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ENVIRONMENTALLY SOUND DESIGN (ESD) SECTOR ENVIRONMENTAL GUIDELINES

SMALL-SCALE DRYLAND AGRICULTURE

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Cover Photo: Small-scale crops marketing. Photo credit: SAIEA

TABLE OF CONTENTS

About this document and the *Sector Environmental Guidelines*

This document presents one sector of the *Sector Environmental Guidelines* prepared for USAID under the Agency's Global Environmental Management Support Project (GEMS). All sectors are accessible at www.usaidgems.org/bestPractice.htm.

Purpose. The purpose of this document and the *Sector Environmental Guidelines* overall is to support environmentally sound design and management (ESDM) of common USAID sectoral development activities by providing concise, plain-language information regarding:

- the typical, potential adverse impacts of activities in these sectors;
- how to prevent or otherwise mitigate these impacts, both in the form of general activity design guidance and specific design, construction and operating measures;
- how to minimize vulnerability of activities to climate change; and
- more detailed resources for further exploration of these issues.

Environmental Compliance Applications. USAID's mandatory life-of-project environmental procedures require that the potential adverse impacts of USAID-funded and managed activities be assessed prior to implementation via the Environmental Impact Assessment (EIA) process defined by 22 CFR 216 (Reg. 216). They also require that the environmental management/mitigation measures ("conditions") identified by this process be written into award documents, implemented over life of project, and monitored for compliance and sufficiency.

The procedures are USAID's principal mechanism to assure ESDM of USAID-funded Activities—and thus to protect environmental resources, ecosystems, and the health and livelihoods of beneficiaries and other groups. They strengthen development outcomes and help safeguard the good name and reputation of USAID.

The Sector Environmental Guidelines directly support environmental compliance by providing: information essential to assessing the potential impacts of activities, and to the identification and detailed design of appropriate mitigation and monitoring measures.

However, the Sector Environmental Guidelines *are **not** specific to USAID's environmental procedures. They are generally written, and are intended to support ESDM of these activities by all actors, regardless of the specific environmental requirements, regulations, or processes that apply, if any.*

Region-Specific Guidelines Superseded. The *Sector Environmental Guidelines* replace the following region-specific guidance: (1) *Environmental Guidelines for Small Scale Activities in Africa* ; (2) *Environmental Guidelines for Development Activities in Latin America and the Caribbean*; and (3) Asia/Middle East: *Sectoral Environmental Guidelines*. With the exception of some more recent Africa sectors, all were developed over 1999–2004.

Development Process & Limitations. This document represents a new sector in the *Sector Environmental Guideline* series, fully updating and going beyond dryland agriculture content in the "agriculture and irrigation" guidelines.

Further, *The Guidelines* are not a substitute for detailed sources of technical information or design manuals. Users are expected to refer to the accompanying list of references for additional information.

Comments and corrections. Each sector of these guidelines is a work in progress. Comments, corrections, and suggested additions are welcome. Email: gems@cadmusgroup.com.

Advisory. *The Guidelines are advisory only. They are not official USAID regulatory guidance or policy. Following the practices and approaches outlined in the Guidelines does not necessarily assure compliance with USAID Environmental Procedures or host country environmental requirements.*

LIST OF ACRONYMS

AIDS	Acquired Immunodeficiency Syndrome
AR4	Fourth Assessment Report (of IPCC)
C	Carbon
CO_2	Carbon Dioxide
CA	Conservation Agriculture
CBD	United Nations Convention on Biological Diversity
CBNRM	Community Based Natural Resource Management
CBO	Community Based Organisations
CC	Climate Change
CF, CFU	Conservation Farming, Unit
EIA	Environmental Impact Assessment
ESD	Environmentally Sound Design
ESDM	Environmentally Sound Design and Management
FAO	Food and Agriculture Organization
GCM	General Circulation Model
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HWCM	Human Wildlife Conflict Management
HIV	Human Immunodeficiency Virus
INP	Indigenous Natural Products
IPCC	Intergovernmental Panel on Climate Change
ISLM	Integrated Sustainable Land Management
MDG	Millennium Development Goal
N	Nitrogen
P	Phosphorus
RCM	Regional Circulation Model

SACSCC	South African Country Study on Climate
SADC	Southern African Development Community
SD	Sustainable Development
SEA	Strategic Environmental Assessment
SEMP	Strategic Environmental Management Plan
SLM	Sustainable Land Management
SOM	Soil Organic Matter
TAR	Third Assessment Report (from IPCC)
UNCCD	United Nations Convention on Combating Desertification
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNSO	United Nations Sudano-Sahelian Office
WWF	World Wildlife Fund

SMALL-SCALE DRYLAND AGRICULTURE

Drylands are distinguished by a set of characteristic features relating to climate, soils, vegetation, livestock keeping, and ethnic and governance attributes.

In turn, drylands lend themselves to specific agricultural practices. By understanding the defining features and limitations of drylands, agricultural programs can best leverage available resources.

Farmers in Ethiopia threshing teff. Photo credit: SAIEA.

INTRODUCTION

The world's drylands include hyperarid, arid, semi-arid and dry subhumid areas where rainfall is highly variable, droughts are common and water is the principal limiting factor for agriculture. Dryland soils, which are characterized by low levels of moisture, organic matter, and biological activity, often display poor fertility. When inappropriately utilized for agriculture, these soils are susceptible to rapid fertility loss, erosion, desertification, and salinization.

The native vegetation of the world's drylands is naturally adapted for high water-use efficiency. Plants are typically able to survive high temperatures and periods of drought and the prevalent leguminous woody species play an important role in maintaining dryland soil fertility, as their roots support nodules containing nitrogen-fixing bacteria. Consequently, the loss of natural vegetation cover (through overgrazing and/or deforestation) on drylands can dramatically increase the risk for reduced soil fertility, erosion, and/ or bush encroachment.

Despite the stringent climatic and topographical constraints on drylands, rain-fed subsistence food production (typically mixed crop and/or livestock farming on smallholdings) remains a predominant livelihood activity for the majority of people living in these areas. Indigenous crops such as millet and teff are well adapted to dryland conditions, but others (for example maize), which are not particularly arid-adapted, have become popular amongst many small dryland farmers in the last 100 years. While traditional methods of cropping (e.g., intercropping and agroforestry) have proved to be resilient to dryland conditions, monoculture is still frequently practiced, at times with large environmental costs.

Livestock used traditionally on drylands (including indigenous cattle, camels, goats, and fat-tailed sheep) have high tolerance for water stress. They are generally less susceptible to local tick and other vector-borne diseases, and are able to survive on low-quality forage. Traditional livestock farming practices - in particular nomadic pastoralism - developed to suit the dryland conditions of high rangeland and climatic variability, but these practices are no longer as prevalent as they once were. Most animal husbandry in dryland areas is becoming increasingly sedentary and localized, and overgrazing is a constant, particularly in drought years.

A widowed farmer casts high-yield seeds on her field in Jawzjan Province, northern Afghanistan. Photo credit: USAID/Afghanistan.

The root causes of many of the impacts that arise from agricultural activities on drylands are varied. These include: inadequate knowledge of best practice poorly considered policies that encourage subsidies for water and agrochemicals, uncertainty about land tenure, government control over markets and pricing, poorly supported resettlement programs, and non-participatory and undifferentiated extension support. Ultimately, the combination of excessive use of agrochemicals, the over-abstraction of water, land clearing practices (such as slash-and-burn agriculture and deforestation), overgrazing, and inappropriate land preparation methods (for example, deep tillage using disc harrowers) can result in biodiversity loss, soil erosion, reduced soil fertility, and reduced local water availability and quality – all of which translate into fewer livelihood options, increasing rural poverty and vulnerability to climate change.

Waterlogging, soil pH changes, and soil salinization are common environmental problems associated with irrigation projects on drylands. Weaker community ties, increased inequity, increased exposure to poisonings (linked to contact with agro-chemicals), and vector-borne water related diseases are also experienced. Institutions working to improve crop production in dryland countries should reconsider the need to use commercial weed-killers. In the medium to long term, these can lead to the proliferation of persistent new 'superweeds', dependency on genetically modified crops (resistant to the weed-killer), rising farm costs, lower crop quality and yields, higher food prices, and increasing rates of soil and water pollution (through aerial drift).

For subsistence farmers that are already living off marginal land and who have limited opportunities to adapt and apply other livelihood options, the impacts of climate change are likely to be highly significant at the household level. The threat of raised global temperatures, higher climatic variability, and the possibility of more frequent and prolonged droughts will cause changes in soils, vegetation and water availability which, in turn, will affect all aspects of dryland agriculture by 2050 – 2080. In order to reduce vulnerability to the foreseen impacts, it is considered best practice to choose land-management options that enhance carbon sequestration and, concurrently, prevent erosion and land degradation.

Sustainable land management (SLM) practices aim to prevent and mitigate the impacts associated with inappropriate agriculture in drylands by managing agro-ecosystems for sustained productivity, increased profits, and improved food security whilst reversing and preventing water stress, soil erosion and desertification. There is no single solution that can be used to solve the many challenges that face small-scale dryland crop farmers; stakeholders need to design the most appropriate sustainable practices for their specific climatic, geographical, and socio-economic conditions.

This guideline details how conservation agriculture, rain water harvesting, agroforestry (especially with indigenous trees), the use of cross-slope barriers, integrated soil fertility management, integrated crop and livestock management, sustainable forest management, and improved irrigation design can all be employed. When these strategies are effectively implemented, in combination or alone, they can help conserve water, enhance soil fertility, improve crop water-use efficiency, and boost rangeland health, while preventing the unintended negative consequences associated with dryland farming.

Ensuring environmental and social integrity is essential for long term sustainability of agriculture in drylands. The main mechanism to protect environmental resources, ecosystems and the health and livelihoods of beneficiaries of USAID programs, is through the EIA process as defined by Title 22 of the Code of Federal Regulations (22 CFR) part 216. The Environmental Procedures Training Manual (EPTM); the document on Environmental Compliance Procedures and the Environmental Compliance Management System, Standard Operating Procedure Manual can all be referred to, to assist USAID staff and their implementing partners in their attempts to meet EIA requirements and ensure that the potential environmental and social impacts of agricultural projects on drylands are identified, avoided and/or mitigated. In order to be successful, EIAs must also pay specific attention to indigenous and community participation in decision making, community access to benefits, women’s involvement and human health issues.

PART 1: CHARACTERISTICS OF DRYLANDS

GENERAL CHARACTERISTICS AND DISTRIBUTION

The Food and Agriculture Organization (FAO) (2004) describes drylands as *areas where the average rainfall is less than the potential moisture loss through evaporation and transpiration*. An aridity index[1] is used to classify drylands into hyperarid, arid, semi-arid and dry subhumid areas (see below table). Aridity is also assessed by the length of the growing season based on how many days the water balance allows for rain-fed crop growth. In the particularly harsh dryland environments of Africa and West Asia, water is the principal factor limiting crop yield and primary production on rangelands.

Dryland characteristics (adapted from FAO 2004)[2]

CLIMATE CLASSIFICATION	ARIDITY INDEX PRECIPITATION / POTENTIAL EVAPO-TRANSPIRATION (P/PET)	AVERAGE ANNUAL RAINFALL (MM) AND VARIABILITY	GROWING SEASON (DAYS) & TYPICAL CROPS	PASTORALISM	EXAMPLES OF BIOMES
HYPERARID	< 0.05	150 mm Inter-annual variability 100%	0 days (unless irrigated) No rain-fed crops	Very limited, fodder available only for short periods (<4 months)	Desert
ARID	0.05 - 0.20	150 - 250 mm Inter-annual variability 50 - 100 %	< 70 days No rain-fed crops	Marginal pasture, available for short periods. Mainly small stock & cattle in transhumance systems	Desert, xeric shrubland, desert scrub
SEMI-ARID	0.20 - 0.50	250 – 500 mm Inter-annual variability 25 – 50 %	70 -119 days Bulrush millet*, sorghum*, sesame (suitable for rain-fed agriculture)	Large and small stock	Savanna, Steppe

[1] Aridity Index = Precipitation (P)/Potential Evapotranspiration (PET)

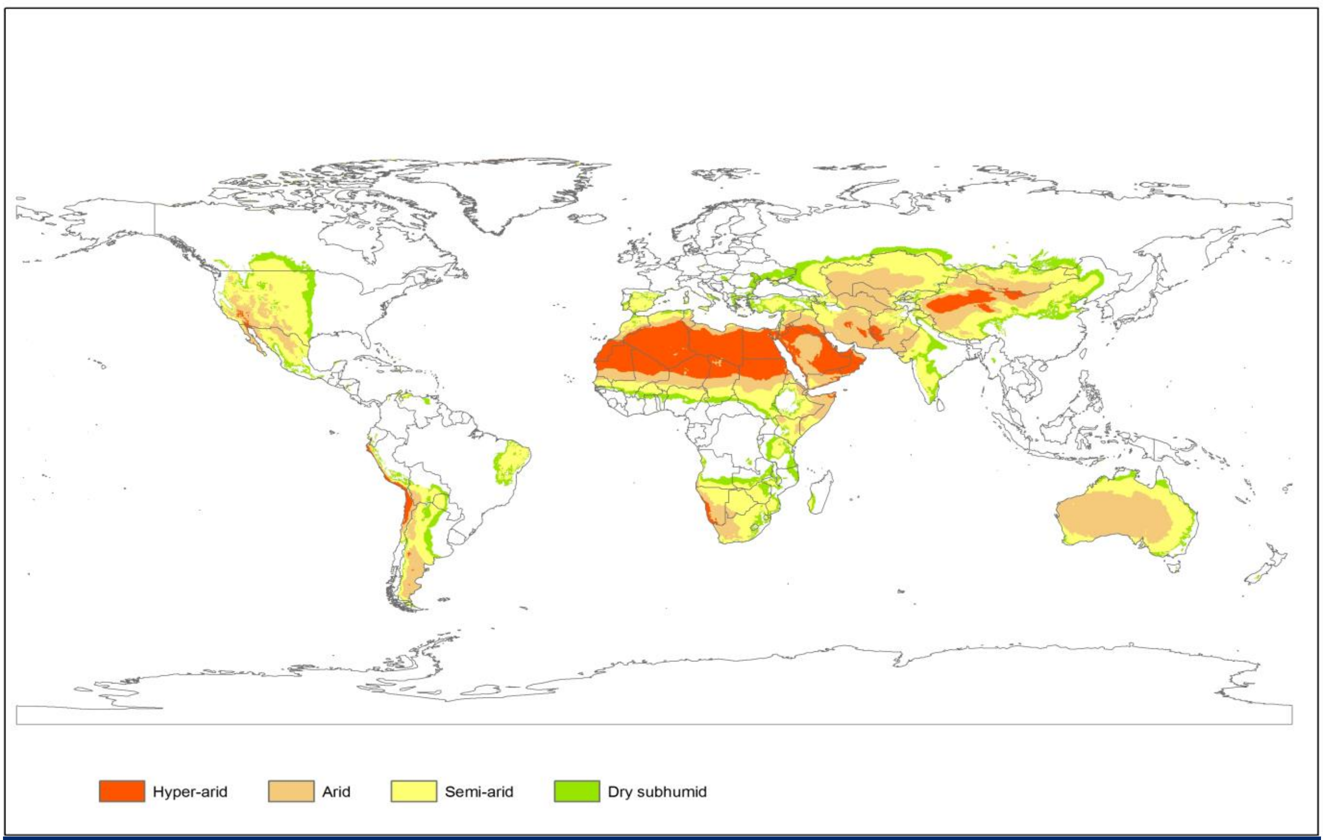
[2] See also Millennium Ecosystem Assessment (2005) *Dryland Systems*. Chapter 22, pp. 623–62. Available at: http://www.millenniumassessment.org/documents/document.291.aspx.pdf;

DRY SUB-HUMID	0.50 - 0.65	500 – 700 mm Inter-annual variability < 25 %	120 -179 days Maize, bean, groundnut*, peas, barley, wheat, teff* (suitable for rain-fed agriculture)	Large and small stock	Open woodland, savanna, Steppe

**Traditional crops well adapted to dryland conditions*.

Most dryland areas are located between the latitudes of 20° and 35° (see below figure on global drylands located in warm-weather climates). About 2 billion people, or more than 35% of the global population, live in drylands (United Nations Environmental Programme (UNEP) 2011 estimates), in many cases under extremely poor conditions. The main semi-arid areas are located on each side of the arid zone and include Mediterranean-type and monsoonal-type climates[3]. Another type of dryland (not considered in this document) is the cold desert, which is generally located in high-altitude continental areas.

Drylands cover 40 % of the earth's land surface, including 15% of Latin America , 66% of Africa, 40% of Asia and 24% of Europe. Developing nations support a significantly greater proportion of all drylands (72%), and almost 100% of all hyper-arid land occurs in the developing world.



Global Map of Drylands Located in Hyper-Arid, Arid, Semi-Arid, and Dry Subhumid Climates.

[3] Mediterranean climates are characterized by cold wet winter and dry hot summers whereas monsoonal-type climates have hot wet summers and warm dry winters.

DRYLAND SOILS AND NATURAL VEGETATION

SOILS

Because chemical breakdown is retarded by low moisture levels, dryland soils tend to be thin and coarse with slow rates of decomposition. They generally have low levels of organic matter and biological activity. These characteristics, combined with the fact that vegetation cover is often sparse so that the binding function of roots is absent, make dryland soils susceptible to erosion. Also, high evaporation rates and the shallow depth of soil means that salts are easily drawn upwards and precipitated in the surface layers. This process is common where irrigation water is applied to dryland soils, mobilizing the salts to an extent that salinization becomes pronounced.

Desertification

Desertification threatens one-quarter of the earth's land and costs US$42 billion every year (UNEP, 2000). It is caused by unsustainable land management practices, which result from inappropriate farming techniques and/or increasing population pressure, which leads to land degradation. About 65 percent of all arable land has already lost some of its biological and physical functions and drylands are particularly susceptible (United Nations Sudano-Sahelian Office (UNSO 2002); UNEP 2000). Desertification will be exacerbated by global warming

(See climate change section below).

The low organic content of dryland soils results in low fertility, low germination rates, and high seedling mortality; the main causes of low plant productivity in these regions.

NATURAL VEGETATION

Natural vegetation ranges from almost nothing on barren plains, to grasslands, shrublands, savannahs, and dry woodlands. Dryland plants are able to survive irregular rainfall, high solar radiation and periods of drought. They are adapted to arid soils and display high water-use efficiency. Leguminous woody species play an important role in maintaining dryland soil fertility as their roots support nodules containing nitrogen-fixing bacteria. Natural woodlands on drylands have traditionally been used in the developing world for fuel wood and gathering wild foods (including bushmeat, berries, fruits, tubers etc.[4]), but these livelihood activities are now severely threatened by human population pressure, land-use changes, and loss of biodiversity.

Dryland plants play a vital role in protecting the soil from wind and water erosion. The loss of vegetation cover results in a very high risk of reduced soil fertility and erosion.

[4] A great diversity of wild plants and animals on drylands were traditionally used during lean times as a 'safety net' for vulnerable people during times of drought. Forty-seven such species of herbs, grasses, trees and shrubs were utilized by villagers during the drought in the Sahel from 1972 – 1974.

DESERTIFICATION AND LAND DEGRADATION

These terms are often used loosely and interchangeably. Land degradation can occur anywhere, but when it occurs in drylands it is also called desertification - meaning becoming more desert-like in terms of lowered productivity and carrying capacity. Desertification is often only reversible with major mitigation costs.

SMALL-SCALE AGRICULTURE AND LIVELIHOODS ON DRYLANDS

Despite the low and erratic rainfall experienced on drylands, rain-fed subsistence food production, typically mixed crop and/or livestock farming on smallholdings, remains a predominant livelihood activity for the majority of people living in these areas. Shifting cultivation (slash and burn) on wooded grasslands is also commonly practiced in semi-arid/sub-humid areas.

In addition to the cereals suited to dryland cropping mentioned in the above table, irrigated dryland crops also include oil crops (mostly rape and linseed), fruits, vegetables, herbs and spices. Crops such as millet, sorghum and teff are well adapted to dryland conditions, but other crops which are not particularly arid-adapted (e.g., maize) have become the popular choice amongst many small and large-scale dryland farmers, particularly in Africa. Traditional methods of cropping e.g., intercropping and agroforestry, have proved to be far more resilient to dryland conditions. Nevertheless monoculture is often practiced, sometimes with large environmental costs.

Livestock used traditionally on drylands (e.g., Sanga and Boran cattle, camels, goats, fat-tailed sheep) have physiological adaptations such as fat storage and tolerance for water stress, which make them resilient to dry conditions. These animals are also less susceptible to local tick and other vector-borne diseases, and are able to survive on low-quality forage which is often too tough and salty for other species' tolerances.

Cattle gather at a drinking trough. Photo credit: SAIEA.

Traditional livestock farming practices have developed to suit the conditions of rangeland variability – both across space and in time – found in dry climates. For instance, rainfall that is patchily distributed, and that shows great seasonal differences, both of which determine pasture availability, also demand that movement of herds is practiced. The great wildlife migrations of the world, such as saiga antelope in the steppe and wildebeest in the Serengeti, attest to the natural response of grazing animals to varying conditions. Similarly, traditional transhumance practiced by the Fulani in West Africa, Maasai in East Africa, and Bedouins in the Middle East, exemplify this principle.

The following characteristics of drylands have a major bearing on agriculture:

- *Low average rainfall with high inter-annual variability;*
- *High temperatures and potential evaporation rates (more than double the rainfall);*
- *Low incidence of runoff;*
- *Poor soils with low fertility (SOM 1 - < 0.5 %), low nutrient content (particularly N), frequent water stress and correspondingly low productivity;*
- *High vulnerability to overgrazing, soil erosion, salinization; and*
- *High vulnerability to droughts, floods, and to the negative impacts of climate change and increased demand from numbers of people and livestock.*

Agriculture limited scope grant agreement-Yemen

The USAID/Yemen Agriculture Limited Scope Grant Agreement (LGSA), operated from 2008-2010 with the following primary objectives: provision of technical support to boost agricultural promotion and trade, capacity-building for agricultural extension agents, farmers and community groups, and development of linkages in the private sector.

Within these objectives, LGSA implemented the following activities to support dryland agriculture productivity and livestock management.

Horticulture

- Delivery of extension workshops on topics such as: Application of fertilizers; Irrigation techniques; Water conservation techniques; Marketing management, including crop sorting and packaging and; Application of above to boost farmer productivity
- Establishment of pilot farms for the following crops in the following governorates: **Amran**: olives, grapes and coffee; **Shabwah. Marib and AI-Jawf**: date palms; **Shabwah**: fish fanning, fish aggregation devices and; **Sa'ada**: pomegranates, apples, olives and date palms
- Establishment of baseline data regarding horticulture productivity

Livestock

- Establishment of animal fattening pilots in all governorates, with particular focus on sheep.
- Provision of services to combat disease outbreaks
- Delivery of workshops on topics such as, animal feed, shearing, clipping animal hooves, fattening techniques, increasing farmer knowledge of animal diseases, and animal hygiene handling
- Establish baseline data regarding livestock productivity

The project implementers used baseline data on productivity in order to perform comparative analyses throughout implementation to gauge the efficacy of the targeted programming. Additionally, to help minimize potential environmental impacts, horticulture techniques did not involve the promotion of pesticides or agro-chemicals.

Source: USAID. Agriculture Limited Scope Grant Agreement. Initial Environmental Examination, USAID, 2009.

PART 2: CROSS CUTTING ISSUES

Sustainable and environmentally sound agriculture and livestock management on drylands must address a common set of challenges. Resilience of production, good governance aligning with agricultural development efforts, responsiveness to a changing climate, and integration of social considerations are essential characteristics of successful project design and implementation.

A farmer in Pakistan gathers his harvest from drought-tolerant wheat. Photo credit: Khaukab Jhumra Smith, USAID.

RESILIENCE

Dryland systems are highly vulnerable to inter-annual climate fluctuations, global warming and climate change. Although improved farm outputs are a major aim of many government and NGO support programs in dryland developing countries, these outcomes should not be at the cost of people's livelihoods, nor should they be at excessive cost to the environment. Support programs should aim to strengthen people's resilience and adaptability to unforeseen shocks through:

- Diversifying livelihood options;
- Providing access to, and tenure over, as many natural resources as possible (water, grazing, land, woodlands, indigenous natural products);
- Providing land tenure and embracing an on-farm contract grower approach;
- Being sensitive to the importance of social connectivity in rural communities (e.g., how the extended family can play an important role in helping people cope with natural mal-entities like floods and drought);
- Designing projects that are suited to the soils, climate, and social conditions that prevail in an area, using crops and livestock varieties that are suited to dryland conditions.
- Ensuring environmental integrity: avoiding any unnecessary pollution, biodiversity loss and land degradation. Healthy ecosystems provide a safety net for rural livelihoods and for medium and long term sustainability.

Natural ecosystems support all the essential ecological processes that underlie successful agriculture. If we allow environmental degradation and biodiversity loss, the Earth's ability to provide ecosystem goods and *services becomes severely challenged, and agriculture in drylands becomes increasingly difficult, expensive, and less productive.*

GOVERNANCE

Good governance is essential to realize an agriculture-for-development agenda, including both formal and customary governance structures. Governance problems such as inappropriate fertilizer and pesticide subsidies and misappropriation of funds are a major reason why many agriculture projects fail, but good governance can also be a factor in success.

User or management committees are informal governance structures frequently used to support local level participation in an activity and improve sustainability. Appropriately applied, the management committees function as the oversight and ruling body for local level operation and maintenance of assets. When properly structured, they can greatly improve the efficiency of repairs, increase the effectiveness of the infrastructure intervention, reduce cost, and build community cohesion as additional positive outcomes of the activity. But when they are improperly structured, or lack the proper participation, they can undermine the objectives of the program. For example, user committees for water control structures are critical to equitable allocation of resources and for ensuring repair; however, those user committees frequently do not, or cannot, determine how to integrate upstream landowners. Without inclusion of upstream farmers, water quality and watershed integrity can easily be degraded by hillside agriculture that washes massive amounts of topsoil into the streams and collects behind dams, rendering them useless.

Other more formal governance structures, particularly at the local level, can make big strides in the environmental soundness and sustainability of the overall project. For example, "dinas" (or social contracts) were emphasized as part of a traditional but legally recognized governance system for farmers in a Madagascar Food for Peace (FFP) Program. New dinas were developed with the user committees to strengthen their governance over the asset. Dinas were drafted to identify taxes for use of the structure, dictate repair schedules and participation, and even identify punishable infractions. This formal, yet locally relevant, governance component added strength and legitimacy to the environmental mitigation measures in place for the project.

Birner et al (2010) report on a range of promising governance interventions in South Asian countries — including decentralization and devolution, women's empowerment self-help groups, participatory planning, improved rights to information, and public-sector management reform. However, they point out that policy reform has often been stalled by vested interests, resource mismanagement, elite capture, and corruption. Strengthening internal accountability mechanisms in implementing agencies, improving the effectiveness of incentives and sanctions, and fostering professionalism are key strategies for improving governance in agriculture.

Liniger et al (2011) stress the importance of an enabling environment for best practices to be up-scaled and replicated. In particular, the institutional, policy and legal frameworks need to be in place and properly functional. These frameworks must enable and facilitate local participation, land-use planning, capacity building, monitoring and evaluation, and research.

The governance problems that can hamper a sustainable land use management agenda include:

INSTITUTIONAL

- Inappropriate national and local political agendas
- Lack of operational capacity
- Overlapping and unclear demarcation of responsibilities
- Ineffective decentralization
- Lack of good governance

POLICY / LEGAL FRAMEWORK

- Often there are laws in favor of sustainable land management, but they are not enforced
- Enforcement is difficult, costly and can create adverse relationships between government and land users

LAND TENURE AND USER RIGHTS

- Inappropriate land tenure policies and inequitable access to land and water
- Insecurity about private and communal rights
- Modern laws and regulations may enhance conflicts and insecurity if they ignore traditional user rights, by-laws and social and cultural norms

CLIMATE CHANGE

The Intergovernmental Panel on Climate Change (IPCC) has indicated that climate change will have far-reaching implications for future global food production. The threat of raised global temperatures, higher climatic variability and the possibility of more frequent and prolonged droughts in dryland areas by 2050 -2080, will cause changes in soils, vegetation and water availability (IPCC 2007). Elevated CO_2, raised temperatures and increasingly unpredictable precipitation could favor fast-growing, nutrient poor, weedy plants in dryland regions. As soils become drier they will become more vulnerable to desertification. The most significant impacts of climate change include:

- Increased water stress in plants, resulting in lower crop yields
- Higher irrigation water demand
- Increased risks of soil erosion and salinization
- Changes in the nutritional value of grasslands and lowered carrying capacity for livestock
- Reduced conception rates of livestock due to increasing thermal stress

- Increased climate variability and extreme droughts, leading to livestock losses
- Significant increase in water requirements for livestock to combat heat stress.

While determining the exact effects of climate change on dryland agriculture is difficult, it is certain that a decline in rainfall on drylands will lead to lowered production, regardless of how well the land is managed. For poor subsistence farmers that have limited opportunities to adapt and apply other livelihood options, the impacts of climate change are likely to be highly significant at the household level. In 2014, USAID's African & Latin American Resilience to Climate Change (ARCC) Initiative developed four papers on climate change adaptation. Specifically, these papers cover implementation, analysis, economic evaluation of, and engaging stakeholder participation in, climate change adaptation activities and may offer program implementers a strong resource during program design and planning (see reference section for link).

Strengthening Governance through CBNRM

Key strategies for improving governance in agriculture rely on strengthening internal accountability mechanisms in implementing agencies, using strategic incentives and regulations, and fostering professionalism. Community-based natural resource management (CBNRM) is a powerful tool for achieving these aims.

For example, USAID's Living In a Finite Environment (LIFE) Project in Namibia addressed a wide range of resources with an initial focus on wildlife conservation, which has subsequently extended to managing other agricultural resources too. Community-based organizations were trained in financial and business management, annual planning, and strategic collaborations. This has improved accountability in the Community Conservancies. Law enforcement responsibilities have been granted to Conservancy Game Guards so that they are allowed to apprehend and arrest, and are incentivized to do so through the benefit-sharing principle of a Conservancy. Additionally, establishment of water point and grazing committees, set up to control and manage use of communal water points, including water for livestock, has empowered communities and made them accountable for their decisions and finances.

Source: NACSO 2011, USAID 2008.

CLIMATE CHANGE AND DRYLAND SOILS

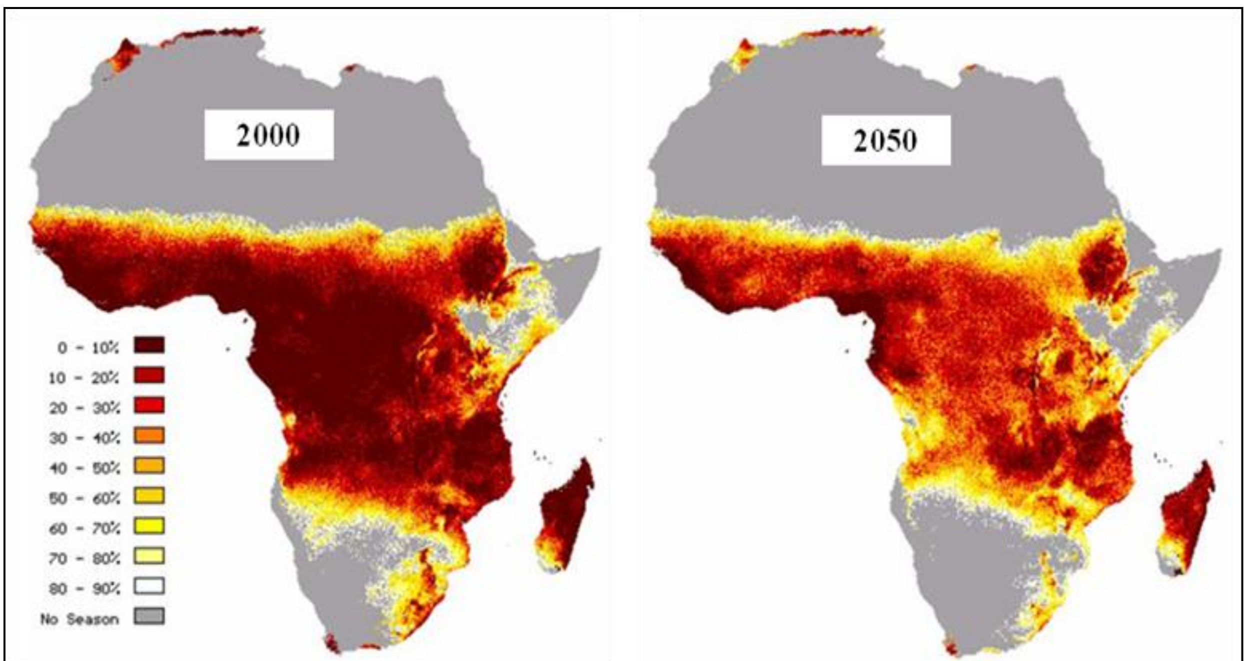
Soils act as an important reservoir for carbon. Certain agricultural outcomes (e.g., land clearing and soil degradation) are recognized as some of the major causes of increasing carbon emissions (IPCC 2007; FAO 2004). Consequently, any action to sequester carbon in biomass and soils will generally increase the organic matter content of soils, which, in turn, will have a positive impact on land productivity (FAO 2004). Thus, it is considered best practice to choose land-management options that enhance carbon sequestration and concurrently boost plant productivity and prevent erosion (see below table).

Some agricultural practices that enhance productivity and increase the amount of carbon in dryland soils (FAO, 2004)

TRADITIONAL PRACTICES	RECOMMENDED
Deep plough/ tillage	Ripper furrowing or zero-till
Crop residue removal or burning	Crop residues returned to soil as mulch
Summer fallow	Growing cover crops
Regular fertilizer use	Judicious use of fertilizers, integrated nutrient management, soil-site specific management
No water management	Water management/conservation, irrigation, water table management
Fence-to-fence cultivation	Conversion of marginal lands to nature conservation
Monoculture	Improved farming systems with inter-cropping and several crop rotations
Land use and water management within political boundaries	Cross-boundary, Integrated watershed management
Draining wetlands	Preserving and restoring wetlands

POTENTIAL IMPACTS OF CLIMATE CHANGE ON DRYLAND AGRICULTURE

Rain-fed cropping practices in some drylands of the world (e.g., those in sub-Saharan Africa) are currently very near their margins of production, and increasing temperatures in these countries, combined with a steady decline in rainfall[5] may lead to reduced annual harvests and a corresponding



Predicted impact of climate change on crop failure probability in Africa by 2050 Source: Turpie et al. 2010.

[5] e.g. predictions based on several GCMs suggest that there is a moderate likelihood that countries in drought-prone southern Africa will experience a 10-20% decline in rainfall by 2050, and a 20-30% decline by 2080 (Turpie *et al.*. 2010)

trend towards regular crop failure (Turpie *et al.* 2010) (see figure below). For example, the growing vulnerability of Ethiopia to climate variability has made the government prioritise, amongst other things, drought and crop insurance programs, smalll-scale irrigation and water harvesting schemes, and enhanced rangeland management practices in pastoral areas (World Bank 2011).

POTENTIAL IMPACTS OF CLIMATE CHANGE ON DRYLAND IRRIGATION

It is likely that most parts of the world will experience a higher relative irrigation water demand due to global warming, irrespective of how precipitation patterns are affected. Schulze *et al. (*2005) predict that virtually all irrigated lands in drought-prone southern Africa will require at least 10% more water applications by 2050. Other impacts linked to climate change could include:

- An increase in the prevalence of fast-growing weeds and crop pests;
- An increase in the rate of leaching of pesticides and fertilizers from irrigated land into rivers. If it rains after a recent application of agrochemicals then deep percolation beyond the root zone, or stormflow from the surface is likely to take place. This will cause an increase in water pollution (eutrophication); an impact that threatens freshwater and wetland ecosystems. Severe eutrophication in Lake Victoria demonstrates the risk of intensifying crop production with artificial fertilizers, where these have caused high nitrogen loads in the water and subsequent algal blooms. Lowered water quality impacts the food and livelihood security of local communities (Lubovich 2009).

POTENTIAL IMPACTS OF CLIMATE CHANGE ON DRYLAND GRAZING AND LIVESTOCK

The impacts of global warming on grazing and livestock health are expected to be severe:

- Reductions in forage quality and palatability could occur because of increasing carbon to nitrogen ratios, particularly on rangelands where low nutritional value is already a problem (in Tarr 1999).
- Declining vegetation cover will significantly increase the rate and extent of soil erosion (*ibid*).
- A reduction in ground cover and reduced Net Primary Productivity (NPP) is likely to occur throughout much of the world's drylands by 2050 (exacerbated by 2080) – particularly if expected temperature increases are accompanied by reduced annual rainfall. Vegetation shifts in spatial dominance will occur e.g., areas that currently support grassy savannah may shift to desert and arid shrubland - a situation that will have important implications for rangeland carrying capacity and livestock productivity (Midgley *et al.* 2005).
- With increasing aridity some drylands will become less suited to large stock husbandry and may have to shift to small stock. Areas currently only able to support small stock may have to give up free range animal husbandry altogether.
- Climate change will have direct impacts on livestock morbidity and mortality.
- Impacts of global warming on livestock are likely to include lower conception rates, increasing heat stress, and water requirements.

- Altered geographical ranges of livestock and wildlife diseases are expected as changes in temperature and precipitation affect the distribution, timing and intensity of both vector-borne and non-vector-borne diseases. Higher temperatures linked to climate change may shorten generation times and increase the number of generations of pathogens per year for, amongst others, anthrax, 'blackleg', fungi and parasitic worms (Dirkx *et al.* 2008). However, under a general aridification scenario, reduced risk of some livestock diseases could be accompanied by less stock diseases in previous sub-humid/humid areas.

INTEGRATING SOCIAL ISSUES INTO PROJECT IMPLEMENTATION

The integration of socio-economic issues into project implementation is essential to ensure sustainable development. Small-scale agricultural projects on drylands need to pay particular attention to:

- **Indigenous and community participation.** A lack of appreciation of people's knowledge of land management on drylands, as well as a disregard for their priorities as resource users, has led many development interventions to fail or to be rejected by local communities. In view of this, it is important for project implementers and evaluators to assess the degree to which a project has encouraged public participation in decision making and whether indigenous local knowledge has been consulted.

- **Community access to benefits.** EIAs should assess the degree to which communities have access to project benefits and the degree to which agricultural projects and programs are designed to improve household food security. Without benefit sharing, the long term sustainability of a project is doubtful.

- **Women's involvement and gender issues.** In developing countries rural women are generally responsible for caring for small livestock, vegetable gardens and gathering fuel, fodder, water, and wild foods. They control less than 2% of the land despite providing households with 80% of their food. Men are still largely responsible for land ownership, large stock management, decision-making and planning of farming activities. Both formal and customary land policies seldom account for impacts on women. Despite this, men increasingly leave degraded areas to look for jobs in urban areas or as migrant laborers, leaving women to assume the main responsibilities on the farm.

Labor intensive dates production. Photo credit: SAIEA.

Field experience in combating dryland degradation has demonstrated that women and men's full and equal participation is essential for the success of sustainable development and the management of drylands (FAO 2003). Increasing opportunities for women can have a powerful impact on productivity and agriculture-led growth. For example, in Kenya, researchers found that women could increase their crop yields by approximately 20% percent if given the same access to the same resources as men (including training and other services) (Saito et al, 1994).

- **Human health issues.** Close links exist between environmental health, household food security, human health and poverty.
  - Agricultural projects can result in a plethora of human health issues, including: exposure to hazardous agro-chemicals, reduced water availability and quality, and exposure to water-borne and communicable diseases – particularly through poorly planned and managed irrigation schemes (see the Impacts section).
  - The linkages between increased HIV prevalence and development projects in the developing world are well documented and are due, largely, to the presence of mostly male migrant workers (UNDP 2012). USAID planners and their implementing partners must consider the fact that in areas with high HIV and AIDS prevalence, the labor force becomes depleted as both men and women may be unable to engage in agricultural activities (either because they are infected or they are caring for others who are infected).

PART 3: BEST PRACTICE GUIDANCE

A. SMALL-SCALE IRRIGATION AND RAIN-FED CROPPING ON DRYLANDS

The major constraints to crop production in dryland regions (in particular Africa and West Asia) are limited access to water, low soil fertility, insecure rainfall, low-productive genotypes, low adoption of improved soil and crop management practices, and lack of appropriate institutional support (Van Duivenboodew, 2000).

The erratic rainfall that characterizes drylands results in a high variation in timing for crop planting and reaping. This means that planting and harvesting may have to be readjusted rapidly, sometimes within a season and often between seasons. Other factors that affect small-scale crop farmers in drylands include soil depletion/erosion; pestilence; illness (resulting in lost labor); and variability regarding prices and availability of inputs such as seed, labor, food, and crop outputs. Good management of the little available water is essential. Drought preparedness and risk mitigation are also essential for the proper management of dryland areas.

IMPACTS TO AVOID DURING PROJECT IMPLEMENTATION

All agricultural practices have potential environmental impacts. Almost all of these are exacerbated on drylands where land degradation is a constant threat. Without mitigation and sustainable land use practices, these impacts result in reduced crop outputs, lowered food security, fewer livelihood options, and increased rural poverty in the dryland areas of the developing world.

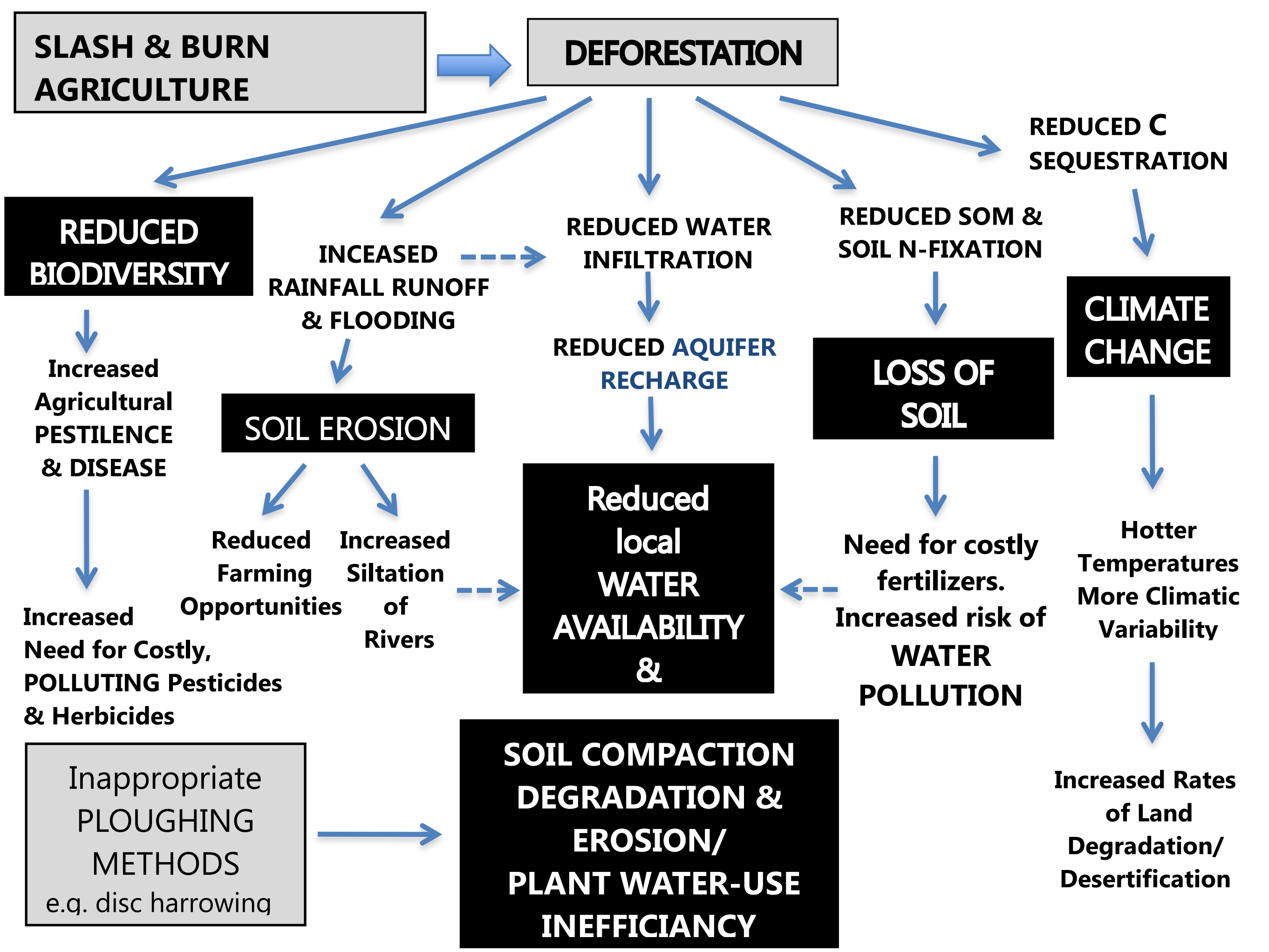
The root causes of most impacts include:

- Inadequate knowledge of best practice at the local level (i.e. government extension officers, village farmers). For example, in Namibia, extension officers encourage and provide the equipment for outdated and damaging tillage practices which exacerbate crop failure.
- Poorly considered policies that encourage:
  - Uncertainty about land tenure, which leads to poor land stewardship;
  - Subsidies for water and agrochemicals encourage wastage and excessive use. This leads to water shortages and pollution (e.g., eutrophication of wetlands);
  - Government control over markets and pricing can have a negative impact on small-scale farming practices and goals, affecting food security at the community level;
  - Resettlement programs can exacerbate rates of deforestation, overstocking and other causes of rapid land degradation;
  - Non-participatory and undifferentiated extension policies can override the need for local solutions to local problems, exacerbating rates of land degradation.

IMPACTS TO AVOID ON RAIN-FED CROPLAND

On rain-fed croplands the main impacts to avoid are summarized in the below figure. Agricultural practices that can lead to reduced soil productivity include:

- Land clearing activities such as slash-and-burn agriculture and deforestation. Indigenous trees in drylands play a vital role in creating shade, securing nutrients from the soil, and holding moisture in the soil and the body of the plant. These functions provide shelter and food for other biodiversity, and promote soil health.
- Inappropriate (deep) tillage e.g., using ploughs with disc harrowers with too short or no fallow period. This causes soil compaction, reduced biological activity in soils and inefficiency in water utilization by crops.



Overview of negative environmental impacts of rain-fed agriculture on drylands

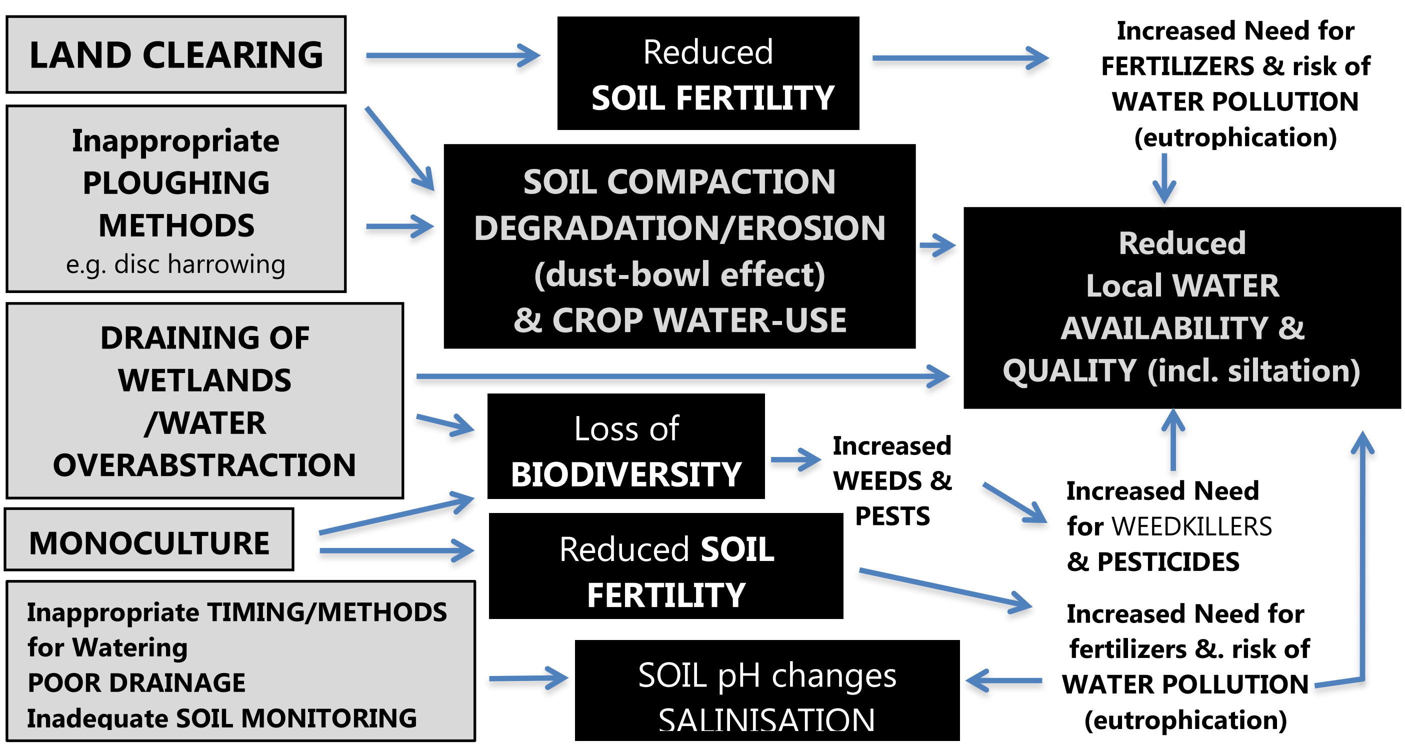
IMPACTS TO AVOID WITH DRYLAND IRRIGATION

Waterlogging, soil pH changes and, in particular, soil salinization (which is near-irreversible) are common environmental problems encountered on dryland soils which are high in salts and low in organic matter. These impacts are exacerbated by poor drainage and/or extensive watering during the heat of the day, when evaporation rates are highest. The main practices to avoid (see figure below on negative environmental impacts of irrigation projects) include:

- Inadequate drainage;
- Watering saline soils when evaporation rates are highest;
- Excessive deforestation (in the fields and also in surrounding areas);
- Inappropriate soil preparation techniques (as with rain-fed cropping); and
- Over-abstraction of ground- and surface water,
- Monoculture with no crop rotation (particularly if the crop types are not suitable to dryland conditions).

Waterlogging and Salinization

About 2 to 3 million hectares of irrigated farmland go out of production worldwide each year due to salinity problems (FAO 1997). Waterlogging results from inadequate drainage, over-watering, and seepage from canals and ditches. It exacerbates salinization by concentrating salts (drawn up from lower in the soil profile) in the crop's rooting zone. This reduces plant growth dramatically. Alkalization, the build-up of sodium in soils, is a particularly detrimental form of salinization which is difficult to rectify. Comprehensive studies of irrigation-induced salinity indicate that the yields of wheat are around 50% lower on the degraded soils and net incomes in salt-affected lands are an estimated 85% lower than the unaffected land (FAO 1997). In many cases, when the levels of salinity are too poor, the land has to be abandoned.



Negative environmental impacts of irrigation projects in drylands

Case Study: The impacts of using glyphosate weed-killers

Clearing large areas and planting only one type of crop (monoculture) causes a loss of local biodiversity and rapidly drains nutrients from the soil. This in turn can result in an increase in weeds and other pests. In response, many governments and NGOs subsidize and/or strongly encourage the use of commercial weed-killers and pesticides to help improve crop productivity. Weed control is also a significant complementary tool in no-till agriculture, which favors reduced erosion.

Glyphosate is a weed-killer that is commonly used on small- and large-scale farms throughout the world, including most developing countries. However, there has been evidence of weeds developing resistance among other problems, summarized below, that should be considered and understood prior when considering approaches to weed control in project design and implementation:

- Glyphosate has led to the proliferation of persistent new 'super weeds' which affect millions of hectares of crop land worldwide.
- Over time, crops on farms affected by these weeds typically have to be sprayed with increasing amounts of herbicides. In some cases, farmers may instead re-adopt outdated methods of harsh tillage to up-root the weeds – a practice which reduces biological activity in the soil and causes soil compaction.
- When used in excessive quantities, glyphosate destroys beneficial soil organisms, promotes fungal growth, interferes with photosynthesis, and reduces the absorption of soil nutrients by crops (though it should be noted that plowing also has its drawbacks).
- Glyphosate is toxic to all plant species, except the newly evolved super weeds and those crops that have been specifically genetically modified ("e.g., "Roundup Ready") to resist their effects.
- In the medium to long term, the use of these popular products may lead to rising farming costs, lower crop quality and yields, higher food prices and increasing rates of soil and water pollution.

Institutions working to improve crop production in dryland countries should fully consider the range of costs and benefits of using weed-killers when designing and planning new activities. At the level of small-scale crop farming, alternative approaches to weed removal include, manual removal of the weeds and subsequent use as mulch, as well as biological methods of pest control. Alternatives such as these can reduce the need to import potentially expensive and/or harmful pesticides and weed-killing chemicals. Providing support to farmers to re-adopt traditional methods of small-scale multi-cropping amongst indigenous trees (particularly leguminous species that fix nitrogen) could help maintain a diversity of crops and reduce weed problems.

Source: Zabalov et al 2011; Scientific American, 2009; Neuman & Pollack, 2010.

MAIN SOCIO-ECONOMIC AND HUMAN HEALTH IMPACTS LINKED TO IRRIGATION PROJECTS

The following impacts are often associated with medium-sized to larger scale irrigation schemes on drylands in developing countries (FAO 2005, Carvalho 2004, Goldmann 2004, WHO 2010, WHO 2014):

DID YOU KNOW…

Population groups at risk from health issues linked to irrigation projects include agricultural workers, consumers of crops and meat from wastewater-irrigated fields, and people living nearby.

- **Weaker community ties and increased inequity**. Irrigation can be very expensive. Projects that aim to introduce costly modern equipment can significantly increase energy consumption and lead to reduced employment opportunities for local communities.
- The increased incidence of vector borne **water-related diseases** including malaria, bilharzia (schistosomiasis) and river blindness (onchocerciasis).
- Other irrigation-related health risks include those associated with **deterioration of water quality**, **increased population pressure** in the area and increased risk to **poisonings and certain cancers** – especially in children (linked to high exposure to agro-chemicals). The re-use of wastewater for irrigation has the potential to transmit communicable diseases.

The risk that one or more of the above diseases is introduced or has an increased impact is most likely in irrigation schemes where:

- Soil drainage is poor, and drainage canals are either absent, badly designed or maintained;
- Night storage reservoirs are constructed;
- Borrow pits are left with stagnant water; or
- Canals are unlined and have unchecked vegetation growth.

B. SUSTAINABLE LAND MANAGEMENT SOLUTIONS FOR DRYLAND AGRICULTURE

The benefits of sustainable land management (SLM) to small-scale farmers are far-reaching and provide attractive solutions to mounting socio-economic issues in drylands, particularly those pertaining to food insecurity and poverty. SLM aims to manage agro-ecosystems for sustained productivity, increased profits and food security (see table below) whilst reversing and preventing water stress, soil erosion and desertification.

Planners should also be aware of innovative projects that can indirectly help meet the goals of improved land management (e.g., employing communities to help design and manufacture fuel efficient wood burning stoves that are suited to their local cooking needs). The participatory involvement of local communities is essential to the long term sustainability of all projects and, wherever possible, traditional knowledge and practices should be considered.

Checklist of selected Sustainable Land Management (SLM) Practices

(Adapted from Liniger et al. 2011, IPCC 2007; FAO 1997)

PRIMARY GOAL	DESIGN USING SELECTED SUSTAINABLE LAND MANAGEMENT PRACTICES
Increased land productivity	• **Increase water-use efficiency / improve rainwater management** - Rain water harvesting: micro-catchments, macro-catchments, earth dams, sand dams, ponds, or roof catchments (storage tanks). - Reducing soil water losses from evaporation through mulching. - Managing excess water runoff: afforestation, agroforestry, terraces, contour farming, cross-slope barriers. - Water-use efficiency at the at the conveyance and distribution level for irrigation projects: create well maintained, lined canals and piping systems; check regularly for leakages and fix these timeously. - Efficient water application on irrigated fields: micro-irrigation e.g., drip irrigation (provision of small volumes of water at frequent intervals close to the roots); low pressure sprinkler irrigation during the night or early morning; avoid irrigation on windy days; avoid deep seepage of water beyond rooting level; practice supplementary irrigation by only irrigating rain-fed cropland during periods of water deficits or at water-stress sensitivity stages in plant growth. • **Enhance soil fertility and nutrient cycling and improve water infiltration** - Reduce de-vegetation, deforestation, overgrazing, excessive tillage and other actions that cause nutrient leaching, soil structure changes and erosion. - Use organic fertilizers: mulches, manure, compost and crop residues to build-up SOM. - Allow fallow periods and plant leguminous (nitrogen fixing) indigenous plants (intercropped or planted in rotation). - Use of trees (preferably indigenous species) in agroforestry as nutrient 'pumps' i.e. to absorb nutrients from the subsoil and return them to the topsoil and rooting depth of annual crops in the form of leaf fall and mulch. - Apply inorganic fertilizers cautiously (in micro-doses and used with organic fertilizers as in Integrated Soil Fertility Management as Precision Conservation Agriculture). - Minimal soil disturbance (e.g., conservation agriculture). • **Improve plant material (crops/pastures) without damaging the environment** - Increase plant productivity and diversity through 'new' green revolution approaches that support selection and experimentation with local/indigenous crop varieties. - Encourage seed exchange and adoption of indigenous knowledge. - Avoid dependency on improved plant varieties that demand high inorganic fertilizer, pesticides, and herbicide inputs. - Practice integrated pest management (IPM) and labor-intensive weed management. - Optimize planting dates. - Use locally sourced organic fertilizers i.e. manure, compost, crop residues. - Practice intercropping, relay planting, crop rotation to maintain soil health.

PRIMARY GOAL	DESIGN USING SELECTED SUSTAINABLE LAND MANAGEMENT PRACTICES
	• **Ensure more favorable micro-climates** - Reduce soil and atmospheric moisture losses/mechanical damage from high winds and excessive heat: plant trees as wind-breaks, shelter-belts, agroforestry, multi-story cropping and organic mulching.
Improved livelihoods	• **Improve short and long term benefits** - Provide assistance if costs for initial investments are beyond subsistence land user's means. • **Improve access to machinery, seeds, fertilizers, markets and knowledge.** • **Address health issues (HIV-AIDS, malaria and others) that affect well-being & labor productivity.** • Choose practices that **encourage innovation and local adaptation to climate change** e.g., the local manufacture of fuel-efficient wood burning stoves that reduce rates of deforestation.
Improved ecosystems	• **Prevent, mitigate and rehabilitate land degradation** - Implement measures that improve soil cover, enhance soil organic content, fertility and structural integrity e.g., mulching, manure use and conservation tillage. - Encourage afforestation, planting live fences, trees, shrubs, grasses and perennial herbaceous strips. - Use terraces, bunds, dams, pans, ditches. - Select management measures that help mitigate/rehabilitate damaged land. • **Maintain/improve biodiversity** - Practice integrated pest and ectoparasite management (IPM). - Avoid unnecessary and excess use of herbicides and other agrochemicals. - Promote the genetic diversity of crops and livestock. • **Choose 'climate smart' practices and policies – focus on mitigation & adaptation** - Almost all the above-mentioned SLM practices – particularly those pertaining to improvements in water-use efficiency, soil fertility, and prevention of land degradation- will enhance carbon sequestration and small-scale farmers' ability to adapt to increasing environmental variability.

There is no single solution that can be used to solve the many challenges which face small-scale dryland crop farmers. Consequently, local stakeholders need to determine the most appropriate sustainable practices for their specific climatic, geographical, and socio-economic conditions.

PROJECT DESIGN

Projects should be designed to meet the goals described in the above table. In particular, the specific local conditions must be considered, regarding:

- The soils (and their susceptibility to degradation);
- The water quality and availability ;
- The topography and geohydrology (the slope of the land and geology with respect to catchments);
- The choice of crops and their suitability to the local climate; and
- The costs involved, or the ease with which the project can be managed and sustained.

Furthermore, the participatory involvement of local communities is essential to the long term sustainability of the project and, wherever possible, traditional knowledge and practices should be considered.

Live fencing to protect crop field. Photo credit: SAIEA.

Some SLM approaches that have had excellent success with enhancing rain-fed and irrigated crops in arid, semi-arid and sub-humid conditions are listed below. *Conservation agriculture, rain water harvesting, agroforestry* and the use of *cross-slope barriers* to reduce rainfall runoff and soil erosion are discussed in more detail. Case studies showing the opportunities and costs of adopting these approaches are provided.

1. **Conservation agriculture** combines minimum soil disturbance (ripper tillage or no-tillage), with permanent soil cover (e.g., mulches) and crop rotation to reduce soil moisture losses and enhance crop production.
2. **Integrated soil fertility management** uses supplementation with a variety of organic and inorganic plant nutrients to enhance crop production.
3. **Rainwater harvesting** aims to improve the use of rainfall, making it available for agricultural or domestic uses in areas where rainfall is the primary limiting factor.
4. **Smallholder irrigation management** aims to achieve higher water-use efficiency through more efficient water collection and abstraction, water storage and distribution, and using drip or micro-spray applications which have low wastage.
5. **Cross-slope barriers** use soil bunds, stone lines, vegetative strips etc. to reduce rainfall runoff velocity and soil erosion.

6. **Agroforestry** integrates the many benefits of trees to enhance soil and water resources. Trees provide fuel and fodder products, while various fruits and their oils can be directly used as food. The deep roots of trees bring moisture and nutrients to the surface, while their branches funnel water to the patch of shade around the trunk creating localized patches of shelter and pasture. Trees play an important role in combating desertification and mitigating climate change.
7. **Integrated crop and livestock management** optimizes the use of crop and livestock resources through the beneficial interactions between them.
8. **Sustainable forest management in drylands** encompasses administrative, legal, technical, economic, social and environmental aspects of the conservation and use of dryland forests.

THE NORTH SINAI INITIATIVE (NSI) - EGYPT

The North Sinai region of Egypt, specifically the central area of the governorate, has faced changing weather patterns in recent years that have negatively affected traditional practices of seasonal agricultural and nomadic herding in the area.

USAID's North Sinai Initiative (NSI) began in 2010, coordinating with Egypt's Ministry of Planning and International Cooperation (MPIC) to assist the Government of Egypt (GOE) in the implementation of agribusiness boosting activities as well as working to develop infrastructure, small and medium enterprises, and education.

The NSI's focus on agribusiness included provision of technical support across agricultural value chains – such as those for peaches and olives - as well as the introduction of improved farming techniques, formulation of farmer crop associations, improving post-harvest storage, and coordination with agriculture-focused technical education programs to ensure that graduating students are well qualified and familiar with improved agricultural techniques for drylands.

In 2013, the NSI added new activities, such as the procurement of potable water tankers for water distribution in rural areas, water desalination plants, well-drilling and the rehabilitation of wells, and the improvement of potable water pipelines and house connections. Among other mitigative measures, NSI will take particular care to ensure the underground water aquifer can support all new water supply projects, including those connected to agriculture.

In addition, a complete environmental screening questionnaire will be conducted for each small activity, and the activity manager will ensure the construction contract includes this measure, as well as provisions to ensure worker health and safety and responsible management of construction waste.

NSI represents a targeted intervention by USAID to boost dryland agricultural productivity. Focus on dissemination of improved technologies and provision of technical support will best prepare new and current agricultural laborers to tackle the challenges posed by drylands.

USAID. *North Sinai Initiative (NSI).* Initial Environmental Examination, USAID, 2013.

SLM APPROACH: CONSERVATION AGRICULTURE

Case studies from many parts of the world[6] show how combining minimal tillage, the use of organic mulches (e.g., crop stubble) and crop rotation can improve the carbon sequestration and water retention ability of the soil, support soil health and raise crop production sustainably and profitably. Known as Conservation Agriculture (CA), this approach meets all three of the SLM goals of improved production, livelihoods, and environmental health.

Key aspects of Conservation Agriculture include the following:

- Minimum soil disturbance: zero or reduced tillage (using ripper furrowing instead of ploughing);
- Permanent soil covering (e.g., crop residues and organic mulches);
- Crop rotation;
- Direct planting of crop seeds into mulch;
- Labor-intensive weed control and minimal use of herbicides; and
- IPM in place of pesticides.

Bare field with crop residues removed. Photo credit: SAIEA.

Benefits of this approach are seen in increased crop yields and reliability and reduced risk of crop failure. For farmers, there are the benefits of increased farm income and lower farm inputs (fuel, machinery costs repairs, fertilizer), reduced labor requirements (unless hand weeding is done), and improved food and water security.

[6] These include the rice–wheat areas of the Indo-Gangetic Plains (South Asia), irrigated maize–wheat systems of northwest Mexico, and croplands in semi-arid Zimbabwe, Zambia, Malawi and Kenya) (Aagaard 2010; Hobbs *et al.* 2008; Liniger *et al.* 2007; Mele and Carter 2009; Mupangwe *et al.* 2007)

KEY ENVIRONMENTAL BENEFITS OF CONSERVATION AGRICULTURE APPROACHES

- Improved soil cover and soil structure (long term) ➔ *reduced vulnerability to desertification*
- Improved soil moisture and water availability ➔ *increased resilience to climate change*
- Increased organic matter and soil fertility ➔ *improved carbon sequestration*
- Reduced evaporation/improved micro-climate ➔ *increased resilience to climate change*
- Reduced water/wind soil erosion ➔ *reduced vulnerability to desertification*
- Reduced surface runoff and improved recharge of aquifers ➔ *reduced vulnerability to desertification*
- Reduced reliance on commercial fertilizers ➔ *reduced incidence of eutrophication/pollution of water bodies*
- Reduced reliance on herbicides due to weed suppression by mulch and/or cover crops ➔ *improved soil health and reduced pollution from weed-killers.*

Case Study: Small-scale Conservation Tillage, Umande, Kenya

Most farmers in the sub-humid area of Umande have about 1 ha of land on which to subsist. Few of these families have alternative sources of income. Farms in this area suffer from high rates of soil moisture loss, soil compaction and the loss of top-soil due to water erosion. The loss of soil occurs mostly during heavy storms at the beginning of the rainy season.

Conservation Agriculture (CA) methods were introduced, using crop residues as mulch, adding compost and biodegradable household waste, ripping the soil with a plough modified for animal traction, applying nitrogen and phosphorous fertilizers close to the seeds, and interplanting with a legume. Labor input was initially high, but then reduced to lower than conventional tillage.

Crop yields increased by more than 60%, giving increased food security and income for families even in below average rainfall years. Soil moisture was improved and there was reduced soil loss, with the result that downstream siltation was also reduced. Farmers improved their knowledge of conserving the soil and preventing erosion. Conservation Agriculture methods in Zambia and Zimbabwe have shown increases in yield from 25% to over 100% in the first year. In seasons of poor rains, CA can make the difference between total crop failure and a reasonable yield.

The approach obviously does have its challenges. Contingency plans are needed for draining excess water in very wet years, and conflict can arise between using residues as mulch rather than as livestock food. To compensate, greater yields can lead to greater income for buying fodder, leaving the residues for mulch.

Source: Liniger *et al*. 2011.

SLM APPROACH: RAINWATER HARVESTING

Rainwater harvesting (RWH) technologies aim to enhance agricultural production and minimize the effects of seasonal variations in water availability in dryland areas. They are especially effective in semi-arid regions that are prone to droughts. RWH can be done at various scales, from increasing the catchment for individual plants, to small dams.

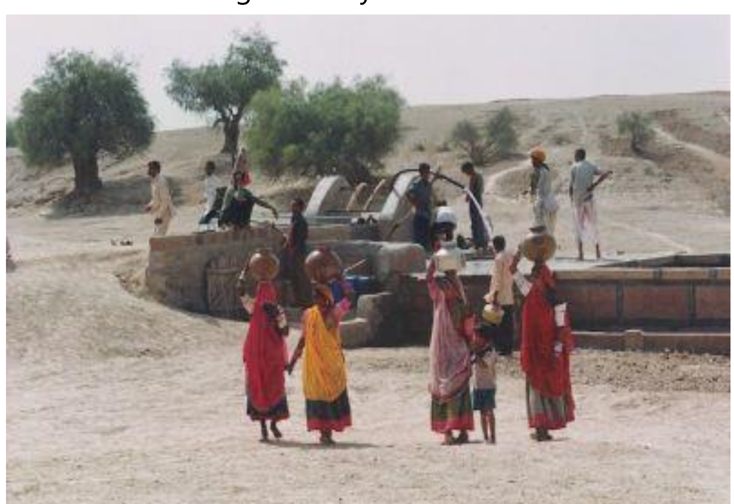
- **Micro-catchments:** Holes, pits, basins, or bunds constructed to collect surface runoff over a small catchment up to 10 times larger than the cropping area. This can be done as a component of conservation agriculture, agroforestry or fertility management using compost, manure and/or mineral fertilizers.

- **Macro-catchments:** Check-dams, water diversion channels, or large earth canals can provide water for crops or pasture through the diversion of storm floods from gullies, ephemeral streams, and roads directly onto the agricultural field. This can harvest rainwater over an area up to 1000 times larger than the cropping area. To improve its efficiency, soil surface structure and vegetation cover are manipulated so that evaporation from the soil surface and surface runoff is reduced, infiltration is enhanced and water availability in the root zone increased.

- **Small earth dams: Small earth dams** collect and store runoff from hillsides, roads, rocky areas, open rangelands or furrows below terrace banks. They can be used for irrigation, livestock or domestic use during dry periods.

- **Sand Dams:** Sand dams can store up to 20 million liters of water, providing a year-round supply of clean water for up to 1,000 people[7]. They have extremely low operation and maintenance costs and, by storing water underground, it is protected from evaporation. Sand dams are comprised of a steel reinforced concrete (rubble stone masonry) wall built across a seasonal sandy riverbed. Sand and silt carried downstream during the rainy season accumulates behind the dam, whilst the finer suspended clay particles wash over the dam wall. Within one to four rainy seasons the dam fills with sand and trapped water, with up to 40% of the volume comprising water stored between the sand particles. Water can be abstracted from the dam via traditional scoop holes, or an infiltration gallery leading to a tank or well.

- **Roof catchments:** Water collected off roofs (tiled or corrugated iron) and stored in plastic can be a source of water for domestic use.



Residents harvest rain water for drinking, agriculture and sanitation during the dry season in India. Photo credit: Jal Bhagirathi Foundation.

[7] http://www.excellentdevelopment.com/articles/people-amp-communities/what-are-sand-dams

Benefits arising from rainwater harvesting include increased crop yields and fodder production, reduced risk of crop failure, and enhanced water availability. It can relax the pressure on limited water resources.

ENVIRONMENTAL BENEFITS

- Rehabilitation of degraded land → *reduced vulnerability to desertification*
- Improved water infiltration → *increased resilience to climate change*
- Reduced velocity of runoff → *reduced susceptibility to flooding & soil erosion*
- Reduced net surface runoff → *improved aquifer recharge*
- Increased net soil moisture -→ *increased resilience to climate change*
- Reduced soil erosion and soil loss → *reduced vulnerability to climate change*
- Improved excess water drainage → *reduced vulnerability to salinization*
- Reduced sedimentation /Increased streamflow in dry season → *reduced siltation*

SLM APPROACH: AGROFORESTRY

Agroforestry involves practices in which trees are deliberately integrated with agricultural crops and/or livestock for a variety of soil and water management benefits and services. Many agroforestry approaches are traditional land-use systems. They can involve a spatial mixture of crops with trees or a temporal sequence (e.g., to improve fallows) and include: alley cropping, farming with trees on contours, perimeter fencing with trees, multi-story cropping, relay cropping, intercropping or multiple cropping.

Agroforestry is extremely useful on drylands, especially when indigenous trees that are well-adapted to the local soil/climatic conditions are used to enhance crop production and improve resilience to environmental change.

Agroforestry can help to diversify food and income sources, simultaneously improving food and water security, and improving resilience to climate shocks.

Case Study: Farmer Managed Natural Regeneration (FMNR)

Since 1983, FMNR, through which farmers manage reforestation on their own land through the cultivation of native tree stumps, has evolved into a predominant form of agroforestry.

FMNR was introduced in Niger as an alternative to then-more conventional reforestation efforts premised on large, expensive nurseries of exotic species. Over time, FMNR has demonstrated that targeting and cultivating robust stems produced by on-site, native tree stumps more effectively instigates reforestation efforts than the previously conventional approaches.

Further, the benefits of this type of reforestation are multi-faceted; small-holder farmers improve the quality of their land, making agricultural yields greater. In addition, they have ownership over the valuable commodity of wood, which they may be able to sell, use for firewood, or cultivate for fruit (e.g., during famine).

While FMNR remains an evolving practice, it's past successes suggest that project planners should consider use of FMNR strategies when applying agroforestry techniques to sustainable land management challenges.

Sources: Davila, 2013 and Rinaudo, 2012

ENVIRONMENTAL BENEFITS

- Improves soil organic content, soil structure, soil biological activity, increases water infiltration, reduces runoff and enhances soil fertility ➔ *prevents and reverses land degradation* ➔ *increased resilience to climate change* ➔ *reduced vulnerability to desertification*
- Preserves biodiversity ➔ *enhanced ecosystem resilience*
- improved C sequestration ➔ *helps mitigate climate change*
- improved micro-climate ➔ *increased resilience to climate change*

Case Study: Agroforestry enhances maize production in Zambia

Maize has a high potential as a staple crop, which is seldom realized in most of Africa. Despite its poor suitability and lack of resilience to dry periods, maize has become the preferred crop in Zambia, occupying most of the land cultivated by smallholders. Farmers practice shifting (slash and burn) cropping by cutting or burning back woodlands to make way for new fields when soils are exhausted – a practice that is unsustainable in the face of growing population pressure.

Agroforestry projects, interspersing trees and crops, have improved yields by 100% and more, without any use of fertilizers. *Faidherbia albida* is a particularly useful tree as it is arid-adapted, being naturally widespread in the drylands of Africa and the Middle East. The seeds are dispersed by wildlife and livestock that consume the pods. *Faidherbia* is particularly valuable because it loses its leaves in the rainy season and refoliates during the hot dry season, providing shade for the growing crops. Pods and leaves that fall to the ground, combined with the tree's ability to fix nitrogen in the soil, greatly increases soil fertility beneath the tree canopy. A windbreak element is also provided by the trees.

The benefits from using *Faidherbia* trees take 5-8 years to start showing, and young trees can be damaged and uprooted by livestock. Nevertheless the combination of *Faidherbia* with conservation agriculture is probably the most effective climate change adaptation strategy available to smallholders in dryland regions of Africa and the Middle East.

Source: Aagaard, 2010 and Kasuta, 2002.

SLM APPROACH: CROSS-SLOPE BARRIERS

Cross-slope barriers are developed on sloping lands in the form of earth or soil bunds, stone lines, and/or vegetation in order to reduce steepness or the length of a slope. They are used to reduce runoff velocity and soil loss, thereby contributing to soil, water and soil nutrient conservation. Terraces develop gradually behind the bunds due to soil movement from the upper to the lower part of the terrace. While cross-slope barriers are primarily intended to reduce soil erosion, they also ease cultivation or agroforestry between the barriers, which are usually developed along contours. In drylands, cross-slope barriers have proved to be invaluable for restoring and conserving catchment services.

The main production and livelihood benefits are improved crop yields and food security, and the opportunity to develop irrigation schemes due to improved water management. With regard to the soil in the terraces, there is improved fertility and infiltration, and greater access to water for the plants grown.

MITIGATION MEASURES (BEST PRACTICE GUIDANCE)

The table below provides a general mitigation checklist for designing environmentally sound small-scale cropping and irrigation projects in dryland areas.

Mitigation checklist for planning environmentally sound dryland crop & small–scale irrigation.

1. SOILS

<table>
<tr><th>PROBLEM</th><th>CAUSES</th><th colspan="2">MITIGATION MEASURES (BEST PRACTICE)</th></tr>
<tr><td rowspan="2">Fertility loss</td><td rowspan="2">Repeated
monoculture

Overwatering

Harsh plough which causes compaction and loss of soil biological activity

Inadequate nutrient replenishment</td><td>Reduce nutrient leaching</td><td>• Composting and manuring (e.g., corralling).
• Integrated fertility management (organic combined with inorganic).
• Micro-fertilization.
• Green manuring.
• Crop rotations using N-fixing legumes.
• Improved fallows with leguminous trees and bushes.
• Enrichment planting of grazing land, rotational grazing.</td></tr>
<tr><td>Improve soil nutrient holding capacity and plant nutrient uptake</td><td>• Conservation agriculture methods.
• Increase soil organic content.
• Mulching.
• Avoid burning (crop residue management).
• Use adapted crop varieties.</td></tr>
<tr><td rowspan="2">Plants wilting or dying</td><td>Heat stress/
high rates of evaporation</td><td>Reduce soil moisture loss and evapo-transpiration</td><td>• Windbreaks.
• Agroforestry.
• Vegetative mulches.</td></tr>
<tr><td>Loss of soil fertility</td><td colspan="2">• Composting, manuring (e.g., corralling), mulching.
• Integrated fertility management (organic combined with inorganic).
• Micro-fertilization.
• Rotate crops with N-fixing legumes and improve fallows with leguminous trees and bushes.
• Crop residue management.
• Enrichment planting of grazing land, rotational grazing.</td></tr>
</table>

Plants wilting or dying	Poor choice of crop Pests/diseases	• Choose crop varieties that are suited to the local conditions or that are used traditionally. • Avoid monoculture – rather practice intercropping and agroforestry. • Support local biodiversity. • Avoid or reduce the use of commercial pesticides. • Practice integrated pest management and biological control whenever possible.
Water logging and soil salinization (ultimately results in crop failure and lost land)	Overwatering Rising water table (brings salts to surface) Exacerbated by : overwatering; high temperatures & evapo-transpiration; no fallow periods; and inadequate drainage Soil has low levels of biological activity	• Avoid excessive flooding /over watering on irrigated fields. • Design for adequate drainage – including disposal of excess water to evaporation ponds or the sea, especially if nearby wetlands/rivers will be adversely affected by the drainage water. • Use alternative irrigation methods (e.g., drip irrigation) and adjust watering schedules. • Prepare the land with minimal tillage/CA methods. • Ensure fallow periods. • Install & maintain sub-surface drainage system. • Incorporate soil additives (e.g., gypsum added to water or soil). • Plant salt tolerant crops. • Reduce rates of evapotranspiration by creating windbreaks, practice agroforestry, and ensure good soil cover.
Soil acidification	Soil pH too low Over-use of inorganic fertilizers	• Avoid over–use of commercial inorganic soil fertilizers. • Service irrigation & drainage systems regularly. • Analyze soils and monitor changes regularly so that potential problems can be managed.

2. WATER

PROBLEM	CAUSES	MITIGATION MEASURES (BEST PRACTICE)	
Dry wells /groundwater depletion Inefficient water uptake by crops	Reduced infiltration resulting from deforestation and overgrazing	Minimize runoff; Maximize rainfall infiltration and storage in the soil	• Improve soil cover (plant trees and grasses). • Increase soil organic content by composting. • Contour cultivation. • Conservation agriculture. • Use vegetation barriers, soil / stone bunds or terracing. • Agroforestry. • Promote improved cooking stove designs as a way of combating deforestation. • Rain water harvesting.
		Reduce evaporation	• Intercropping, mulching, windbreaks, agroforestry.
	Over-abstraction of local groundwater or surface water from wetlands Reduced water availability	Minimize water losses from irrigation system	• Line canals. • Make canals deep and narrow instead of shallow and broad. • Improve maintenance (check regularly for leakages).
		Improve water application efficiency	• Use drip irrigation, micro sprinklers, low pressure irrigation system, improved furrow irrigation, supplemental irrigation, deficit irrigation, etc.
		Recharge aquifer / groundwater; Harvest water to enable off-season irrigation	• Reduce runoff and improve underground water infiltration with afforestation. • Establish small dams, subsurface tanks, percolation dams and tanks, diversion and recharging structures, etc.

<table>
<tr>
<td rowspan="5">Declining water-use efficiency and availability for crops in rain fed agriculture</td>
<td rowspan="4">Climate change with higher temperatures, lower annual and more variable precipitation</td>
<td>Minimize runoff; Maximize rainfall infiltration</td>
<td>• Improve soil cover (afforestation/ avoid overgrazing), composting, contour cultivation, conservation agriculture (CA), life barriers, soil / stone bunds, terracing.</td>
</tr>
<tr>
<td>Reduce evapo-transpiration</td>
<td>• Intercropping, mulching, windbreaks, agroforestry.</td>
</tr>
<tr>
<td>Harvest and concentrate rainfall through runoff to crop areas</td>
<td>• Use planting pits, semi-circular bunds, microbasins, contour bunds, stone lines, vegetative strips, runoff and floodwater farming, small dams.</td>
</tr>
<tr>
<td>Increase plant water-use efficiency uptake</td>
<td>• Agroforestry.
• Crop rotation.
• Intercropping.
• Improved crop varieties.
• Alter planting dates.
• Choose crops that are better adapted to arid conditions (e.g., pearl millet in place of maize).
• Manage soil fertility.</td>
</tr>
<tr>
<td>Irrigation return-flows containing inorganic fertilizers, pesticides and herbicides.

Siltation caused by deforestation and soil erosion</td>
<td colspan="2">• Designate land for saline water disposal; build separate disposal channels.
• Avoid siltation through afforestation, agroforestry and other means of soil erosion control.
• Educate for pesticide, herbicide, inorganic fertilizer and sewage contamination dangers.
• Use alternative means to improve/maintain soil fertility, control weeds and pests (e.g., adopt integrated disease and pest control and non-polluting weed management).
• Monitor irrigation water quality regularly.</td>
</tr>
</table>

3. SOCIO-ECONOMIC ISSUES

PROBLEM	CAUSES	MITIGATION MEASURES (BEST PRACTICE)
Increased incidence of water related , vector borne, communicable and other diseases	Poorly planned irrigation systems A reduction in local biodiversity (especially birds, frogs and fish) that eat mosquito larvae, flies, snails and other vectors of diseases → directly linked to eutrophication from excessive fertilizer in runoff Poisonings from careless use of herbicides and pesticides(especially children)	• Educate about causes of water-borne and water-washed diseases. • Improve local health facilities. • Ensure good soil drainage on irrigation schemes; avoid night storage reservoirs. • Make sure borrow pits are not filled with stagnant water; • Line canals and keep them clear of vegetation growth; • Educate for pesticide, herbicide, inorganic fertilizer and sewage contamination dangers. • Educate for biodiversity conservation. • Use alternative ways to improve/maintain soil fertility, control weeds and pests (e.g., adopting integrated disease and pest control and non-polluting weed management. • Monitor irrigation water quality regularly.
	Marginalization of women and people from poorer social classes when irrigation projects are developed Lack of tenure over land and other resources	• Allow sufficient time and money for public participation to ensure that plans are optimal, that all sections of affected society are considered. Design projects to ensure women, migrant laborers, and the poorest community members are not compromised by reduced access to resources. • Consider markets, financial services and agricultural extension in conjunction with proposed irrigation and drainage changes. • Ensure that agricultural intensification does not preclude other economic or subsistence activity, such as household vegetables, fodder or growing trees for firewood. • Provide short-term support and/or skills for an alternative livelihood if irrigation removes existing livelihood. • Establish and support women’s groups; promote alternative income-generating activities for women; empower women by providing management and organizational skills training.

C: LIVESTOCK & RANGELAND MANAGEMENT

Livestock are an essential feature of dryland production systems, either solely in grazing systems carried out by pastoralists, or in combination with crops in a system of mixed farming. Intensive, industrial-style stock farming, such as in feedlots, also takes place in drylands but this aspect is addressed in the *USAID Sector Environmental Guideline (SEG) on Livestock*.

Dryland livestock farming systems use cattle, goats, and sheep, with some use also of native species such as vicuna in South America and camels in the Middle East. The world's growing population is increasing livestock pressure on natural forests (which are cleared to make way for pastures) and on old rangelands which are susceptible to degradation.

Zebu cattle in the marketplace in Ethiopia. Photo credit: SAIEA.

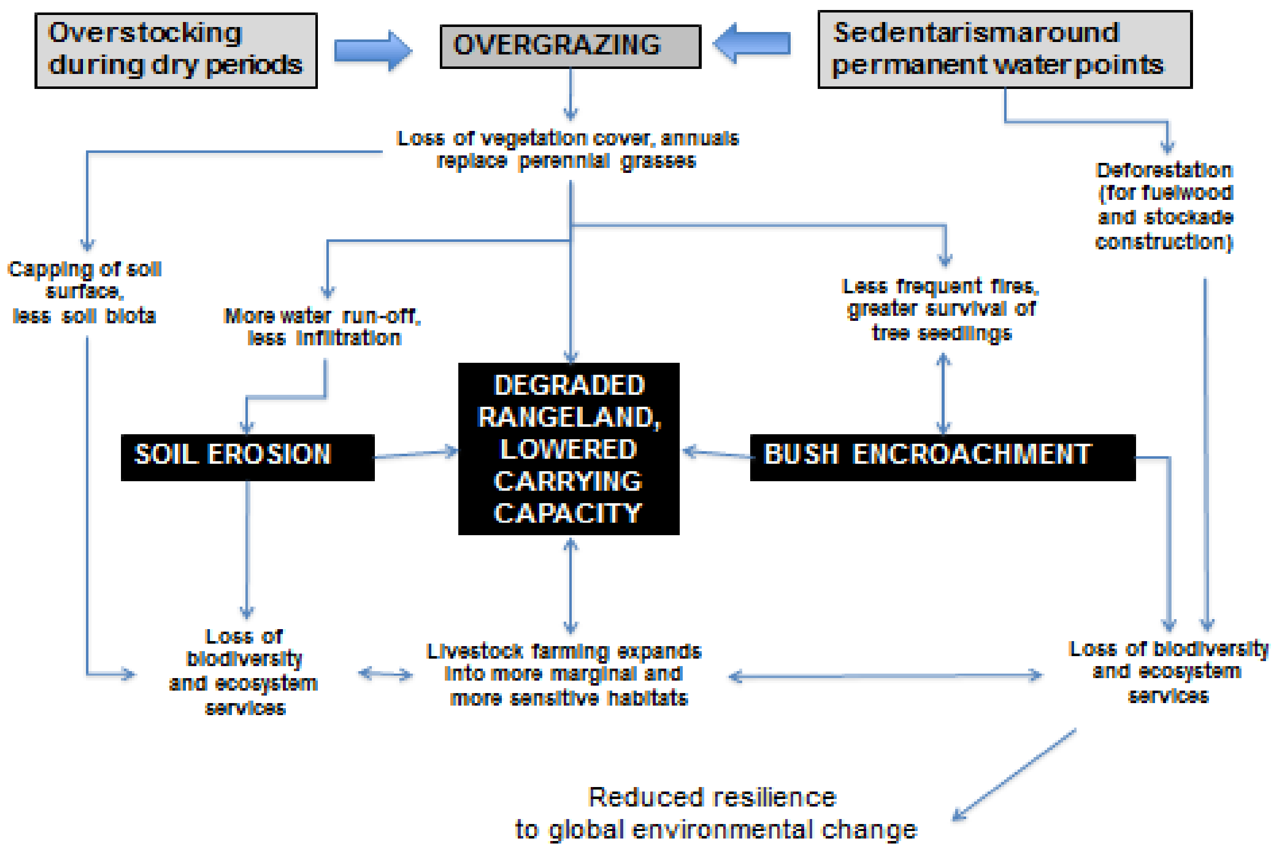
Within the world's drylands, some traditional cultures still consider livestock to be a symbol of wealth. The main challenge is to ensure that livestock production on these climatically challenged lands helps to improve livelihoods without exacerbating current rates of land degradation and biodiversity loss.

IMPACTS TO AVOID

OVERGRAZING

Overgrazing is common on drylands and results from the number of livestock exceeding the stocking rate at that time. In a variable environment, carrying capacity is highly variable, so periods of low rainfall can drop the carrying capacity quickly. If livestock numbers are not reduced in keeping with the capacity, land degradation results.

Overgrazing reduces the density of vegetation and the amount of pasture or browse generated. Perennial grasses, being more favored by livestock, are replaced by annuals, which have less root growth to hold the soil, and only produce grazing after it has rained. Soil erosion, from water or wind, is the usual consequence of loss of perennial grasses, and this further decreases soil fertility through loss of nutrients. The ultimate outcome is desertification which can be very difficult to reverse when the suite of grasses has changed from perennials to mainly annuals, and invasive less palatable species have grown dominant. With well-managed herding and stocking practices, rangeland integrity can be restored i.e., perennial grasses and palatable plants can be restored to dominance.



Negative environmental impacts of livestock overgrazing in drylands

BUSH ENCROACHMENT

Counter-intuitively, overgrazing on drylands can lead to denser vegetation cover through bush encroachment, but the net result of reduced carrying capacity is the same. Invasive bushy trees, very often thorn trees, can form impenetrable thickets so that productivity of the land is seriously reduced. In southern Africa, most bush encroachment happens on cattle and sheep farms. The first factor in the chain of causation is loss of grasses. Their shallow roots draw moisture from upper layers of the soil, thus limiting water availability for the deeper roots of trees. When the grasses are removed woody plants can boom. A

Bush encroachment. Photo credit: SAIEA.

second factor, reduction in bush fires, is also important. Without grass, there is no fuel to sustain regular fires, and woody plants can flourish when fire (as an important natural controlling factor in savannah) is absent. With the occasional spell of above-average rainfall, thorn bushes can quickly reach dominance and grow into a problem that is very difficult to eradicate.

OVER-USE OF MARGINAL LAND AND SENSITIVE HABITATS

A common consequence of growing numbers of people and livestock is that livestock get moved into more marginal areas. Areas that naturally have less fodder or accessibility (e.g., mountain slopes, sandy dunefields, more saline soils) become invaded. These more marginal areas might support specialized biota or be more vulnerable to overgrazing, so their vulnerability is higher and the negative impact of land degradation grows.

Farming landscape, Lalibela Mountain, Ethiopia. Photo credit: SAIEA.

Linked to growing pressure on marginal land is greater use of environmentally sensitive habitats. Rangeland in a typical river basin can be vulnerable to changes in the hydrological cycle. Runoff in a river catchment is determined, among other things, by the condition of soils and the vegetation: denuded areas are more prone to capping of the soil as the surface is baked hard by intense sunlight and there is less invertebrate life to tunnel into and mix the soil. These factors reduce infiltration and increase the runoff, thus further reducing the carrying capacity of the land. At the same time, groundwater recharge is compromised, and faster surface runoff causes increased soil erosion. Poor rangeland practices can therefore have a negative impact on water resources.

Infiltration in karst topography (i.e. areas underlain by limestone or dolomitic rocks) is usually directly into small sinkholes called dolines. Where livestock enclosures and water points are situated close to dolines, the accumulated dung can lead to infiltration of high-nutrient water into the groundwater. Nitrate contamination is a common problem in such terrain, especially in drylands where the soil layer is often thin.

Drylands frequently contain ‘pockets’ of vegetation in isolated habitats such as individual hills or mountains (commonly called inselbergs, monadnocks, or, in southern Africa, kopjes) or linearly along dry river courses. Inselbergs often host vegetation that is both more abundant and more diverse, but commonly quite restricted in range, making them valuable for small stock but susceptible to loss of endemic species. Similarly, dry river courses that hold alluvial water underground are important as linear oases through dry terrain, and they support much wildlife that would otherwise not survive the arid conditions. However, pods and browse on the trees attract livestock farming, which through over-use can reduce food availability for indigenous wildlife.

POISONING AND POLLUTION THROUGH USE OF VETERINARY PHARMACEUTICALS AND INSECTICIDES

The increasing use of agrochemicals globally plays a role in biodiversity loss. The consequences of veterinary activities trying to boost livestock production can be severe, witnessed by the decline of three species of Asian vultures caused by a widely used anti-inflammatory drug, *Diclofenac*, used for cattle. Use of Diclofenac has subsequently been banned in India and Pakistan but the vulture population in these countries is still critically low, and the indirect effects such as an increase in feral dogs and the subsequent spread of rabies into the human population carries a heavy economic cost (Ogada *et al.* 2011).

Tsetse flies in southern Africa are the vectors for *Nagana*, a disease that affects both humans and cattle.

Chemicals used to control such insect vectors (such as endosulfan) can have harmful environmental impacts, especially when broadly applied by aerial spraying. The accuracy of application has improved with modern navigation techniques, and less invasive methods such as bait traps and sterile insect techniques have brought environmental improvements; nevertheless, poison use associated with livestock farming still has serious impacts on local biodiversity and, as a result, environmental resilience. (Chaudhry *et al.* 2012).

NATURAL PARASITE CONTROL – OXPECKERS AND CATTLE IN SOUTH AFRICA

Oxpeckers, most usually associated with grazing ungulates in southern Africa, glean ticks, lice, flies and other ectoparasites from their hosts. However, the use of poison dips to rid cattle of ticks in commercial farming areas of South Africa and Zimbabwe led to a critical drop in oxpecker populations, especially of the more widespread red-billed oxpecker. Recent translocations of birds from wildlife reserves with strong oxpecker populations (e.g., Kruger National Park) have led to the re-establishment of these useful birds in cattle-farming areas. In areas where they are being distributed, farmers are encouraged to reduce the use of the most toxic pesticide dips, so that the birds are not harmed. These measures have helped to bring oxpeckers back to fulfilling their useful role on farms, a more ecologically sound way to keep control over cattle parasites.

SEDENTARISATION AROUND WATER POINTS

Provision of water infrastructure for projects, even if there is no intention to support livestock, commonly ends up becoming foci of settlement with permanent herds of animals that quickly deplete the available pastures. It is important to recognize that provision of water usually attracts human settlement and consequently also livestock.

LOSS OF WILDLIFE DIVERISTY AND ABUNDANCE, AND CONFLICT WITH WILDLIFE

As people and settlements expand their range and rangelands, so wildlife areas diminish. This is a common phenomenon in dryland developing countries. Fragmentation of habitat, isolation of conservation areas, the disruption of movement corridors between them, deforestation, and the over hunting of animals, all lead to reduced biodiversity.

A common consequence of livestock farming in drylands is conflict with wildlife, such as predation by wild carnivores and scavengers (e.g., lion, leopard, cheetah, baboon and hyena in Africa) and damage to water points caused by large animals such as elephant. These are particularly prominent in drylands where communal areas or private farms are established increasingly on marginal areas which were originally designated for the use of wildlife and/or tourism activities.

In relatively arid parts of the world there can be an economic advantage to wildlife and tourism activities since conventional stock farming is so marginal and risky. In southern Africa, scenic arid and semi-arid landscapes are generating more income from their wildlife and wilderness qualities than can be gained from livestock farming.

Case Study: Combining Wildlife and Livestock Production through Community Based Natural Resource Management (CBNRM)

In Burkina Faso, Fulani farmers have a system of transhumance in an area where there is also the largest elephant population remaining in West Africa. Their movement routes have become blocked by unplanned settlements, and the co-existence of livestock and wildlife is threatened by the over-exploitation of natural resources due to population growth and the weakening of traditional institutions that control access to grazing resources and the protection of wildlife. The UNEP funded Drylands Livestock Wildlife Environment Interface Project (DLWEIP) sought to restore good practices of integrated management aimed specifically at mitigating land degradation and enhancing biodiversity conservation for the improvement of community livelihoods.

The project secured access to transhumance routes and grazing areas for the overall welfare of the pastoralists. The routes go over community hunting land which is leased out to the pastoralists for a fee. These routes also involve neighboring countries (Benin, Togo, and Niger) and gained acceptance there. Restoration of the system has brought about increased income for the pastoralists and improved livestock sales. Training in business management has led to setting up of a milk processing enterprise, while establishment of a disease control committee and grazing guards has improved the reporting of diseases to veterinary officers.

Important elements in the project, which was also active in Kenya, were:

- Making the effort to establish strong partnerships amongst all the stakeholders,
- Making rehabilitation an income-generating activity (e.g., through reseeding of pastures);
- Arranging exchange visits between communities to facilitate sharing and dissemination of information on good practices as well as inspire community members;
- Setting up local committees, with government support, as a platform for enhancing negotiations over shared resources such as grazing, wildlife, and water points. Training in negotiation skills helped to reduce conflicts between sedentary farmers and pastoralists.

Source: UNEP-GEF, 2010; GEF.

DEFORESTATION

Deforestation in drylands is linked to slash and burn cultivation and the dependency of rural populations on wood fuel. The loss of forests has many negative effects on livelihoods and the world's resilience to climate and other environmental changes. When areas are denuded of trees, catchments can dry up, carbon sequestration is reduced, and the local climate becomes hotter. Soil health is compromised and this in turn affects rangeland health.

LOSS OF ECOLOGICAL INTEGRITY OF RANGELANDS AND ASSOCIATED HABITATS

There are numerous pressures on dryland ecosystems, and on wetlands and other habitats that are ecologically linked to drylands through food webs and nutrient cycles. Habitat conversion and fragmentation, grazing pressures, alien and invasive species, over-exploitation of resources, and climate change can all exert pressures that reduce the carrying capacity of drylands. Fire is an important natural event in savannahs, so changing the fire regime (through changing the frequency or the intensity of fires) can have a significant impact on the ecological integrity of an area. Likewise, changing patterns of water availability or water quality can be critically important. The livelihoods of small-scale farmers in drylands are closely dependent on the ecological services provided by the natural environment.

LOSS OF INDIGENOUS KNOWLEDGE

Animal husbandry on the world's drylands has traditionally involved nomadic pastoralism. Transhumance ensured that sensitive soils were protected from overgrazing and degradation. There are few cultures remaining today that have intact traditional nomadic pastoral systems. The Himba people in south-western Angola/ north-western Namibia are among the few traditional pastoralists remaining. However, these societies are currently in transition and have begun to respond to western and cash-based lifestyles.

These and other indigenous peoples living in drylands have developed highly participatory and successful land and grazing management systems which have held up for centuries, assisting them in surviving some of the worst droughts in history. As these cultures become increasingly modernized, they will become less self-sufficient and increasingly dependent on government and donor support. The loss of these cultures translates into a loss of valuable traditional knowledge regarding pastoralism in drylands.

LOSS OF RANGELANDS TO OTHER COMMERCIAL ENTERPRISES

Communal drylands, used by rural communities that often have little political or economic clout, are easily annexed or privatized for other more 'profitable' purposes such as private farms or large-scale irrigation schemes. It must be remembered that livestock fulfill many roles over and above food: they can be used for draught power and as a source of fertilizer (manure), as a means to store wealth, and as a 'reserve' that can be converted to capital in hard times or during emergencies. Reducing the land available for livestock, with its important livelihood support role, can exacerbate poverty.

D: SUSTAINABLE LAND MANAGEMENT OPTIONS FOR RANGELANDS

PROJECT DESIGN

CHOOSE BREEDS APPROPRIATE TO ARID CONDITIONS

Traditionally nomadic pastoralists living in the world's driest areas have farmed livestock that is well-adapted to drought conditions, have high resilience to local vector-borne diseases and are able to gain nourishment from local arid-adapted pastures. These breeds include Saanga cattle, Bedouin goats, fat-tailed sheep and many others.

Teff fields and livestock in Ethiopia. Photo credit: SAIEA.

For instance, physiological specializations allow Bedouin sheep to exploit pastures far from watering points in the Negev Desert. They are able to lose as much as one third of their body weight when deprived of water over two to three days, and can replace this loss when drinking. Their black color is an advantage in winter when they can absorb more heat than white goats. They are generalist feeders, able to sustain themselves on a wide variety of plants including woody and thorny shrubs with low nutritional value.

INTEGRATE CROP AND LIVESTOCK MANAGEMENT

Integrating crops and livestock create valuable synergies and allow optimal use of resources on drylands. Manure can be used to enhance soil fertility, while crop residues and by-products can provide supplementary feeds for animals. Shifting night enclosures can be used to fertilize the fields directly with urine and manure. Manure collection can be made more efficient by enclosing animals at night, and this also serves as protection. In Togo people use a so-called '*fosse fumiere*', an enclosure for goats and sheep centered over a circular pit which collects the droppings and urine. Animals are fed in the *fosse,* so that the put gradually fills with chopped organic matter and manure.

PROVIDE INFORMATION

Access to information can improve livelihoods for rural people living in drylands. For example, a Farmer Communication Programme (FCP) in East Africa shares knowledge about ecological agriculture via a monthly newsletter, *The Organic Farmer*, as well as radio programs and a web-based platform called Infonet-Biovision. In addition to these channels, the FCP also strives to be present on the ground in farmers and teachers interactions. Small operations doing sustainable chicken breeding and tree cultivation have benefited from the information.

SECTOR PROGRAM DESIGN – SOME SPECIFIC GUIDANCE

The three main themes for achieving sustainable land management in the cropping sector are equally applicable to livestock farming; namely sustaining and improving land productivity, improving livelihoods, and maintaining ecosystem integrity. Various practices that can help to reach these goals are listed in the below table.

PRIMARY GOAL	SELECTED SUSTAINABLE LIVESTOCK MANAGEMENT PRACTICES
Sustain and improve land productivity	• **Maintain and enhance soil fertility and nutrient cycling** - Sustain vegetation cover as much as possible. - Retain animal manure on the land. - Sustain indigenous shrubs and trees to act as nutrient pumps, especially indigenous leguminous plants. - Maintain habitat diversity for ecosystem stability. - Prevent overgrazing. • **Improve fodder production** - Manage access to pastures (through herding, fencing, rotation) so that desirable plants (especially perennial grasses) are not eradicated through over-use. - Retain large shrubs and trees (pods/leaves) as sources of fodder. - Prevent soil degradation/erosion, frequent fires. - Allow flexibility in grazing systems – e.g., animal movements or marketing in response to fodder availability and climatic responses. • **Improve animal production** - Use indigenous breeds or cross-breeds that are hardier with respect to disease and demand less in terms of quantity and quality of fodder and water. - Encourage a diversity of herbivores (including both grazers and browsers) to maximize use of all available plant resources.
Improve livelihoods	• **Widen the resource base** - Promote the sustainable use of local natural products (often found in or associated with rangelands) such as fish, indigenous fruits, fuel wood. • **Improve tenure over rangeland resources** - Suggest, introduce, or help implement policies that give people rights over rangeland resources and create incentives for environmentally sound practices. - Encourage active herding and planned grazing so that there is control over where livestock feed, water and move; shepherds and herders should be accorded an important place in the social hierarchy, so as to have appropriate value place upon properly managed livestock and land and vegetative quality. - Facilitate transhumance patterns where this is/was traditional practice and is still possible.

	• **Facilitate community based rangeland management** - Improve control and responsibility over grazing areas - Integrate rangeland considerations with other livelihood practices - Seek agreement amongst communities on use of grazing areas, rotation, and non-use for seasonal recovery of pastures, capitalizing upon or reinvigorating customary land governance practices where possible. • **Where appropriate, improve access to markets to enable commercial trade of livestock, including cross-border movement.** • **Provide information on environmentally sound livestock practices and other aspects of agriculture** • **Address health issues (HIV-AIDS, malaria, and others) that affect labor productivity, especially for shepherding.**
Maintain ecosystem integrity	• **Prevent, mitigate, and rehabilitate land degradation** - Encourage any measures that improve soil cover, enhance growth of perennial grasses, and allow seasonal rest of pastures. - Select management measures that help mitigate/rehabilitate damaged land e.g., rock fill erosion gullies, wind breaks. • **Maintain/Improve biodiversity** - Practice integrated pest management e.g., encourage natural predators of parasites such as oxpeckers, egrets. - Promote livestock genetic diversity. - Where possible, promote combined wildlife and livestock grazing systems. • **Choose 'climate smart' practices and policies** - Almost all the above-mentioned SLM practices – particularly those pertaining to diversifying the resource base, preventing land degradation and encouraging flexibility in rangeland use - will enhance adaptation to environmental variability. - See for example, the FAO Climate-Smart Agriculture Sourcebook (2010), www.climatesmartagriculture.org/72611/en/, or the World Bank Climate-Smart Agriculture Call to Action: http://www.worldbank.org/content/dam/Worldbank/document/CSA_Brochure_web_WB.pdf

Case Study: Planned Grazing through Combined Herding (PGCH)

MCA-Namibia developed a new strategy for improved rangeland management in communal areas of Namibia, focusing on communal areas in Northern Namibia. The strategy, termed Planned Grazing through Combined Herding (PGCH), signals a notable shift away from interventions based on fixed carrying capacities and fixed rotations. PGCH requires re-stocking and de-stocking animal to adjust to the amount of fodder produced during a given season. A grazing plan must be developed that is both flexible and ensures that the water cycle and soil organic matter/mineral cycle improve over time. Additionally, the plan must ensure that plants receive adequate growth periods and that underutilization of grasses is avoided.

PGCH involves combining herds from neighboring farms and herding all livestock from a single or several water points to a different patch to graze each day. The PGCH process is as follows:

1. Define who the livestock owners are and establish the grazing committee.
2. Identify a vision for the area, establish the root cause of degradation of rangelands, and then implement the plan to improve production and profit per hectare of rangelands.
3. The committee defines the grazing area to be used. This area must also be endorsed by the Traditional Authority.
4. The grazing plan and a land use plan are established.
    a. The aim of the grazing plan is to get the animals to the right place at the right time for the right reasons – meaning recovery periods of plants are accounted for, leaving good camps for the last few months of pregnancy, etc., taking into account social, economic, and environmental factors.
    b. The aim of the land plan is to ensure that infrastructure development is financially sound, well planned, and sited in the correct place. This is particularly necessary for the provision of alternative water sources which are expensive and require careful planning.

Focusing on land use patterns at the outset is important, with key questions including: how is land used? Who uses the land? Who owns or has customary or legal title? And, who are the stakeholders that influence pastoral land use? Communities need capacity building in analysis and decision making to effectively tackle the sophisticated decision making on tradeoffs required for well-functioning complex land use livestock herding systems, especially in the face of cycles of drought.

Evidence from the PGCH approach in Namibia shows that farmers are able to maintain or increase stocking rates while simultaneously improving the resource base. Moreover PGCH has resulted in improved body condition scores at the end of the dry season (compared to non-herded animals), increased calving rates because of more contact between bulls herded and kraaled daily with cows, and decreased losses due to predators. The PGCH concept combines science with traditional knowledge and low stress livestock handling, but communal farmers need to agree to change their habits to destock early in years of poor rainfall and restock when rains return. Failure to do this can do serious damage to the resource base and hence the ability of the land to support animals and wealth will decline over time.

Case Study: Planned Grazing through Combined Herding (continued)

Marketing is also an important but complex issue, as currently the ability to sell in the communal lands is limited, farmers' price expectations are often too high, and transport costs are also high. Numbers of livestock remain an important indicator of wealth, but to sustain this metric, livestock management must improve and costs must be reduced in order to allow for increased production and profit per hectare.

The most important factors to consider in this respect are that the farmer needs to grow more grass cheaply (PGCH should do this), while maintaining low animal input costs. Using animals bred from the area, and conditions familiar to the farmer, will most likely be the most effective way to increase profit per hectare over time in an inexpensive manner.

The PGCH approach is more culturally acceptable in communal areas and fits well in the communal farmer set up. Larger commercial farmers in Namibia are also turning to PGCH within their fenced off areas to achieve improved profit and production per hectare. Unfortunately, herding has lost its high status within the community, and a restoration of status would be of significant benefit. Namibia needs to establish academies that produce sound land and livestock managers able to undertake various tasks, at appropriate levels, under the different setups in the country.

Results are harder to achieve on communal lands, due to the fact that the principles are harder to apply, achieving cohesion is a challenge, and there is no legislative framework that allows rules to be enforced. Evidence suggests that the principles work, but the challenge is getting them to work in diverse and complex communal settings. This requires good facilitation over extended periods and buy-in at all sorts of local and regional government levels.

Source: John Pallett & Colin Nott, 2014.

MITIGATION MEASURES (BEST PRACTICE GUIDANCE)

The below table describes suggested mitigation measures for designing effective and environmentally sound livestock farming interventions in drylands.

Mitigation checklist for livestock farming projects

ACTIVITY	IMPACT	MITIGATION
Improvement of marketing infrastructure e.g., access roads, establishment of auction / marketing facilities, abattoirs	The activity may not be effective as there are many factors affecting whether people sell livestock.	Check the supply chain for other possible obstacles e.g., veterinary standards imposing unaffordable quarantine requirements, cultural reluctance to sell animals, poor condition of livestock means expected selling prices not achieved. Ensure that the high cost of the intervention will be worth it in social and economic benefits. Run thorough cost-benefit analysis during planning.
Introduction of high quality stud animals as breeding stock	High quality animals might have requirements which beneficiaries cannot provide e.g., high-quality fodder and water, enclosures or fencing, access to veterinary attention.	Ensure the introduced animals are appropriate to what beneficiaries can provide (e.g., suitable, adequate fodder, access to water, veterinary requirements).
Introduction of new livestock breeds and species	Often not practical, people may be reluctant to switch. Might have unintended negative impacts e.g., introducing new parasites, or susceptibility of new stock to existing diseases and conditions. Variability of dryland climate may jeopardize success.	Requires thorough community consultation, local expert advice, and testing before implementation.

ACTIVITY	IMPACT	MITIGATION
Introduction of improved rangeland management systems	Can be difficult to implement if there is strong commitment to traditional practices. Might be jeopardized by needing more labor which communities cannot give.	Requires much community-level preparation for social acceptance. Can be helped by on-site pilot projects to prove that changed practices are do-able and worthwhile. Ensure labor availability and willingness.
Establishment of cattle farming infrastructure e.g., boreholes, fences, marketing points	Can cause wildlife conflicts if livestock brought into close proximity to wildlife reserves or movement corridors.	Integrate plans with other sectors and with land use planning guidelines to optimize land use.
Use of insecticides or veterinary pharmaceuticals	Can cause dangerous pollution or long-term poisoning impacts on wildlife populations.	Treatment of carcasses and veterinary wastes should ensure that the materials are not infectious and leave no hazardous or toxic by-products. Legislation and law enforcement should be supported so that one cannot bypass responsible waste treatment and disposal.
Resettlement of people onto farms	Can be misguided if main (sometimes hidden) agenda is political.	Ensure viability of the farming units and suitability of the offered rangelands. Ensure local governance requirements, land ownership and social issues are addressed and understood by stakeholders. Ensure adequate capacity of the beneficiaries to farm as intended.
Introduction of new breeds or new species	Weaknesses or susceptibility to diseases might only manifest during abnormally low or abnormally high rainfall seasons.	Monitor livestock condition. Support veterinary surveillance and response readiness for disease epidemics e.g., Newcastle disease in chickens, tick-borne disease in small stock.

ACTIVITY	IMPACT	MITIGATION
Expansion of livestock farming areas and / or enhancement of livestock activities	Human- wildlife conflict, or conflict with other economic sectors e.g., tourism, intensive irrigation cropping. Overstocking and land degradation can occur if stocking rates are pushed up.	Support forums for integrated land use planning and resource management. Encourage community-level involvement, whilst being aware of the governance hierarchy. Support forums for integrating advice from government extension officers, NGOs and donor organizations, traditional practices.
Change to the fire regime	Increased frequency of fires can damage trees and reduce soil fertility. Reduced frequency of fires can lead to bush encroachment.	Fire management strategies should be work-shopped and implemented.
Any dryland farming activities	Rural livelihoods susceptible to drought.	Diversify livelihoods. Support activities that help to detect early onset of drought, as part of drought preparedness. Facilitate mechanisms to destock and restock as conditions dictate, so that stocking rate tracks fodder and water availability.

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SUGGESTING READING LIST

CONSERVATION FARMING UNIT (CFU)

The CFU Zambia web site is useful for those interested in the promotion of Conservation Farming and Climate Smart Agriculture. The following documents can be accessed via the CFU website: http://conservationagriculture.org/articles.

Green Rocks and Green Trees.pdf

CA-Productivity-and-Climate-Change-20.5.11.pdf

Conservation-Farming-Food-and-Productivity-25.1.2011.pdf

Key-Ag-Sector-Challenges-Zambia.pdf

Maize-Production-And-Cf-In-Zambia.pdf

OTHER RESOURCES:

1. Winterbottom, R., et al. 2013. “Improving Land and Water Management.” Working Paper, Installment 4 of Creating a Sustainable Food Future. Washington, DC: World Resources Institute. Accessible at: http://www.wri.org/publication/improving-land-and-water-management

2. ECHO Community: Global Agriculture Network, http://www.echocommunity.org/

3. EcoAgriculture Partners strives for a world where agricultural communities manage their landscapes