disturbance or continued heavy grazing. cf. increaser.

Invasion: The migration of organisms from one area to another area and their establishment in the latter. cf. ecesis.

Key Species: (1) Forage species whose use serves as an indicator to the degree of use of associated species. (2) Those species which must, because of their importance, be considered in the management program.

Kind of Animal: An animal species or species group such as sheep, cattle, goats, deer, horses, elk, antelope, etc. cf. class of animal.

Land Use Planning (rangelands): The process by which decisions are made on future land uses over extended time periods that are deemed to best serve the general welfare. Decision-making authorities on land uses are usually vested in state and local governmental units, but citizen participation in the planning process is essential for proper understanding and implementation, usually through zoning ordinances.

Leaf Area Index (LAI): The ratio of the total upper leaf surface of the plant community to the corresponding ground area expressed as a proportion. LAI may exceed 1.

Life-Form: Characteristic form or appearance of species at maturity, e.g., tree, shrub, herb, etc.

Light Grazing: A comparative term which indicates that the stocking rate of one pasture is relatively less than that of other pastures. Often erroneously used to mean under use. cf. heavy and moderate grazing.

Litter (rangelands): The uppermost layer of organic debris on the soil surface; essentially the freshly fallen or slightly decomposed vegetal material.

Mixed Grazing: Grazing by two or more species of grazing animals on the same land unit, not necessarily at the same time but within the same grazing season.

Moderate Grazing: A comparative term which indicates that the stocking rate of a pasture is between the rates of other pastures. Often erroneously used to mean proper use. cf. heavy and light grazing.

Monitoring (rangelands): The orderly collection, analysis, and interpretation of resource data to evaluate progress toward meeting management objectives. This process must be conducted over time in order to determine whether or not management objectives are being met.

Multiple Use: Use of range for more than one purpose, i.e., grazing of livestock, wildlife production, recreation, watershed and timber production. Not necessarily the combination of uses that will yield the highest economic return or greatest unit output. Use of range for more than one purpose, i.e., grazing of livestock, wildlife production, recreation, watershed and timber production. Not necessarily the combination of uses that will yield the highest economic return or greatest unit output.

Native Species: A species which is part of the original fauna or flora of the area in question. Syn. Indigenous. Cf. introduced and resident species.

Net Primary Production: The net increase in plant biomass within a specified area and time interval, i.e. primary production minus that used in metabolic processes.

Niche (rangelands): The ecological role of a species in a community.

Non-Selective Grazing: Utilization of forage by grazing animals so that all forage species and/or all plants within a species are grazed. cf. mob grazing. Non-selective grazing is generally attempted by using high stocking rates or high stocking densities during short time periods. In practice, non-selective grazing is achieved rarely.

Noxious Species: A plant species that is undesirable because it conflicts, restricts, or otherwise causes problems under management objectives. Not to be confused with species declared noxious by laws concerned with plants that are weedy in cultivated crops and on range.

Nutritive Value: Relative capacity of a given forage or other feedstuff to furnish nutrition for animals. In range management, the term is usually prefixed by high, low or moderate.

Open Herding: Allowing a herd to spread naturally while grazing. cf. free ranging.

Opportunistic Species: A species adapted for utilizing variable, unpredictable or transient environments; tends to be characteristic of ephemeral plants.

Oven-Dry Weight: The weight of a substance after it has been dried in an oven at a specific temperature to equilibrium.

Overuse: Utilizing an excessive amount of the current year's growth which, if continued, will result in range deterioration. cf. overgrazing.

Paddock: (1) A grazing area that is a subdivision of a grazing management unit, and is enclosed and separated from other areas by a fence or barrier. (2) A relatively small enclosure used as an exercise and saddling area for horses, generally adjacent to stalls or stable. cf. grazing.

Palatability: The relish with which a particular species or plant part is consumed by an animal.

Pan (Soils): Horizon or layer in soils that is strongly compacted, indurated, or very high in clay content. cf. caliche, claypan, hardpan.

Percent Use: Grazing use of current growth usually expressed as a percent of the current growth (by weight) which has been removed. cf. degree of use.

Plant Community: An assemblage of plants occurring together at any point in time, thus denoting no particular successional status. A unit of vegetation.

Plant Succession: Vegetation change.

Preferred Species: Species that are preferred by animals and are grazed by first choice.

Prescribed Burning: The use of fire as a management tool under specified conditions for burning a predetermined area. cf. maintenance burning.

Primary Productivity: The rate of conversion of solar to chemical energy through the process of photosynthesis.

Pristine: A state of ecological stability or condition existing in the absence of direct disturbance by modern man.

Propagule: Any part of an organism, produced sexually or asexually that is capable of giving rise to a new individual.

Proper Grazing: The act of continuously obtaining proper use.

Proper Stocking: Placing a number of animals on a given area that will result in proper use at the end of the planned grazing period. Continued proper stocking will lead to proper grazing.

Proper Use Factor: An index to the grazing use that may be made of a specific forage species, based on a system of range management that will maintain the economically important forage species, or achieve other management objectives such as maintenance of watersheds, recreation values, etc.

Range Condition: Historically, has usually been defined in one of two.

Ways: (a) a generic term relating to present status of a unit of range in terms of specific values or potentials. Specific values or potentials must be stated. (b) the present state of vegetation of a range site in relation to the climax (natural potential) plant community for that site. It is an expression of the relative degree to which the kinds, proportions, and amounts of plants in a plant community resemble that of the climax plant community for the site. This term is being phased out. Preferred terms are successional status and range similarity index.

Range Degradation: The process that leads to an irreversible reduction in capability of an ecological site to produce vegetation.

Range Improvement: Any activity or program on or relating to rangelands which is designed to improve production of forage, change vegetation composition, control patterns of use, provide water, stabilize soil and water conditions, or provide habitat for livestock and wildlife.

Range Management: A distinct discipline founded on ecological principles and dealing with the use of rangelands and range resources for a variety of purposes. These purposes include use as watersheds, wildlife habitat, grazing by livestock, recreation, and aesthetics, as well as other associated uses.

Salt Lick: Spots containing unusually large quantities of salts in the soil where animals consume the soil to obtain salt.

Seasonal Use: (1) Synonymous with seasonal grazing, (2) Seasonal preference of certain plant species by animals.

Seed Scarification: Mechanical or acid treatment of seed-coats to improve water absorption and enhance germination.

Seedbed Preparation (rangelands): Soil treatment prior to seeding to: (1) reduce or eliminate existing vegetation, (2) reduce the effective supply of weed seed, (3) modify physical soil characteristics and (4) enhance temperature and water characteristics of the microenvironment.

Semiarid: A term applied to regions or climates where moisture is normally greater than under arid conditions, but still definitely limits the production of vegetation. The upper limit of average annual precipitation in the cold, semiarid regions is as low as 15 inches (380 mm), whereas in warm tropical regions it is as high as 45–50 inches (1,100–1,300 mm).

Short-Duration Grazing: Grazing management whereby relatively short periods (days) of grazing and associated non-grazing are applied to range or pasture units. Periods of grazing and non-grazing are based upon plant growth characteristics. Short-duration grazing has nothing to do with intensity of grazing use. cf. grazing system.

Species Composition: The proportions of various plant species in relation to the total on a given area. It may be expressed in terms of cover, density, weight, etc.

Standing Crop: The total amount of plant material per unit of space at a given time. Often is divided into above ground and below ground portions and further may be modified by the descriptors "dead" or "live" to more accurately define the specific type of biomass.

Stocking Density: The relationship between number of animals and the specific unit of land being grazed at any one point in time. May be expressed in animal units per unit of land area (animal units at a specific time/area of land). cf. stocking rate.

Stocking Rate: The relationship between the number of animals and the grazing management unit utilized over a specified time period. May be expressed as animal units per unit of land area (animal units over a described time period/area of land). cf. stocking density.

Strip Grazing: Confining animals to an area of grazing land to be grazed in a relatively short period of time, where the paddock size is varied to allow access to a specific land area. Strip grazing may or may not be a form of rotational stocking, depending on whether or not specific paddocks are utilized for recurring periods of grazing and rest. cf. rotational stocking, ration grazing.

Stubble: The basal portion of herbaceous plants remaining after the top portion has been harvested either artificially or by grazing animals.

Succession: The progressive replacement of plant communities on a site which leads to the potential natural plant community; i.e., attaining stability. Primary succession entails simultaneous succession of soil from patent material and vegetation. Secondary succession occurs following disturbances on sites that previously supported vegetation and entails plant succession on a more mature soil. cf. plant succession.

Supplement (rangelands): Nutritional additive (salt, protein, phosphorus, etc.) intended to remedy deficiencies of the range diet.
Supplemental Feeding: Supplying concentrates or harvested feed to correct deficiencies of the range diet. Often erroneously used to mean emergency feeding. cf. maintenance feeding.

Supplemental Feeding: Supplying concentrates or harvested feed to correct deficiencies of the range diet. Often erroneously used to mean emergency feeding. cf. maintenance feeding.

Terracing: Mechanical movement of soil along the horizontal contour of a slope to produce an earthen dike to retain water and diminish the potential of soil erosion.

Trampling: Treading underfoot; the damage to plants or soil brought about by movements or congestion of animals.

Trend (Range Trend): Trend in range condition or successional status should be described as up, down or not apparent. Up represents a change toward climax or potential natural community; down represents a change away from climax or potential natural community; and not apparent indicates there is no recognizable change. This category is often recorded as static or stable. There is no necessary correlation between trends in resource value ratings, vegetation management status, and trend in range condition or successional status.

Understory: Plants growing beneath the canopy of other plants. Usually refers to grasses, forbs and low shrubs under a tree or shrub canopy. cf. overstory.

Undesirable Species: (1) Species that conflict with or do not contribute to the management objectives. (2) Species that are not readily eaten by animals.

Ungulates: Large mammals with hooves.

Vigor: Relates to the relative robustness of a plant in comparison to other individuals of the same species. It is reflected primarily by the size of a plant and its parts in relation to its age and the environment in which it is growing. Syn. plant vigor. cf. hybrid vigor.

Watershed (rangelands): (1) A total area of land above a given point on a waterway that contributes runoff water to the flow at that point. (2) A major subdivision of a drainage basin.

Xeric: Having very little moisture; tolerating or adapted to dry conditions.

Biotic: Refers to living components of an ecosystem, e.g., plants and animals.

Indigenous knowledge: A body of knowledge built up. by a group of people through generations of living in close contact with. Nature.

Landscape Connectivity: The degree to which the landscape enables or hinders movement among resource patches. Alternatively, connectivity may be continuous across a landscape.

Legitimization: To making something legal or legalized.

Over-grazing: Over-grazing occurs when plants are exposed to intensive grazing for extended periods of time, or without sufficient recovery periods. Overgrazing reduces the usefulness, productivity, and biodiversity of the land and is one cause of desertification and erosion.

Sustainable Land Management (SLM): “The use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions”.

Under-grazing: Under-grazing means permitting the growth, quality or species composition of grazed vegetation to deteriorate significantly through the lack of, or through insufficient, grazing or management.

IUCN Protected Area Categories: Category Ia: Strict Nature Reserve.

Category Ib: Wilderness Area. Category II: National Park. Category III: Natural Monument or Feature. Category IV: Habitat/Species Management Area. Category V: Protected Landscape/Seascape. VI Protected area with sustainable use of natural resources.
https://www.iucn.org/theme/protected-areas/about/protected-area-categories

INTERNATIONAL UNION
FOR CONSERVATION OF NATURE
Regional Office for West Asia

Abdel Latif Salah Street, bldg.29, Sweifiyeh,
Amman, Jordan
Tel : +962 (6) 5546912/3/4
Fax: +962 (6) 5546915
www.iucn.org
www.iucn.org/resources/publications