Designing for Displacement: A Spatial Guide for Planning Along Seasonal Rivers in Drylands

Nature-based Solutions for Use in Arid and Semi-Arid Land Regions of East Africa

UN-HABITAT

Acknowledgments

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People in Kakuma Refugee Camp crossing a large lagga.
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Foreword

UN-Habitat is mandated by the UN General Assembly to promote the development of socially and environmentally sustainable human settlements. As outlined in the New Urban Agenda, this encourages national and local authorities, as well as other actors, to invest in sustainable urban development strategies to address challenges facing urban areas, such as informal growth, widening inequalities, climate change, environmental degradation, spatial segregation, economic exclusion, irregular migration, and displacement.

Over recent decades, the world has witnessed a rise in displacement caused by conflicts, crises, and the effects of climate change. Coupled with longer-lasting instability and an increase in the frequency and impact of natural disasters, increasing numbers of people end up in situations of long-lasting exile. Moreover, a disproportionately large percentage of forcibly displaced people[1] are hosted by some of the poorest and most resource-scarce countries in the world; 39% of refugees live in temporarily planned humanitarian 'camps,' while 61% live outside of camps,[2] often in urban and peri-urban areas where they are particularly likely to face tension and conflict with host communities.

However, humanitarian aid alone is unable to address the long-term needs of displaced populations and their hosting communities. At the same time, development actors need to recognise the inter-linkages between humanitarian crises, climate change, and settlement planning to mobilise projects that take stock of the inter-connectedness of humanitarian-development-peace nexus approaches. Moving forward, strategic and inclusive urban planning and environmental management will need to play a more dominant role in how humans more effectively mitigate, and more resiliently adapt to, the intersecting challenges of forced displacement and climate change.

One of UN-Habitat's key strengths is in working with urban experts across line ministries and municipal sectors to facilitate transformative initiatives that promote local expertise and respond to local contexts. Through resilience principles underpinned by the triple nexus, UN-Habitat collaborates with municipalities, humanitarian actors, and displaced and hosting communities to develop strategies that leverage the spatial, as well as socio-economic benefits, that migrants can bring to settlements and urban areas.

Collective global action is urgently needed in order to mitigate and adapt to the impacts of climate change. This publication builds on desktop research and field experience to establish a catalogue of spatial strategies and socio-economic approaches that could be implemented in humanitarian-development contexts. These strategies are best suited for settlements along intermittent rivers in the dryland regions of East Africa, where much of UN-Habitat's spatial planning expertise in protracted climate-vulnerable displacement situations has been developed.

This guide aims to provide an initial step towards amassing a knowledge base that can be drawn upon by both humanitarian and development practitioners, national and local governments, and other stakeholders in order to expedite planning processes and provide affordable, cost-effective, resilient, and often nature-based design solutions. Planning and design should always be context-specific, though, therefore the strategies outlined here are not meant to serve as precise specifications or construction drawings but should provide inspiration for practitioners to develop and implement context specific, Nature-based Solutions (NbS) that lay a foundation for self-reliance and overall resilience.

Endnotes

1 At the end of 2019, UNHCR reported 15.7 million refugees in protracted situations. UNHCR Global Trends: Forced Displacement in 2019 p. 24.

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One of the larger laggas adjacent to Kakuma Refugee Camp.
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Glossary & Acronyms

Arid and Semi-Arid Lands (ASALs)

Arid and Semi-Arid Lands (ASALs) is a classification of drylands that is used specifically in Kenya to describe lands experiencing annual rainfall ranges between 150 mm to 550 mm for arid areas and between 550 mm to 850 mm for semi-arid areas.[1] In the context of Kenya, nearly 90% of the nation's total land surface is classified as ASALs, a land area that is home to around 38% of the Kenyan national population, 70% of the livestock population, and 90% of wildlife.[2] In all, 29 of the of the nation's 47 counties contain ASALs.[3]

Aridity Index (AI)

The Aridity Index, commonly abbreviated as AI, refers to a ratio of the average amount of annual precipitation (P) to the potential amount of evapo-transpiration (PET).[4] This ratio creates a numerical indicator that is used to identify how dry a climate is in a specific area and is therefore commonly used in the classification of drylands, in particular.[5]

Artificial Recharge of Groundwater (ARG)

The Artificial Recharge of Groundwater (ARG) refers to the process of manually promoting and encouraging the infiltration of surface water into the ground using a variety of techniques in order to restore the aquifer where that water can be stored.[6] ARG techniques are often implemented in areas where natural infiltration rates are poor due to geologic and climate conditions and where long dry seasons are interrupted by only occasional heavy rains that can easily overwhelm the dry soil.

Community-Based Natural Resource Management (CBNRM)

Community-Based Natural Resource Management (CBNRM) refers to a human-centred approach that combines land conservation and natural resource stewardship with development goals.[7] This approach is focused around a self-defined community with shared goals and the desire to cooperate on the management of land and renewable natural resources (e.g., vegetation, forests, water, wildlife).[8] The group's efforts should be governed by agreed upon rules and regulations that specify how resources should be used and at what rate.[9] Successful and well-managed CBNRM are able to support the development of increased livelihood opportunities and expanded access to environmental services that simultaneously help to improve social justice conditions.

Desertification

Rising temperatures associated with climate change are leaving more and more of the earth's land surface vulnerable to desertification, which refers to the transformational process of drying as a result of changing climate conditions. This is understood to be a largely irreversible deterioration of land that was once arable, a change that threatens to dramatically reduce the portion of the earth's surface that is habitable and useful for the production of food. The risk of desertification is most severe in drylands where rainfall is already limited and often also unpredictable and inconsistent. These trends are of particular concern, because drylands already account for more than 40% of the earth's total land area.[10]

Disaster Risk Reduction (DRR)

As urbanisation, climate change, and inadequate preparedness converge, natural hazards are increasingly responsible for ever more frequent disasters that often lead to loss of life and severe economic costs. In response, Disaster Risk Reduction (DRR) refers to those measures and actions that are taken to prevent new, minimise existing, and manage persistent natural hazards with the aim of reducing their negative impacts while improving resilience and pursuing sustainable development.[11]

Drylands

Drylands refer to hyper-arid, arid, semi-arid, and dry sub-humid zones, which are broadly defined as geographic land areas with a scarcity of water and an Aridity Index (AI) value of less than 0.65, as defined by the United Nations Environment Programme (UNEP).[12] Together, drylands account for about 41% of the earth's total land surface.[13]

Ephemeral Water Systems

Ephemeral Water Systems is a term that refers to the primarily dry water channels which flow exclusively during, and immediately following, major precipitation events. They typically flow with water less than 20% of the year but are highly prone to flash flooding during those occasional periods of heavy precipitation.[14]

Farmer Field Schools (FFS)

Farmer Field Schools are programs that focus on participatory and human-centred learning approaches aimed at creating an environment for knowledge exchange between small independent farmers and other actors engaged in agricultural activities that are working in a shared context. FFS groups are typically composed of around twenty to thirty farmers who have expressed an interest in learning from each other as well as experts and research about ways to improve the techniques used in their farming practices. Groups are organised and managed by trained facilitators who lead participants through informal instruction and hands-on experimentation that explore and compare sustainable, local, and improved agricultural techniques.

Flood Risk

Flooding is a natural process that occurs when the level of a body of water rises until it overflows its natural banks or artificial levees and submerges land that is usually dry.[15] Floods are generally caused by heavy rainfall, storm surge, or damage to water management or diversion infrastructure and can manifest annually or even seasonally. Riverine floods are the most common form of flooding and occur when the volume of water that typically passes between natural or engineered river banks is increased due to heavy rainfall, overflows those confines, and subsequently flows into the surrounding areas.[16] Flood risk is a multifaceted challenge that affects various sectors and can require that physical, socio-economic, and hydrological measures be combined in order to mount an effective response. Floods can cause widespread devastation and result in loss of life along with damage to personal property, critical infrastructure, and public facilities. Furthermore, these consequences are often further amplified when flooding and other pre-existing vulnerabilities converge.[17] Flood waters also can pose serious health risks, because they may easily become contaminated with pollution, untreated sewage, and other hazardous materials which can lead to outbreaks of, among other diseases, typhoid, malaria, hepatitis A, and cholera. Already the second-most widespread environmental hazards on Earth, after wildfires, floods, and the extreme precipitation events that often cause them, are also increasing in frequency and intensity, a trend that is expected to continue as a result of climate change.[18] (See Figure 4)

Forced Displacement

Forced displacement describes the involuntary or coerced movement of people away from their home or home region. It's generally recognised as a result of persecution, conflict, violence, human rights violations, or events seriously disturbing public order. Furthermore, climate change and natural hazards are also common drivers, as well as rising global food shortages and higher costs of living. Forced Displacement may occur within the borders of a nation-state, as with so-called Internally Displaced People (IDPs), or across international borders, where the displaced may seek asylum and protection as refugees but may also include other various People of Concern (PoCs) which may not be granted refugee status.[19] Critically, according to the 1951 Refugee Convention and its 1967 Protocol, the agreed upon definition of refugee and their protection status doesn't relate to environmental or economic drivers of displacement of migration.[20]

Genetically Modified Organisms (GMOs)

A genetically modified organism (GMO) refers to any plant, animal, or other lifeform that has been altered from its natural state through the editing of its DNA by humans using genetic engineering for research or, most commonly, to make changes to crops that play a significant role in the food supply system. Although this approach can have various effects, genetic modifications are typically made in order to produce crops with greater resistance to pests and disease and higher yields alongside outputs that can taste better and exhibit a longer shelf life.[21]

Gully

A gully is a channel or a ravine, that is formed by rapidly moving water which has sharply eroded the soil or another similarly erodible material over time. Gullies typically form on hillsides and in river valleys and are particularly common where intermittent and seasonal rivers occur.

Humanitarian-Development Contexts

Humanitarian action and development assistance represent two distinct discursive and institutional segments of the international system. Humanitarianism's apolitical and imminent needs-based approaches build on established humanitarian principles that are fundamentally different from the more long-term, political, rights-based approaches of development. The Humanitarian-Development Context is important where humanitarian conditions are protracted and require an expanded focus on long-term development including more strategic planning and interventions.[22] There is a growing consensus about the inclusion of Peace as a third component, as well, leading to the establishment of the Humanitarian-Development-Peace Nexus (HDP). The system works towards achieving sustainable collective outcomes that reduce need, risk, and vulnerability, over extended timeframes, based on the comparative advantages of engaging a diverse range of actors. Eliminating needs by reducing risks and vulnerability is now a shared vision, under the 2030 Sustainable Development Goals (SDG) umbrella, that transcends this divide.[23]

Integrated Watershed Management (IWM)

Integrated Watershed Management (IWM) refers to stewardship programs established with community and government participation and support that seek to promote the responsible management and monitoring of the water resources, both surface and groundwater, that compose and sustain a watershed system.[24]

Integrated Soil Fertility Management (ISFM)

Integrated Soil Fertility Management (ISFM) refers to coordinated techniques implemented in order to manage the capacity of a given area of land to support sustainable and economically viable agricultural activities through the use of various organic inputs (e.g., mineral fertilisers) combined with local knowledge.[25] The goal of implementing ISFM practices is to maximise the agronomic efficiency of the soil to grow the desired crops given the site-specific conditions.

Intergovernmental Panel on Climate Change (IPCC)

Intergovernmental Panel on Climate Change (IPCC) refers to the United Nations international and intergovernmental body of scientific experts responsible for assessing and advancing the science related to climate change, in particular as it is impacted by human activity. It is not responsible for conducting its own research, but compiles and reviews the extent of relevant published literature and data. It is also tasked with anticipating and evaluating the social, economic, and political effects of climate change while presenting a range of potential scenarios, responses, and eventual outcomes.

Indigenous and Local Knowledge (ILK)

Indigenous and Local Knowledge (ILK) refers to skills, expertise, understandings, traditions, techniques, and beliefs that have developed over time based on long and deep relationships between a local population and the land that its people have inhabited over an extended period of time.[26] For indigenous societies, especially those in rural or isolated areas, these relationships, and the local knowledge that has been created as a result, are central to the way that the population interacts with its natural surroundings and inform many aspects of everyday life. This knowledge can be deeply integrated with the culture, often informing languages, rituals, systems of knowledge management, spiritual practices, and social behaviours. As described by UNESCO (United Nations Educational, Scientific and Cultural Organization), "these unique ways of knowing are important facets of the world's cultural diversity, and provide a foundation for locally-appropriate sustainable development."[27] Recognizing the depth and inherent value of Indigenous and Local Knowledge, UNESCO endeavours to collect, collate, and preserve these learnings as valuable resources that can inform efforts to combat the effects of climate change.[28]

Intermittent River

For the purposes of this document, the term intermittent, when used in reference to a body of water, encompasses all temporary, non-perennial, ephemeral, seasonal, and episodic streams and rivers that flow through defined water channels.[29] As described by Thibault Datry, et al., "[i]ntermittent rivers constitute more than half of the length of the global river network and are increasing in number and length in response to climate change, land-use alteration, and water abstraction,"[30] which underscores their prevalence and importance. In this document, the term encompasses seasonal rivers, which are typically understood as water channels fed from seasonal water flow of between 20-80% annually.[31]

Internally Displaced Person (IDP)

An Internally Displaced Person, often abbreviated simply as IDP, is a person forced to leave their home who, unlike a refugee, remains within the boundaries of their country of origin.

Lagga

'Lagga' is a Turkana term, widely used in the Turkana region of Kenya, that refers to intermittent water bodies, typically seasonal rivers, and their corresponding dry riverbeds.

Land Degradation

Land Degradation refers to a deterioration of the natural condition of an area of land that can result from a variety of natural forces and human activity. These forces can include drought, flooding, pollution, and poor land management practices.[32] Land Degradation is often characterised by a decline in biological diversity, ecological integrity, and soil quality.[33] These factors impact the land's ability to produce food and form the foundation of sustainable and productive livelihoods. Therefore, any degradation is likely to represent an overall reduction in the land's utility, productivity, and usefulness for sustaining human settlement and economic activity.[34]

Nature-based Solutions (NbS)

Nature-based Solutions (NbS) represent a component of sustainable land management which involve both climate change adaptation and mitigation strategies that harness natural resources, local conditions, and weather events, such as flooding, to reduce greenhouse gas emissions, improve resilience and land productivity, address socioeconomic challenges, and promote human well-being by employing natural, often traditional, knowledge, strategies, and techniques.

Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index, typically abbreviated as NDVI, is the most widely used remotely sensed vegetation index, providing a measure of canopy greenness that is related to the quantity of standing biomass over an area of land. It is commonly used as an indicator to assess and compare the health of ecosystems.[35]

Organic Agriculture (OA)

Although the exact definition of Organic Agriculture can vary widely, it is generally understood that, as FAO describes, "it is a system that relies on ecosystem management rather than on external agricultural inputs."[36] Centrally, it strives to reduce or avoid altogether any reliance on artificial inputs (e.g., synthetic fertilisers or pesticides, genetically modified seeds, veterinary antibiotics, or inorganic preservatives or additives) and prioritise environmental and social considerations.[37] In place of artificial inputs and inorganic technologies, a focus is placed on promoting and preserving the health and vitality of the soil and other environmental conditions through natural approaches based in traditional knowledge and regional or even site-specific practices. Although outputs or practices may be certified as organic, they often are not, and criteria for the label can vary by jurisdiction or certifying entity, so care should be taken when relying on the designation. It can, though, have the added benefit of increasing the value of agricultural outputs on the market in addition to the long-term environmental benefits.

Payment for Ecosystem Services (PES)

Payment for Ecosystem Services (PES) involves programs and policies that provide compensation to individual farmers and landowners, as well as to communities, as an incentive to pursue responsible and sustainable stewardship of land and natural resources and to simultaneously provide ecological, environmental, or ecosystem services, which can be understood as benefits derived from the natural environment by and for people.[38]

Protracted Displacement Crisis

In the humanitarian context, a Protracted Displacement Crisis refers to a situation where 25,000 or more refugees and/or other displaced people have fled from the same country or region for a shared reason and have been living in exile for more than five consecutive years.[39]

Sexual and Gender Based Violence (SGBV)

Sexual and Gender-Based Violence (SGBV) refers to any acts of violence, aggression, or discrimination that are perpetrated against a person without their consent, at least in part because of gender norms and/or a real or perceived power imbalance resulting from their gender and/or sexual identity. This can include, but is not limited to, physical, emotional, psychological, and sexual acts, but can also include the threat of such acts or coercion resulting from such threats. Persons of concern and members of various population groups such as older persons, persons with disabilities, adolescents, children, persons who identify as LGBTQIA+, and female heads of household are at particularly high risk of SGBV, though such acts can be experienced by anyone and represent a serious violation of human rights.[40]

Sustainable Land Management (SLM)

Sustainable Land Management (SLM) refers to the protection of land and responsible use of land resources, (i.e., soils, water, animals, and vegetation) to fulfil changing human needs and evolving environmental conditions, while ensuring that the long-term socioeconomic and ecological viability of the land and existing natural resources are preserved.

RCP and SSP Pathways

According to the IPCC, "Representative Concentration Pathways (RCPs) Scenarios include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. Shared Socio-economic Pathways (SSPs) were developed to complement the Representative Concentration Pathways (RCPs) with varying socio-economic challenges to adaptation and mitigation. The SSPs are based on five narratives describing broad socioeconomic trends that could shape future society: a world of sustainability-focused growth and equality (SSP1); a 'middle of the road' world where trends broadly follow their historical patterns (SSP2); a fragmented world of "resurgent nationalism" (SSP3); a world of ever-increasing inequality (SSP4); and a world of rapid and unconstrained growth in economic output and energy use (SSP5). The combination of SSP-based socio-economic scenarios and RCP-based climate projections provides an integrative frame for climate impact and policy analysis."[41]

United Nations High Commissioner for Refugees (UNHCR)

The United Nations High Commissioner for Refugees (UNHCR) is the United Nations Refugee Agency and the premier global organisation concerned with protecting the lives, rights, safety, and wellbeing of the world's refugees and all of those people who are forcibly displaced or stateless. For all those fleeing their homes to escape from violence, persecution, war, or disaster, UNHCR works to preserve and expand the right to seek asylum and secure safe refuge while also ensuring the opportunity to build toward a better future.[42]

Wadi

Wadi, which is a common term in some Arabic speaking countries, is used to describe a dry riverbed, often visible as a valley or channel, that flows only during the wet season and/or when heavy rain occurs.[43] This landform typically occurs on dry desert lands with a minimal slope that remains dry for the majority of the year as there is not sufficient water to sustain a flowing waterway except when heavy rains occur.

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Chapter 1: Introduction

I. Protracted Displacement and Climate Change

Considering the extensive scope and scale of forced displacement in the 21st Century, humanitarian aid in its current form has failed to meet the long-term needs of displaced people, host communities, and local governments. According to UNHCR, the number of people forcibly displaced as a result of persecution, conflict, or generalized violence, both internally and across borders, has increased by over fifty percent in the last ten years. In fact, from 2009 to the end of 2018, the global population of forcibly displaced people grew from 43.3 million to 70.8 million, with an estimated one out of every 108 people in the world currently displaced.[1]

For decades, governments and humanitarian organizations have worked to address the challenges associated with long-term planning for refugees and internally displaced people (IDPs), developing frameworks such as 'Linking Relief, Rehabilitation and Development (LRRD),' the 'Early Recovery' approach, and the 'Humanitarian to Development Continuum.' However, with three in four refugees caught up in protracted crises,[2] there is exigent need to bridge the divide between humanitarian and development sectors. At the 2016 World Humanitarian Summit, UN Secretary General António Guterres announced 'A New Way of Working' to promote the humanitarian-development-peace nexus, which responds to immediate needs while also addressing systemic causes of conflict and vulnerability such as poverty, inequality, and a lack of institutional accountability. This emphasis on a more coherent approach reduces the frequency of and builds resilience against cyclical and recurrent shocks and stresses by integrating peacebuilding and sustainable development while ensuring continued investment and support.

As the global refugee situation continues to escalate, the climate crisis looms as another one of this century's greatest existential threats. With many of the aforementioned shocks and stresses resulting from natural disasters, unpredictable weather events, and extreme temperatures, the impacts of human-induced climate change affect socio-economically disadvantaged communities most profoundly. According to the Intergovernmental Panel on Climate Change (IPCC), "Populations at disproportionately higher risk of adverse consequences with global warming of 1.5°C and beyond include disadvantaged and vulnerable populations, some indigenous peoples, and local communities dependent on agricultural or coastal livelihoods (high confidence)."[3] Globally, the urban poor are particularly vulnerable; slums, camps, and other informal settlements are often located in fragile ecosystems and hostile climates, such as on slopes, flood plains, river deltas, and littoral zones. Furthermore, "land degradation and climate change act as threat multipliers for already precarious livelihoods (very high confidence), leaving them highly sensitive to extreme climatic events, with consequences such as poverty and food insecurity (high confidence) and, in some cases, migration, conflict and loss of cultural heritage (low confidence)."[4]

"Populations at disproportionately higher risk of adverse consequences with global warming of 1.5°C and beyond include disadvantaged and vulnerable populations, some indigenous peoples, and local communities dependent on agricultural or coastal livelihoods (high confidence)."

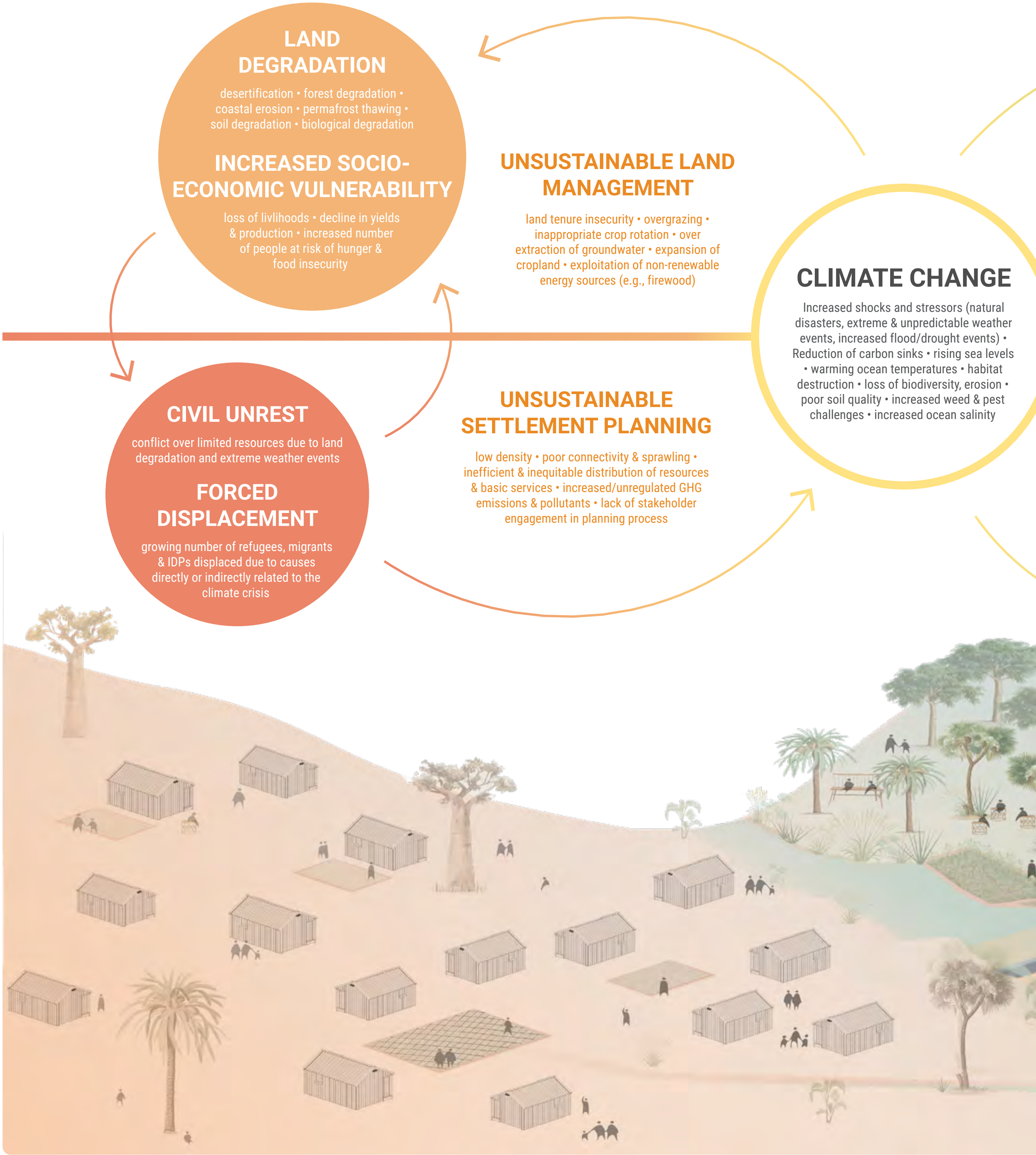
People in Kakuma Refugee Camp crossing a large lagga. © UN-Habitat

People in Kakuma Refugee Camp crossing a large lagga.

As the climate crisis intensifies, the frequency and severity of extreme weather events and natural disasters (e.g., hurricanes, cyclones, typhoons, flooding, and wildfires) increase concurrently, exacerbated by land degradation, which is defined by the IPCC as “a negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as long-term reduction or loss of… biological productivity, ecological integrity or value to humans,” (e.g., soil erosion, land subsidence, scarcity of water and other natural resources, habitat degradation, and loss of biodiversity).[5] These adverse climate trends have dire consequences, including loss of life and destruction of livelihoods, putting pressure on scarce natural resources and land while also threatening the health and economic resilience of impacted communities. Faced with threats to their survival, including resource scarcity and loss of yields, affected communities might seek better conditions elsewhere, or they may choose to expand settlements and croplands into previously uncultivated areas. Climate-induced migration can incite or exacerbate existing conflict due to abrupt population influxes and demand for limited resources.

Land in arid, semi-arid, and dry sub-humid climates, collectively known as drylands, has been seriously impacted by a type of land degradation classified as desertification, which has been induced by human activity, poor land management practices, and climatic variation. With the rising temperatures associated with climate change, more and more of the earth’s land surface is vulnerable to desertification, which refers to the transformational process of drying as a result of changing climate conditions. This is understood to be a largely irreversible deterioration of land that was once arable, a change that threatens to dramatically reduce the portion of the earth’s surface that is habitable and useful for the production of food. The risk of desertification is most severe in existing drylands where rainfall is already limited and often also unpredictable and inconsistent. But land degradation and desertification are also deeply connected to poor land governance, particularly weak land tenure security of local communities, which is most common in areas with inadequate government capacity. This is of particular concern, because drylands already account for more than 40% of the earth’s total land area.[6]

Figure 1 **A way forward: climate change, land degradation, and forced displacement**



SUSTAINABLE LAND MANAGEMENT

land tenure security • integration of nature-based & renewable strategies in resource, agriculture & infrastructure management • limits to urban growth boundary • protection of riparian areas and other fragile ecosystems • accountability in governance

MITIGATION

limiting GHG emissions • expanding footprint of carbon sinks • conserving & protecting natural resources, biodiversity, & ecosystems

RESTORATION & REGENERATION

more equitable access to green infrastructure & renewable resources • higher, sustained crop yields with reduced reliance on expensive pesticides, fertilizers & GM seeds • sustained or increased biodiversity & protection of native species • access to diverse & sustainable economic opportunities

SUSTAINABLE SETTLEMENT PLANNING

compact urban/spatial form • non-motorized transit/public transportation • equitable access to infrastructure, basic services & socioeconomic opportunities; use of renewable energy sources • regulation of pollution & contaminants • inclusive planning processes

ADAPTATION

maximising available resources using sustainable strategies • diversifying livelihoods to plan for uncertainty • adapting supply of food, water & energy to changing climatic conditions • building resilient infrastructure & shelters to withstand extreme weather events •Implementing disaster risk reduction measures

The ongoing expansion of drylands across Africa, particularly in the Sahel and the Horn of Africa, has resulted in a permanent loss of livelihoods that are no longer viable in the affected regions. The impacts of desertification on dryland communities have played a significant role in, and will inevitably continue to accelerate, urbanization, irregular migration, and the growing number of IDPs and refugees in these regions.

Following and contributing to pre-existing urbanisation patterns, towns and cities represent the primary destination for the majority of the world's migrants, which include refugees, internally displaced people (IDPs), and asylum seekers, as well as economic and environmental migrants. Already it is estimated that more than 60% of refugees and 80% of IDPs now live in urban environments.[7] Urban areas are often the preferred destination because they offer greater protection, existing social networks, better access to services and opportunities, and because there is commonly an aspiration to participate in existing urban economic activity. Any rapid influx of this kind can have major impacts on municipalities and aggravate existing challenges in delivering the physical infrastructure, basic services, and access to adequate and affordable housing, as well as place an even greater strain on land and property challenges. Displacement flows also exacerbate the economic and social risks related to these spatial challenges, which make it difficult for cities to respond with durable long-term solutions.

Unless cities are equipped with inclusive integration frameworks and policies, as well as climate resiliency strategies, migration to urban areas will likely continue to contribute to the proliferation of slums and informal settlements and place greater numbers of people in vulnerable conditions. These types of unstable settlements can be problematic because, despite the promise of the city, their residents often face scarce economic opportunity and poor living conditions that threaten their health and safety. Conflict and discrimination are also common in these settings, especially between those living in the informal conditions and those living in adjacent formal settlements who often fear that their security is threatened by any influx of migrants.

Spatial planning plays a pivotal role in efforts to respond to the climate crisis by mitigating future risks and building resilient human settlements. Unsustainable settlement planning has severe environmental and socio-economic repercussions, including compounding greenhouse gas (GHG) emissions and shrinking carbon sinks. For example, without defined boundaries, unplanned urban growth often leads to urban and peri-urban sprawl, which is characterised by low-density development typologies that contribute to destruction of natural habitats, disruption of water and carbon cycles, reduction of biodiversity, encroachment onto indigenous lands, and establishment of automobile dependent mobility models. The urban design, including spatial form and adjacency, of housing, roads, public spaces, and municipal services, as well as building codes, zoning regulations, and land use planning, have immediate and long-term consequences on an area's habitability, equitability, and carbon footprint. Figure 1 visualizes the negative feedback loop that exists between climate change, land degradation, and forced displacement, while proposing an alternative path that enables actors to break the cycle through the introduction of climate adaptation and mitigation measures.

Adaptation devices such as Disaster Risk Reduction (DRR) and mitigation strategies such as Sustainable Land Management (SLM) are critical for the resilience of not only established urban areas, but also for settlements across the humanitarian-development spectrum, including developing urban environments, informal settlements, and refugee and IDP camps in protracted states. Spatial planning must contribute to the low-emission development of human settlements by configuring functions and services to minimize their carbon footprint and restrict emissions caused by destructive land uses and land-use changes. Spatial planning, though, must also be concerned with social cohesion, which has often been strained in the humanitarian-development context, but is critical to the development of and strengthening of community resilience.

Social inclusion, community resilience, and aligned long-term goals are important components of successful climate mitigation strategies, as well. These are always important components of resilient planning, but achieving these qualities in displacement contexts is of particular importance because of the unique challenges that these circumstances pose. Refugee settlements typically already demonstrate reduced resilience and require additional effort to rebuild or even establish social cohesion, particularly between refugee or IDP communities and host communities, as well as within camps and settlements which are often shared by communities representing diverse cultures and nationalities.

Thoughtful spatial planning and design techniques can be highly effective in cultivating unity and promoting shared prosperity; planners in humanitarian-development contexts can promote social cohesion by understanding and leveraging pre-existing social structures within and between the displaced communities whenever possible in order to catalyse participation in community based SLM and DRR initiatives. Mutually beneficial exchange between camp communities and nearby host communities is also critical to ensuring that interventions are successfully adopted and maintained in the long-term, so social cohesion between disparate communities should be nurtured, and, whenever possible, any pre-existing connections (e.g., economic, trade) should be identified and taken advantage of. In such dynamic, unstable, and often unpredictable contexts, these strategies are essential to ensuring successful uptake of initiated interventions and securing their durability.

II. Purpose and Organisation of the Guide

The need for climate change adaptation and mitigation measures in dryland areas is well established and already there are numerous planning and design strategies that have been successfully deployed to leverage the benefits of intermittent rivers in arid and semi-arid environments. However, these various strategies and techniques have not been collected or collated in a way that demonstrates the unique opportunities that they can offer when applied in the context of displacement.

In response, this document aims to serve as a spatial design guide for use in settlements affected by protracted displacement (i.e., humanitarian-development) in the context of drylands where intermittent rivers occur. In support of this goal, the guide presents a curated selection of particularly relevant ecological and landscape strategies alongside economic development and livelihood opportunities and offers guidance on their implementation. Furthermore, it presents some conceptual design proposals in order to demonstrate how the guide might be utilised and offer some inspiration to actors seeking to deploy these suggestions in creative and innovative new ways.

Following this first introduction chapter, the document is organised into four main chapters:

1. **Chapter 2: East African Drylands: Geographic Background** — provides geographic background information on dryland areas in the Arid and Semi-Arid Land (ASAL) regions of East Africa, including the challenges and impacts of desertification, and an explanation of the opportunities and constraints presented by the intermittent rivers that commonly present in the environments found there.
2. **Chapter 3: Humanitarian Principles for Planning in the Context of Dryland Displacement** — outlines principles drawn from key humanitarian references and resources, including primarily the "The Sphere Handbook: Humanitarian Charter and Minimum Standards in Disaster Response" and the UNHCR Emergency Handbook "Master Plan Approach to Settlement Planning Guiding Principles." The chapter aims to highlight the standard humanitarian-development considerations that are uniquely relevant to designing for displacement along intermittent waterways in dryland regions. These standards incorporate circulation systems, land management, energy supply, water supply, sanitation, and waste management. In addition, two additional resources, "Guidelines for a Landscape Approach in Displacement Settings (GLADS)" and "Building climate resilience of urban systems through ecosystems-based adaptation Toolkit," are introduced for further consideration.
3. **Chapter 4: Strategies for Sustainable Land Management and Opportunities for Economic Development** — presents possible planning and design strategies in the format of a 'Kit of Parts.' It first outlines a collection of ecological and landscape strategies, or Nature-based Solutions (NbS), for sustainable water and land management, with a particular focus on water harvesting and storage and flood mitigation. Second, the chapter highlights strategies for economic development and livelihood opportunities which could be coupled with the previously described Nature-based Solutions and sustainable land management (SLM) practices. Case studies punctuate the chapter as a way to exemplify the application of these NbS and sustainable socio-economic approaches.
4. **Chapter 5: A Way Forward** — summarises the viewpoints and strategies proposed in this document and presents a collection of possible design proposal ideas for integrating various combinations of NbS, disaster risk reduction (DRR), and Disaster Risk Management (DRM) strategies, alongside income-generating activities within the specific context of ASAL regions. The goal of this chapter is to offer some initial inspiration for practical implementation of this guide and the various strategies, techniques, and approaches presented herein. It also presents preliminary criteria for effective evaluation and selection of strategies and suggests areas for further development and research.

Endnotes

1 UNHCR, 2019: Global Trends: Forced Displacement in 2018.

2 UNHCR, 2019: Global Trends: Forced Displacement in 2018.

3 IPCC, 2018: Summary for Policymakers. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

4 Olsson, L., H. Barbosa, S. Bhadwal, A. Cowie, K. Delusca, D. Flores-Renteria, K. Hermans, E. Jobbagy, W. Kurz, D. Li, D.J. Sonwa, L. Stringer, 2019: Land Degradation. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

5 IPCC 2019: Land Degradation. In: Climate Change and Land: an IPCC special report

6 https://www.un.org/en/events/desertification_decade/whynow.shtml

7 World Refugee Council, 2018

Waterlogged streets in Kakuma Refugee Camp.
© UN-Habitat

Chapter 2: Geographic Background: Drylands

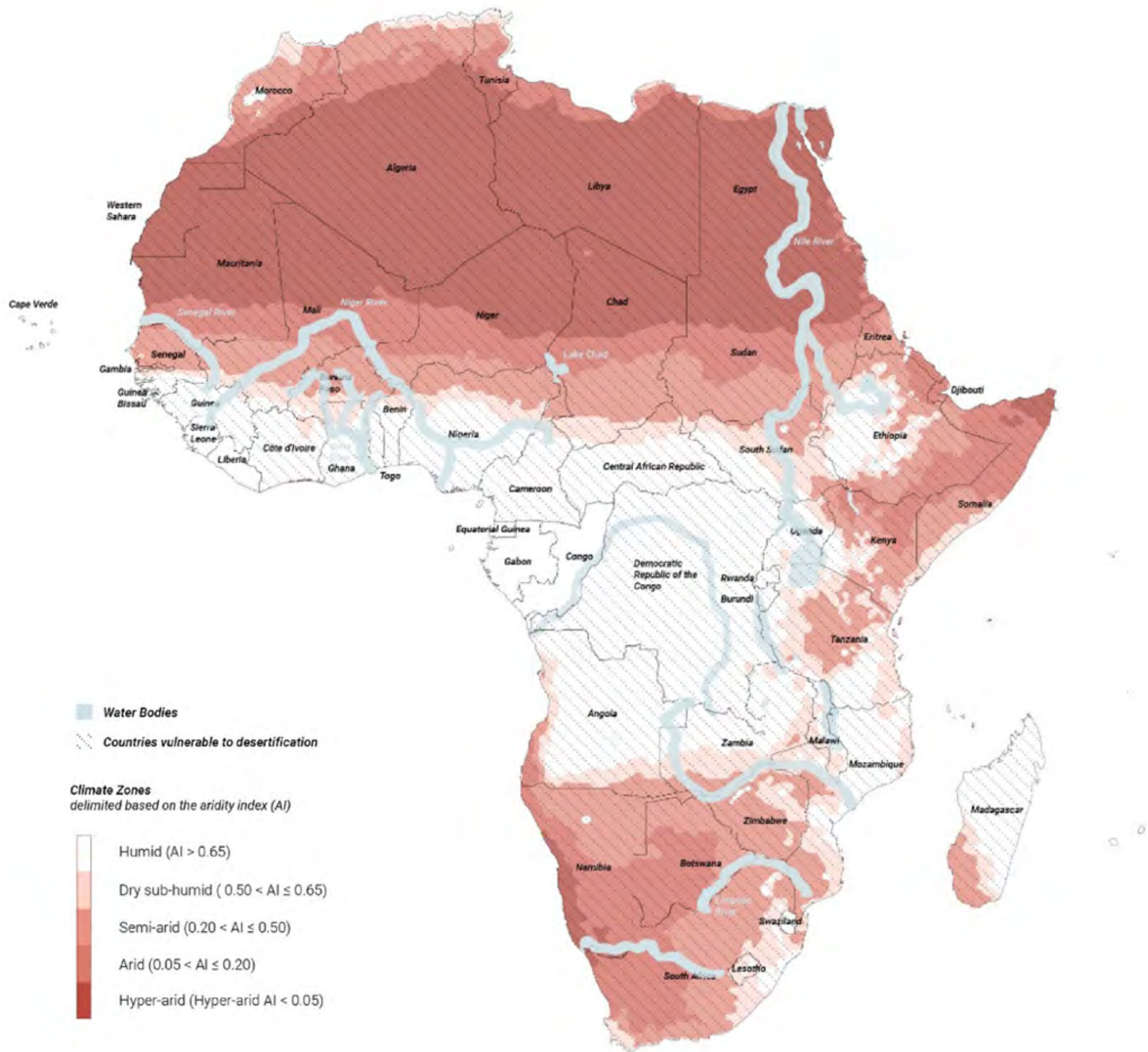
I. Challenges and Impacts of Desertification

While socioe-conomically disadvantaged communities have been disproportionately forced to grapple with the costs of climate change, certain geographic regions have similarly sustained harsher and more accelerated degradation. The IPCC's Summary for Policymakers (2018) reports that, "regions at disproportionately higher risk include Arctic ecosystems, dryland regions, small island developing states, and Least Developed Countries (high confidence)."[1] Recent estimates suggest that drylands cover approximately 46.2% of the global land area and are home to 38.2% of the global population, roughly 3 billion people.[2] While less than 10% of drylands globally are currently undergoing desertification, these affected areas are home to approximately 20% of the global population, which has increased from approximately 172 million in 1950 to over 630 million today.[3] The IPCC also predicts that "climate change will amplify water scarcity, with negative impacts on agricultural systems, particularly in the semi-arid environments of Africa."[4]

> **While less than 10% of drylands globally are currently undergoing desertification, these affected areas are home to approximately 20% of the global population, which has increased from approximately 172 million in 1950 to over 630 million today.**

Lagga stream passing close to the neighborhood. © UN-Habitat

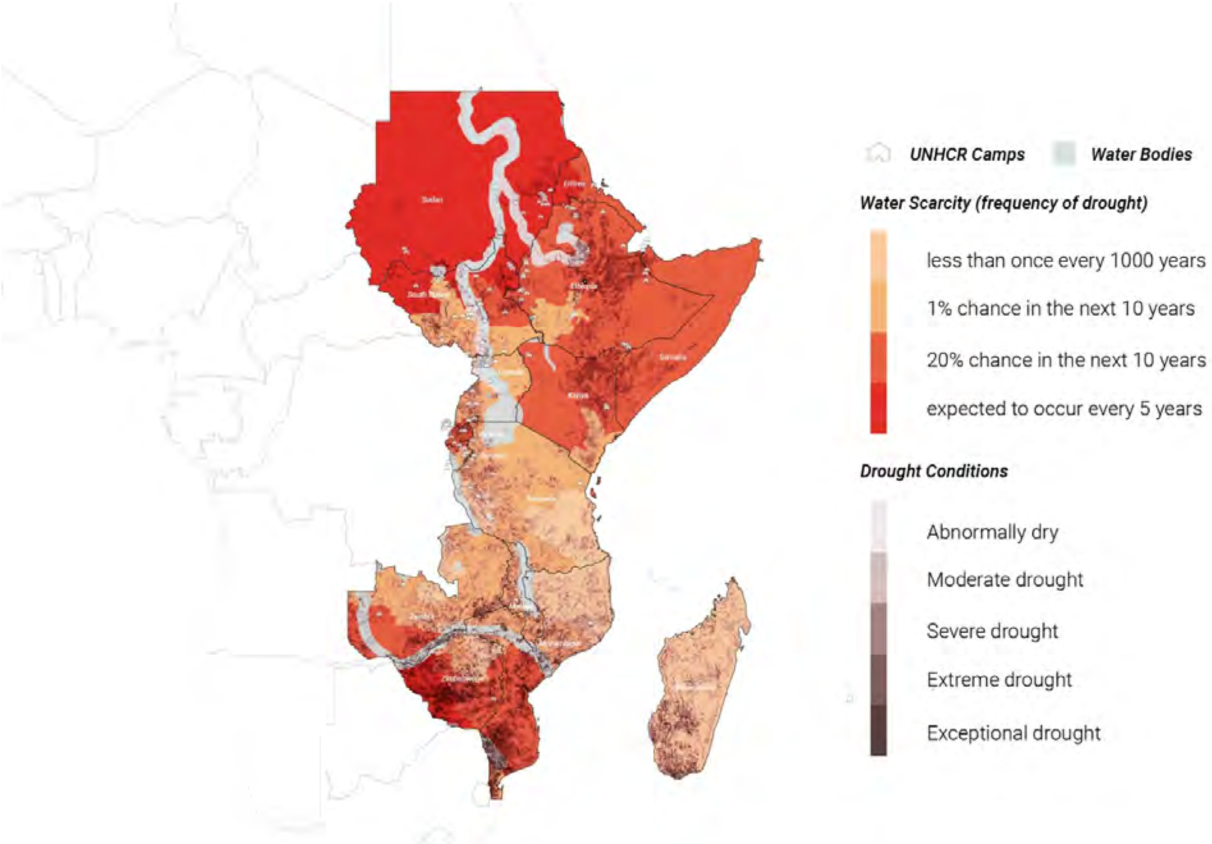
Figure 2 **Geographic distribution of drylands in Africa**[5]



Source: IPCC, 2019

Over the past several decades, the range and intensity of desertification has increased in many dryland areas. Several mechanisms, including changes in vegetation cover due to drought, sand and dust aerosols from dust-storm activity, and greenhouse gas fluxes, have weakened ecosystem health and productivity, which has exacerbated climate change while reducing the availability of natural resources. An estimated 46 out of 54 countries in Africa are vulnerable to desertification, and many have already been critically impacted.[6] Figure 2 illustrates the geographic distribution of drylands in Africa based on the aridity index (AI). In the Horn of Africa, moderate to high levels of degradation have been detected in many major river basins, including 42% of the Nile River basin, 50% of the Niger, 51% of the Senegal, 67% of the Volta, 66% of the Limpopo, and 26% of Lake Chad.[7]

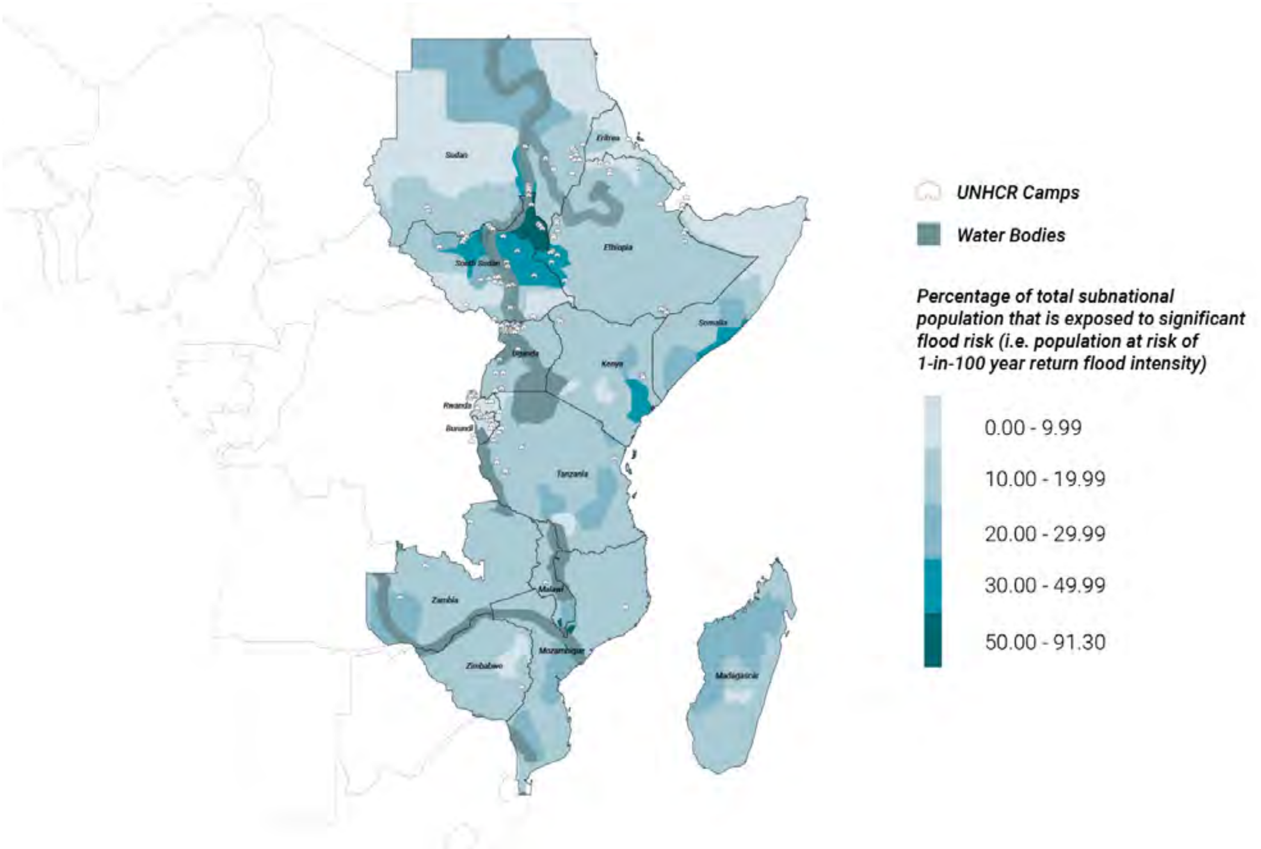
Figure 3 **Water Scarcity (Drought Frequency),[8] Drought Conditions (Severity), and UNHCR Camps in East Africa[9]**



Source: UNHCR, 2021

A view of Kalobeyei Settlement Village 2 from a water tank tower. © UN-Habitat

Figure 4 **Percentage of Population Exposed to Flood Risk & UNHCR Camps in East Africa**[10]

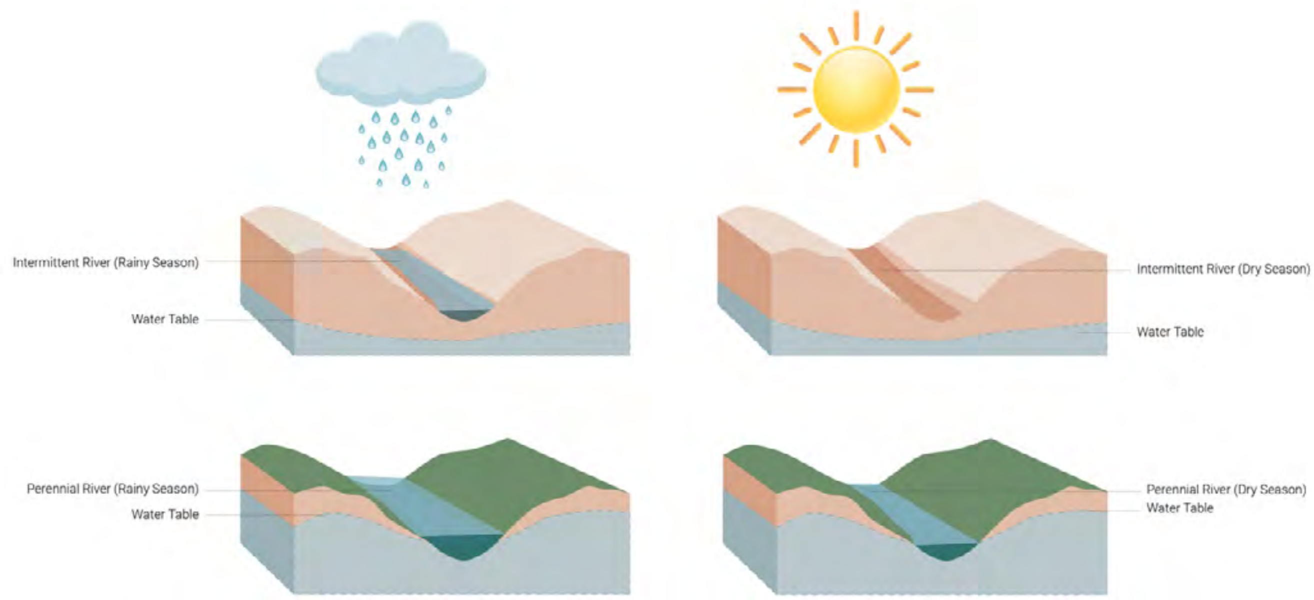


Source: The World Bank, 2020; UNHCR, 2021

Figure 3 illustrates the frequency and severity of drought and Figure 4 illustrates the exposure of the present subnational populations to significant flood risk, both alongside the distribution of UNHCR camps across East Africa. Together, these maps reveal a correlation between high concentrations of vulnerable populations and areas that are prone to significant climate-related hazards. Human health and activity are major factors in the cyclical relationship between climate change and land degradation, as pictured in Figure 1. These hostile environmental conditions limit potential for economic development and social mobility, reduce access to essential services and resources, pose direct and indirect health and safety risks, and may lead to already vulnerable people of concern (POCs) being subjected to further displacement and conflict, while challenges spread to expose wider populations.

Unsustainable land management and increased pressure on land due to population growth are some of the major drivers of human-induced desertification. Moreover, unsustainable land management in dryland areas has exacerbated the impacts of droughts, floods, and dust storms. Without the tools, training, and resources needed to implement effective adaptation and mitigation measures, vulnerable communities, especially those reliant on agriculture and pastoralist livelihoods, are more likely to engage in unsustainable behaviours that exacerbate desertification and climate change, such as expansion of cropland and overgrazing. Dryland communities in East Africa are uniquely susceptible to these environmental transformations due to the reliance on agriculture and pastoralism as the predominant livelihoods. Financial instability further limits the capacity of individuals and communities to adapt to climate change, while the reduced availability of resources and viable land contribute to conflicts over usage rights among pastoral communities and sedentary growers.

Figure 5 **Diagram of Perennial vs. Intermittent Rivers during wet and dry seasons**



II. Rivers in Dryland Areas

Intermittent fluvial ecosystems are of critical importance in dryland regions. These non-perennial rivers generally exist as dry channels where surface water may interrupt dry conditions for only hours, a few days, or sometimes weeks, primarily after heavy rainfall events which may produce destructive flash floods.[11] Unregulated intermittent rivers in informal and refugee settlements have been known to trigger conflict over usage rights and frequent Sexual and Gender-Based Violence (SGBV) incidents due to low visibility surrounding proximate resources (e.g., firewood), which are typically collected by women. Moreover, children may use riverbeds for recreational purposes and are prone to drowning, unsanitary activities, such as open defecation and waste dumping, are also common, and wet conditions following flash floods make riverbeds an ideal breeding ground for mosquitoes and other disease vectors. Consequently, the potential for intermittent rivers to alleviate water insecurity and soil degradation is often overlooked, leaving them underutilised and regarded primarily as health and safety hazards among affected communities.

However, the following case study and the Nature-based Solutions (NbS) discussed later in this design guide demonstrate how strategic and sustainable interventions along with shifts in land use practices can transform intermittent rivers and riparian areas into highly productive ecosystems with controlled water flows. Sustainable Land Management (SLM) measures that target intermittent rivers, specifically nature-based flood mitigation and water harvesting devices, have the potential to transform socio-economic and environmental conditions in dryland settlements. Yet, in order to overcome the challenges and reap the benefits associated with intermittent rivers, it is critical that technical, socio-economic, and cultural complexities are incorporated into design strategies. Through case studies and design proposals, this guide will explore possibilities for economic, social, recreational, and environmental uses of intermittent rivers in protracted displacement contexts through a humanitarian-development lens.

One of the smaller Laggas in Kalobeyei Settlement. © UN-Habitat

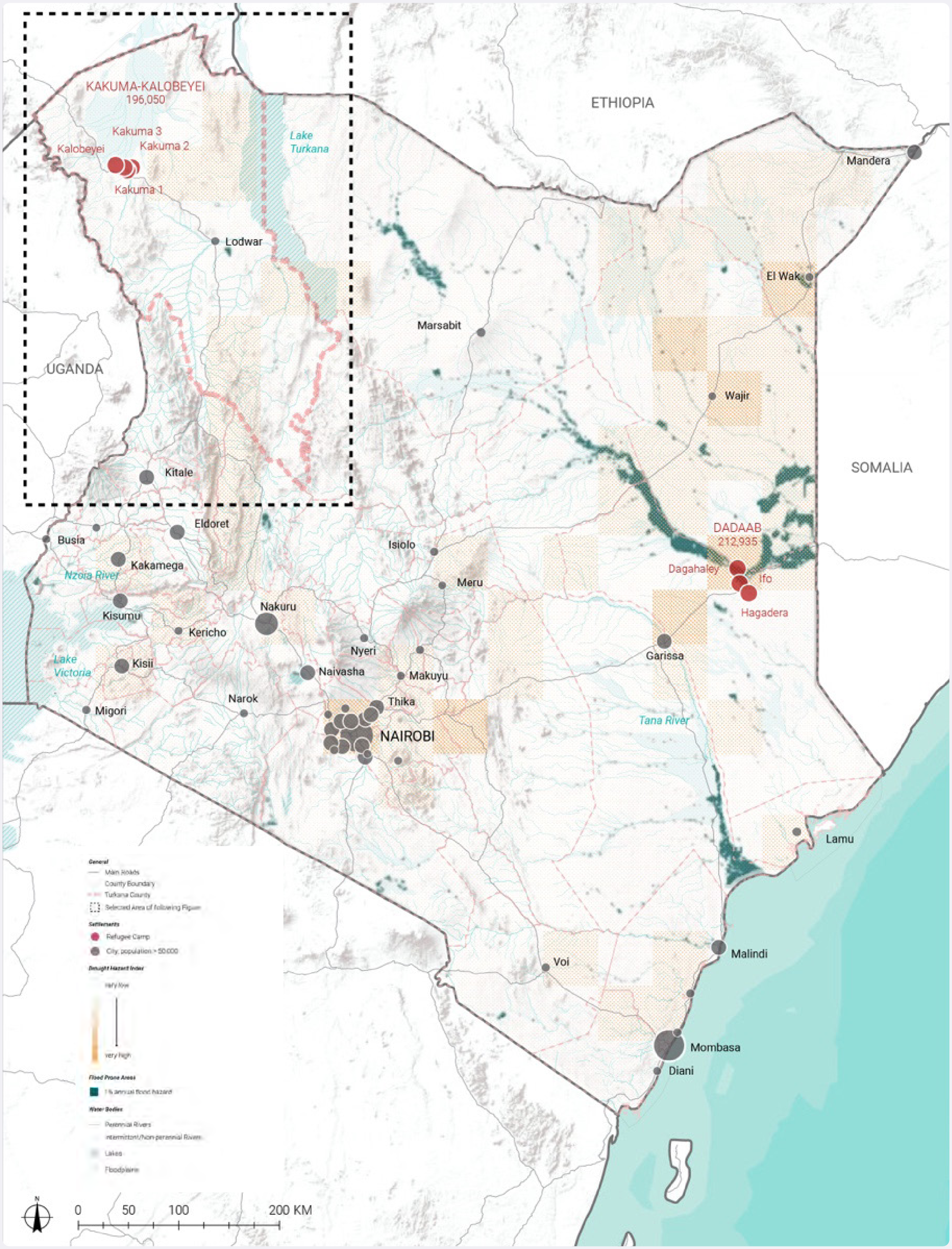
Case Study:
Kakuma-Kalobeyei Settlement

In Kenya, the recent rise in extreme weather events and disruption of typical weather patterns across Arid and Semi-Arid Land (ASAL) regions has resulted in "extensive loss of life, socioeconomic disruption, damage to infrastructure and 'shocks' to livelihood systems."[12] Even in predominately dry settings such as the Kakuma-Kalobeyei Settlement in Turkana County, high intensity rainstorms occurring around April and October often result in flash floods, which are further exacerbated by the relatively flat topography, shallow waterways, and low infiltration rates.[13]

However, there are opportunities in Kenya to address both water scarcity and flash flooding, two of the region's most critical challenges, by increasing investment in water management strategies and floodwater harvesting techniques along laggas, or seasonal rivers, and the corresponding dry basins or riverbeds that are typically present in these settings.

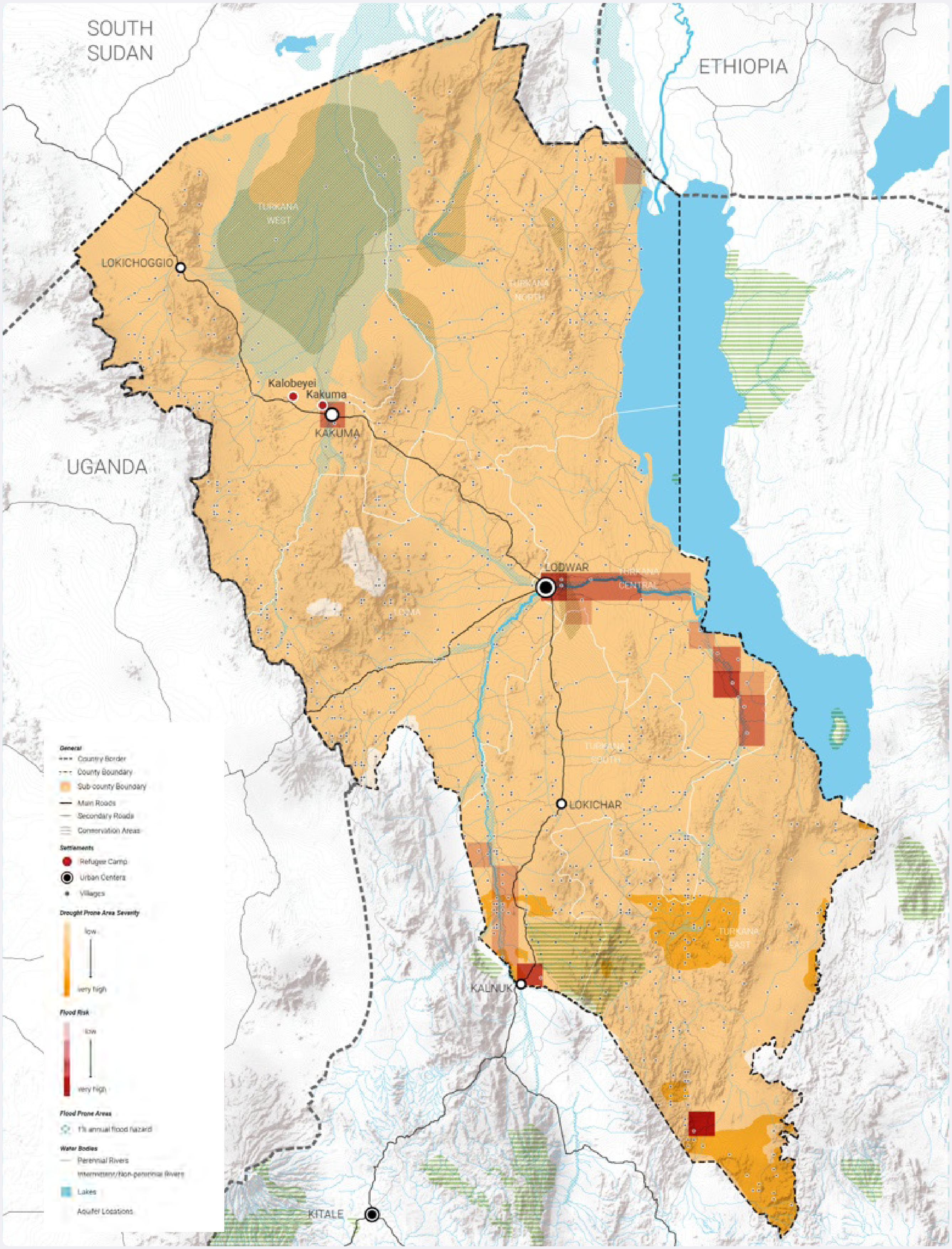
Aerial view of Kakuma Town and Kakuma Refugee Camp.
© UN-Habitat

Figure 6 **Flood and Drought Hazard in Kenya**[14]



Source: KNBS, ESRI, KWS, WRI, GFDRR, World Bank Group

Figure 7 **Flood and Drought Hazard in Turkana County, Kenya**[15]



The Kenya Disaster Risk Profile determined both flood and drought hazard based on a combination of variables, specifically the frequency and location of drought/flood events, the location of assets which intersect with hazard locations, and the vulnerability of these assets. According to the modelled flood impact, an average of 150,000 people, 200 educational and health facilities, and 400 km of transportation infrastructure are exposed to flood hazards annually, which can be expected to cause USD $250 million worth of building damages and USD $5 million worth of crop damages each year.[16] The scope of the flood hazard model is limited to river flooding, so surface flood events (e.g., urban flooding from rainfall) are not included in the risk projections described above, but additional flood prone areas may be inferred based on floodplains identified in Figure 6. Flood hazard is notably high in the eastern parts of Kenya, the downstream portion of the Tana River near the coast, as well as parts of the Nzoia River appear to be flood prone.

The modelled drought hazard impact, which includes both agricultural (soil moisture deficit) and hydrological (river flow) drought events, found that an average of 5.5 million people are affected annually, with an average annual loss of USD $150 million.[17] The severity of the modelled drought hazard is consistent with the Normalized Difference Vegetation Index (NDVI) residuals, which show that Kenya experienced persistent negative trends in over 21.6% of the country during the period 1992–2015.[18]

Corresponding with the desertification trends identified in Figures 3 and 4, Figure 6 reveals that geographies surrounding refugee camps and urban areas in Kenya generally have a higher risk of flood and/or drought events compared to less populated areas. The Kakuma Refugee Camp and the neighbouring Kalobeyei Settlement, both located in Turkana County, make up one of Kenya's two major refugee complexes, with a population of over 250,000 in 2023.[19] According to Figure 6, a significant portion of the settlement is located within a floodplain and field sources have reported regular and increasingly frequent flash floods, which result in extremely rapid water level rise that can catch residents by surprise and even lead to drowning.[20] Despite this flooding, though, and although each camp contains a number of intermittent rivers and various water sources, the area is also prone to frequent drought. The impacts of these hazards have been exacerbated by climate change, and while previously, "drought was a relatively predictable phenomenon that occurred once every 5-10 years, providing adequate time for households and communities to recover their assets and livelihoods, drought now occurs every 1 to 3 years."[21] In addition to climate change, "key causes arise from a lack of resilience of the landscape," stemming from unsustainable land and water management practices.[22]

Kalobeyei's synergistic relationship with its pastoral host community is a fundamental component of the newer settlement's integrated approach to these environmental challenges and the present protracted crisis. However, unregulated livestock grazing, a key component of pastoral livelihoods in Turkana County, has resulted in widespread land degradation and a depletion of natural resources while acting as a serious hindrance to natural regeneration.[23] Combined with unsustainable land use and land management practices, these factors threaten the settlement's stability by exacerbating conflicts between residents, particularly those representing distinct communities. These conditions, coupled with increased frequency and intensity of the flash flood events common to arid and semi-arid lands (ASAL) have amplified risks.

In the case of Kakuma-Kalobeyei, there are numerous intermittent waterways that pass directly through the settlements that bring these risks directly into daily life. Poor soil conditions such as potholes form areas for water to pool and provide the optimal conditions for mosquitoes, a common disease vector, to breed in.[24] Due to limited clean water supply and accessibility challenges during flood events, households often will source water from intermittent rivers, exposing them to serious health risks. During flash flood events, people are also often forced to wade through dirty water, which is of particular concern given the reliance on pit latrines, which, when flooded, can easily spread sewage and disease through the settlement. Similarly, unsustainable, and unhygienic practices such as open defecation and solid waste burning in seasonally dry riverbeds further jeopardize both human and environmental health.

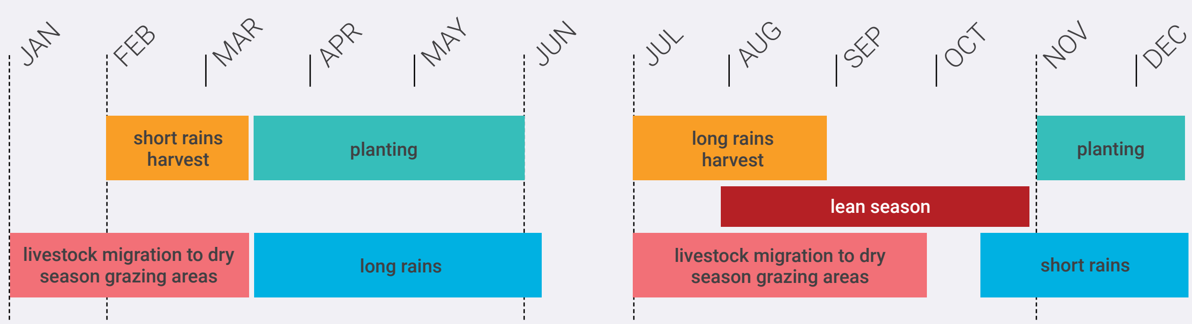
Improving sanitation and waste management in settlements like this is critical to limiting the negative effects associated with intermittent rivers and flash flooding. In response, relatively simple solutions such as shifting from pit latrines to elevated latrines could go a long way toward improving the settlement's ability to manage flash flooding and protect the health and well-being of residents. At present, humanitarian-development actors are working to implement this solution in Kakuma-Kalobeyei.

Public misuse of laggas in Kakuma-Kalobeyei poses a different type of threat to the settlement's most vulnerable residents, as well, though. As described in "The Impact of Sexual and Gender-Based Violence in Kalobeyei Integrated Settlement and Host Community," a report produced by UN Women, "the most common locations for SGBV (and therefore the most dangerous places for females and other vulnerable persons) were laggas, bushes near shelters, and spaces used for drinking alcohol."[25] One of the contributing factors to this correlation between SGBV and laggas is the prevalence of firewood in the areas around these riverbeds. "Collection of firewood, the primary source of fuel among the refugee and host communities, is primarily done by adult females who (in the process of wood collection) are exposed to several risks and challenges, including thorn pricks, snake bites, long distances causing fatigue, fear of bandit attacks and even rape."[26]

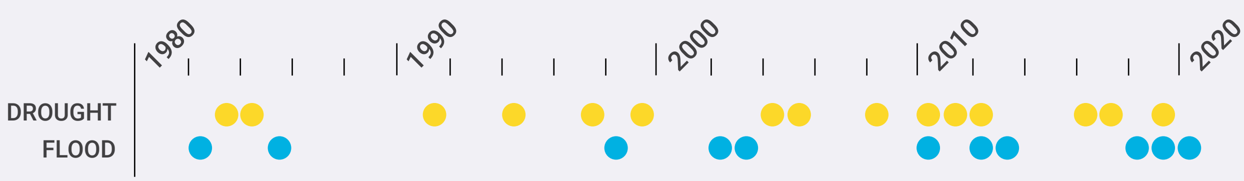
Because the flow of water is not subject to political or administrative borders, unsustainable local practices are only part of the problem. New water infrastructure projects in Ethiopia correlate with a significant reduction in size of Lake Turkana, as well as increased salinity, which "has resulted in reduced fish stocks, even as growing numbers of local Turkana people turn to fishing as drought has killed off their herds."[27] Without immediate regeneration efforts and the establishment of additional stable water sources, the shrinkage of Lake Turkana will have widespread and lasting consequences for the region. Major bodies of water are not only essential to the livelihoods of populations living in ASAL regions, but also produce a cooling effect that helps to regulate temperatures and limit desertification.[28]

Laggas also play an important role in the spatial formation of Kalobeyei Settlement, acting as natural boundaries to contain the camp sections and help to limit sprawl.[29] Riverbeds crossing the site have the capacity to become both stable sources of water and productive corridors for public space, agriculture, managed livestock grazing, and biodiversity, with the potential to adopt different functions and programming seasonally as conditions shift from wet to dry and back to wet again. In addition to acting as hubs for small-scale agriculture, "areas along the laggas are essential to pastoralists because they rely on moving herds between dry and wet season pastures based on rights of use negotiated between various groups to regulate sharing of resource[s]."[30]

Figure 8 Typical Seasonal Calendar for Eastern and Northern Kenya[31]

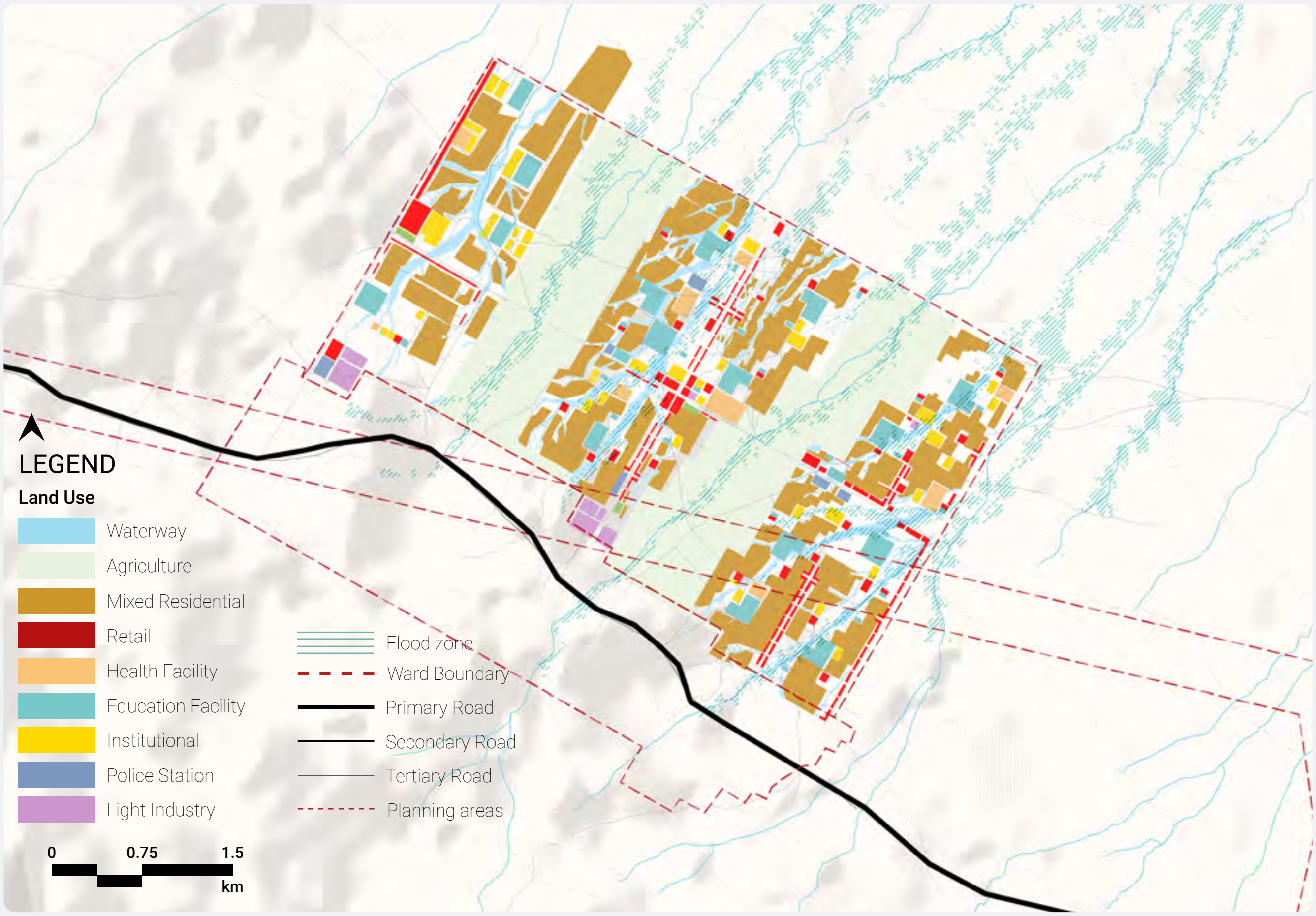


Typical Seasonal Calendar for Eastern and Northern Kenya



Years of Severe Drought and Flood in Kenya (1980 - 2020)

Figure 9 **Kalobeyei Settlement land use and planning areas**[32]

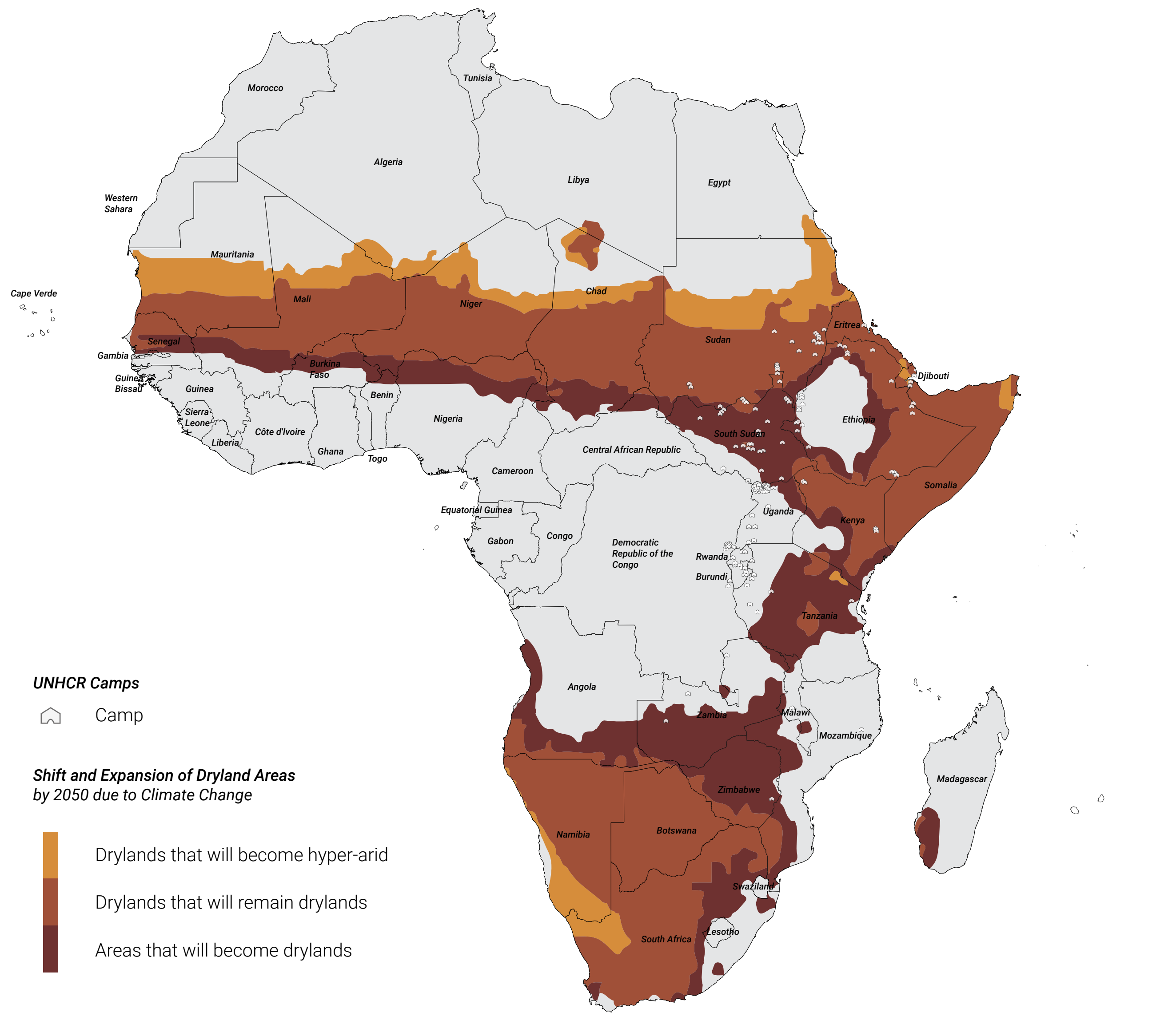


Sources: UN-Habitat, KNBS, ESRI, UN-Habitat analysis

III. Future Predictions and Recommendations

In 2018, the World Bank predicted that by 2050, unless immediate action is taken to reverse the effects of climate change, uninhabitable conditions caused by land degradation and extreme weather events will result in the displacement of 86 million climate migrants across Sub-Saharan Africa.[33] According to the IPCC Special Report on Climate Change and Land, risks from desertification are projected to increase due to climate change, and both desertification and climate change, individually and cumulatively, will lower the viability of dryland ecosystem services, health, and biodiversity. Projections include reduced livestock and crop productivity, modifications to the composition of plant species, expansion of invasive species favoured by rising CO2 levels, disruptions to animal food chains, and increased risk of wildfires.[34]

Figure 10 Shift and Expansion of Dryland Areas by 2050 due to Climate Change[35]



Sources: Estimates based on Intergovernmental Panel on Climate Change (IPCC) data[36]

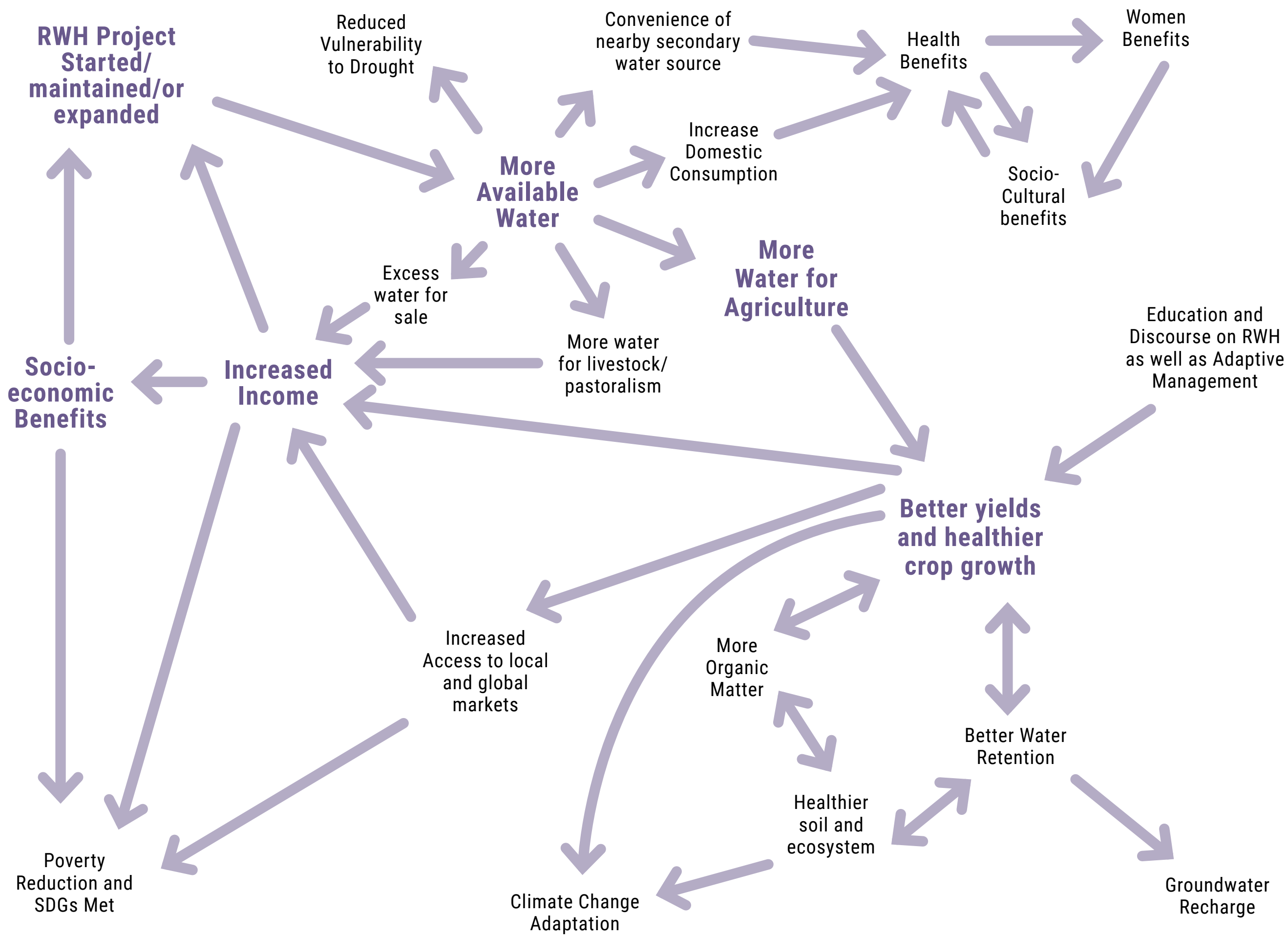
According to the IPCC, "with regards to climate impacts, the analysis of global and regional climate models concludes that under all representative concentration pathways (RCPs) potential evapo-transpiration (PET) would increase worldwide as a consequence of increasing surface temperatures and surface water vapour deficit."[37] In alignment with these projections, Figure 9 illustrates the predicted impacts of desertification through an expansion of drylands to formerly non-arid lands as well as an increase in hyper-arid land. The severity of the impacts of desertification is not only measured by temperature and precipitation levels but it also depends on climate variability and extremes. Furthermore, ecosystem responses are contingent on diverse vegetation, meaning that drier ecosystems are more vulnerable.[38] The IPCC also reports that high variability in precipitation correlates with lower livestock densities, meaning that "social vulnerability in drylands increases as a consequence of climate change that threatens the viability of pastoral food systems," while "forecasts for Sub-Saharan Africa suggest that higher temperatures, increase in the number of heatwaves, and increasing aridity, will affect the rainfed agricultural systems."[39]

Populations in drylands are projected to increase about twice as rapidly as non-drylands, reaching an estimated 4 billion people by 2050.[40] By 2030, the population of East and West African drylands is expected to increase by 65-80%; while at the same time, as illustrated in Figure 9, predicted climate change scenarios include an expansion of dryland areas by 20% across this same region, with some countries facing even greater losses of non-arid land.[41] According to the IPCC, it is also projected that "without rapid and inclusive progress on eradicating multidimensional poverty, climate change could increase the number of the people living in poverty by between 35 million and 122 million people by 2030."[42]

Even though these projections are global, it is also expected that the populations most affected, by share of national population, will be those living in the drylands of the Sahel region, eastern Africa, and South Asia. Higher population density and increased vulnerability due to climate change, coupled with existing trends of growing outside investment in large scale commercial agriculture and other extractive industries, will put considerable strain on already scarce resources, and many regions may be pushed beyond regenerative capacity. In this scenario, competition over land and resources is likely to intensify, while the capacity of communities as well as local and national governments to recover from climate change related hazards or political conflict will decrease.[43]

Fortunately, existing site and regionally specific technological solutions are available to avoid, reduce, and even reverse desertification and its consequences.[44] Sustainable Land Management (SLM) in drylands not only increases agricultural productivity, but also contributes to climate change adaptation with mitigation co-benefits. Specifically, an integrated approach to crop, soil, and water management has been shown to effectively reduce soil degradation while increasing the resilience of agricultural production systems and infrastructure to the impacts of climate change. Moreover, investments in SLM, as well as land restoration and rehabilitation efforts in drylands, have demonstrated positive long-term economic returns. Typically, SLM ventures become financially profitable within 3 to 10 years, with each USD $1 invested reaching returns of USD $3–6 over a 30-year period.[45] Figure 10 portrays the positive feedback loop generated by an effective Rainwater Harvesting (RWH) intervention, for example.

Figure 11 **RWH Positive Feedback Loop - Example of a RWH Positive Feedback Loop**[46]



Source: The World Agroforestry Centre (ICRAF), 2012

Evidence suggests that when necessary funds are made available alongside effective incentives and knowledge sharing initiatives, farmers in dryland areas, including those in the contexts of displacement along intermittent rivers, are likely to invest in SLM practices.[47] The strategies outlined in this document align with recommendations from the IPCC's Special Report on Climate Change and Land (2019), which promotes an integrated approach to climate change adaptation and mitigation, poverty eradication, and food security through the adoption of SLM practices based on indigenous and local knowledge (ILK) coupled with modern technological innovations and opportunities to diversify livelihoods beyond the agricultural sector.[48]

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15 Drought Hazard Index/Flood Prone Areas map adapted from GFDRR, World Bank Group. Disaster Risk Profile: Kenya (2019). River flood risk excludes urban/surface flooding is excluded) is estimated at 1km resolution using global meteorological data, global hydrological and flood-routing models. Base map layers sourced from KNBS, ESRI, KWS, WRI

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30 Kakuma & Kalobeyei Spatial Profile; State policies have historically undermined this system and thus weakened pastoral livelihoods by failing to recognize their right to resources, resulting in escalated conflict. Ensuring that the laggas fall under Kenya's Community Land Bill will help secure the rights of pastoralists and mitigate potential conflicts.

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36 The map shows the extent to which drylands (defined to include all zones with an aridity index 0.05–0.65) could shift and expand by 2050 as a result of climate change. To visualize the largest possible impacts, the map reflects the fastest growth of GHG (greenhouse gas) concentration (RCP 8.5 [Representative Concentration Pathways]) under the driest of a set of over 40 climate models.

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Chapter 3: Humanitarian Principles for Planning in the Context of Dryland Displacement

> "The planning and design of settlements near intermittent rivers must be contextually grounded with the acknowledgment that fluvial environments are dynamic and interactive systems."

I. Overview

Where intermittent rivers intersect with protracted refugee and IDP settlements in drylands, specific humanitarian principles related to spatial planning and design should be considered. As the core reference document for humanitarian operations, The Sphere Handbook[1] serves as the foundation for this chapter, which is intended for humanitarian and development planners, as well as local government officials. UNHCR's Master Plan Approach to Settlement Planning – Guiding Principles[2] provides more focused settlement planning guidelines for humanitarian operations and is therefore also referenced here. Together, these two documents provide a basis for examining the challenges related to planning interventions along intermittent rivers in humanitarian-development contexts.

It is important, to note, though, that the guidelines outlined here are not exhaustive; they are a selection that are particularly important to consider in these contexts. These considerations should be taken in conjunction with all others that are relevant to each individual situation. Therefore, in any situation, initial and ongoing context-specific research and analysis should be undertaken in order to identify the real risks, complexities, and opportunities while selecting or intervening in any specific site.

To initiate context-specific site research, some strategies might include:

- conducting a historical review of water flow and flood patterns;
- undertaking user analysis observations, surveys, and interviews, including field observations and participatory planning strategies (e.g., transect walks);
- gathering GIS and remote-sensing data;
- mapping of existing interests among local communities and other relevant stakeholders (e.g., private sector), which can be particularly important in contexts of low resources; and
- physical geological and geographical research, including identifying signs of erosion and high-water events, which can also indicate potential risks and serve as indicators critical to siting a settlement appropriately.

Development permissions along rivers will vary depending on the natural and topological conditions of the river and river basin as well as regulations enforced by the political jurisdiction(s) responsible for the river basin. The planning and design

Waterlogged streets in Kakuma Refugee Camp. © UN-Habitat

of settlements near intermittent rivers must be contextually grounded with the acknowledgment that fluvial environments are dynamic and interactive systems. Therefore, it's critical that how development might affect hydrological processes and other functions within the larger landscape be assessed holistically before any intervention is implemented. Human inputs or interventions at one point along a river, for instance channelling or diverting water, can result in flooding at other locations. Therefore, any intervention needs to be carefully studied so as not to interfere with ecological functions, aggravate tensions over natural resources, or undermine safety within the broader context.

While the impacts of development along intermittent rivers in protracted refugee and IDP settlements, as well as the role of intermittent rivers in settlement contexts, are not new areas of research, few, if any, guidance documents exist that delineate what factors need to be considered while planning and designing in such contexts. In the following sections, humanitarian standards that are of particular relevance in these contexts are highlighted for further consideration. By outlining humanitarian-specific planning guidance for designing interventions near waterways—with particular attention to principles that might be more pertinent to protracted settlements in dryland regions—this chapter aims to provide a baseline upon which further research, including field experiences, can be built.

II. Circulation Systems

A safe, well-planned, and accessible circulation network is essential to maximising potential socioeconomic benefits within an integrated humanitarian context for members of both refugee and host communities living in protracted situations. Such systems promote equitable access to resources, increase economic potential by ensuring that livelihood sources, such as markets and agricultural land around laggas, are easily accessible, and provide more opportunities for integration by encouraging movement throughout the camp and, in some cases, beyond.[3]

Of particular importance in the context of intermittent rivers is the need to anticipate seasonal changes that may not always be easily visible at the time of planning. Circulation systems should be designed so that they will not be impacted in any significant way by predictable changes that might limit accessibility and circulation or threaten the safety and security of the residents that rely on these systems.

Road Access

- Consider seasonal constraints, hazards, and security risks.
- Consider the needs of populations facing mobility or access barriers.
- Consider alternative access routes in case evacuation is required.

Fire Safety

- Consider the impact of intermittent rivers on fire access routes and ensure that emergency response will not be limited seasonally as is often the case in similar contexts.

Lighting

- Provide communal lighting solutions to promote accessibility and safety in general, but in particular, in more remote areas of resource collection along intermittent rivers where conditions have often been known to become less safe seasonally as a result of their isolation and the changes in the landscape.

III. Land Management

A sustainable, resilient, and thorough land management strategy is critical to the long-term success of integrated refugee settlements, particularly in dryland regions where water and other natural resources are scarce, and threats are exacerbated due to climate change. Any plan should protect natural resources and maximise the potential of intermittent rivers and other water sources through water storage and harvesting strategies that account for and even leverage extreme weather events such as flash floods.[4]

Good land governance practices should also be promoted, particularly with regard to improving the land tenure security of local communities (host and displaced) and to clarify and strengthen the roles and responsibilities of local land management actors, including local authorities, customary and religious structures, and informal and community based mechanisms. The key aspects to be regulated are the allocation of land rights, the management of land use practices, and the resolution of disputes among different land users and groups (e.g. displaced and host communities, urban and rural land users, farmers and pastoralists, etc.).

Erosion

- Conserve and plant trees and other vegetation to stabilise soil and maximise shade.
- Follow natural contours when designing and constructing services such as roads, pathways, and drainage networks to minimise erosion and flooding.
- Implement drainage channels where necessary.
- Piped drainage should run under roadways or planted earth banks to prevent soil erosion. Where the slope is more than 5%, engineering techniques must be applied to prevent excessive erosion.

Flood Mitigation

- Include rainfall/floodwater drainage planning in site selection and settlement development.
- Provide appropriate drainage facilities to prevent standing water and keep stormwater drains clear.
  - » Ensure sufficient drainage systems based on site selection and infrastructure development, because poor drainage can limit living space, mobility, and access to services.
  - » Avoid siting settlements on floodplains, because doing this can compromise safety and security and flooding poses risks to health, livelihoods, and overall well-being.
- Anticipate and manage poor drainage, especially anywhere where standing water might collect, as these conditions create the optimal conditions for the breeding of common disease vectors (e.g., mosquitoes).
- Protect toilets and sewers from flooding in order to avoid structural damage and leakage, which is often responsible for the contamination of flood waters.
  - » Poor drainage poses a major public health threat due to increased exposure to diarrhoeal diseases from contact with contaminated water.
  - » Uncontrolled flood waters can also damage other infrastructure, facilities, dwellings, and personal property and belongings, which can severely limit livelihood opportunities and cause stress.

Land and Use Planning

- Provide sufficient and uninterrupted year-round space for all functions, accessibility to all shelters and services, and ensure adequate safety measures are implemented throughout the settlement that should remain largely unaffected by the seasonal changes of intermittent rivers.
  - » Include planning for shared resources such as water and sanitation facilities, communal cooking facilities, child-friendly spaces, gathering areas, religious spaces, and food distribution points.
  - » Ensure that the placement of essential services within settlements follows standards for safety, protection, and dignity.
  - » Provide space for social facilities such as places of worship, meeting points, and recreation areas, culturally appropriate burial areas, and livestock accommodation with adequate separation from residential spaces (see Livestock Emergency Guidelines and Standards (LEGS)).
- Areas that have been identified to be at high risk of seasonal flooding from intermittent rivers should be planned and managed with particular care to reduce risks.
  - » Areas deemed to be at exceptionally high risk should be designated as non-buildable conservation areas wherever possible.
  - » Where high risk areas have already been settled, these areas should be considered for resettlement and rehabilitation where space and resources allow.
  - » Where space is extremely limited and in high demand, development in risk areas should be strictly limited to certain types of structures, ideally those that can sustain seasonal flooding without severely impacting lives, livelihoods, and access to critical services.
- Ensure that the affected population has access to essential services and facilities, including livelihood opportunities, that won't be severely impacted by the changing landscape of intermittent rivers.
  - » Establish acceptable distance parameters and ensure safe travel (or transport) to essential services and facilities is available through collaboration across sectors throughout the year independent of seasonal changes in order to avoid interruptions.
- Identify available land for conservation, open space, cultivation, grazing, livestock migration routes, and access to markets and/or employment opportunities, which may often coincide with buffer zones along intermittent rivers and the seasonal riverbeds.
  - » Support these planning efforts with effective land management alongside training and education programmes.

Case Study:
Kakuma Refugee Camp and Kalobeyei Settlement

Flooding in Kakuma in 2014 affected approximately 500 shelters and resulted in 9 deaths, as well as damage to public facilities. In 2018 and 2019, floods impacted the then newly established Kalobeyei Settlement. Even as recently as 2021, Kakuma Refugee Camp has suffered from flood impacts including significant destruction to Napata Secondary School and Don Bosco Vocational College in Kakuma Camp 1. The consequences of flooding have included destruction of school infrastructure, cutting off of roads which hinders transportation of essential goods and services and limits access by emergency vehicles, collapsing of sanitation facilities, and increased risk of waterborne diseases.[5] Shelters constructed over the gentle flat areas experience a different set of drainage challenges to those located on gently sloping areas along the existing laggas. Mainly the areas tend to concentrate surface runoff in gullies and minor water courses within the settlement.[6]

Environmental Sustainability

- Protect, restore, and improve the ecological value of operational sites (such as temporary settlements) during and after use.
  - » Assess environmental baseline conditions and available local natural resources for each site and identify environmental hazards, including those due to previous commercial or industrial use.
  - » Remove immediate and obvious hazards from the area and repair any serious environmental degradation, while minimizing removal of natural vegetation and disruption of natural drainage systems.

Sexual and Gender-Based Violence (SGBV)

- Ensure that measures are implemented to create a safe environment around intermittent rivers for women and children. This can be done by improving visibility (i.e., through installing adequate street and path lighting) and establishing productive social and economic activity near rivers through the development of livelihood opportunities there integrated with public space interventions.
- Since residents are often reliant on firewood for cooking fuel, women are often assaulted in bushes collecting firewood or producing charcoal, which are activities common along intermittent riverbeds.[7] In combination with promoting safety, providing alternative sources of cooking fuel can also help to reduce instances of SGBV.

Case Study:
Kakuma Refugee Camp and Kalobeyei Settlement

Among households in Kakuma Refugee Camp and Kalobeyei Settlement, a large proportion are headed by women, which can contribute to why women and girls are at particularly high risk of sexual and gender-based violence (SGBV), though men and boys are not immune to this risk, as well. This type of violence is known to occur most commonly during the gathering of firewood, at unwatched water access points, and as well in the home, in particular where shelters are temporary. In Kalobeyei Settlement, for example, laggas, where firewood is often gathered, were found to be among the most common locations for SGBV, making these areas some of the most dangerous places for women and other vulnerable groups.[8] According to UN-Women, the Gender-Based Violence Support Centre in Kakuma generally receives around fifteen to twenty cases per month, making this a very real concern that should be addressed through spatial planning and design strategies that promote safety and security especially in the areas known to be of highest risk.[9]

IV. Energy Supply

Supplying residents with energy from renewable sources (e.g., wind and solar) allows refugees to perform essential household tasks that use electricity while minimizing environmental impacts and long-term costs. Dryland regions have ideal conditions for solar power generation, which, in turn, minimizes the need to exploit riparian areas around intermittent rivers to collect firewood.[10]

- Establish, restore, and promote safe, reliable, affordable, and environmentally sustainable energy supply systems.
  - » Determine whether existing energy supply systems have a negative environmental impact on natural resources, pollution, health, and safety.
  - » Ensure that any new or revised energy supply options meet user needs, and provide training and follow-up as needed.

V. Water Supply

Supplying refugee and host communities with water for drinking, household needs, agriculture, and livestock is not only essential for well-being and livelihood, but also minimises potential conflicts over the often scarce resource by ensuring equitable access and sufficient supply.[11]

- Encourage use of protected water sources.
  - » People may prefer unprotected water sources such as rivers, lakes, and unprotected wells for reasons of taste, proximity, and social convenience. Understand the rationale of community members and develop messages and activities that promote the protection of water sources, including making other sources safe, accessible, affordable, and equitable.
  - » Particularly in areas along intermittent rivers or on flood plains, contamination of water sources is a serious risk. Education around maintaining protected sources and avoiding unprotected sources should also encompass avoiding reliance on any and all sources that might be impacted seasonally by significant rainfall, flooding, or the changing conditions along intermittent rivers.
- Strategically locate water points to provide safe, affordable, uninterrupted, and equitable access.
  - » Understand how the refugee and host communities use and access water, whether there are any access limitations, and how these may change seasonally as a result of changing conditions.
  - » Take into account that social, political, or legal factors affecting the control of water sources might be controversial. Water and sanitation responses should address the needs of both host and displaced populations equitably to avoid tension and minimize conflict.
  - » While designing water supply systems, consider that needs vary across age groups and sex, as well as for persons with disabilities and those facing mobility barriers. Locate accessible water points sufficiently close to households to limit exposure to any protection risks.
    - › Ensure that the distance from any household to the nearest waterpoint remains under 500 metres throughout the year, accounting for any anticipated changing conditions.
- Implement collective and long-term management of water infrastructure.
  - » Engage stakeholders in decisions regarding siting, design, and use of water points for both immediate and long-term plans.
    - › During planning, consult community members and relevant stakeholders to inform optimal locations for water points.
    - › This includes bathing, cooking and laundry facilities, toilets, and institutions such as schools, markets, and health facilities. Use feedback to adapt and improve access to water facilities.
    - › Consider vulnerable populations when establishing water points and implement measures to ensure that all users are protected equitably.
  - » Taps, wells, and pipes often fall into disrepair and access may be limited due to conflict, natural disaster (including seasonal flooding), or lack of functional maintenance systems.
  - » Identify the most appropriate groundwater or surface water sources, taking potential environmental impacts into account.
  - » Consider seasonal variations in water supply and demand, and mechanisms for accessing uninterrupted drinking water, domestic water, and water for livelihoods across seasons and throughout the year.
- Water Provisioning for Livestock[12]
  - » Networks of water points must meet the needs of both humans and livestock.
  - » The safety, security, and welfare of livestock are always a primary concern of livestock keepers, but these concerns are of special importance following a natural disaster or conflict when livelihoods are particularly vulnerable (i.e., there are many cases of livestock keepers prioritizing the shelter needs of their livestock, irrespective of whether support is provided by intervening agencies).

Waterway across the road near Kalobeyei Primary School. © UN-Habitat

- » Water points are thus critical for the preservation of livestock during emergencies, as well as under normal conditions. During an emergency, strategies such as changing management of existing points to provide broader access, rehabilitating degraded water points, and establishing new water points are all recommended.
- » Protect water sources from contamination by separating livestock and human points and ensuring that chemicals and acaricides do not enter water sources and that they wouldn't easily be contaminated by flood waters.

VI. Sanitation & Waste Management

Implementing necessary sanitation measures and waste management infrastructure and ensuring that residents are equipped with the knowledge and tools needed to practice good hygiene is critical to protecting both human and environmental health in protracted humanitarian contexts. In particular, good sanitation will keep intermittent rivers free from solid waste and avoid pollution of the natural, living, learning, working, and communal environments.

- Implement measures to prevent contamination of the water supplies and to reduce health risks caused by unhygienic practices.[13]
  - » Promote good hygiene practices and positive health-seeking behaviour by building on a population's existing knowledge of risk and disease prevention.
  - » Identify primary public health risks and current hygiene practices that contribute to these risks; implement solutions that motivate positive behaviours and preventative actions.
  - » Provide communal facilities, supplies, and resources for maintaining environmental hygiene, such as solid waste receptacles and cleaning equipment.
  - » If the water supply is intermittent, provide larger storage containers or alternative sources to compensate when supplies are limited or unreliable.
  - » Identify and address any barriers to accessing distribution locations or distribution systems, including those that may only appear seasonally. Specific attention should be given to ensuring access for children, women and girls, older people, and persons with disabilities.

- Control disease vectors by eliminating potential breeding and feeding sites, including taking steps to mitigate those that may occur only seasonally, and/or through the implementation of environmental engineering measures.[14]
  - » Eliminate stagnant water or wet areas around water distribution points, bathing areas and laundry facilities or washing points.
  - » Manage solid waste storage at household level, during collection and transportation, and at treatment and disposal sites.
  - » Provide lids for water containers and waste storage containers.
  - » Keep wells covered and/or treat them with larvicide, for example where dengue fever is endemic.
  - » Ensure good drainage in settlements at all scales, including water point drainage in households and communal laundry areas, bathing facilities, cooking areas, and handwashing facilities.[15]
  - » Drain standing water and thin out vegetation around open canals and ponds to control mosquitoes.
- Strategically locate toilet facilities in order to protect water sources from excreta contamination.[16]
  - » Ensure faecal material from containment facilities (e.g., trench latrines, pits, vaults, septic tanks, soakaway pits) will not contaminate water sources under any reasonably foreseeable circumstances.
    - › Though faecal contamination is not an immediate public health concern unless the water source is consumed, it may still cause environmental damage.
    - › Because the dry riverbeds of seasonal rivers and their banks are sometimes used for open defecation, effective management of human excreta is a critical strategy for preventing unsanitary conditions, deterring spread of disease, and reducing health risks.
  - » Conduct soil permeability tests to determine the infiltration rates and use the findings to inform service and facility siting and to help guide the minimum distances between containment facilities and water sources.
  - » In high groundwater table or flood situations, ensure that the containment infrastructure is watertight to minimise groundwater contamination.
    - › Alternatively, build elevated toilets or septic tanks to contain excreta and prevent it from contaminating the environment.
  - » Take measures to prevent any drainage or spillage from septic tanks from contaminating groundwater sources or surface water, including those that only appear seasonally.
  - » Implement a safe, efficient, and culturally sensitive, and environmentally sustainable solid waste management system to ensure that solid waste management facilities meet the needs of households and that solid waste is safely contained.[17]
  - » In protracted and/or urban contexts, solid waste management infrastructure may be integrated with other service systems, so it's important to work with existing authorities and systems to accommodate the extra solid waste burden and to avoid conflict with host communities.
  - » Assess spatial network and identify capacities for local reuse, repurposing, recycling, and composting.
  - » Consider the potential for small-scale business opportunities or supplementary income from waste recycling, and the possibility of household or communal composting of organic waste.
  - » Provide clearly marked and adequately sized waste storage containers to serve the needs of households as well as public facilities and markets and ensure that collection points are sited to ensure accessibility and to limit the risk of pollution or contamination.

VII. Additional Resources

In addition to these discussed humanitarian standards, as outlined in the SPHERE Emergency Handbook, there are some other valuable resources that complement well the strategies outlined in this guide and that are of particular relevance in the context areas of focus. These such resources include the "Technical Guide on the Integration of the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security into the Implementation of the United Nations Convention to Combat Desertification and Land Degradation Neutrality," the "Guidelines for a Landscape Approach in Displacement Settings (GLADS)" and the "Building climate resilience of urban systems through ecosystems-based adaptation Toolkit." A brief introduction to each is provided here alongside some preliminary suggestions on its compatibility with and relation to the content of this guide. Each of these complementary resources might be helpful to practitioners utilising this guide.

Technical Guide on the Integration of the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security into the Implementation of the United Nations Convention to Combat Desertification and Land Degradation Neutrality

The "*Technical Guide on the Integration of the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security into the Implementation of the United Nations Convention to Combat Desertification and Land Degradation Neutrality*," which was published in 2022 as a result of a collaboration between the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Convention to Combat Desertification (UNCCD), is one of the key global guidance documents on land degradation and desertification in relation to Housing, Land, and Property (HLP) rights, particularly land governance and tenure security. These are key considerations in connection to the themes of this report, because poor land governance and weak land tenure security are major challenges that drive both conflict and displacement. Furthermore, these are primary factors that contribute to the vulnerability of local communities and limit their ability to develop resilience in relation to their use of natural resources and inhabitation of the lands where the live and work. Given that land degradation affects 20-40% of the world's total land area and that much of this is caused, at least in part, by human activity (e.g., agriculture, pastoralism, deforestation, etc.) in order to support the needs of a rapidly growing global population, it is more important than ever that efforts be made to improve the relationship between humanity and the land it inhabits and depends on.[18]

This technical guidance builds on the earlier work of the "Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries, and Forests in the Context and National Food Security (VGGT)," while expanding the scope and reiterating the importance of establishing and strengthening an "internationally accepted framework on the responsible governance of tenure."[19] This follow-up effort starts from the position that "land degradation is [both] avoidable and reversible," that "[r]esponsible land governance that improves tenure security can accelerate the pivot from degradation to restoration," and that "reform of land governance constitutes a promising series of opportunities to address the drivers of land degradation and affirm the human right to a healthy environment by providing the necessary incentives to scale up the sustainable use and management of land resources."[20] It further seeks to present technical guidance on strategies that promote the idea that human life can be brought into balance with nature, the land, and the physical environment and that such efforts can meaningfully contribute to efforts to combat land degradation, desertification, and drought conditions.

The guide argues that security of tenure and access to land and natural resources are foundational elements of sustainable development and must be incorporated into all humanitarian and development activities. Security of tenure offers a multitude of compounding benefits that can include "reducing poverty, increasing food security, empowering women and youth, avoiding resource conflicts and forced migration, and enhancing both biodiversity conservation and climate change mitigation and adaptation."[21] This is particularly relevant in rural areas and those affected by migration and displacement, where a combination of weak governance structures, limited rights to land and property tenure due to refugee status, and a need for land reform often combine to make residents more vulnerable. In these areas, as well, land and natural resources are often some of the most important and valuable assets for livelihood development, as the majority of economic activity is frequently tied to agriculture and pastoralism while other livelihood opportunities remain underdeveloped.

The guide presents Land Degradation Neutrality (LDN) initiatives and demonstrates the benefits of such efforts, with

One of the smaller laggas in Kalobeyei Settlement and Donou road being applied. © UN-Habitat

policy and decision-makers, as well as land administrators, and community members that might participate in such initiatives as its primary target audience. Although the proposed strategies are fairly universal and are presented in a way that allows flexibility, it's important, as with all of the strategies, techniques, and solutions presented throughout this report, that any intervention be adapted to the specific local needs and conditions of a given context. This requires that initiatives include community participation and consultation and that underlying inequities be investigated to ensure that interventions incorporate local knowledge without reinforcing existing vulnerabilities. With this approach, such activities, combined with improved tenure security, can provide meaningful economic, social, and economic benefits while issues of land degradation and desertification are addressed.

To achieve these goals, the guide lays out a series of pathways that incorporate actionable solutions to some of the typical challenges connected to improving land tenure security. These pathways to increase tenure security through Land Degradation Neutrality (LDN) initiatives include:

- **Pathway 1**: Enhancing policy and legal frameworks
- **Pathway 2**: Establishing targeted policy coordination mechanisms
- **Pathway 3**: Securing women's tenure rights and access to land and natural resources
- **Pathway 4**: Setting up accessible and transparent grievance and dispute resolution mechanisms
- **Pathway 5**: Designing and implementing tenure-responsive and participatory integrated land use planning
- **Pathway 6**: Supporting LDN through land administration tools
- **Pathway 7**: Recognizing and documenting legitimate tenure rights on public lands
- **Pathway 8**: Recognizing and documenting tenure rights for the sustainable management of commons
- **Pathway 9**: Allocating and strengthening rights and duties on private land[22]

Guidelines for a Landscape Approach in Displacement Settings (GLADS)

The "*Guidelines for a Landscape Approach in Displacement Settings (GLADS)*" is a European Union-funded initiative, led by the Center for International Forestry Research (CIFOR) and World Agroforestry (ICRAF) in partnership with key stakeholders. It assists humanitarian and government actors alongside local stakeholders in targeting landscape-level planning, implementation and rehabilitation that contribute to livelihood resilience of refugee and host communities alike. The GLADS initiative resulted in a guiding document for all stakeholders operating in displacement settings to shape landscape relevant collaborations and planning, including practical examples from the sites and links to relevant instruments. It integrates and consists of the following five key guidelines:

1. Understanding of displacement settings
2. Integrated approach to sustainability and resilience in refugee hosting landscapes
3. Target social, environmental, and economic sustainability outcomes in refugee hosting landscapes
4. Appropriate monitoring, evaluation and learning to adjust and guide best possible sustainability outcomes
5. Mainstream gender equity and social inclusion (GESI) in refugee hosting landscapes

Thereby GLADS utilises the Integrated Landscape Approach (ILA), a framework to integrate policy and practice for multiple land uses within a given geographic area and to ensure equitable access to and sustainable use of land while strengthening measures to mitigate and adapt to the effects of climate change. It also aims to balance competing demands on land through the implementation of adaptive and integrated management systems, including not only physical characteristic features but all internal and external socio-economic and socio-political drivers, as well.[23] Targeting sustainable development and resilience at the level of a landscape through an ILA is increasingly being recognised as a productive approach and it appears to be particularly relevant within displacement settings.

Regarding the context of arid and semi-arid land regions of East Africa, especially in areas of intermittent rivers, ILA, as well as the reference to GLADS, is particularly important. Due to the often protracted nature of displacement, the long-term support provided and the dependence of forcibly displaced people on natural resources, the ILA aims to overcome sectorial gaps and find solutions by encouraging dialogues between various actors at multiple levels. Thereby the goal is to balance competing demands between displaced and hosting communities and to promote finding a solution through policies and practices for multiple land uses and sustainable usage while simultaneously adapting to and mitigating aspects of climate change. GLADS includes the focus on displacement settings and adds valuable aspects regarding hosting landscapes with practical examples from sites in Central and East Africa which are important for displaced and hosting communities alike residing in settlements along intermittent rivers in dryland regions.

Building climate resilience of urban systems through ecosystems-based adaptation Toolkit

The "*Building climate resilience of urban systems through ecosystems-based adaptation Toolkit*" published by United Nations Human Settlements Programme (UN-Habitat) in association with United Nations Environment Programme (UNEP) and funding from the Global Environment Facility (GEF) was developed under the project 'Building Climate Resilience of Urban Systems through Ecosystem-Based Adaptation in the Asia-Pacific Region.'

The Toolkit aims to assist city planning and management authorities and local governments, as well as national governments, practitioners, and the wider development community to integrate Ecosystem-based Adaptation (EbA) strategies into urban development through practical guidance and recommendations. The objectives include, amongst others, to convey the value of nature in cities, familiarise users with the process of urban climate adaptation, prepare users to assess key climate risks, and improve their decision-making capacity and ability to choose the most appropriate EbA option while providing guidelines on how to plan and implement EbA projects. The Toolkit contains the following phases: (1) Getting started; (2) Developing the Vulnerability and Risk Assessments (VRA); (3) Planning for climate change adaptation; and (4) Implementing EbA projects in urban areas.

Ecosystem-based Adaptation (EbA) is defined as the use of biodiversity and ecosystem services as part of an overall strategy of adapting to the effects of climate change and aims to maintain and increase resilience as well as reduce vulnerability of ecosystems and people. Whereas Nature-based Solutions (NbS) are actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges, effectively and adaptively while simultaneously providing benefits for human well-being and general biodiversity. EbA is considered as a subset of NbS which is especially concerned with climate change adaptation by using nature and thereby supports the adoption of ecosystem approaches when planning for climate-resilient development.

The specific conditions of settlements along intermittent rivers in dryland regions of East Africa represent protracted climate-vulnerable displacement situations where rising temperatures associated with climate change can lead to an increased amount of land which is vulnerable to desertification processes. Thereby Nature-based Solutions, and specifically Ecosystem-based Adaptation, are recommended to help adapt to and mitigate the effects of climate change while balancing the competing needs of the various communities that share the limited available resources in these vulnerable regions.

Endnotes

1 https://handbook.spherestandards.org/en/sphere/#ch001

2 https://www.sheltercluster.org/global/documents/master-plan-approach-settlement-planning-guiding-principles

3 Adapted from SPHERE Emergency Handbook "Location and Settlement Planning"

4 Adapted from SPHERE Emergency Handbook "Location and Settlement Planning"

5 Rehabilitation Strategy for Flood Affected Land and Provision of Sustainable Urban Utilities in Kalobeyei Settlement: A Desk Review Report

6 Rehabilitation Strategy for Flood Affected Land and Provision of Sustainable Urban Utilities in Kalobeyei Settlement: A Desk Review Report

7 See Kalobeyei SGBV Report. UN Women, 2019.

8 https://www.genderinkenya.org/wp-content/uploads/2019/07/Kalobeyei-SGBV-Rep-digital-27-Feb-003.pdf

9 https://africa.unwomen.org/en/stories/news/2022/06/sexual-violence-convictions-a-reality-for-kakumas-refugee-community

10 Adapted from SPHERE Emergency Handbook "Location and Settlement Planning"

11 Adapted from SPHERE Emergency Handbook "Water Supply"

12 Adapted from SPHERE Emergency Handbook, "Livestock Emergency Guidelines and Standards (LEGS) "

13 Adapted from SPHERE Emergency Handbook "Hygiene Promotion"

14 Adapted from SPHERE Emergency Handbook "Vector Control"

15 Adapted from SPHERE Emergency Handbook "Water Supply"

16 Adapted from SPHERE Emergency Handbook "Excreta Management"

17 Adapted from SPHERE Emergency Handbook "Solid Waste Management"

18 FAO and UNCCD. 2022. "Technical Guide on the Integration of the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security into the Implementation of the United Nations Convention to Combat Desertification and Land Degradation Neutrality." FAO, Rome and UNCCD, Bonn. https://doi.org/10.4060/cb9656en. Accessed online on 16 November, 2023 at: https://www.unccd.int/sites/default/files/2022-05/cb9656en.pdf

19 Ibid.

20 Ibid.

21 Ibid,

22 Ibid,

23 Reed, James & Deakin, Liz & Sunderland, Terry. (2015). What are 'Integrated Landscape Approaches' and how effectively have they been implemented in the tropics: A systematic map protocol. Environmental Evidence. 4. 10.1186/2047-2382-4-2.

Chapter 4: Strategies for Sustainable Land Management and Opportunities for Economic Development

> **The planning and design of settlements near intermittent rivers must be contextually grounded with the acknowledgment that fluvial environments are dynamic and interactive systems.**

I. Introduction

Building on the minimum humanitarian standards for settlements developed along intermittent rivers outlined in the previous chapter, the 'Kit of Parts' presented in this chapter aims to provide possible planning and design strategies that can be implemented alongside economic opportunities that could be realized in such contexts. While development cannot move forward without a baseline understanding of legal, geographic, ecological, climatic, cultural, demographic, economic, governance, and humanitarian constraints, the array of opportunities that exist for managing resources along intermittent rivers should also be considered. This chapter thus aims to provide an introductory guide to spatial strategies in the form of a 'Kit of Parts' that can be incorporated into landscape architecture, settlement development, and other urban and spatial planning strategies specifically relevant to protracted humanitarian contexts where intermittent rivers are present in arid and semi-arid regions.

The first part of the chapter outlines a collection of ecological and landscape strategies, termed Nature-based Solutions (NbS), that can support and enable more sustainable and resilient access to water, which is generally unpredictable and unreliable in areas where communities are largely dependent on seasonal intermittent rivers as the primary source. These strategies and techniques similarly seek to help manage the risks and challenges associated with the precipitation patterns common to ASAL regions, where long dry seasons are interrupted periodically (seasonally) by heavy rains that can lead to flash flooding, property damage, loss of life, and other risks. These strategies, therefore, seek to provide a range of solutions to two of the most serious challenges that vulnerable communities, in particular, face in the humanitarian-development contexts of East Africa and other regions with ASAL conditions.

Waterlogged streets in Kakuma Refugee Camp. © UN-Habitat

The second half of this chapter presents a selection of economic development and livelihood opportunities that can be considered alongside the previously described strategies for gathering and managing water in dryland regions along intermittent rivers in dryland contexts. It highlights models that integrate sustainable land use and resource management with socio-economic incentives or the production of outputs that can be monetised. At the same time, they promote both capacity building and value chain development that can offer the kinds of long-term and sustainable benefits that are so critical in the humanitarian-development context. As in the previous section, these programmes and initiatives are presented as a 'Kit of Parts,' because, while benefits can be obtained through any of these schemes implemented in isolation, many can be applied in combination with others for compounding effects.

Together, the two sections presented here offer a range of strategies and opportunities that should be considered for use in protracted displacement contexts in arid and semi-arid land regions of East Africa, especially in contexts where intermittent rivers are present. They should be considered collectively as a 'Kit of Parts' with numerous individual approaches and techniques that can be used alone or in various combinations for compounding benefits. In total, this following should be utilised as a design guide and any implemented strategies should be further developed and customised to match the existing conditions and constraints of any particular case. It is also important to note that selection of appropriate solutions should be made thoughtfully, as everything proposed here may not be relevant or applicable in every situation.

II. A Kit of Parts

This section presents a collection of effective Nature-based Solutions (NbS) for sustainable land and water management along intermittent rivers in Arid and Semi-Arid Land (ASAL) regions in the form of a 'kit of parts.' The strategies that make up this kit of parts are organised into three primary categories, which are then further divided into sub-categories based on the type of water catchment system that is implemented:

1 Floodwater Harvesting

Floodwater Harvesting techniques are characterised by turbulent channel flows harvested either by runoff diversion or by spreading within the riverbed or valley floor so that runoff is stored in the soil profile.

Characteristics include:

- Turbulent channel flow harvested either by diversion or by spreading within channel bed/ valley floor - runoff stored in soil profile
- Catchment long (may be several kilometres)
- Ratio catchment: cultivated area above 10:1
- Provision for overflow of excess water

Floodwater Harvesting catchment systems include:

1. Runoff Diversions
2. Within Riverbeds
3. Along Riverbeds

2 Micro-Catchments

Micro-Catchments are characterised by overland flow harvested using a short catchment length (of between 1 and 30 metres), where runoff is stored in the soil profile, and plant growth is typically even.

Characteristics include:

- Overland flow harvested from short catchment length
- Catchment length usually between 1 and 30 metres
- Runoff stored in soil profile
- Ratio catchment: cultivated area usually 1:1 to 3:1
- Normally no provision for overflow
- Plant growth is even

Types of Micro-Catchment systems include:

1. Planting Pits and Micro-Basins
2. Cross-Slope Barriers

3 Macro-Catchments

Macro-Catchments, which are generally similar to micro-catchments, are characterised by their larger catchment lengths (of between 30 and 200 metres) and typically uneven plant growth. Some strategies classified under the category of micro-catchments, though, may be scaled up to meet macro-catchment criteria.

Characteristics include:

- Overland flow or rill flow harvested
- Runoff stored in soil profile
- Catchment usually 30 - 200 metres in length
- Ratio catchment: cultivated area usually 2:1 to 10:1
- Provision for overflow of excess water
- Uneven plant growth unless land levelled

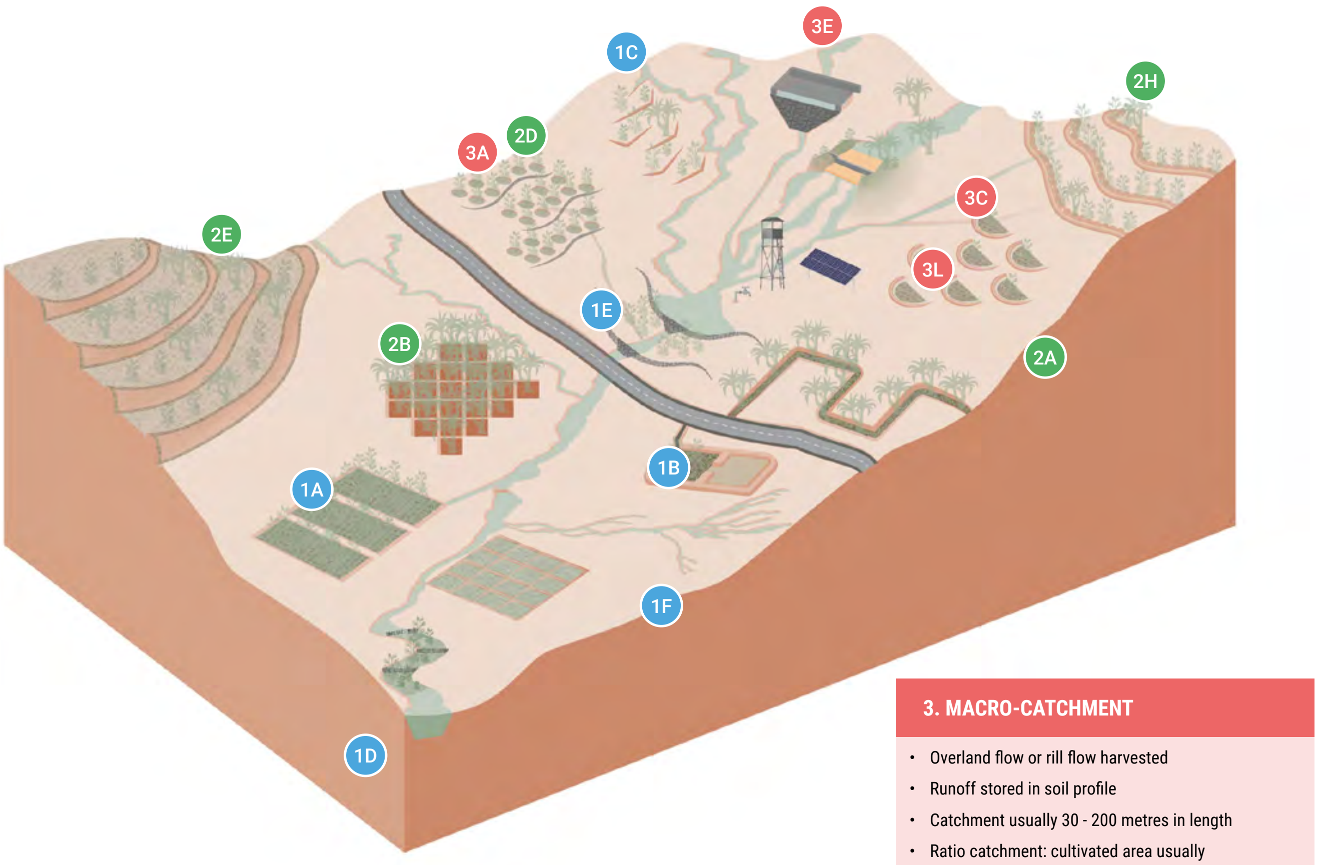
Types of Macro-Catchment systems include:

1. Cross-Slope Barriers
2. Subsurface Storage Facilities
3. Surface Storage Facilities
4. Pumped Water Harvesting

In addition, the likely water sources for each strategy are also identified. These can include, but may not be limited to:

1. Precipitation
2. Surface Runoff
3. Road Runoff
4. Flood Water from Intermittent Rivers
5. Riverbed Water
6. Floodwater Runoff
7. Groundwater Aquifer
8. Natural Springwater

Depending on the geographic context and site conditions, these strategies can be used separately or combined to maximise the water harvesting potential of intermittent rivers and/or other sources of surface water and runoff (i.e., roads, as well as floodwater and precipitation). In addition, many of these strategies simultaneously address the impacts of land degradation by controlling erosion, boosting soil fertility, and/or acting as flood mitigation strategies by capturing and diverting excess runoff for productive uses such as crop irrigation.



1. FLOODWATER HARVESTING

- Turbulent channel flow harvested either by diversion or by spreading within channel bed/valley floor - runoff stored in soil profile
- Catchment long (may be several kilometres)
- Ratio catchment: cultivated area above 10:1
- Provision for overflow of excess water

Runoff Diversions

- 1A Spate-Irrigation
- 1B Road Runoff Harvesting
- 1C Water Spreading Bunds

Within Riverbeds

- 1D Check Dams
- 1E Permeable Rock Dams

Along Riverbeds

- 1F Floodplain Irrigation

2. MICRO-CATCHMENT

- Overland flow harvested from short catchment length
- Catchment length usually between 1 and 30 metres
- Runoff stored in soil profile
- Ratio catchment: cultivated area usually 1:1 to 3:1
- Normally no provision for overflow
- Plant growth is even

Planting Pits & Micro-basins

- 2A Demi-lunes
- 2B Negarims & V-Basins
- 2C Compost Basket
- 2D Planting Pits (T-basins, Zai Pits, 5 x 9 Pits...)

Cross-Slope Barriers

- 2E Fanya-Juu Terraces
- 2F Vegetated Strips & Buffers
- 2G Bench Terraces
- 2H Contour Earth Bunds
- 2I Contour Ridges

3. MACRO-CATCHMENT

- Overland flow or rill flow harvested
- Runoff stored in soil profile
- Catchment usually 30 - 200 metres in length
- Ratio catchment: cultivated area usually 2:1 to 10:1
- Provision for overflow of excess water
- Uneven plant growth unless land leveled

Cross-Slope Barriers

- 3A Stone Lines
- 3B Trapezoidal Bunds

Subsurface Storage Facility

- 3C Sand Dams
- 3D Sub-Surface Dam

Surface Storage Facility

- 3E Rock Catchment
- 3F Small Earth Dams/Weirs
- 3G Water Pans
- 3H Lagoons

Pumped Water Harvesting

- 3I Boreholes/Wells
- 3J Protected Springs
- 3K Shallow Wells
- 3L Solar Powered Water Pumping

1

Floodwater Harvesting

Runoff Diversions

1A Spate Irrigation[1]

Category:
Floodwater Harvesting –
(1) Runoff Diversions

Water sources:
(1) Precipitation, (2) Surface Runoff,
(4) Floodwater from Intermittent Rivers

Figure 12 Schematic diagram of floodwater, from the mountains to the fields[2]

Source: Nabeel Rizwan

Figure 13 A field-to-field distribution in Eritrea; cuts on the bunds allow water to irrigate the next field[3]

Source: FAO, 2010

Overview

Spate Irrigation is a traditional water diversion and irrigation technique used in arid and semi-arid climates to divert seasonal floods and stormwater from intermittent rivers onto downstream farmlands following the natural flow that results from gravity. Floodwater is then distributed either from field to field or onto a single field, which may involve either extensive distribution (over a large area) or intensive distribution (concentrated on a small area) systems. The water soaks deep into the soil profile and can provide moisture sufficient for up to two or three harvests, depending on residual soil moisture.[4]

Advantages[5]

Spate irrigation enables farmers to harness the power of floodwater over relatively large areas and control flooding that could otherwise damage shelters and infrastructure. Additionally, after long periods of spate-irrigation in an area, groundwater supply has been found to improve due to extended recharge periods, which offers significant long-term benefits.[6]

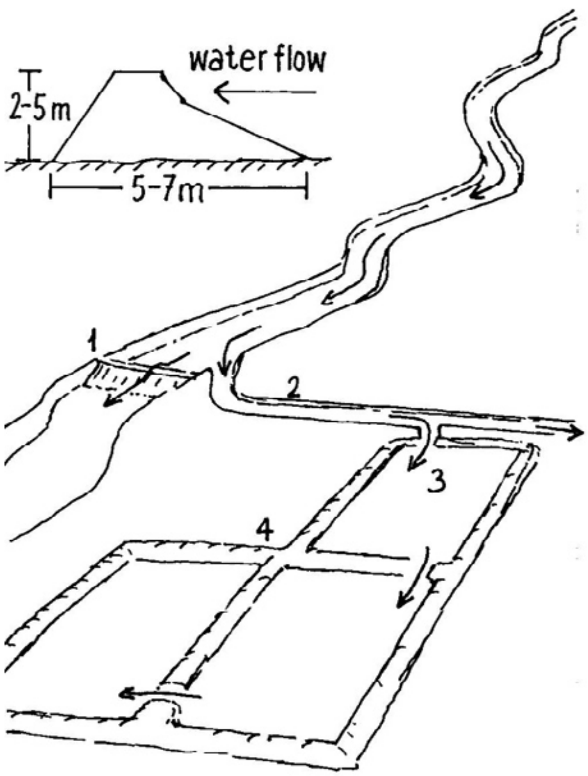
Challenges[7]

Due to the unpredictable nature of flood water, this strategy's success can be unpredictable and vary significantly from one year to the next. Water rights and the needs of down-stream land users must be considered to avoid conflicts and ensure that the system design doesn't negatively impact anyone's access to water. Therefore, this strategy can be challenging from both a social perspective and a technical one. Sediments must be removed and sedimentation basins must be flushed frequently to ensure that they do not pass through irrigation water to croplands, where they can damage the soil and impact crop production.[8] In addition, because it is an unpredictable natural technique that can vary significantly, irrigation constructions may need to be adjusted regularly to match changing river beds. Diversion structures can be easily damaged or washed away, as well, so maintenance can be demanding. To match unpredictable and variable results, crop selections that rely on this technique should be drought tolerant and resilient.

Design

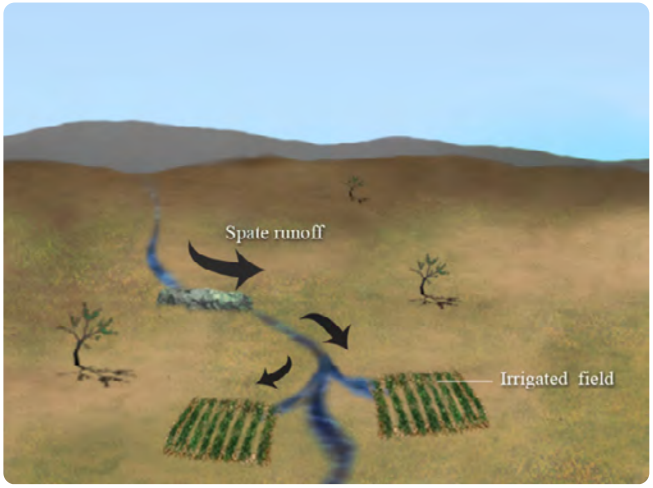
The typical spate irrigation system is comprised of (1) an 'agim', a temporary 3 to 4 metre high river diversion structure on the low-flow side of the channel, made from brushwood, tree trunks, earth, stones/ boulders; (2) distribution canals; and (3) rectangular irrigated fields surrounded by (4) earthen embankments.[9]

Figure 14 Field-to-Field Spate Irrigation System: (1) agim; (2) distribution canals; (3) fields; (4) earthen embankments[10]



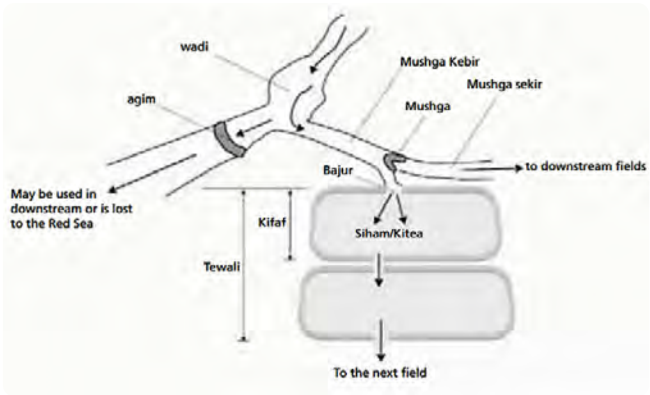
Source: Liniger, H. P., et al. Sustainable Land Management in Practice: Guidelines and Best Practices for sub-Saharan Africa. FAO, 2011.

Figure 15 Road runoff has the potential to concentrate water in a desired location[11]



Source: Critchley, et al., 1994

Figure 16 A field-to-field irrigation distribution system in Eritrea[12]



Source: SSWM: Spate Irrigation

Case Study:
Spate Irrigation - Flood Mitigation and Groundwater Restoration in Iran[13]

Figure 17 **Spate Irrigation systems in Iran[14]**

Source: https://floodbased.org/wp-content/uploads/2021/05/OP_07_Spate_Iran_SF.pdf

Figure 18 **Degãr, a spate irrigation system in Baluchestãn, southeast Iran[15]**

Source: https://floodbased.org/wp-content/uploads/2021/05/OP_07_Spate_Iran_SF.pdf

Figure 19 **Darband, a spate irrigation system in Baluchestãn, southeast Iran[16]**

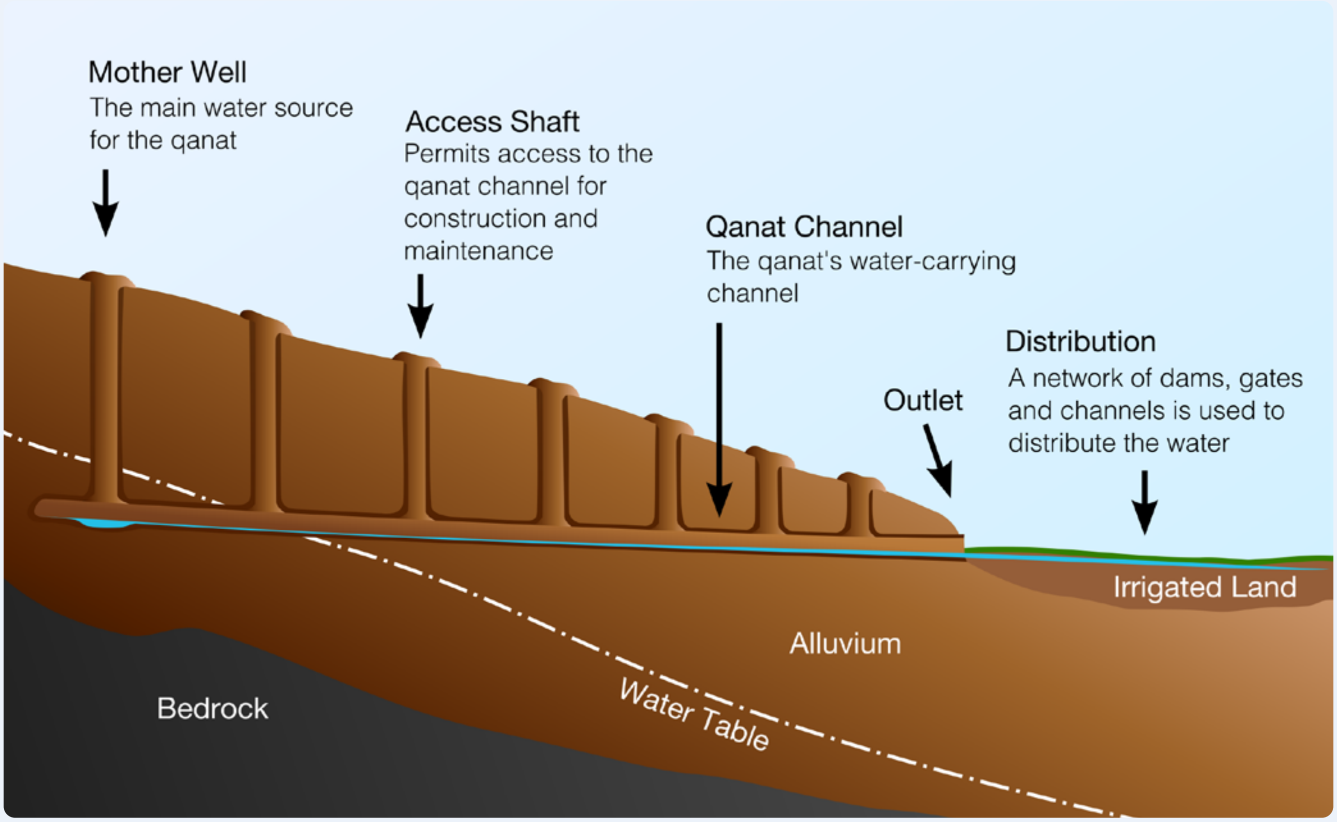
Source: https://floodbased.org/wp-content/uploads/2021/05/OP_07_Spate_Iran_SF.pdf

Background

In Iran, prolonged and cyclical meteorological droughts have impacted the country for thousands of years. Like climate conditions in other arid and semi-arid regions, though, heavy precipitation events and flash floods interrupt periods of drought, often resulting in mortalities and significant financial and structural damages, which creates a vicious cycle of famine and flooding. In response, Iranian water management systems that date back thousands of years were carefully adapted to these challenging conditions.

Ancient Persian nomads, for example, settled in grass covered flood plains along alluvial fans ("triangle-shaped deposit[s] of gravel, sand, and even smaller pieces of sediment, such as silt")[17] and debris cones ("alluvial fans with a steep slope, closer to the shape of a half-cone than a flat fan"),[18] in order to take advantage of both permanent and intermittent springs that occur there. The water from these springs spread nutrient-rich floodwaters onto their lands, irrigating crops and enriching soils, while simultaneously recharging the underlying aquifers. They began digging through this seepage face and arrived at saturated strata, leading to a major turning point in Iranian civilization. As populations rose, ancient Iranians invented a new technology to meet growing water demand known as the Qanat, an underground system that uses gravitational force to drain upland aquifers through a mild-sloping gallery with shafts used to remove earth and for ventilation.[19] This system remains highly regarded for its efficiency, minimal environmental impact, and for enabling equitable and sustainable water sharing and distribution.[20]

Figure 20 A cross section of a typical Qanat[21]



Source: Samuel Bailey (sam.bailus@gmail.com), CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Qanat_cross_section.svg

Unfortunately, modernisation efforts following World War II disrupted traditional water management methods. As a result, motorised pumps were imported and large and expensive dams were constructed with little consideration for the geological and climatological conditions, resulting in high levels of sedimentation, evaporation, and leakage.[22] In addition, 20th century policies regarding nomad decentralisation, land reform, and self-sufficiency resulted in water mismanagement. As groundwater supplies about 60% of water needs in Iran, over-exploitation, specifically over-pumping, has resulted in a hydrological drought since 1945. It is estimated that more than two out of every three of the qanats have dried up, likely as a result of this increasing demand and improper management, and the falling water table has accelerated urban migration as many farmers are forced to abandon their farms and seek other employment opportunities.[23]

Spate Technology Applications in Iran

Spate irrigation, both as an irrigation tool as well as a method for artificial recharge of groundwater (ARG), has proven to be a promising solution to rejuvenating Iran's dried up qanats, improving crop yields, restoring biodiversity, mitigating flood damage, and promoting more sustainable, efficient, and cost effective agriculture and water-management systems.[24] Spate irrigation practices are already widespread throughout Iran and thousands of years of trial and error have enabled Iranian dryland farmers to develop a range of effective techniques for creating conditions that can still produce yields even during dry years.[25] These methods include growing drought-tolerant crops and varieties adapted to the local agro-climatic conditions and planting the most water demanding crops, such as maize, on the lowest parts of the fields.[26]

Lagga cutting a cross an earth road in Village 2. © UN-Habitat

Improved Water Management and Distribution

Sedimentary deposits cover nearly 40% (639,241 km^2) of Iran's geographic area. Of that area, it's estimated that about 23% (149,000 km^2) are highly suitable, 10% (62,700 km^2) are suitable, and 17% (110,300 km^2) are relatively suitable for ARG through Spate Irrigation.[27] With an estimated 61.97 km^3 of floodwater wasted every year, 42km^3 of this could instead be harvested to irrigate the most suitable areas through Spate Irrigation systems, the construction and maintenance of which could result in the creation of over 4 million direct employment opportunities.[28] Moreover, equitable distribution of water resources through Spate Irrigation has a long tradition in Iran, traditionally conducted through a methodical division by a just authority, at times historically appointed by the king.[29] The well-established relationship between spate systems and water usage rights also helps mitigate potential upstream/downstream conflict.

Disaster Risk Reduction (DRR) Potential

There is significant quantitative evidence to demonstrate the effectiveness of spate irrigation systems in Iran as a strategy to support sustainable water management, climate change adaptation, and disaster risk reduction (DRR). In The Gooyom meadow, a 550-ha spate irrigation system retained about 57 m^3s^{-1} of a flood in December of 1986. The peak flow of the flood event was 343 m^3/s^{-1}, meaning that the 550-ha spate system had reduced the maximum flow of the flood by 14% and saved parts of the city from flooding.[30] A flood of similar magnitude in January 2002 in an area lacking spate infrastructure resulted in 30 fatalities and USD $3.75 million in flood-related damages.[31]

1B

Road Runoff Harvesting

Category:
Floodwater Harvesting –
(1) Runoff Diversions

Water Source:
(2) Surface Runoff, (3) Road Runoff

Figure 21 Example of an embankment pond fed by a road culvert[32]

Source: F. Sambalino, MetaMeta, 2015

Figure 22 Example of concentrated road runoff harvesting by diverting flows into retention ditches or basins[33]

Source: Thomas, 1997

Figure 23 Example of concentrated road runoff harvesting by diverting flows into retention ditches or basins[34]

Source: Thomas, 1997

Overview

Road Runoff harvesting involves external catchment systems that capture, divert, and store stormwater flows from roads, footpaths, railway lines and other paved or unpaved surfaces that tend to shed water. Technologies range from simple diversion structures directing surface water into crop fields (as green water), to deep trenches with check-dams that enable both flood and subsurface irrigation.

Road runoff harvesting is considered untapped potential for the "greening" of dryland regions.[35] Water may be spread directly to crop fields (ideal for cereals), or ponded and used for supplementary irrigation (preferable for horticultural crops, both vegetables and fruit trees). Runoff that is ponded can be used to irrigate vegetables in greenhouses, resulting in produce that can be sold directly at markets.[36]

Advantages

There is a positive downstream impact of reducing otherwise erosive drainage water that can cause damage to roads and adjacent land and structures.[37] Additionally, where surface conditions permit, storage of runoff in tanks, pans, and ponds can be a particularly cost-effective rainwater harvesting technique.

Challenges

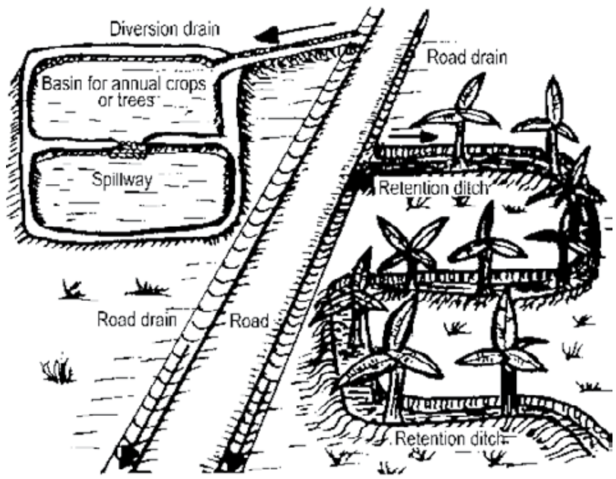
Conflict can arise between up- and down-road farmers where there may be competition over limited resources and rights to runoff may be unclear and difficult to establish.[38] Because the road surfaces are being used as the catchment, caution must be taken to prevent pollutants in the runoff and water from road catchments should not be used for domestic consumption, especially if the water is from murram and dirt roads which may contain dung and other pollutants, or if the water is from tarmac roads which may contain tar that can be toxic if consumed.[39]

Another challenge, which has been noted in Kakuma-Kalobeyei in Kenya, is that in humanitarian-development contexts, road conditions may be poor and there are limited resources to develop adequate road infrastructure, which may limit the successful implementation of this strategy.

Design

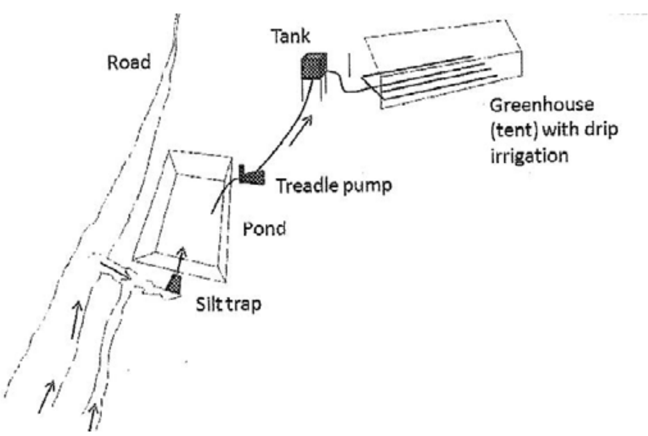
Road Runoff Harvesting can be implemented in a variety of situations, but precise strategies should be adapted to the context and vary depending on road surface material and slopes. In most cases, though, rainwater runoff from the road surface is directed to the edge of the road into trenches or gullies by sloping the surface of the road out from the centre. Trenches along the sides of the road are then sloped toward culverts that gather the runoff at intervals. From there, trenches can be dug to distribute that water across cultivated fields through various irrigation methods, including bunds and ditches, that may be varied according to the crops and their needs.

Figure 24 Example of concentrated road runoff harvesting by diverting flows into retention ditches or basins[40]



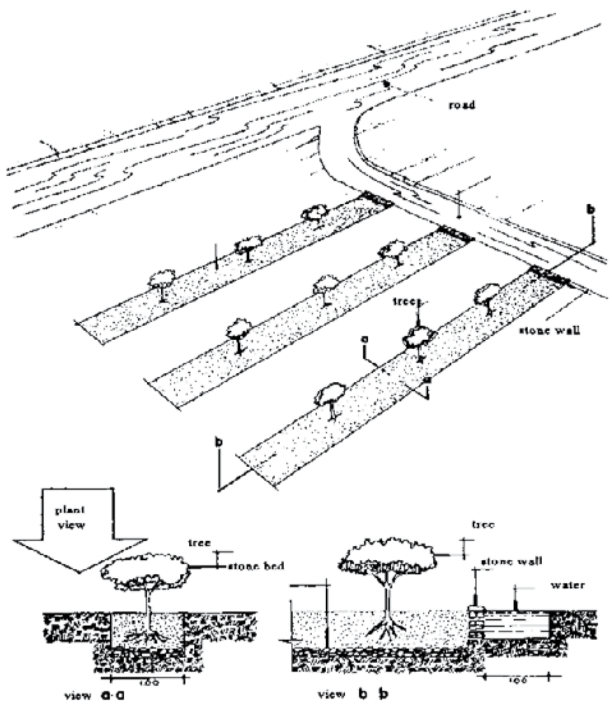
Source: Thomas, 1997

Figure 25 Combining a pond with a greenhouse in Kenya[41]



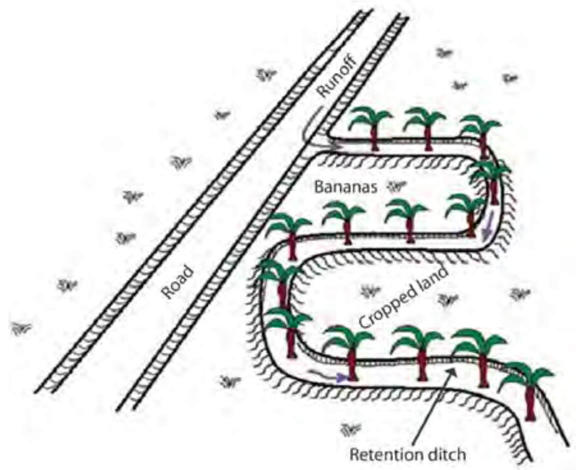
Source: Kubbinga, 2012

Figure 26 A Schematic Representation of Runoff Collection from Paved and Unpaved Roads, Using Underground Galleries for Storage[42]



Source: Dos Anjos, Nelson Da Franca Ribeiro. 1.4 Runoff collection from paved and unpaved roads in: "Source book of alternative technologies for freshwater augmentation in Latin America and the Caribbean." International Journal of Water Resources Development (1998).

Figure 27 Road runoff harvesting into channels for crop production[43]



Source: Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Road-runoff-harvesting-into-channels-for-crop-production_fig12_254426136 [accessed 15 Aug, 2022]

1C Water Spreading Bunds

Category:
Floodwater Harvesting –
(1) Runoff Diversions

Water Source:
(2) Surface Runoff, (4) Floodwater from Intermittent Rivers

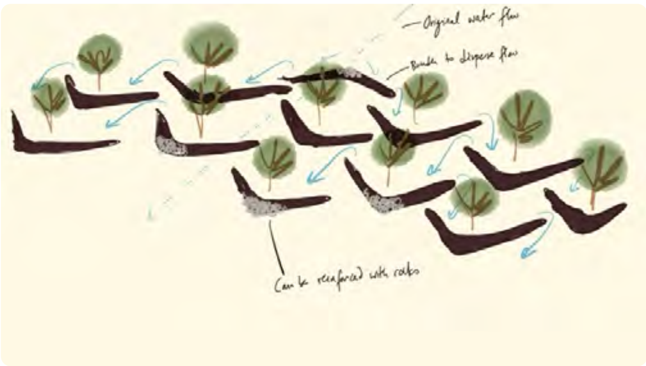
Figure 28 **Water spreading bunds in Kalobeyei Settlement, Kenya**

Source: UN-Habitat

Figure 29 **Water spreading bunds in Kalobeyei Settlement, Kenya**

Source: UN-Habitat

Figure 30 **An illustration of small boomerang shaped water spreading bunds[44]**



Source: https://ananas.design/journal/2019/4/23/how-to-prepare-your-land-before-the-monsoons

Overview

One of the key characteristics of water spreading bunds is that they are designed to spread water, not to impound it. The technology is typically used in arid and semi-arid regions to spread floodwater that has naturally spilled onto a floodplain or to artificially divert it from a natural watercourse. The bunds, which are usually made of earth, are used to slow the flow of floodwater and spread it over cultivated land where it can infiltrate the soil.[45]

Advantages

Water spreading bunds are often implemented in situations where runoff discharge is high and could damage trapezoidal bunds or where the crops to be grown are susceptible to the temporary waterlogging that may occur with another strategy since they do not impound much water for any length of time.

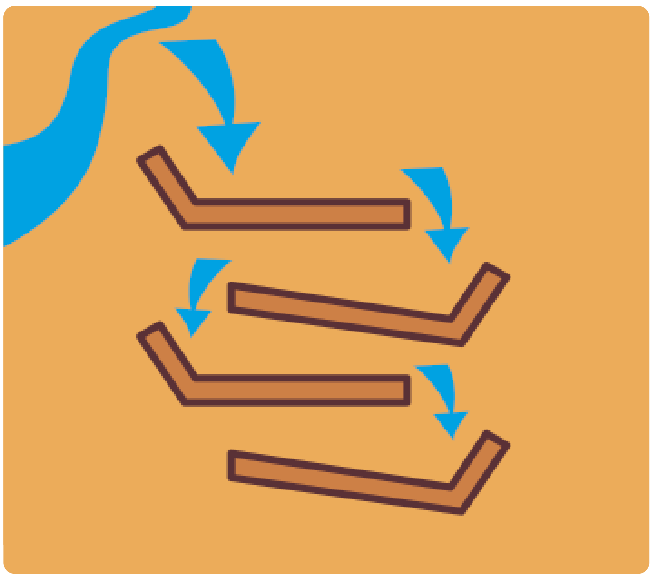
Challenges

One challenge is that Water Spreading Bunds can require regular maintenance in order to preserve the desired forms, especially in the early stages after construction. This means that resources, knowledge, and community participation are desirable in order to ensure the benefits of this strategy can be extended.

Design

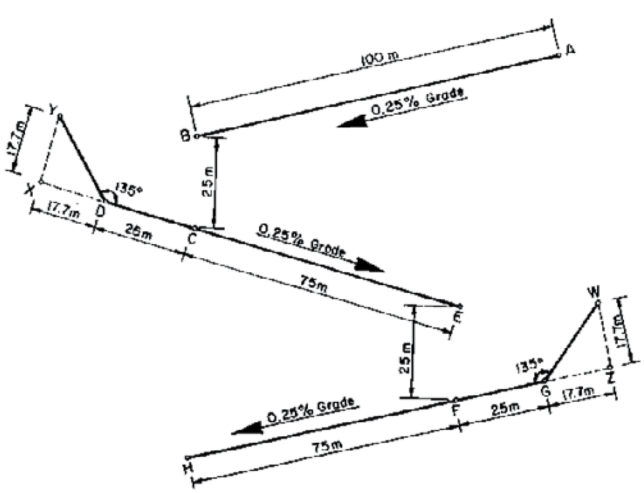
For slopes of less than 0.5%, open ended bunds placed across the slope help slow and spread the flow across a field. For slopes of greater than 0.5%, a series of graded bunds should be used where each successive bund is graded from different ends. A short wingwall should be constructed at 135° to the upper end of each bund to allow each successive bund to gather the flow from the bund above.[46]

Figure 31 Illustration of water spreading bunds[47]



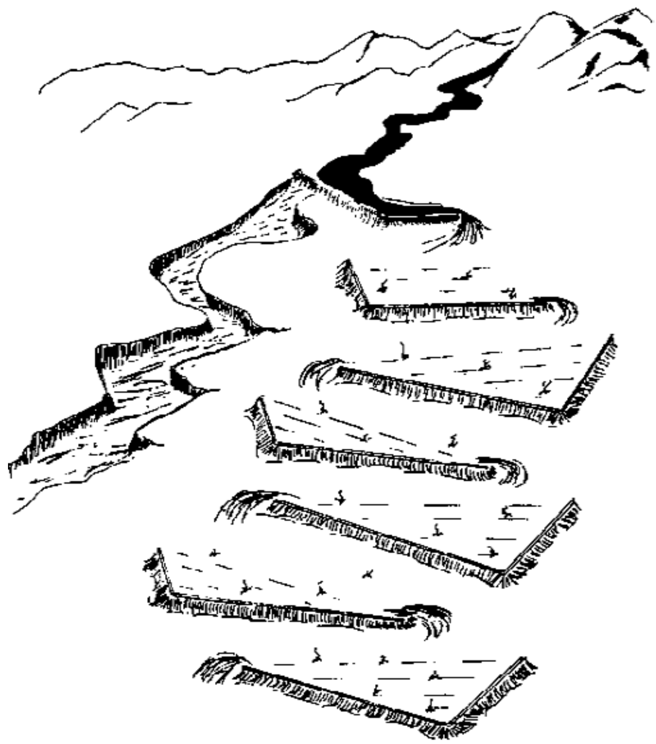
Sources: Greener Land: Water Spreading Bunds

Figure 32 Setting out of graded bunds: groundslope > 0.5%[48]



Source: Critchley, Will, and Klaus Siegert. "A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production." FAO (1991)

Figure 33 Flow diversion system with water spreading bunds in Pakistan[49]



Source: Nas, 1980

Within Riverbeds

1D

Check Dams / Gully Plugs[50, 51]

Category:
Floodwater Harvesting –
(2) Within Riverbeds

Water Source:
(2) Surface Runoff, (4) Floodwater from Intermittent Rivers, (5) Riverbed Water

Figure 34 **Rock gully plug near Amman, Jordan after rainfall event in 2018[52]**

Source: Stefan Strohmeire

Figure 35 **Loose stone dam in East Africa to stop the gully erosion[53]**

Source: MALESU, et al., (2007)

Figure 36 **An example of a log check dam[54]**

Source: fs.usda.gov and Tardio, G.

Overview

One strategy for rehabilitating gullies and converting them into productive land can involves building check dams. Check Dams can allow dry riverbeds to be cultivated using residual moisture at the end of the rainy season. As dams reduce runoff speed and stop the eroded sediment, the areas between dams fill up with eroded soil and residual moisture. In addition, over time the agricultural land that was divided by the gully, will become reconnected.[55]

Advantages

The trapped flow created by check dams allows for water harvesting and conservation as well as crop growing to take place in gullies even in regions with relatively low precipitation. They are an excellent strategy for erosion and runoff control while also helping to settle sediments and pollutants in order to ensure water quality. They also can help to promote female economic empowerment, because valley bottoms are traditionally used to grow “women’s crops” such as arrow roots, sweet potatoes, fruits, vegetables, sugarcane, and rice.

Challenges

Unfortunately, check dams and gully plugs can be labour intensive, as they typically require regular maintenance of both structural components and their plantings in order to promote longevity and sustain effectiveness. From a design perspective, inappropriate and irregular spacing may lead to dams being washed away and integration of both physical and biological elements is crucial.[56] In addition, proper treatment of the upper catchment area is critical to protecting check dams.

Design

Check dams are built with locally available materials (e.g., stones, timber, brushwood, or vegetated hedges) and spaced according to the slope of the riverbed. The dams are built in stages over time by raising the height of the check dam by approximately 0.3 metres each year.[57]

Figure 37 An example of a gabion check dam[58]

Source: https://forestrybloq.com/different-types-of-check-dams/

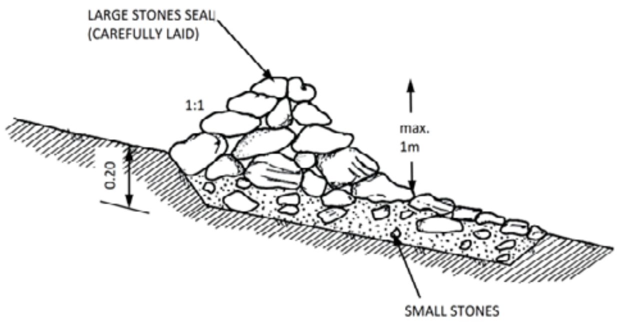
Figure 38 An example of a brushwood check dam under construction[59]

Source: https://forestrybloq.com/different-types-of-check-dams/

Figure 39 An example of a brushwood check dam[60]

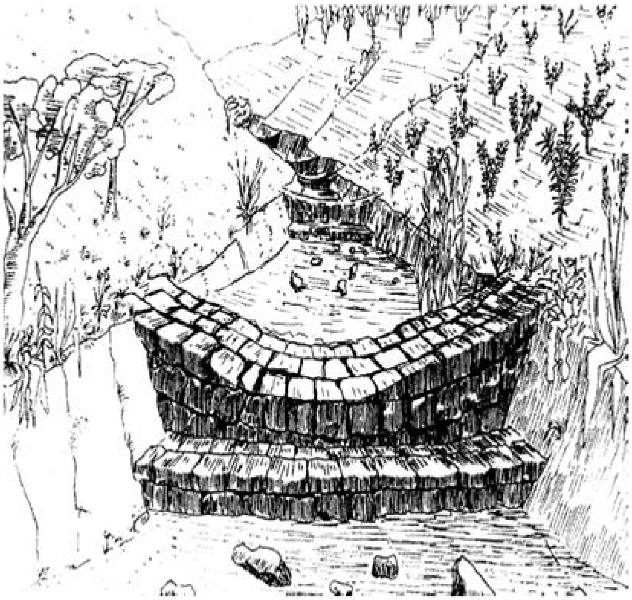
Source: https://forestrybloq.com/different-types-of-check-dams/

Figure 40 **Cross Section of a stone check dam**[61]



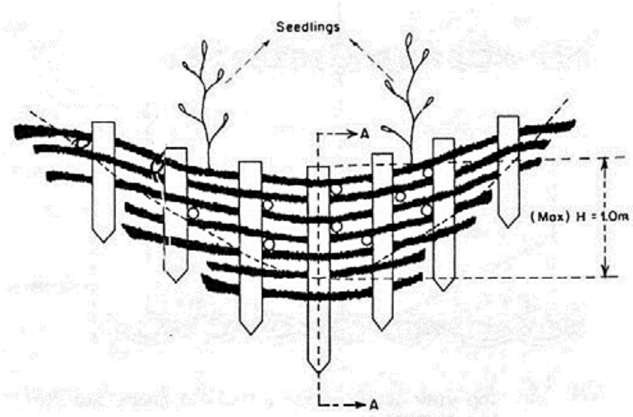
Source: MWI. Practice Manual for Small Dams, Pans and Other Water Conservation Structures in Kenya (2015)

Figure 41 **A typical loose stone check dam**[62]



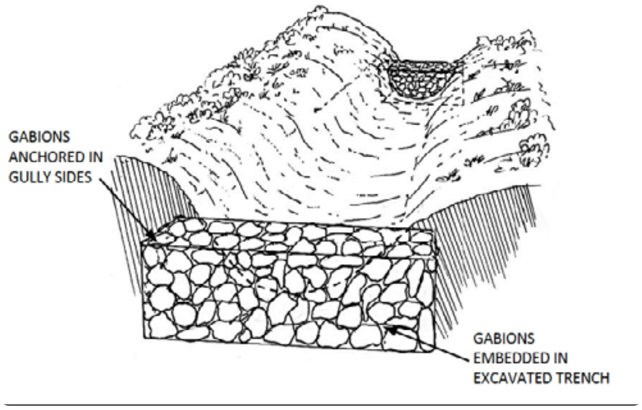
Source: Desta, L., and B. Adunga. "A field guide on gully prevention and control Nile Basin initiative, eastern Nile subsidiary action program (ENSAP)." Eastern Nile, Technical Regional Office (ENTRO), Eastern Nile Watershed Management Project, Addis Ababa (2012).

Figure 42 **Brushwood check dam placed across the gully**[63]



Source: FAO, 1986

Figure 43 **Gabion Check Dam**[64]



Source: http://design-of-small-dams.appspot.com/project_preparation/

1E

Permeable Rock Dams (PRD)

Category:
Floodwater Harvesting –
(2) Within Riverbeds

Water Source:
(2) Surface Runoff, (4) Floodwater from Intermittent Rivers, (5) Riverbed Water

Figure 44 Permeable rock dam spillway[65]

Source: Critchley, Will, and Klaus Siegert. "Chapter 5: Water Harvesting Techniques" in "A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production." FAO (1991) https://www.fao.org/3/u3160e/u3160e07.htm#5.8%20 permeable%20rock%20dams

Figure 45 An example of a permeable rock dam (PRD) being used for Soil and Water Conservation (SWC)[66]

Source: Grimaldi et al., 2012

Overview

Permeable rock dams spread floodwater from river and valley bottoms in a way that can result in improved crop production and erosion control. Runoff that is naturally concentrated in the centre of a riverbed is better distributed across the whole valley floor while excess water is allowed to filter through the dam, or overtop during peak flows, to continue downstream at a more restrained flow. Usually, a series of dams are incrementally positioned along the same valley floor for stability and to slow the flow of floodwaters and allow for more distributed infiltration. Over time, these dams will gradually silt up with fertile deposits that can be utilised for agricultural activities.[67]

Advantages

By implementing Permeable Rock Dams, floodwater can be harvested and spread more evenly across a valley, which has the potential benefit of increasing crop production. In addition, by reducing the flow of runoff, erosion can be better controlled, and groundwater recharge can be promoted. Gullies are created at each dam that can silt up and collect fertile deposits, which can have benefits on the quality of water and soil, in addition to the overall river course.[68]

Challenges

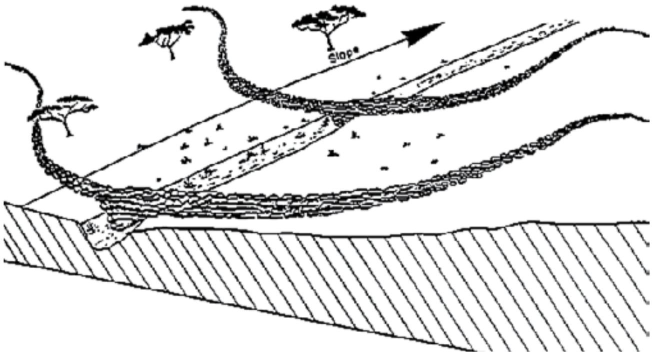
The main limitations of permeable rock dams are that they are highly site-specific and can be costly to implement because they require considerable quantities of loose stone, which often must be transported to remote sites.[69]

Design

Dam structures are typically long and low walls of around 1 metre in height within a gully, and between 70 and 150 centimetres in height at various points along its length depending on the topography.[70] Dams are typically between 50 and 300 metres in length and are made primarily from loose stone.[71] They run perpendicular to the watercourse, while the extensions of the wall typically curve down following the contour of the landscape. When constructed on wide and relatively flat valley floors, dams may be built straight across, where the height of the wall slopes down from the centre to maintain a level crest.[72]

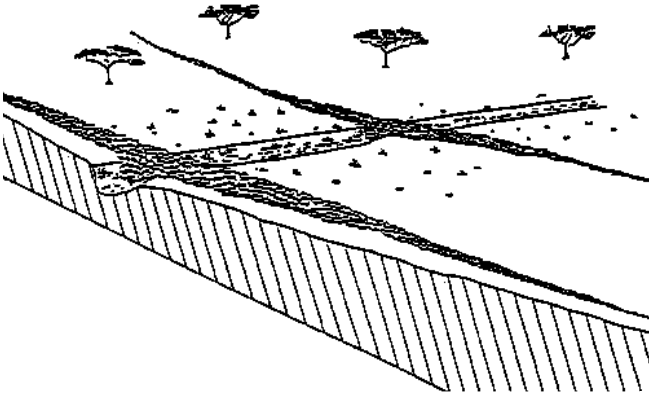
A shallow trench should be dug to help create a foundation condition for the dam and the larger stones should be placed on the exposed portions of the wall, while smaller stones can be used internally. Because the structure is generally composed of piled loose stones, it is sloped on either side for stability and ease of construction, though the slope of the wall itself should be flatter on the downslope side (2:1 to 3:1) and steeper on the upslope side (1:2 to 1:1).[73]

Figure 46 Permeable rock dams: general layout[74]



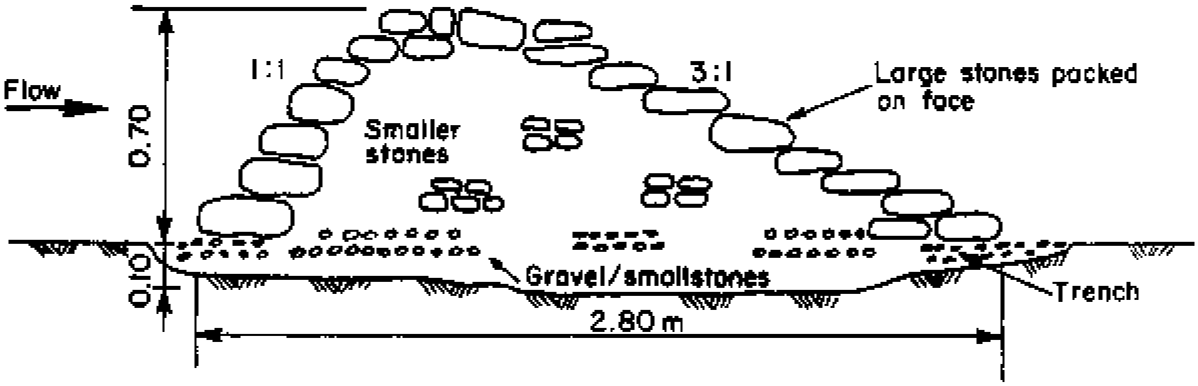
Source: Critchley and Reij, 1989

Figure 47 Permeable rock dams: alternative layout[75]



Source: Critchley and Reij, 1989

Figure 48 Permeable rock dam dimensions[76]



Source: Critchley and Reij, 1989

Along Riverbeds

1F Floodplain Irrigation

Category:
Floodwater Harvesting –
(3) Along Riverbeds

Water Source:
(2) Surface Runoff, (4) Floodwater from Intermittent Rivers

Figure 49 **Floodplain Irrigation in Kakuma Refugee Camp, Kenya**

Source: UN-Habitat, 2022

Figure 50 **Floodplain Irrigation in Kakuma Refugee Camp, Kenya**

Source: UN-Habitat, 2022

Overview

Flood-based agricultural systems such as Floodplain Irrigation leverage (ideally predictable) flood water to aid farming and other water-dependent livelihoods (e.g., fisheries), (agro)forestry, grazing, and groundwater recharge and storage. Floodplain Irrigation involves cultivation in gently sloping floodplains and can rely on receding (flood recession) and/or rising (flood-rise) systems.[77]

Advantages

In some areas, flooding cycles and strategic cropping allow for two cropping cycles using both flood recession and flood rise technologies.[78] Overflowing intermittent rivers cause floodplains to become inundated, and the high sediment load carries fine particles that increase fertility.[79]

Disadvantages

While floods are often varied and unpredictable, this technique works best when flooding is regular and predictable, therefore results and crop yields are not always reliable or consistent. In addition, topography and soil type influence spread, retention properties, and permeability of the land and upstream infrastructure projects may be developed without regard for downstream systems, rendering formerly productive flood-based technology ineffective.[80]

Design

Flood recession agriculture usually involves leverageing the post-inundation residual moisture of floodwaters to irrigate crops. On the other hand, flood-resistant crops such as rice and sorghum can be planted in rising water levels. Low lying areas are ideal for flood recession as moisture is conserved for longer periods of time.[81]

Figure 51 Floodplain Irrigation in Kakuma Refugee Camp, Kenya

Source: UN-Habitat, 2022

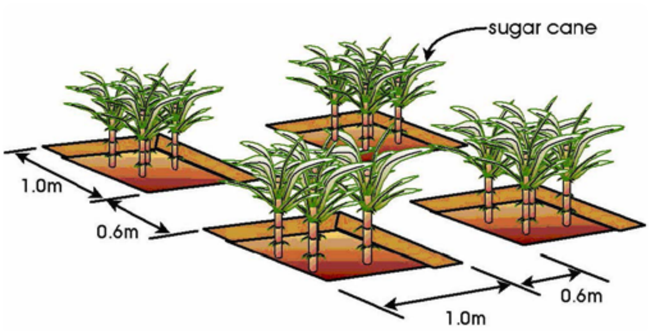
Figure 52 Floodplain Irrigation in Kakuma Refugee Camp, Kenya

Source: UN-Habitat, 2022

Figure 53 Active irrigation for rice cultivation in the Inner Niger Delta[82]

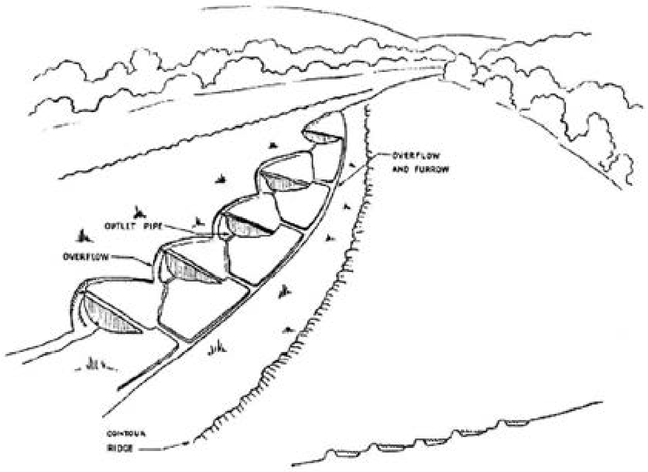
Source: onisdin.info/en/socio-economy/natural-resources

Figure 54 Sugar cane growing in residual moisture from floods[83]



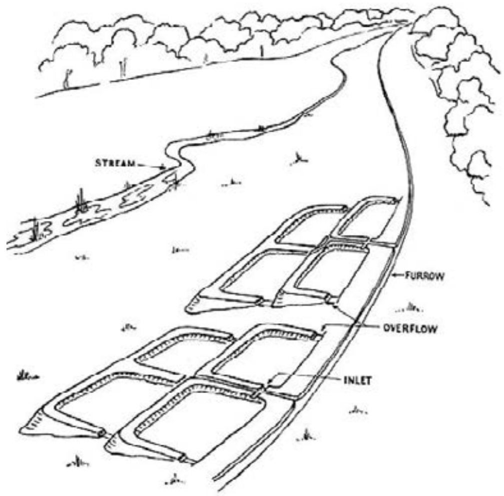
Source: Mati, B. M. "100 ways to manage water for smallholder agriculture in Eastern and Southern Africa: A compendium of technologies and practices." IMAWESA (2007).

Figure 55 Barrage ponds[84]



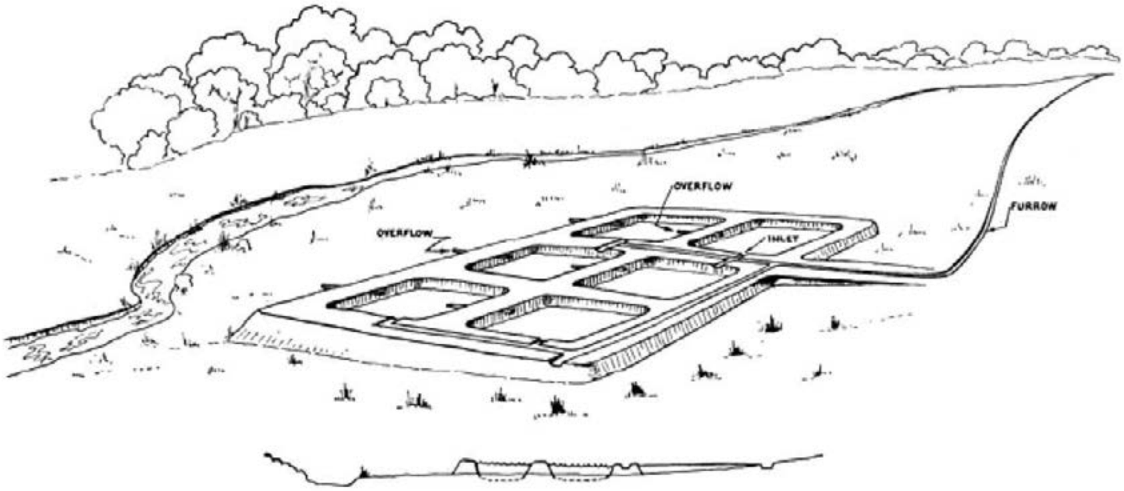
Source: https://floodbased.org/wp-content/uploads/2021/05/OP_05_Flood-based-farming-in-Africa_SF.pdf

Figure 56 Contour ponds[85]



Source: https://floodbased.org/wp-content/uploads/2021/05/OP_05_Flood-based-farming-in-Africa_SF.pdf

Figure 57 **Paddy ponds made in a flat dambo**[86]



Source: https://floodbased.org/wp-content/uploads/2021/05/OP_05_Flood-based-farming-in-Africa_SF.pdf

Case Study:
Flood-Based Farming in Ethiopia[87]

Background

Throughout many of Ethiopia's regions, annual flooding is expected, and distinct wet and dry seasons allow flood levels to fluctuate somewhat predictably in these environments. Over the course of a year, river floodplains, margins of lakes, and seasonal wetlands, distributed across Ethiopia's high and lowlands, experience these significant fluctuations, creating the ideal environmental conditions for the practice of flood recession agriculture.

In terrain where flood recession agriculture is practiced, this seasonal inundation carries fertile topsoil from the upper catchment area; the soils in these areas typically contain fine-grained sediment that settles when water flows slowly over the floodplains. Moreover, floods often carry fertile organic material from the surface in the upper catchment, which is allowed to settle due to the slow pace of water flowing in inundated areas. Due to this annual deposit of sediment and organic material, the soil is extremely fertile and no additional fertilizer is needed to farm.

A major challenge in flood prone areas may be that crops cannot be grown during their optimal growing period due to the timing of floods. In response, planting often begins at the beginning of the dry season in order to utilise residual moisture in the soil after the floodwaters recede. In this way, rain towards the end of the wet season and early in the dry season after the flood recession crops are planted can help contribute to the production of higher yields. Some farmers own land in both low-lying areas, where they practice flood-recession farming, as well as in adjacent elevated areas where they may practice rain-fed agriculture during the wet season, in order to take advantage of both conditions.

Figure 58 **Four stages of water retreat in Lake Koka at Gora Leman kebele**

Top left is maximum inundation, top right floods are retreating, bottom left shows further retreat, bottom right shows plowing in dried floodplain (note that photos are not taken from the exact same spot)[88]

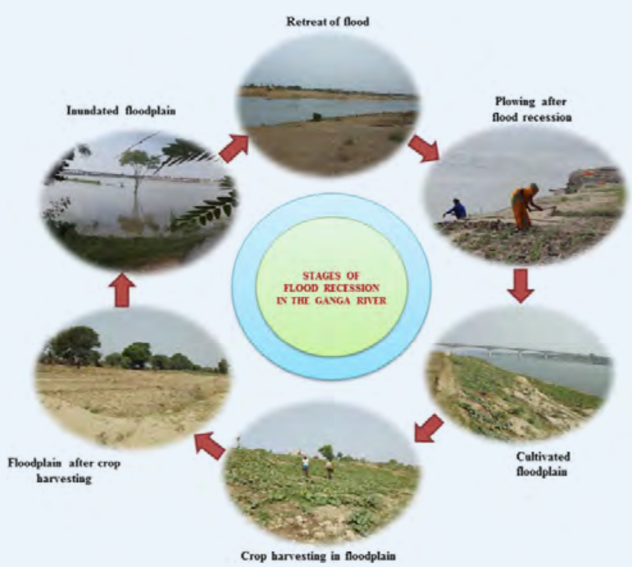
Source: Nederveen, S. Coenraads. "Flood Recession Farming: An Overview and Case Study from the Upper Awash Catchment, Ethiopia Master thesis Hydrology, code 450122, 39 ECTS." (2012). https://www.semanticscholar.org/paper/Flood-Recession-Farming%3A-An-Overview-and-Case-Study-Nederveen/03eba87943e16228e75336c9829155ed7bbcc07b

Figure 59 Four stages of flood recession in Becho plain

Top left shows maximum inundation, top right the retreat of the flood, bottom left plowing after retreat, bottom right growing of the crops (pictures are taken in the longer inundated area)[89]

Source: Nederveen, S. Coenraads. "Flood Recession Farming: An Overview and Case Study from the Upper Awash Catchment, Ethiopia Master thesis Hydrology, code 450122, 39 ECTS." (2012). https://www.semanticscholar.org/paper/Flood-Recession-Farming%3A-An-Overview-and-Case-Study-Nederveen/03eba87943e16228e75336c9829155ed7bbcc07b

Figure 60 Different stages of flood recession in the Ganga River influencing the farming practice[90]



Source: Singh, Rinku, et al. "Assessment of flood recession farming for livelihood provision, food security and environmental sustainability in the Ganga River Basin." Current Research in Environmental Sustainability 3 (2021)

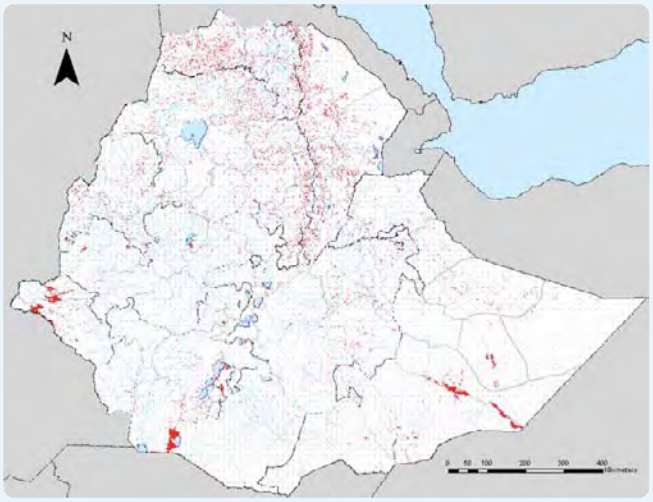
Despite the risk of property damage that floods typically incur, flood recession areas in Ethiopia are often fairly densely populated and flood-based agriculture helps mitigate risks. Each region has distinct characteristics and management systems since timing, duration, and scale of flooding varies throughout the country.

Flood recession farming practices also vary regionally based on unique traditional practices, which means that there is a diverse range of planting techniques used and crops that are cultivated, as well as various risk mitigation and income generating activities. The primary regions in Ethiopia where farmers are known to practice flood recession agriculture are Lake Tana, Baro-Akoba, Omo Valley, Wabi Shebelle and Upper Awash.

Flood recession agriculture is integral to Omo River Valley livelihoods. The primary crops grown there—maize, sorghum, and finger millet—are planted along the banks of the Omo River as the annual floodwaters retreat and the residual moisture enables their growth. Some communities have constructed inundation canals to distribute water across a greater area, up to 1,000 ha,[91] as the water level of the river rises. While the fluctuation of annual flood intensity makes it difficult to measure the exact scope, it is estimated that 100,000 people in the region depend on the system.[92]

Flood recession agriculture is also a traditional practice around Laka Tana where maize and sorghum are similarly grown using residual moisture following the flood period. However, over the past few decades, farmers have adapted their practice to include both flood-recession and flood-rise systems. In the early 1990s, Laka Tana farmers began cultivating rice during the wet season using rising floods. Paddies were formed by constructing small bunds to retain, as well as regulate, the flow of water into and out of the rice plots. Water is retained within the bunds for 3 to 4 days, avoiding longer periods to prevent disease vectors from breeding. Following the rainy season, the previously flooded, nutrient-rich land is then used to grow maize, teff, oats, lentils, and chickpeas. Some conditions even allow for a third phase of planting during the dry season, which requires irrigation from a supplemental water source, such as shallow groundwater, which can be pumped to irrigate vegetables, cereals, and pulses. Outside of crop cultivation, 4,000 ha of the inundated area is also allocated for livestock grazing.

Figure 61 Map of Ethiopia where red zones indicate presence of wetlands[93]



Source: Flood Based Farming Practices in Ethiopia: Status and Potential. Spate Irrigation Network Foundation (2021)

Figure 62 Groups of sorghum that are planted on temporarily inundated land in the southern Omo River valley[94]

Source: Nederveen, S. Coenraads. "Flood Recession Farming: An Overview and Case Study from the Upper Awash Catchment, Ethiopia Master thesis Hydrology, code 450122, 39 ECTS." (2012). https://www.semanticscholar.org/paper/Flood-Recession-Farming%3A-An-Overview-and-Case-Study-Nederveen/03eba87943e16228e75336c9829155ed7bbcc07b

Advantages and Recommendations

As discussed, flood recession farming practices have a long history in Ethiopia, and recent improvements to traditional systems have proven the potential of the strategy within a climate adaptation framework. Specifically, the use of bunds, dikes, canals, and drains have enabled farmers in Ethiopia to expand inundation areas, avoid standing water, and retain the water for longer periods of time. Moreover, the shift to rice-based flood rise agriculture around Lake Tana has enabled farmers to practice sequential multi cropping, with rice planted at the peak of the annual flood, followed by the cultivation of relatively drought tolerant crops such as chickpeas in the residual moisture. A potential third phase might additionally include using shallow groundwater for irrigation. These cases demonstrate that flood-based farming systems can be extremely productive, with high potential to adapt practices to different conditions and minimal initial input needed for crop cultivation.

2 Micro-Catchment

Planting Pits and Micro-Basins

2A Semi-Circular Bunds (Demi-Lunes or Half-Moons)[95]

Category: Micro-Catchment – (1) Planting Pits and Micro-Basins	Water Source: (1) Precipitation, (2) Surface Runoff

Figure 63 Example of demi lunes planted with sorghum[96]

Source: Strengthening Agricultural Water Efficiency and Productivity on the African and Global Level: Status, Performance and Scope Assessment of Water Harvesting - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Example-of-demi-lunes-planted-with-sorghum_fig9_328290421 [accessed 5 Aug, 2022] Salman, M., et al. "Strengthening agricultural water efficiency and productivity on the African and global level." FAO (2016). https://www.fao.org/3/i5976e/i5976e.pdf

Figure 64 Demi-lunes / semi-circular bunds[97]

Source: Greener Land: Demi-lunes / semi circular bunds

Overview

Half-Moons or Demi-Lunes are small, semi-circular bunds with the tips of the arcs aligned with the contour lines of slopes of less than 2% in semi-arid regions. The pond area inside the Demi-Lunes collects water runoff and rainfall. The Half-Moons act as micro-catchments collecting and transporting water to the cropping area placed in the centre of the pit.[98] The excavated planting pits are filled with a mixture of organic manure and topsoil to provide the required fertility and to help retain the gathered moisture. This technology is common in the semi-arid areas of Kenya, Ethiopia, and Tanzania for runoff harvesting to support the growth of young tree seedlings. The dimensions of the holes and the spacing of the contours are dictated by the type of crop or the farming system being utilised.[99]

Advantages

Semi-Circular Bunds can be used for various purposes including land rehabilitation and regeneration, cultivating annual crops, tree cultivation, and increasing fodder production. They also can promote biodiversity and help to improve soil fertility when manure and/or compost are added.

Challenges

Construction of Semi-Circular Bunds does involve some challenges. Because the process cannot be easily mechanised and the basins are vulnerable to breakage, they can therefore be labour-intensive to construct and maintain.

Design

Planting holes should generally have a minimum radius of 0.6m and depth of 0.6m. The sub-soil excavated from the pit is used to construct a semi-circular bund with a radius ranging from 3m to 6m on the lower side of the pit. The resulting bund height is typically around 0.25 m.[100]

Figure 65 Examples of half moons for water harvesting - Illela, Niger[101]

Source: Shaxson, T. F., and Richard G. Barber. "Minimizing Water Stress & Improving Water Resources," in "Optimizing soil moisture for plant production: The significance of soil porosity." FAO. 2003.

Figure 66 Vegetation of semi-circular bunds implemented by Justdiggit in Arusha, Tanzania

Source: Justdiggit

Figure 67 Vegetation of semi-circular bunds implemented by Justdiggit in Arusha, Tanzania

Source: Justdiggit

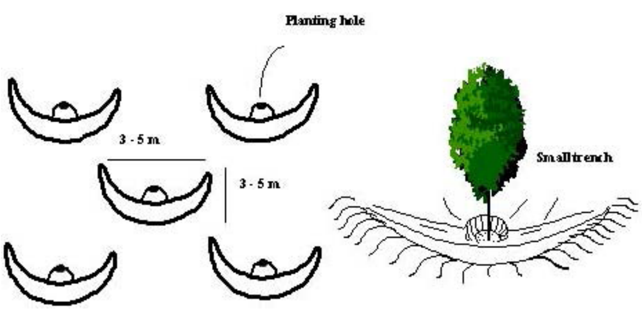
Figure 68 Vegetation of semi-circular bunds implemented by Justdiggit in Arusha, Tanzania

Source: Justdiggit

Figure 69 Vegetation over time (before and after) of semi-circular bunds implemented by Justdiggit in Pembamoto, Tanzania

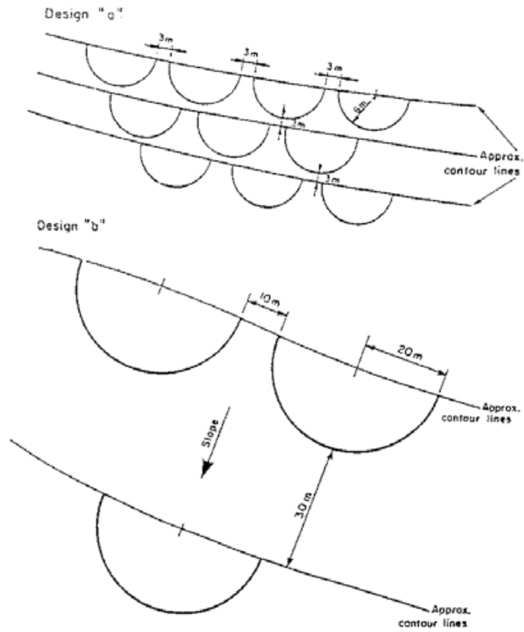
Source: Justdiggit

Figure 70 Catchment Design[102]



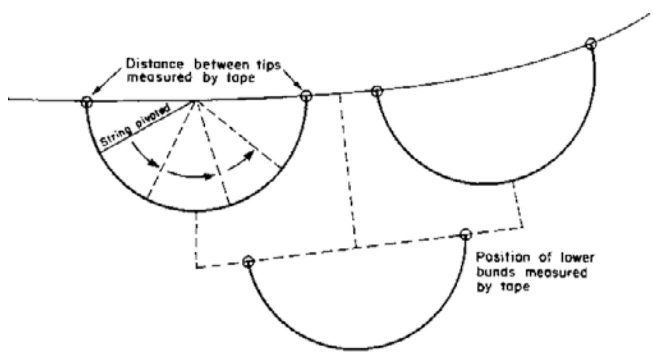
Source: Mati, B. M. "100 ways to manage water for smallholder agriculture in Eastern and Southern Africa: A compendium of technologies and practices." IMAWESA (2007).

Figure 71 Semi-circular bunds: field layout[103]



Source: Critchley and Siegert, 1991

Figure 72 Layout technique[104]

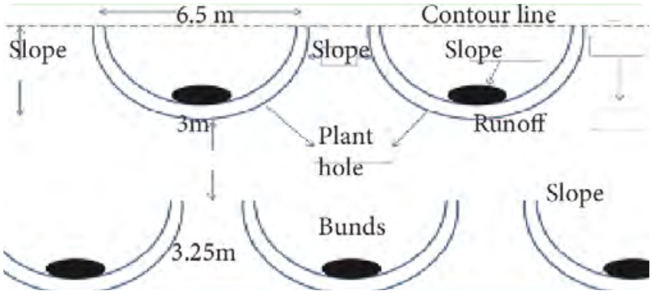


Source: Critchley and Siegert, 1991

Figure 73 **Semi-circular bunds used to retain water for trees**[105]

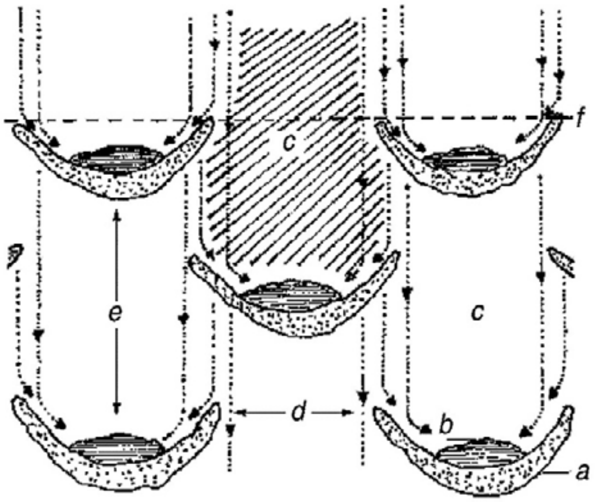
Source: https://www.samsamwater.com/projectdata.php?projectid=53

Figure 74 **Semi-circular bunds/micro-catchments**[106]



Source: RELMA

Figure 75 **Layout of semi-circular bunds**[107]



a - bund

b - cultivated area

c - catchment area

d - distance between two structures

e - catchment length

f - contour line

Source: ANSCHUETZ et al., 2003

Case Study:
Justdiggit: Kuku Group Ranch, Kenya[108]

Figure 76 **Bunds implemented by Justdiggit in Kuku, Kenya**

Source: Justdiggit

Figure 77 **Bunds implemented by Justdiggit in Kuku, Kenya**

Source: Justdiggit

Figure 78 **Bunds implemented by Justdiggit in Kuku, Kenya**

Source: Justdiggit

Justdiggit, a Dutch organisation with the mission to regreen Africa alongside the continent's farmers, has sought to harness the power of nature to cool down the planet by regreening degraded land and bringing back natural vegetation. The organisation supports subsistence farmers to implement proven Sustainable Land Management techniques like those presented in this guide.

One of the primary strategies employed is that of semi-circular bunds, which are dug in their project areas across Africa to capture rainwater that would otherwise get washed away over the dry barren soil. The top layer of the soil becomes hard, which prevents rainwater from infiltrating into the soil. Their activities help to open the hard top layer to allow the land to better retain the rainwater. Capturing and holding the rainwater with the help of bunds allows more time for runoff to enter the soil. The water balance is restored, and more water is available for seeds naturally present in the soil. These seeds then get the chance to sprout, which contributes to regreening efforts. Sometimes they additionally give the regreening process a little push by sowing extra seeds within the bunds. This way the area can be restored more quickly. Ultimately, not only inside the bunds, vegetation has grown back, the area surrounding the bunds also gets increasingly greener. The power of these bunds comes from the sum of its parts. The more bunds, the larger the area that will regreen.

One example of their work can be found in Kenya, where they've collaborated with the Kuku Group Ranch to dig over 150,000 semi-circular bunds to bring back vegetation across the ranch land. Importantly, the ranch is home to around 29,000 Maasai people who primarily depend on the land for their primary source of food and income. Before their efforts, land in the area had become very dry as a result of climate change and overgrazing, which presented challenges for residents reliant on that land. Together with their local partner organization, Maasai Wilderness Conservation Trust, they started digging rainwater harvesting bunds and setting up grass seed banks. As a result, more than 1,000 hectares have already been restored and regreened and five women-managed seed banks have been established.

2B

Negarims

Category:
Micro-Catchment –
(1) Planting Pits and Micro-Basins

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 79 Negarims coupled with planting pits for optimal tree production[109]

Source: Joshua, Black & Malesu, Maimbo & Oduor, Alex & Kipruto, Cherogony & Robert, Meerman. (2012). Rainwater Harvesting Inventory of Kenya. An overview of techniques, sustainability factor and stakeholders. https://www.researchgate.net/figure/Negarims-coupled-with-planting-pits-for-optimal-tree-production-Critchley-1991b_fig6_265842519

Figure 80 Negarim micro basins with almond trees in Iran[110]

Source: Tavakoli, 2004

Figure 81 Negarim micro-catchment structure with plantation[111]

Source: Development-durable.org

Overview

Negarims are a newer micro-catchment method, often used for fruit trees in arid and semi-arid regions, that collects runoff in small runoff basins. Tree seedlings are planted in a pit at the base of each diamond-shaped basin formed by low earth bunds. These diamonds are generally arranged in a field at the start of the rainy season. They are common in the Turkana Region of Kenya.

Advantages

This method allows for more efficient utilisation of space than typical square bunds. Open-ended variations are particularly useful on broken terrain and for growing a small number of trees around homesteads. They are particularly effective in arid and semi-arid regions and are also effective at managing erosion.

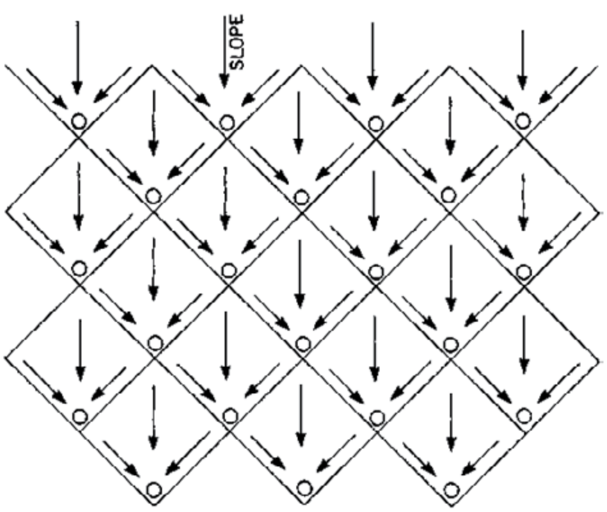
Challenges

Although relatively stable, Negarims can be damaged if they encounter heavy storms before they are fully consolidated and set after initial construction. Failure at any one point in a field can also quickly lead to damage across numerous adjacent basins. In addition, the capacity of open-ended variations is less than that of a closed system.[112]

Design

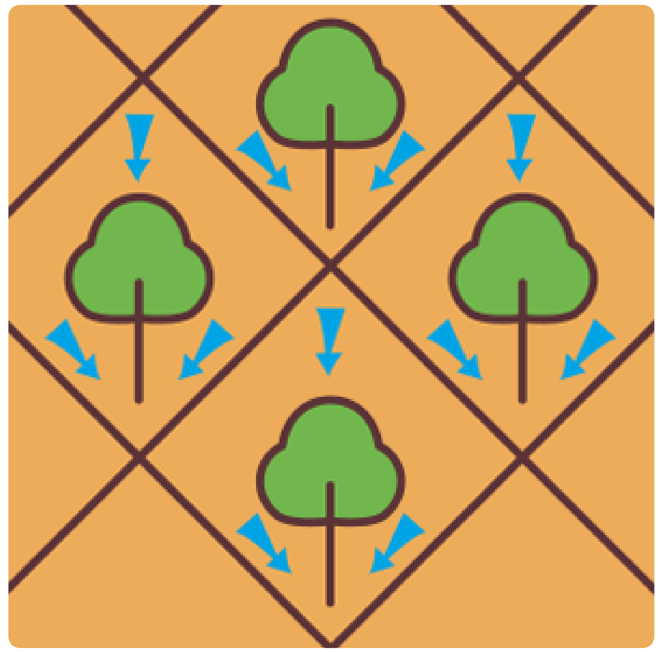
Negarims are tegular square or diamond-shaped earth bunds, rotated 45° from the contour of the landscape. This allows surface runoff to be concentrated at the lowest corner of the basin. They are constructed with 10m ridges extending upslope, while the tips lie on the contour. A common variation is to build, open-ended structures in "V"-shape so that surplus water can flow around the tips of the bunds and into adjacent catchments. The catchment area can vary but be up to about 150m^2 in the driest areas, with a capacity of about 2.5m^3 for crops.

Figure 82 Negarim microcatchments - field layout[113]



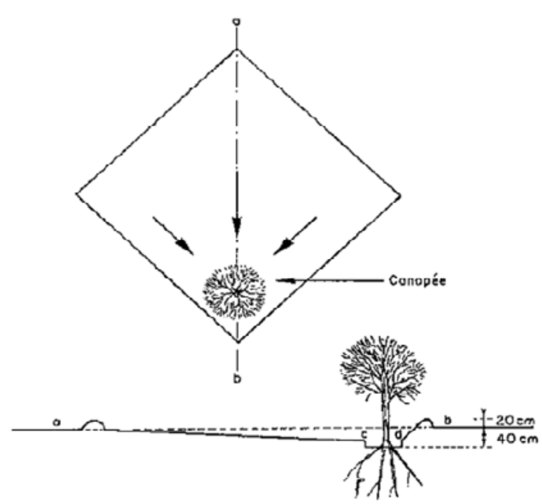
Source: Critchley, Will, and Klaus Siegert. "Chapter 5: Water Harvesting Techniques" in "A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production." FAO (1991)

Figure 83 Negarims Illustration[114]



Source: Greener Land: Negarims

Figure 84 Diagram of a micro basin[115]



Source: ROOSE,1996

2C
Basket Composting

Category:
Micro-Catchment –
(1) Planting Pits and Micro-Basins

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 85 Woven Compost Basket[116]

Source: https://www.sarabackmo.com/garden-diy-making-a-woven-compost-basket/

Overview

When implementing Basket Composting, land users place their decomposable home garbage, garden and farm waste, and leguminous leaves into baskets which are half-buried in the ground. Crops are planted inside the baskets and utilise the nutrients from the compost while it decomposes. The water retention properties of the compost have made this a popular strategy among commercial Kenyan banana growers who have no access to irrigation.

Advantages

The compost basket absorbs and retains water which can nourish plants during the dry season.[117] Plants can also derive nutrients directly from the rotting materials without waiting the typical three-to-four-month period for the compost to break down traditionally. Moreover, by holding materials in place, the basket reduces nutrient depletion and run off, and the organic matter in the compost strengthens the soil aggregate, making it resistant to heavy rainfall, thus lessening erosion. It also helps to prevent livestock and wildlife from scattering compost materials.[118]

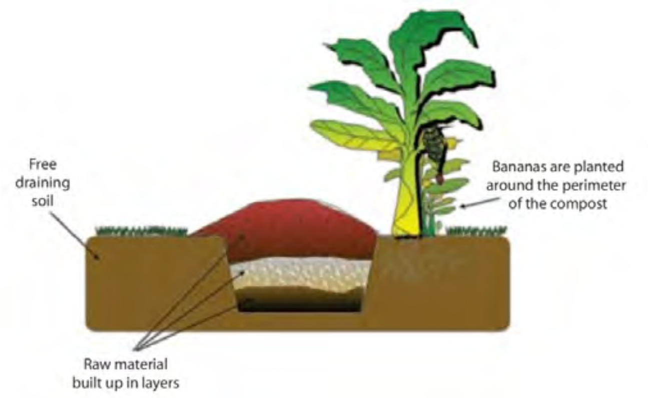
Challenges

Unless properly protected, household waste and other garbage used in Compost Baskets can attract livestock and wildlife and lead to damage of the basket and crops and the scattering of materials.

Design

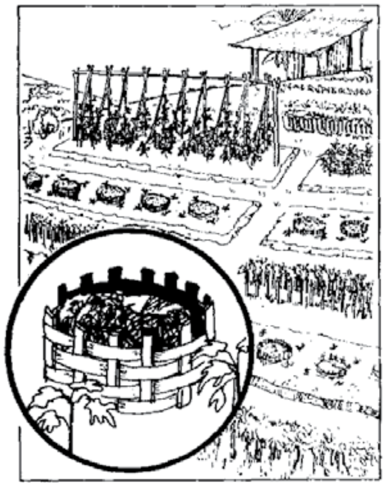
Baskets are woven from twigs and positioned within beds with holes of at least 15 cm deep and 30 cm wide, dug along the centreline of a bed spaced about 1 metre apart. Baskets are filled with manure and household waste, which serves nutrients to the soil below the basket. The roots of trees or crops planted adjacent will grow toward the baskets and gather the moisture and nutrients provided by the compost baskets.[119]

Figure 86 Compost basket with a banana plant[120]



Source: Mati, B. M. "100 ways to manage water for smallholder agriculture in Eastern and Southern Africa: A compendium of technologies and practices." IMAWESA, 2007

Figure 87 Compost Baskets on a field[121]



Source: Soil and Water Conservation (SWC) Technologies and Agroforestry Systems (International Institute for Rural Reconstruction (IIRR), 1992)

2D

Planting Pits (T-basins, Zaï Pits, Five by Nine Pits, etc.)[122]

Category:
Micro-Catchment –
(1) Planting Pits and Micro-basins

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 88 Zaï pits or Tassa, for water harvesting - Illela, Niger[123]

Source: https://www.fao.org/3/y4690e/y4690e09.htm

Figure 90 Zaï Pits[125]

Source: GIZ, 2012

Figure 89 Zaï Pits[124]

Source: https://historiesofgeography.wordpress.com/2013/02/15/84/

Figure 91 An example of taditional Zaï Pit[126]

Source: Some Ezechias S., Burkina Faso, Inspector of Water and Forestry

Overview

Planting pits, which can occur in many different forms and have many different names including T-basins, Zaï Pits, and Five by Nine Pits, are typically used to gather and store water runoff and build up soil fertility. T-basins, for example, use runoff from external catchments (e.g., footpaths, roads) conveyed through a system of narrow channels, to interconnected basins where the water infiltrates into the root zone of surrounding crops.

They are commonly utilised in arid and semi-arid areas to grow perennial crops (e.g., sorghum, maize, sweet potatoes, bananas, etc.).[127] In Western Kenya, the system is used most often for growing bananas, mangoes, citrus fruits, and passion fruit.

Advantages

Planting pits have many advantages, because the design is very flexible and they can be effective in a range of conditions, including shallow and uneven soil and soil with low permeability, like clay. They are also relatively simple and easy to implement and maintain. They are good at increasing infiltration and can have regenerative effects on the soil. They can also be used to introduce additional nutrients into the soil when filled with compost, which can also attract termites, which offer further benefits by carrying nutrients from deeper in the soil to the surface.[128]

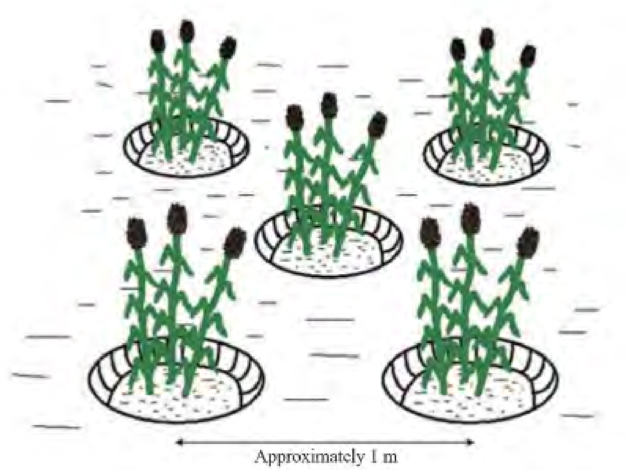
Challenges

Though very versatile, it is important to consider the various options, as different types of planting pits are better suited to certain contexts and uses. T-basins, as opposed to the circular root zone basins, for example, can be used for both tree and non-tree crops. Although relatively simple to design and implement, construction is still labour-intensive, because it cannot be mechanised. When water is abundant, pits may become waterlogged when compost and debris in the pits soak up the excess water, which can be detrimental for some crops. And, because this strategy is often implemented where soil is relatively thin, it means that soil can be very thin where pits are dug, which may make planting challenging.[129]

Design

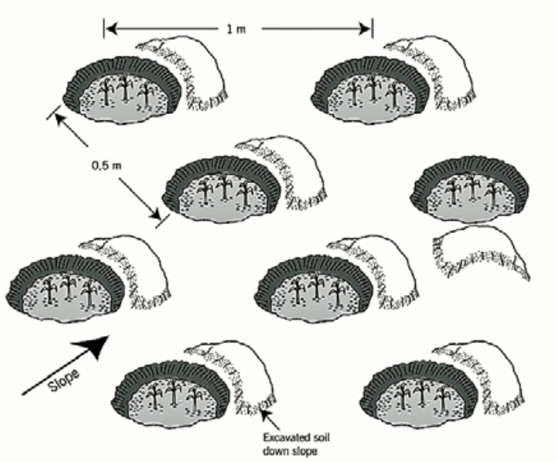
Planting Pits are generally dug to a depth of about 5-15 cm at a spacing of around 50-100 cm.[130] One example, Zaï Pits, are shallow and wide pits of around 0.6 m diameter and 0.3 m depth, in which several cereal crop seeds are planted. Manure is usually added into the pit to improve fertility. Other examples include Five by Nine pits, which are similar to Zaï pits but square-shaped and deeper.

Figure 92 Illustration of Zaï Pits for water harvesting and conservation[131]



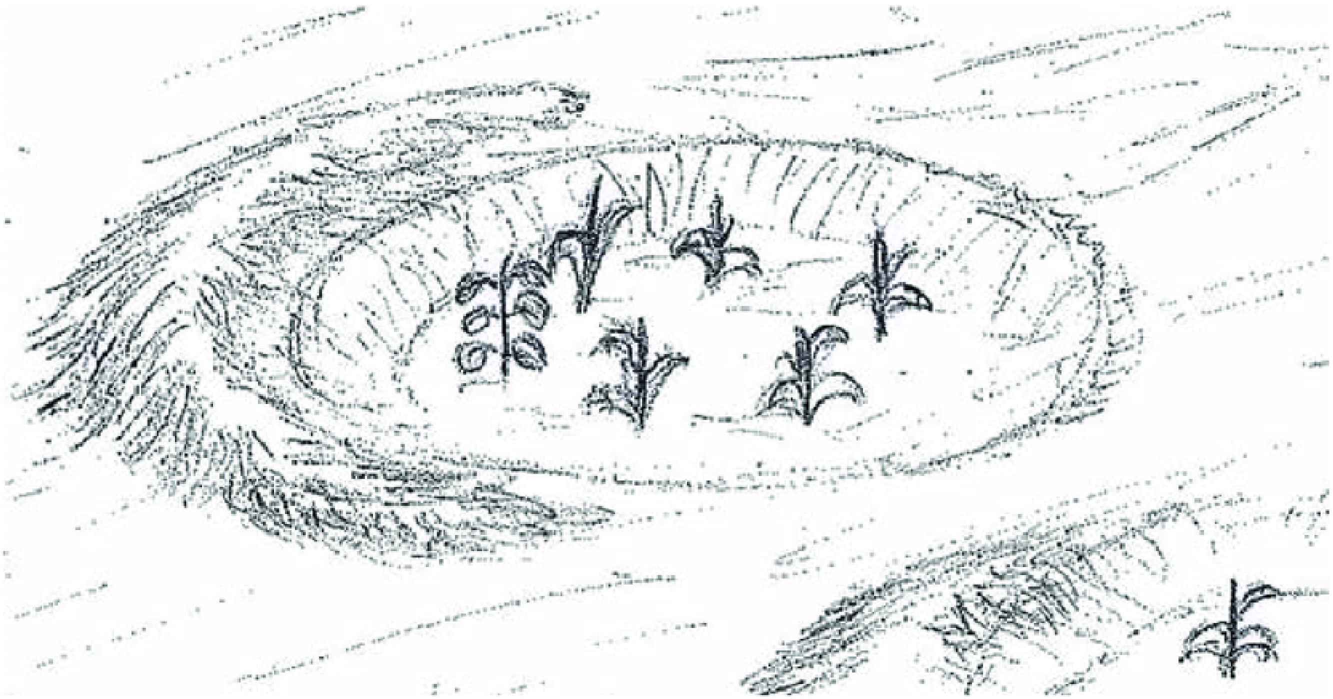
Source: Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Zai-pits-for-water-harvesting-and-conservation_fig10_254426136 [accessed 12 Aug, 2022]

Figure 93 Diagram of planting pits[132]



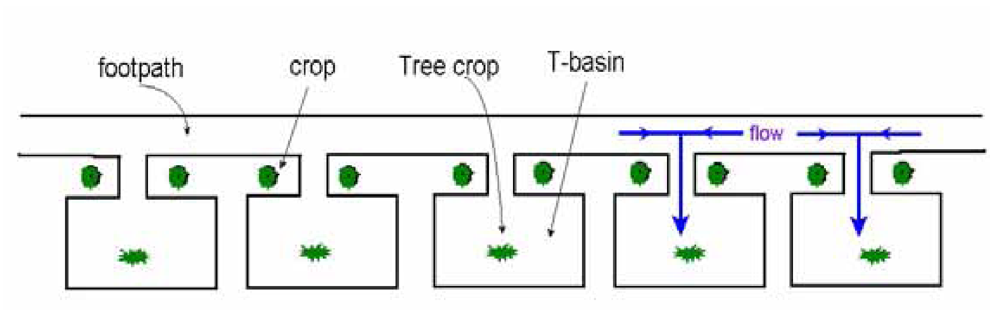
Source: MALESU et al., 2007

Figure 94 Schematic representation of a Zaï planting pit[133]



Source: Adoptability of sustainable intensification technologies in dryland smallholder farming systems of West Africa - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Schematic-representation-of-a-zai-planting-pit_fig3_283458146 [accessed 12 Aug, 2022]

Figure 95 Section of T-basins[134]



Source: Mati, B. M. "100 ways to manage water for smallholder agriculture in Eastern and Southern Africa: A compendium of technologies and practices." IMAWESA (2007).

Case Study:
The Environmental, Economic, Social, and DRR Benefits of Zaï Pits in Burkina Faso[135]

Figure 96 Making of Zaï pits in Tougou village, Burkina Faso[136]

Source: Sylvain Zabre, IUCN

Background

In the Sahel, slow onset disasters, such as drought and food insecurity, have existed in the region for centuries with growing intensities.[137] Burkina Faso, like other drylands, has become trapped in a cycle of prolonged periods of drought, resulting in water scarcity, diminished yields, and desertification, interrupted by short but intense precipitation events that cause destructive flash floods that damage houses and infrastructure and wash away crops. As discussed earlier in this publication, desertification, and the ensuing loss of livelihoods, is a significant catalyst for urban migration. As a consequence, women and children who remain in underdeveloped areas are often put at greater risk of SGBV as they are forced to travel greater distances to gather vital resources like water and firewood.

In the 1980s, farmer-led initiatives to improve water supply, restore biodiversity, and improve soil fertility commenced in the Central Plateau of Burkina Faso. These initiatives involved innovative and sustainable land management practices together with enhanced applications of traditional farming practices, specifically the use of **[2D] Zaï Planting Pits**, **[3A] Contour Stone Bunds**, and agroforestry techniques, which successfully produced higher crop yields, regenerated tree and vegetation cover, and generated additional economic and environmental advantages.

Figure 97 Example of rehabilitated farmland with improved Zaï pits. In the foreground, a pile of organic matter to be placed in the pits[138]

Source: Reij et al., 2009

Method and Knowledge-Sharing

Zaï Planting Pits, locally known in Burkina Faso as Tassa, are part of a traditional agriculture practice that is used most effectively in regions with an annual rainfall between 300 and 800 mm to rehabilitate degraded soils.[139] Modern improvements to the ancient technique include digging larger and deeper holes and adding organic matter and compost to enrich the soil. During the dry season, farmers dig pits spaced 80-120 cm apart, 10-20 cm deep and 20-40cm in diameter, while the excavated soil is used to form a 'half-moon' shape along the edge of each pit to collect water.[140] In addition to water, the pits retain nutrients from windblown sediments and organic matter while attracting termites which dig deep channels between the pits that help improve water and nutrient infiltration. Seeds are planted in early June, with the process repeating annually, with new Zaï pits dug between existing pits each year. The pits are helpful not only for planting crops, but trees as well, and seeds found in the fertilizer and compost indicate the potential for using Zaï pits in the development of an agroforestry system.

In Burkina Faso, farmer-organised market days and open-air festivals, attended by farmers from over a hundred villages, showcased the benefits of Zaï Pits, while creating a market for the tools used for constructing the pits. Moreover, these events served as a vehicle for farmers to discuss their concerns around related social, economic, and environmental issues and brainstorm potential solutions. In 1992, Zaï Schools were established to promote and disseminate information about the experimental and traditional techniques used to improve crop yields to complement farmer-to-farmer learning in the field. These social and educational interactions encourage collaboration and innovation, as help to increase motivation and sense of personal achievement among participating farmers.[141]

Outcomes and Recommendations

Over the last three decades, it is estimated that more than 200,000 ha of degraded land in the Central Plateau have been regenerated through the use Zaï Pits and Contour Stone Bunds.[142] In findings from a 2003 study conducted in the Central Plateau, a greater biodiversity among tree species on regenerated farms than on control plots with degraded soil was observed. This can be largely attributed to the Zaï Pit technique which enables greater water and nutrient retention so that crops are able to survive dry spells. Higher yields have been observed in areas where Zaï Pits and Contour Stone Bund techniques have been implemented, and while they have proven effective individually, integrating both techniques have yielded even better results over time.

Zaï Pits and Contour Stone Bunds implemented on degraded agricultural land were found to improve crop yields within the first year, rendering them highly advantageous in responding quickly to the needs of Burkina Faso's growing population. Due to the simplicity and low-cost of these techniques, adopting them is both attractive and extremely practical. In this example, replication following the initial farmer-led pilot project occurred naturally and rapidly, while governmental authorities, NGOs, and international donors, in partnership with farmer and village associations, helped facilitate knowledge transfer.

Nature-based climate adaptation strategies such as Zaï Pits offer sustainable, long-term alternatives to crisis-response efforts to restore degraded land and reduce risk, which often require high initial investments with little or no financial returns. In addition to improving food and livelihood security and overall well-being among participating communities in Burkina Faso, Zaï pits have contributed to curbing rural migration and reducing slow-onset disasters in the Sahel. For example, over time, the restoration of tree cover and soil fertility mitigated the effects of cyclical droughts and helped communities build resilience to cope with desertification. Moreover, women and children no longer needed to travel long distances to fetch supplies, instead having the opportunity to spend time engaging in social and economic activities. For example, women were able to gain financial independence by owning trees and selling products at the market. Over time, the farmer-led green movement in Burkina Faso helped restore the function of its dryland ecosystem while improving economic, social, and climate resilience.

This case study demonstrates how reversal of desertification can be achieved through strategic, sustainable management of dryland ecosystems. Furthermore, "poverty is considered both a cause and consequence of land degradation,"[143] and is a well-known indicator of high vulnerability to disasters. Therefore, promoting effective, locally adapted, sustainable agricultural livelihoods has additional poverty-reduction and DRR co-benefits, given that economic security is an important factor in enabling the protection and restoration of local natural resources, and helps farming communities avoid becoming climate refugees. This case also demonstrates the pivotal role that political and social contexts play, for example, through technical and financial support provided by governments and NGOs, or through guaranteed usage rights, in promoting, sharing, and sustaining innovative agricultural practices.

Figure 98 Individual and combined impacts of Zaï and contour stone bunds on cereal yields in two villages in Burkina Faso[144]

Village	No intervention (kg/ha)	Zai (kg/ha)	Yield increase (kg/ha)	Contour stone bunds (kg/ha)	Yield increase (kg/ha)	Stone bunds + zai (kg/ha)	Yield increase (kg/ha)
Ziga	434	772	+346	576	+130	956	+522
Ranawa	376	804	+428	531	+155	922	+546

Source: Sawadogo, 2008

Cross-Slope Barriers

2E Fanya-Juu Terraces[145]

Category:
Micro-Catchment –
(2) Cross-Slope Barriers

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 99 Fanya-Juu Terraces[146]

Source: https://www.greener.land/index.php/product/fanya-juu/

Overview

Fanya-Juu (which means "throw it upwards" in Kiswahili)[147] Terraces are earthen embankments or bunds and ditches positioned along the slope of the land and used to reduce erosion, stabilise slopes, and improve biodiversity by reducing water and nutrient runoff. This technique is suitable on slopes with average annual rainfall of 500-1,000 mm.

Advantages

In some cases, the enlarged embankments created by Fanya-Juu Terraces allow ponding of harvested runoff so that the structure can be used in water harvesting systems with external catchments. They are generally associated with manual construction and are well suited to small-scale farming. This technique is applicable where soils are too shallow for level bench terracing and on moderately steep slopes of 5-20%.[148]

Challenges

This technique is not suitable for stony soils. Water and tillage erosion can cause sediment to accumulate behind the bunds, which may require farmers to manually build up the embankment periodically by throwing silted material from the trench upslope, making it a strategy that may require regular maintenance.

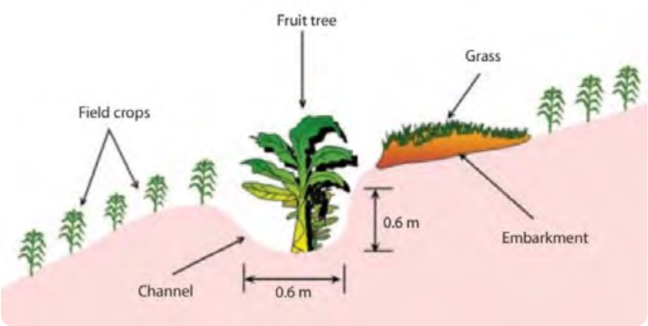
Design

Fanya-Juu Terraces are constructed by digging a trench about 0.6 m wide along the contour of the slope of the land and pushing the soil upslope to form a ridge, effectively reducing slope-length and soil erosion. Planting grass, trees, and bushes along the banks stabilises bunds and contributes to productivity and biodiversity such as fodder, fuel, and fruits. By adding silted material upslope, they gradually develop into forward sloping bench terraces.

Figure 100 Fanya juu diagram[149]

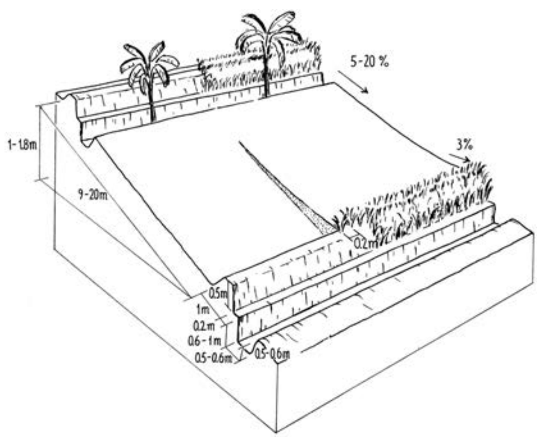
Source: https://www.greener.land/index.php/product/fanya-juu/

Figure 101 Illustration of a fanya juu terrace[150]



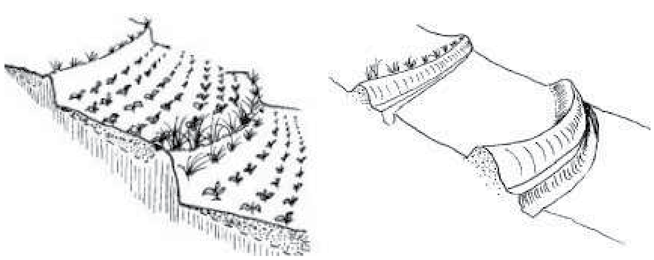
Source: Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Illustration-of-a-fanya-juu-terrace_fig2_254426136 [accessed 15 Aug, 2022]

Figure 102 **Fanya-Juu cross section diagram**[151]



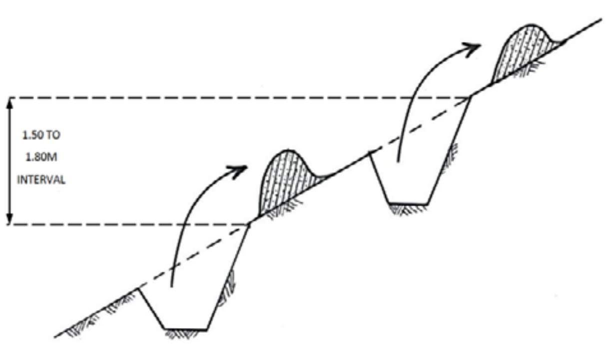
Source: https://www.fao.org/3/i1861e/i1861e07.pdf

Figure 103 **An illustration of Fanya Juu terraces over time, visualising new terraces and their change after about five years**[152]



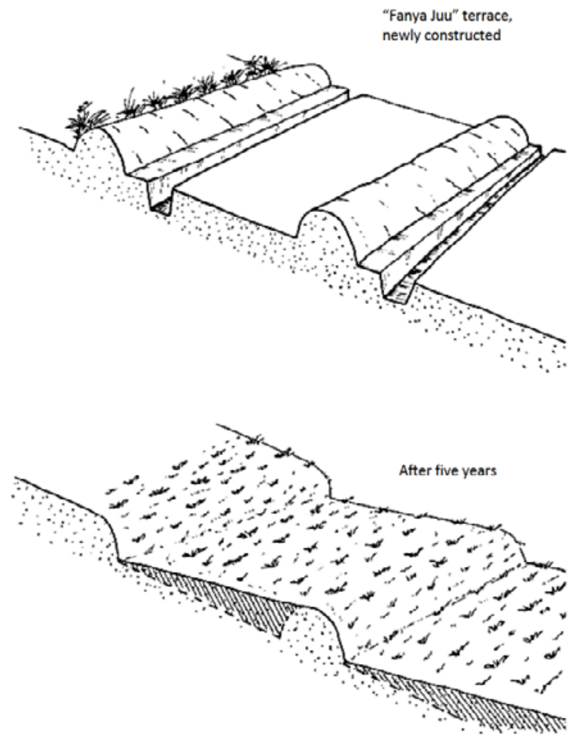
Source: IIRRI

Figure 104 **"Fanya Juu" Terracing**[153]



Source: http://design-of-small-dams.appspot.com/project_preparation/

Figure 105 **Progression of a Fanya Juu Terrace**[154]



Source: http://design-of-small-dams.appspot.com/project_preparation/

2F

Vegetative/Grass Strips and Buffers[155]

Category:
Micro-Catchment –
(2) Cross-Slope Barriers

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 106 Example of a vegetative sediment trapping measure: grass strip upper Blue Nile Basin, northwest Ethiopia[156]

Source: Mulatie Mekonnen

Figure 107 Grass strips integrated with contour furrows to improve infiltration[157]

Source: Strengthening Agricultural Water Efficiency and Productivity on the African and Global Level: Status, Performance and Scope Assessment of Water Harvesting - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Grass-strips-integrated-with-contour-furrows-to-improve-infiltration_fig7_328290421 [accessed 7 Aug, 2022]

Overview

Vegetative or Grass Strips and Buffers are narrow strips of the land that are left unploughed or planted in order to form permanent, cross-slope barriers of naturally established grasses, vegetation, and herbs to contour the land. These lines act as barriers and filters that minimise erosion and slow the flow of runoff.[158]

Advantages

Vegetative Strips provide a low-cost technique, because no planting material is generally required if vegetation is naturally occurring, and only minimal labour is necessary for implementation and maintenance. They are generally considered to the cheapest and easiest to implement cross-slope barrier technique. These buffers effectively control soil erosion and prevent loss of fertilisers while improving infiltration of runoff, by slowing its flow over surface.[159] Furthermore, soil that is eroded between strips will collect at each strip naturally forming terraces over time, meaning that they are one of the easiest ways to terrace a slope, albeit the process takes time.[160] In addition the vegetation can act as feed for livestock in certain cases.[161]

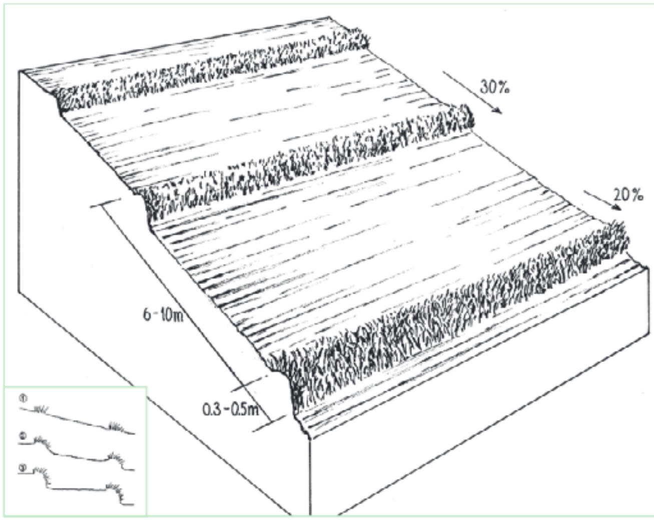
Challenges

Although relatively minor, there are some challenges that can present when implementing Vegetative Strips. Because they are often implemented with naturally occurring vegetation, they can sometimes be difficult to establish from the start if naturally occurring vegetation does not support the technique. Because this technique often means placing natural vegetation alongside crops, it may require weed and pest control.[162]

Design

Grass is planted or existing vegetation is allowed to grow naturally in dense strips about 0.5 to 1 m wide, along the contour of the land at spacing that should be varied depending on the slope. The spacing is increased between strips on more gentle slopes (20-30m) and reduced on steeper slopes (10-15m).[163]

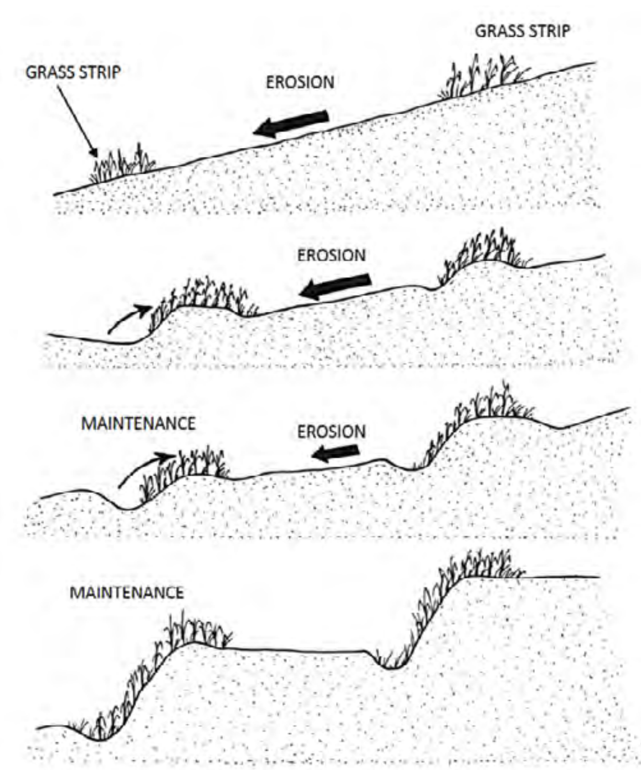
Figure 108 An illustrated diagram of the spacing for natural vegetative strips based on slope[164]



Spacing of natural vegetative strips depends on the slope. Terraces evolve over time through tillage and soil erosion, leading to accumulation of sediment behind the strips

Source: https://www.thesurvivalgardener.com/natural-vegetative-strips/

Figure 109 Development of Bench Terraces from Grass strips[165]



Source: http://design-of-small-dams.appspot.com/project_preparation/

2G Bench Terraces/Reverse Slope Bench Terraces[166]

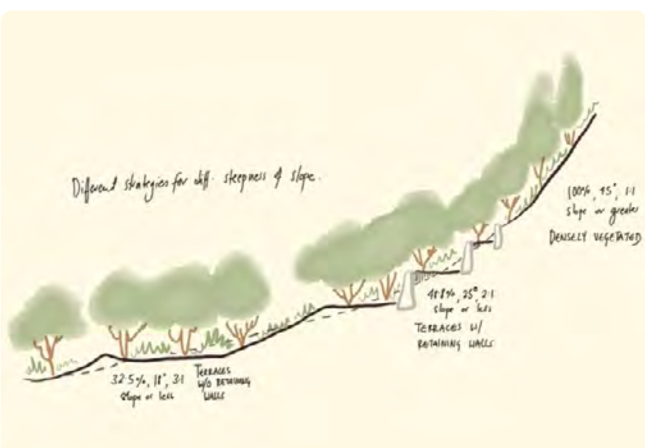
Category:
Micro-Catchment –
(2) Cross-Slope Barriers

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 110 Illustration of bench terraces[167]

Source: Integrated Soil Fertility Management (ISFM) Training Module Integrated Soil Fertility Management (ISFM) Training Module for Agriculture Teachers in Secondary Schools - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Illustration-of-bench-terraces_fig2_332963719 [accessed 7 Aug, 2022]

Figure 111 Different types of Bench Terraces[168]



Source: https://ananas.design/journal/2019/4/23/how-to-prepare-your-land-before-the-monsoons

Overview

Bench Terraces are a slope terracing technique involving alternating series of 'shelves' and 'risers.' With Bench Terraces, the riser is often reinforced with stones and/or vegetation cover and the runoff that is stored in the catchment basin nourishes the plants placed immediately above the riser wall. This design increases the amount of water available for the plants and reduces erosion. They are usually developed on relatively steep slopes with deep soils that can support this type of landscaping. Generally, an increase in the inward slope of the shelf increases water storage and soil protection.

Advantages

Bench Terraces can be easily modified to optimise their performance in a variety of conditions to effectively limit runoff and manage erosion. The alternating flat surfaces help reduce both water and nutrient runoff and increase the amount of water that can be stored in the soil profile. In arid areas, the distance between terraces is increased and a portion of the sloping land is left to act as a catchment area. Sediment can be trapped here, which can help contribute to the fertility of the soil for the long-term. Cut-off drains can be used in cases where there is evidence of large flows to prevent water from flowing down terraced slopes.

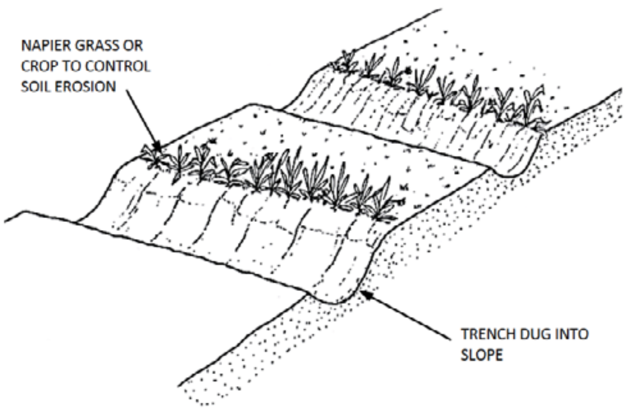
Challenges[169]

There are some challenges with Bench Terraces, though. This technique can reduce productivity of the land over the first two to three years after implementation and see delayed benefits, because of the amount of soil that is disturbed during construction. In that way, it is a fairly labour-intensive strategy that requires significant up-front investment in skilled construction and ongoing maintenance that will not pay off immediately. This strategy also requires a lot of land and many conditions, including shallow, unstable, and poor soils, are not suitable to its implementation.

Design

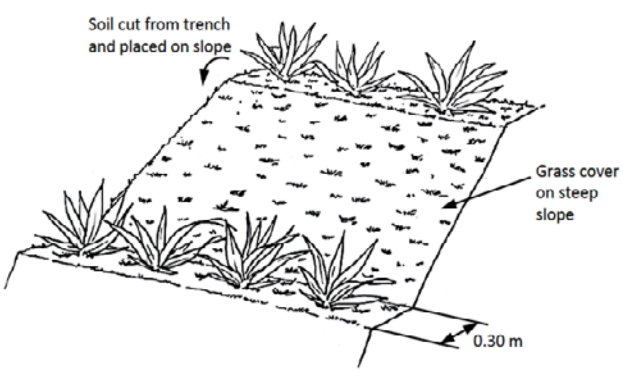
Bench Terraces are generally constructed using a combination of cutting and filling of the land on a slope in order to terrace the slope with a series of level steps or benches. Typically developed on slopes of between 15-55%, these steps should be spaced along the contours of the land so that the vertical distance between terraces remains consistent.[170] The vertical spacing should not vary much from about 1 metre in most cases, unless the slope drops below 15%, where the spacing can be reduced to about 0.75 m.[171] In order to maintain the vertical spacing, horizontal spacing should be adjusted depending on the slope and therefore may be adjusted for each terrace. Bench Terraces can be developed through a combination of natural and manual techniques including the natural erosion that will occur between vegetation strips or through a manual dug method such as Fanya Juu. Although terraces are generally made to be level over time, on slopes of between 35% and 55%, a sloping terrace may be preferable.[172]

Figure 112 **Bench Terraces (slope < 55%)**[173]



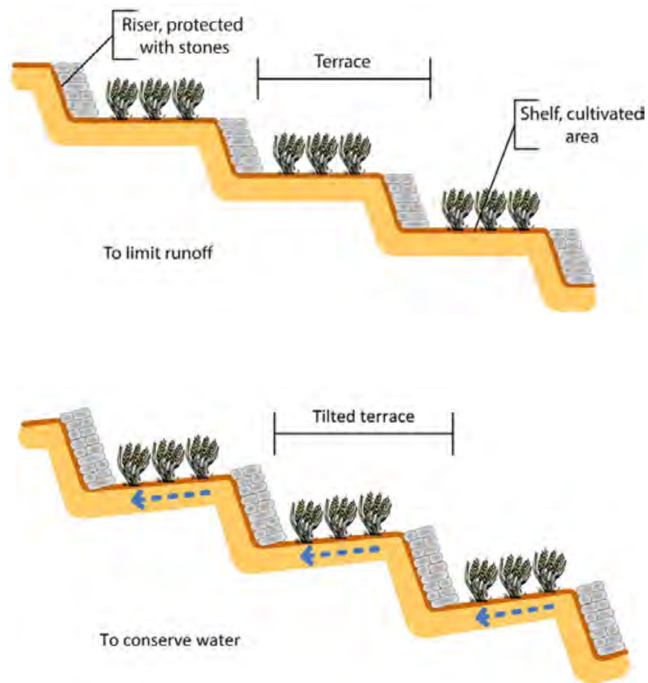
Source: http://design-of-small-dams.appspot.com/project_preparation/

Figure 113 **Modified Bench Terraces (35% < slope < 55%)**[174]



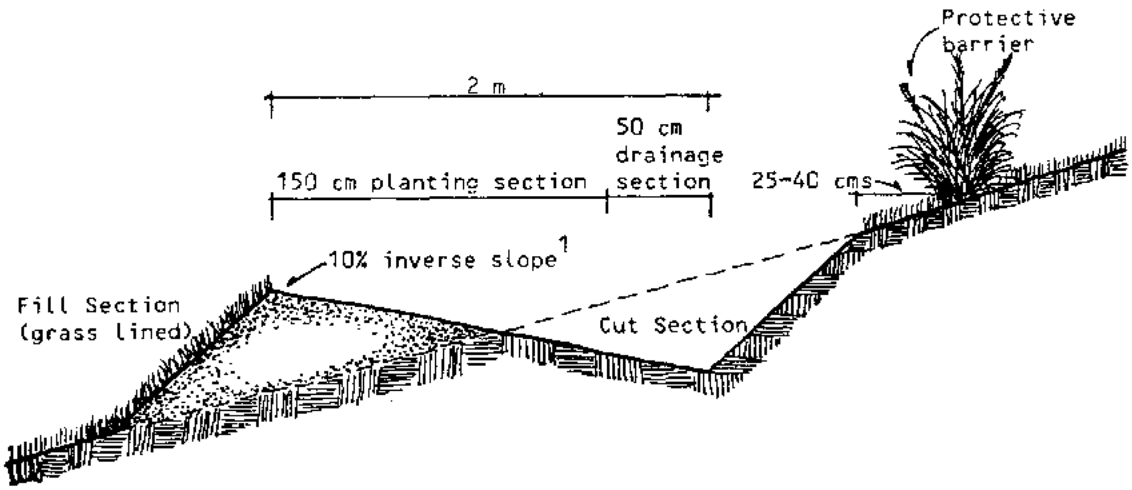
Source: http://design-of-small-dams.appspot.com/project_preparation/

Figure 114 **Bench terrace to limit run-off (top) and bench terrace with back sloping bench to increase water retention time and capacity (bottom)**[175]



Source: https://www.fao.org/3/i5976e/i5976e.pdf

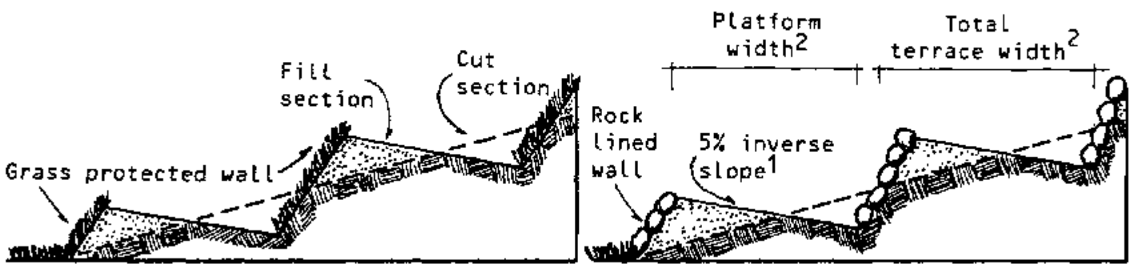
Figure 115 Discontinuous narrow terrace[176]



1 If initially constructed with an inverse slope of 15-20%, some self-compaction occurs resulting in a slope of approximately 10%.

Source: http://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0hdl--00-0----0-10-0---0---0direct-10---4-------0-0l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-10&cl-=CL1.16&d=HASHbdde2fe3749493c1a0de2d.4.2.4&gt=1

Figure 116 Continuous bench terraces[177]

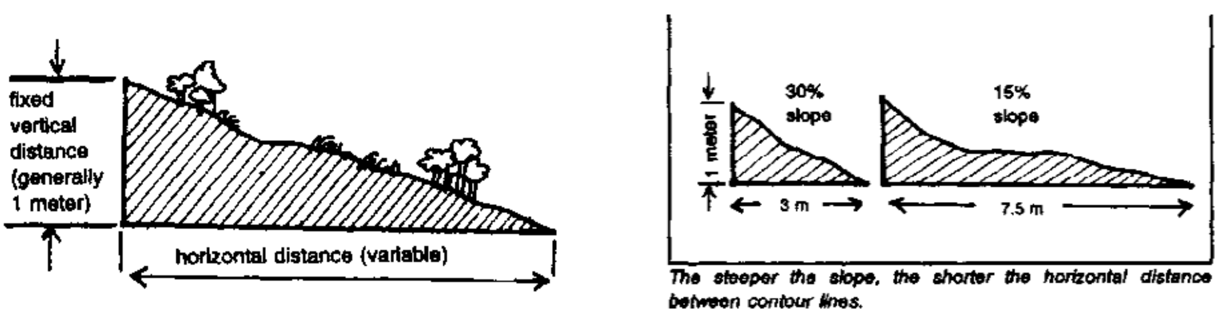


1 If initially constructed with an inverse slope of 10%, some self compaction occurs, resulting in a slope of approximately 5%.

2 Platform width and terrace width vary according to slope and depth of soil. (See TABLE 5)

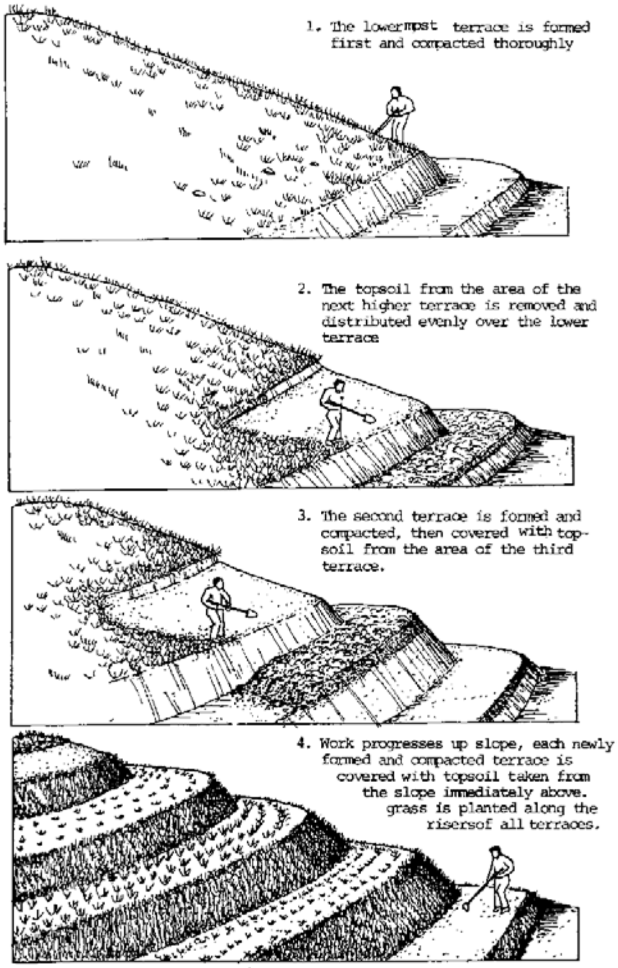
Source: http://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0hdl--00-0----0-10-0---0---0direct-10---4-------0-0l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-10&cl-=CL1.16&d=HASHbdde2fe3749493c1a0de2d.4.2.4&gt=1

Figure 117 Distance between terraces vary depending on the slope[178]



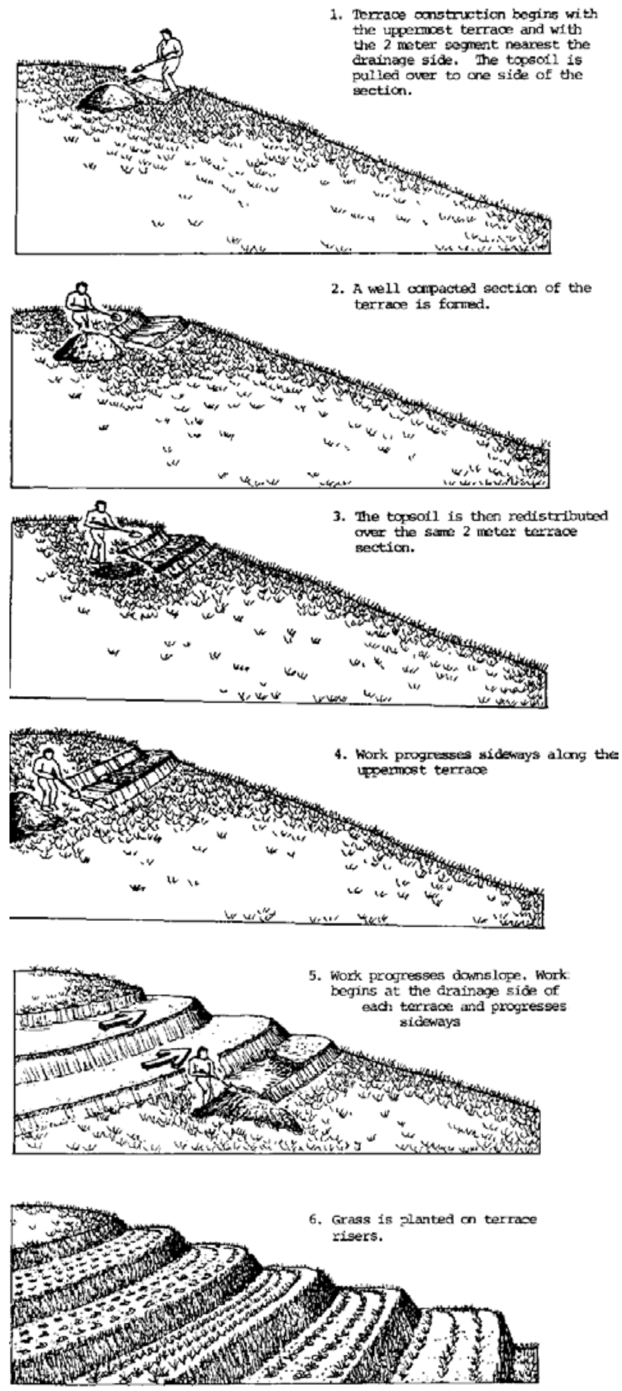
Source: http://www.nzdl.org/cgi-bin/library.cgi?e=d-00000-00---off-0hdl--00-0----0-10-0---0---0direct-10---4-------0-1l--11-en-50---20-about---00-0-1-00-0-0-11-1-0utfZz-8-00&cl=CL3.33&d=HASHf4f4e22a00c96a613b24e0.10.8&gt=1

Figure 118 **Bench terrace construction sequence A**[179]



Source: http://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0hdl--00-0----0-10-0---0---0direct-10---4-------0-0l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-10&cl=CL1.16&d=HASHbdde2fe3749493c1a0de2d.4.2.4&gt=1

Figure 119 **Bench terrace construction sequence B**[180]



Source: http://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0hdl--00-0----0-10-0---0---0direct-10---4-------0-0l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-10&cl=CL1.16&d=HASHbdde2fe3749493c1a0de2d.4.2.4&gt=1

Case Study:
Disaster Risk Management through Greening and Slope Stabilisation in the Rohingya Refugee Camps

Figure 120 **Terracing with leguminous trees and grasses in Kutupalong Refugee Camp, Bangladesh**[181]

Source: Haseeb Md. Irfanullah

Background

Since 1978, Bangladesh has provided shelter to Rohingya refugees, the Muslim minority group from Myanmar. Experiencing the greatest influx in August 2017, more than half a million Rohingyas fled genocide into the Cox's Bazar region. As of April 2020, there are approximately 860,000 Rohingya refugees, more than half of whom were children, placed in 34 extremely congested camps, spread across 2,500 ha of degraded and largely cleared forestland. The lack of remaining tree cover has contributed to an extremely hot and dry climate, with the barren hilly terrain particularly susceptible to soil erosion and landslides without vegetation to hold the soil. Unsustainable land management, including extensive earthwork, exacerbated the instability of the slopes, while the removed topsoil filled up existing stream channels. The result of this degradation left the world's largest refugee camp extremely vulnerable to natural disasters, including landslides, cyclones, and monsoon floods, which in any given year can bring more than 3 meters of rainfall to the region.[182]

Prior to the monsoon of 2018, an effort to tackle the climatic and geological vulnerabilities of the refugees involved relocating thousands of refugee families to more secure higher ground. Additionally, risky slopes were covered with tarpaulin sheets, while drainage systems were installed in some camps and many kilometres of hilly stream channels were re-excavated.[183]

The ensuing successes and failures of some of these strategies prompted ongoing efforts to implement Nature-based Solutions to improve DRR in Cox's Bazar. A particularly crucial intervention has been the construction of [2G] Bench Terraces across tens of thousands of square metres of slope in the Kutupalong Refugee Camp using bamboo fences, geo-textile and reinforced concrete rings, along with the planting 27 different species of grasses, shrubs, legumes, and tree saplings to restore biodiversity in order to help guard against erosion.

Figure 121 **Ongoing site development works**

(a) placement of bamboos, (b) sandbags to stabilise hill slope, and (c) construction of drainage system to channelize the flow of rainwater[184]

Source: Fieldwork, May 2019

Outcomes

The construction of vegetated Bench Terraces has increased the stability of the hilly slopes, reduced the vulnerability of refugee shelters to landslides, decreased soil erosion, improved soil fertility, and helped restore and protect riparian areas. Other additional benefits include improving the micro-climate of the camps, increasing shade cover through tree planting, and improving refugee nutrition with yields from fruit-bearing trees.

Moreover, refugees are able to generate income by participating in the interventions as labourers through site preparation, planting, and maintenance, while cultivating sapling and tufts in nurseries to be planted along the terraces. These measures have simultaneously generated employment and business opportunities among host communities and neighbouring localities, as well.

Future Applications/DRR Potential

While the data needed to quantify the DRR effectiveness, ecosystem benefits, and cost-benefit analysis of the bench terraces and other nature-based solutions implemented in the camps is lacking, observational findings indicate promising results.

Replication of bench terracing has continued in the Kutupalong Refugee Camp area, and results showcase its potential to be expanded or applied outside of the camp. Moreover, the nature-based approaches tested in the Rohingya refugee camps demonstrate the potential for NbS to mitigate disaster risk, improve living conditions, and reverse land degradation in even the most dire situations. The positive results may also strengthen ongoing efforts to incorporate long-term planning approaches into refugee responses. And, looking forward, The Joint Response Plan 2020, published in early March 2020, introduced plans to include an additional 200 ha in the environmental restoration programme in 2020, which showed that a commitment to these approaches have persisted.

2H Contour Earth (Soil) Bunds, Contour Bunding Technology (CBT)[185]

Category:
Micro-Catchment –
(2) Cross-Slope Barriers

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 122 An example of Contour Earth Bunds[186]

Source: Greener Land: Contour Bunds

Overview

Contour Earth or Soil Bunds are a technique that produce simple micro-catchments formed by excavating a channel and creating a small earth ridge or bund on the downhill side across the slope on the contour of the land for soil conservation and rainwater retention. Various earth formations are used to create catchments for runoff water.

Contour Earth Bunds are best suited to regions with annual rainfall of between 200 and 750mm, on slopes of less than 5%, and on land with a soil depth of around 1.5 - 2 m, but at least 0.5 m.[187] They are used widely across Africa.

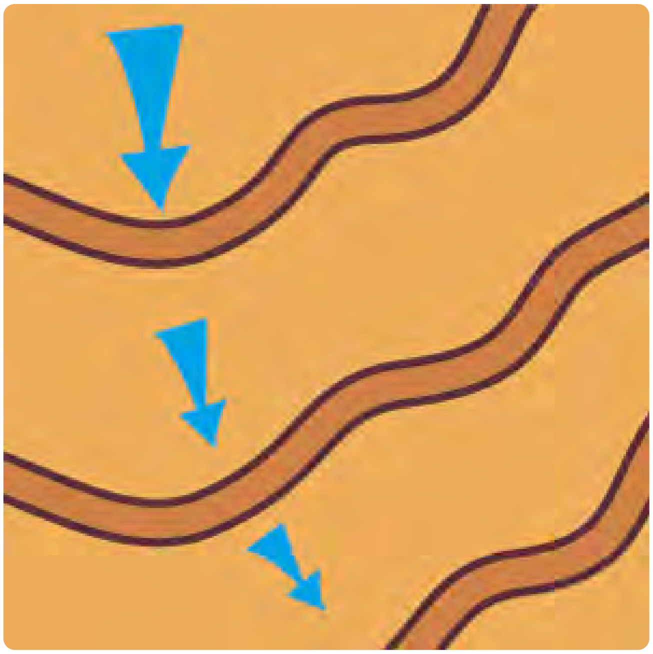
Advantages

Contour Earth Bunds are relatively simple and cheap to implement and maintain and can be used to collect and store surface runoff while managing flooding and soil erosion. They have the added benefit of being a technique that can be implemented on land that has already been cultivated. They have also shown an ability to increase rainwater infiltration (1-10%) and also crop yields, with reports from Somalia suggesting that sorghum yields were increased by as much as 80% as a result of the implementation of Contour Earth Bunds.[188]

Challenges

Contour Bunds are best suited to slopes where a relatively even ground surface can be established between bunds, which can be difficult on steeper slopes and because they are most successful where soil depths are sufficient, their effective implementation can be limited by shallower soils.

Figure 123 Contour Bunds diagram[189]

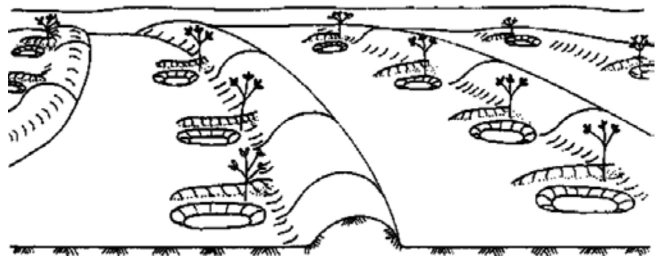


Source: https://www.greener.land/index.php/product/contour-bunds/

Design[190]

Contour Earth Bunds are arranged in a sequence of small bunds running along the contours of a slope with spacing that varies depending on the slope, i.e., spacing is increased the steeper the slope is. Bunds are generally built up to a height of around 20-40 cm with a base of at least 75 cm in width using soil excavated from the slope to create a series of depressions for catchment and planting. Small ridges of at least 2m in length are also constructed perpendicular to the contours and above the bunds at regular intervals to divide the catchment into smaller micro-catchments. Where the primary contour bunds and perpendicular ridges intersect, additional infiltration pits of around 80 x 80 x 40 cm should be added to promote infiltration.

Figure 124 Contour Bunds for tree planting in Arba'at, Red Sea State, Sudan[191]



Source: Adaptation strategies to increase human resilience against climate variability and change: Lessons from the arid regions of Sudan - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Contour-bunds-for-tree-planting-in-Arbaat_fig1_228660994 [accessed 9 Aug, 2022]

21 Contour Ridges, Contour Furrows, Micro-Watersheds[192]

Category:	Water Source:
Micro-Catchment – (2) Cross-Slope Barriers	(1) Precipitation, (2) Surface Runoff

Figure 125 Example of graded contour ridges

With cross ties lower than the main ridges to retain water between them, but allow excess rainwater to flow between the ridges rather than spill over or break the main ridges[193]

Source: T.F. Shaxson

Overview

Contour Ridges, sometimes also referred to as Contour Furrows or Micro-Watersheds, are typically used for crop production. Contour Ridges follow the contours of the landscape and are spaced at regular intervals. Surface runoff is collected from the uncultivated strip of land between ridges and stored in a furrow just above the ridges. Crops are planted on both sides of the furrow to utilise the gathered and stored runoff.

Advantages

This technique is good for crop cultivation in semi-arid areas, especially where soil is relatively fertile and easy to work. It has the key advantage of being a system that is simple and easy to construct and maintain. It can be implemented by hand or by machine and can be even less labour intensive than the conventional tilling of a plot.

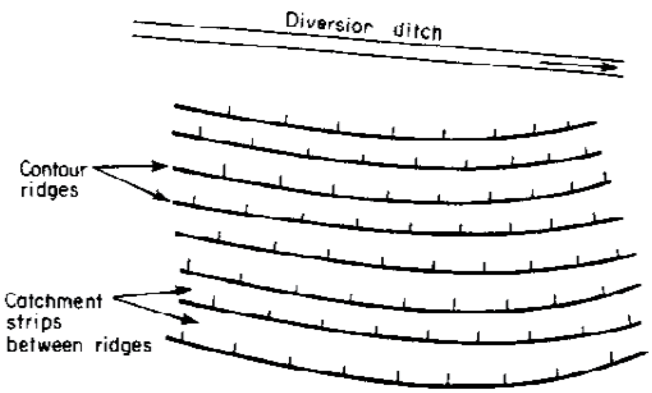
Challenges

Despite its advantages, though, Contour Ridges utilise a new technique of land preparation and planting that may be unfamiliar and therefore may face obstacles to acceptance. In addition, because catchment areas are typically fairly modest with this technique, the amount of runoff that can be harvested is generally somewhat limited. Therefore, this technique should only be deployed in areas with comparatively high rainfall and ideally where soil is already fairly fertile to begin with.[194]

Design

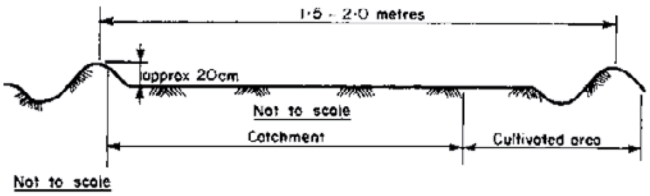
Contour Ridges are typically positioned at a spacing of around 1-2 metres apart and built up to a modest height of around 15-20 cm.[195] Because runoff is collected from only the narrow area between ridges, the ridges need only be tall enough to prevent collected rainwater from flowing over the ridges. However, if spacing is greater than 2 metres, the height should be increased.

Figure 126 Contour ridges field layout[196]



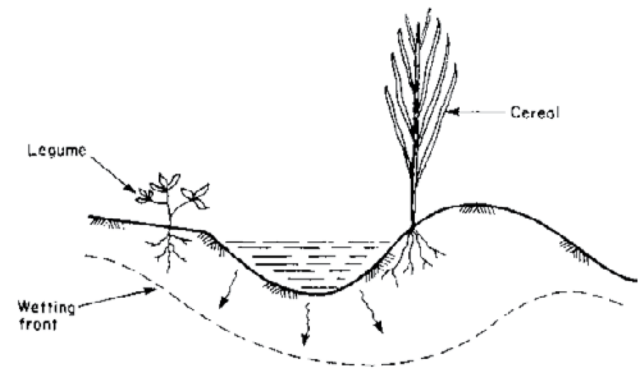
Source: FAO Water Harvesting Techniques https://www.fao.org/3/u3160e/u3160e07.htm#5.5%20contour%20ridges%20for%20crops

Figure 127 Contour ridge dimensions[197]



Source: https://www.fao.org/3/u3160e/u3160e07.htm#5.5%20contour%20ridges%20for%20crops

Figure 128 Planting configuration[198]



Source: FAO Water Harvesting Techniques https://www.fao.org/3/u3160e/u3160e07.htm#5.5%20contour%20ridges%20for%20crops

3 Macro-Catchment

Cross Slope Barriers

3A Contour Stone Bunds/Lines[199, 200]

Category:
Macro-Catchment –
(1) Cross-Slope Barriers

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 129 Stone bunds as soil and water conservation measures in the Sahel[201]

Source: https://farmingfirst.org/2012/09/stone-bunds-as-soil-and-water-conservation-measures-in-sahelian-countries/

Figure 130 Constructing stone lines[202]

Source: https://www.greener.land/index.php/product/stone-lines/

Overview

Stone bunds are buffer strips created by arranging stones along the contours of a slope in order to form an incremental barrier. Crops are grown just in front of the stone bunds, so the upper end of the terrace is free for catchment.

Each bund line is usually spaced about 15 to 30 metres apart with narrower spacing on steep slopes. Bunds can be reinforced with soil, vegetation, and crops to make them more stable.

Advantages

Stone bunds are permeable, so they slow down runoff, filter it, and spread water over the land area, which enhances water infiltration and reduces soil erosion. For that reason, stone bunds are common in areas receiving 200-750 mm of annual rainfall. Compared to some other strategies, stone bunds are safer and more resilient to failure due to their porous nature, which slows down runoff, but is unlikely to fail in cases of even extreme flooding.

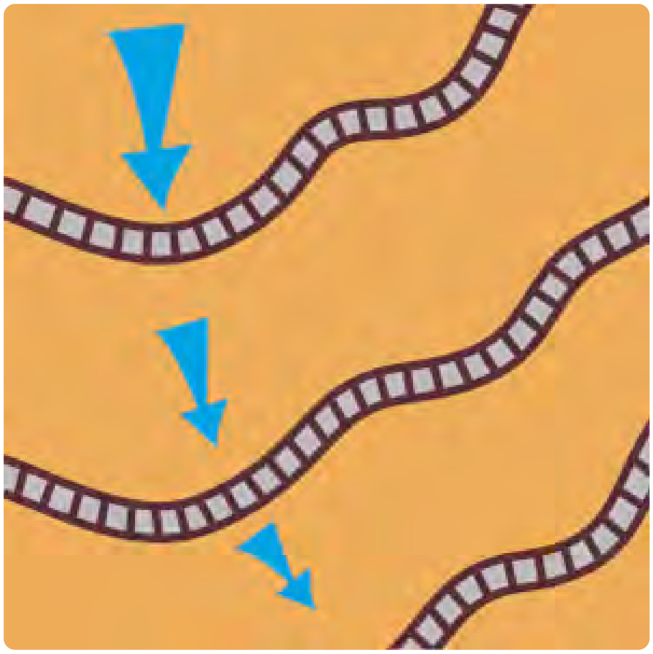
Challenges

The primary challenge associated with Stone Bunds is that they require a ready supply of stones in order to construct. If there are not stones available at the site, this can add an additional cost and present the further challenges of acquiring and transporting stones to the site. Moreover, as the technique becomes more popular in an area, demand for stones may increase, placing a strain on the supply and pushing up costs. Additional care must be taken in stone placement, so construction may require some experience and may also require more time to install than some other techniques, though the resulting bunds may also be more durable over time and require less maintenance, as a result of the up-front effort. Because the system takes time to settle and to collect sediment, the land should only be cultivated after a season has passed.

Design[203]

Stone bunds are built by first surveying and analysing the contours of a slope. Lines are marked and then shallow trenches are dug to hold the foundation of each bund. Stone Bunds should typically be spaced about 15-30 metres apart depending on the slope. Each bund should be built up to a height of around 25-30 cm from a base of around 30-40 cm wide set into a 5 cm deep foundation trench. Larger stones should be placed at the downslope side of the bund, while smaller stones can be used to build it up. Soil extracted from the trench should be placed at the front of the bund, while vegetation can be planted after some time there, as well, to add strength.

Figure 131 Contour Stone Bunds/Lines Diagram[204]

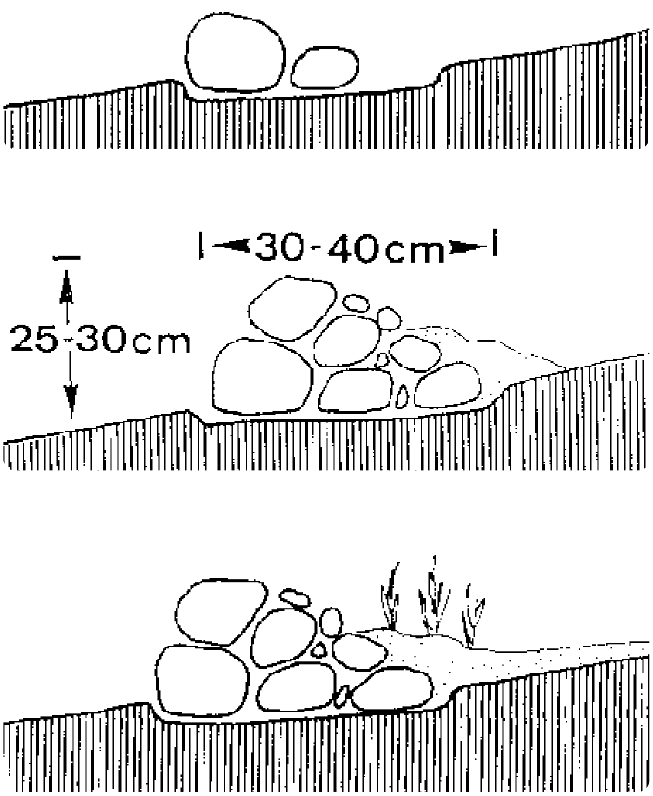


Source: https://www.greener.land/index.php/product/stone-lines/

Figure 132 Contour stone bunds: field layout[205]

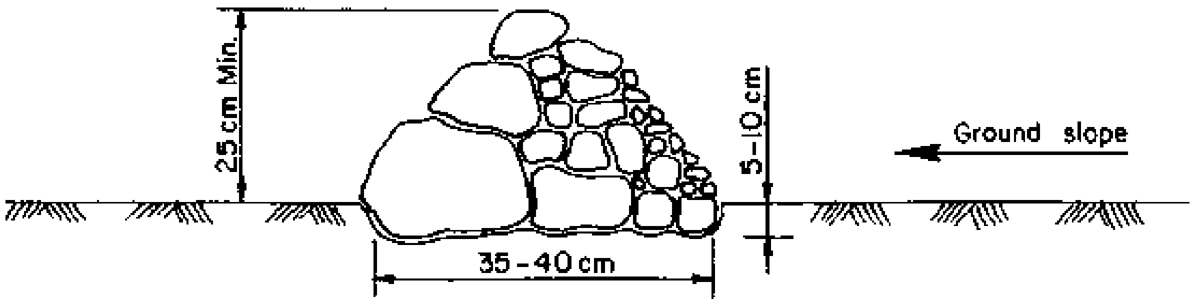
Source: Critchley and Reij 1989

Figure 133 A diagram of the construction process of a contour stone bund[206]



Source: https://www.fao.org/3/x5301e/x5301e0a.htm

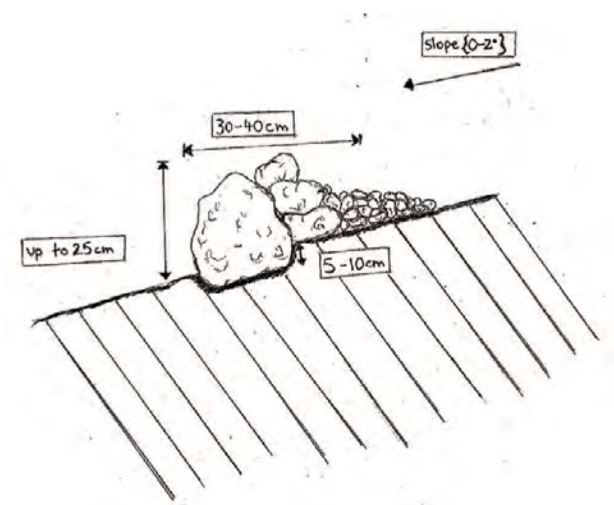
Figure 134 Contour stone bund dimensions[207]



Source: https://www.fao.org/3/u3160e/u3160e07.htm#5.7%20contour%20stone%20bunds

Case Study:
Environmental, Economic, Social, and Disaster Risk Reduction (DRR) Benefits of Contour Stone Bunds in Burkina Faso[208]

Figure 135 Vertical section of a stone contour bund[209]



Source: Critchley et al., 1992

Figure 136 Stone Bunds (to the left of the tree) used to enhance the water catchment capacity of Zaï Pits[210]

Source: Chris Reij, 2009

In the 1980s, local NGO technicians and farmers in the Yatenga region of Burkina Faso collaborated on experiments to improve existing contour stone bund building techniques. This merging of advanced scientific and technical knowledge with traditional local practice allowed the coalition to develop a new method that improved the bunds' effectiveness in harvesting rainwater and reducing soil erosion. The resulting technique involved placing the stones as accurately as possible along the contours of the field's topography.

This crucial technological advancement involved the use of a simple low-cost (USD $6) hosepipe water level, which helped ensure correct alignment of the stones.[211] The updated method dictates that the stones can be up to 20 cm thick with a base width of 35-40 cm, and must be placed 5 to 10 cm under the ground to maximise stability, while the bunds themselves are typically spaced between 15 to 30 cm apart.[212] Placing the stones at an even height allows for an even distribution of runoff throughout the field and better soil infiltration.[213] If the bunds are placed on a slope, farmers work upwards from the bottom of the slope and work upwards. Excess water is able to trickle through the spaces and infiltrate additional specified areas.

As discussed in the earlier case study involving land regeneration in Burkina Faso using Zaï Pits, there is a wide range of advantages to these innovations that maximize the potential of traditional Nature-based Solutions. The methods have already proven to be effective in rehabilitating soil and generating crops in formerly degraded and barren farmlands, with an estimated 200,000 ha of degraded land in the Central Plateau transformed through a combination of Zaï Pits and Contour Stone Bund applications over the last 30 years.[214] The success, attractiveness, and cost-effectiveness of these updated techniques can be largely attributed to the careful consideration that was given to local conditions and the availability of resources, making these strategies extremely well-adapted to their environments.

Figure 137 Individual and combined impacts of Zaï and contour stone bunds on cereal yields in two villages in Burkina Faso[215]

Village	No intervention (kg/ha)	Zai (kg/ha)	Yield increase (kg/ha)	Contour stoe bunds	Yield increase (kg/ha)	Stone bunds + Zai (kg/ha)	Yield increase (kg/ha)
Ziga	434	772	+346	574	+130	956	+522
Ranawa	376	804	+428	531	+155	922	+546

Source: Adapted from Sawadogo, 2008

Figure 138 A comparison of the same field in 1988 (left) and in 2008 (right)

Showing a significant increase in on-farm trees, which was enabled by investment in land rehabilitation using Zaï and Contour Stone Bunds that began in 1985; Ousseni Kindo, an innovator in agroforestry and soil fertility management, is pictured alongside this transformation in 2008[216]

Source: Reij, Chris & Tappan, Gary & Smale, Melinda. (2010). Agro-environmental transformation in the Sahel: Another kind of "Green Revolution." https://www.ifpri.org/publication/agroenvironmental-transformation-sahel

3B

Trapezoidal (Stone Contour) Bunds[217]

Category:
Macro-Catchment –
(1) Cross-Slope Barriers

Water Source:
(1) Precipitation, (2) Surface Runoff

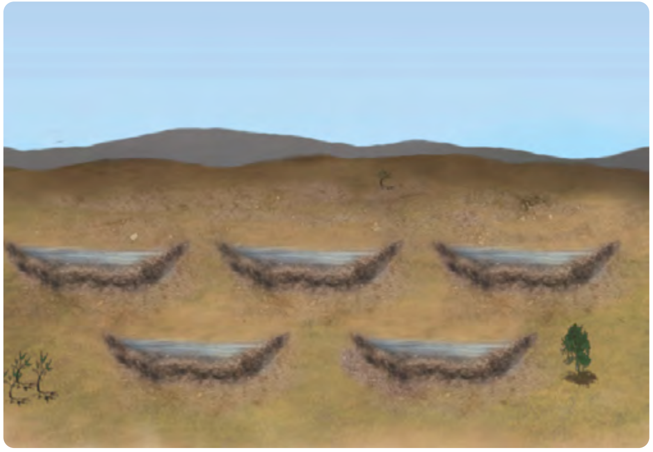
Figure 139 Trapezoidal Bunds along intermittent rivers as viewed from above in Kalobeyei Settlement, Kenya

Source: Google Earth, 2022

Figure 140 Trapezoidal Bunds along intermittent rivers as viewed from above in Kalobeyei Settlement, Kenya

Source: Google Earth, 2022

Figure 141 Illustration of Trapezoidal Bunds: Prevention of water and topsoil loss by the stone contour bunds provides more opportunity for biomass success[218]



Source: Critchley, 1991

Overview

Trapezoidal bunds are used to enclose larger areas of land, up to 1 hectare, and impound larger quantities of runoff, harvested from an external or "long slope" catchment area. They are generally used to support the cultivation of crops, trees, and grasses in arid and semi-arid regions where annual rainfall generally falls between 250 and 500 mm.[219] They are most effective on slopes of between 0.25 and 1.5% and on soil that is not generally susceptible to cracking, i.e., soils with high clay content.[220] They are a commonly used traditional technique in many parts of Africa and are similar to semi-circular bunds.

Advantages

The simplicity of design and construction and the minimum maintenance required are the main advantages of Trapezoidal Bunds.

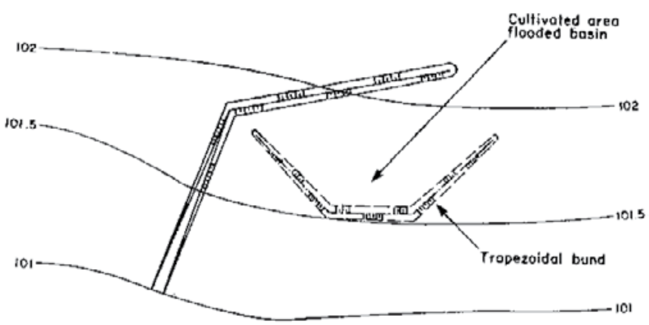
Challenges

Although this technique can be implemented on slopes of up to 1.5%, it is most effective on those of between 0.25 and 0.5%, meaning that it's largely limited to fairly gentle and even slopes.[221]

Design

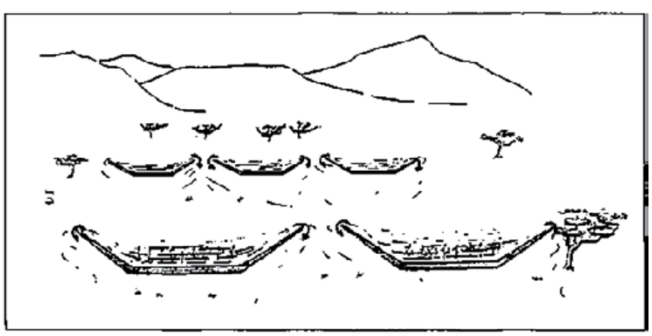
The structure of Trapezoidal Bunds consists of a base bund connected to two side bunds or wingwalls that extend upslope at an angle of about 135° to form a trapezoidal catchment area. Crops are planted within the enclosed area and overflow discharges over the tips of the wingwalls. Trapezoidal catchments can operate successfully in isolation or in sequence across a field. When implemented in sequence, they should be offset from one another in a staggered configuration. In one example, as implemented in Turkana County, Kenya, the base bund was 40 m in length and the maximum bund height was 0.6 m at the lowest point and the minimum height was 0.2 m at the wing tips.[222]

Figure 142 Trapezoidal bund: diversion ditch[223]



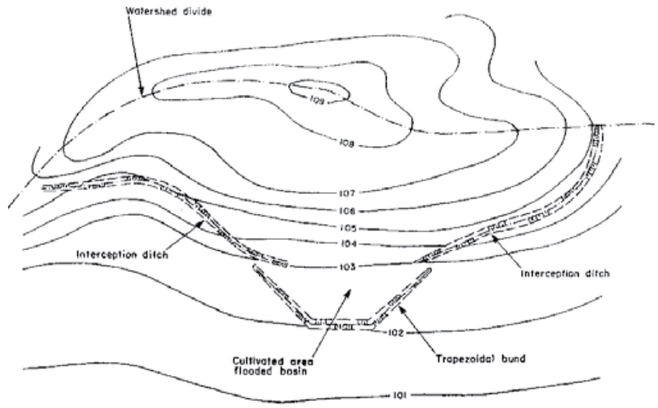
Source: https://www.fao.org/3/u3160e/u3160e07.htm#5.6%20trapezoidal%20bunds

Figure 143 External catchment system: trapezoidal bunds for crops[224]



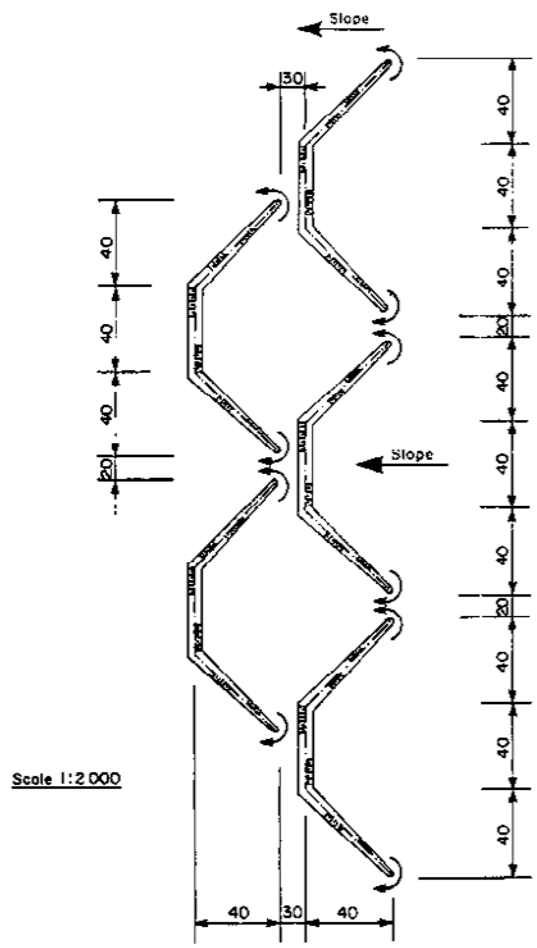
Source: Critchley and Reij, 1989

Figure 144 Interception ditch[225]



Source: https://www.fao.org/3/u3160e/u3160e07.htm#5.6%20trapezoidal%20bunds

Figure 145 A diagram of a trapezoidal bunds field layout for 1% ground slope[226]



Source: https://www.fao.org/3/u3160e/u3160e07.htm#5.6%20trapezoidal%20bunds

Subsurface Storage Facility

3C Sand Dams[227, 228]

Category:
Macro-Catchment –
(2) Subsurface Storage Facilities

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 146 Sand Dam[229]

Source: MWI 2015. Practice Manual for Small Dams, Pans and Other Water Conservation Structures in Kenya. http://design-of-small-dams.appspot.com/quick_links/photos/ch12/sand-dams/

Figure 147 Sand Dam at Kijabe, Kenya[230]

Source: http://design-of-small-dams.appspot.com/quick_links/photos/ch12/sand-dams/

Figure 148 Sand Dam Construction at Kijabe, Kenya[231]

Source: http://design-of-small-dams.appspot.com/quick_links/photos/ch12/sand-dams/

Figure 149 A Sand Storage Dam in the Kiindu river near Kitui, Kenya (2005)[232]

Source: https://www.samsamwater.com/projectdata.php?projectid=46

Figure 150 **A Sand Storage Dam shortly after the first rains of the wet season (2005)**[233]

Source: https://www.samsamwater.com/projectdata.php?projectid=46

Overview

Sand Dams consist of a reservoir created when a short wall is constructed across a seasonal riverbed to restrict surface flow, allowing water and sand carried by floodwaters to settle and get stored in the dam. Water from sand dams is often used for livestock watering and can also be used for the supplemental irrigation of crops.

Advantages[234]

Because the water is stored within the sand in Sand Dams, the reservoir is protected from significant evaporation losses, is less likely to be contaminated by livestock, wildlife, and human activity, and also will not be used as a site for insect breeding.

The sand itself further acts as a filter for the water that passes through the system. Water stored in a Sand Dam raises the water table which improves soil quality in the surrounding area, as well.

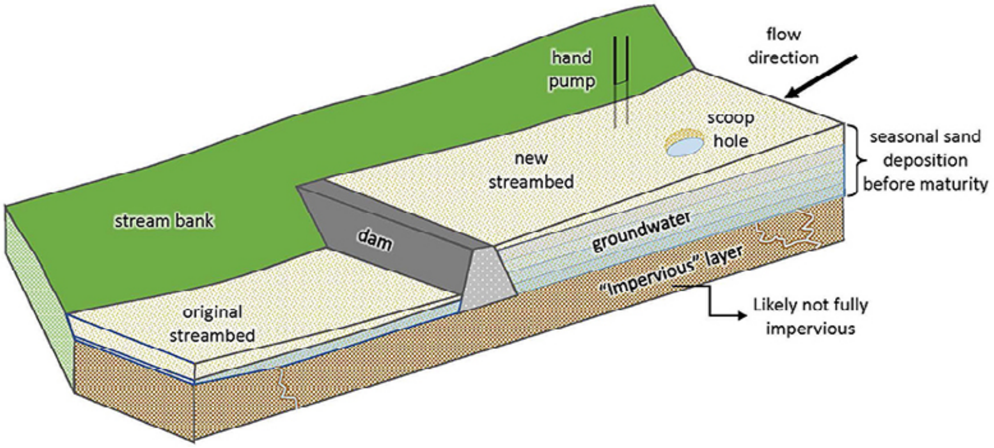
Challenges[235]

Although there are many advantages, Sand Dams can also require significant resources to implement. In most cases, outside support should be enlisted to provide the technology and capital that may be required. In addition, there are concerns with this technique about the effect on downstream groundwater flow, which may be disrupted or depleted, having unanticipated consequences, which can lead to wider environmental impacts and even social conflict, especially where livelihoods are affected.

Design

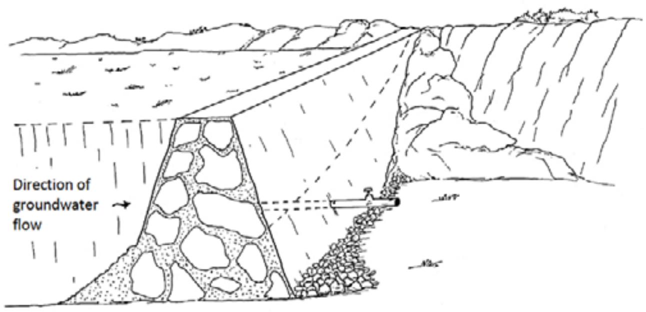
To avoid collecting silt, Sand Dams are built up in stages over several years and dam walls are typically increased by about 0.3 m after floods have deposited sand to the level of the spillway. Because of this incremental and sometimes lengthy implementation process that involves particular attention, it is critical that communities be involved in their planning, construction, and maintenance in order to imbue a feeling of ownership and ensure effective follow through. Sand Dams may be constructed using locally available materials, but are generally formed of earth, stone masonry, or reinforced concrete.

Figure 151 **Sand dam schematic showing seasonal sand deposition before maturity and two common abstraction methods**[236]



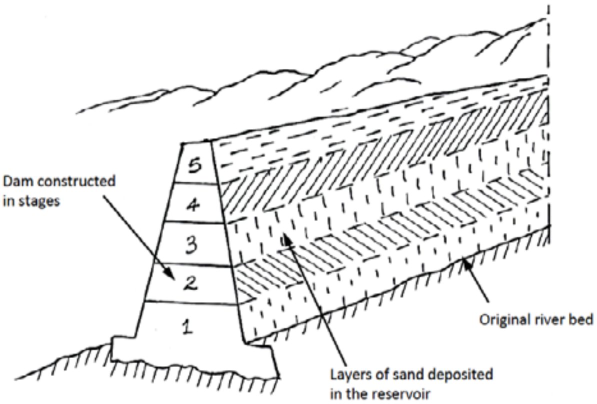
Source: Adapted from Eisma and Merwade, 2020

Figure 152 Typical Sand Dam Construction[237]



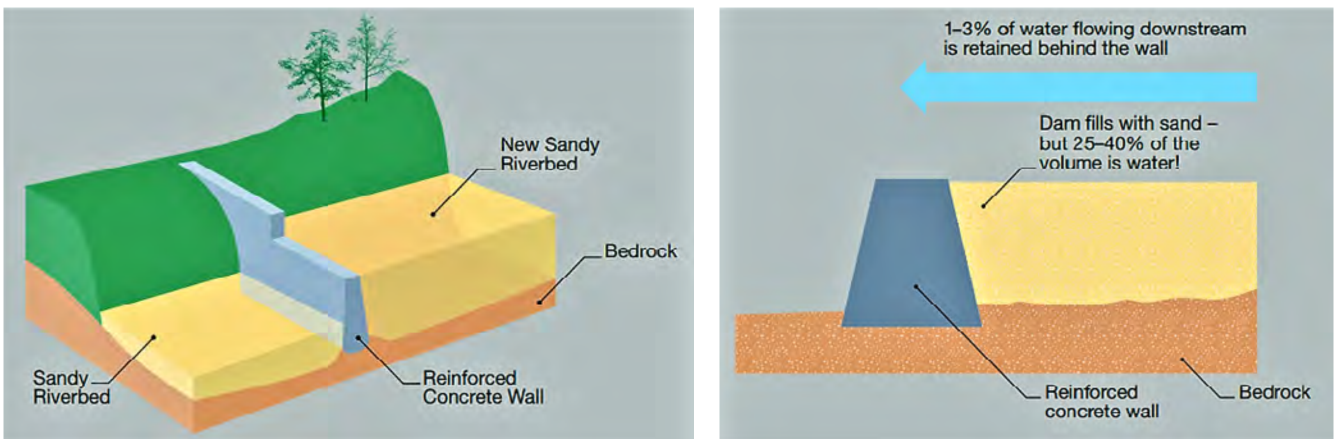
Source: http://design-of-small-dams.appspot.com/structures/#ch15

Figure 153 Sand Storage Dam Constructed in Stages[238]



Source: http://design-of-small-dams.appspot.com/structures/#ch15

Figure 154 A schematic cross-section of a sand dam (left) and sand accumulating until the dam is completely full of up to the spillway (right)



Resulting in water being stored within the sand, protected, and filtered, composing up to 40% of the total volume of the sand amassed behind the dam[239]

Source: ED, N.Y.

3D

Sub-Surface Dam[240]

Category:
Macro-Catchment –
(2) Subsurface Storage Facilities

Water Source:
(2) Surface Runoff, (5) Riverbed Water

Figure 155 **Two local people fetching water using a hand pump from a closed well near a sand dam[241]**

Source: DREW, 2018

Figure 156 **One of the dams under construction[242]**

Source: https://www.agrinextlevel.nl/ikalaasa-subsurface-dammen/

Overview

Sub-Surface Dams are used to create a reservoir when an embankment is constructed across a seasonal riverbed to restrict sub-surface flow, allowing for water to be stored in the dam. Unlike a sand dam, the embankment wall is below the surface of the stream bed. Constructed with stone masonry or compacted clay, the foundation should extend down to the impervious layer below the sand. If possible, Sub-Surface Dams may be located at a natural dike in the riverbed which collects and stores water.

Figure 157 **Water retained by the dam[243]**

Source: https://www.agrinextlevel.nl/ikalaasa-subsurface-dammen/

Advantages

Where deep sand can be found, Sub-Surface Dams can provide a cost-effective approach to the storage of harvested water that may only present seasonally. Water in this type of sand dam can be reserved for a long time because water stored within the raised bed level is subject to low evaporative losses. This technique also can help to reduce risk of contamination, in particular from livestock or other wildlife. In some cases, the dam structure can be integrated with a drift for river crossing purposes, thereby lowering the overall cost. Water from Sub-Surface dams is generally used for livestock and can also be used for supplemental irrigation of crops.

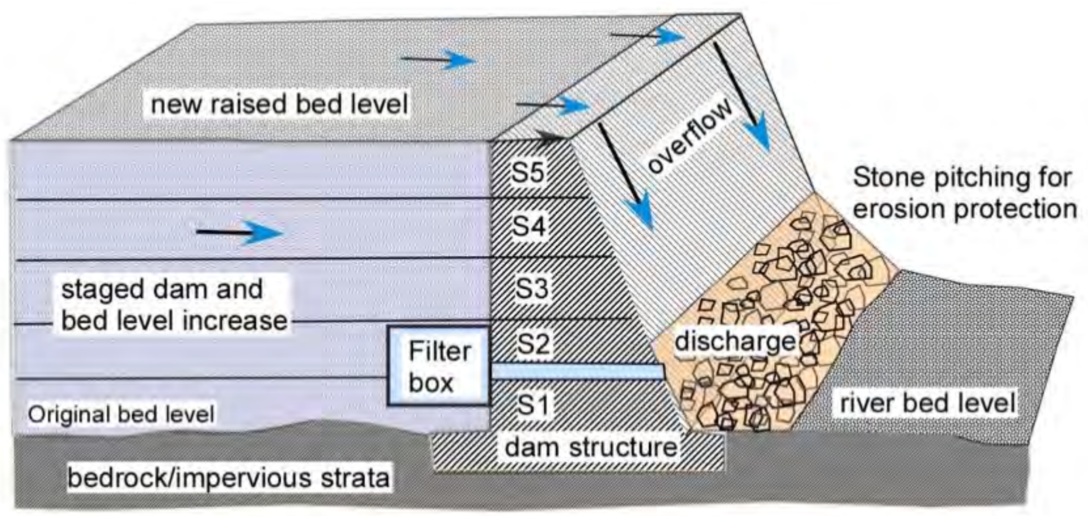
Challenges

As with Sand Dams, Sub-Surface Dams can also require significant resources to implement. In most cases, outside support should be enlisted to provide the technology and capital that may be required. In addition, there are concerns with this technique about the effect on downstream groundwater flow, which may be disrupted or depleted, having unanticipated consequences, which can lead to wider environmental impacts and even social conflict, especially where livelihoods are affected.

Design

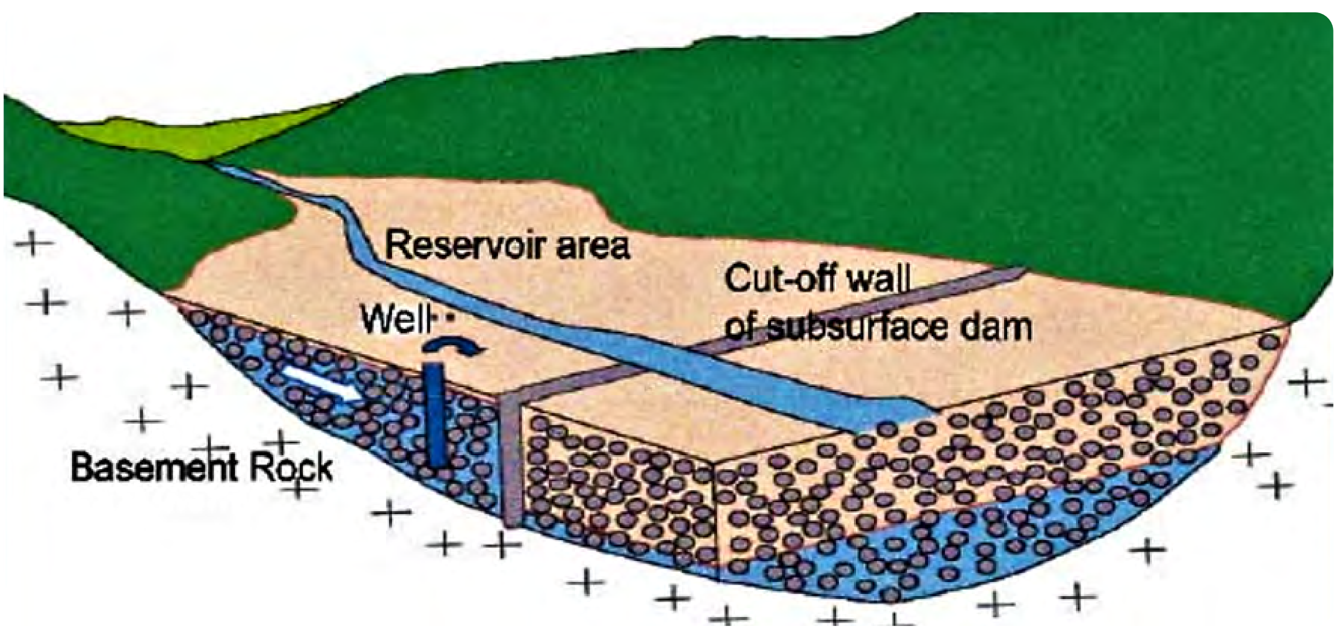
Sub-Surface Dams are constructed in much the same ways as Sand Dams, except that the dam wall structure is set below the surface of the stream bed. Typically constructed from compacted clay or stone masonry, the foundation of the dam structure should extend down to the bedrock or impervious layer below the sand of the riverbed. This means that it can be a particularly effective technique where deep sand is found. To assist with construction, it can be beneficial to site Sub-Surface Dams at natural dikes in the riverbed.

Figure 158 **Typical subsurface dam design**[244]



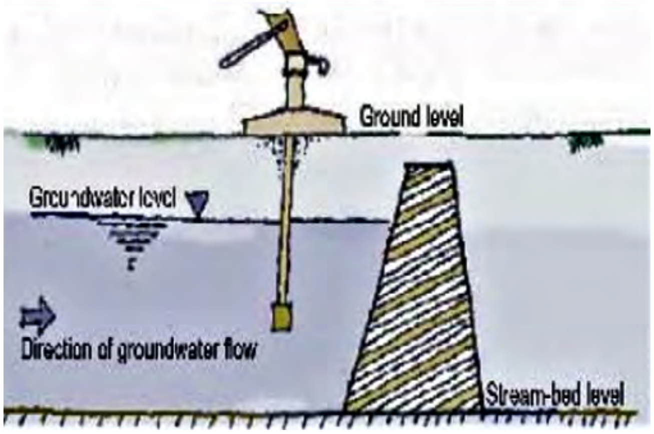
Source: Groundwater Dams, General Characteristics and Historical Development - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Typical-scanrio-of-a-subsurface-dam_fig1_312172913 [accessed 11 Aug, 2022]

Figure 159 **Concept of a subsurface dam**[245, 246]



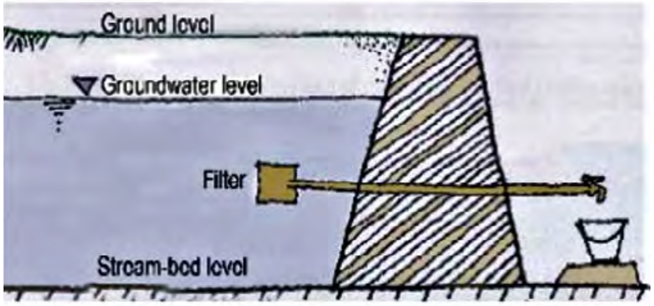
Source: Vétérinaires sans Frontières, 2006

Figure 160 Cross-section of subsurface dam with a Hand pump for water extraction[247]



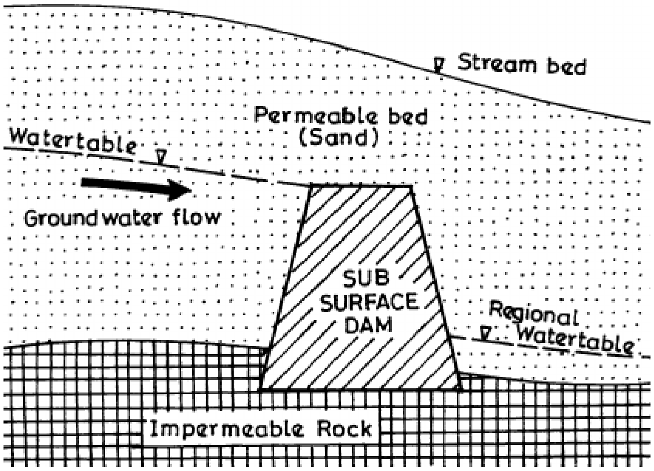
Source: Vétérinaires sans Frontières, 2006

Figure 161 Cross-section of subsurface dam with a hand pump for water extraction[248]



Source: Vétérinaires sans Frontières, 2006

Figure 162 Schematic diagram of subsurface dam[249]



Source: Subsurface dams to harvest rainwater - A case study of the Swarnamukhi River basin, Southern India - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Schematic-diagram-of-subsurface-dam_fig2_225958278 [accessed 11 Aug, 2022]

Surface Storage Facilities

3E

Small Earth Dams/Weirs[250]

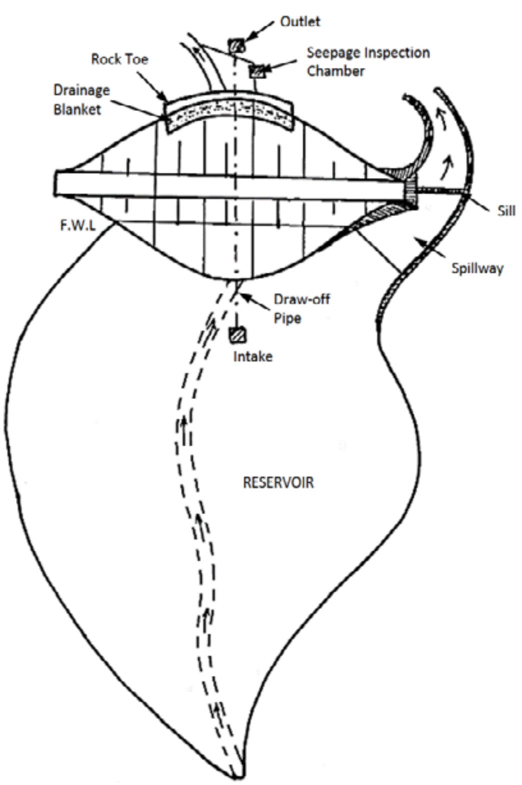
Category:
Macro-Catchment –
(3) Surface Storage Facilities

Water Source:
(2) Surface Runoff, (4) Floodwater from Intermittent Rivers, (5) Floodwater Runoff

Figure 163 A small earth dam in Kenya[251]

Source: https://www.agriceng.cloud/blog/climate-change-6/what-is-an-earth-dam-small-earth-dams-and-water-pans-part-3-21

Figure 164 Section through a small earth dam[252]



Source: Nelson, 1985

Overview

Small Earth Dams or Weirs are constructed to collect and retain surface and floodwater runoff of perennial rivers or on dry riverbeds during the rainy season. Earth Dams, which are generally dug manually, can be large enough to provide sufficient water for irrigation projects as well as for livestock.

Advantages

Due to the size and stability that can be achieved, the primary advantage of Small Earth Dams is that they can gather and store significant volumes of water.

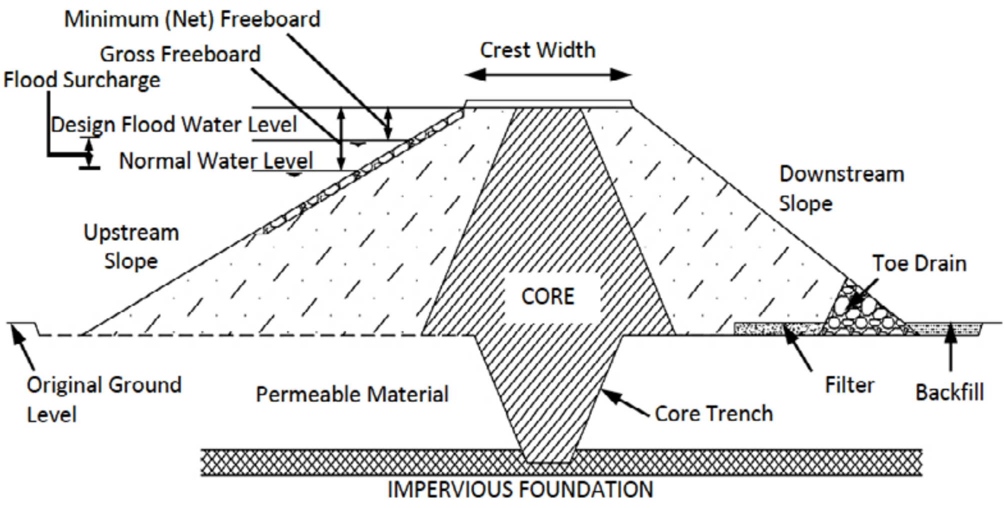
Challenges

Due to the high costs of construction and significant labour required, Small Earth Dams are usually only constructed through donor-funded projects and are therefore not achievable in all circumstances. In general, this strategy is often too major of an intervention in many situations.

Design

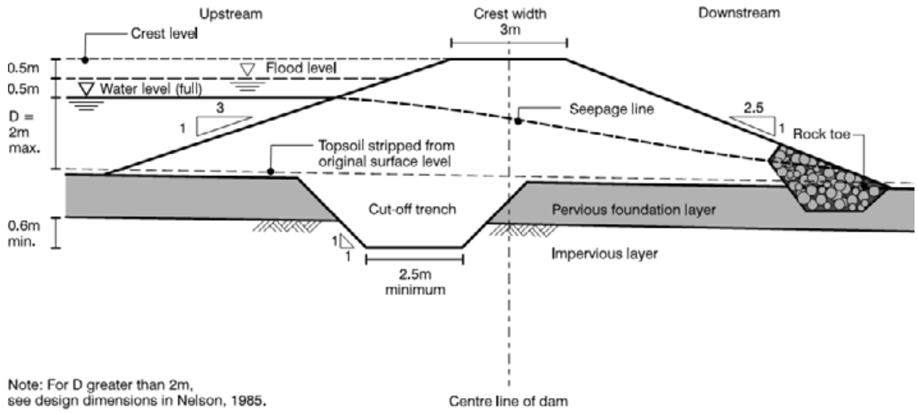
Small Earth Dams are typically composed of a dam wall that is 2-5 metres high, with a clay core, stone apron, and a spillway to discharge excess runoff. These dams typically have a maximum volume of water in the range of hundreds to tens of thousands of cubic metres of water (reservoirs with a water volume of less than 5,000 m3 are often referred to as pans or ponds).

Figure 165 Cross Section of a Small Earth Dam[253]



Source: http://design-of-small-dams.appspot.com/structures/

Figure 166 Layout Plan of a Small Earth Dam[254]



Source: http://design-of-small-dams.appspot.com/structures/

3F

Rock Catchment[255, 256]

Category:
Macro-Catchment –
(3) Surface Storage Facilities

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 167 Rock Catchment – Lokuchura (Marsabit)[257]

Source: https://openjicareport.jica.go.jp/pdf/12246914.pdf

Figure 168 Gravity Wall and Rock Catchment[258]

Source: MWI 2015. Practice Manual for Small Dams, Pans and Other Water Conservation Structures in Kenya. http://design-of-small-dams.appspot.com/quick_links/photos/ch12/rock-catchment/

Overview

Rock Catchments are rainwater harvesting facilities with a catchment surface and water tank that are constructed on the lower reaches of bare rock that naturally support the collection of runoff and the gathering of that runoff into a basin or tank. Runoff is typically channelled along stone and cement gutters constructed on the rock surface into reservoirs contained by concrete or stone masonry dams or into tanks. Where rock elevation is higher than the surrounding land, water can be supplied to standpipes through a gravity-fed network of pipes.

Advantages

Many of the advantages of Rock Catchments come from the fact that they generally leverage naturally occurring rock formations, which can allow for fairly large catchment surfaces that don't require significant labour or investment to establish. As a result, they can yield large volumes of water with minimal resources.

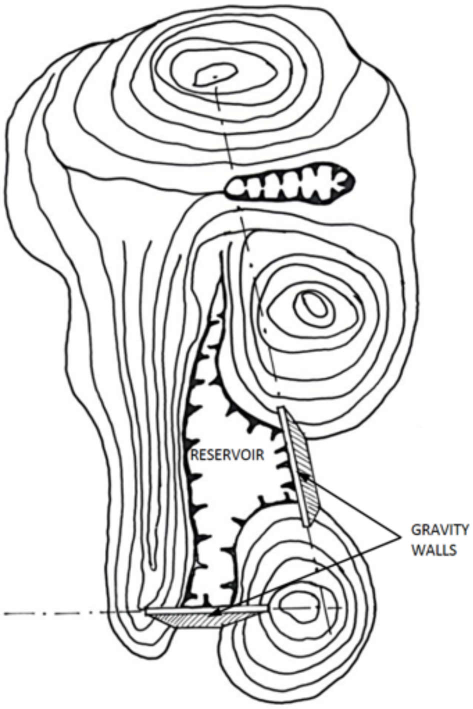
Challenges

As Rock Catchments are generally constructed using mainly existing and naturally created geological formations, they are easiest to implement where favourable conditions exist. In addition, water quality can easily be contaminated from the catchment surface by humans or animals. Since they are large and typically uncovered, they are also usually exposed to significant evaporative losses. To minimise water losses, rock should be free of fractures or cracks as much as possible, or these imperfections should be treated.

Design

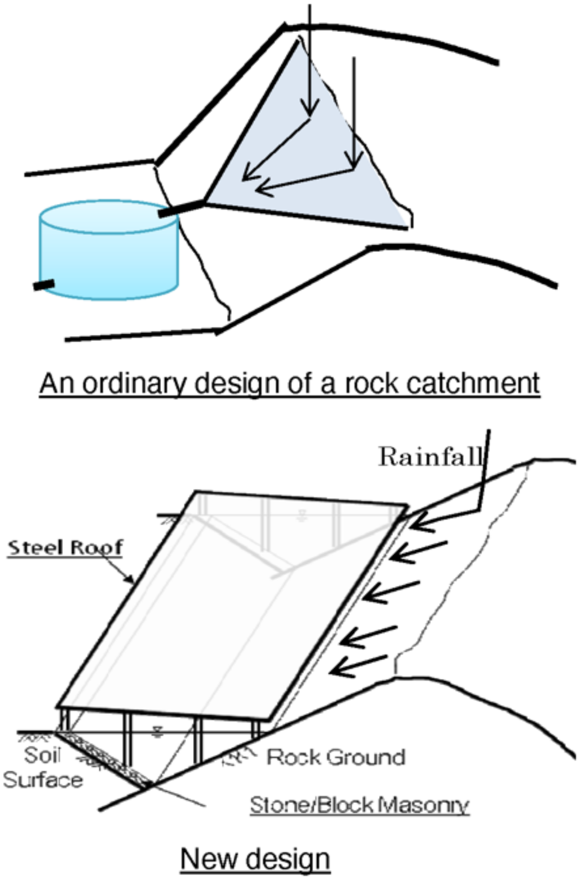
Because Rock Catchments rely heavily on naturally formed elements, their designs can vary significantly depending on the existing conditions. However, they should always endeavour to utilise those existing conditions and take advantage of the natural flow of runoff. Dams or gravity walls should be constructed at points along the catchment where they can be minimised and where the force of gravity can help to support the structure and the subsequent build-up of water behind. If budgets allow, both a concrete side wall and an impervious paint-coating on rock surfaces are recommended to minimise leakage. And, wherever possible, it is recommended that storage reservoirs be constructed underground or in a way that they can be enclosed, such as within a tank, so as to limit the challenges of contamination and evaporation. This can have the added benefit of lowering construction costs in some cases, as well.[259]

Figure 169 Rock Catchment Reservoir on Rock with Depressions[260]



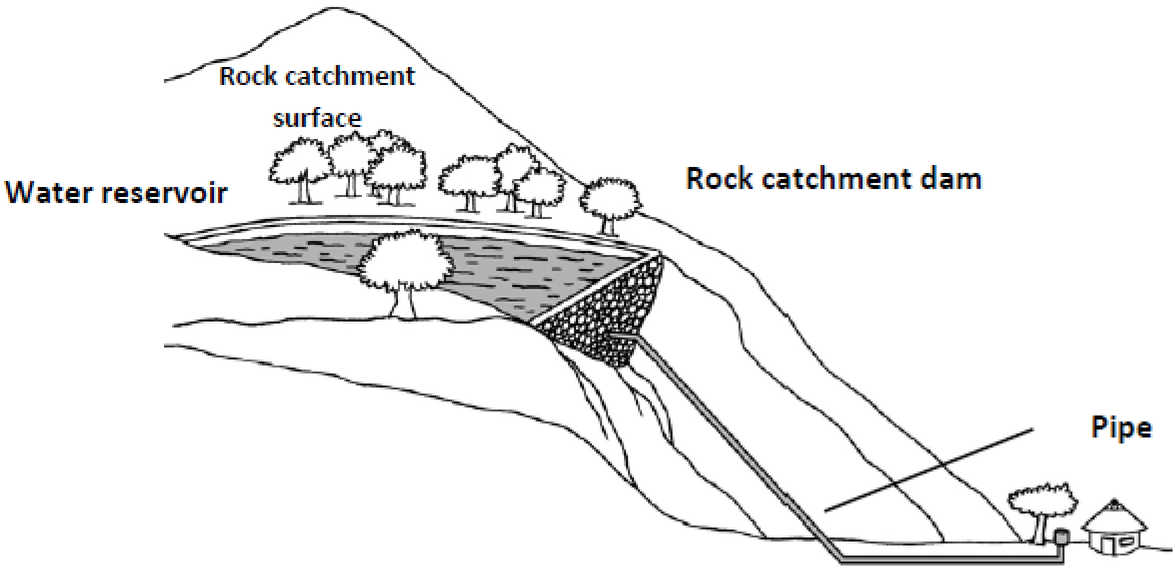
Source: MWI 2015. Practice Manual for Small Dams, Pans and Other Water Conservation Structures in Kenya

Figure 170 Schematic Images of New Rock Catchment[261]



Source: JICA Project Team

Figure 171 Rock Catchment Dam[262]



Source: UNEP IETC, 1998 in Clements et al., 2011

3G Water Storage Pans and Reservoir Ponds[263]

Category:
Macro-Catchment –
(3) Surface Storage Facilities

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 172 Water pan – Dirib Gombo (Marsabit)[264]

Source: Republic of Kenya MDP/JICA 2015. The Project for Enhancing Community Resilience against Drought in Northern Kenya

Overview

Water Storage Pans and Reservoir Ponds are excavated water storage reservoirs established in order to collect and store precipitation and surface runoff in ponds in arid and semi-arid regions where drought is common and where runoff during rainy seasons is often largely lost. They are typically located where surface runoff can be directed into the structure at a relatively low cost. They are typically smaller in size than Lagoons and also, unlike Lagoons, they may be unlined, though this is not the preferred approach. To establish a Water Pan, a large pond is dug so that water can be stored at a level below the natural ground level. They are often used for livestock watering and where topography is not suitable for a dam.

Advantages[266]

The primary advantage of Water Storage Pans and Reservoir Ponds is that they are relatively easy to construct, especially compared with other strategies like dams that may require more advanced engineering and higher investment. Because they are generally recessed into the natural landform to establish a catchment area and storage reservoir, structural failure is also not a serious concern. This strategy is also fairly flexible and can be sized according to the needs of the community.

Challenges[267]

However, there are a number of challenges associated with this technique. Depending on how they are built, the capacity can be relatively small, and if a liner is not used, seepage and infiltration will result in a natural loss of collected water through the ground. In addition, losses through evaporation are a major disadvantage of exposed reservoirs. Without a liner or a covering, Water Pans can be particularly vulnerable to contamination. When a liner is utilised, the lifespan is largely reliant on the lifespan of the liner material, which will require a more significant up-front investment in order to prolong. Water collected and stored in Water Pans is also generally high in silt content and requires that desilting measures be taken, which can be labour intensive and require significant community cooperation.

Design

Water Storage Pans and Reservoir Ponds are generally only around 1-3 metres deep and can hold in the range of 100-50,000 m^3 of water, depending on land availability and needs. They should be sized appropriately to the land area that should be irrigated with water from the reservoir, the volume needed for the desired crops, and the anticipated loss of water collected based on evaporation rates.[268] They are generally constructed on flat or gently sloping land with a grade usually between 1-3%.[269] In most cases, the pan's volume tapers, meaning that the dimensions at the top of a pan are larger than at the bottom.[270]

Figure 173 Refugees collecting water from a water pan in Kalobeyei Settlement, in Kenya

Martha Kasafi (right) and her daughter, both refugees from Democratic Republic of Congo, collect water for their vegetable crops at a water pan in Kalobeyei settlement for refugees in Turkana County, Kenya on 2 October, 2019[265]

Source: https://www.voanews.com/a/new-law-in-kenya-allows-refugees-to-work-/6320046.html

Figure 174 A lined water pan in Dadaab, Garissa County, Kenya

Source: UN-Habitat

Figure 175 A lined water pan in Dadaab, Garissa County, Kenya

Source: UN-Habitat

Figure 176 Water pan in Kalobeyei Settlement

Source: UN-Habitat

Figure 177 Water pan in Kalobeyei Settlement

Source: UN-Habitat

Figure 178 A water pan in Kalobeyei Town supplied by nearby river

Source: UN-Habitat

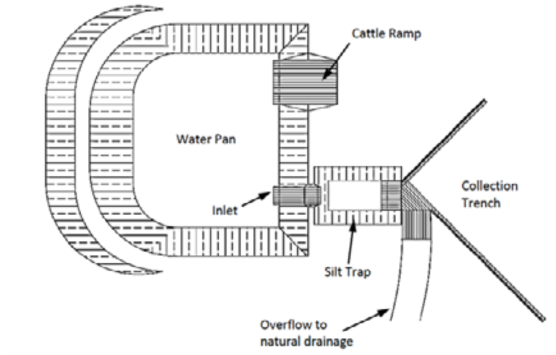
Figure 179 A water pan in Kalobeyei Town supplied by nearby river

Source: UN-Habitat

Figure 180 A water pan in Kalobeyei Town supplied by nearby river

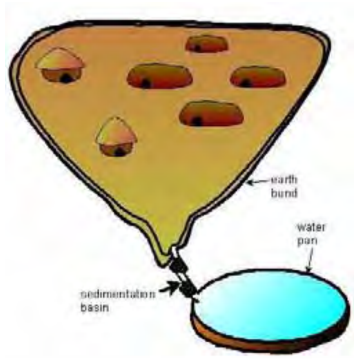
Source: UN-Habitat

Figure 181 Typical Site Layout of Water Pan showing silt trap and overflow[271]



Source: MWI 2015. Practice Manual for Small Dams, Pans and Other Water Conservation Structures in Kenya. State Department for Water, Ministry of Water and Irrigation, Government of Kenya. http://smalldamsguidelines.water.go.ke/structures/#ch14

Figure 182 Illustration showing drainage from upslope settlement into water pan using earth bunds[272]



Source: Mati, B. M. "100 ways to manage water for smallholder agriculture in Eastern and Southern Africa: A compendium of technologies and practices." IMAWESA (2007).

3H

Lagoons[273]

Category:
Macro-Catchment –
(3) Surface Storage Facilities

Water Source:
(1) Precipitation, (2) Surface Runoff

Figure 183 **Lagoon Construction**[274]

Source: http://design-of-small-dams.appspot.com/quick_links/photos/ch12/lagoons/

Figure 184 **Lagoon Under Construction**[275]

Source: http://design-of-small-dams.appspot.com/quick_links/photos/ch12/lagoons/

Figure 185 **Lagoon Lining**[276]

Source: http://design-of-small-dams.appspot.com/quick_links/photos/ch12/lagoons/

Figure 186 **Lagoon at Horticulture Farm**[277]

Source: http://design-of-small-dams.appspot.com/quick_links/photos/ch12/lagoons/

Overview

Lagoons are excavated water storage reservoirs that have been lined with compacted clay or an artificial lining material that are established in order to collect and store precipitation and runoff. They are typically constructed on land with a slope of up to 10% so that an earth embankment dam can be formed at one end of an excavated pan. They are typically positioned below farms in lower elevations in order to collect runoff.

Advantages

Lagoons have the key advantage of being lined, which helps to control any seepage and limit ground contamination. They are fairly versatile and can be constructed on any soil type. Because this technique can allow for large reservoirs, they have the potential to store large quantities of water and can be adapted to the needs of the community.

Challenges

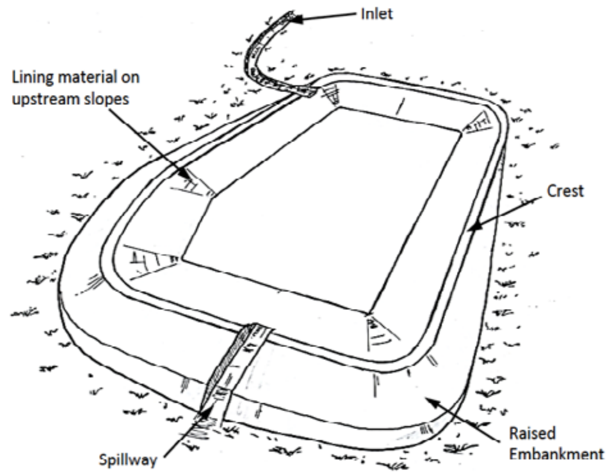
However, due to their size and the need for establishing an unbroken lining, Lagoons can be expensive to construct. They are also vulnerable, because any damage to the lining can lead to the failure of the entire lagoon. More durable liners can be an expensive upfront investment and can be difficult to acquire. Controlled access is critical to preventing damage, in particular by livestock and wildlife.

In addition, because they are quite large and generally exposed, they do expose the stored water to some contamination and can also create a breeding ground for insects. The water tends to also present a high silt content that must be managed.

Design

Lagoons are generally larger than Water Pans and are therefore fairly sizable, often with a depth of around 5-7 metres, and a capacity of around 30,000 -70,000 m³. The crest level should equal the ground level at the highest spot in the original ground to allow runoff to fill the lagoon. In most cases, an artificial liner should be used to contain the Lagoon and prevent seepage and contamination.

Figure 187 **Example of a typical lagoon**[278]



Source: http://design-of-small-dams.appspot.com/structures/#ch14

Pumped Water Harvesting

31 Borehole Wells[279, 280]

Category:
Macro-Catchment –
(4) Pumped Water Harvesting Systems

Water Source:
(7) Groundwater Aquifer

Figure 188 **A borehole in Kenya's Turkana County**[281]

Source: Isaiah Esipisu/IPS

Overview

There is a wide range of groundwater well types, but one of the most common utilised in arid and semi-arid regions and in areas where intermittent rivers occur is Borehole Wells. In Uganda, for example, where there are estimated to be nearly 40,000 boreholes, more than a third of the overall population and nearly half of the rural population relied on Boreholes as a primary source of water as of 2016.[282]

Boreholes are generally deeper and narrower than some other types of wells and are generally drilled mechanically. They are also particularly popular to serve the needs of livestock and are therefore often established strategically in dry season grazing areas, where water is extracted with a pump and directed into a trough for livestock through a pipe.

Advantages

The primary advantage of Boreholes is that because of their depth, they can provide access to water where little to no surface water is present and ensure that access to the groundwater aquifer is maintained even during times of drought or high demand. In addition, the deeper the well is, the better protected the water being supplied is from surface contamination.

Challenges

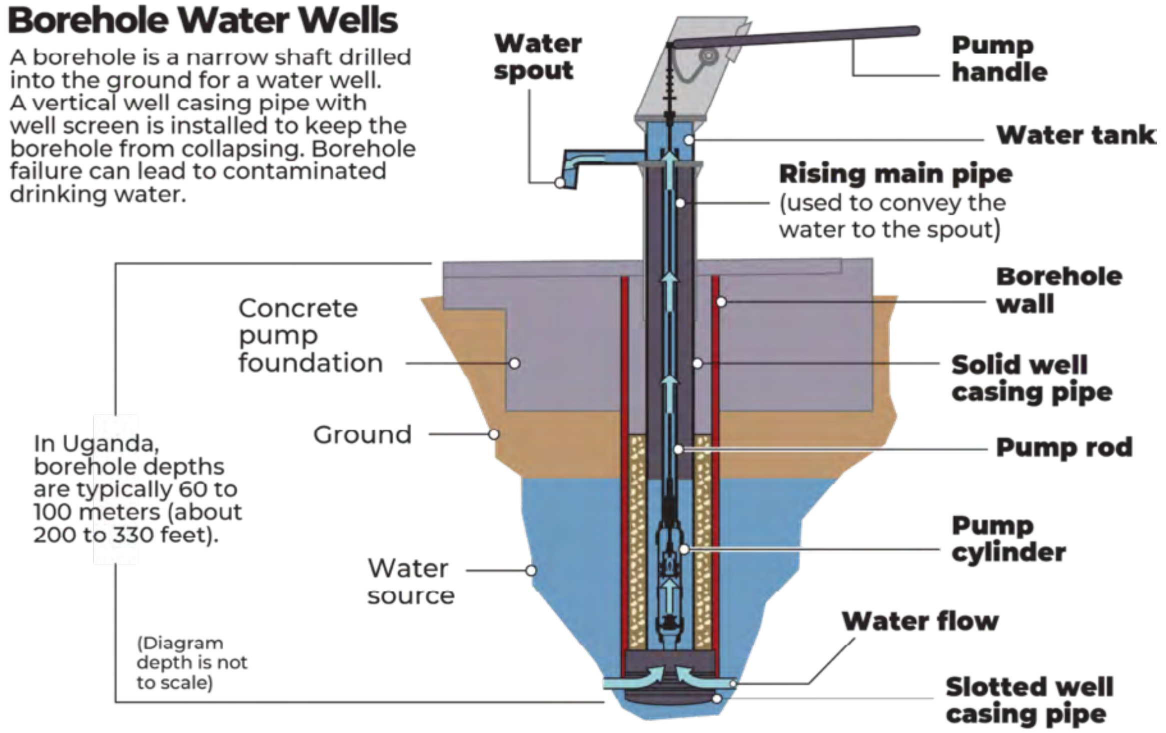
There are some challenges associated with deep water wells like Boreholes, though, as well. Boreholes tend to be more expensive and require more effort and heavy machinery to construct than many shallower alternatives. With this technology, the pumps are generally positioned below the surface of the ground, which can add a level of difficulty when service is required.

In addition, although the water supplied from deeper in the ground is better protected from contamination, it will also often contain more minerals resulting in harder water that may need to be treated with softeners.[283]

Design[284]

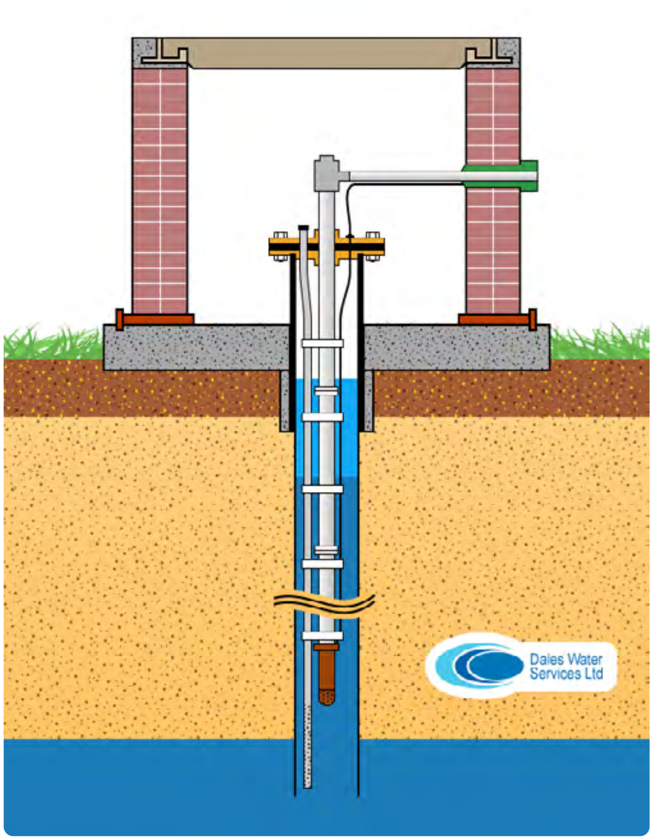
In the initial planning for a borehole well, the key considerations include siting the well appropriately and choosing an appropriate method of construction. Siting should include a survey to estimate the yield that can be extracted, assess the quality of the water itself, identify any potential sources of contamination, and plan accessibility for construction and future collection. Once a site is selected, the specifications for the well itself must be determined based on the desired result, site conditions, and available resources and technology. Next the specifications are determined, the borehole should be designed to accommodate a pump that will provide the flow and pressure desired. After the preliminary pit is dug to house the system, a lining should be installed to the appropriate depth with a well screen extending to a further depth, with the entire installation packed with gravel to fill the excess space and serve as an additional structuring and filtering layer. At the ground level, a borehole chamber should be installed along with a sealed well head and a supply pipe where the harvested water can be served from. A Borehole Well typically can take three to five days to construct, but once operational, should last at least 20 years if effectively maintained.[285]

Figure 189 **Borehole schematic design**[286]



Source: Matt Haney, Global Press Journal

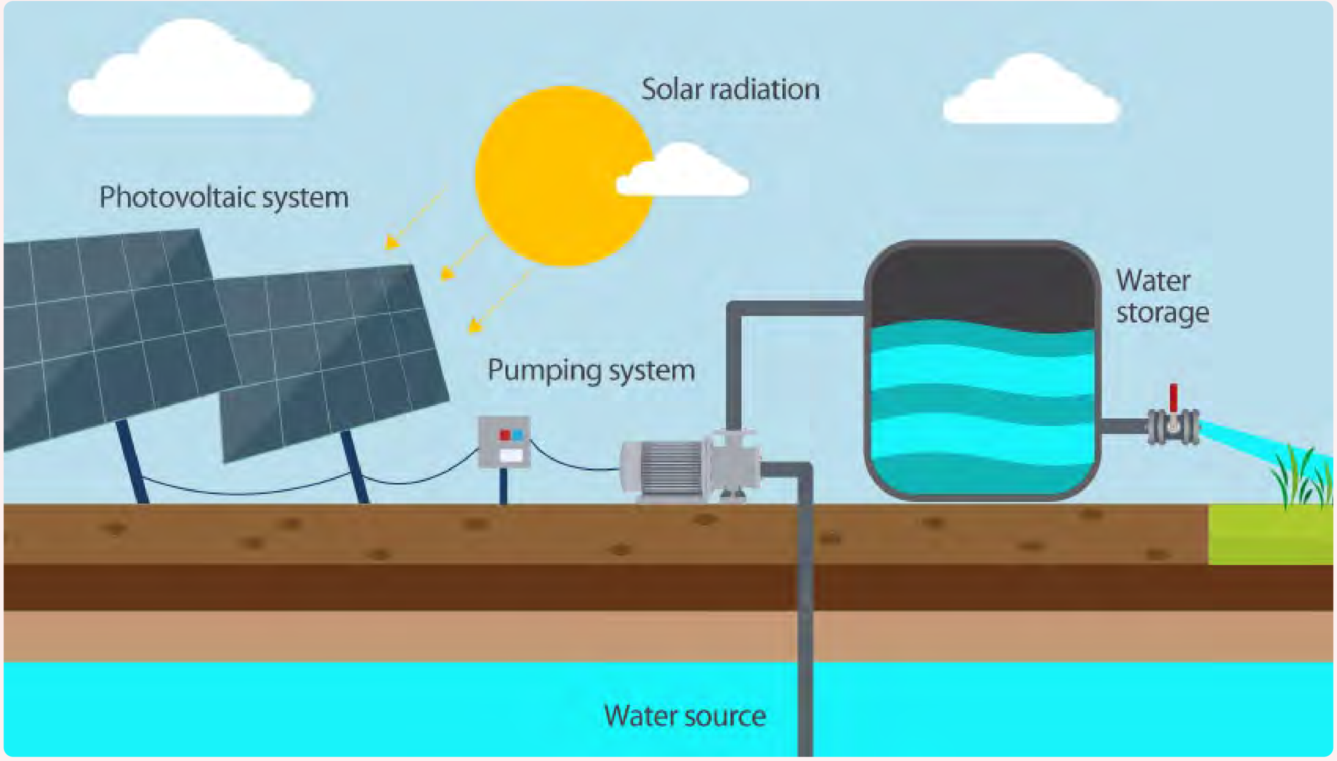
Figure 190 Borehole schematic design[287]



Source: Dales Water Services, Ltd.

Case Study:
Solar Powered Water Pumping Systems – Supplying Clean Water and Irrigation in South Sudan and Sudan

Figure 191 **Diagram of a solar powered water pumping system**[288]



Source: http://solarqpumps.com/

South Sudan

In order to scale the benefits of Boreholes and improve their capacity and efficiency, solar energy can be gathered to power the pumping system and eliminate the need for or at least reduce reliance on costly and often non-renewable power sources. In South Sudan, for example, which is the world's least electrified country, many rural and remote communities do not have access to energy. At the same time, access to clean water is critical to surviving the dry seasons and reducing health risks such as cholera during the rainy seasons. For many of these communities, solar powered systems offer a highly successful and cost-effective solution. They are typically easy to maintain, rarely break down, and don't rely on a costly fuel supply, which means that they require very little financial investment beyond the initial construction.

Figure 192 **Solar-powered system in Akauch water yard in Rumbek City, South Sudan**

The yard, renovated by ICRC, supplies water to 15 water kiosks that together provide for 15,000 people. It consists of a deep borehole, a water tank and a (formerly diesel-powered) generator. In 2014, just 2 years after its construction, while running on diesel, it had stopped working, reportedly due to rising costs of diesel fuel which the community was unable to pay for; however, since then it has been converted to run on solar energy[289]

Source: CC BY-NC-ND / ICRC / Crystal Wells

Figure 193 **A Sudanese farmer digging an irrigation trench to utilise water from a solar-powered water pumping system**[290]

Source: https://borgenproject.org/solar-powered-water-pumps-in-sudan/

The extremely low maintenance cost is vital to enabling water systems, such as the Akauch water yard in Rubek City in South Sudan, to serve as sustainable solutions for communities that may not consistently have the financial resources needed to refuel a system that relies on a different power source. A solar-powered water system in the remote town of Yambio has transformed access to clean water, enabling the community to meet their water needs during both seasons, while improving overall well-being and freeing up time for women and children to engage in educational, economic, and social activities instead of traveling long, often dangerous, distances in search of clean water. The system uses solar energy to pump treated water from a borehole to different communities, schools, and the community's main health centre.[291] Moreover, solar-powered water pumps are a green technology with minimal environmental impact, contributing to both climate adaptation and mitigation efforts.

Sudan

Sudan's agricultural sector accounts for about one third of the country's Gross Domestic Product (GDP) and reportedly employs about 80% of the nation's total workforce.[292] As a result, about 65% of Sudan's total population, particularly those living in poverty, are heavily reliant on livelihoods connected to agricultural activities.

At the same time, it is estimated that 20 million Sudanese live without access to electricity, accounting for about 65% of the national population, while in rural parts of the country, access to electricity drops closer to 20%.[293] Meanwhile, Sudan's primarily arid and semi-arid climate receives negligible rainfall, with drought conditions exacerbated by climate change and desertification. These hostile conditions, combined with scarce access to electricity, have forced many farmers to rely heavily on diesel pumps for crop irrigation, which not only produce harmful greenhouse gases, but also can reduce agricultural efficiency as expensive and fluctuating prices of diesel limit growing seasons and prevent farmers from planting consistently. In addition, the pumps often contaminate the surrounding water, contributing to smaller-scale environmental and potential health hazards.[294]

Outcomes

Solar energy and solar-powered irrigation dramatically reduce reliance on fossil fuels and nearly eliminate energy-related costs for farmers, while simultaneously increasing agricultural productivity. These strategies provide a fuel-free alternative that is stable, reliable, and effectively cost-free beyond initial installation and regular, though minimal, maintenance.[295] A UNDP pilot program in Sudan's Northern State found that the introduction of solar-powered water pumps increased the amount of land cultivated by farmers by 47% overall and 87% during the summer months, while participating farmers generally reported significant savings as well as a reductions in overhead costs for management. Extended growing seasons and reduced irrigation costs also enable farmers to enhance production by planting high-value crops (e.g., lemons, mangoes, and cotton) with high potential to improve livelihoods for individual Sudanese farmers who are particularly susceptible to poverty and food insecurity.[296]

3J

Shallow (Dug) Wells

Category:
Macro-Catchment –
(4) Pumped Water Harvesting Systems

Water Source:
(4) Floodwater from Intermittent Rivers, (7) Groundwater Aquifer

Figure 194 The Water Project: Sand Dams in Kenya, Dug Well and Hand Pump[297]

Source: https://thewaterproject.org/community/projects/kenya/new-shallow-well-in-kenya-4313

Overview

Shallow or Dug Wells, are wells that are dug manually or drilled mechanically in locations where the underlying water table is high enough that it can be tapped into with relative ease and without digging too deep, a condition that can present along intermittent rivers. Once implemented, water is abstracted by pump and manual power.

Advantages[298]

The two primary advantages of Shallow Wells are that they are typically far less expensive and labour-intensive to implement than their deeper counterparts, because both material and labour costs are minimised with this technique. In addition, the pump itself is positioned above ground allowing for greater access, which enables easier and cheaper maintenance. As a result of the shallower depth, Dug Wells also typically collect lower levels of minerals in their output depending on local geological conditions.

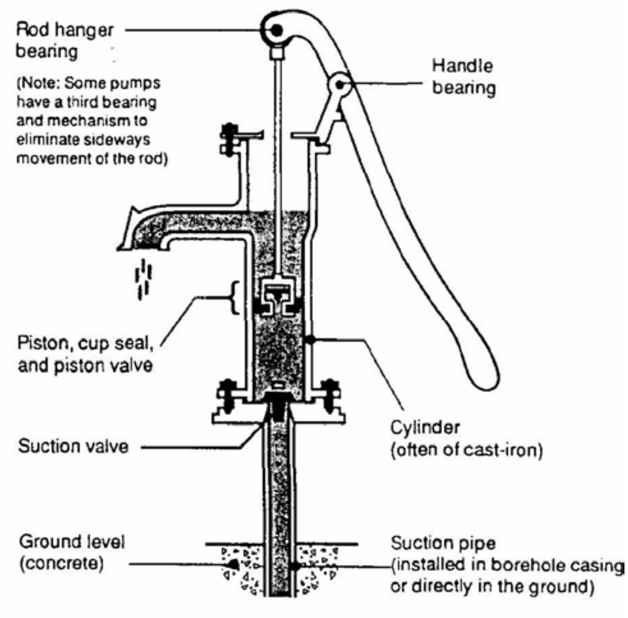
Challenges

The primary challenge associated with Shallow Wells is that, because they rely on a relatively high water table, they do present the risk of running dry if water levels drop.[299] This can be of particular concern in arid and drought-prone climates where such levels may drop gradually over a number of years. In addition, due to their shallow nature, water drawn from Shallow Wells is at a greater risk of becoming contaminated by human activities at the surface, such as by fertilisers from agricultural activity and sewage from septic systems.[300] To address this concern, water from Shallow Wells should be tested periodically and treated, as necessary, to ensure a clean supply.

Design

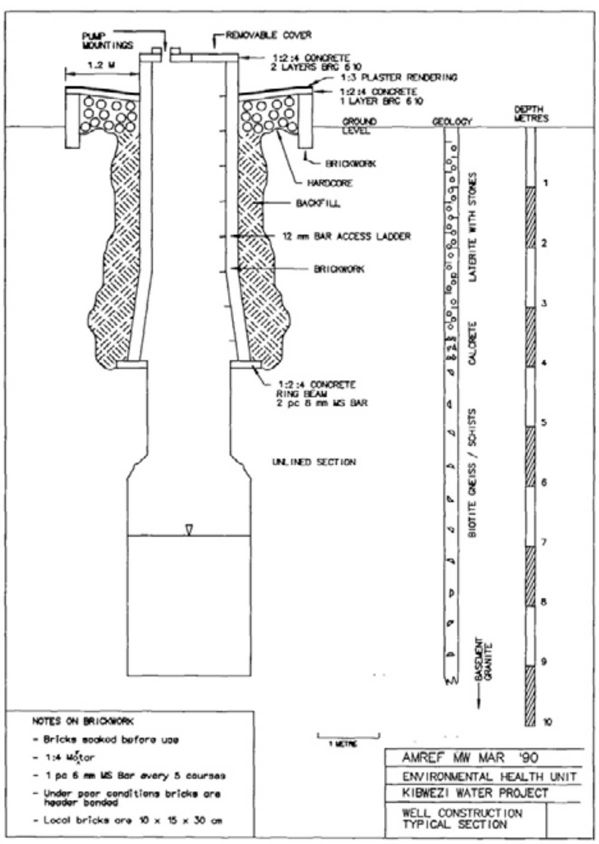
The first step in establishing a Shallow Well involves siting it favourably. With some basic training, community members have shown a fairly high level of success in identifying productive sites by analysing the contours of the landscape and observing the surface conditions of the land, such as soil and vegetation.[301] Once a site is selected, the well is typically dug by hand. Initially, an exploratory pit, often round in shape and around 1.5m in diameter, should be dug to verify the chosen pit's potential productivity. Once the exploratory pit begins to yield water, the shaft should be widened to the desired size and lined with a durable material to preserve the well's form. The lining layer should be built up from a foundation using materials that can vary based on cost and what is locally available, but may include concrete rings, stone, or brick.[302] The lining should be plastered to a depth of at least 3m below ground level.[303] Once complete, the well must be capped and an apron added around the access point, which may include a pump and a spillway. Where space allows, aprons should extend out from the well a distance of around 1.2-1.5m and spillways should run about 6m out from the well at a slope of 1:10.[304]

Figure 195 Design for shallow-well piston pump[305]



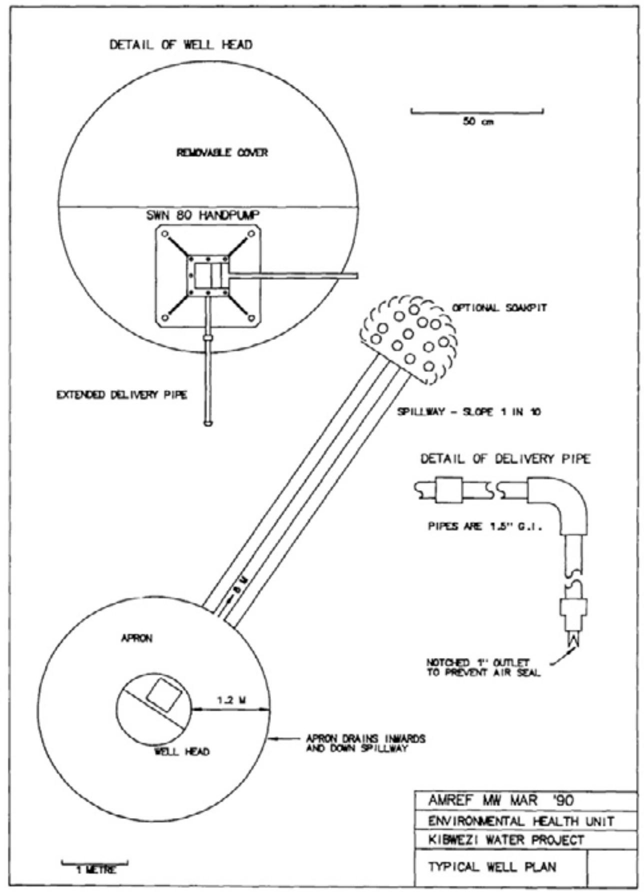
Source: https://sswm.info/sites/default/files/reference_attachments/OLLEY%20 2008%20Human%20Powered%20Handpumps%20for%20Water%20Lifting.pdf

Figure 196 Section drawing showing section through a typical well in Kibwezi, Kenya[306]



Source: https://www.ircwash.org/sites/default/files/212.5-90SH-8382.pdf

Figure 197 Plan drawing showing section through a typical well in Kibwezi, Kenya[307]



Source: https://www.ircwash.org/sites/default/files/212.5-90SH-8382.pdf

3K

Protected Natural Springs[308]

Category:
Macro-Catchment –
(4) Pumped Water Harvesting Systems

Water Source:
(1) Precipitation, (8) Natural Springwater

Figure 198 **A protected spring for the Abangi-Ndende Community in Uganda[309]**

Source: https://thewaterproject.org/community/projects/uganda/new-spring-protection-project-6085

Figure 199 **Protected Springs in Kenya[310]**

Source: https://wasrag.wordpress.com/2015/09/29/rotary-builds-protected-springs-in-kenya/

Overview

Natural springs occur where groundwater emerges from the earth's surface through a hole in the earth, a crack in rocks, or a wet spot of earth. Where the flow and volume are sufficient, springs can offer an excellent source of clean high-quality water. In order to ensure quality is maintained, though, natural springs used as a primary source should be protected and the quality should be checked regularly.

Advantages[311]

There are many advantages to Protected Natural Springs because they require little effort to implement where they are naturally occurring. Generally, construction and maintenance costs are very minimal, especially where gravity fed distribution is possible and no pumps are required. If properly protected, a high level of quality can generally be maintained, and the flow usually experiences only minimal seasonal variations, making it a reliable source.

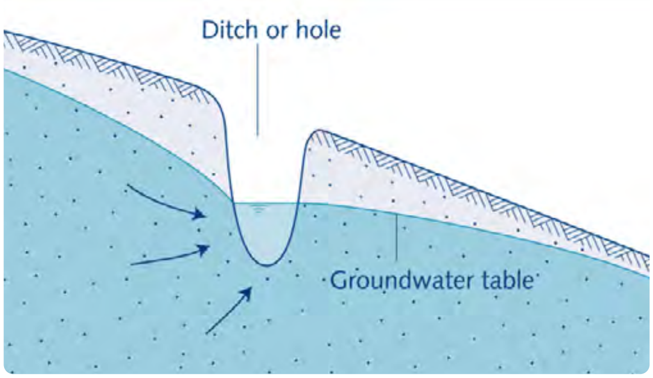
Challenges[312]

One of the primary challenges, though, of natural springs, is that there is little to no control over where or if they exist, so can only be taken advantage of when and where they are discovered. There are no guarantees that springs will be discovered in convenient or easily accessible locations. Although natural springs are generally reliable, some gravity springs, in particularly, can be highly dependent on rainfall and are therefore far less reliable. In any case, as a natural system, it is impossible to increase the flow or yield. In addition, all springs run the risk of simply drying up and disappearing.

Design

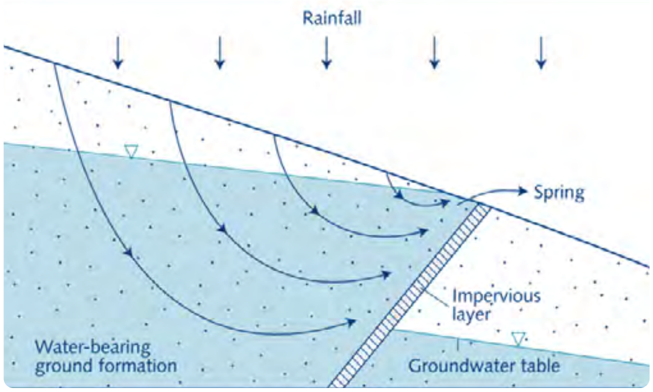
Designs of springs can vary significantly depending on the context, conditions, and requirements of the users, but one of the most critical aspects of designing around a natural spring is ensuring that the catchment area is properly protected. Beyond that, selection of spring type and its design are highly specific to the site.

Figure 200 **Gravity depression spring**[313]



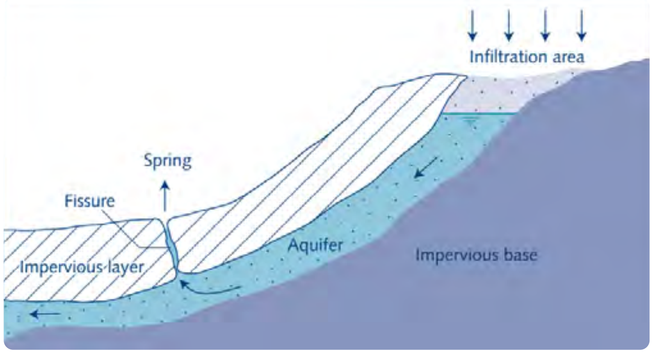
Source: SMET & WIJK, 2002

Figure 201 **Gravity overflow spring**[314]



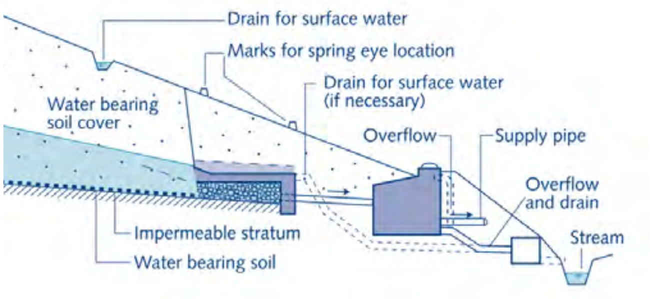
Source: SMET & WIJK, 2002

Figure 202 **Artesian or fissure spring**[315]



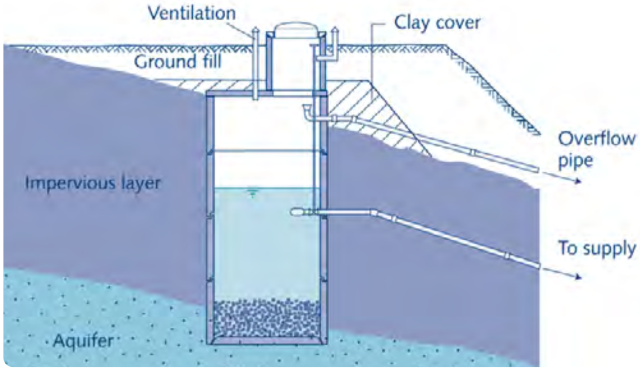
Source: SMET & WIJK, 2002

Figure 203 **Layout of a spring water collection area (gravity spring)**[316]



Source: SMET & WIJK, 2002

Figure 204 **Tapping of an artesian spring of large capacity**[317]



Source: SMET & WIJK, 2002

III. Economic Development and Livelihood Opportunities

The strategies presented in this section, which represent a range of economic development and livelihood opportunities that could be implemented alongside the design and planning strategies presented in the previous section, are organised into three categories of socio-economic approaches:

1. **Environmental Management and Ecosystem Services**, which are those that can incentivise sustainable practices among individual and community land users through institutional support. This includes those that help finance SLM initiatives, such as [1.1] Payment for Ecosystem Services (PES) and those that empower community organising around natural resource management such as [1.3] Community-Based Natural Resource Management (CBNRM).
2. **Agriculture, Fish, and Livestock Value Chain Development**, which are those that support the expansion of livelihood activities connected to traditional and regional agricultural activities and also new or adapted activities or approaches that offer improved productivity or capacity for income-generation. Through strategies such as [2.1] Organic Agriculture (OA) or [2.2] Fair Trade/Eco-Labelling and Certifications, existing activities might be enhanced so as to improve marketability, trade opportunities, or monetary value of typical outputs. In contrast, through strategies such as [2.5] Fish Farming, livelihoods that are typically uncommon in landlocked ASAL regions might be implemented, especially in humanitarian contexts where skills and knowhow have been brought with displaced communities.
3. **Public Service and Infrastructure-Related Livelihood Opportunities**, which are those that support the creation of economic opportunities through the process of expanding or improving access to and capacity of the public services and basic infrastructure serving a community. Some examples discussed here include energy production, as in [3.1] Solar Power; waste management, as in [3.4] Cooperative Model for the Recycling Value Chain; and sanitation-related opportunities, as in [3.3] Black Soldier Fly (BSF) Waste Treatment.

I — Environmental Management and Ecosystem Services	II — Agriculture, Fish, and Livestock Value Chain Development	III — Public Service and Infrastructure-Related Livelihood Opportunities
1.1 — Payment for Ecosystem Services (PES)	2.1 — Organic Agriculture (OA)	3.1 — Solar Power
1.2 — The 'Gestion de Terroirs' (GT) Approach/ Participatory Catchment Approach	2.2 — Fair Trade/Eco-Labelling and Certifications	3.2 — Bioenergy/Biogas Production
1.3 — Community-Based Natural Resource Management (CBNRM)	2.3 — Medicinal Plants	3.3 — Black Soldier Fly (BSF) Waste Treatment
1.4 — Training, Research, and Agricultural Information Centres	2.4 — Honey Harvesting Around Laggas	3.4 — Cooperative Model for the Recycling Value Chain
1.5 — Integrated Watershed Management (IWM) Approach	2.5 — Fish Farming	
1.6 — Pastoralism and Rangeland Management	2.6 — Ecotourism/Agrotourism	
	2.7 — Smallholder Irrigation Management	
	2.8 — Integrated Soil-Fertility Management (ISFM)	
	2.9 — Optimising Water Usage	
	2.10 — Maximising the Potential for Micro-Climates	
	2.11 — Gully Rehabilitation and Planting	
	2.12 — Agro-ecological Crop Management	

Each section summarises a selection of practices with high potential for success in the contexts addressed in this guide, that could be further explored through field research, planning exercises, and design iterations in order to assess a community's social structure, cultural practices, built and natural resources, and needs in order to identify the opportunities and constraints of a particular location and the present communities. These programmes and initiatives could be implemented to enhance existing measures, as standalone schemes, or applied in various combinations. Implementation of the proposed opportunities should maximise synergies between the environmental context, (e.g., challenges and opportunities due to dryland conditions and desertification), the socioeconomic and cultural context, and the humanitarian-development context. It should also be noted that sectors such as transportation and cash-transfer models, though outside of the scope of this guide, are critical components of a successful integrated settlement and should be included in long-term socioeconomic development schemes, as well as considered in relation to these proposed growth opportunities.

Environmental Management and Ecosystem Services

1.1 – Payment for Ecosystem Services (PES)[318]

Payment for Ecosystem Services (PES) programs are economic instruments that provide financial incentives to land users to supply continuous beneficial environmental services, consequently promoting more sustainable livelihoods and land management practices. Payments often provide compensation for positive externalities, correcting a 'market failure' in which users in one location take actions that positively impact another location, but go uncompensated by the beneficiaries. However, PES could also be used to compensate for negative externalities, in which practices or infrastructure projects upstream, sometimes in another country, reduce yields or water flow to downstream areas. PES programmes generally rely on voluntary transactions for well-defined environmental or ecosystem services (ES) between an ES buyer and an ES provider (or benefactor), such as direct payments to upstream land users, or between companies and governments compensating for emissions.

In addition, the service must be either a measurable benefit (e.g., tons of carbon stored) or a change of land use. For example, PES initiatives in Sub-Saharan Africa have included paying for carbon storage in forests, watershed services, and Green Water Credits. And while these initiatives have, overall, had positive impacts, notable constraints included a lack of clearly defined property rights, difficulty quantifying land management services, challenges with determining prices, and insufficient institutional capacity to implement payment systems.

Case Study:
Equitable Payments for Watershed Services (EPWS) in Tanzania[319]

Figure 205 Man observing maize growth after changing his practices to Fanya Juu terraces[320]

Source: Erasto Massoro

Figure 206 Farmers excavating Fanya Juu terraces to reduce run off and improve crop production[321]

Source: Erasto Massoro, 2009

The Equitable Payments for Watershed Services (EPWS) programme in Tanzania uses PES incentive mechanisms to improve rural livelihoods by rewarding upstream landowners who adopt SLM measures which enhance the availability and/or quality of downstream water resources. SLM strategies implemented include excavation of terraces (especially Fanya Juu and Fanya chini bench terraces), agroforestry and reforestation, agronomic practices such as intercropping and legume crops, grass strip planting, and applications of manure and indigenous pesticides. In addition to SLM, sustainable livelihood activities were also implemented.

The EPWS approach is an effective pro-poor conservation initiative because it provides the necessary financial compensation for farmers to implement SLM strategies. Farmers are compensated up front with cash and through material support to establish the land use changes and then for delivery of watershed services (freshwater) as well as maintenance. The costs for this initiative are primarily covered through international donors (DANIDA) as well as investors from the private sector. EPWS helps bring SLM technologies to communities through capacity building and raising awareness of the benefits of SLM for land productivity. Groups of farmers are established to lead the implementation of SLM, while the programme provides supervision, support, and training of farmers to ensure effective implementation, efficient soil erosion control, and continued monitoring of hydrological and livelihood statuses. Methods include demonstration plots and farmer-to-farmer extension. Capacity building efforts incorporate gender mainstreaming, good governance, and relevant laws and policies. Efforts to promote gender inclusivity have already yielded positive results, with farmer groups comprised of more than 35% women.[322]

1.2 – The 'Gestion de Terroirs' (GT) Approach/ Participatory Catchment Approach[323]

The Gestion de Terroirs (GT) approach uses local empowerment and capacity building to address the immediate socio-economic needs of a local population as well as the long-term demand for sustainable land and natural resource management. Control over natural resources is transferred from a central government to the local people, with emphasis on the technical aspects of environmental protection, natural resource management, and integration of local knowledge. The GT approach focuses on natural resource management at the village or community level through three interrelated systems:

1. Technical projects, such as soil conservation
2. Socio-economic factors related to local organisational structures of livelihoods
3. The legal system and its administration, specifically related to the enforcement of use rights

The GT approach associates groups and communities through the notion of 'terroirs,' a socially and geographically defined space within which communities' resources and associated rights are located, while supporting skill-building and institutional development and enabling natural resources to be negotiated at a local level. It includes a combination of initiatives and elements such as Community-Based Natural Resource Management (CBNRM), resource conflict resolution facilitation through mutual management of resources and participatory appraisal, and identifying local priority concerns and goals.

The GT Approach has evolved significantly from a pilot programme in francophone West Africa addressing environmental degradation into a framework that is shaping general principles of community involvement in natural resource management. Past decades have shown a rapid expansion of the use of participatory approaches in natural resource management in the Sahel region of Africa. The World Bank, United Nations Development Program (UNDP), and several other small NGOs are major supporters of GT projects due to the potential for poverty reduction, local empowerment, and sustainable development within the Sahel.

1.3 – Community-Based Natural Resource Management (CBNRM)[324]

Community-Based Natural Resource Management (CBNRM) is generally associated with approaches where the community is the focal unit for joint natural resource management. In particular, decentralisation and governance reforms are initiated to enable a transition from a project-based approach toward legally institutionalised popular participation. A notable constraint, though, is that most current 'decentralisation' reforms are rendered ineffective due to an insufficient transfer of powers and funding to local institutions. In Kenya, for example, there have been numerous instances where municipality boards have faced major challenges in obtaining and decentralising power and resources from the county governments in order to implement their planning initiatives.

In response to these challenges, the CBNRM model instead relies on the use of community development and investment funds, which are part of a decentralisation policy that directly funds a community's own development efforts. The local population has sovereignty over these funds within a specific domain (e.g., agricultural intensification).

Landcare is a common community-based approach that helps local leaders build social capital through voluntarily resolving local problems while preserving land resources. This requires an effective partnership with both the government and business sectors as well as other organisations that can provide financial support and technical advice, enabling the integration of technical knowledge from scientific sources with indigenous knowledge and skills.

1.4 – Training, Research, and Agricultural Information Centres[325]

Skill building and knowledge sharing between refugees and host communities, in combination with inputs from technical experts and local farmers with knowledge of endemic methods, are essential to the development of new, innovative, and sustainable approaches to agricultural livelihoods.

The following initiatives have been successful in facilitating and promoting these highly effective collaborations in a variety of contexts:

- **Learning for Sustainability:** Describes a multi-level and multi-stakeholder approach with active, process-oriented and situated learning. This approach facilitates group learning processes related to sustainable development with the purpose of sharing knowledge and developing communal goals.

- **Farmer Field Schools (FFS) and Informal farmer study circles:** Describe a group learning approach that builds knowledge and capacity among land users to enable them to diagnose problems, identify solutions, and develop plans to implement them with or without external support. Such schools can bring together land users who live in similar ecological settings with comparable socio-economic and political conditions. FFS provide opportunities for learning-by-doing while extension workers, SLM specialists, or trained land users facilitate the learning process.
- **Local Innovation Initiatives:** identify traditional practices with a SLM potential and support recent innovations (e.g., self-help groups, self-teaching). This approach is based on the key notion that more attention and support should be given to local innovation as well as to traditional systems, rather than focusing solely on project based SLM implementation of standard technologies. These initiatives in particular support the transfer of knowledge within a community and over generations. Land users continuously adapt and experiment with new seeds and plants, as well as new practices and technologies, in order to cope with changing environmental conditions and new challenges. Adoption can then be supported through local institutions and community organisations such as land user groups, marketing cooperatives, irrigation and range management associations, women's groups, and land user to land user extension groups.

1.5 – Integrated Watershed Management (IWM) Approach[326]

The Integrated Watershed Management (IWM) Approach generates both private and communal livelihood co-benefits through wide-ranging technological and institutional interventions. The concept of IWM pushes the boundaries of traditional integrated technical interventions for soil and water conservation to incorporate restructuring institutional arrangements for collective action and market related innovations that support and diversify livelihoods. Similar to how the GT approach (1.2) is based on 'terroirs,' IWMA ties together the biophysical notion of a watershed as a functioning hydrological landscape unit with the social and institutional factors that regulate local demand and determine the viability and sustainability of resource management interventions.

1.6 – Pastoralism and Rangeland Management[327]

Within the context of an integrated settlement, it is essential to support, learn from, and leverage traditional ways of life that have sustained communities for centuries, while also providing support to enable necessary adaptations to the new challenges posed by climate change. These programs encourage and assist pastoralists in adopting opportunistic land use strategies.

In the last decade, traditional pastoral strategies have been increasingly recognised as economically viable, environmentally sustainable, and compatible with development goals, especially if effectively adapted to current environmental conditions. A common challenge for pastoralism and rangeland management is a lack of sustainable management of land use rights of pastoralists and farmers (and different sub-groups of the two categories), which is a frequent driver of conflict and cause of displacement in East Africa and the Horn of Africa. This is further aggravated by climate change, population growth, and increasingly unsustainable pastoralist practices.

As such, it is important to consider mobility patterns in resource planning, because these may be seasonal or follow a regular course between well-defined pasture areas and may be easily impacted by conditions such as erratic rainfall, evolving trade opportunities, and conflict.

Specific initiatives to support pastoral livelihoods include:

1. Establishing feed banks, which improve herd composition and health
2. Implementing denser well distribution to minimise conflict
3. Increasing water collection and storage through small-earth dams and other NbS
4. Operationalising inter-communal dialogue mechanisms for the identification, implementation, and monitoring of shared approaches for the use of land-based resources (including wood, grazing, agricultural land, water, etc.) and the prevention and resolution of conflicts arising from accessing such resources
5. Promoting adaptive grazing strategies
6. Developing equitable and sustainable land use plans
7. Improving access to markets
8. Promoting local empowerment and community activation

Case Study:
Migration Dialogues Between Host Communities and Pastoralists in South Sudan[328]

During the dry season, nomadic pastoralists travel over the border between Sudan and South Sudan to find water and grazing land for their livestock, before crossing back over to Sudan when the rains return.[329] During this annual migration, various communities and tribes come into contact, often competing over the same limited land and water resources. Unfortunately, this can often lead to conflict and violence between these communities. Nomadic movement is, however, a critical part of the regional economy, especially for the many living in the borderlands of both countries whose livelihoods depend on pastoralism.

This all occurs in the context of long and ongoing conflict in South Sudan, which contributes further to the challenges faced by nomadic pastoralists. It is well understood, as well, that disputes over land, resources, boundaries, and migration are major contributors to broader conflict and have often resulted in escalating violence.

In order to reduce tensions and address these challenges, the UN Mission in South Sudan (UNMISS) and the Civil Affairs Division (CAD) have sought to bring affected communities, the nomadic pastoralists and the various host communities, together for dialogue and to establish agreements in relation to the disputed territories. In order to maintain peace and address the underlying causes of conflict, these actors have undertaken these activities to promote social cohesion, manage conflict, and ultimately achieve reconciliation. It has been well understood that conflict over land and resources, especially between host communities and the migrant pastoralists, is one of the essential issues.

These activities have resulted in the creation of migration dialogues, which include a multi-stage approach that begins with planning meetings, followed by migration dialogues held in advance of any movement, and finally post-migration dialogues and exchanges based on experience and learnings. Prior to migration, nomadic communities that intend to move, especially across borders, can send representatives to visit host communities in order to meet with leaders to plan future migration. This process continues on through the pre-migration dialogue meetings between leaders from both communities to discuss on experiences from past seasons, the challenges that have arisen, and potential solutions based in a common understanding of the situation. Following the migratory season, leaders are reengaged to discuss on how the process as gone and critically to limit the possibility of conflict, which occurs most commonly at the end of the season. If any parts of the agreements have not been upheld, this is an opportunity to discuss and agree on ways to ameliorate any disagreements and avoid conflict escalating.

Together, these interventions have resulted in a series of positive results, including:

- Local agreements
- Improved social cohesion
- Increased trade opportunities and activity
- Reduction in conflict

Agriculture, Fish, and Livestock Value Chain Development

Refugee and host communities can maximise profits by leveraging international demand for certain types of products and experiences and by establishing a local "brand identity" that can build a reputation and value over time, while giving consumers the opportunity to directly support refugees and development. In addition, meeting certain certifications and standards can increase market value and marketability, as well.

In order to produce many of these desirable products and crops, though, farmers in flood prone drylands will need to implement NbS that maximise the water harvesting potential of intermittent rivers. These strategies help to improve land productivity and yields by utilising the most efficient, low-cost, and environmentally sustainable strategies and practices for agricultural production. They also enable farmers to extend the limited, but consistent, water resources while preparing for and leveraging, rather than fearing, flash flood events. When implemented, these strategies have the potential to provide immediate and long-term benefits for individuals and their families, both the environment and for the economy.[330]

2.1 - Organic Agriculture (OA)

Through a holistic production management system, avoiding the use of synthetic fertilizer, pesticides, or genetically modified organisms (GMOs), Organic Agriculture (OA) minimizes nitrogen pollution, conserves soil and water, and optimizes the health and productivity of interdependent communities of plants, animals, and people. In this way, farmers seek to maximise the potential of local resources by implementing a series of practices that optimise nutrient and energy flows and minimise risk.

These practices include:

1. Rotating crops
2. Expanding crop diversity
3. Combining a wider range of livestock and plants
4. Symbiotic nitrogen fixation with legumes
5. Application of organic manure
6. Biological pest controls, such as 'push-pull' methods (See #2.8 - Integrated Soil Fertility Management (ISFM))
7. Agro-ecological management of vegetable crops (e.g., placing nets over tomato crops instead of using intensive chemical fertilisers and pesticides)[331]

Case Study:
Organic Cotton – Ioba Province, Burkina Faso[332]

In the Ioba Province of Burkina Faso, by employing a circular farming model that relied on internal inputs and outputs, community members were able to improve income-generation through the cultivation and sale of organic cotton. The best adapted cotton variety was found to be an organic variety; not only did the quality (which had formerly been reduced with the use of Monsanto's genetically modified variety) improve in the long term, but so did return on investment, which led to improving profits despite smaller yields than both conventional and Genetically Modified methods.

The cultivation of Organic cotton depends on a combination of different measures, including:

1. The use of organic fertilizers (manure or compost) and the recycling of organic matter
2. Crop management and maintenance strategies such as weeding, crop rotation, and intercropping; in Ioba, crop rotations include cash crops such as sesame, as well as food crops such as cereals and legumes, while intercrops are typically those used for leguminous green manure and trap plants
3. careful selection of varieties adapted to local conditions (climate, soil, pests, and diseases)
4. biological pest management, such as organic 'bio-pesticides' that are produced using neem seeds (Azadirachta indica), in combination with careful monitoring of crops
5. clear separation of organic and conventional cropland, e.g., by growing border crops to avoid contact with chemical substances through spray drift or surface runoff
6. soil and water conservation measures

These measures help to improve soil fertility, reduce production costs (and therefore financial risk), and avoid many of the concerns associated with conventional farming such as declining yields, pest and disease resistance, contamination of water supply, and other environmental health hazards and challenges that are caused by the use of chemical fertilizers and pesticides.

By relying on a circular model and the higher market value for certified organic products, profitability of the farm was improved in the long-term despite reduced yields compared to conventional or genetically modified (GM) cotton. It is important to note, though, that a 3-year conversion period is needed for a farm to fully transition from a conventional system to an organic one, and farmers are required to maintain records and documents for periodic inspection and certification (internal control system), which may be a constraint in many refugee contexts, but can easily be addressed with minimal external support.

2.2 - Fair Trade/Eco-Labelling and Certifications

Fair Trade promotes equitable social relations, enhances trading conditions for small-scale businesses, improves labour conditions for employees, and empowers communities through ethical and sustainable trade. It involves producers, traders, retailers, support organisations, and the consumers of fair-trade products. Fair Trade is particularly effective in refugee camps because it helps provide market access to otherwise marginalised producers through direct connections with customers while simultaneously helping to reduce the number of middlemen involved.

As a result, it also provides higher wages than those typically paid to producers, while helping those same producers to develop knowledge and skills and incrementally build on resources to support long-term success. Moreover, Fair Trade promotes sustainable land management through consumers' preferences and production demand.

The Fair Trade certification system covers a growing range of products produced in Sub-Saharan Africa (SSA), including, coffee, cocoa, tea, cotton, fresh fruits, honey, spices, shea nut butter (beurre du karité), wine, flowers, and handicrafts. A label for organic production, or for ecological wood production (FSC),[333] serves as an incentive to implement service-level management (SLM) and allows the land user to earn a higher income on certain products. There is also potential for a range of labelling schemes that can be applied for in addition to fair trade and eco-labels, such as 'SLM-friendly' certified products. Other Eco-labelling schemes such as origin labelling may be used specifically in a humanitarian-development context to develop a "brand" for the camp.[334] In this scenario, products from the camp would be associated with high quality as well as positive socio-economic solutions, while forging deeper connections and mutual awareness among producers within refugee camps and consumers globally.

2.3 - Medicinal Plants

There are many medicinal plant species that are indigenous to Africa, including Devil's Claw (Harpagophytum procumbens) and Aloe Vera, which presents a major opportunity.[335] Aloe Vera, in particular, has a high international demand and there is significant local supply and knowledge in East Africa, where it presents a potential income opportunity for unskilled workers and vulnerable populations. Combined with Fair Trade markets that enable direct connections between growers and retailers, as well as strategies such as origin branding and eco-labelling strategies that were discussed in approach 2.2, medicinal plants may yield high profits for growers selling to an international market, with the added benefit of serving any existing demand for these products within settlements and among host communities, as well.

Case Study:
Medicinal Plants Used by Rwandan Traditional Healers in Refugee Camps in Tanzania[336]

This study from 2008 interviewed Rwandan traditional healers in refugee camps in Ngara District, Kagera region, Tanzania. They identified 57 medicinal plants which were grown and used within the refugee camps by healers to treat a myriad of physical and mental health problems.

2.4 - Honey Harvesting Around Laggas[337]

Well-managed ethical bee farming in sub-Saharan Africa may be an opportunity for a highly profitable conservation industry. There is high demand for honey internationally, and the product is conducive to increasing value with origin and eco-labelling schemes. In addition, sustainable honey harvesting protects a crucial pollinator, promotes biodiversity, preserves forests, provides sustainable income and business opportunities, and can even help mitigate human-wildlife conflict through "Beehive fences" positioned around a field of crops or a water source. Heavily vegetated riparian areas may provide ideal habitats for bees.

2.5 - Fish Farming[338]

Fish farming on intermittent rivers and even using human-made pits have high income-generating potential, if successfully implemented. They require a combination of nature-based water storage and harvesting solutions as well as capital investment from external organisations.

Case Study:
Fish Farming in Kakuma[339]

Despite the semi-arid climate, a Burundian refugee named Noah Ilambona was able to start a successful fish farm in Kakuma by digging a small pit behind his home, filling it with water, and purchasing fish from a local businessman who transports fish from Lake Turkana. Although many in the community were sceptical at first, Noah, who had been a fisherman for his entire life found a way to continue to utilise the skills that he had honed in Burundi before being forced to flee. The venture was well received in the community due to a high demand and low supply of fish. UNHCR helped him to significantly grow the venture and involve more members of the community, and the business has become very lucrative. The group now supplies 30 to 40 kg of fish every three months to the camp; experiencing such high demand that supply typically runs out in 3 days, and they make up to 15,000 shillings (USD $700) every three months from the project.

2.6 - Ecotourism/Agrotourism

Globally, there is increasing demand for opportunities to travel to ecologically rich and agriculturally innovative areas to understand the cultural and natural history of the environment. For example, it is estimated that in 2019 more than 2 million tourists visited Kenyan wildlife areas and contributed more than USD $1 billion, which accounts for more than 1% of the national GDP in that year.[340] In total, the tourism sector contributed more than USD $1.5 billion to the national GDP and employed around 1.6 million people in 2019.[341] In settlements where entry is not restricted, eco/agro-tourism initiatives can build on a reputation developed through the sale of Fair Trade and organic products. The establishment of a tourism industry could provide an overall boost to the local economy and create dozens of new jobs and income-generating activities in the process, which would, in turn, incentivise local communities and authorities to pursue efforts to maintain the integrity of the natural ecosystem and implement attractive and innovative NbS, such as Fanya-Juu.

2.7 - Smallholder Irrigation Management[342]

Intermittent rivers in humanitarian settlements provide opportunities to promote self-reliance, cooperation, and knowledge sharing through Smallholder Irrigation Management. With this strategy, riparian and adjacent areas can be designated for smallholder agriculture, and farmers can employ targeted NbS to irrigate their fields using runoff and even groundwater from the laggas. Smallholder Irrigation Management optimises water usage through more efficient systems including water collection and abstraction, storage, distribution, and application. In drylands, intermittent rivers, equipped with floodwater harvesting strategies such as spate irrigation are some of the most efficient farming systems within this context and offer major benefits in terms of varieties that can be planted, annual yields, and even the ability to extend the land's productive seasons by engaging in multi-cropping techniques.

Case Study:
Kalobeyei Kitchen Garden Programme

In Kalobeyei, each household is allocated space along the intermittent streams that run between the villages where they are encouraged to construct a kitchen garden outside of their home. These kitchen gardens have been associated with better food security, dietary diversity, and daily calorie intake. Residents are trained in a range of dryland agricultural techniques, and supported through the distribution of tools, seeds, and gardening materials. Most gardens use the 'sunken plot' technique designed to grow vegetables in contexts of limited water where holes of about 45 cm are dug and filled partway with topsoil. The soil is mixed with manure and spread on top, creating a surface layer to prevent desiccation.[343] Access to the water needed and to seeds to get started have proven to be the primary challenges.[344]

2.8 - Integrated Soil-Fertility Management (ISFM)[345]

Integrated Soil Fertility Management (ISFM) involves a combination of techniques to regenerate degraded soils in a way that maintains their fertility without over-exploiting the often-limited available nutrient resources. This approach aims to maximise efficient use of all natural resources, but in particular water and soil, through the implementation of conservation techniques.

ISFM is centred on three primary principles:

1. Sustainable agriculture requires maximising the use of organic and mineral fertilisers and the implementation of organic matter management practices, while the use of inorganic fertilisers should be minimised as much as possible.
2. In order to minimise the loss of nutrients and efficiently utilise the nutrients that are available, seeds (or other germplasm) that are well adapted (disease- and pest-resistant) to the local conditions should be utilised.
3. In order to efficiently utilise the scarce available nutrient resources, responsible agricultural practices should be implemented, such as:

- Coordinated planting dates
- Managed planting densities
- Weeding

The resulting increased nutrient replenishment and soil fertility maintenance will enhance crop yields and therefore increase food and livelihood security.

Case Study:
Anchor Farm Business Development Project, Malawi[346]

Launched in 2008 by the Clinton Development Initiative (CDI) and the Alliance for a Green Revolution, the Anchor Farm Project was established in the Mchinji District of Malawi to join smallholder farmers with a largescale commercial farming operation that would improve their access to markets and resources.

Through this program, more then 30,000 Malawian farmers, many of them women, have been trained on ISFM techniques such as:

1. Manuring
2. Composting
3. Crop rotation
4. Conservation farming using nitrogen fixing vegetation

As a result, participating farmers have been able to increase their yields, solicit higher prices, and reinvest in their farming activities as well as in other aspects of their lives. Additionally, more than two million trees have been planted, which provide new sources of fruit, timber for construction, fuel for household use, and importantly income generation.

Already the success of this project has received attention from the Malawian government and plans are underway to replicate the initiative in Tanzania.

2.9 - Optimising Water Usage[347]

Optimising water usage is an important and highly impactful strategy in any effort to expand agricultural activities, especially as a way to promote sustainable economic growth. Some of the most prominent approaches to optimising water usage include:

Rainfed Agriculture

The availability of water for plants can be increased through rainfed agriculture strategies that help to minimise runoff, improve the infiltration of surface water into the ground, and maximise the soil's capacity to store that rainfall over time.

Some examples of Rainfed Agriculture strategies include:

- Soil cover
- Composting
- Contour cultivation
- Conservation agriculture
- Earth / stone bunds
- Terracing
- Fanya juu

- Microbasins
- Vegetative strips
- Trash lines
- Runoff and floodwater farming
- Small dams

Irrigation

Irrigation is an important strategy in agriculture for minimising water loss and increasing water infiltration, especially where rain is inconsistent, unpredictable, or highly seasonal.

Some proven irrigation strategies that support these goals include:

- Lining canals
- Using deep and narrow instead of shallow and broad canals
- Drainage pipes
- Consistent maintenance

In addition, efficient and effective application of water can be achieved through strategies such as:

- Watering can irrigation
- Drip irrigation
- Micro sprinklers
- Low pressure irrigation systems
- Improved furrow irrigation
- Supplemental irrigation
- Deficit irrigation

Furthermore, some additional strategies that can help to promote the health and longevity of the local aquifer and recharge the groundwater supply, include:

- Water collection to enable off-season irrigation using small dams
- Farm ponds
- Subsurface tanks
- Percolation dams and tanks
- Diversion
- Recharging structures

Improving Water Uptake

Techniques such as afforestation, agroforestry, optimum crop rotation, intercropping, improved crop varieties, and optimising planting dates can all increase plant water uptake, which can in turn help to enable productive transpiration. In addition, water uptake can be promoted by supporting strong root health and development through techniques such as soil fertility and organic matter management, disease and pest control, and weed management.

Rainwater Harvesting[348]

Rainwater harvesting methods collect and concentrate rainfall to utilise it for agricultural or domestic uses in dry areas where water deficits are a primary limiting factor. Rainwater harvesting using NbS strategies is one of the more economical ways of securing water for household use as well as for farming and production, because harvesting techniques can be scaled to meet a wide range of needs. One of the key economic opportunities associated with Rainwater Harvesting is that it can reduce the significant amount of time that can be spent retrieving water by community members. As this task is often assigned to women and children, it can free women up to pursue economic activities and children to attend school.

2.10 - Maximising the Potential for Micro-Climates[349]

The riparian vegetation that is common to the zones surrounding intermittent river systems can help to promote the creation of micro-climates that are particularly favourable for agricultural activities. In order to effectively exploit these benefits, though, the potential for the creation of micro-climates should be encouraged through the deployment of techniques such as:

1. Reducing evapo-transpiration through windbreaks, agro-forestry, hedges, living barriers, parklands, good soil cover, dense canopy cover, etc.
2. Optimising temperature and radiation through agro-forestry, vegetative and non-vegetative mulch, etc.
3. Reducing the mechanical damage of plants through windbreaks, barriers, vegetative and non-vegetative mulch, etc.

2.11 – Gully Rehabilitation and Planting[350]

Gullies can be rehabilitated and utilised for productive, income generating use while simultaneously mitigating erosion risk through the implementation of Nature-based Solutions. Tree planting, natural grass regeneration, and structural interventions such as Micro-Basins (See NbS #2 Microcatchment) and Check Dams or Gully Plugs (*See NbS #1D - Check Dams/Gully Plugs) made of soil, stones, and branches are common methods for rehabilitating gullies and preventing further soil erosion.

Untreated and unutilised gullies should be considered a significant loss of productive agricultural land. 'Gully Gardens' constitute rich 'microenvironments' since they are well supplied with water and sediment from upstream. However, potential upstream and downstream conflicts must be considered when implementing these strategies. In order for the practice to be upscaled, research is required to investigate resource ownership issues related to the gullies and their runoff. In all cases, productive gullies also need to be protected from livestock.

This method, though, when successful, can allow farmers to produce resource-intensive and in-demand crops that would otherwise be unavailable. These crops are higher yielding and result in significantly greater proportional revenues compared to the input investments of capital, time, and labour. Potential cash crops include fruit trees, bananas, sugar cane (as in Tigray, Ethiopia), nut trees (e.g., cashew), vegetables, rubber trees, etc.

2.12 – Agro-ecological Crop Management

In order to maximise the production of nutritious and in-demand crops, such as fruits and vegetables, in drylands, it is advantageous to utilise Agro-ecological Crop Management techniques.[351] These strategies seek to implement the most sustainable and efficient farming systems and leverage opportunities for water harvesting. Agro-ecological management of vegetable crops can be as simple as placing nets over tomato crops to protect them from pests instead of using intensive chemical pesticides, a practice that should be encouraged.[352]

Some other examples of Agro-ecological Crop Management techniques include:

1. Flood Recession Farming (FRF), which uses the residual moisture from seasonal rivers between rainy seasons. This approach can have a significant impact on the production and income generation potential in arid areas. Furthermore, these crops are traditionally considered to be "women's crops," and therefore provide a potential income-generating activity for women.
2. Multi-Cropping, which is the practice of growing multiple crops on the same area of land in sequence over the course of a year, offers farmers the opportunity to grow more food on the same piece of land.[353] In contrast to monoculture farming, this approach can help to avoid market saturation and over-competition to promote a more cooperative model. However, it is important to consider factors such as land and water access and soil quality, because a mono-crop option or a single agricultural value chain may make sense when these resources are limited. It is also important not to be careful not to overtax the soil.

Case Study:
IKEA Foundation Cooperatives Model[354]

Over a seven-year period beginning in 2012, the IKEA Foundation partnered with UNHCR and invested approximately USD $100 million in the Dollo Ado Refugee Camp in Ethiopia. Although the funding was initially used for emergency relief, the foundation increasingly transitioned to supporting long-term initiatives for economic development and livelihood opportunities that benefited both refugees and the host community. The new goal became "to pilot a new and more sustainable model for refugee response that might ultimately be replicated on a larger scale elsewhere."[355] The IKEA Foundation's livelihoods and self-reliance grants were used to promote "diversified livelihood opportunities resulting in a global increase in household income through skills and vocational training, paid employment, agricultural programmes, livestock support, and business development."[356] The projects have mainly focused on agriculture, livestock value chain, energy, and the environment through a cooperative model facilitated by national and local implementing partners. By the end of 2018, the livelihoods programmes had created income-generating activities for more than 2,050 cooperative members.[357]

Based on findings, the Ikea Foundation and UNHCR developed a framework for building self-reliance, consisting of five critical factors: the political will of the host country, investment in infrastructure, the comparative advantage within the context (what market sectors have the most potential), socio-cultural appropriateness, and external inputs from both public and private sectors.[358] Investment in new and existing nature-based strategies, especially those developed from local knowledge and practices are essential to supporting climate adaptation and mitigation in refugee settlements and other vulnerable communities, while promoting healthier, more inclusive, sustainable, and resilient settlements.

Public Service and Infrastructure-Related Livelihood Opportunities

In the context of development and urbanisation, especially where refugee communities are present along intermittent rivers, there are important economic opportunities that appear in the form of the development of the public services and infrastructure for the emerging settlement. Most prominently, there are a number of activities related to energy production, waste management, sanitation, and other services that can all present livelihood opportunities for these communities and simultaneously promote the overall sustainability and resilience of the settlement.

The energy sector, for example, represents a major economic growth opportunity that is accessible at a multitude of scales, from meeting the needs of refugees and host communities at the household, neighbourhood, and settlement levels, to generating additional renewable power for sale to a broader market.

From a cost and risk perspective, though, improper waste management and sanitation practices, which are particularly common where adequate public services are not present, can be especially harmful in areas near freshwater and where communities are reliant on those water sources. Flash flooding, which is very common in areas with intermittent or seasonal rivers, will often bring flood waters into settlements where it can pass through pit latrines and other sanitation systems, which can result in the contamination of that water and consequently spread sewage throughout the settlement and into water supplies. Where people are in contact with that freshwater, as is often the case in resource constrained areas such as refugee camps and on arid or semi-arid land, this can present significant public health risks. As a result, practices that address these challenges can help to limit the amount of waste that ends up in riverbeds and reduce risk of contamination while also generating resources for the local community.

3.1 - Solar Power

Securing access to energy often persists as a major challenge in humanitarian and developing contexts, especially amongst refugee communities and in rural. Solar power, however, is a renewable energy source that can help to overcome this challenge, especially where infrastructure is limited and connection to a national grid service are not available.

In addition, though, increasing access to reliable energy can also help with efforts to expand access to water and support the creation of business opportunities. It can be used for water pumping for drinking and irrigation, as well as countless other clean energy applications. Solar powered micro-grids enable economic development, reduce the reliance on natural resources that can lead to land degradation, help communities save time that might be spent gathering fuel, water, or other resources, and increase public safety across communities, particularly for women.[359]

One particular benefit for many refugee settlements is that access to solar power can reduce demand for firewood, which is often a primary source of cooking fuel. This kind of reliance on firewood can result in the exploitation of existing woodlands, increased risk of SGBV for women and children responsible for collection, and increased tensions between communities as resources are depleted. Solar power, in contrast, could be used to power streetlamps, which can enable markets and public spaces to stay open longer while increasing safety for all users and allowing for more positive social interaction and economic exchange. Solar power could also be used to power health and education facilities as well as households and businesses. Furthermore, there is notable income-generating potential for mobile phone charging stations and operating money transfer services such as M-Pesa using solar power.

Case Studies:
Solar-Powered Boreholes in Kenya

In Turkana West in Kenya, only about 5% of the population had access to electricity as of 2018.[360] At that time, there were eight "hybrid" powered boreholes is Kakuma which run on a mix of solar and diesel and are expected to reduce operation and maintenance costs in water service delivery by around 40%.[361] While, in Dadaab, Africa's largest solar powered borehole, with 278 solar panels, provides 16,000 refugees with approximately 280,000 litres of water daily, safe for drinking, cooking, and personal hygiene.[362]

3.2 - Bioenergy/Biogas Production[363]

Bioenergy or Biogas is gas that is naturally produced during the decomposition of organic waste. The gas is captured in a storage tank (on site) to be used for household energy needs such as cooking, heating, and lighting. The most common form of input material is cow dung, making it particularly appropriate for rural settings.

The technology offers two major advantages:

1. Energy can be produced on-site and at a low cost from existing inputs that might otherwise be treated as waste
2. The resulting reduced usage of fuelwood, which translates into fewer trees being cut down, can contribute to reduced deforestation and land degradation

Because of the inputs, biogas is a suitable strategy for farms, cattle posts, or rural setting where the inputs are easily available. As a result of implementing this technology, energy can be saved at every level of use and produce positive environmental effects as a sustainable approach.

3.3 - Black Soldier Fly (BSF) Waste Treatment[364]

Managing solid and human waste is a major challenge for growing settlements with underdeveloped infrastructure, especially where effective waste management and sanitation systems are not in place. One technique that has been determined to be highly effective in helping to manage organic waste, though, is to utilise it as a feed substrate for the larvae of Black Soldier Flies (BSF), which are efficient at breaking down such waste.

Engaging in this practise can not only help to reduce waste that is typically disposed of in more resource intensive ways, but also produce a useful and productive by-product that can be used in agriculture.

Under optimal climate conditions, which are common to ASAL regions, high yielding organic waste materials, such as vegetable and poultry waste, can be reduced by as much as 50-80% when used as a feed substrate for Black Soldier Flies (BSF).[365] This process can also convert up to 20% of the waste material into larval biomass within around two weeks, which produces grown larvae which, in turn, make an excellent source of protein in animal feed. Feeding these waste materials to BSF larvae then has the potential to not only help manage sanitation and provide a source of protein in animal feed, but eventually, as edible insects become more widely accepted, a greater source of nutrition for humans, as well.[366] The sale of this by-product can offset waste treatment costs while also supporting agricultural activities and creating a good potential source of income generation.[367]

Case Study:
Sanergy, Nairobi, Kenya

In Nairobi, Kenya, for example, Sanergy, a Kenya-based social enterprise that has been operating there since 2011, is using BSF systems to address the challenges of sanitation and waste collection in Nairobi's informal settlements. According to the company's cofounder, "[i]n Nairobi, 66% of all faecal waste generated ends up untreated back in the ecosystem, polluting the environment and harming public health."[368] In response, Sanergy is developing systems (i.e., toilets and sanitation facilities) to gather and treat that waste and transform it into various productive and profitable outputs. By 2019, the company was already operating 2,500 toilets with a combined daily count of over 100,000 users.[369] The waste is gathered on a daily basis and transported to central processing facilities where large volumes of waste are transformed into products that can be used for agricultural purposes (e.g., organic fertilisers and animal feed) as well as biomass briquettes.[370, 371]

3.4 - Cooperative Model for the Recycling Value Chain[372]

Learning from existing waste management and recycling initiatives and coordinating with the private sector are essential components of establishing a beneficial waste management system. Optimising waste management through the recycling value chain may have positive economic impacts in addition to improving environment, health, and social cohesion. This may be achieved through community-based co-design processes and the creation of formal partnerships between private networks and humanitarian and development partners. For example, the growing waste conversion industry in Nairobi may create market potential for the sale of pre-processed waste to Nairobi. Potential private partnerships include:

1. **EcoPost –** Nairobi based social enterprise engaged in converting recycled waste plastics into a durable lumber alternative to preserve Kenyan forests and manage waste
2. **TakaTaka Solutions –** Nairobi company that is active in waste collection, sorting, recycling, and composting, as well as educating local farmers about the benefits of compost

Moreover, promoting ownership and decentralisation of waste management can promote adaptation of more sustainable practices at the neighbourhood level, as well as foster a sense of environmental responsibility.

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Children travelling along a main road where water streams in parallel. © UN-Habitat

Chapter 5: A Way Forward

I. Conclusions

In the context of protracted displacement, environmental challenges, such as those connected to the management of land that is occupied by growing settlements and the natural resources required to sustain them, are often some of the most difficult to address. Any large and sudden influx of migrants to an area will test the productivity of that land and its capacity to support an emerging urban condition and a rapidly growing population. This is particularly true where meaningful planning has not been undertaken previously and where existing services, infrastructure, and economic development are limited.

In addition, any influx of displaced people will be exposed to the natural hazards that already exist where they settle and will often have a very limited capacity to manage and respond to those risks due to the serious vulnerabilities that come with being displaced. As a settlement forms in this setting, the existing natural resources are often inevitably utilised in unsustainable ways that may result in rapid depletion, which may compound existing pressures on and increase the vulnerability of all present communities. In the drylands of the arid and semi-arid land regions of East Africa, these challenges can be particularly pronounced, especially where livelihoods are primarily reliant on the land and available natural resources and when combined with the increasingly severe effects of climate change.

In response, it's critical then that measures be taken to promote responsible land and resource use alongside the development of resilient livelihoods as part of planning for sustainable physical and economic development. The UN's Intergovernmental Panel on Climate Change, for example, has emphasised that "land degradation can be avoided, reduced or reversed by implementing sustainable land management, restoration and rehabilitation practices that simultaneously provide many co-benefits, including adaptation to and mitigation of climate change (high confidence)."[1] Achieving sustainable development of dryland livelihoods requires preventing desertification through sustainable land management (SLM) and restoring and rehabilitating degraded lands to maximise potential ecosystem benefits and strengthen human livelihoods and economies.[2] A broad suite of on-the-ground response measures exist to address desertification[3] ranging from improved fire and grazing management to the control of erosion, integrated crop, soil, and water management through infrastructure such as dams and solar-powered water pumping.[4]

The goal of this guide is to provide a general overview and analysis of the factors and conditions that should be considered when responding to these challenges, especially when accompanied by displacement. After providing a general introduction to the topics and exploring the geographic conditions of the focus area, the report explained the challenges and effects of desertification while

> **The planning and design of settlements near intermittent rivers must be contextually grounded with the acknowledgment that fluvial environments are dynamic and interactive systems.**

presenting some of the benefits and opportunities that might be leveraged where intermittent rivers are present. The report went on to provide an analysis of the humanitarian principles that are of particular relevance in the context of planning for dryland displacement and some additional resources to be considered alongside this one.

Then, in Chapter 4, which comprises the main body of the document, actionable strategies for sustainable land and resource management and opportunities for economic development were introduced in the form of a flexible "Kit of Parts." The chapter presented possible planning and design strategies that incorporate various techniques in landscape architecture, civil engineering, settlement development, and other urban and spatial planning approaches. The first section provided a collection of ecological and landscape strategies, which can help to manage risks and challenges in the specific context of ASAL regions in East Africa. It presented a selection of Nature-based Solutions, both traditional and more innovative ones, but all with a particular focus on the specific conditions found along intermittent rivers. This report emphasises the importance of incorporating local knowledge into any design process in order to create solutions that are appropriate to and effective for a specific context, but that also draw on traditional knowledge and techniques that may not be as familiar to those tasked with planning there.

In the second part, a complementary selection of economic development and livelihood opportunities is presented to promote a multi-faceted approach. These various suggestions dealt with managing and gathering water in this context while integrating sustainable land use and resource management with socio-economic incentives or production of outputs that can support capacity building and value chain development. Throughout the section, case studies were also presented to demonstrate the application of these various NbS and sustainable socio-economic approaches and to begin to direct practitioners to relevant examples and possible partners or advisors.

In this final chapter, some preliminary design concepts will be presented to suggest how various strategies might be implemented alongside one another in the right context to leverage their various strengths and combine for compounding benefits. In this way, these proposals seek to provide inspiration to humanitarian-development actors on how the guide might be practically and creatively implemented in the field. Importantly, these proposals also provide a connection between the physical planning recommendations and the socio-economic opportunities presented in Chapter 4 in order to demonstrate how they might complement each other. Nevertheless, the strategies can be used separately or combined to maximise water harvesting potential, address impacts of land degradation by controlling erosion, boost soil fertility, and act as flood mitigation strategies. In addition, these proposals should be taken as initial inspiration and do not offer a comprehensive application of the provided "Kit of Parts."

II. Preliminary Design Proposals

The purpose of this section is to propose some preliminary examples for how the strategies from the 'Kit of Parts' presented in the previous chapter might be implemented in practice alongside one another. The described planning and design strategies which can be used alone but also in various combinations should be selected thoughtfully in order to achieve compounding benefits across sectors and on multiple dimensions. Preliminary research and planning activities should therefore always be undertaken in order to establish a common baseline understanding of the legal, geographic, ecological, climatic, cultural, demographic, economic, governance, and humanitarian constraints of any given site and context.

The purpose of these proposals is to demonstrate the versatility of the various techniques and solutions and provide some practical examples of how they can be part of a larger humanitarian and development strategy for not only managing land and resources, but also in improving access to water, limiting exposure to natural risks like drought and flooding, and increasing access to economic and livelihood opportunities to support sustainable development and limit further displacement and migration.

In this section, three unique design proposals are presented which integrate a combination of the strategies and opportunities described in Chapter 4. Each proposal shows diverse scenarios within the extreme opposing conditions of ASAL regions that result from long dry seasons and periodically (seasonally) heavy rains, especially where intermittent rivers occur. They each incorporate a selection of land and resource management strategies and furthermore suggest various economic and livelihood opportunities that might be explored alongside their implementation and linkages to the relevant SDG targets.

1C 2C

Design Proposal #1: Water Spreading Bunds with Kitchen Gardens

This proposed design strategy integrates the nature-based water spreading technology of **[1C] Water Spreading Bunds** with the Kitchen Garden model, a socioeconomic initiative that promotes land productivity and self-reliance through small-scale agriculture using small household scale sunken plots. The water spreading bunds are located between the shelters and an intermittent river, enabling land users to leverage floodwater from the river while also controlling it, therefore mitigating risk of damage to their shelters and the gardens. The kitchen gardens allow families to grow produce for their own home use, while any excess can be traded for other crops, products, and services or sold for small monetary profits in local markets.

In addition to Water Spreading Bunds, other small-scale NbS, such as **[2C] Compost Baskets**, can also be employed to improve quality and yields within the plots, which are already embedded to promote water infiltration. During dry seasons, gardens may be able to use residual moisture to grow drought-tolerant crops, while others can be repurposed as gathering spaces to facilitate knowledge-sharing and skill development, as play areas for children where they can be easily supervised by family members while they work, and for alternative livelihoods such as making fair-trade products. The integration of NbS with income-generating activities creates a financial incentive to implement and maintain sustainable practices.

Figure 207 Design Proposal #1 during the wet season

An illustration of a scenario where Water Spreading Bunds and Kitchen Gardens have been successfully implemented during the rainy season to promote crop growth and biodiversity

Relevant Socioeconomic Opportunities

Wet Season

- 1.1 – Payment for Ecosystem Services (PES)
- 1.5 – Integrated Watershed Management (IWM) Approach
- 2.1 – Organic Agriculture (OA)
- 2.3 – Medicinal Plants
- 2.7 – Smallholder Irrigation Management
- 2.8 – Integrated Soil-Fertility Management (ISFM)
- 2.9 – Optimising Water Usage
- 2.10 – Maximising the Potential for Micro-Climates
- 2.12 – Agro-ecological Crop Management

Dry Season

- 1.4 – Training, Research, and Agricultural Information Centres
- 2.2 – Fair Trade/Eco-Labelling and Certifications
- 2.9 – Optimising Water Usage
- 3.4 – Cooperative Model for the Recycling Value Chain

Figure 208 Design Proposal #1 during the dry season

An illustration of that same scenario where Water Spreading Bunds and Kitchen Gardens have been successfully utilised during the dry season for alternative uses

SDG Targets

1-4 1-5 2-1 2-3 2-4

4-7 5-4 6-4 6-5 6-6

6-A 6-B 8-1 8-4 9-1

9-A 10-7 11-5 11-B 12-2

13-1 13-2 13-3 15-1 15-3

15-5 15-A 17-7

Aerial view of the Tarach River, Turkana County, Kenya. © UN-Habitat

1E 2G

Design Proposal #2: Floodable Amphitheatre

This proposed design strategy combines **[1E] Permeable Rock Dams** and **[2G] Bench Terraces** to form a floodable vegetated amphitheatre. Stone lined bench terraces are excavated directly upstream of the dam and water-tolerant trees are planted perpendicular to the contour in rows. During the dry season, the amphitheatre's stage area becomes a multi-purpose public space, used for performances, recreation, congregating, education, and more. The tree-lined bench terraces provide ideal shaded seating. During the rainy season, the amphitheatre is intentionally flooded and used for water collection, storage, and harvesting. The dam helps mitigate and control flooding to prevent damage to the surrounding area while also improving soil fertility through infiltration.

Figure 209 Design Proposal #2 during the wet season

An Illustration of a Terraced Permeable Rock Dam Amphitheatre during the rainy season

Relevant Socioeconomic Opportunities:

Wet Season

- 2.3 - Medicinal Plants
- 2.5 - Fish Farming
- 2.6 - Ecotourism/Agrotourism
- 2.8 - Integrated Soil-Fertility Management (ISFM)
- 2.9 - Optimising Water Usage
- 2.10 - Maximising the Potential for Micro-Climates

Dry Season

- 1.4 - Training, Research, and Agricultural Information Centres
- 2.2 - Fair Trade/Eco-Labelling and Certifications
- 2.6 - Ecotourism/Agrotourism
- 2.8 - Integrated Soil-Fertility Management (ISFM)

Figure 210 Design Proposal #2 during the dry season

An Illustration of that same Terraced Permeable Rock Dam Amphitheatre during the dry season showing public space usage

SDG Targets


1-5
2-1
2-4
4-7
6-4
6-5
6-6
6-A
6-B
8-4
8-9
9-1
9-A
11-5
11-B
12-2
13-1
15-1
15-3
15-5
15-A
17-7

Aerial view of Kakuma Settlement Camp, Turkana County in Kenya. © UN-Habitat

3C

Design Proposal #3: Sand Dam Orchard and Productive Public Space

This proposed design strategy aims to demonstrate that the area surrounding a **[3C] Sand Dam** has the potential to form a key productive public space where a collective of community members could receive compensation for contributing to the maintenance of the land and the dam itself while participating in agricultural activities along the riverbanks and surrounding area. Sand Dams promote soil fertility, which makes the surrounding area an ideal location for the development of an orchard and/or other more demanding, high value crops and trees. Rest, play, and other recreation facilities should be emphasised to promote the inclusion of women in income-generating activities who might be restricted to working alongside child-friendly spaces. Spaces can also be created that are accessible and welcoming to elderly community members and those with disabilities, as well. Furthermore, an adjacent orchard's biodiversity could also be leveraged for other sustainable income-generating activities such as honey harvesting. Floodwater and residual moisture could be used for flood-based farming methods along the riverbanks during both the wet and dry seasons and the nutrient-rich soil that collects behind the Sand Dam should be periodically harvested in order to support those farming activities and protect the longevity of the dam. Riverbed farming itself is not recommended due to the unpredictability of intermittent rivers and the speed at which flooding can occur and present very real dangers.

Figure 211 Design Proposal #3 during the wet season

Sand Dam and orchard during the wet season, including flood-rise agriculture system for water-tolerant crops

Relevant Socioeconomic Opportunities:

Wet Season

- 1.1 - Payment for Ecosystem Services (PES)
- 1.3 - Community-Based Natural Resource Management (CBNRM)
- 2.1 - Organic Agriculture (OA)
- 2.4 - Honey Harvesting Around Laggas
- 2.8 - Integrated Soil-Fertility Management (ISFM)
- 2.9 - Optimising Water Usage
- 2.10 - Maximising the Potential for Micro-Climates
- 2.11 - Gully Rehabilitation and Planting
- 2.12 - Agro-ecological Crop Management

Dry Season

- 1.4 - Training, Research, and Agricultural Information Centres
- 2.8 - Integrated Soil-Fertility Management (ISFM)

Figure 212 Design Proposal #3 during the dry season

Sand Dam and orchard during the dry season, including flood recession-based irrigation for crop production during the dry season

SDG Targets


1-4
1-5
2-1
2-3
2-4
4-7
5-4
6-4
6-5
6-6
6-A
6-B
8-1
8-4
9-1
9-A
10-7
11-5
11-B
12-2
13-1
13-2
13-3
15-1
15-3
15-5
15-A
17-7

III. Evaluation and Implementation

The often unpredictable nature of rain patterns and flooding within the specific context of ASAL regions must be well understood to determine which interventions might be appropriate in any given context. In areas where there is a significant variation in rainfall seasonally or from year to year, for example, the implementation of inappropriate strategies can lead to social conflicts over access to limited water, as well as technical difficulties that may lead to failure or compound existing problems. Thereby it's critical to consider the impact that any intervention might have on access to water, the need for regular adjustments over time, and the demand for maintenance.

Ability to properly respond to change or maintain an intervention over time depend significantly on the site-specific resources and capacity such as knowledge, technical experience, community participation, public acceptance and adoption, available skilled and unskilled labour, adequate technology, and infrastructure. Furthermore, there are various site-specific environmental and physical challenges like soil composition, water table depths, and the slope and contours of the land that must be considered in order to ensure the success of various strategies. It must be well understood that altering the existing flows of water and other natural processes has the potential for adverse effects and unanticipated consequences. To avoid negative potentialities, an extensive prior site analysis is essential, and interventions should be monitored, maintained, and continually iterated on as necessary.

Although this list requires further study and it should not be understood to be comprehensive, in order to perform a thorough evaluation of any context and determine which strategies are most appropriate and applicable in any given location, some factors, indicators, and conditions that should be considered include:

1. Environmental and Physical

- **Topography –** What are the geographic conditions of the land and what kind of topography and slope is exhibited?
- **Soil Conditions –** What type(s) of soil are present? To what depth does the present soil cover extend to?
- **Water Table –** At what depth does the water table lie? What kind of variation in water table depth is experienced seasonally? Can the water table depth be predicted to rise or fall in the coming years?
- **Water Quality –** What is the quality of the water found there? For what purposes can it be used? Does it need to be treated (e.g., filtered, desalinated)?
- **Annual Rainfall –** How much annual rainfall can be expected based on historic records?

2. Economic

- **Estimated Costs –** What are the estimated costs of implementation based on local material and labour costs? How can those costs be offset? Which economic opportunities can help to offset implementation and maintenance costs in order to promote sustainable solutions?
- **Timeframe –** How long will a given strategy take to implement and how long will any physical components take to construct? How long before benefits can be realised and initial costs recuperated if funded locally? How often will maintenance be required?
- **Resource Availability –** What resources and materials for construction and implementation (e.g., stones, sand, concrete, timber, artificial lining materials, stone face, storage facilities,) are available?

3. Social

- **Local Capacity –** What is the capacity of the local community, including skills, knowledge, and buy-in, for initial implementation and continued maintenance over time?
- **Local Engagement –** How engaged is the local community in other participatory initiatives? Is the local community open to and supportive of experimenting with more traditional techniques in place of more complicated and costly interventions that might require outside support in order to achieve?
- **Downstream Effect –** What kind of downstream effects might be anticipated as a result of any intervention? It's important to understand how any intervention will impact the broader region. Especially in the context of intermittent rivers, there can often be unintended downstream consequences of implementing the types of interventions presented here.

Together, an assessment that includes these considerations will provide a valuable understanding of context and allow practitioners to make an informed selection of which strategies or techniques are appropriate and may offer the greatest potential benefits. It is recommended that humanitarian-development actors work collaboratively with affected communities, local institutions, and other stakeholders to develop context-specific solutions that address the key factors and conditions discussed above. Monitoring and evaluation mechanisms should also be put in place to assess the effectiveness of solutions over time and make necessary adjustments.

In addition, in order to improve the viability and practicability of these strategies in a given context and encourage the successful implementation and adoption of Sustainable Land Management (SLM) practices while further supporting the development of both environmental and economic resilience, some broader goals that should be adopted include:

- Improve access to and quality of infrastructure public facilities in order to ensure delivery of reliable basic services
- Regularise and secure land tenure systems and structures
- Diversify the local and regional economy and expand livelihood options in order to reduce reliance on activities that are particularly vulnerable to environmental factors, such as agricultural and pastoralist activities
- Expand access to local, regional, and international markets with improved connectivity and trading opportunities
- Strengthen capacity for collective action
- Develop a greater understanding gender-specific differences over land use and land management practices
- Develop, enable, and promote access to clean energy sources and technologies
- Institute policy responses to drought risk based on proactive preparedness strategies and risk mitigation
- Combine economic and social inclusion strategies for food security and poverty reduction and eradication alongside any climate adaptation and mitigation solutions

Far from comprehensive, these recommendations help to support the premise that short-term thinking is not enough. Long term planning is essential to sustainable development of the vulnerable lands along intermittent reivers, especially those affected by humanitarian challenges. As part of a holistic approach to development in dryland areas, financial, institutional, and political support are necessary for promoting the widespread adoption of Sustainable Land Management (SLM) measures based on both indigenous and local knowledge (ILK) as well as modern technological innovations. Together, these improvements can help to encourage the adoption of SLM practices while simultaneously introducing alternative livelihood opportunities outside of agriculture and ensuring that undertaken strategies are affectively managed, adapted, and expanded, as necessary, over time.

Furthermore, in order to strengthen this guide and increase its usefulness and practicability, it is recommended that this set of criteria and considerations be further developed and tested in order to guide and assist users in selecting the most appropriate solutions for a given site and a specific context. Of course, it's important that the visible physical conditions of a site be understood and considered, but it is equally as important that social, cultural, economic, climatic, geologic, geographic, policy, and other conditions be well understood to inform and guide any planning or design decisions.

IV. Land Governance and Tenure Security

All legitimate tenure rights should be recognised, recorded, and protected in line with the continuum of land rights approach. This would enable all the land rights holders, including individuals and communities, to engage in and contribute to the sustainable management of drylands and to land degradation neutrality initiatives as decision-makers and to benefit from the positive impact achieved.[5] It would also contribute to a more sustainable use of land and reduction of conflicts over its ownership or use.

Good land governance and functioning land management systems are crucial for the protection of land rights. They create an enabling environment for land degradation neutrality and are indispensable for the resolution of land conflicts and the sustainable use of land resources. Conflict-sensitive, fit-for-purpose land administration plays a key role in documenting land rights, protecting land tenure security, supporting sustainable land use, and preventing or resolving land disputes, which are all essential elements to combating land degradation and ensuring good land governance.

Fit-for-purpose land administration can also play a role in supporting the voluntary return of displaced people, contribute to securing women's land rights, and address land-related historical injustices, which are frequent root causes of conflict and displacement, therefore constituting a critical component of peacebuilding.[6] Enhancing access to justice and strengthening multiple dispute resolution mechanisms that may co-exist on the ground can mitigate land-related conflicts and address some of the causes of land degradation and desertification. These include the lack of investment in sustainable land-use practices, the reluctance to invest in land restoration and land degradation neutrality actions.

V. Looking Forward

Looking forward, there remains a need to continue to develop, refine, and expand the strategies and spatial design proposals presented in this document. This will require ongoing research and collaboration with communities and stakeholders. It will also be important to develop monitoring and evaluation frameworks that can be used to assess the effectiveness of these strategies over time. The challenges of displacement in drylands are likely to become more acute in the coming years, as the impacts of climate change continue to contribute to growing displacement and the vulnerability of more communities. As such, there is a growing need to invest in long-term, sustainable solutions that can support affected communities in the face of these challenges.

Because this guide provides a diverse range of solutions and opportunities that can be considered, it is critical that the present conditions in a given location be thoroughly evaluated before any strategy is selected or implemented. This guide should be utilised responsibly. Any intervention should be adopted only after a well-informed understanding of the context is developed. Any solution should be adapted, as needed, to fit the given particularities. Good intentions are not enough to ensure success, because one approach might work quite well in one context while being disruptive in another, resulting in unforeseen consequences and unnecessary harm.

As suggested through the preliminary design proposals presented in this chapter, there remains a meaningful opportunity to continue to explore further examples of where multiple strategies can be implemented alongside economic opportunities in order to demonstrate a more a varied selection of ideas and recommendations that might suggest other creative, innovative, and integrated new approaches. There is also a need to develop further opportunities for multi-purposing affected lands through the expanded integration of public spaces into these design proposals.

Finally, it is important to recognize that climate adaptation, natural resource management, economic development, and displacement are all complex and multifaceted challenges that cannot be addressed through a single set of strategies. Instead, it will be necessary to continue to develop a range of solutions that can be adapted to meet the unique needs of different communities and contexts. Further research should be undertaken in order to explore and assemble additional opportunities for the integrated and multi-purpose use of land selected for the implementation of these strategies. How can efforts to respond to the challenges of managing land and natural resources along intermittent rivers offer opportunities not only for livelihoods and economic development, but also for social benefit? One opportunity, for example, that deserves further study involves the opportunities for integration of these strategies with the creation of vibrant and inclusive public spaces, for example. By working together and building on the insights presented in this document, we can make meaningful progress towards addressing the challenges of displacement in drylands.

Endnotes

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Annex: Developing Along Intermittent Rivers in Kenya

In this Annex section, a particular focus is given to the relevant policies and guidelines that apply in Kenya. Kenyan statutes that specify required buffer space measurements between rivers and development are outlined below. Other geographically relevant considerations covered by the Kenyan National Environment Management Authority's (NEMA) Integrated National Landuse Guidelines[1] are then highlighted in the second part of this annex.

I. Riparian Buffer Guidelines

One of the most critical factors in planning along rivers is allowing for a setback or "buffer space" between the water and any planned development, known as a Riparian Buffer. This area often represents the area that would be flooded in a storm event likely to occur once in every 100 years. Meeting national and local requirements for this buffer area can be confusing because water levels fluctuate significantly between rainy and dry seasons, and water may not visible year-round; however, in dryland areas of East Africa – where floods are also a part of the water cycle and can devastate infrastructure, households, lives and livelihoods – establishing a baseline distance between rivers and development is as important around intermittent rivers as it is around perennial rivers.

The conditions which have been broadly outlined in the previous sections of this report are, of course, not entirely new, but to the contrary, have and are contributing to the formulation and further development of national guidelines concerning buffer space along rivers. However, minimum standards for buffer space between rivers and development exist on a country-by-country basis and need to be investigated before considering development opportunities along rivers, both perennial and intermittent. Furthermore, even within countries, discrepancies exist in how much space should be allocated for the ebb and flow of rivers. These standards are often not associated with only one particular act or regulation, but to the contrary, are typically spread over an array of different pieces of national legislation. To illustrate this, the regulations concerning buffer space development along rivers in Kenya are outlined in the table below.

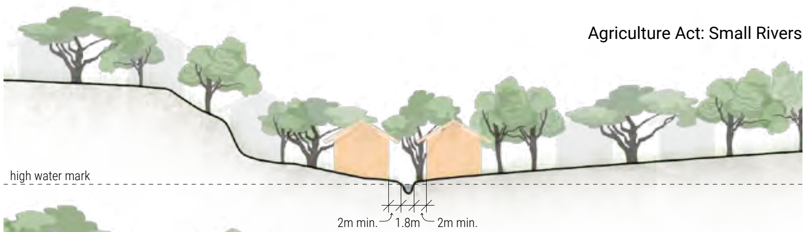
Statute	Recommended buffer space between river and development
Water Act (2002/2012)	**Riparian buffer:** 1. 6m minimum, or equal to width of water course, with a maximum 30m buffer on either side, measured from top edge of the bank. 2. Level with 2m vertical height or 30m horizontal distance, measured from the highest recorded water level. Building of permanent structures shall not be done within a minimum of 6m or equal to the full width of the water course up to a maximum of 30m on either side of its banks.[2] The riparian land on each side of a watercourse shall be defined as a minimum of 6m or equal to the full width of the watercourse up to a maximum of 30m on either side of the bank. The width of the watercourse shall be equal to the distance between the top edges of its banks. The riparian land shall be measured from the top edge of the bank of the watercourse and this shall also apply to seasonal and perennial watercourses.[3] The riparian land adjacent to a lake, reservoir or stagnant body of water shall be defined as minimum of 2m vertical height 30m horizontal distance, whichever is less, from the highest recorded water level.[4] **Activities proscribed on riparian land are:** • Tillage or cultivation; • Clearing of indigenous trees or vegetation; • Building of permanent structures; • Disposal of any form of waste within the riparian land; • Excavation of soil or development of quarries; • Planting of exotic species that may have adverse effect to the water resource; • Or any other activity that in the opinion of the Authority and other relevant stakeholders may degrade the water resource.[5]
Environmental Management and Coordination Act (EMCA) (1999/2012)	**Riparian buffer:** minimum 6m, maximum 30m from highest recorded flood level. No person shall cultivate or undertake any development activity within full width of a river or stream to a minimum of 6 metres and a maximum of 30 metres on either side based on the highest recorded flood level… which may not necessarily be the top edge of a river.[6]
Agriculture Act Cap. 318 (1986/2012)	**Riparian buffer:** equal to width of watercourse, minimum 2m (for small rivers), maximum 30m. Any person who, except with the written permission of an authorised officer, cultivates or destroys the soil, or cuts down any vegetation or depastures any livestock, on any land lying within 2 metres of a watercourse, or, in the case of a watercourse more than 2 metres wide, within a distance equal to the width of that watercourse to a maximum of 30 metres, shall be guilty of an offence.[7] Nothing in this Act or any rules made thereunder shall prejudice or affect the provisions of the Water Act (Cap. 372), and where anything in this Act or any rule is inconsistent with any such provision that provision shall prevail.[8]
Physical Planning Act Cap. 286 (2010/2012)	**Riparian buffer:** minimum 10m. During the submission of sub-division plans for consideration for approval, reserves provided along any river, stream or watercourse shall not be less than 10 metres wide, on each bank. This applies except in areas where there is established flooding.[9] Wayleaves or reserves along any river, stream or water course shall be provided of not less than 10 metres in width on each bank, except in areas where there is an established flooding.[10]
Survey Act Cap. 299 (2010/2012)	**Riparian buffer:** minimum 30m for tidal rivers and lakes, no mention of smaller rivers, measured from high water mark. Only applies to rivers on public land. Minimum 30 meters in width above high water mark for tidal rivers only. No mention of other smaller rivers. Minister has discretion in special cases.[11] Tidal River Reservations: On all tidal rivers a reservation of not less than 30 metres in width above high-water shall be made for Government purposes: Provided that, the Minister may direct that the width of this reservation shall be less than 30 metres in special cases.[12]
Local Government Act (1998/2012)	**Riparian buffer:** 3m, 6m, equal to width of river or twice the width of the river. Ad hoc to a planner's discretion: 3m, 6m; in some instances, it is taken as equal width of the river or twice the width of the river.[13]

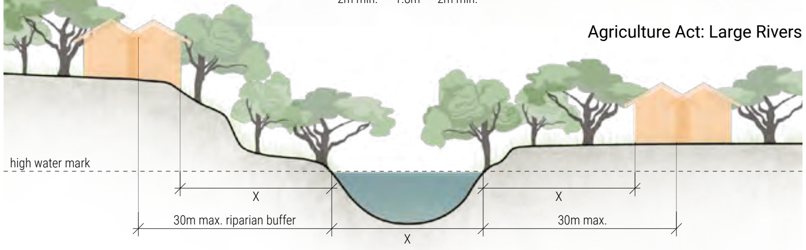
City Council By-Law	**Riparian buffer:** Maximum 30m measured from high water mark.
National Environment Management Authority Land Use Guidelines (2011)	**Riparian buffer:** Equal to width of the watercourse, minimum 2m (for small rivers), maximum 30m measured from the highest water mark. Provide buffer zones of between 2m - 30m width measured from the highest water mark for rivers/ streams depending on the width, water volume, whether permanent or seasonal and the use of that water. Where the highest water mark cannot be determined consider the width of the river on either side to arrive at an appropriate buffer.[14] The distance of cultivated land from rivers should be 30m from the highest water-mark during peak of the rainy season. The minimum on both side of the river should be 2m for small rivers and maximum of 30m. Generally the standard should be the same size of the river on both sides of the river, with a minimum of 2m and up to a maximum of 30m.[15]

Figure 213 Riparian corridor guidelines and recommendations based on Kenyan national policies

Agriculture Act

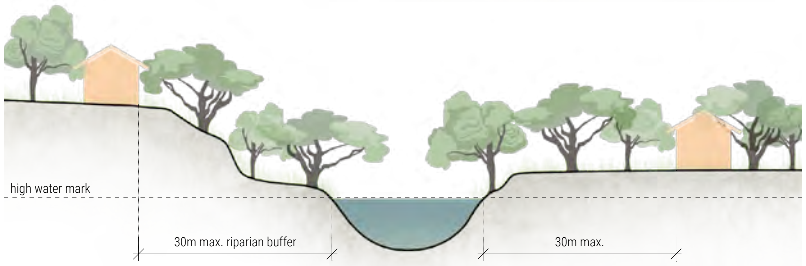
The Agriculture Act stipulates that interference on either side of the river within a distance equal to the width of the water course (X), up to a maximum of 30m, is prohibited by law. Interfering within a minimum of 2m from the edge of small rivers is prohibited for rivers under 2m wide.*





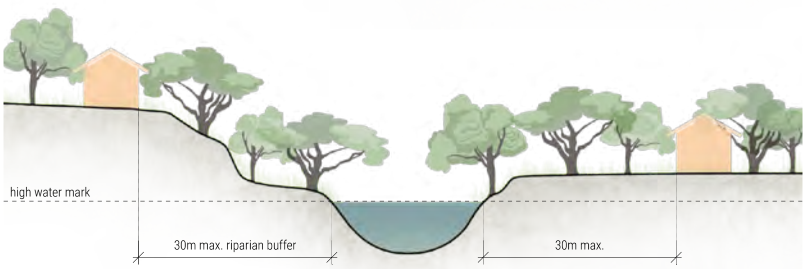
Survey Act

The Survey stipulates that, for tidal rivers on public land, a minimum of 30m must be provided as buffer space on either side of the river, measured from the high water mark.



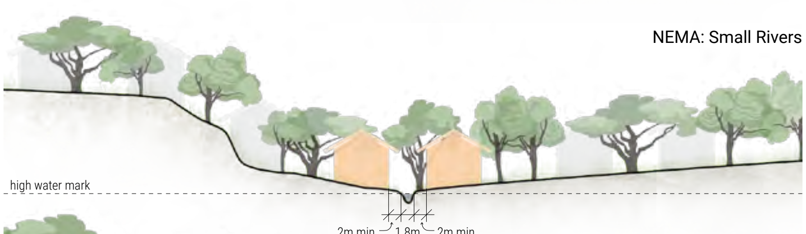
City Council By-laws

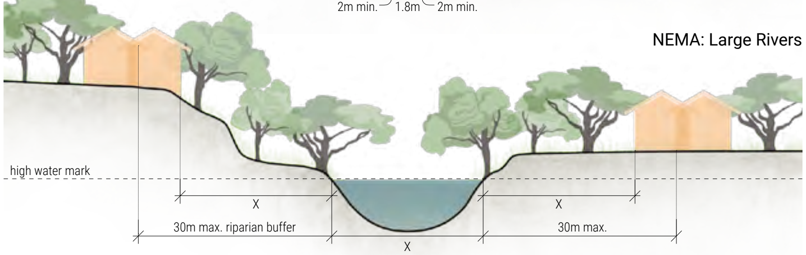
The City Council Bylaws require a maximum buffer of 30m on either side of the river, measured from the high water mark.



National Environment Management Authority (NEMA) Land Use Guidelines

NEMA's Land Use Guidelines require a buffer zone between rivers and cultivated land equal to the width of the watercourse, with a maximum width of 30m and a minimum width of 2m for small rivers; measured from the high water mark.





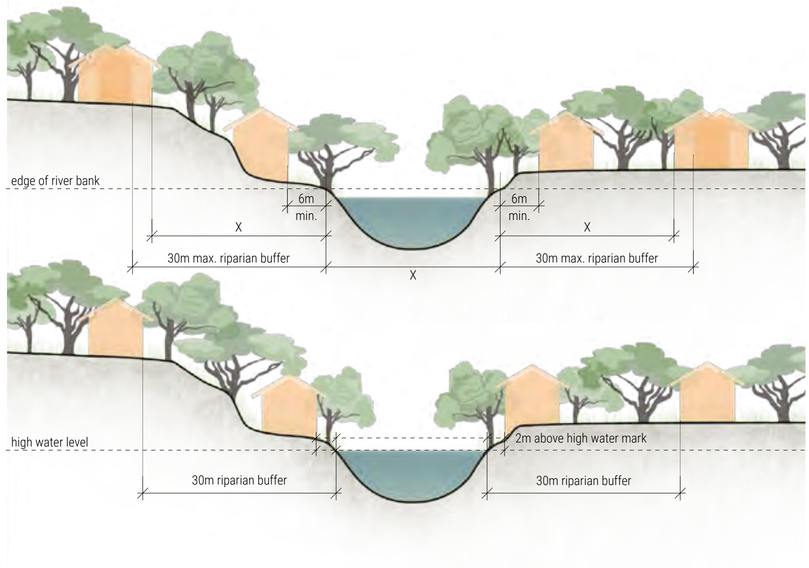
*Measured from high water point when statute does not specify

Figure 214 Riparian corridor guidelines and recommendations based on Kenyan national policies

Water Act

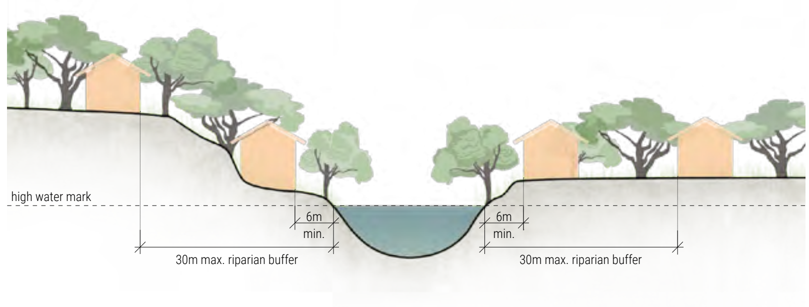
1. The Water Act stipulates that permanent structures are not be built within a minimum of 6m or within a distance equal to the full width of the water course (X), up to a maximum of 30m measured from the top edge of each bank.

2. The Water Act defines riparian land to include land that is a minimum of 2m vertical height or 30m horizontal distance, whichever is less, from the highest recorded water level.



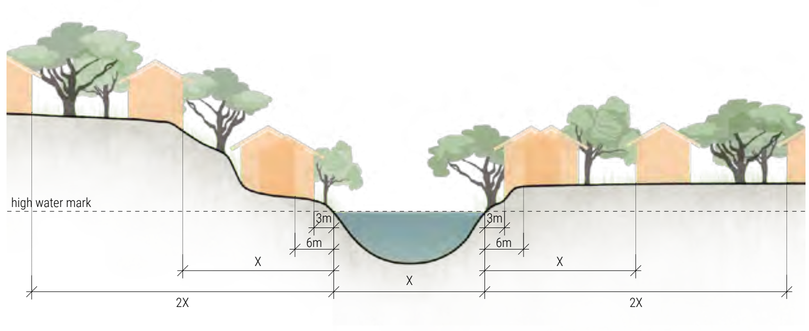
Environmental Management and Coordination Act (EMCA)

The EMCA prohibits cultivation or development within a minimum of 6m from either side of the river, up to a maximum buffer of 30m on either side, measured from the highest recorded flood level.



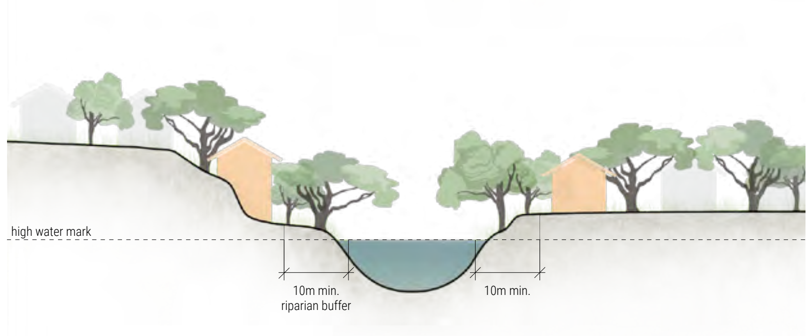
Local Government Act

The Local Government Act recommends that the width of the riparian buffer be either 3m, 6m, or equal to width of river (X) or twice the width of the river (2X).*



Physical Planning Act

The Physical Planning Act stipulates that approval must be granted for planned development within 10m of a water course.*



*Measured from high water point when statute does not specify

II. National Environment Management Authority Land Use Guidelines, 2011

3.1.1 Guidelines for Rivers and Lakes

Riparian Areas

I. Management of the riparian areas should be considered once they are identified - specify activities that can be allowed in such areas such as bee keeping and indigenous vegetation through WRUAs and District Environment Committees (DECs) who can come up with by-laws.

II. All activities within the riparian area must be reviewed and approved by DECs.

Conservation

I. Preserve the aesthetic and biological values of the rivers and streams as part of open space system.

II. Preserve and maintain the rivers, natural streams and drainage ways within the developed areas by designating them as part of the open space system. To the extent possible, limit any modifications to natural gulches and drainage ways, unless they are necessary for flood protection, to preserve water quality and protect aesthetic and biological resources.

III. If modifications are necessary, mitigate impacts on biological habitats by using stream-side vegetation, rip-rap boulder lining of stream banks, v-shaped bottom channels to maintain a stream flow during low rainfall periods, and other designs to enhance aeration.

IV. The WRUAs (Water Resources User Associations) shall incorporate best management practices that prevent pollution of rivers, streams, wetlands, near shore waters, lake setbacks, utilize erosion control devices; integrated pest management plans, and rehabilitate disturbed areas.

V. Water Management

» Integrate planned improvements to the drainage system into the open space system by emphasizing the use of retention basins and recreational access in the design approach.

» Establish permanent in-stream flow standards for perennial streams. These standards should weigh the benefits of in-stream and non-stream uses of water resources, including the economic impact of restrictions of such uses.

VI. Planting

Discourage the planting of eucalyptus and invasive species in the water resource areas while giving preference to alternative species such as bamboo among others as envisioned in the “Guidelines on Eucalyptus” developed by the Kenya Forest Service (KFS).

VII. Land Use

Where possible, provide public access to these open spaces and for recreational purposes.

Limit uses in these areas to conservation, compatible recreation such as hiking, fishing, religious and cultural practices and controlled diversion for agricultural purposes.

Survey

I. Develop monitoring plans for discharge of effluents into the aquatic environment to ensure that standards are met.

II. Carry out Environmental Impact Assessment (EIA) for activities likely to have negative impacts on the river/ stream, lake, wetland and ground water.

3.1.2 Guidelines for Wetlands and Wetlands Resources

Conservation

I. A wetland shall under no circumstance be drained. Bunding of fields to control the water level within the wetland must similarly ensure that the water table does not fall below about 0.5 metres of the soil surface. Users of a wetland must ensure that the overall water balance is maintained so that the surface does not dry out.

II. Ridging and trenching may be performed within the wetland, allowing the growth of crops requiring drier soils, as long as the water level does not fall below 0.5 metres from the top of the ridges.

III. Environmentally significant wetlands should be declared protected areas for the purposes of their protection and develop management plans for their sustainable use incorporating zoning (wise use) principles. Protection can be achieved through fee acquisition, land banking, cooperative agreements with public agencies and private landowners, conservation easements and other strategies.

IV. Efforts should be made to rehabilitate degraded wetlands through exclusivity to allow natural regeneration, enrichment planting and controlled use. Efforts should be encouraged to construct wetlands for effluent management

Income Generating Activities

I. Any change of use of a wetland must allow those beneficial traditional uses to continue without loss or hindrances of any other user. These benefits may include cutting of papyrus, trees, reeds, grass, water supply, fishing and grazing among others.

II. Harvesting macrophytes is a traditional usage, which should always be catered in the planning of multipurpose use of wetlands. The frequency of harvesting one area should not be greater than once in every 15 months, otherwise the rate of growth and the amount, which can be harvested, will decline. Separate areas should be set aside to be harvested in sequence, so that a continuous supply of papyrus can be maintained.

III. Clearing of wetland vegetation, for purposes other than domestic use should only be done with the approval of the DEC.

IV. The DEC should control all activities in wetlands (e.g. regulating brick making, sand and clay harvesting) requiring that the users form voluntary societies and where necessary be licensed in accordance with the EMCA (Wetland Regulations) of 2009. Sensitize opinion leaders' especially political leadership on the importance of conserving the wetlands.

V. Aquaculture

» Fish ponds constructed within a wetland should be constructed on the sloping sides of the wetland. The recommended practice is to make use of gravity flow of water from the spring line, which often arises from the soils at the edges of the wetlands. Wastewater from the ponds may be allowed to flow into the wetland. It is unwise to site a fishpond low in a wetland, as seasonal flooding can cause loss of stock and damage to bunding.

» Promote and regulate the development of an aquaculture centre and nature reserves around the wetlands that would serve as an attraction for both visitors and residents. It could feature a working aquaculture farm and include educational programs on modern aquaculture techniques and the history of the wetlands. The facility could also include walkways extending into the wetlands for interpretive nature walks.

VI. Grazing Land

» Grazing of cattle in wetlands, particularly seasonal wetlands, is permitted but this should be considered as a public amenity to all those who require it, and access must be in consultation with the stakeholders and fencing should not be erected to exclude any user or group of users.

» Notwithstanding the paragraph above, there will be a maximum total number of cattle, which will be able to use the productivity of the wetland sustainably. This number will vary from place to place, and so the DEC in consultation with the cattle owners should advice on the optimum numbers to be kept in any particular wetland.

» Where wetlands are located in protected areas, the cattle owners shall seek permission to access the wetland from the relevant lead agency. It must be ensured that all areas upstream and around a wetland are properly managed to prevent wetland degradation. Growth of wetland plants should be allowed at the edges of riverbanks.

3.1.3 Guidelines for Groundwater Management

Threat Mitigation

I. Locate industries and other activities that are likely to cause pollution or changes to groundwater away from ground water areas/sources used for water supply.

II. Control industrial development, settlements and other human activities on known ground water recharge zones in order to control possible ground water pollution and allow recharge.

Water Management

I. Develop mechanisms to allow ground water recharge through damming, artificial ground water recharge and enhancing precipitation infiltration by allowing certain percentage of land free of pavements

II. Provide for a buffer zone between the irrigation schemes and ground water sources and natural water bodies.

3.9.1 Guidelines on Agricultural Land

Riparian Areas

I. Discourage cultivation on areas identified and demarcated as riparian – the distance of cultivated land from rivers should be 30m from the highest water-mark during peak of the rainy season. The minimum on both side of the river should be 2m for small rivers and maximum of 30m. Generally the standard should be the same size of the river on both sides of the river, with a minimum of 2m and up to a maximum of 30m.

Nature-Based Strategies

I. Cultivation on the slopes from 0% - 12% contour farming is recommended and to use soil conservation measures; 12% - 55% one is obliged to apply soil conservation measures; and above 55% one should plant perennial/ permanent crops (e.g. Napier, grass, tea and bananas and trees).

II. Protection of the soil against erosion: plough and plant along the contours, practice crop rotation, apply manure to crops, leave crop residue on the ground and practice terracing.

3.9.8 Guidelines on Livestock Rearing

Water Points

I. Ensure that the siting, distribution and density of water points is done in consultation with relevant stakeholders after doing an EIA.

II. Encourage rotational grazing (wet season and dry season grazing areas) through regulated grazing procedures developed by grazing committees.

III. Locate livestock and human water points in consultation with public health officers and the DEC.

IV. Control human settlements near watering points.

Threat Mitigation

I. Develop conflict resolution mechanism by forming natural resource committees and ensure adequate facilitation.

II. Develop early warning and disaster management systems.

3.11.1 Guidelines for Flood-Prone Areas

Assessment

I. Identify and map flood prone areas

II. Undertake an EIA (Environment Impact Assessment) for proposed construction of dykes and dams

Risk Mitigation

I. Flood early warning system

II. Nature-based Interventions

- » Carry out afforestation, tree-planting, water and soil conservation in catchment areas and along water courses
- » Control the flow of water along water courses using appropriate technology through Construction of flood control structures such as dykes and dams
- » Encourage the planting of water-logged tolerant crops (e.g. rice, arrow roots) in flood plains

III. Human Settlements

- » Discourage human settlement in flood-prone plains
- » Create a buffer zone between the flood plain and human settlement as a contingency measure to ensure safety of the local community
- » Involve the local communities in the construction of water-flow control structures

Endnotes

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11 SUSTAINABLE CITIES AND COMMUNITIES