Evaluating the impact of natural resource management interventions on land, water and pastoral livelihoods in the Afar Region of Ethiopia

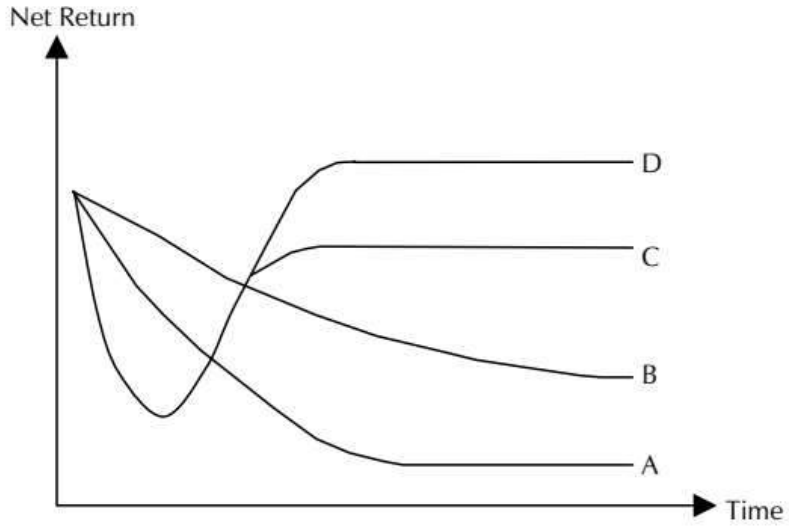
Roger Calow, Eva Ludi and Florence Pichon

Draft Research Report v1, January 2018,

ODI

Contents

Figures and Tables



1 Natural Resource Management and Rural Livelihoods: Interventions and Outcomes

Key Messages

The relationship between rural poverty and the environment is complex and dynamic, but if well managed, natural resources are a renewable source of social and economic benefits for the rural poor.

Natural resource management interventions have evolved towards participatory, pro-poor approaches that explicitly recognise human dependence on the natural world.

Most soil and water conservation activities are done at a micro-scale, which can create a mosaic effect of many self-contained watershed development efforts. Building institutional linkages between micro and macro-watersheds is key for managing upstream and downstream interactions.

There is a lack of rigorous monitoring of natural resource management interventions, including soil and water conservation interventions. A rigorous M&E system should track off-site (upstream and downstream) impacts, poverty reduction and social outcomes, and both land-based changes and changes in the hydrological cycle.

Natural resource management interventions can create an uneven distribution of costs and benefits because people use and access natural resources differently. Without a mechanism to ensure inclusive participation, marginalised people are at risk of being even worse off than before the intervention.

1.1 Introduction

The majority of the world's one billion poor live in rural communities, where their livelihoods are underpinned by natural resources such as land, water, forests, pasture, and fisheries.[1] Dependence on these resources is a double-edged sword; when natural ecological systems are healthy, they provide a source of subsistence and economic opportunity for the poor. When natural resources are under pressure, however, people are left without the means to sustain themselves and their families. As trends of climate change, land degradation, water scarcity, and loss of biodiversity accelerate across the globe, the importance of restoring and sustaining the natural resource base has become an urgent issue for alleviating rural poverty.

Efforts to raise the productivity of natural resources must first recognize the complicated and sometimes counter-intuitive dynamics between rural poverty and the environment. When the rural poor over-extract natural resources they depend on, they damage the environment in ways that fuel poverty, creating a self-reinforcing cycle of degradation and impoverishment. Equally, poverty reduction and environmental management can be de-coupled; some efforts to restore the environment have worsened poverty by excluding the poor from accessing resources they depend on (USAID, 2006). Other efforts to alleviate poverty have improved living standards but worsened environmental conditions through pollution and over extraction (Reed, 2001). Yet natural resources are renewable, and they provide goods and services that have economic and social benefits for the poor. On balance, evidence shows that *well designed* and carefully implemented natural resource management interventions can create the conditions for sustainable livelihoods, producing a win-win scenario for both the poor and the environment.

[1] As defined by the World Bank's international poverty line.

As understanding of these relationships have evolved, community-based natural resource management has gained prominence in international development interventions, marking a conceptual departure from "development" as an export-driven exploitation of natural resources for industrialization. The 1992 Rio Earth Summit reshaped development policy towards a human centric, pro-poor sustainable development agenda that explicitly recognized people's right to a life in harmony with nature (United Nations, 1992). Today, natural resource management interventions have a greater focus on participation of the people that depend on the resource, as well as building capacity for sustainable resource management amongst local institutions. This has been done with mixed success; because political and social boundaries do not overlap perfectly with boundaries of ecological systems, defining the appropriate spatial and political unit to manage the natural resource base is a difficult balance to strike (Darghouth, Ward, Gambarelli, Styger, & Roux, 2008).

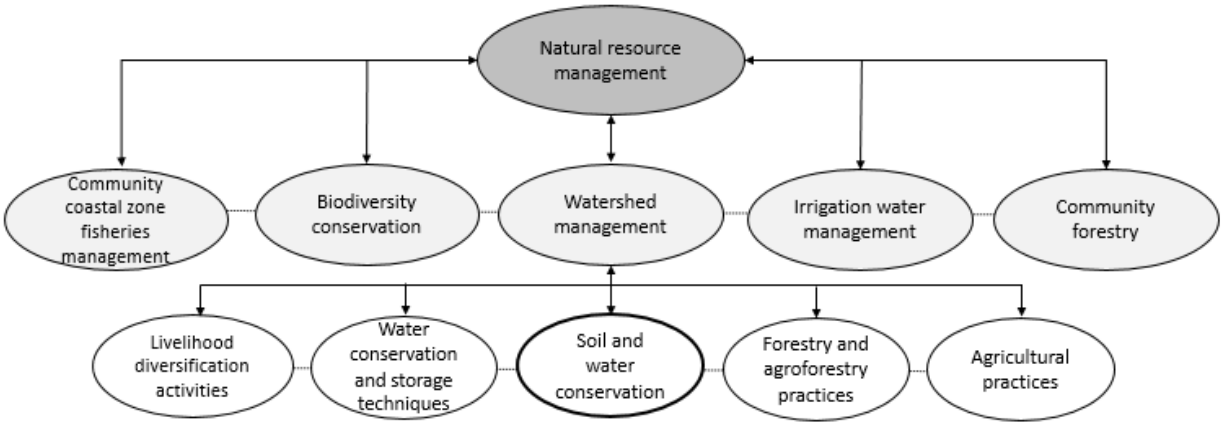
Key to restoring natural ecosystems is acknowledging that natural resource management interventions produce an uneven distribution of costs and benefits, and explicitly trying to address these. Within the same community, richer and poorer people use and access natural resources in diverse ways, with the rich generally able to exercise greater claims to resources. Simple, technocratic approaches to natural resource management that do not recognize different, overlapping, and sometimes conflicting uses of natural resources are likely to reinforce patterns of inequality or inadvertently favour some groups over others (Kerr & Chung, Evaluationg Watershed Management Projects., 2002). Benefits of natural resource management are spread sequentially, too; the slow delivery of benefits over time can make it difficult to achieve sufficient buy-in from stakeholders that do not understand biological processes or expect immediate, tangible benefits from development interventions (Kerr, Milne, Chhotray, Baumann, & James, 2007). Addressing the time horizon of natural resource management interventions and the heterogeneity of resource users is important for ensuring benefits do not accrue only to some groups or that worthwhile efforts are prematurely abandoned.

1.2 Types of Natural Resource Management Interventions

Natural resource management interventions cover a broad spectrum of activities across different ecological zones, and which intend to support diverse livelihoods. They range from community forestry, biodiversity conservation, coastal zone fisheries management, to watershed management, to name a few (see Figure 1). This review will focus on watershed management, and more specifically, on soil and water conservation initiatives.

Watershed management is a cornerstone of many natural resource management strategies. Watershed management is intended to optimise the use of water, soil, and vegetation in a given area to strengthen the natural resource base, make agriculture more productive, and ensure sustainable livelihoods (Kerr, Milne, Chhotray, Baumann, & James, 2007). Watershed management projects are implemented in an area that drains to a common point – which can range from a transboundary river system to a micro watershed along a small slope. The watershed is linked by an interconnected hydrological relationship, through both surface water and groundwater.

Figure 1: A typology of natural resource management interventions



Source: Author's illustration.

Soil and water conservation technologies are a common starting point for a watershed development project. These measures can be broadly defined into four categories – physical, agronomic, vegetative and management (Table 1). These four categories of soil and water conservation technologies intend to control erosion and improve soil quality, manage the flow of runoff and increase recharge and groundwater levels in the watershed. A structure is put in place to reduce erosion, which in turn reduces the amount of silt that is carried by runoff water and halts gullying of the land. Soil and water conservation technologies often include water harvesting structures, which are aimed at increasing soil moisture or are used to provide water for productive purposes such as irrigation. Alternatively, soil and water conservation can focus on a specific farmer's land, using terracing, stone or vegetative barriers, or small barriers along the slope to reduce erosion, trap water and sediments and make it more amenable for cultivation (Kerr, Milne, Chhotray, Baumann, & James, 2007).

If successful, these measures are designed to improve rural water supply, increase drought resilience, further agricultural productivity and achieve food security for the rural poor who depend on the land. Water spreading weirs and associated dry stone measures promoted by the Ethiopian Government and supported by GIZ in Afar Region are one of these soil and water conservation technologies (Figure 2).

Table 1: Soil and water conservation measures

Type	Activities	Characteristics
Agronomic	Composting, manuring, mulching; crop rotation	Can relatively easily be integrated into normal farming practices, require relatively low inputs, but frequently have a direct and rapid impact on crop productivity.
Vegetative	Agroforestry systems, protective bushland, vegetative strips, etc.	Often multi-purpose: reforestation has conservation effects through achieving better ground cover while also being directly useful for the production of fodder, fruits, firewood, as well as for nitrogen fixation. However, they can also directly compete with crops for nutrients, water and land, and are therefore not always beneficial.

Physical	Stone terraces, check dams, retention reservoirs, artificial waterways, etc.	Physical structures are hardly ever adequate on their own, and commonly involve high investment and maintenance costs.
Management	Land management practices; area closure (see box 3); pasture management	They represent a precondition for effective watershed management. Especially important to regulate grazing land.

Source: (Ludi, Water for Food Security. Lessons learned from a review of water-related interventions, 2017)

A soil and water conservation project in one part of the watershed will necessarily have an impact on hydrology and natural resources in another part of the watershed, which adds another layer of complexity to improving the productivity of the natural resource base and creating sustainable benefits for the people living upstream and downstream of the intervention. In practice, many watershed development interventions focus on a micro-watershed, creating a 'mosaic' effect of many self-contained, local watershed development initiatives. Though the mosaic effect is not optimal when it does not link to the macro-watershed, focusing on the local level has some advantages. Small-scale projects can have more intensive and face-to-face interaction with local stakeholders, and it is more cost effective to focus intensively at the local level than trying to control a much larger system (FAO, 2006).

1.3 Approaches and modalities for implementation

1.3.1 Funding

Despite the low-cost options available, soil and water conservation is often not a profitable investment for smallholder farmers. Without the requisite knowledge and expertise, soil and water conservation measures are unlikely to be successful. Subsidized initial investments are required and farmers need to be supported throughout the process of implementing a soil and water conservation technology (Ludi, Economic Analysis of Soil Conservation. Case studies from the Highlands of Amhara Region, Ethiopia., 2003).

Though restored landscapes provide ecosystem services that are, in theory, a public good, generating public funds to support watershed management remains a challenge in developing countries. Stepping in to fill the gap, international donors have played a central role in financing watershed management across Latin America, Asia and Africa, which has in turn led to the proliferation of various approaches by development agents.

Increasingly, projects are being implemented in partnership with national and local governments, with opportunities to join funds and achieve greater political buy-in. One such example is Ethiopia's Productive Safety Net Programme, which finances soil and water conservation work across the country. Section 4.1.3 provides more information about the initiative.

1.3.2 Design

Approaches vary from project to project, as different interventions must invariably be adapted to the local environment, social and economic conditions, and the institutional context. Understanding the hydrological nature of the intervention site is typically the first step of a soil and water conservation programme, and appropriate conservation measures are selected depending on the type of agroecological zone and land uses in the area. Though natural resource management interventions combine components from different approaches, a few generic approaches are outlined here:

Collaborative watershed management – An approach that emphasizes active stakeholder engagement, recognizes the authority of multiple agencies, and draws on resources and technical

expertise across sectors. This approach capitalises on the complementarity of different actors and their role in watershed management. One example of such an initiative is the United States' Clean Water Action Plan, which promotes this approach (Erdogan, 2013).

Landscape planning approach – An approach that focuses on scientific understanding of natural system and links this understanding to sustainable community development. Landscape planning is a participatory method that allows for different land uses through zoning, which should respond to the different priorities of stakeholders. This approach is used by IUCN and the World Wildlife Fund (Darghouth, Ward, Gambarelli, Styger, & Roux, 2008).

Payment for ecosystem services – This approach offers land owners or users payment in return for implementing natural resource management activities. By rewarding conservation efforts financially, this approach increases the incentives for participation of stakeholders in natural resource management initiatives which can create benefits that accrue to users further downstream in the watershed. This approach has been trialled in Latin America (Kerr, Pangare, & Pangare, Watershed Development Projects in India. An Evaluation., 2002).

Participatory approaches – An approach that attempts to foster community ownership by involving all stakeholders with an interest in the watershed, so that they may participate in decisions that affect them and receive some of the benefits that accrue from the initiative (Turton, Warner, & Groom, 1998). In an evaluation of five different approaches to watershed management, (Kerr, Pangare, & Pangare, Watershed Development Projects in India. An Evaluation., 2002) found that participatory projects were more successful in protecting upper catchments.

1.3.3 The Role of Local Actors

Marking a shift away from the top-down management of watersheds common in the 1970s, the participation of local communities is now considered essential for effective natural resource management programmes. Participatory approaches are designed to increase ownership of the intervention, and in turn enhance the long-term sustainability of the project. Through community participation, natural resource management interventions can be shaped to be more socially and politically acceptable to local stakeholders. In Ethiopia, soil and water conservation designs must follow national standards, manuals and guidelines for participatory and community-led natural resource management planning and implementation.

In theory, soil and water conservation initiatives are based on voluntary participation, operating under the assumption that the benefits of restoring ecosystem services are self-evident to participants. Although evidence from India shows that participatory approaches are more effective, building an equitable and effective participatory management arrangement is challenging (Kerr, Pangare, & Pangare, Watershed Development Projects in India. An Evaluation., 2002). Different stakeholders may have conflicting interests, and watersheds typically cover areas that are not governed by a single social or political entity. Participatory management affect power dynamics within and between communities, and thus must be deployed with a careful commitment to equity and inclusion.

Participatory approaches should also consider the differences in access to soil and water conservation benefits between stakeholders. Landowners will receive direct benefits from conservation measures, while landless people may not benefit or be able to afford to participate. Several studies of watershed management programmes in India have found that landless farmers did not benefit at all, and inequalities within the community increased as a result of the intervention (Sharma & Scott, 2005).

Furthermore, stakeholders' entitlements and socioeconomic position affect their motives to participate in soil and water conservation interventions. In an assessment of farmers' participation in

soil and water conservation activities in Ethiopia's Gusha Temela watershed, (Biratu & Asmamaw, 2016) reported that farmers had perceived the existence of soil erosion problems on their farm land and had good motives to participate in the programme. However, in a similar study in Ethiopia's North-Western Highlands, (Moges & Taye, 2017) indicate that the farmers' decision to *invest* in soil and water conservation technologies was highly determined by socioeconomic, institutional, attitudinal and biophysical factors (for instance, education level, access to training, land ownership, plot size, slope type and extension contact). For this reason, understanding the constraints to farmers' motivation to use and invest in such technologies is an important first step to designing and implementing a successful programme.

1.3.4 Monitoring performance

Natural resource management interventions require a system to track performance against stated objectives that can track physical and socio-economic outcomes over time. For interventions that state poverty reduction as an objective, the M&E system should be able to link project inputs to outputs, to outcomes, and finally, to development objectives. A conventional development project monitors on-site changes, such as agricultural production, water availability, or poverty reduction. For a watershed development intervention, this is only one piece of the puzzle: the project's monitoring system should also be tracking downstream, off-site environmental impacts that may be affected by an upstream intervention, including reduced sedimentation, changes in flood pattern, and increased biodiversity and wildlife.

The complications associated with tracking project 'externalities' have discouraged M&E systems from attempting to capture these. As a result, comprehensive M&E systems for natural resource management that track downstream environmental outcomes are rare (Darghouth, Ward, Gambarelli, Styger, & Roux, 2008). Still, monitoring changes beyond the direct intervention site is essential to understand and justify the project's achievements.

Even regarding on-site impacts, monitoring and evaluation systems for natural resource management interventions have traditionally been inadequate, lacking the robust scientific monitoring to track whether the hydrological impacts across the watershed are progressing as planned, and whether that has resulted in positive and equitable socio-economic benefits for participants (Darghouth, Ward, Gambarelli, Styger, & Roux, 2008). As a result, natural resource management evaluations lack the evidence needed to substantiate claims about what projects can achieve. Common shortfalls of these evaluations include the oversimplification of the multiple and variable factors affecting crop yield (from transpiration to slope gradient, organic matter content to fertiliser use), the absence of comprehensive baseline data, and the lack of control sites to track progress.

Box 1: Making the case for investing in natural resource management: The Economics of Land Degradation Initiative

Land degradation can wipe out livelihoods and ecosystems, but its costs are not well documented. To generate robust evidence about the benefits of sustainable land management, the flagship Economics of Land Degradation (ELD) initiative applied robust economic and physical analysis to natural resource management interventions across the world. The initiative sets out a method to analyze the costs of land degradation and the economic benefits of land-based ecosystems. Ethiopia features as a case study in ELD's global analysis. In the study, the Water and Land Resource Centre and Centre for Development and Environment examine the economic implications of soil degradation and land management practices in Ethiopia's rainfed agricultural areas.

Using remote sensing data to derive land cover, the team developed spatial data sets to map land use and any conservation efforts (using stone terraces and soil bunds, for instance) in agricultural areas. The team used these maps to estimate current soil erosion and crop production, and used these data to

compare current and future crop production up to 2045, modeling scenarios in which different land management options are taken.

The analysis showed that soil erosion is the most important process of land degradation in Ethiopia, with a net soil loss of 20 t/ha/year on cropland. All eight scenarios modelled showed a positive net present value (NPV) for improved sustainable land management technologies. For the average Ethiopian farmer, the study shows that it is advantageous to invest into structures that can reduce soil erosion and retain water, and these benefits are even greater if farmers plant grass on the structures. The study concludes that *all* sloped croplands should be treated with some conservation practices – an important finding for a country with much rolling terrain. However, the study also cautions that a population boom in rural areas will undermine even the best land management interventions, as the resource base will not sustain a further doubling of Ethiopia's rural population without significant increases in the productivity per hectare. Because the population is expected to grow to 160 million in 2045, finding livelihood options that are not dependent on the land is critical.

Globally, the ELD's analysis showed that, on balance, the costs of taking action to reverse land degradation are typically less than the value of the benefits that can be obtained through better land management practices. For the rural poor, the consequences of land degradation will only grow in severity. For policy makers, the message is clear: decisions made today will have benefits decades into the future.

This study builds on the ELD's Total Economic Valuation for natural resource management methodology, and gratefully acknowledges the contributions of the WLRC and CDE in developing the knowledge base on land management in Ethiopia.

Sources: (Hurni, et al., 2015) (ELD Initiative, 2013) (Prizzon & Rogerson, 2013)

1.4 Lessons learned from natural resource management interventions

Decades of practice in soil and water conservation and watershed development initiatives provide a host of lessons about how to rehabilitate degraded environments for broad-based benefits. These lessons are often based off experiences of projects that were not able to deliver on their promises to sustainably increase the productivity of the land or the availability of water. The source of failure is diverse; technical, social, financial issues are equally capable of undermining well-intentioned initiatives, and these lessons point to the importance of paying sufficient attention to the process of implementation.

1.4.1 Integrate design principles for managing the commons

Encouraging a community with diverse interests to work collectively to improve a watershed faces the same set of problems that typically plague efforts to manage common property. Though the benefits of organising to solve a problem may be high, the individual costs and the uneven distribution of benefits between users can disincentives people from working to improve a public good. Yet the conventional theory which posits that open access resources will result in a 'tragedy of the commons' has been challenged by scholarship that argues that, with clear rights and duties of participants, a group of people can sustainably manage and benefit from a public good in the long-term (Ostrom, 1990) (Stern, Dietz, Ostrom, & Stonich, 2002).

Rejecting the idea that privatisation is the only solution to the "tragedy of the commons", (Ostrom, 1990) identified design principles common to robust, self-governed common pool resource systems. The principles she identifies are meant to help create a shared understanding of the distribution of costs and benefits and incentivise participants to adhere to agreed rules. She recommends a participatory approach, which gives users recourse to modify operational rules; a set of rules that allows for the distribution of benefits to be roughly proportional to the costs imposed; clear rights for individuals or households to draw resources from the common pool resource, which should be clearly defined; and a set of mechanisms to ensure monitoring and conflict resolution (Ostrom,

1990). The full set of rules is not intended to be definitive, but rather a guide to help managers of common pool resources understand the conditions that encourage long-term success.

1.4.2 Link the micro to the macro

Most interventions focus on micro watersheds, which is a practical unit for project management and allows for wider participation of stakeholders. The hydrological relationships between micro and macro watersheds, however, render it inefficient to manage micro-watersheds in isolation. The upstream and downstream interactions as a result of watershed development projects can create serious management problems – "*what is good for one small watershed can be bad for other small watershed lying downstream, and what is good for a watershed in the short term can be bad in the long-term*" (Kerr, Milne, Chhotray, Baumann, & James, 2007, p. 11).

To avoid management complications, (Kerr, Milne, Chhotray, Baumann, & James, 2007) encourages building institutional linkages between micro-watersheds based on sound technical planning. This can be done through intra-village collaboration, as well as basin-level interaction, to encourage participatory management at multiple scales, and ensure stakeholders are able to agree on measures from the micro-watershed scale upwards for a comprehensive watershed management plan.

1.4.3 Benefits and costs can be unevenly distributed between stakeholders

Managing a watershed requires collective action, but this is complicated by the distribution of costs and benefits of watershed development (Kerr, Milne, Chhotray, Baumann, & James, 2007). When soil and water conservation measures are implemented, they reallocate water within the hydrological system. This can affect downstream users, but spatial variation of costs and benefits is only one dimension of the issue; there are different, overlapping, and sometimes conflicting uses of the resources in the watershed by different users.

Indeed, the literature on soil and water conservation points to evidence of trade-offs between productivity of rehabilitated land and equity between stakeholders. In India (Kerr & Chung, Evaluationg Watershed Management Projects., 2002) and South Africa (Hope, Gowing, & Jewitt, 2008), for example, watershed interventions have benefited landholders to the expense of landless people, particularly herders and women. A principle reason for this is that the poorest groups within a community who depend most heavily on common pool resources and so are most affected if area closures and rules of use and access are introduced.

Even though guidelines call for the involvement of local actors in closure and access decisions, projects frequently fail to adequately consider pre-existing arrangements around livestock grazing or farming practices, around which the poorest groups within a community often depend. Even if strong consultative processes and the engagement of conservation committees are established, without a mechanism to ensure *inclusive* participation, those marginalised from the community are at risk of being even worse off than before. These groups, often lacking access to economic resources and access to legal institutions, may not have the political power and capacity to negotiate new by-laws and therefore are at risk of losing access to key water or vegetative resources (Bolwig, Cold-Ravnkilde, Rasmussen, Breinholt, & Mortimore, 2009).

Equity concerns have also been raised over downstream impacts of soil and water conservation efforts. In specific situations, interventions might lead to decreasing groundwater recharge or reduced stream flow. A better understanding of the hydrology and the interconnectedness of watersheds is therefore needed to ensure downstream users are not deprived of water 'conserved' upstream (Ludi, Water for Food Security. Lessons learned from a review of water-related interventions, 2017).

1.4.4 Focus on both land management and the water cycle

Studying watershed management practices in India, Turton, et al. (2007) point out that watershed management practices focus on land-based activities, often at the expense of considering hydrological dynamics. Watershed management practices can both increase and decrease availability of water, and projects that focus too narrowly on the productivity on-site will miss out on sustaining broader environmental objectives associated with the water cycle.

In more complex hydrological systems, long-term and robust scientific research is needed to assess and understand the hydrological impacts of some practices, rather than exclusively focusing on the visible impacts on site. In Himachal Pradesh and Madhya Pradesh in India, some natural resource management initiatives to improve upland agriculture were based on incorrect assumptions about interactions within the watershed. In these areas, soil and water conservation efforts reduced surface runoff and groundwater infiltration elsewhere in the watershed (Calder, 1998), (Hayward, 2005).

1.4.5 Weak empirical evidence linking watershed management projects to poverty reduction

Although the benefits are widely assumed to exist, there is limited evidence linking watershed management interventions to poverty reduction. Darghouth, et al. (2008) review of various projects found that evidence was sparse for a multitude of reasons – one of which was that no indicators related to poverty reduction were even measured, even though most projects reviewed had deliberately set poverty reduction as an objective. Though measuring poverty reduction requires longer time frames and sophisticated monitoring and evaluation approaches, tracking both the physical and the socio-economic impacts of soil and water conservation interventions is essential for projects that intend to alleviate rural poverty through natural resource management.

A lack of watershed-wide assessments that examine the downstream impacts of upstream interventions and social and economic impacts (especially between different socio-economic groups) could increase the likelihood of further undesirable outcomes, relating to geographic, social and economic equity. And, despite the uptake in research since the 1990s, the number and breadth of quality reviews has not kept pace with the rapid proliferation of watershed management projects – especially in arid and semi-arid regions.

One such programme is Ethiopia's Productive Safety Net Programme (PSNP), the government's flagship social protection initiative. The PSNP uses public work programmes to deliver social protection. The public work component of the PSNP intends to restore local environments through soil and water conservation practices, including construction of stone and soil embankments, hillside terraces, deep water infiltration trenches, and creating ponds for irrigation. Through restoring watersheds and creating natural capital, soil and water conservation activities are designed to improve livelihoods and food security.

Though public work programmes are a more expensive way of delivering social protection than cash transfers, the PSNP operates under the assumption that the public work programmes are delivering benefits through creation of natural assets and an improved natural resource base that supports people's livelihoods. (Ludi, et al., 2018 (forthcoming)) working in a PSNP watershed in the Kalu district, South Wollo zone, in the Amhara region found that although PSNP assets functioned over time and had positive environmental impacts, also found that that "*the [soil and water conservation initiatives] did not result in an improvement in production or better livelihoods*." (Ludi, et al., 2018 (forthcoming)). Though the research project was not designed to evaluate PSNP writ-large, it raises important questions about the design of soil and water conservation programmes and interrogates the assumption that the existence of rehabilitated natural assets will automatically result in livelihood improvements. The study highlights the importance of the process by which natural

resource management assets are selected, designed, and implemented, positing that this is responsible for the lack of livelihood improvements after public work programmes measures were implemented in the Kalu District.

Box 2. Myth or reality? Links between watershed protection and groundwater availability

A watershed is an area from which all water drains to a common point, making it an attractive unit for efforts to manage water and soil resources for production and conservation. Watershed protection promises a 'triple-win' in which natural resource conservation, agricultural productivity and poverty reduction go hand-in-hand.

Ethiopia has a long history of implementing watershed protection programmes extending over 30 years. These have evolved from largely technical initiatives in the 1970s and 80s to more participatory ones in which local people help design and implement plans. More recently, their role in increasing resilience to climate change has received growing attention. However, while claims are often made about watershed development in enhancing groundwater recharge, only a few (e.g. MERET, Tana Beles) include measures designed specifically to enhance water availability, and the target is water for production rather than domestic use. Groundwater recharge interventions are implemented in Ethiopia, but these are generally restricted to local NGO projects, and do not form part of government-sponsored watershed or rural water supply programmes.

Although much has been written on the impacts of watershed protection programmes, there have been very few attempts to systematically assess them – in Ethiopia or elsewhere. Moreover, claims about their impact on water resource conditions and, by implication, on groundwater availability and access, should be treated with caution. This is because of the complex relationship between climate, land use and groundwater recharge. Drawing on the few rigorous studies that have been carried out, we make the following observations, if only to challenge a few prevailing myths:

Myth 1 – planting trees and restoring native vegetation increases groundwater recharge and availability. While much will depend on local conditions, recharge may decrease even if runoff declines following the re-establishment of vegetation. This is because in dry climates, trees and perennial native vegetation evaporate more water than field crops or grassland because of their greater rooting depth and a longer growing season.

Myth 2 – non-vegetative measures to improve soil moisture retention will automatically lead to increases in groundwater recharge and availability. This is not necessarily so in drier climates where evapotranspiration is much greater than rainfall, and recharge processes are dominated by rapid seasonal flows from rivers beds and wadis.

Myth 3 – groundwater recharge from check dams and percolation ponds can impact groundwater conditions at scale. These interventions can have positive, localised effects on groundwater availability, but are unlikely to make much difference to the overall water balance of an aquifer system.

Myth 4 – water conserved is water that would otherwise be lost. There is often an assumption that upstream water conservation 'saves' water that would otherwise be lost. In practice, upstream conservation may deprive downstream users of water, so conservation is essentially about upstream-downstream reallocation, at least in those basins where water is intensively used.

Source: Calder, 2005; (Gale, et al., 2006), (Kerr, Pangare, & Pangare, 2002); Taylor, et al., 2013. (Conway & Schipper, 2011). (Ludi, et al., 2018 (forthcoming))

2 Natural Resource Management Interventions and Livelihoods in Afar

Key Messages

Pastoralism is a major livelihood system that dominates 60% of Ethiopia's territory, employs roughly 12% of the population, and represents a large, albeit often overlooked, contribution to the Ethiopian economy.

In the past half century, pastures in semi-arid lands have undergone rapid change as a result of increasing human and environmental factors. The resulting fragmentation of rangelands has inhibited mobility, which is a crucial strategy for pastoralists to manage common pasture.

To deal with pressures on pastoral resources, pastoralists in Afar deploy a range of strategies, including seasonal mobility, mutual help and sedentarisation. The frequency and intensity of drought, however, has undermined the effectiveness of these strategies, further impoverishing pastoral households.

In an effort to reverse these trends, GIZ supports the Ethiopian Government to construct water-spreading weirs intend to provide a range of benefits for pastoral households, including increased crop production, increased pasture production, increased availability and quality of shallow groundwater, amongst others.

The ways benefits from water-spreading weirs unfold can be traced using causal chains, which explicitly state the assumptions underpinning these potential benefits from water-spreading weirs.

2.1 Pastoral and agro-pastoral livelihoods under stress

Pastoralism is an important livelihood in semi-arid lands across Africa and Asia. Pastoralism - as in mobile livestock rearing, marketing and trading - is practiced by more than 20 million people on close to 50% of African territory (Rauch, Beckmann, Neubert, & Rettberg, 2017) and contributes significantly to the GDP of many countries (PRISE, 2017). Mobile pastoralism provides livelihood systems in arid and semi-arid areas that are economically efficient and are well suited to the highly variable climatic conditions, soil qualities and bio-physical environments. Pastoral systems show an inherent adaptive capacity to climatic and non-climatic stresses and shocks based on their extensive and opportunistic use of resources (land, vegetation and water) by a broad range of livestock (camels, cattle, sheep and goats) (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016). Mobility is a crucial strategy underpinned by institutions where collective action is a central plank of managing common pool resources. Mobility allows herds and people to use distinct pockets of available grazing resources and water by mixed-species herds. The effectiveness of herding strategies depends on the flexibility of herders to seize opportunities and avoid hazards in variable and unpredictable rangeland environments (Lind, Sabates-Wheeler, & Kohnstamm, 2016).

Over the past century semi-arid and arid lands – the dominant home of most pastoral groups – have undergone rapid change. Land use changes have led to fragmentation, driven by socio-economic factors, including globalisation, intensification of production, competition for land, population growth or conflict (See section 4). Even without these socio-economic pressures, many pastoral areas have seen significant changes to ecosystem service flows as the result of climatic variability and changes, with implications for the resilience of those whose livelihoods depend on them (Carabine, Jouanjean, & Tsui, 2015). On top of these stressors, increased climate variability and frequency of extreme events adds a further layer of complexity. Arid and semi-arid lands (ASAL) will

feel the impacts of climate change, interacting with non-climate related stressors particularly severely, based on evidence provided by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2014).

Many governments, have – and still are – regarding pastoralist as an anachronistic way of life, producing little economic value and degrading their natural environment. This is particularly dominant in countries such as Ethiopia or Kenya where political elites have generally come from an agrarian background. Numerous government attempts, often supported by donors with similar views, over the past decades have attempted to push pastoralists into full-time farmers, ranchers or traders. The perception that pastoral drylands were of little economic value has justified government neglect in terms of providing public services and investments in favour of high-potential agrarian highlands (Lind, Sabates-Wheeler, & Kohnstamm, 2016).

(Lind, Sabates-Wheeler, & Kohnstamm, 2016) describe several trends observed across East African pastoral landscapes that also apply to Afar Region:

- Fragmentation of rangelands through processes of excision, privatisation (often in the form of enclosures) and commodification of rangelands, making mobility and access to crucial resource areas either difficult or impossible
- Large-scale irrigation for export crops (especially cotton and sugarcane) often occupying important dry-season grazing areas
- Processes of sedentarisation – planned or voluntarily - and the uptake of dryland farming, charcoal burning and harvesting of fuel wood
- Provision of social services and infrastructure, especially roads and markets, which have enabled some pastoralists to seize opportunities and improve their livelihood opportunities
- Increasing impacts of droughts on pastoral societies, not because they have become necessarily more severe or frequent as often perceived, but because they overlap with a range of other trends. These pressures on pastoralism include land use changes, declining resource availability, fragmentation of pastures, conflict, limited access to education and information, gender inequalities and social marginalisation. These pressures often overwhelm the already compromised adaptive capacity of pastoralists.

Different livestock-based production systems have evolved in different political-economic and socio-ecological settings. Today, variants of pastoralism include commercialised forms of livestock-keeping oriented towards domestic and international export markets; small-scale livestock keeping for subsistence and local marketing combined with dryland farming; combining the rearing of few small-stock with other activities, usually on a task-for-cash basis in and around towns; and customary pastoralism based on long-distance movement and maintaining a network of kinship and friendship bods through which to exchange livestock and labour (Lind, Sabates-Wheeler, & Kohnstamm, 2016). All of these forms of pastoralism can be found in Afar Region. Especially around growing towns such as Semera, Mille and Chifra, more and more people are settling and engaging in dryland farming or daily labour. These households would keep livestock, whereby small stock would usually be kept around fixed homesteads whereas part of the household – generally young and middle-aged men – would travel with cattle and camels to pastures further afield for a number of months. In areas further away from major settlements, pastoralists still engage in long-distance customary pastoralism. In areas closer to the highlands such as Chifra, where rainfall allows some modest dryland farming, a number of households have settled permanently and engage in dryland farming for the majority of their income with livestock playing a minor role.

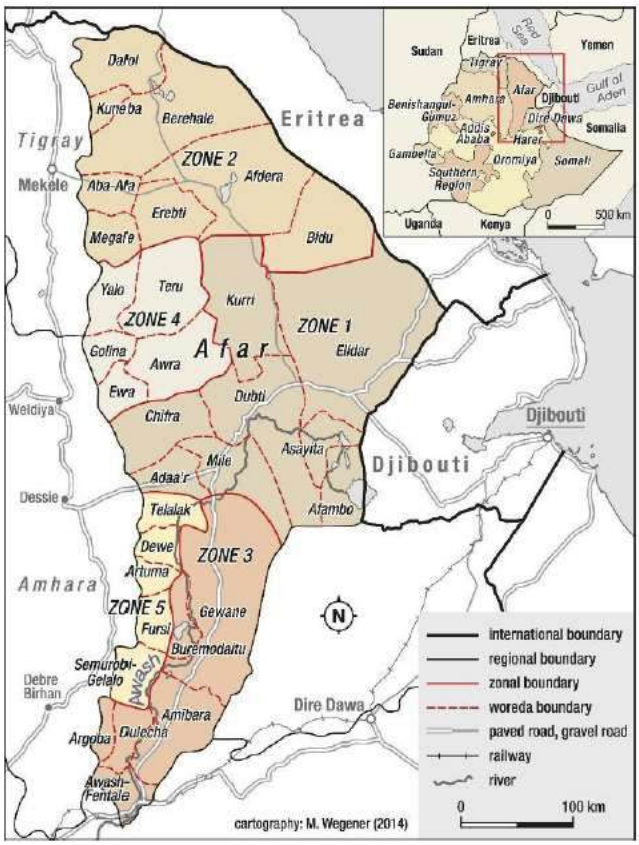
Pastoralists occupy 60% of Ethiopia's territory and constitute approximately 12% of the total population. There are at least 29 different ethnic groups belonging to the Cushitic and Nilotic language families. The largest pastoralist groups are the Borena Oromo, the Somali and the Afar, with smaller groups occupying large parts of the Southern Nations, Nationalities and Peoples' (SNNP)

Region, as well as groups in the eastern, western and the north-western lowlands of the country (Mussa, 2004). Pastoralists own about 42% of the total livestock population of the country and the contribution of live animals and their products to the agricultural GDP accounts for at least 47% - excluding the values of draught power, manure or transport of goods and people (IGAD Centre for Pastoral Areas and Livestock Development (ICPALD), 2013). The value of livestock exports has so far been grossly underestimated - approximately half of the livestock sector's exports are not recorded officially and not recognized by the National Bank of Ethiopia which is responsible for calculating the GDP because they are produced by cross-border trade in live animals, which the government deems to be illegal and therefore does not recognise. Including 'illegal' cross-border live animal exports, the value of livestock export for 2008/09 increases from USD 52.7 million to USD 302.7 million (IGAD Centre for Pastoral Areas and Livestock Development (ICPALD), 2013).

2.2 Biophysical and socio-economic context in Afar and the GIZ project intervention areas

Afar Regional State, one of nine administrative regions of Ethiopia, is located in the north-eastern lowlands of Ethiopia, bordering Djibouti to the east and Eritrea to the north. Afar is part of the Afar Depression where the East Rift Valley extends towards the Red Sea, making it a tectonically active area with frequent earthquakes and volcanic activity. The location on a tectonically still active area is responsible for its current topographic and geomorphological characteristics, made up of volcanic outcrops and lava fields, faults, salt lakes in depressions, stony deserts and large alluvial deposits along the footslopes towards the highlands along the eastern escarpment. Climatically, Afar is a tough place, with temperature maxima reaching 50°C or more in the Danakil Depression, while average annual temperatures easily reach 30°C (see Figure XX).

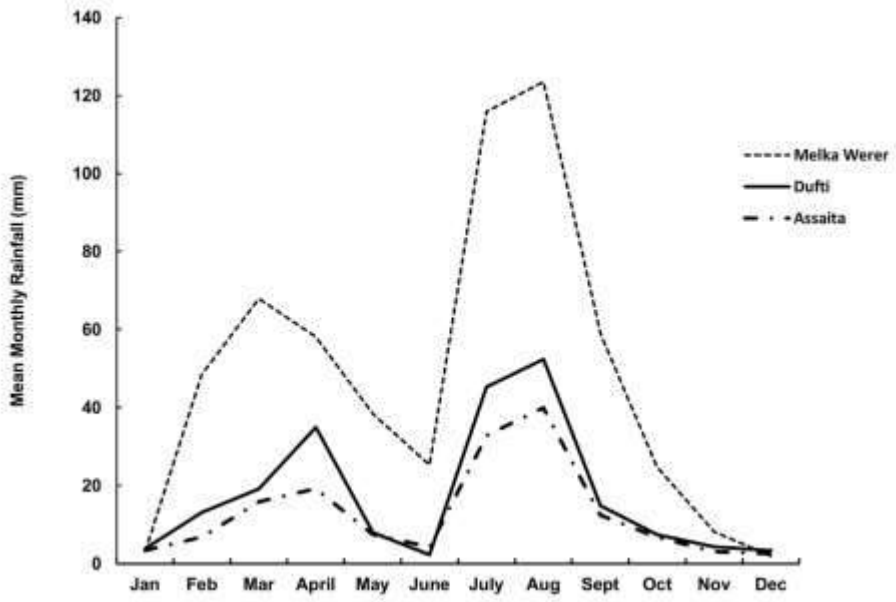
Figure 2: Administrative subdivisions of Afar Region



Source: (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016)

Rainfall shows a clear south-west – north-east pattern with rainfall in the south-west along the escarpment to the central highland highest at around 700 mm / year and lowest at around 100 mm/year in the north-eastern parts (SOURCE). Long-term rainfall patterns show a clear pattern of two distinct rainy seasons – mid February to mid/end April and July – August – and two distinct dry seasons in between, as well as a clear SW-NE aridity gradient (Wakie, Evangelista, Jarnevich, & Laituri, 2014). Both the spatial and temporal variability of rainfall and its extremes have been a defining element of the pastoral livelihoods in Afar as well as of cycles of drought and food insecurity.

Figure 3: – Long-term rainfall in Afar. Average monthly precipitation for Melka Werer, Dubti and Assaita stations (1968-2001)



Source: (Wakie, Evangelista, Jarnevich, & Laituri, 2014)

The perennial Awash River crossing Afar Region in the southern and central part, has always been a key resource for pastoral livelihoods. The Awash originates in the Central highlands of Ethiopia, flows through Afar Region and drains into a sequence of lakes along the border with Djibouti. Several perennial rivers, among them the Kesem, Mille and Ewa Rivers, originate in the Highlands of Amhara Region and drain into the Awash River. Rivers further north are generally intermittent and drain into the Teru depression, which is an important dry grazing area and drought retreat next to the flood plains along the Awash River (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016).

Afar, numbering at least 2 million people, live across 3 countries in the Horn of Africa – Ethiopia, Eritrea and Djibouti. The territory that is now Afar along the Awash River was part of the Aussa Sultanate and was fully integrated into Ethiopia by a mix of political violence, 'deal-making', state co-option and coercion (Nicol & Otulana, 2014). The Awash valley with its rich soils attracted the attention of the Ethiopian Government as a potential source of wealth through the production of cotton and sugarcane. The construction of the Koka dam upstream of the Awash providing reliable water supply along the Awash and the establishment of the Awash Valley Authority in the 1960s further promoted the individual and commercial exploitation of cotton and sugarcane along the river. During the 1960s and 1970s large schemes were developed which were perceived a major threat by the Afar. Under the Derg, the land reform forced the integration of the Afar into the newly established state system, including its attempts to collectivised agriculture. The 1995 Ethiopian Constitution legalised full-scale exploitation of these lands for irrigated agriculture through formalising state ownership of all pastoral lands. Afar pastoralists resisted the appropriation of their land politically and by establishment of armed resistance at irrigation scheme level (Nicol & Otulana, 2014).

Disrupted transhumance patterns as a result of the establishment of large-scale irrigated plantations and erosion of political and economic power added to the challenges of surviving in the harsh environments of the Awash Valley. A succession of droughts in the 1970s led to distress sales of livestock. At the same time, human-induced pressure on grazing lands increased – highlanders moving downslope in search of additional crop land – pushing Afar towards territories claimed by other groups, in particular the Issa Somali and the Oromo Kereyu, who themselves were subject to wider political forces (Nicol & Otulana, 2014). Wealthier and politically and economically better

connected Issa Somali have further increased their presence in Afar, pushing towards the road to Djibouti and the Awash River. Attempts by Somali herders to access the fertile flood plains along the Awash has led to intermittent conflict (Rettberg, 2010).

The spread of *Prosopis juliflora*, especially along water courses, further limited pastoralists options and constrained coping strategies of mobile herders and limited options for restoring herd sizes after droughts. Rangeland degradation on remaining land available to pastoralists has increased tremendously over the past few decades. This is compounded by increasingly frequent droughts or floods and changes to rainfall patterns, with seasonality, distribution and duration of rainfall more of a problem than the overall amount (ANRS - Afar National Regional State, 2010).

Box 3: The threat of invasive species

Almost all agro-pastoralists interviewed reported the proliferation of invasive species, such as *Prosopis juliflora* (local name: *woyane*), *Acacia nubica* (local name: *goronto*) and *Parthenium hysterophorus* (local name: *democracy* or *congress weed*) (Tilahun Amede, 2016) (Gebrehaweria, Aregaw, Abdelah, & Bushra, 2017). Such species increase soil degradation on the highly fertile plains, where grasses like *malif* used to grow. The baseline study for the weirs notes that pastoralists attributed increased erosion to the disappearance of *malif*, and blamed the lack of pasture (at least partially) on the proliferation of unpalatable invasive species.

While the weirs have brought with them many benefits such as increasing soil moisture, fertile ground around the weirs could enable rapid spread of invasive species that deplete soil nutrient and compete with productive crops for water. The sustainability of the water spreading weirs hinges on effective management of invasive species. Overall, almost 10% of land is not being utilized due to invasive species.

Strategies to cope with these pressures centre around livestock, seasonal mobility and mutual help to maintain the sustainability of the system ecologically, socially and economically (Piguet, 2007). This also includes strategies towards more settled livelihoods, whether chosen voluntarily or because other options are no longer available. Weakening of social ties in rapidly urbanising environments and weakening of arrangements that once meant that resources could be transferred to households in stress, however, have meant impoverishment for some Afar, while others were able to benefit from increasing commercialisation, leading to further stratification of the Afar society. Wealth, as defined by contemporary Afar, is based on ownership of livestock and support of the poor ((Davies & Bennet, 2007) in (Nicol & Otulana, 2014)), with wealthier households much more likely to both contribute and receive help than poor households, which in turn strengthens both household level and intra-clan ties and networks of rich households but not of poor ones. Overall, mutual self-help has become weaker and vulnerable to environmental stress resulting in loosening of clan relationships as people respond to economic and ecological changes (Piguet, 2007).

Afar, as other pastoral lowland areas in Ethiopia and the greater Horn of Africa have been severely affected by recurrent droughts in recent years. The ongoing drought has been labelled “the most severe drought ever” due to its intensity, duration and coverage, affecting the main pastoral groups of Somali, Borena and Afar. Nine consecutive dry months have been recorded and the amount of rainfall received was insufficient to have a meaningful impact (FAO, 2017). Since 2000, six droughts have affected pastoral Ethiopia, with the most severe in 2011 and 2016/17. Insufficient regeneration of rainfed pastures, on which most pastoralists in Ethiopia rely, combined with other stressors, has undermined livelihood strategies of pastoralists and agro-pastoralists. Floods at the end of the drought periods have washed away the natural seed reserve and denuded large tracts of land of grassy vegetation. At the same time, invasive species have spread and are now covering an estimated 1 million hectares in the four major pastoral eco-systems in Ethiopia. And finally,

pastoralists have lost prime dry-season grazing reserves along major rivers due to state and private investments and projects (FAO, 2017).

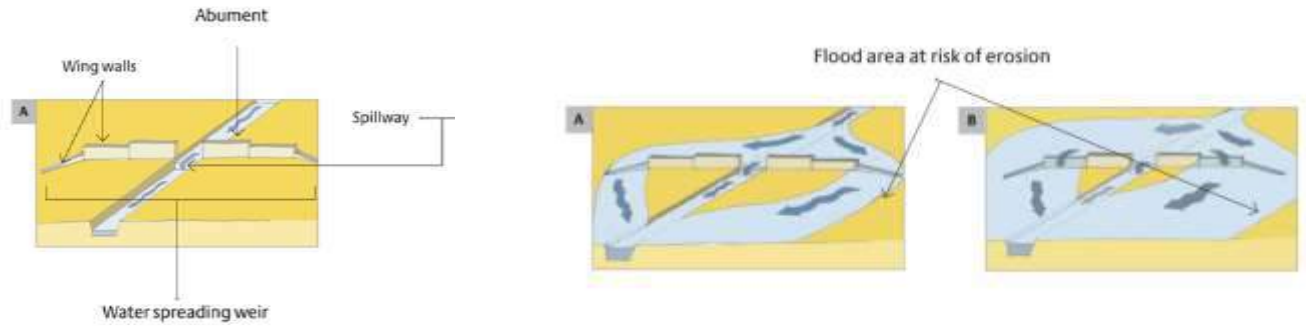
2.3 Water Spreading Weirs - natural resource management interventions in Afar Region

GIZ is supporting the Regional Bureau of Pastoral and Agriculture Development (BoPAD) and its devolved Pastoral and Agriculture Development Offices (PADO) at Woreda level in piloting and implementing a range of natural resource management practices in selected Woredas (Chifra, Gulina, Yalo, Teru, Ewa, Awra, Kori and Mille) across the Region. These measures are aimed at encouraging land use planning with inputs from all users and authorities as a means to establish reliable access to soil and water while improving pastures; rehabilitating degraded catchments and pasture areas through the constructions of weirs to reduce runoff and erosion from sporadic flash floods and to retain eroded soil and water in the river channel; increasing food security and incomes of local people through fodder production on rehabilitated sites; safeguarding migration routes and promoting income generation measures; and planning future activities towards combating rapidly spreading invasive species such as *Prosopis juliflora* and *Parthenium hysterophorus* (GIZ, 2017)

The focus of this study is on water spreading weirs built in a cascade of weirs across gullies or intermittent rivers with the aim of slowing down the flow of water and increase the area that is regularly flooded and trap fertile sediments dissolved in the floodwater. This approach has been adopted in parts of Burkina Faso, Niger and Chad over the past 2 decades, with positive outcomes reported: water infiltrates, gullies in the valley are filled and river beds are raised; groundwater levels rebound, providing more water for people and livestock; and the arable land area – for food and/or fodder – increases. Looking further along the results chain, positive impacts on production, income, food security and poverty are reported and attributed to the weirs (BMZ, 2012). These results were achieved with relatively modest investments – on average, a water spreading weir – depending on size – cost between €20,000 and €50,000 or €400 to €2000 per ha of rehabilitated land in the West African context (Ackermann, et al., 2014).

In contrast to different types of dams, the idea of water-spreading weirs is not to retain water behind the dam and store it for some time for other purposes, but to force water laterally to inundate land. In theory, the water will slowly infiltrate into the soil and become available to plants. This would benefit either the growth of food crops, the growth of fodder crops or pasture rehabilitation or be aimed at replenishing shallow groundwater reservoirs and help to increase the water table (WOCAT, 2017).

Figure 4: Components of water spreading weirs and how they work



Source: (BMZ, 2012)

Currently, 34 WSW have been built in Yallo, Awra, Gulina and Chifra Woredas. The area expected to be flooded is estimated at 17 km^2. WSW are built in different agro-ecologies (see Figures 5 and 6). While those established in Shakay Boru are expected to largely support crop and high-value fodder production, which has a long tradition in this site close to Chifra town, others, for example those in Awra, are mainly meant to flood pasture land and contribute to rangeland rehabilitation.

Figure 5: Weir in Shakay Boru, Chifra in support of agricultural production

(Source: Ludi, 2017)

Figure 6: Weir under construction on degraded pasture in Awra

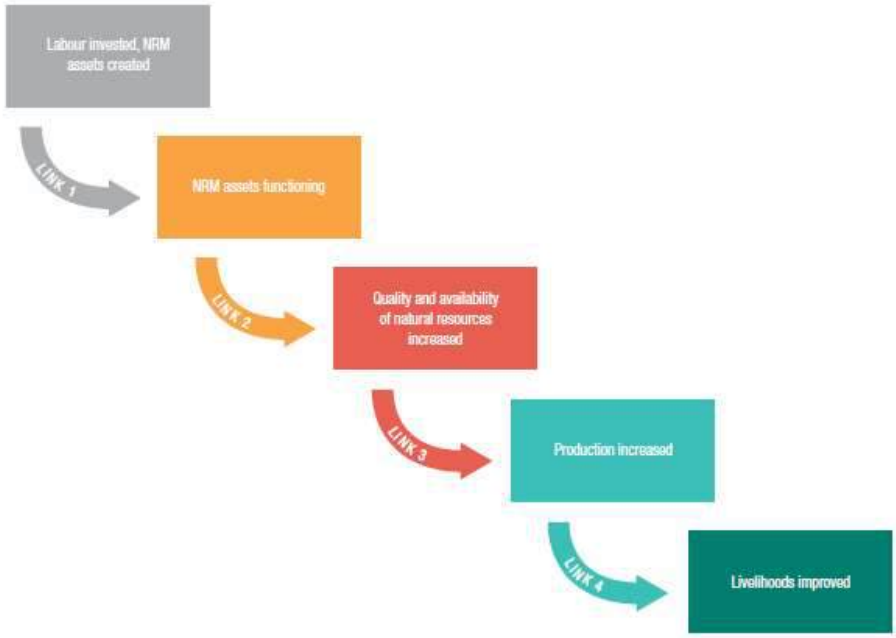
(Source: Ludi, 2017)

2.4 Pathways to impact

Underlying the project interventions is a Theory of Change, which explains how natural resource management investments (water spreading weirs, dams or drystone terraces) are meant to lead to desirable social, economic or environmental impacts. Such pathways to impact are a simple model unpacking the 'black box' of the relationship between project inputs and outcomes and are based on insights gained from theory-based approaches to evaluation (Funnell & Rogers, 2011) (White, 2009). Unpacking this 'black box' and making visible the assumed links by way of which inputs are assumed to result in outcomes and impacts helps in understanding whether design or implementation of the

natural resource management interventions could be improved to achieve impact and who is benefiting from the interventions (Ludi, et al., 2018 (forthcoming)).

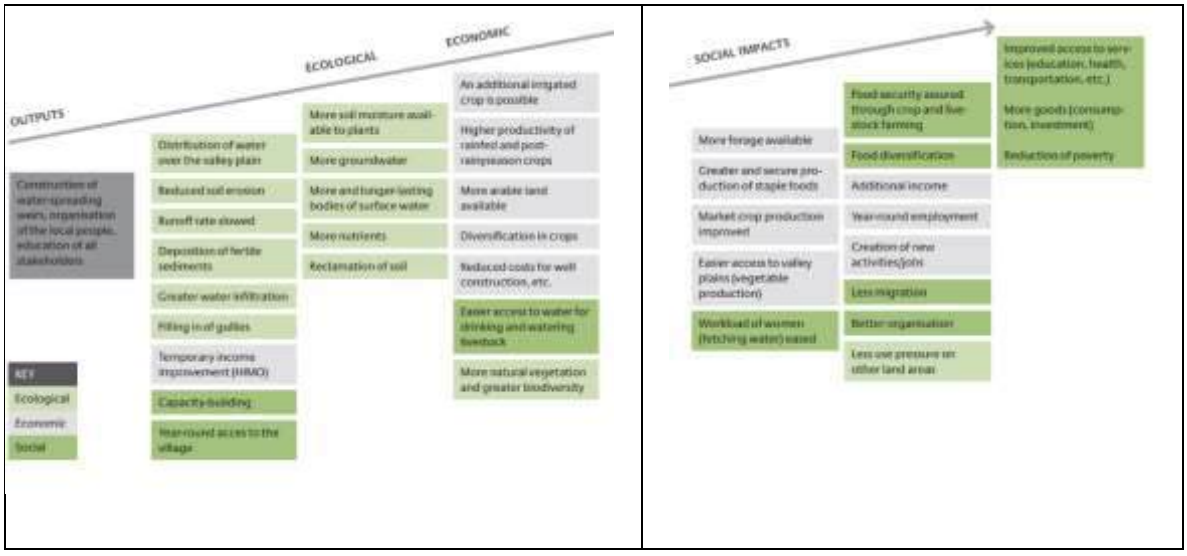
Figure 7: Pathways to impact



Source: (McCord, Ludi, & Levine, 2015)

Based on the experiences made and results observed in West Africa, GIZ has developed an impact chain linking project outputs (water-spreading weirs, organisation of local population, capacity building) to ecological, economic and social outcomes (Figure 8).

Figure 8: Results observed in West Africa as a result of investments in water spreading weirs, social organisation and capacity building.



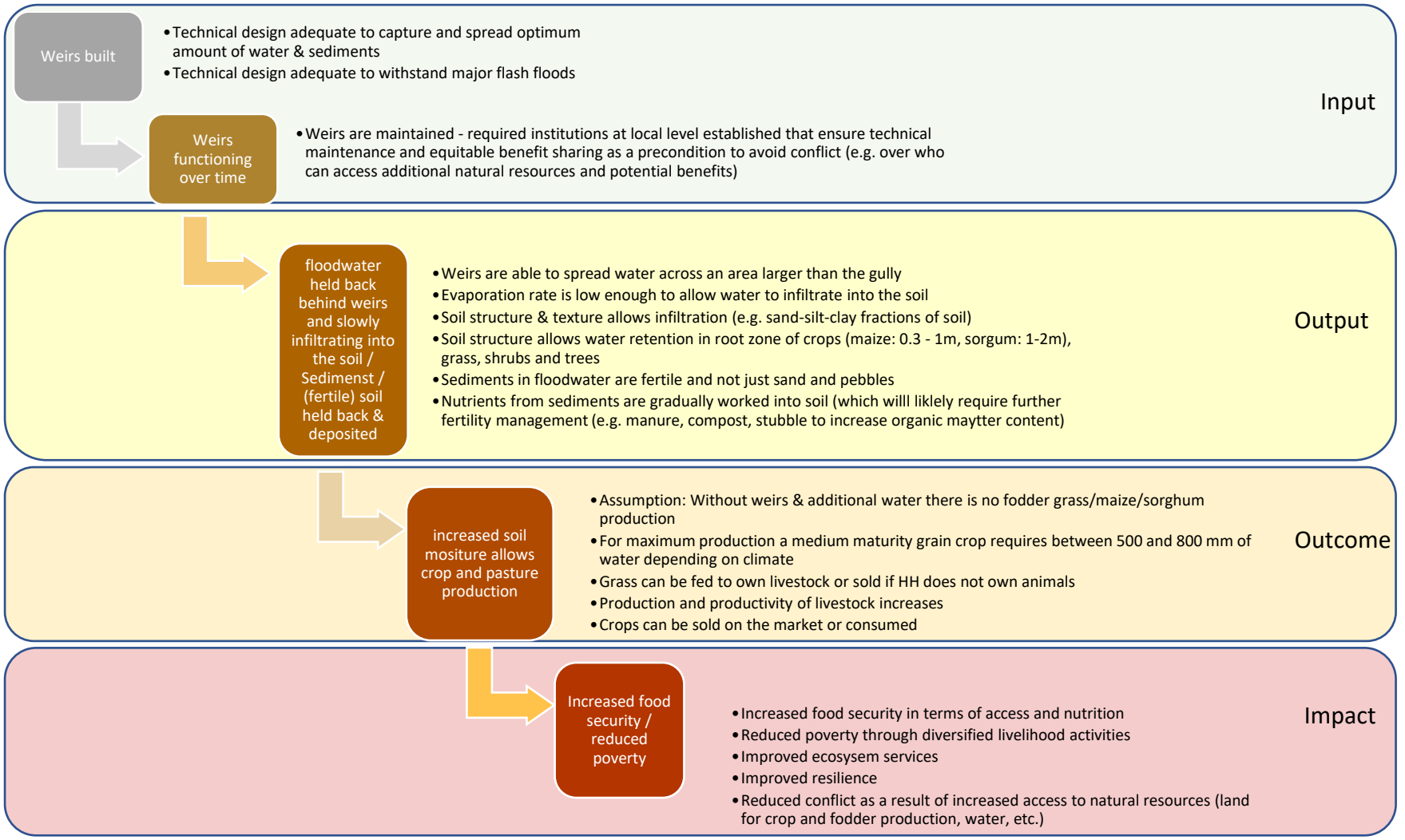
Source: (BMZ, 2012)

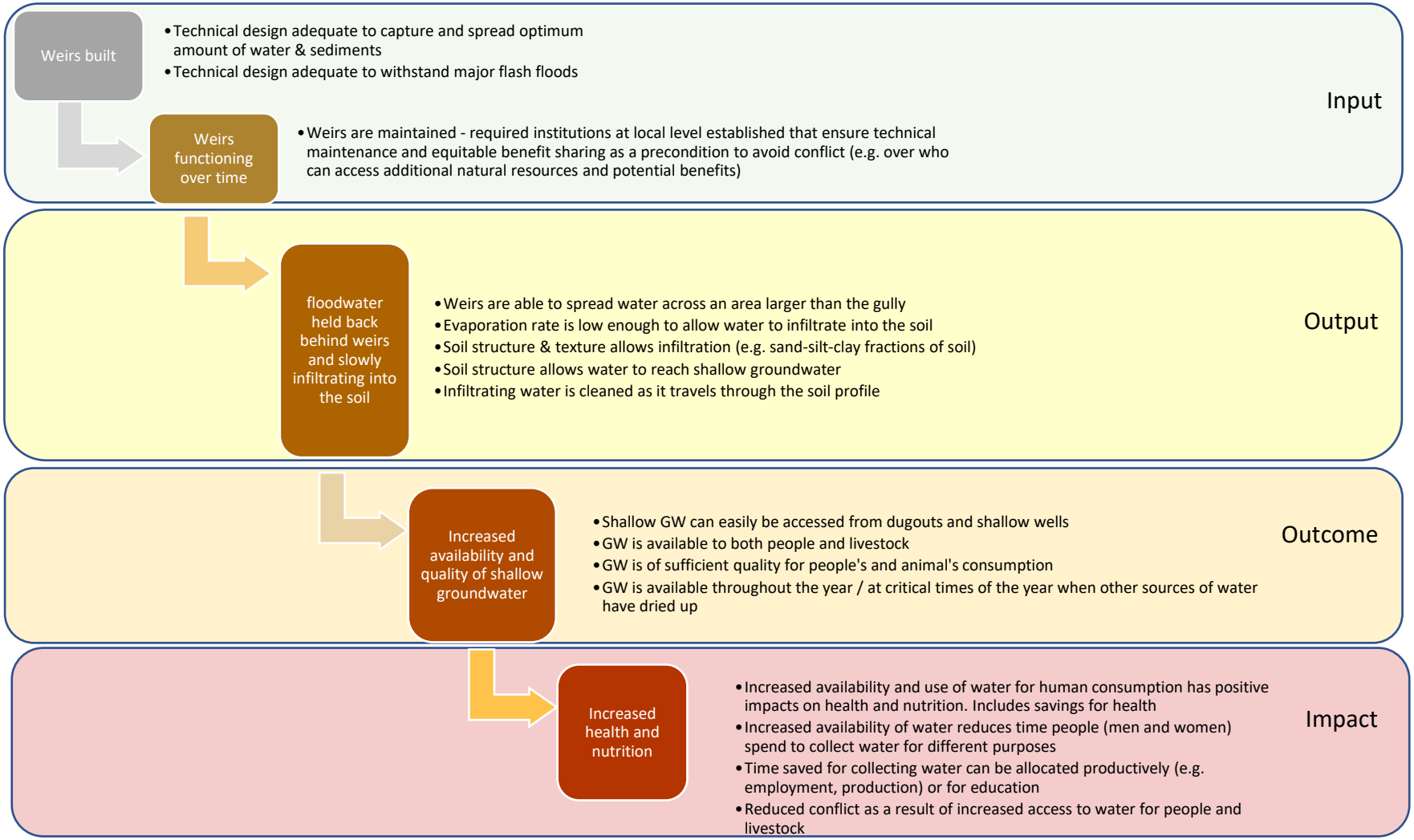
For the situation in Afar and the GIZ-supported natural resource management interventions, such a pathway to impact links investments in natural resource management to the provision of ecosystem

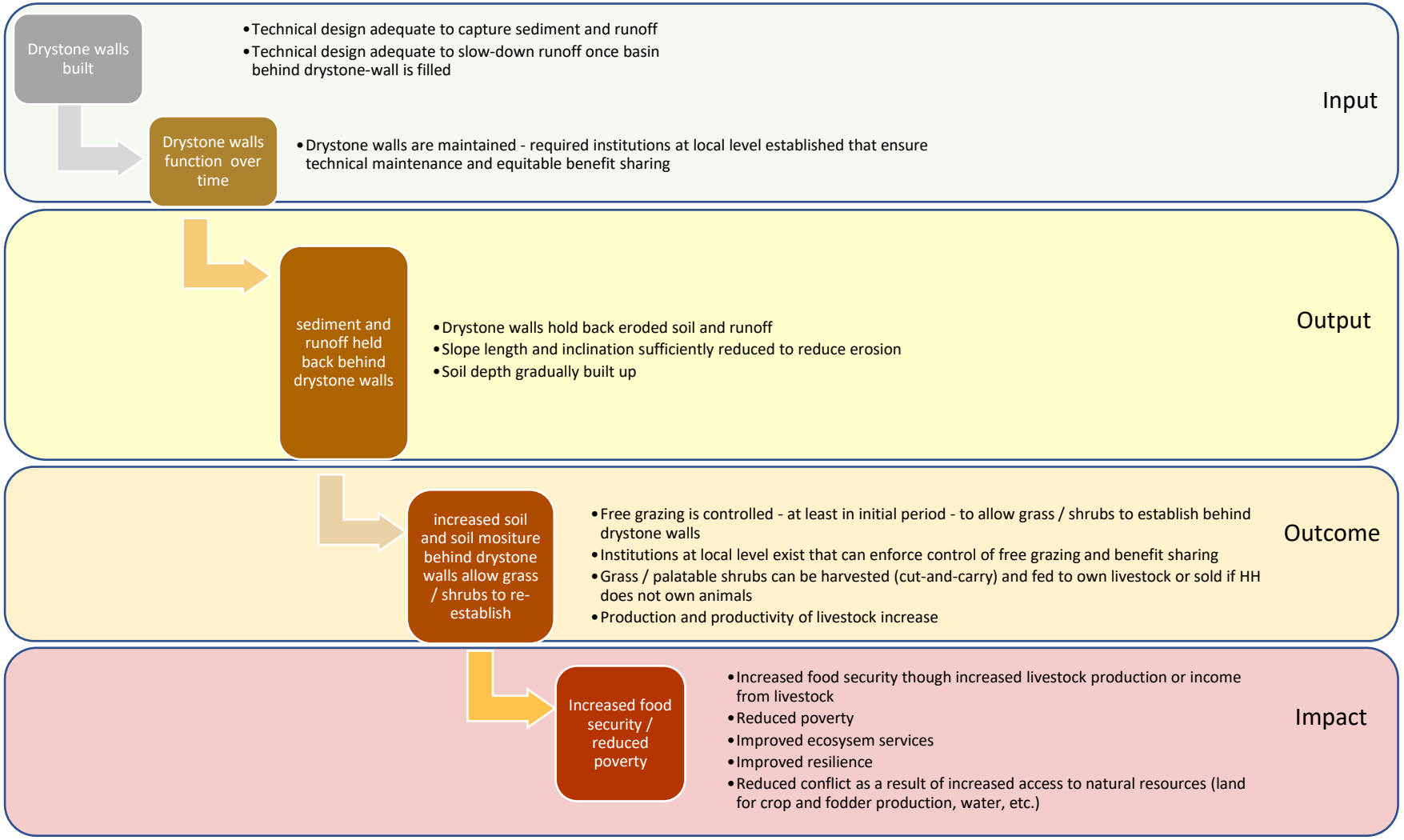
services (e.g. increased water availability, decreased flooding) that translate into positive outcomes for people (e.g. increased food or fodder production, increased availability of drinking water) and the environment (e.g. reduced erosion) with longer term social, economic and environmental impacts (e.g. reduced poverty, increased food security).

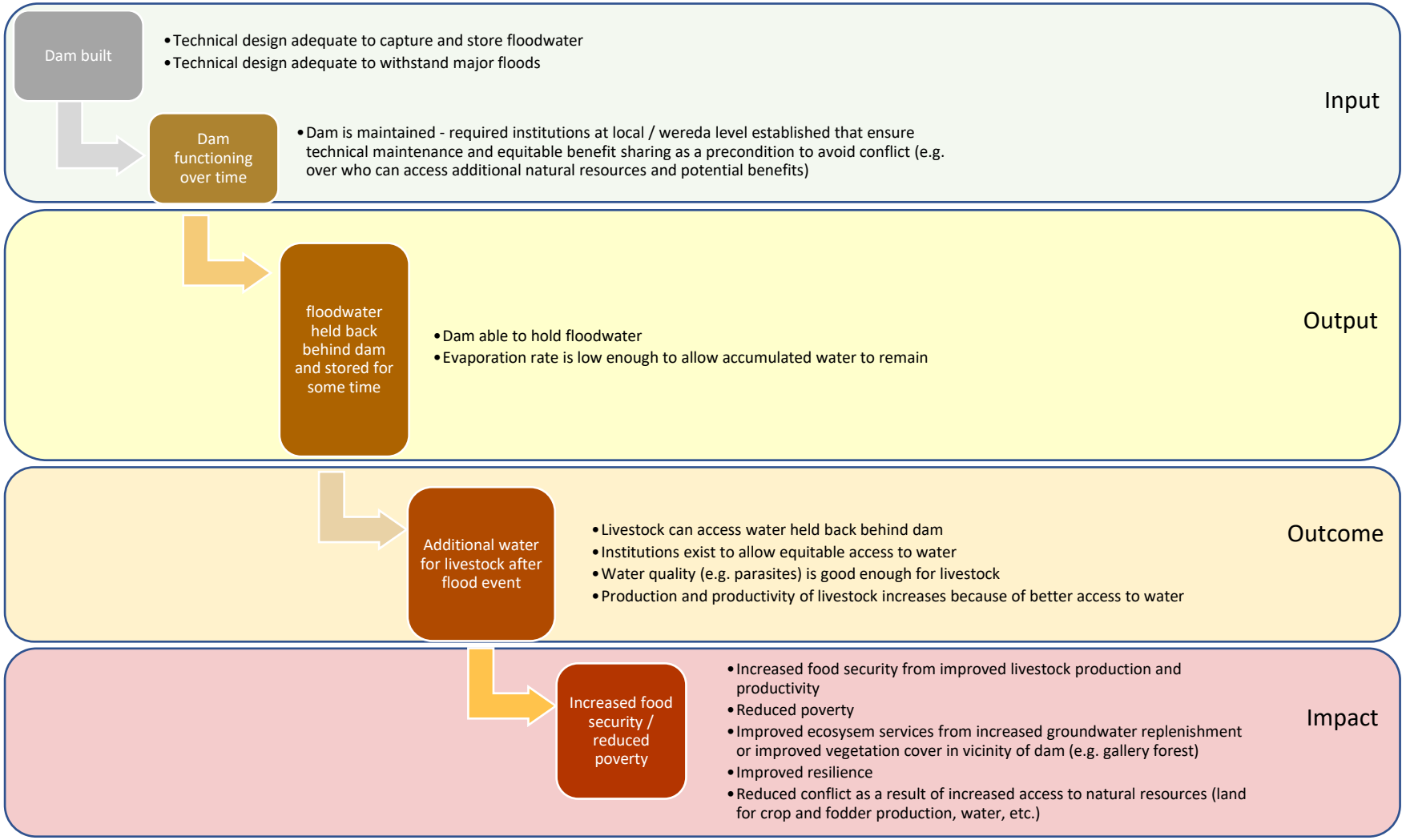
We have developed impact chains linking inputs - initial project investments - to outputs, outcomes and expected impacts (Figure 9) for water spreading weirs, drystone walls and dams. The impact chain for water spreading weirs shows two possible outcomes – the first focuses on increased soil moisture and sediment deposition leading to improved crop and pasture production and ultimately resulting in increased food security and poverty reduction, while the second assumes that water spreading weirs support recharge of shallow groundwater that can be accessed to provide safe domestic water and increased water for livestock resulting in positive health impacts and time savings. These impact chains also list some of the conditions that need to be met for inputs to result in outputs, outcomes or impacts. Impact chains as shown in Figure 9 were then used as the basis on which to develop the framework for the cost-benefit analysis.

Figure 9: Impact chains linking project interventions (inputs) to outputs, outcomes and expected impacts




Weirs built
•Technical design adequate to capture and spread optimum amount of water & sediments
•Technical design adequate to withstand major flash floods
Input
Weirs functioning over time
•Weirs are maintained - required institutions at local level established that ensure technical maintenance and equitable benefit sharing as a precondition to avoid conflict (e.g. over who can access additional natural resources and potential benefits)
floodwater held back behind weirs and slowly infiltrating into the soil
•Weirs are able to spread water across an area larger than the gully
•Evaporation rate is low enough to allow water to infiltrate into the soil
•Soil structure & texture allows infiltration (e.g. sand-silt-clay fractions of soil)
•Soil structure allows water to reach shallow groundwater
•Infiltrating water is cleaned as it travels through the soil profile
Output
Increased availability and quality of shallow groundwater
•Shallow GW can easily be accessed from dugouts and shallow wells
•GW is available to both people and livestock
•GW is of sufficient quality for people's and animal's consumption
•GW is available throughout the year / at critical times of the year when other sources of water have dried up
Outcome
Increased health and nutrition
•Increased availability and use of water for human consumption has positive impacts on health and nutrition. Includes savings for health
•Increased availability of water reduces time people (men and women) spend to collect water for different purposes
•Time saved for collecting water can be allocated productively (e.g. employment, production) or for education
•Reduced conflict as a result of increased access to water for people and livestock
Impact


Drystone walls built
•Technical design adequate to capture sediment and runoff
•Technical design adequate to slow-down runoff once basin behind drystone-wall is filled
Input
Drystone walls function over time
•Drystone walls are maintained - required institutions at local level established that ensure technical maintenance and equitable benefit sharing
sediment and runoff held back behind drystone walls
•Drystone walls hold back eroded soil and runoff
•Slope length and inclination sufficiently reduced to reduce erosion
•Soil depth gradually built up
Output
increased soil and soil mositure behind drystone walls allow grass / shrubs to re-establish
•Free grazing is controlled - at least in initial period - to allow grass / shrubs to establish behind drystone walls
•Institutions at local level exist that can enforce control of free grazing and benefit sharing
•Grass / palatable shrubs can be harvested (cut-and-carry) and fed to own livestock or sold if HH does not own animals
•Production and productivity of livestock increase
Outcome
Increased food security / reduced poverty
•Increased food security though increased livestock production or income from livestock
•Reduced poverty
•Improved ecosysem services
•Improved resilience
•Reduced conflict as a result of increased access to natural resources (land for crop and fodder production, water, etc.)
Impact


Dam built
•Technical design adequate to capture and store floodwater
•Technical design adequate to withstand major floods
Input
Dam functioning over time
•Dam is maintained - required institutions at local / wereda level established that ensure technical maintenance and equitable benefit sharing as a precondition to avoid conflict (e.g. over who can access additional natural resources and potential benefits)
floodwater held back behind dam and stored for some time
•Dam able to hold floodwater
•Evaporation rate is low enough to allow accumulated water to remain
Output
Additional water for livestock after flood event
•Livestock can access water held back behind dam
•Institutions exist to allow equitable access to water
•Water quality (e.g. parasites) is good enough for livestock
•Production and productivity of livestock increases because of better access to water
Outcome
Increased food security / reduced poverty
•Increased food security from improved livestock production and productivity
•Reduced poverty
•Improved ecosysem services from increased groundwater replenishment or improved vegetation cover in vicinity of dam (e.g. gallery forest)
•Improved resilience
•Reduced conflict as a result of increased access to natural resources (land for crop and fodder production, water, etc.)
Impact

2.5 Indicators and data needs to assess costs and benefits of water spreading weirs

		Indicators / data needs
	• A water spreading weir in the vicinity of Chifra.	• Costs / weir: • costs for person days - unskilled labourers, skilled labourers, supervisors, technical expertise (national and international) • per diem for employees • construction material (cement, sand, water, other) • transport costs of water and material • transport costs for workers, experts, supervisors, etc. • tools (weir construction, weir surveying (maps, satellite images, etc.)) • training of new skilled labourers • mobile phone credit • costs for mobilising people (planning weirs, getting buy-in and agreements, etc.)
	• Their functioning depends on ongoing maintenance – see area in the middle of the wing hollowed out by runoff and susceptible to further damage • Maintenance will require setting up appropriate institutional arrangements involving local government and possibly beneficiaries	• Existing management systems documented (committees, description of roles and responsibilities of different stakeholders, meeting notes / attendance sheets, etc.) • Costs for ongoing supervision of weirs (GIZ and Afar authorities) • Costs for ongoing maintenance of weirs (skilled labour, local government experts, unskilled labour) • Material costs for ongoing maintenance (cement, sand, water, etc.) • Expert input for community meetings to establish institutions for maintenance of weirs • Opportunity costs for attending meetings • Costs for running meetings (refreshment, material, etc.) • Transport costs (material and personnel)

	• Weirs are able to hold back water and sediments. Water can either be used directly (e.g. for livestock) or slowly infiltrates into the soil. It then becomes available either as soil moisture for vegetation growth (grass, crops, shrubs & trees) or percolates into deeper groundwater storage. Increasing groundwater recharge can translate to increased availability of drinking water (e.g. through wells) for both humans and livestock or to increasing base flow. It might also lead to improved quality of water, less time spent to collect water, improved health outcomes, and opportunities to spend saved time in productive enterprises or education. • There might also be costs attached to stagnant water such as increased malaria or other diseases and parasites affecting both humans and livestock. More easily available water for humans and livestock might also alter migration and settlement patterns and lead to increased competition or conflict over access rights.	• Area behind weir covered by water and sediment • Amount of water and sediment trapped behind weir • Area with improved soil moisture • Area with improved vegetation cover / diversity of species • Groundwater table • Water quality • Soil texture, structure and nutrient content in parent material and sediments • Consumption of water by humans and livestock • Time spent to water animals and collect drinking water • Use of water for productive purposes • Malaria incidence, other health impacts and parasite infestation among people resulting from stagnant water • Incidence of livestock diseases and parasites resulting from stagnant water • Area coverage of invasive species • Conflict incidences over access to water, land and vegetation

	• For water to infiltrate into the soil, and the amount of water that infiltrates, depends on a range of factors (Oosterbaan & Nijland, 1994): - the saturated hydraulic conductivity of the soil profile (influenced by texture (% share of gravel-sand-silt-clay) in various soil layers (e.g. deposited sediment and parent material); soil salinity, sodicity, and acidity; geomorphology) - the degree to which pores are already filled with water when the infiltration process begins - the inclination and roughness of the soil surface - chemical and physical properties of water - organic surface layers - rain compaction of the soil - in-washing of fine sediments into larger pores - swelling and drying • A certain portion of water will also evaporate – depending on humidity, temperature, air pressure, the rate of airflow and characteristics of the surface area.	• Soil structure and texture • Evaporation rate

	• Weirs may lead to a slowdown of the velocity (and thus erosive power) of runoff. This can lead to decreasing loss of life and livestock, reduced streambank erosion and thus loss of potential pasture or crop land, reduced damage to gallery forest or infrastructure (e.g. roads, bridges) and reduced loss of household property and assets.	• Vegetation cover and composition along gullies / streambanks • Stream bank erosion / loss of land • Loss of human life due to flooding • Loss of livestock due to flooding • Damage to infrastructure • Damage to and loss of property / assets of households •
	• Increased soil moisture leads to increased vegetation growth and biomass production. This can either be grass (pasture), crops or woody biomass. • Not all vegetation, however, is necessarily beneficial. Increased soil moisture might also lead to the spread of invasive species (e.g. *Prosopis juliflora, Parthenium hysterophorus*) and lead to increased competition with palatable grasses and crops. • Increased soil moisture and changing patterns of vegetation growth might also lead to changing land use patterns, whereby formerly communal dry season grazing areas are converted to enclosures having the characteristics of private property (in picture at the left).	• Area coverage of grass and crops • Grass biomass production per ha • Crop yield production per ha • Crop residue production per ha • Area coverage of invasive species • Migration patterns • Settlement location • Inhabitants per settlement • Conflict incidences over access to water, land and vegetation •

	• Changing land use patterns might also alter migration and settlement patterns and lead to increased competition or conflict over access rights.	
	• Increased or stabilised production – fodder or crops – are expected to lead to stabilised or improved nutrition of people and livestock. Changing patterns of biomass production might lead to changes in herd composition. Crops or grass can be sold and income used to buy other household goods or services. There are also possibilities for diversified income generation and ultimately for diversified and increased asset holding. • • However, increased biomass production is specific areas might also lead to a change in mobility patterns, increased settlement, in-migration from other areas and increased competition or conflict over natural assets. This might lead to increased costs for conflict resolution.	• Nutritional status of people • Nutritional status of livestock • Number of livestock • Herd composition • Livestock productivity • Milk production • Household income (absolute, diversity) • Household expenditure (absolute, diversity) • Household asset holding (absolute, diversity) • Settlement location and number of inhabitants • Migration patterns • Conflict incidences over access to water, land and vegetation •

3 Cost-benefit analysis: from theory to practice in watershed/rangeland rehabilitation in Afar

Key Messages

This cost-benefit analysis assesses the value of a cascade of weirs, based on an existing cascade in Chifra of six completed weirs. We assume the cascade has a lifespan of 10 years and a total inundated area of 35.5 ha.

The CBA is sensitive to a number of assumptions – the most important of which is the area of land inundated around the weir, which is a multiplier for other benefits. If the area inundated increases to 50ha, the investment becomes significantly more attractive.

Weirs generate a positive Net Positive Value (NPV), which means the discounted benefit stream is larger than the discounted costs over the lifetime of 10 years. In the scenarios modelled in this section, the only exception is if there was a major flood event which affects benefits and damages the weir. In the case of a drought that impacts benefits, the weir still generates a positive cost / benefit ratio.

Weirs provide significantly more benefits if they are accompanied by improved water points, which create significant time saving and health benefits for beneficiaries who would otherwise depend on unsafe water sources. Benefits from water are greater than those from crops and livestock.

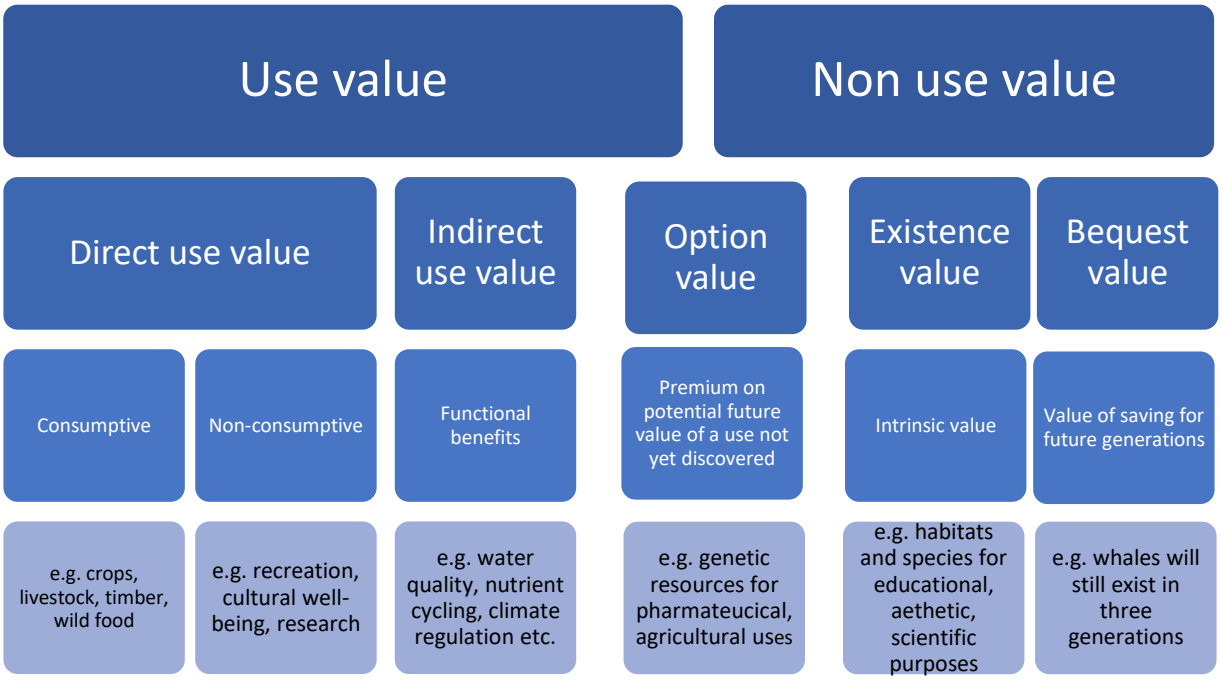
Yet weirs on their own are generally not able to generate enough revenues compared to counterfactual scenarios to be economically viable under the assumptions described in Section 3. In other words, the additional benefits from the installation of the water points – time savings and health benefits – turn the overall investment into an economically viable one – even when considering shocks such as droughts or floods.

3.1 Measuring costs and benefits within the Total Economic Value framework

Originally designed to inform business decisions, cost-benefit analysis is a useful tool to monitor and quantify the costs and benefits from watershed rehabilitation. Clarifying the value of social and economic benefits from an intervention creates accountability to the taxpayers who fund projects and help decision-makers weigh the relative value of one development investment over another. In the case of water spreading weirs, the benefits generated have what the Total Economic Value (TEV) framework call a “use value”. This means that the outputs delivered by the intervention have a consumptive use (see Figure 10). The TEV framework encompasses the sum of all use and non-use values of all services that flow from the natural capital now and in future. Use values are generally those that are directly used by humans, whether in a consumptive manner (e.g. crops, livestock, wild foods) or a non-consumptive manner (e.g. recreation, cultural, research). Option values are sometimes also considered part of the use values as humans are willing to maintain them (instead of consuming them now) to preserve the option of using the service in future (McKenney & Sarker, 1994); (Pearce, Atkinson, & Mourato., 2006). Option values are sometimes also considered part of the use values as humans are willing to maintain them (instead of consume them now) to preserve the option of using the service in future (McKenney & Sarker, 1994); (Dlamini, 2012); (Pearce, Atkinson, & Mourato., 2006). Direct use values can be assigned a monetary value, as they are either traded in formal and informal markets or alternative methods exist that allow eliciting a shadow

price (for all methodologies of valuing use and non-use ecosystem services and biodiversity see (Pascual & Muradian, 2010)).

Figure 10: Total Economic Value Framework.



Source: (Albon, et al., 2011)

Use values can be measured in a number of ways. The three main categories are market price approaches, revealed preferences and stated preferences (for further details on these methodologies, refer to (Pascual & Muradian, 2010). We combine revealed preference with market price approaches as our main mode of measuring benefits. Market price approaches reflect the value of ecosystem services through market prices. The value of increased soil moisture resulting from water spreading weirs, for example, can be expressed as the value of additional crop yield resulting from increased soil moisture compared to a baseline scenario, valued at market prices. Another example is increased carrying capacity of natural pasture, expressed by the value of additional animals (valued at market prices for animals and animal products) that can be kept on such improved pasture compared to a baseline scenario.

3.2 Basic principles of CBA and their application to environmental interventions

Because society has limited resources to allocate between worthy causes, cost-benefit analysis can help illuminate the trade-offs involved in making different kinds of investments. CBA is one of several evaluation approaches used to determine whether an activity corresponds to the desired and envisaged aims (*effectiveness*), whether the overall benefits exceed the overall costs – including direct, on-site effects and indirect off-site (downstream) effects on production and income (*efficiency*), how costs and benefits are distributed between different societal groups and across generations (*equity*) and whether they eventually have positive effects (*impact*) on the welfare of a community (de Graaff, 1996) (Ludi, Economic Analysis of Soil Conservation. Case studies from the Highlands of Amhara Region, Ethiopia., 2003).

The principle of the economic analysis of natural resource management investments such as those supported by GIZ in Afar Region involve calculating the difference in the flows of costs and benefits between the case where current degradation processes continue without any measures to prevent them (baseline scenario or counterfactual) and the case where a specific conservation practice is adopted (intervention scenario). The CBA is not to be confused with a 'before and after' analysis, but rather a comparison of an intervention scenario to a counterfactual scenario where no weirs are built. Furthermore, a CBA is an analysis that takes into account one specific action or investment and compares it to a base case. If the results show that this one specific investment is not profitable, this does not imply that all other investments are not profitable either. The main difficulty in the economic analysis of environmental degradation and resource management investments is to find a way of quantifying the impact the land or water degradation, both on-site (e.g. decreasing yields, decreasing pasture production, decreasing water tables) and off-site (e.g. siltation of dams), and to collect the required economic data to put a monetary value on these different impacts.

The key question, though, is not to just establish the costs of natural resource conservation, but rather whether the long-term benefits of reduced land and water degradation justify the costs of the resource management intervention. Any assessment of the impact of natural resource management investments thus requires an assessment of the overall productivity decline and increase without and with the investments over time (Ludi, Economic Analysis of Soil Conservation. Case studies from the Highlands of Amhara Region, Ethiopia., 2003).

CBA is based on the principle of ***opportunity costs***. Resources (e.g. land, labour, capital) invested in, for example, water spreading weirs, could also be invested in any other enterprises. The value for these inputs is therefore assumed equal to the foregone benefit of investing these resources in an alternative enterprise.

Net Present Value (NPV)

The traditional project appraisal criterion is that discounted net benefits, the net present value (NPV), should be non-negative (Pearce et al., 1990 in (Ludi, Economic Analysis of Soil Conservation. Case studies from the Highlands of Amhara Region, Ethiopia., 2003)).

$$\sum_{t=1}^{t=T} \delta[B_t - C_t] > 0$$

With Benefits B_t as

$$B_t = \sum_{i=1}^{i=I} P_i \times Q_i$$

Where P_i is the price of commodity *i* and Q_i the quantity of output at time *t.*

Costs C_t can accordingly be expressed as

$$C_t = \sum_{j=1}^{j=J} P_j \times R_j$$

Where P_j is the price of commodity *j* and R_j is the quantity of input in time *t*.

The discount factor δ is:

$$\delta = \frac{1}{(1 + r)^{t}}$$

With *r* the discount rate at time *t*.

When considering an investment proposal, always two questions should be asked:

- Does the project represent a good use of funds and is it worthwhile?
- Is the project under consideration to be preferred to other projects that could be carried out with the same funds available?

A CBA of resource management interventions should thus compare the two situations - C 'counterfactual' or baseline scenario with uncontrolled degradation on the one hand and I 'intervention' scenario where resource management interventions are carried out on the other hand. If the NPV of uncontrolled degradation – project C – is higher than the NPV which can be achieved if investments in resource management are carried out – project I – then the investments in resource management are economically not worthwhile.

An NPV of a conservation project that is positive only tells us that this specific investment is preferable to ongoing degradation. It does not tell us whether this investment is the best of different options. For this question (the second question above) we would have to compare the NPV of different investments – for example comparing water spreading weirs aimed at increasing soil moisture to allow crop production versus drilling a borehole to access groundwater for irrigated agriculture to find out which of the two options is preferable if the same amount of funds is invested.

Before calculating the NPV, the returns of the two considered projects have to be estimated. In the case of resource degradation (C) and resource conservation (I), the following equations are used to calculate returns (π) under the different practices each year:

$$\pi_t^C = py_t^C - c^C y_t^C$$

py_t^C is the yield (crops, livestock, natural pasture, etc.) *y* in year *t* under the degrading practice multiplied by the price *p* for the considered output.

$c^C y_t^C$ the corresponding annual costs of production.

The returns in the case with natural resource management interventions would similarly be:

$$\pi_t^I = py_t^I - c^I y_t^I - c_t^{NRM} + pz_t^{NRM}$$

With:

py_t^I and $c^I y_t^I$ as above but now for the intervention scenario and

c_t^{NRM} representing the costs of establishing and maintaining the resource management interventions in year t

z_t^{NRM} any additional yield which can be realised as a result of the resource management interventions.

The net benefit obtained from adopting resource management practices in any given period would thus be:

$$\pi_t^I - \pi_t^C, t = 1, 2, 3, \dots \dots T$$

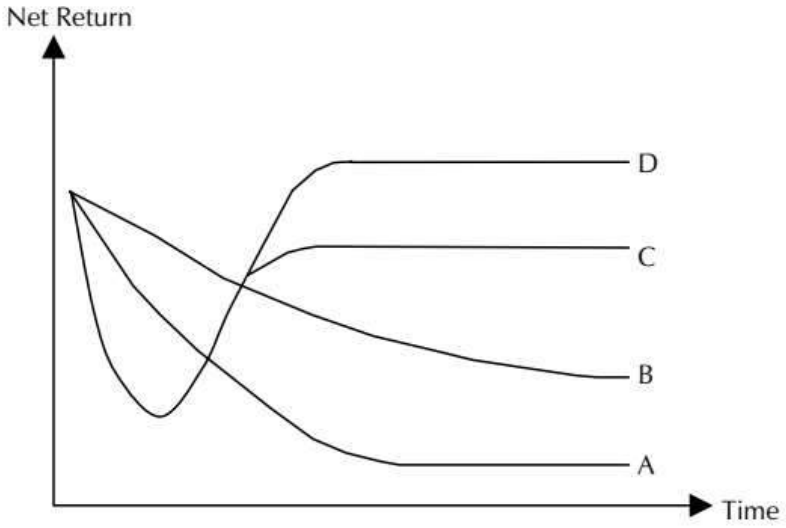
The ***Discounted Net Gain DNG*** tells us how much we gain (or lose) from switching from the degrading practice to one where specific natural resource management interventions have been carried out.

$DNG = NPV^I - NPV^C$

where NPV^I and NPV^C are the discounted flows of net benefits with (intervention scenario) and without natural resource management interventions (counterfactual scenario)

In the case of investments in water spreading weirs, for example, relatively high initial investment costs accrue in the first year and result in a negative net benefit. The following figure shows this in a schematic manner. It is assumed that uncontrolled resource degradation leads to declining net returns, as shown by path A in Figure 11. Investments in water spreading weirs let net returns in early years drop to low levels because of the considerable initial investment costs. After some years, net returns might recover or even increase (path B and C, respectively), if, for example, marketable crops can be grown that lead to higher returns than those which could be achieved with just pasture regeneration.

Figure 11: Possible profiles of net returns over time with and without resource management interventions



Source: (Ludi, Economic Analysis of Soil Conservation. Case studies from the Highlands of Amhara Region, Ethiopia., 2003)

Because the CBA considers the stream of costs and benefits over time, the discount rate and the time horizon of analysis are of paramount importance. The higher the discount rate the less weight is attributed to benefits in later years. If the discount rate is set to zero, immediate costs and future benefits are weighed equally. If the time frame of analysis is too short, benefits in future might not be considered adequately.

For the following analysis of costs and benefits of natural resource management investments in Afar, a discount rate of 3.5% has been assumed (HM Treasury, 2011). This is the rate recommended for environmental investments for projects with a life-time of up to 30 years and one that deals with sustainability and intergenerational equity issues adequately.[2]

A time horizon of ten years has been assumed for analysis based on discussions with GIZ staff, who indicated this to be the approximate lifetime of a well-maintained weir.

3.3 Application to GIZ interventions in Afar

GIZ has multiple weir interventions that have already been implemented or are planned in Zone 1 and 4 of Afar Region (Figure 1) covering all woredas of Zone 4 (Awra, Ewa, Gulina, Teru, Yallo) and three woredas of Zone 1 (Chifra, Kori, Mille), shown in the map below (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016). As of November 2017, a total of 34 weirs have been installed. GIZ estimates the area rehabilitated by these 34 weirs to be 1700 ha, assuming that one weir rehabilitates (or inundates) 50 ha.

The cost-benefit analysis (CBA) takes the cascades of weirs in the Shakay Boru and Gariro areas of Chifra Woreda as a model, largely because the majority of data to date has been collected from these sites. In addition, Chifra is also the area where agriculture is relatively widespread, as it is an area where farmers from the Amhara Highlands have settled a long while ago which led to the

[2] The discount rate is calculated as: $r = \rho + \mu \times g$, with ρ the rate at which individuals discount future consumption over present consumption, assuming that no change in per capita consumption is expected, μ the elasticity of marginality of consumption and g the annual growth in per capita consumption. Keeping ρ and μ constant at $\rho = 1.5\%$ and $\mu = 1$, but adjusting g for actual per capita rate of growth in consumption in Ethiopia over the past decade of around 8%, the discount rate r would have to be increased to 9.5%.

adoption of agriculture – both irrigated river bank farming as well as rainfed crop cultivation – more widely. In comparison, other sites are still much more pastoral.

In comparison to other Woredas across Afar Region, Chifra receives relatively higher rainfall from June to August, the season locally known as *Karma* because of its location close to the escarpment. The hottest temperature in the area are recorded from May to September. Early June sees strong winds leading to wind erosion that destroys the natural resources and leads to very high evapotranspiration rates (ANRS, 2011a). During the rainy season, floods emerging from the Tehuledere (Amhara) highlands are affecting Chifra area, with runoff concentrated in channels leading to gully erosion and washing away farmland, rangelands and livelihoods (Tilahun Amede, 2016).

The program aims to benefit a total of 2,500 (agro-) pastoralist households (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016), with Chifra Woreda housing most beneficiaries. The map of the cascade below shows the various settlements in the Shakay Boru and Gariro areas. A total of 292 households or 2044 individuals (assuming an average household size of 7) are benefiting from the interventions across approximately 212 ha[3] of rehabilitated area from the 6 weirs in place that make up the cascade (Interviews 2017).

Figure 12: Sketch of cascades and location of beneficiary households

Source: constructed from interviews, 2017

3.4 Unit of analysis: Cascade of water-spreading weirs

The unit of analysis for this CBA is a cascade of weirs, which is defined as a series of weirs built across one gully with the aim of slowing down the energy of the flood and change the flow regime Because individual weirs are vulnerable to strong flood waters unless they are 'protected' by upstream and downstream weirs, the cascade is the logical unit of analysis. By building a full cascade of weirs, GIZ aims to reduce further gully erosion, prevent downstream damages, and increase water availability for crops, pastures and people.

[3] Some interviews suggested the rehabilitated area ranged from 100-180 ha. The 212ha used throughout the report is based on the size of the ICRISAT research site (Tilahun Amede, 2016), scaled up to a cascade of 6 weirs.

In the Shakay Boru area of Chifra Woreda, six out of nine weirs have been completed to date. We assume thus a total of six weirs to form a typical cascade, which is our unit of analysis, though cascades can have more or fewer numbers of weirs in practice. Because the cascade is our unit of analysis, we assume that the weirs start accumulating benefits when the cascade is complete. This means that rather than representing the weirs as being built over a period of several years, and benefits gradually building up accordingly, we assume that all weirs in the cascade are built in year zero and benefits begin accruing in year one.

While historic data for lifetimes of weirs and cascades of weirs for the Afar and Chifra region are not available, the GIZ baseline study (2014) suggests 2 to 10 years before the rehabilitated land area reaches its optimum use potential. Thus, the CBA analysis assumes a lifetime of 10 years. Several factors may alter the overall lifetime of a weir – velocity and flow of flood water, scour behind walls, rate of sedimentation that affects the time it takes for the weir being filled with sediment and level with the rest of the land. All these factors vary significantly across seasons and the heterogenous impacts are too complicated to be modelled within a CBA.

3.5 Scenarios

Depending on the purpose weirs are built to serve, the rehabilitated land will yield different types of benefits. This cost benefit analysis assesses the net benefits provided in multiple scenarios – if the weirs are designed to maximize crop yields, to improve livestock productivity, to provide water access to the population, or a combination of these scenarios.

Yet the benefits derived from weirs are subject to a range of environmental pressures. Severe floods and droughts, which are virtually inevitable over the course of 10 years, will lower the net benefits accrued over the lifetime of the weir. The scenario analysis takes into account these shocks, and discounts the benefits accordingly. In a flood year, we assume that 40% of returns from crop and fodder production and 10% of livestock benefits are lost. Weirs are more vulnerable to flood events in early years, before sediment has built up behind the weir, so the major flood event in the CBA is calculated in year 2. We assume that 80% of the weir is being destroyed by such a major flood event and must be re-built. To maintain consistency and refrain from inflating benefits in a drought scenario, the drought event is also built into year 2. Even though droughts can last over multiple years in Afar Region, only one drought year is assumed to happen within the lifetime of weirs of 10 years in the assessment of net benefits of investments. In a drought year, we assume that 80% of crop benefits and 40% of livestock benefits are lost.

A key feature of a cost-benefit analysis is a counterfactual scenario – what would have happened if no investments were carried out and the situation continued unchanged? For this CBA, the counterfactual scenario consists of the benefits realized without a cascade, using baseline information of land under crop cultivation and crop yields and biomass production as assessed before project interventions, livestock productivity, and water access and availability in the Chifra region prior to 2014. Importantly, the counterfactual is explored through multiple scenarios – looking at benefits accrued in the face of drought, flood, and for different land use patterns. In addition, we halve also constructed scenarios that assume that additional investments in water points are made to enhance the direct benefits to the population of increased water availability resulting from investments in weirs.

Table 2: Summary of scenarios and potential shocks envisaged

Intervention	Land use pattern	Shock and stress scenarios			
		Normal (no shock)	Drought in year 2	Flood in year 2	5% land lost annually to gullying
Cascade of weirs built	Pasture and crops	X	X	X	
	Pasture exclusively				
	Water points + pasture and crops	X	X	X	
Counterfactual (without weirs)	Pasture and crops	X	X	X	X
	Pasture exclusively	X			X

This analysis will be complemented by qualitative data to gain a more rounded view of costs and benefits of weirs, including intangible costs and benefits, and how these are distributed among different societal groups both within a specific area as well as between upstream and downstream areas.

3.6 Data collection methods and methodology for CBA

The mixed-method approach to the CBA analysis consisted of documentary analysis, interviews and participant observations, along with the CBA (Creswell & Clark, 2007); (Yin, 2009). Such a mixed-methods approach is also crucial to elicit intangible costs and benefits related to option and existence values of resources and ecosystem services.

Primary surveys were used to collect baseline data for the CBA. Samara University led three studies on pastoral livelihoods, soil quality, and water access in GIZ intervention areas (Gebrehaweria, Aregaw, Abdelah, & Bushra, 2017) (Dereje & Hailemariam, 2017) (Sileshi & Habtamu, 2017). The studies were conducted in three selected research sites: Finto, Garriro, and Hidalu kebeles in Chifra and Awra Woreda. A purposive sampling technique was employed to select respondents based on their proximity to the weirs and their livelihoods. A total of 120 households (40 from each study area) were interviewed. District pastoral agriculture officers, natural resource management officers, animal health officers, and community elders were also interviewed as key informants. Additional information was collected through sex-disaggregated and age-differentiated focus groups which helped to elicit relevant perceptions about the costs and benefits of weirs as well as challenges faced by agro-pastoral and pastoral households.

Documentary analysis was a key method of data collection. Sources were triangulated as much as possible with other documentary sources to ensure validity of the data used. Additionally, data was collected from GIZ location offices and PADO in Chifra.

Another method used were *semi-structured interviews*. In order to minimize researcher bias, questions were worded carefully and leaving many open ended so that respondents could direct and control the interview rather than having the conversation prompted by researchers. To maintain data validity, interview findings were cross referenced where possible with data from documentary analysis and participant observations. Questions referred to environmental history, current challenges, land tenure, mobility patterns, livelihood choices, livestock ownership, water security, food security and coping strategies.

Participant observations and transect walks: The fourth method used was participant observations and transect walks, which helped in obtaining a more holistic picture of contexts (Spradley, 2016).Transect walks were used to gain an understanding of the community, existing natural capital and the related degradation/regeneration processes.

3.6.1 Limitations in data collection

Several challenges were encountered while developing the CBA. Only limited baseline data on land use and livelihoods was available that would have allowed a detailed representation of a counterfactual, the 'without a weir' situation. Similarly, data on specific parameters for the 'with' situation was hard to come by and several assumptions had to be made. Project bias was another issue, whereby respondents felt not comfortable answering questions or raising contentious issues such as those related to benefits of weirs and how they are shared among community members or conflicts over natural resource access.

Data was only collected at one point in time which in a semi-arid environment with highly variable climatic conditions is problematic. In addition, Afar was severely impacted by the El Nino phenomenon between 2015 and 2017 which led to widespread drought, water shortages, loss of livestock and poverty, including in the research areas. Data collected from respondents will most certainly have been influenced by the drought and the hardship pastoralists and agro-pastoralists experienced. As opposed to the Ethiopian Highlands, Afar in general has also suffered from neglect of regular and long-term meteorological, agro-ecological and socio-economic research and monitoring which could have provided time series of data to inform the CBA.

Because of these data limitations, the CBA shows results in a generalized way. It was not possible to access panel data that would have allowed to study variation across time. The CBA, therefore, was constructed in an open manner that will allow entering more precise data as it becomes available during the project life time.

3.7 Estimating costs in the Cost-Benefit analysis

3.7.1 Costs for building a weir

The starting point for the CBA is estimating the costs for building a cascade of weirs. This cost is fixed – though it may vary slightly between locations and the structure of individual weirs, it is a predictable expense that holds constant across the intervention scenarios presented in section 3.1.

Fixed costs primarily consist of physical capital (e.g. materials such as stone, cement, fuel), natural capital (e.g. water, sand), labour (e.g. human capital - ranging from construction workers to supervisors) and tools (e.g. jerry cans, wheelbarrow, transportation equipment) to construct the water spreading weirs.

Fixed costs vary by the size of the weirs constructed (or the assumptions made in that regard). In the example calculated, it is assumed that one weir is approximately 300m^3 – consisting of the spillway and the wings on either side of the spillway. Fixed costs for cement, sand, labour, tools and transporting material to the construction site are calculated accordingly.

Assuming the volume of a weir to be 300m^3, total fixed costs would add up to ETB 646,560 (€ 20,080 – at current exchange rate of € 1 = ETB 32.2) per weir or ETB 3,879,360 (€120,477) for a cascade of 6 weirs. The breakdown of fixed costs is shown in Table X below.

Table 3: Fixed costs of the cascade

Costs	Fixed cost across cascade (ETB)	Percentage share of main capital costs
Material costs (including transport)	1,802,160	46
Labour costs	1,897,200	49
Technology/ tools	180,000	5
Total fixed cost cascade	3,879,360	

The data is estimated using GIZ baseline data for a single weir as much as possible, and extrapolating the results across all 6 weirs in the cascade. We recognize that there are differences in the dimension of weirs, but for ease of use we use the same dimension for all weirs in a cascade in our initial calculation. As more accurate data per weir become available, the CBA calculation for the average dimension of a weir can relatively easily be adjusted by inputting the dimensions (length x height x depth) of each weir in the cascade separately.

Recurrent costs consist of materials, technology costs and labour costs. Recurrent costs for materials are assumed to be 5% of total capital costs. Labour costs are assumed to be 20% of the initial construction labour, at current wage rate.

In addition, a fixed amount of 5% of labour costs for weir construction is assumed to be spent on managing and attending community committees who would resume ownership of the weirs. This amount reflects opportunity costs of organizing community committees and oversight as well as participating in meetings.

3.7.2 Excel sheet interpretation:

The worksheet **Cost weir data input** collects all the information required to calculate the fixed and recurrent costs for constructing and maintaining one weir.

In a first step, the average dimension of weirs is estimated based on the actual dimensions of the weirs in the cascade under consideration (J25 – J88). In a second step, fixed costs are broken down into main categories – stones, sand, cement, water and tools - itemizing the different types of costs for both materials and transport (C5 – E42). The total fixed costs for each category is calculated based on the average dimension of the weir under consideration. Transport costs are calculated based on a truck capable of carrying $5m^3$ of material (M7) and a set of reasonable assumptions regarding rental costs, fuel efficiency, fuel costs, salary for drivers and distance travelled to bring material to the weir site. Total number of unskilled and skilled labour days as well as days for supervision are estimated based on what a worker can accomplish per day (C49) and the dimension of an average weir. Wage rates as currently paid by GIZ are used where available, otherwise they have been estimated. Recurrent costs are calculated based on a percentage of initial capital and labour costs.

3.8 Estimating benefits in the CBA

We assumed three main benefit streams - crop productivity, livestock productivity and drinking water benefits – resulting from the construction of water spreading weirs.

For the CBA, we assume that 35.3 ha are rehabilitated by one weir or 212 ha considering a cascade consisting of 6 weirs. This figure is based on the actual rehabilitated land around the weir studied by ICRISAT, where agricultural inputs and support have been provided (Tilahun Amede, 2016). As we

will show in Section X.X, the area of land inundated by the weirs is a multiplier for other benefits, and a higher or lower assumption about how many hectares of land are rehabilitated by a weir will exert a significant influence on the net benefits.

For a cascade of weirs, we use the number of households estimated to be living in the vicinity of the Shakay Boru and Gariro cascades of 292 households (or 2044 people, assuming a household size of 7) as direct beneficiaries. These are defined as households living within approximately 1.5 km of the weirs in the cascade and therefore being likely to benefit directly from the weirs through, for example, access to crop land, improved pasture for their animals or access to an improved water source.

Table X below shows how land use has changed before and after the weirs were built. Pre-cascade, land use patterns are estimated through interviews with agro-pastoralists and extension officers, while the post-cascade values are derived from the ICRISAT study (Tilahun Amede, 2016) and scaled to the level of the cascade[4]. To ensure consistency in the CBA, we use the same area of analysis – 212 ha – for the counterfactual scenarios and for the intervention scenarios to estimate benefits from and costs for pasture and crop production.

Table 4: Land use change pre- and post-cascade

Land use	Pre-cascade (%)	Post-cascade (%)	Comment
Agriculture (crops)	12%	36%	Pre-cascade was primarily rainfed agriculture. Post-cascade crop land also includes land dedicated to high-value livestock fodder production
Natural pasture, bush land, long-term fallow used for livestock grazing	63%	38%	Pre-cascade mostly bush land and rangeland
Unusable area (degraded land, land covered by sediments, land infested by weeds and built-up area (roads, settlement)	25%	26%	

Source: (Tilahun Amede, 2016), ODI Interviews 2017

3.8.1 Benefits from crop production

Calculating net benefits is a 3-step process (see Box 4). Step 1 involves calculating the costs and benefits of growing food crops before the cascade was built to represent the counterfactual or baseline situation. Step 2 involves calculating the costs and the benefits associated with growing crops after the cascade was built. Step 3 consists of estimating net benefits accrued as a result of weir construction. For ease of use, we show both gross and net benefits for the intervention and the counterfactual scenario separately in the relevant Excel worksheet (Crop benefits data inputs) and only at a later stage calculate the net benefits N.

Box 4: Three step calculation of net crop productivity

Step 1: Net benefits counterfactual: B_c- C_c, where B_c = benefits before cascade; C_c = costs before cascade

Step 2: Net benefits intervention: B_i- C_i, where B_i = benefits after cascade; C_i = costs after cascade

[4] Land use data has not been collected across every weir in the cascade. For the CBA we extrapolate the ICRISAT results to the entire cascade under consideration.

Step 3: Net benefits $N = (B_c - C_c) - (B_i - C_i)$

Overall, annual net benefits (gross benefits from crop production minus all costs associated with producing these crops such as labour costs, costs for renting oxen to plough the land, seed and fertilizer costs) amount to ETB 749,634 for the intervention scenario and ETB 115,219 for the counterfactual scenario 1. The difference between the two results can be explained by:

- A considerably larger area under crops in the intervention scenario (76 ha) compared to the counterfactual scenario (25.4 ha)
- A different crop mix with more high-value crops (e.g. sesame, mung bean) grown after weirs were built
- Higher yields in the intervention scenario resulting from additional soil moisture and sediment deposition as well as higher fertilizer use
- Higher prices people were able to attract from crops grown on rehabilitated land

The main crops grown are maize (grown on 82% of crop land), sorghum (8%), cowpea (5%), and teff (5%) before the weir was in place. The increased availability of extension services has improved growing practices since weirs were installed. For instance, farmers now intercrop row spaces between maize and sorghum with cowpea, mung bean and forage crops (Tilahun Amede, 2016). This has enabled both increasing crop diversity and improve in-situ moisture conservation (ibid). The land use distribution as well as the crops grown on the land post weir-construction have changed from the baseline assumptions. Under the intervention scenario, maize is still the most important crop grown (77%), but this has now been complemented by high-value crops such as cowpea (9%), mung bean (4%) or sesame (2%). Yields for the counterfactual scenario were estimated based on interviews and for the intervention scenario were taken from (Tilahun Amede, 2016) or, where not available, from the literature. To estimate the value of B_c and B_i, local market prices across each type of crop grown were used.

We assume that no extra fixed costs such as for tools accrue. Variable costs for crop production are labour, renting oxen for ploughing, fertilizer and seeds. These are:

- Labour: 44 days per ha, assuming: 2x4 days for ploughing, 4 days for sowing, 16 days for weeding, 8 days for harvesting and 8 days for transporting the crop (and biomass) to the homestead or a protected area at ETB 70 per day. ETB 70 is the average daily labour rate assumed for farm work in the vicinity of Chifra.
- Renting of oxen for ploughing: 12 days per ha at ETB 100
- Fertiliser: fertiliser use in the area is low and has been estimated at 5kg/ha for the counterfactual and 20 kg/ha for the intervention scenario. Fertiliser cost are ETB 2.1 per 1kg DAP.
- Seed: is assumed as an average of 25kg/ha at an average cost of ETB 15. Seeds in the area are still expensive, as the only functional nursery site within Chifra Woreda mainly produces tree seedlings for fodder and fruit trees and fodder grass seeds.

Total variable costs for crop production without weirs is estimated at ETB 118,578 and with weirs ETB 358,137.

Table 5 below shows the gross value of crop production before (B_c) and after (B_i) weirs were built.

Table 5: Total production value before and after weirs in ETB

	Counterfactual (baseline)				Intervention			
Crops grown	ha	Price (ETB/kg)	Yield (t/ha)	Production value B_c (ETB/year)	ha	Price (ETB/kg)	Yield (t/ha)	Production value B_i (ETB/year)
Maize	20.8	6.2	1.53	197,699	58.8	7.6	1.80	804,891
Cowpea	1.3	12.0	0.08	1,220	7.2	15	0.07	7,565
Sorghum	2	5.9	0.86	10,317	4.2	7.1	1.24	37,060
Mung bean					3.0	32.7	2.00	196,324
Sesame					1.8	35	0.66	41,606
Pigeon pea					1.2	15	0.25	4,566
Teff	1.3	15	1.28	24,562	0.6	17.5	1.50	15,760
Total Gross Value	25.4			233,798	76.8			1,107,771
Variable costs				118,578				358,137
Total Net Value				**115,219**				**749,634**

Source: Interview data 2017, HCIE 2011, (Tilahun Amede, 2016)

A series of alternative scenarios have been built to reflect the conditions of crop farming in Afar (see Table x). These include:

- A drought affecting production, reducing crop yields by 80%
- A flood affecting production, reducing crop yields by 40%
- Continuing gully erosion and loss of land for crop cultivation for the case without weirs, reducing the arable area by 5% annually.

Below, a simple simulation is used to assess the resilience of the farming system. We model what would happen in a situation of drought and different assumptions regarding crop yield lost between 10% and 90%. Variable costs remain constant as we assumed that they are accrued before the loss of crop yield would materialize. Table xx shows how resilient the baseline and the intervention scenarios are to drought, or in other word, how severe a drought would need to be to push net values of crop production to below Zero.

Under the intervention scenario, net returns would only become negative if a drought would destroy close to 70% of the total crop yield, whereas under the baseline scenario, net returns would become negative if a drought would destroy just over 50% of the yield. In other words, there is a resilience dividend that can be realized thanks to the construction of weirs and the changes in land use patterns and practices that were made possible as a consequence.

Table 6: Resilience of the crop production system to drought impacts

	Baseline		Intervention	
	Gross	Net	Gross	Net
10%	210,418	91,840	996,994	638,857
20%	187,038	68,460	886,217	528,080
30%	163,658	45,080	775,440	417,303
40%	140,279	21,700	664,662	306,526
50%	116,899	(1,679)	553,885	195,749
60%	93,519	(25,059)	443,108	84,971

70%	70,139	(48,439)	332,331	(25,806)
80%	46,760	(71,819)	221,554	(136,583)
90%	23,380	(95,199)	110,777	(247,360)

3.8.2 Excel sheet interpretation:

The worksheet **Crop benefits data input** collates all the information required to calculate net benefits from crop production.

Assumption on costs for crop production: This box holds basic data on labour input for major farming tasks (ploughing, sowing, weeding, harvesting and transportation (N6 - N10). As not all households own a pair of oxen for ploughing, households generally have to hire someone with oxen to do the ploughing for them (Costs for renting oxen, P14)). Fertiliser costs (P15) and volume (P16 and P17), as well as seed costs (P18) and amounts (P20) need to be estimated for the counterfactual and the intervention scenarios.

Area inundated by weirs in cascade and share of area used for crop cultivation: As more detailed information becomes available regarding the size of the area influenced by each weir, these data can be modified to better reflect the actual situation on the ground (P25 – P34). To calculate the gross crop production, an average inundated area is calculated and used for subsequent analysis. The share of the inundated area used for crop cultivation (in %) should be estimated or assessed through mapping or with remote sensing data (Q25 – Q34). For this analysis, an average percentage across the cascade was used.

Assumptions about drought and flood impacts and land lost to gully erosion: To better reflect the precarious conditions for crop cultivation in Afar Region, we have modelled two different scenarios to represent drought and flood impacts on crop cultivation. An estimate should be made here regarding what percentage of crop cultivation remains after a flood (Q42) or drought (Q39) event, informed by past experiences and key informant interviews with people living in the area. One of the counterfactual scenarios assumes continuous gully erosion leading to an annual loss of crop land. An estimate should be made of how much land is lost annually (in percent of crop land) to gully expansion (Q45).

Calculation of net value of crop production: In order to calculate the net value of crop cultivation for the counterfactual, the percentage of land under crop should be estimated (K35). Secondly, shares of land dedicated to different crops should be estimated for both the counterfactual scenario (no weirs, C19 – C27) and the intervention scenario (a cascade of weirs, D19 – D27). This should be done as an *average* across all weirs. To calculate the gross value (in ETB) of crop production, actual market prices for the different crops (E19 – E27 and F19 – F27) and crop yields (H19 – H27 and I19 – I27) need to be collected separately for the baseline (counterfactual) and the intervention scenarios.

With the above data, gross and net benefits from crop cultivation will be automatically calculated in worksheet “Benefits” for different scenarios.

Monitoring Crop Benefits: An M&E System fit for purpose

To link project inputs to outcomes, data collected should aim to monitor crop productivity, with the intention of linking this to well-being benefits. Here we provide the data needs to collect information for a cost-benefit analysis

Data to input in CBA:

Data Collection for Cost-Benefit Analysis Tool			
Indicator	**How / Where to collect**	**Frequency of collection**	**Purpose**
Area rehabilitated (ha)	Mapping or remote sensing data	Per harvest	To define the perimeter of influence by weirs, for each weir separately
Number of ha under crop production, per crop	Mapping or remote sensing data	Per harvest	To calculate the value of the total harvest within the perimeter of influence by weirs
Yield of each crop in t per ha	Crop harvest data from fixed and randomly selected sample sites, FGD	Per harvest	To calculate the value of the total harvest
Price of each crop per kg	Market price data; FGD	Per harvest	To calculate the value of the total harvest
Labour costs	FGD with farmers	Once	To calculate input costs, for ploughing, sowing, weeding, harvesting, transporting.
Cost for seeds, fertilizer, renting oxen, and other inputs	FGD, PADO office	Once	To establish investment costs

To assess how crop production contributes to household food security requires going beyond a simple cost-benefit analysis. Generally, food security is composed of food production and availability, stability of food supplies, access to food and food utilization.

Food security of households interviewed in the areas where weirs have been built and who had access to crop land stated that they reduced buying cereals from the local market since they began growing crops more intensively. Others stated that they could share the 'extra maize' produced with families who were not located close to the cascade. According to the GIZ baseline study (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016) households spent 56% of their income on food, mainly cereals, for household consumption. Water spreading weirs allowing more common cereal production could potentially lead to a visible reduction in consumption expenditure over the long run.

In terms of food utilization, the food consumed during the time of the survey consisted mainly of cereals (maize), pulses and milk, while vegetables, fruit and meat played a negligible role for consumption (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016), (Tilahun Amede, 2016). However, with the reduction of expenditure on cereal many women claimed to be increasing the share of vegetables they purchase from the shops to diversify their diets. This suggest that increasing crop productivity has facilitated improved food utilization[1].

Data to monitor longer-term changes in food security and income:

Data Collection for wider M&E Programming			
Indicator	**How to collect**	**Frequency of data collection**	**Purpose**
Capital asset accumulation / savings	HH survey	Annually	To assess poverty reduction contribution of the intervention.
HH income from crop sales	HH survey	Annually	To assess income proportion from farming over time
% of HH expenditure on food	HH survey	Annually	To track changes in HH food expenditure, relative to other expenditure, in order to better understand HH food security

Coping Strategy Index (CSI) (Maxwell & Caldwell, 2008)	HH survey	Annually	To assess coping mechanisms related to food insecurity over time
Food Consumption Index (FCI) (Vaitla, Coates, & Maxwell, 2015)	HH survey	Annually	To use as proxy indicator to measure caloric intake and diet quality at HH level, to understand HH food security.

Coping Strategy Index (Maxwell & Caldwell, 2008)

	Weight
Rely on less preferred / less expensive food	1
Borrow food or rely on help from a friend or relative	2
Limit portion size at mealtime	1
Restrict consumption by some members for other members to eat	2
Reduce number of meals in a day	2

Score:
0 = Never
1.5 = Rarely (Once or twice in the past 7 days)
4 = Sometimes (three to five days of the past 7 days)
6.5 = Usually (6 or 7 days in the past 7 days)

EXAMPLE	Weight	Score	Weighted score (Frequency * Score)
Rely on less preferred / less expensive food	1	4 (Sometimes)	4
Borrow food or rely on help from a friend or relative	2	1.5 (Rarely)	3
Limit portion size at mealtime	1	4 (Sometimes)	4
Restrict consumption by some members for other members to eat	2	6.5 Usually)	13
Reduce number of meals in a day	2	1.5 (Rarely	3
Total HH Score			27

Max Weighted score = 52
Min Weighted score = 0

The lower the score the more food secure is a household.

Food Consumption Index (Vaitla, Coates, & Maxwell, 2015)

	Weight
Staples (grains, roots, tubers)	2
Pulses	3
Vegetables	1
Fruits	1
Fish or fish	4
Dairy or eggs	4
Sugar	0.5
Oil	0.5

Score:
0 = Never

1.5 = Rarely (Once or twice in the past 7 days)
4 = Sometimes (three to five days of the past 7 days)
6.5 = Usually (6 or 7 days in the past 7 days)

EXAMPLE	Weight	Score	Weighted score (Frequency * Score)
Staples (grains, roots, tubers)	2	6.5 (Usually)	13
Pulses	3	1.5 (Rarely)	3.5
Vegetables	1	4 (Sometimes)	4
Fruits	1	1.5 (Rarely)	1.5
Meat or fish	4	1.5 (Rarely	6
Dairy or eggs	4	4 (Sometimes)	16
Sugar	0.5	6.5 (Usually)	3.25
Oil	0.5	4 (Sometimes)	2
Total HH Score			49.25

Max Weighted score = 104
Min Weighted score = 0

Determine the household's food consumption status based on the following thresholds: acceptable (> 35, > 42 in areas where oil and sugar are consumed regularly), borderline (21–35; 28–42 in areas where oil and sugar are consumed regularly), and poor (< 21; < 28 in areas where oil and sugar are consumed regularly).

3.8.3 Benefits from livestock production

The process of calculating net livestock benefits is similar to calculating net crop benefits. The method for estimating the value of livestock follows (Behnke & Kerven, Counting the costs: replacing pastoralism with irrigated agriculture in the Awash Valley, north-eastern Ethiopia, 2013) and (Behnke R. , The contribution of livestock to the economies of IGAD Member States., 2010).

The major livestock species in the study area are cattle (3.77 ±4.1), sheep (11.97 ±9.3), goats (23.1 ±15.1), camels (3.34 ±3.4) and donkeys (1.35 ±6.4) of local breeds (Gebrehaweria, Aregaw, Abdelah, & Bushra, 2017). On average, each household owns 11.8 TLU.[5]

Different herd species produce different combinations of dairy, traction/transport or meat products at different rates, and male animals yield differently than female animals. The productivity of Afar herds therefore depends, among other factors, on the species, age and sex composition of those herds (Behnke & Kerven, Counting the costs: replacing pastoralism with irrigated agriculture in the Awash Valley, north-eastern Ethiopia, 2013). A combination of data collected from the research sites (herd composition, milk yields[6]) and assumptions made by (Behnke R. , The contribution of livestock to the economies of IGAD Member States., 2010) with regard to production coefficients are used in the CBA. Market prices are used to estimate the value of milk and meat (offtake) that is consumed by livestock owners in addition to livestock products that are sold.

[5] TLU = Tropical Livestock Units. 1 camel = 1.25 TLU, 1 cattle = 1 TLU, 1 sheep = 0.13 TLU, 1 goat = 0.13 TLU, 1 donkey = 0.6 TLU (Storck, Bezabih, Berhanu, Borowiecki, & Shimelis, 1991)

[6] (Gebrehaweria, Aregaw, Abdelah, & Bushra, 2017) have assessed milk yields across three kebeles (Finto, Garriro and Hidalu):
Average milk yield per cow, wet season: 2.21 l/day, dry season: 0.78 l/day. Average: 1.5 l/day
Average milk yield per camel, wet season: 5.48 l/day, dry season: 1.96 l/day. Average: 3.72 l/day
Average milk yield per goat, wet season: 0.99 l/day, dry season: 0.29 l/day. Average: 0.64 l/day
Average milk yield per sheep, wet season: 0.81 l/day, dry season: 0.20 l/day. Average: 0.5 l/day

The main input costs are deducted from the gross value of output to estimate value added. Afar pastoralism is labour intensive and by far the most important input is family labour supplemented by the assistance of friends, relatives and neighbours. Using values estimated by (Behnke & Kerven, Counting the costs: replacing pastoralism with irrigated agriculture in the Awash Valley, north-eastern Ethiopia, 2013) for labour costs per head of animal adjusted to current daily wage rates (adult daily wage in 2009: ETB 8, adult daily wage in 2017: ETB 70), annual labour costs per head amount to ETB 569 for cattle, ETB 726 for camel and ETB 140 for sheep and goat. No other costs such as providing for security, purchase of water, feed supplements or animal health services or costs for transportation of animals and animal products to markets were included.

To assess the contribution from livestock, we have constructed the following scenarios:

- Baseline scenario C-NP: Assumes a mix of crop land, land under natural pasture and land not used across the cascade of 212 ha. Land used for crop production is equivalent to what has been assumed to calculate benefits from crop production (see section x.x). Average pasture productivity is assumed to be 4.5 t/ha and biomass from crops is used as additional fodder.
- Baseline scenario NP: No land dedicated to crops and all available land is under natural pasture. No crop biomass is available. Average pasture production is assumed to be 4.5 t/ha.
- Intervention scenario: Assumes a mix of crop land and land under natural pasture (same shares as used to calculate crop benefits). Crop residues and specifically grown high-yielding fodder is available in addition to natural pasture. Thanks to weirs, natural pasture now yields 6 t/ha dry matter per year.

In order to estimate the value of livestock production, we first estimated the possible dry matter that can be produced under each of the above scenarios. This is assumed as giving us an indication of the carrying capacity of the area. In their study, Behnke & Kerven (2013) estimate the value of livestock in the Awash valley using two different productivity estimates. A lower productivity of 3 tons per hectare of consumable dry matter was estimated for (degraded) natural pastures and a higher productivity of 6 tons per hectare of consumable dry matter for riverine forage production. Based on (Gebrehaweria, Aregaw, Abdelah, & Bushra, 2017) livestock feed resources have declined over the past five years both in the dry and wet season as a result of drought, overgrazing, bush encroachment and settlement expansion. Palatable plants, especially grasses for different livestock species have decreased, and cattle and sheep are being increasingly forced to rely on browsing plants. For the baseline scenario we use a productivity of 4.5 tons of dry matter per hectare and year. For the intervention scenario, we assume a productivity of 6 tons of consumable dry matter per hectare to reflect both improved productivity post intervention as well as improved fodder quality. Biomass from cultivated crops is added to the fodder production as well as biomass from specifically planted forage grasses such as Napier Grass. Average productivity of 11 tons of consumable dry matter per hectare and year of forage grass was used (Kebede, et al., 2017).

On average, one TLU consumes 2,300 kg of dry matter per year (Jahnke, 1982 in (Behnke & Kerven, Counting the costs: replacing pastoralism with irrigated agriculture in the Awash Valley, north-eastern Ethiopia, 2013)), resulting in a carrying capacity of 650 TLU for the intervention scenario, 415 TLU for the baseline scenario C-NP and 311 TLU for the scenario where all available land is under natural pasture (Baseline NP) (Table x). The total number of TLU is used to estimate the possible number of each kind of animal (cattle, goats, sheep and camel) using the average herd composition as assessed by (Gebrehaweria, Aregaw, Abdelah, & Bushra, 2017) which is then used to calculate the net livestock production under the different scenarios (Table 8).

Table 7: Carrying capacity for different scenarios

	Total dry matter production (t)	Total number of TLU that could be kept	Cattle	Goats	Sheep	Camel
Average herd composition (%)			8.8%	53.2%	27.2%	7.6%
Intervention	1,494	650	57	2,660	1,359	40
Baseline C-NP	955	415	36	1,700	868	25
Baseline NP	715	311	27	1,272	650	19

Table 8: Net livestock production for different baselines and intervention scenarios

	(1)	(2)	(3)	(4)	(5)	(6)	(7.1)	(7.2)	(7.3)
Animal	**Price (ETB)**	**Unit**	**Production coefficients**	**Labour cost of livestock keeping ETB per head per year**	**Average number of animals per household**	**Net value per household (ETB)**	**Baseline C-NP (crops and natural pasture)**	**Baseline NP (all land under natural pasture)**	**Intervention scenario**
Cattle(Total)						**(911)**	**(8,715)**	**(6,523)**	**(13,637)**
Animal offtake	2,887	per head	0.09	569	3.8	(1,174)			
Milk	1.5	L	46			263			
Butter		Kg	2.4			-			
Dung		Kg	0.2			-			
Goat (Total)						**2,935**	**215,990**	**161,669**	**337,989**
Animal offtake	789	per head	0.3	140	23.1	2,506			
Milk	0.64	L	29			429			
Sheep (total)						**1,160**	**85,380**	**63,907**	**133,605**
Animal offtake	794	per head	0.30	140	11.8	1,160			
Wool	1	Kg	0.05			-			
Camel (total)						**1046**	**8,006**	**5,993**	**12,528**
Animal offtake	2,834	per head	0.02	726	3.3	(2,210)			
Milk	3.72	L	265			3,256			
Net livestock production						**4,230**	**300,661**	**225,046**	**470,485**

Monitoring Livestock Benefits: An M&E System fit for purpose

To link project inputs to outcomes, data collected should aim to monitor livestock productivity, with the intention of linking this to well-being benefits. Here we provide the data needs to collect information for a cost-benefit analysis that calculates benefits using (Behnke & Kerven, 2013) method, focused on carrying capacity of the rangeland.

Data collection for Cost-Benefit Analysis Tool			
Indicator	**How / Where to collect**	**Frequency of collection**	**Purpose**
Surface area (ha) under forage crop production	Mapping / Remote sensing data	Annually	To calculate the total volume of forage available for TLU
Yield of forage crop	Crop harvest data	Annually	To calculate the total volume of the forage available for TLU
Biomass from crop residue	Field measurements	Annually	To calculate the total volume of the forage available for TLU
Biomass from natural pasture	Field measurements from fixed and random sample size (representative)	Annually	To calculate the total volume of the forage available for TLU
Price of animal offtake for cattle, goat, sheep, camel, donkey	Market price data; FGD	Prior to, and post-installation of waterpoint	
Price of milk, butter for cattle, goal, and camel; wool for sheep	Market price data; FGD	Once	
Species, age and sex composition of Afar herds	HH survey or FGD	Annually	To reconstruct Behnke & Kerven's production coefficient with local data
Annual labour costs for livestock rearing for sheep & goats, camel, and cattle	FGD / PADO offices	Annually	

To link livestock productivity into poverty reduction and improved food security, data collection would need to go beyond a cost-benefit analysis and collect at the following broader indicators, comparing to a control site with similar characteristics.

Data collection for wider M&E Programming			
Indicator	**How to collect**	**Frequency of data collection**	**Purpose**
HH income from offtake	HH survey	Annually	To assess contribution of livestock income over time and in relation to improved natural resources
Capital asset accumulation / savings	HH survey	Annually	To assess poverty reduction contribution of the intervention.
Composition of herds (species, number, age, sex)	HH survey	Annually	To assess health and size of herds, as a result of the rehabilitation of land with WSWs

% of HH expenditure on food	HH survey	Annually	To track changes in HH food expenditure, relative to other expenditure, in order to better understand HH food security
Coping Strategy Index (CSI) (Maxwell & Caldwell, 2008)	HH survey	Annually	To assess coping mechanisms related to food insecurity over time
Food Consumption Index (FCI) (Vaitla, Coates, & Maxwell, 2015)	HH survey	Annually	To use as proxy indicator to measure caloric intake and diet quality at HH level, to understand HH food security.
The Household Hunger Scale (HHS)	HH survey	Annually	A behavioural measure to capture more severe behaviours in response to food shortages, to understand HH food security.

3.8.4 Excel sheet interpretation:

The worksheet **Livestock benefits data input** collects all the information required to calculate net benefits from livestock production.

To calculate gross value of livestock production, the average herd composition in the study area (O3 – O7) is used. For each livestock type, the value, expressed by average market price (C10, C15, C18, C21 and C24), is entered. Amounts of milk and other products that can be sold (e.g. butter, wool or transport capacity) for each of the different animal types are estimated (C11 – 13, C16, C19, C22 and C25).

As for crop production, to provide a more accurate illustration of the situation in Afar, two scenarios are constructed simulating how a drought or a flood would impact livestock production. The impact of a drought (R26) and of a flood (R20) in year two is estimated and expressed as the portion of livestock production that remains after the event.

Average pasture productivity is estimated assuming a low productivity situation (D28) and a high productivity situation (E28). To estimate the carrying capacity of the land, we assume that each TLU consumes 2.3 t of dry matter per year (D29).

The carrying capacity is estimated for three different scenarios, using the total biomass production that can be realized on the area inundated by weirs (same perimeter as used for assessing crop production):

Intervention scenario: Assuming high-yielding fodder crops are grown, the area dedicated to these (L35) and their yields (L37) needs to be estimated (these estimates are based off ICRISAT data about land use). Similarly, crop biomass production (I46 – I54) needs to be estimated. Total forage production is the sum of dry matter production from high-value fodder crops, crop biomass and from natural pasture. This figure defines the carrying capacity (in TLU).

Counterfactual scenario, no weirs: Only two additional data points are required for this scenario. The first is an estimate of the percentage of the area under consideration that is defined as ‘unusable’ (L71). This land category includes degraded land, land infested with invasive species, land covered by sediments and built-up area such as roads and settlements. The second is an estimate of crop biomass production (I79 – I87) for the before-weir situation.

Based on the total biomass production for each scenario, the carrying capacity in TLU and in absolute numbers for each species of animal is calculated. This is multiplied by the value of each animal type and a species-specific production coefficient (see (Behnke R. , The contribution of livestock to the economies of IGAD Member States., 2010) for further details) to arrive at the gross value of livestock production. Deducting labour costs per head of animal per year produces the net value of livestock production for the scenarios under consideration.

With the above data, net benefits from livestock production will be automatically calculated in worksheet "Benefits" for different scenarios.

3.8.5 Benefits from access to improved water sources

In GIZ's intervention areas, improved access to water consistently featured as a top community priority. The existing water points function intermittently – women estimated they are out of use more often than they function, leaving them reliant on unsafe sources located far from their homes most of the time. By improving groundwater recharge, the WSWs offer an opportunity to improving access to water. If communities and Woreda WASH officials decide to build hand dug wells near the WSWs, or if community members dig traditional *elas* (deep wells) or *buye* (shallow wells) of their own accord near the structures, the WSWs will provide another key benefit stream: improved access to water.

Improved access to water brings two essential wellbeing benefits: improved health from consumption of cleaner water, and time savings for the women and children responsible for fetching water. In 2016, the Global Burden of Disease study[7] identified diarrhoea as the main cause lost healthy years of life (DALYs) in Ethiopia, largely because of consumption of unsafe water and poor hygiene practices (IHME, 2017). Furthermore, women's primary burden in the household is reportedly going to fetch water, with collection times ranging from one to six hours. In Afar's pastoral communities, improved access to water for domestic use is key for more healthy, productive people, and to reduce child mortality and adult morbidity associated with diarrheal diseases.

According to the (Dereje & Hailemariam, 2017) study of Afar, people's primary sources of water for domestic use are rivers, public water points (though many do not work and are too far away from pastoralist communities), and traditional shallow wells dug during the wet season. During the dry season, rivers are the main source of water used for both human and animal consumption (Dereje & Hailemariam, 2017). Drinking from the river for even part of the year is problematic; untreated surface water poses serious health risks, exposing populations to a range of water-borne diseases and microbial infections.

Based on the cascade of weirs in Chifra, a hydrogeological assessment concluded that two hand dug wells could be constructed near the top of the cascade. To capture the potential benefits from availability of safe water sources, this cost-benefit analysis assumes that two community hand dug wells are built to take advantage of increased water storage. We assume that 100% of the population switches from unsafe sources like river water to using improved sources year-round (partial use of the hand dug wells would negate the benefits). We assume the wells are able to deliver 25 litres of water per capita per day, reaching the Government of Ethiopia's targets for water supply.

This analysis is adapted from the methodology developed by (Hutton, Haller, & Jamie, 2007). Our methodology is simplified slightly: we focus on the direct time values (travel and waiting times averted) by improved access to water, and the economic value of days worked as a result of averted

[7] Institute for Health Metrics and Evaluation (IHME). **GBD Compare Data Visualization**. Seattle, WA: IHME, University of Washington, 2017. Available from http://vizhub.healthdata.org/gbd-compare. (Accessed [INSERT DATE])

cases of diarrheal disease. We acknowledge but do not consider the full range of social and economic benefits that water can bring, which include improved school attendance, more leisure time for overburdened women, and the avoided costs on the health system from fewer diarrheal cases.

This analysis presents a comparison to a scenario in which the population continues relying on unprotected surface water, but all other factors remain constant. In aggregate, when comparing the benefits between these scenarios, we find that the net benefits of accessed to improved water sources are ETB 2,652,423 per year.

3.8.6 Calculating Health Benefits

To calculate the health benefits, our starting point is the diarrheal disease burden, which is the primary water-related cause of morbidity and mortality. We use DALYs, or Disability-Adjusted Life Years, as the societal measure of the disease burden in a population. One DALY represents one year of life lost as a result of ill-health, disability, or early death. This analysis relies on data from the 2016 Global Burden of Disease (GBD) study. Using national-level data on Ethiopia, GBD estimated that the risks from unsafe water sources resulted in 2,069.15 DALYs per 100,000 people.

Using this data, we calculated the DALYs for the population living with in the catchment area of a weir - 2044 people (or 292 households). We assume the same rate (2069.15 DALYS per 100,000) applies to the local population. This calculation yielded 42.29 DALYs, or years of life lost, for the population living around the weir. This estimation is likely to be an under-representation of the actual DALYs in Afar; in poor areas the prevalence of diarrhoea is likely to be worse. To improve the integrity of the DALY estimate, collecting local data on exposure and the disease burden envelope could improve the accuracy of our estimate of relative risk of diarrhoea that is attributable to unsafe water sources.

Using local wages (the opportunity cost of the lost years of life), we valued the productivity gains of improved access to water at ETB 14,000 birr, assuming that people could work 200 days per year at a daily rate of ETB 70[8]. Lastly, this kind of quantification of the value of "lost" life years using DALYs is bound to encounter ethical questions about the value of human life. We acknowledge that a valuation of lost years based on income is not sufficient to capture the inherent and unalienable value of a human life, but simply one indicator of how access to water can improve productivity.

Compared to a scenario in which the population remains stable, continues using unprotected surface water, and the rate of DALYs does not change, the value of the health benefits totals to ETB 592,108 per year. These benefits are reaped annually, and over the lifetime of a weir come to ETB 11,753,793 (discounted at 3.5%), assuming that the entire population continues to use only safe water sources year-round.

3.8.7 Calculating Time Saving

The second major benefit, and the one that accounts for the largest contribution to monetary benefits, is the time saving as a result of the access to improved water. Better access to water is crucial across Afar; as the baseline study explains, "*Water scarcity turned out to be a major challenge in all sites visited during the survey, even though it varied in severity. The sites in Kori are worst affected in terms of accessibility, with several days of walking on foot to reach deep elas*" (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016, p. 44). Due to variation, time saving benefits are not uniform across GIZ's intervention sites. The hydrogeological assessment found that the waterpoints in Chifra were best located at the top of the cascade – meaning some households would be within a 10-minute walk, while others would remain an hour or two away. Still,

[8] The Wold Bank estimates the Gross National Income per capita for Ethiopia to be US$ 660 in 2016 – or ETB 18,150 (US$ 1 = ETB 27.5).

based off interviews with beneficiaries who reported spending up to six hours fetching water for the household, the time saving benefits as a result of improved access to water are potentially high even for households located further away.

We estimate that improved water access can generate a time saving of three hours a day, changing from 4.5 hours a day fetching and queuing for water to 1.5 hours. Assuming that people must fetch water every day of the year, the total time each household spent fetching water prior to the weir was 1,643 hours, or 479,610 hours for the entire community. After the weir, this number drops to 548 hours per household, or 159,870 hours for the community. We proxy the opportunity cost of time using the daily wage rate.

Prior to the weirs, the opportunity cost of the time spent fetching water for the entire community was ETB 1,398,863 per year. After the weir provided three hours of saving, this figure fell to ETB 466,288 ETB per year. In aggregate, the value of the time savings as a result of the improved access to water is ETB 932,575 per year across the 292 households that live in the vicinity of the weirs.

3.8.8 Calculating the costs of providing access to water

To determine the net benefit, the model must first factor in the costs associated with the water point – both in terms of initial investment and recurrent costs. Based on expert opinion, the costs of a hand dug well are assumed to be US$ 1000, or ETB 27,500 at current exchange rate. To dig the well, we assume it takes 15 labour days, at the day rate of ETB 70. We assume that maintenance costs are covered by the costs of water, which is how community-based rural water management is designed to function in Ethiopia under the One WASH National Programme. This results in an initial investment cost of ETB 57,100.

To understand the recurrent costs, we calculate the costs of accessing water over a 10-year time period. The two major costs are the installation of the water point(s), and the costs of the water itself. Based on fieldwork in Ethiopia, we assume that when people access an improved source, they have to pay 30 cents (birr) per jerrycan. Because the Government of Ethiopia's target to providing 25L of water per capita every day, we calculate the costs per household per day for water as ETB 2.1 (25l/capita, assuming a household size of 7). For all beneficiaries living within the catchment area of a weir, this would amount to ETB 223,818.

Monitoring water benefits: An M&E System fit for purpose

To link project inputs to outcomes, data collected should aim to tracking the benefits related to improved water access. Here we provide the data needs to collect information for a cost-benefit analysis that calculates benefits in terms of time saving and health gains.

Data Collection for Cost-Benefit Analysis Tool			
Indicator	**How / Where to collect**	**Frequency of collection**	**Purpose**
Time spent collecting water (hrs / day)	FGD with communities all along a cascade	Prior to, and post-installation of waterpoint	To establish a baseline, and compare against baseline
Labour costs per day	Project information, or survey	Once	To calculate opportunity cost of time spent collecting water
Fixed cost of community dug well with handpump	Woreda water office data	Once	To establish investment costs
Cost of water per jerry can	KII at waterpoint or with WASHCO	Once	To establish recurrent water costs

DALYs from water-attributable risk	Global Disease Burden Study; Ethiopia data found under data visualization tool. For more locally accurate data, collect data from Woreda Health post about exposure and diarrheal disease envelope	Annually	To update DALYs as needed

For an M&E system that intends to illustrate increased water availability as a result of the weirs, and not only through water access, a robust physical monitoring programme should be integrated into the project data collection. This data is not for inputting into a cost-benefit analysis, but for understanding the contribution of the project to watershed rehabilitation outcomes.

Data Collection for Wider M&E Programming			
Indicator	**How / Where to collect**	**Frequency of collection**	**Purpose**
Depth and level of water table	Installation of shallow and deep piezometers close to weirs Installation of water level and chemistry loggers in aggradation zones and in existing water wells adjacent to intervention area	Continuously	To monitor impact of weirs on groundwater retention and recharge, creating water-level hydrographs
Volume of groundwater retention	Installation of river discharge gauges upstream and downstream of the intervention area	Continuously	To investigate volume of groundwater retention and recharge and to map relation between surface water and groundwater
Radar based monitoring of flood extent	To map changes in gully geometry and monitor the extent of downstream degradation zones	Continuously	To monitor changes in flood plain course and estimate volume of flows and link this to water availability, to map surface water retention and lose mechanism in the flood plains
Gully depth (m) Gully drainage area (ha)	Radar based-monitoring of the extent of gullification	Annually, post-rainy season	To map sedimentation and changes in morphology of the land
Isotope (^{18}O-^{2}H as well as ^{222}Rn) survey of water bodies	Installation of water-level and chemistry loggers in aggradation zones and in existing water wells adjacent to the intervention area	Continuously	To map extent of groundwater recharge plume; to map the effect of weirs on groundwater retention/storage.

3.8.9 Excel sheet interpretation:

The worksheet **Water benefits data input** collects all the information required to calculate net costs and benefits from investments in water points.

We assume that 2 water points (F15) can be constructed at the top of a cascade of weirs. This involves digging a well shaft of between 10 and 20 m depth and lining this with cement cylinders. We assumed 15 labour days are required for digging one well shaft and producing the cement cylinders (F16). Equipping the well with a standard handpump would cost approximately US$ 1000 (C14), including both the costs for the pump and costs for steel rods, pipes and cement. We assume that with the availability of safe water, each of the assumed 292 households in the vicinity of the cascade (B4) would consume the amount of water as recommended by the Ministry of Water and Energy of 25 l/day/capita (F18) and that this water point is within the recommended distance (in terms of time spent for a return trip) of 1.5h per trip and day (F26). We assumed that on average

each household spent 4.5h (D26) for a roundtrip before the water points were installed, which represents an average across the dry and wet season, assuming that trips during the wet season when water can be collected locally would be quite short, whereas trips during the dry season might involve up to 6h per day. The time savings of 3h per day and household are added up to arrive at a total value of time savings for the entire population in the vicinity of the cascade, i.e. the 292 households. To calculate the health benefits, we use the figure of diarrhoea-related DALYs (see section XX) estimated for Ethiopia (C35) and multiply this with the average income we assume a person could earn. This is based on 200 working days per year (C34) at the current daily wage rate of ETB 70.

3.9 Overall estimated CBA results

This section pulls the CBA together, presenting the cost and benefit streams over a 10-year horizon to calculate the benefit to cost ratio and the Net Present Value (NPV), which adds up the discounted net costs and benefits of the counterfactual and intervention scenarios over the lifetime of the project (see Section 3.2 for a discussion of the different appraisal criteria).

In simple terms, the NPV tells us whether or not, over the longer-term (in this case 10 years), investing in weirs is economically worthwhile. If the NPV with investments (the intervention scenario, NPV^I) is larger than the NPV without any interventions (counterfactual scenario, NPV^C) – expressed as a Discounted Net Gain (DNG) greater than zero, then, *ceteris paribus*, society gains by this investment. If, however the DNG ($NPV^I - NPV^C$) is below Zero, then society would economically be better off without the investments.

The above, of course, does not take into consideration all the externalities or indirect costs and benefits resulting from investments in weirs. In our analysis, for example, we have not included downstream costs and benefits such as damage to infrastructure further downstream along the gully in the counterfactual scenario or benefits from reduced sedimentation of reservoirs in the case of the intervention scenarios. Similarly, we were not able to capture all on-site costs and benefits, such as the risk of increased spread of invasive species due to increased soil moisture, the change in micro-climate due to increased forest cover, or an increase in malarial exposure due to an increase in standing water by the weirs. The omission of these positive and negative on-site and off-site impacts is largely due to difficulties in monetizing them, but also because many of these effects are difficult to model and without further intensive investigation impossible to predict.

To recapitulate (see also Section 3.5) we have built several scenarios for both the counterfactual and the intervention scenario:

Table 9: Description of counterfactual and intervention scenarios

Scenario	Description
Counterfactual 1	Land is used for crop and livestock production
Counterfactual 2	Land is used for crop and livestock production, but affected by a major drought affecting crop and livestock benefits
Counterfactual 3	Land is used for crop and livestock production, but affected by a major flood affecting crop and livestock benefits
Counterfactual 4	Land is used for crop and livestock production and annually 5% of land is lost to gully expansion
Counterfactual 5	Land is used for pastoralism only
Counterfactual 6	Land is used for pastoralism only and annually 5% of land is lost to gully expansion
Intervention 1	Cascade of 6 weirs and 2 waterpoints
Intervention 2	Cascade of 6 weirs only

Intervention 3	Cascade of 6 weirs, flood damage to weir, crop and livestock benefits and 2 waterpoints
Intervention 4	Cascade of 6 weirs, flood damage to weir, crop and livestock benefits
Intervention 5	Cascade of 6 weirs, drought impacting crop and livestock benefits and 2 waterpoints
Intervention 6	Cascade of 6 weirs, drought impacting crop and livestock benefits

3.10 Benefit/Cost ratios

Table 10 below presents the ratio of discounted benefits to discounted costs (B/C ratio). A B/C ratio of less than 1 implies that the present worth of benefits at the given discount rate (in our specific case of 3.5%) is less than the present worth of costs. Put differently, the initial investments could not be recovered and the project would economically not be worthwhile.

Because there are no initial investment costs for the counterfactual, the B/C ratio can only be established for the intervention scenarios. Under the assumptions discussed in the previous sections, B/C ratios for the different intervention scenarios are as follows:

Table 10: The ratio of discounted benefits to discounted costs of investments

Scenario	Description	B/C ratio
Intervention 1 (I1)	Cascade of 6 weirs and 2 waterpoints	2.17
Intervention 2 (I2)	Cascade of 6 weirs only	1.18
Intervention 3 (I3)	Cascade of 6 weirs, flood damage to weir, crop and livestock benefits and 2 waterpoints	1.64
Intervention 4 (I4)	Cascade of 6 weirs, flood damage to weir, crop and livestock benefits	0.83
Intervention 5 (I5)	Cascade of 6 weirs, drought impacting crop and livestock benefits and 2 waterpoints	2.11
Intervention 6 (I6)	Cascade of 6 weirs, drought impacting crop and livestock benefits	1.11

Unsurprisingly I1 results in the most favourable B/C ratio. Benefits are almost 1.8 times higher than costs and can, over the lifetime of the investment (10 years), be easily recouped. Comparing the B/C ratios of I1 and I2 – with I1 not only investing in water spreading weirs but also in 2 waterpoints with the associated benefits – shows how much value can potentially be added by making use of the accumulated shallow groundwater and providing safe water – with the associated time savings and health benefits – to the local population. Flood impacts push the B/C ratio to its lowest levels, largely because we assume that a flood not only damages crops and livestock and thus reduces benefits, but also because we have assumed that the flood damages 80% of the weirs themselves which have to be re-built, which leads to additional investment costs. The B/C ration of I4 (only weirs and flood damage) is below 1, which means that the sum of the discounted costs is larger than the sum of the discounted benefits. Overall, under this assumption, the investment is economically not worthwhile.

While of course it is impossible to foresee if a flood affects the area or not, it does show us that under the specific assumption there is a real danger that the investment is not worthwhile. Floods in the area under consideration are not something that is unheard of. The scenario we built tried to represent such a situation and shows how vulnerable investments to external forces could be.

3.11 Discounted Net Gains from switching from the counterfactual to the intervention scenario

Table X compares the NPV of the different intervention scenarios to the different counterfactual scenarios. If the Discounted Net Gain (DNG) is positive (green cells), then the investment in weirs (and waterpoints in 3 of the cases considered) overall is the preferred option over not carrying out these investments. If, however, the DNG is negative (red cells), this means that society would economically be better off of not carrying out the investments under the assumptions made to calculate the discounted costs and benefits for the different scenarios. Of course, this might change if other costs and/or benefits were costed and included in the scenarios, such as biodiversity conservation on site or avoided costs of sedimentation off-site.

Table 11: Discounted Net Gains (DNG) from switching from counterfactual to intervention scenarios

			Counterfactual scenarios					
			C1 no weir	C2 no weir, drought	C3 no weir, flood	C4 no weir	C5 no weir, all land pasture	C6 no weir, all land pasture
						land lost to gully erosion		land lost to gully erosion
Intervention scenarios	I1 weir	Water point	8,873,238	8,987,352	9,028,530	9,565,350	10,466,788	10,822,206
	I2 weir		(1,932,433)	(1,818,319)	(1,777,142)	(1,240,321)	(338,883)	16,535
	I3 weir, flood	Water point	5,314,152	5,428,266	5,469,444	6,006,265	6,907,702	7,263,120
	I4 weir, flood		(5,491,519)	(5,377,405)	(5,336,227)	(4,799,406)	(3,897,969)	(3,542,551)
	I5 weir, drought	Water point	8,269,485	8,383,599	8,424,776	8,961,597	9,863,035	10,218,453
	I6 weir, drought		(2,536,186)	(2,422,073)	(2,380,895)	(1,844,074)	(942,636)	(587,218)

What the above comparison shows is that weirs on their own are generally not able to generate enough revenues compared to the different counterfactual scenarios to be economically viable under the assumptions as described in the sections above. Although they might generate a positive NPV (i.e. the discounted benefit stream is larger than the discounted costs), the NPV of the counterfactual is still larger. If, however, additional investments in waterpoints were to be carried out, the DNG generally turns positive. In other words, the additional benefits from the installation of the water points – time savings and health benefits – turn the overall investment into an economically viable one – even when considering shocks such as droughts or floods.

3.11.1 Sensitivity analysis

The above findings are sensitive to a number of assumptions. The most important one being the size of the area influenced by each weir. To demonstrate this, we assume the following changes: the size of land inundated by 1 weir is increased to 50 ha (Figure 13) and reduced to 20 ha (Figure 14).

Without going into details about the magnitude of the DNG the two figures below only show whether the comparison of the intervention scenarios with the counterfactual scenarios yields a positive (green) or negative (red) DNG.

Figure 13: Area of influence increased to 50ha per weir

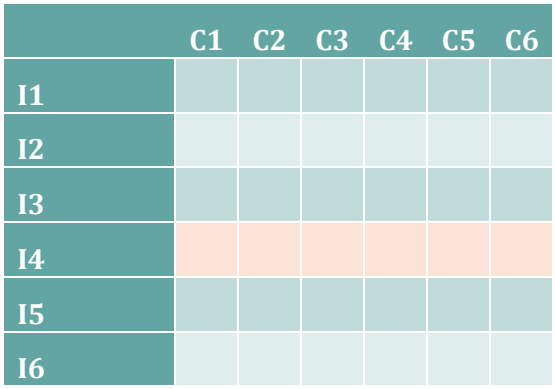
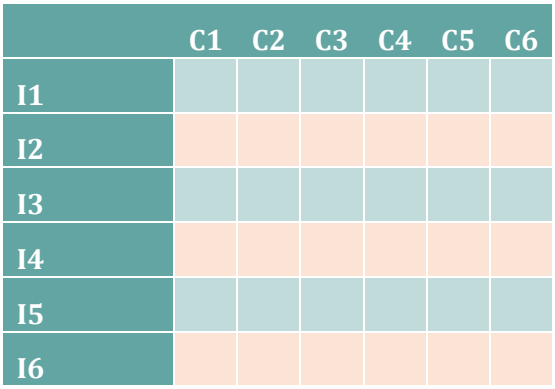


Figure 14: Area of influence decreased to 20ha per weir



Increasing the size of the inundated area around each weir to 50 ha but keeping the share of crop land constant (at 36%) makes investments in weirs more attractive. The exception is where a major flood damages both the weirs and reduces benefits from crop and livestock production (Intervention scenario I4) and there is no waterpoint. Decreasing, on the other hand, the area inundated by each weir to 20 ha – thus reducing overall benefits from crop and livestock production relative to the investment costs - results in only I1, I3 and I5 being positive – again, only thanks to the significant benefits that accrue from providing access to safe water.

4 Equity and sustainability issues

Key messages

Weirs must be managed to ensure equitable distribution of costs and benefits between users, or the weirs may be subject to the same collective action problems described in Ostrom's principles for managing the commons.

The opportunity cost of fencing the land around the weirs is felt primary by secondary users., who might otherwise access the land for livestock grazing under customary clan rules. For people living directly around the weir, this cost is mitigated by new opportunities to produce crops or fodder through a cut and carry system.

The distribution of benefits within household is relevant for equity; women have a disproportionately low access to land, assets, and knowledge that would allow them to benefit from opportunities that the weir provides.

Overlapping land tenure regimes, and decades of state intervention in pastoral areas, have undermined pastoralists' traditional land management practices.

Livelihood systems are rapidly shifting in Afar, and sedentarisation is becoming more common in some areas. These trends are transforming customary pastoral institutions, and promotion of agriculture around water-spreading weirs is likely to play a role in these changes.

In efforts to scale up the intervention, hard infrastructure should not be favored over softer, institutional capacity building. The appropriate management structures that can distribute the costs and benefits equitably are key for sustainability and ownership of the weirs.

Weirs and dry-stone measures do more than transform the physical landscapes, providing erosion control and re-establishing soil moisture in severely degraded rangelands. They may also (purposefully or inadvertently) lead to changes in social and cultural life, particularly for Afar's pastoral communities whose livelihoods are rapidly changing in the face of climate stresses and population growth. Considering the positive and negative social externalities of building water spreading weirs is essential, though these intangible impacts escape simple quantification in a cost-benefit analysis.

4.1 Managing the commons: understanding costs

Where there is an uneven distribution of the costs and benefits from a cascade, expecting resource users to work collectively on natural resource management is unrealistic. Near the top of Ostrom's list of principles for managing the commons is a rule that posits that a natural resource management intervention must strike balance between costs and benefits to ensure "the distribution of benefits [from accessing land] is roughly proportional to costs [associated with the intervention]" (Ostrom, 1990). If the costs borne are greater than the benefits, or if the costs are assigned to one group of people and the benefits are assigned to a different group of people, the sustainability of the outcomes are in jeopardy. Using this basic principle of Ostrom's 'management of the commons' theory, this section investigates the distribution of costs and benefits of the water-spreading weirs in Afar.

For natural resource management interventions like water-spreading weirs, collective action is a vital component to secure long-term benefits. The collective action issue is two-fold: First, resource users must determine when, how, and by whom benefits like livestock grazing or agriculture production can be accessed. Doing so requires everyone in the community to adhere to common rules (i.e. restricting grazing) so people can claim entitlements to the resource without diminishing others' access or affecting future benefits. Secondly, resource users must also work together to maintain the physical infrastructure, like weirs or dry-stone measures. Experiences in Afar show that the weirs need maintenance work after severe floods, and that raising the level of the weir is sometimes necessary after sedimentation has built up behind the structure in the dry river valley. Given their existing capacity constraints, government bodies like PADO cannot be held solely responsible for maintenance; resource users must be tasked with working together to keep weirs in good condition or risk that they fall into disrepair.

Whether collective action works is contingent on the distribution of costs, and whether the distribution is proportional to the spread of benefits. According to the cost-benefit model, the average cost of a weir is around ETB 650,000. This direct cost is subsidized by the GIZ project to avoiding falling on the government with very limited financial resources or on beneficiaries already struggling in the face of severe land degradation. Instead, beneficiaries contribute some in-kind labour for building the weir; after five days of cash-for-work construction, beneficiaries contribute one day voluntarily. This cost on beneficiaries is minimal and time-bound to the construction phase of the weir. Labour contributions are unlikely to affect the longer-term distribution of costs and benefits, though they may increase primary users' sense of ownership and investment in the weir.

Rather than direct costs, the primary cost for pastoralists is the opportunity cost of fencing off the land around the weir, which would otherwise be used for livestock grazing under customary clan rules. For people living directly around the weir, this cost is mitigated by new opportunities to produce crops or fodder through a cut and carry system. The opportunity cost is felt by users that do not have direct access to land around the weir, but would have otherwise been able to access the land through customary rules. The dilemma of these users is explored in section 4.1.1 and 4.1.3.

Yet the opportunity cost of WSWs should be understood through the harsh reality of modern pastoral life. Weirs are built in severely degraded areas, where fodder, water, and trees are increasingly hard to come by. Erosion has been dramatically whittling away the topography of the land, physically washing away productive rangeland and carving out deeper gullies. Prior to the installation of the weirs, pastoralists' ability to realise benefits from land in dry river valleys had been rapidly declining. Households in Chifra interviewed for the study explained, "*We often heard water rushing past the villages at night, but that in the morning there was no trace of the flooding*." Though how benefits are spread is highly contingent on access to land around the WSW, the first few years of Afar's weirs have been instrumental in halting obvious effects of erosion, and slowly regreening areas that were previously desolate. Without some efforts to improve the natural resource base, pastoral livelihoods might disappear altogether.

4.1.1 Distribution of benefits: Secondary users

Without specific provisions for different kinds of resource users, an assumption underpinning GIZ's approach is that benefits from the weir are equitably distributed among resource users (see section 3 for more detail about different benefits). On paper, the WSW intervention begins with participatory land use planning and appraisal of the spatial distribution of resources. In practice, we observed that the land around the weirs in Chifra was allocated by the clan leader, with households voluntarily opting into using the land around the weir. Though the clan leader is a legitimate and respected authority in Afar's pastoral communities, project implementers would do well to understand *how* land around the weir is distributed and the criteria for this decision-making.

Without a clear understanding of these dynamics, the project cannot claim a progressive distribution or equal access to benefits by different users.

The opportunity cost of fencing off the land around the weir is particularly elevated for secondary users (see section 4.2). These pastoralists are mobile and belong to a different sub-clan or clan from the primary users. Importantly, secondary users are not a static group, but relational: every group of mobile pastoralists is a secondary user to another clan, and many arrangements for secondary access to other clans' rangeland are reciprocal (See section 4.2.2). Before the arrival of the weirs, secondary users may have had regular access to land near the weirs as they migrated through the area. With the arrival of the weirs, the primary users can exclude secondary users because secondary users are not traditionally entitled to participate in decisions about land that does not belong to their clan. Furthermore, due to their mobility, secondary users are unlikely to be present during negotiations about land use. The opportunity cost of the weir falls harder on them than any direct costs borne by the primary users located around the weir.

Equally, other households that do not have access to the land directly around the weir may not be able to benefit from the land; interviews with women in Chifra revealed that not all households in the community had plots for farming in ICRISAT's pilot site. This impact could be mitigated by rotating access to the land around the weir, but this strategy is unlikely to cover all the people in a kebele who would like access to the productive land. In this sense, the opportunity costs of the weir are not equally distributed. Those that live close to the weir and are allocated an individual plot are able to benefit from land at the expense of secondary users or others in the community that are not able to access a plot on the land that a weir is capable of rehabilitating.

4.1.2 Distribution of benefits: Intra-household

Lopsided allocation of benefits does not affect only secondary users, who bear disproportionate costs and no direct benefits, but also plays into intra-household dynamics. As good practice, decisions about land-use must consider the power dynamics within communities and households. In Chifra, GIZ has allowed clan leaders to manage the distribution of land amongst community members. By working with the clan system, GIZ has attempted to embed the intervention within pastoralists' indigenous decision-making structures. However, the clan system does not have a specific mechanism for inclusion of women's needs because women do not feature within the village councils that make decisions on behalf of the community. The "Local Participatory Land Use Planning' report in Garriro identifies the stakeholder in local land use as the "local community", but without further interrogating how different people within the same community, including women, might have heterogeneous experiences and needs.

A meaningful consideration of gender is key to ensuring that women are empowered, and not further burdened, by the opportunities the water spreading weirs provide. According to Imburgia (2016) study, gender dynamics in Afar have been changing rapidly as a result of the impoverishment of pastoral households. Though women are still responsible for most of domestic work, they have also begun assuming other activities to generate income for the household. Women care for small ruminants, and this role has become more important in securing household food security as herd composition has shifted to goats, which are more drought-resistant than cows (Imburgia, 2016). Increasingly, women are the bread winners that ensure households can stretch their thin resources and food assistance over the harsh dry season.

Imburgia (2016) stresses that women in GIZ's intervention areas in Afar have disproportionately low access to land and productive assets, and they face constraints in accessing credit, inputs,

equipment, water, and information[9]. Women's lack of opportunities is partially a result of customary exclusions. The customary system assumes women access benefits through marriage, when their husband and his clan take responsibility for sustaining them. Projects that intend to improve the productivity of land should pair these efforts with direct support to women and poorer pastoral households to improve their opportunities for livelihood diversification and access to assets, including the knowledge needed to maximise the productivity of the land. Furthermore, project staff must recognize that married women can be as disenfranchised as women-headed households; their decision-making powers are curtailed by their husbands, and their ability to realise benefits depends on the extent to which a space is created for their participation.

A common pitfall in project implementation is to count women's attendance in meetings or planning process as an example of a "gender-sensitive" project. Simply showing up to meetings where men make decisions, in environments dominated by customary social norms, cannot guarantee equitable outcomes for women. For project staff, step one is to actively interrogate how benefits from natural resource management are spread *within* households. The second step is to trial different methods of women's inclusion; this could be through creating equal representation of women in community institutions for sustainable rangeland management or agriculture, and providing specific support to equip women with knowledge and tools needed to maximize the productivity of rehabilitated land. While gender relations cannot be changed wholesale, small efforts on the margins can be important.

4.1.3 Distribution of benefits: upstream and downstream

The literature review in section 1.3 indicates that natural resource management interventions in a watershed are bound to have impacts on downstream resource users. In many interventions, these unintended outcomes are often overlooked or ignored in project monitoring – but these have serious consequences for the longer-term sustainability of the intervention. In the case of the weirs, the downstream impacts have several components: 1) Downstream effects in terms of water access, as water is retained further upstream; 2) Effects on the topography of the land as a result of aggradation, or the deposition of sediment material by the floods; 3) Sediment transported and deposited downstream (e.g. in dams); and 4) Damage to natural resources or infrastructure along the river bed.

The weirs are expected to increase access to water through groundwater recharge, allowing beneficiaries to dig traditional *buyes* or *elas* near or in the riverbed during the dry season. Though we can be confident that the weirs will have some impacts on the allocation of water within the watershed, these cannot be fully understood without appropriate monitoring tools (See "Monitoring water benefits: An M&E System fit for purpose" in Section 3.8). There are some signs (albeit not proven) that the weirs have led to groundwater storage in retained sediments, and may, by extension, in the pre-existing alluvial materials. In few places one could observe groundwater seepage zones coming out of the retained sediments two months after rainfall ceases. The trees near the originally gullies are much greener than those away indicating overall groundwater storage enhancement.

The importance of the weirs in increasing recharge to deeper groundwater is not obvious. Beneficiaries living around the weir can expect a positive impact, but evidence for this impact is lacking. Before the weirs were built, groundwater recharge to the alluvial sediments as well as to the region's aquifers would take place over the gully bed cross-sectional area. During seasonal flooding,

[9] The majority of respondents to the baseline survey, both women and men, did not belong to cooperatives or credit groups. Helping beneficiaries access and organise in economic institutions is important for sustaining agriculture and fodder production

the flood water is transferred through the gully rapidly, leading to little chance of infiltration because the flood velocity exceeds infiltration capacity through the gully bed and wall sediments.

Since the weirs have been built, recharge takes place both from the original gully bed[10] and walls as well as from the flood plain area around the wings of the weir. The slowed water flow in the gullies and in the flood plain could increase overall recharge to groundwater. However, it should be noted that the recharge zone is restricted in upstream weirs and near the mouth of the gullies where the new sediments are generally coarser. The vast portion of the flood plain and the downstream portion of the weirs may not be contributing to groundwater recharge enhancement as clays and silts fill them.

The extent of downstream degradation that is cause by upstream aggradation is a function of sediment retention upstream, the nature of the gully bed downstream, the water volume leaving the aggradation area etc. A hydrogeological assessment by Seifu Kebede predicted that the effect may stretch over a few kilometres. Yet there are other possible outcomes, too: Gullies downstream of the weirs could continue to deepen and widen as the flood water loses coarse and fine sediments in the flood plain and thus flowing water picks up speed again. Equally, downstream gullies could erode head-ward and create even deeper gullies in the upstream zones, thanks to the higher elevation created as a result of aggradation upstream. Lastly, flood water could spread in unpredictable new directions in the aggraded area, which poses flood risks to crops and livelihoods locally. For downstream and upstream users, these risks of flooding and further gullying must be monitored to ensure any negative impacts are appropriately mitigated or compensated.

4.2 Navigating Land Rights and Transforming Livelihoods

Though many natural resource management interventions strive to be technical and scientific, avoiding politics altogether, soil and water conservation practices improve the value of land that some people have rights to use and access, and other people do not. The distribution of these rights *is* wrapped up in political, economic, and historic conditions, and without deliberately engaging with land rights and how they evolved, a purely technocratic approach to natural resource management may reinforce existing inequalities. Evaluations of natural resource management initiatives in India showed that the those who benefited the most were landowners, while the landless found themselves worse off than before the intervention began (see section 1). When the value of land is improved, questions about who owns, controls, and accesses the land are the key to understanding who will benefit from the environmental goods and services the land provides. In pastoral areas like Afar, where land is technically owned communally, these questions are equally important – and even more difficult to navigate.

4.2.1 Background: land tenure in Afar

Due to the complexity of land tenure issues, interviewees and project staff were reluctant to delve beyond generic responses about land being owned communally. Yet property ownership and production systems have changed radically in Afar in the last half century, and the resultant tensions between customary institutions and government rules have a bearing on people's choices about land use today. Understanding these dynamics is important for any interventions seeking to improve the value of land.

Historically, pastoralist areas have been governed by customary rules that determined access to natural resources. In Afar, access to land is governed by the clan structures; each clan has territory

[10] There is less recharge in the gully bed in the lower zones, which are now filled by clays and silts. These lower zones have lost their pre-weir groundwater recharge service.

over which it exercises control rights, including the right to exclude others and the right to manage the land (Hundie, Property Rights among Afar Pastoralists of Northeastern Ethiopia: Forms, Changes, and Conflicts, 2008). Clans' village councils, consisting of the clan leader and village elders, are responsible for governing a territory that includes dry season grazing, water points, and other key resources for pastoral livelihoods. Councils determine reserve grazing areas so that herds are able to rotate through different pasture while allowing for regeneration. Through this mechanism, every member of a clan has the right to use clan land, as long as the member obeys clan rules and norms.

To enable seasonal migration, Afar pastoralists also developed systems of secondary and tertiary rights to communal land. In the case of secondary rights, clan members have rights to move with their livestock through other clans' land. Access is temporary and must be negotiated with the clan holding primary rights. The negotiation is based on norms of reciprocity; clans can access each other's land, under the conditions that visiting clans respect rules for resource use. In very bad years, Afar pastoralists resort to moving to much more distant pasture controlled by other ethnic groups. If they are able to successfully negotiate access, pastoralists gain tertiary communal rights to this land. According to Hundie (2008), these arrangements are becoming more common due to the increasing frequency of drought.

Pastoral land tenure in Afar is undergoing a transformation, that began with the arrival of large irrigation projects in the lower and middle Awash valley in the 1960s. As part of broader development strategies that gave preference to settled agriculture over pastoralism, the Ethiopian state parcelled up communal pastoral land and redistributed it to irrigated farms located alongside perennial rivers - a key dry season grazing resource for pastoral households (Hundie, Property Rights among Afar Pastoralists of Northeastern Ethiopia: Forms, Changes, and Conflicts, 2008). The existence of state farms nullified customary rights and prevented pastoralists with secondary rights from accessing the land. In other areas, where settlement farms were established to compensate pastoralists, the state provided support to produce crops until the mid-1980s. When support dried up, pastoralists lacked the know-how and inputs to continue farming, and many stopped crop production entirely. Other pastoralists, who were able to secure rights to a parcel of land, leased the land to highlander farming families (Tafere Reda, 2014).

The legacy of these state policies is a system of overlapping land tenure. Though in 2008 the Afar region created a policy to formally recognize pastoral customary land use, there are large pockets of key dry season grazing that are privately held for cultivation, left over from previous state and commercial initiatives. Pastoral rangeland has been lost as a result of private agriculture, big development projects, the arrival of invasive species, and deteriorating land conditions due to overgrazing. As pastoralism becomes less viable, and livestock are lost as a result of recurrent drought, more households are subdividing community land for farming (Nicol & Otulana, 2014).

4.2.2 Shifting livelihoods

Pastoralists in Afar face enormous challenges. Their livelihoods have been pushed to the brink of viability by a multitude of pressures: successive droughts, the proliferation of invasive species on rangeland, population growth, conflicts with neighbouring groups, and reduced access to dry season pasture due to the encroachment of large, state-run farms. Communally owned pasture is overgrazed, leaving it vulnerable to erosion during flooding. The cycle of land degradation has put pastoralist households in a precarious situation, and today the majority of pastoral households must meet food needs through aid, distributed through the PSNP system. As people's livelihood systems shift, and land use patterns change alongside them, traditional tenure systems based on pastoral mobility are likely to undergo major transformations.

Property arrangements in Afar are already fragmented (See section 4.2.1). In theory, communal ownership still exists, but in practice, some settled pastoralist households claim to own individual plots where they grow crops. According to interviews conducted during field research in 2016, and corroborated by (Imburgia, 2016)'s gender study, any kebele member can fence an area and start farming. Both clan leaders and local administrations have been involved fin converting land for agriculture, though interviewees suggested that obtaining permission from kebele or clan leaders was only necessary if there is a conflict of interest over use of land.

As fewer people are able to meet food needs through pastoralism alone, sedentary agriculture-based lifestyles are becoming more prevalent in Afar's communally owned land (See section 2.1). Though the state's initiatives promoted a transition to farming and individual ownership of land, the current trend is characterised by voluntary settlement, with pastoralists choosing to diversify into agriculture. According to Hundie & Padmanabhan (2011), poorer pastoralists in Afar who lost most of their livestock assets in droughts were more likely to engage in agricultural activities than their better-off counterparts. (Hundie & Padmanabham, The Transformation of the Afar Commons in Ethiopia: State coercion, diversification, and property rights change among pastoralists., 2011). People with large livestock holdings gain more benefits from maintaining communally owned lands; those with fewer livestock derive more advantage from fencing off land individually.

Contracting herd sizes alone does not explain why people shift to agriculture. A study by Semera University showed that pastoral livelihoods still dominate in some areas where GIZ is operating, despite growing pressures on the rangeland; 87% of households surveyed in Garriro and 97% of households surveyed in Kalkasa indicated that livestock production was their only major economic activity. In these areas, households also lost significant numbers of livestock in the wake of drought, with 97% of these households reporting that livestock numbers and condition had declined in the last five years (Kidane Reda et al., 2017). This suggests that other factors, such as culture, proximity to markets, knowledge of agriculture, ecological conditions, and access to inputs, influence people's choices to change livelihood strategies. Still, Tsegaye et al. (2013) found that households in Afar that were able to combine pastoralism with crop production appeared to fare better than households who depended on pastoralism alone.

At present, customary pastoral institutions are slowly unravelling. Fencing off farm land de facto excludes secondary users from realising benefits from the land, and reduces the pasture available to primary users for their cattle during dry season. As pastoral mobility is reduced, traditional rangeland management is also breaking down; (Imburgia, 2016) found that pastoralists in GIZ project areas scarcely mentioned traditional *desso*, a system based on restricting access to certain pasture areas during defined periods in order to allow vegetation regeneration. The baseline survey conducted in March 2016 found that people in all of GIZ's intervention woredas claimed that *desso* had been prohibited by the government. This had been done to encourage more peaceful cohabitation, but instead may be contributing to increasing pressure on remaining pasture resources (AHT Group, ICON Institut, Veterinaires sans Frontieres Germany, 2016). Without robust land management, agro-pastoralists are now forced to regularly supplement animal feed through crop residue and purchased fodder (Kidane Reda et al. 2017).

Sharing is at the core of Afar pastoral culture, and the shift to agro-pastoral or agricultural livelihoods has not done away with this norm. Within Afar culture, it is considered impossible to refuse someone asking for help, and the support is often reciprocal. According to interviewees, this reciprocity is also redistributive; once a year, the clan leader distributes livestock from households with many to the poorest households. Tsegaye et al. (2013) describe this '*Irdu'* or '*Hatoita'* mechanism as a method of redistributing herds after a shock, so that the poorest households are assisted after a drought. These mechanisms are reinforced by Islamic norms, which encourage mutual help during Ramadan and charitable giving.

Yet agricultural production from the weir is functionally different from livestock production. Sharing a harvest cannot serve the same function as distributing livestock; maize may feed a household for a few days, while a cow or goat is an asset that can provide food, trade, and social security. One interviewee in Chifra explained that the maize from their enclosure was, *"for subsistence only, but it is not enough for our household even."* Though the norm of sharing may persist in Afar culture, changing production systems will dilute the value of sharing as a means of promoting recovery for the poorest.

The last major lifestyle change that agriculture introduces is a more sedentary life. Living in one place year-round facilitates access to modern facilities: schools, health centres, water points, agricultural extension services. For those living close to towns and markets, sedentarisation offers opportunities to find wage labour and diversify income, though these opportunities are currently limited in Afar. But sedentarisation also brings some new hardship, particularly for women. With children attending school, the burden of household chores falls harder on women, particularly those whose husbands have migrated with livestock (Imburgia, 2016).

Water spreading weirs are not the only, or most important, push - pull factor in people's decisions to shift livelihoods - pushing people out of a pastoral livelihood or pulling them into agriculture. People in Chifra and Awra noted that the trend of permanent settlement began prior to the weirs, though men still migrate regularly with livestock. But water-spreading weirs certainly reinforce some of these trends, and contribute to people's optimism about the viability of agriculture. Beneficiaries we encountered over the course of this research expressed appreciation of the water spreading weirs, especially in communities who had already begun transitioning to an agro-pastoral life. As climate pressures worsen, assuming that small-scale agriculture or fodder production, will be able to support healthy livelihoods, however, is by no means certain. As one man in Garriro explained, "*Our pastoral way of life was very good in the past. What you see now is not how it was 15 years ago. The few cattle we have to go very far in the rangelands to find grass and water, and they cannot support men anymore*." People's hopes, but also their survival, depend on finding a livelihood that will be more resilient to climate, demographic, and economic pressures.

4.3 Scaling and sustaining

To reach more people and cover a greater geographic area, natural resource management interventions like GIZ's WSW are often under pressure to go to scale. But scaling up can entail thorny trade-offs between quantity and quality, and the interactions between different scales can have unforeseen consequences. Though the extent of land degradation in Afar would point to a "*bigger is better*" approach, the challenges of navigating land rights and building capacity for community-based management might necessitate taking a "*small is beautiful*" approach. Finding a balance between expanding a technology and ensuring the results are equitable and sustainable is vital for the long-term success of GIZ's natural resource management efforts.

Typically, successful pilots tend to be small in scale and cannot be easily expanded without replicating the same costs and similar technical support structure in new intervention areas. Benefits that appear in sites in Chifra, where beneficiaries have been supported by scientific research in agriculture varieties, project management backstopping, and regular site visits, may not manifest in places where the initiative is left entirely to the woreda offices and communities to manage. The danger of scaling quickly is that the softer elements of natural resource management are lost in favour of hard infrastructure, leaving weirs without the appropriate management structures that can distribute the costs and benefits equitably. An ODI review of rural development projects found that rapid scale up of successful pilots often led to elite capture, because "*elites were able to monopolise*

the additional resources provided by the programmes. Existing power structures were accepted as a given and no attempts were made to change them" (Buse, Ludi, & Vigneri, 2008, p. 44).

Scaling up also requires buy-in from the government, at the national and regional level. A project-based modality may work for a pilot, but is not suitable for extending an approach at a wider scale. Buy-in is not limited to tacit support, but should be accompanied by governmental policy alignment and concrete commitments to equipping woreda and kebele staff with the knowledge and budget to implement WSWs. Scaling up sustainably necessitates that the government take a much more active role – but without reducing the quality of the intervention delivered during the pilot phase.

Scaling is not only a matter of aggregating project interventions, but also exploring the interactions between interventions and how different scales are interconnected. In a cascade, each WSW is designed to work in conjunction with the others, protecting each other from extreme flooding and capturing sediment. As section 4.1.3. explains, however, the WSWs may also have other unintended downstream and upstream effects as a result of the aggradation in the dry river valleys and gullies. Gullies downstream of the weirs may be exacerbated as the flood waters lose their sediments in the flood plain, or downstream gullies can erode headword. The management system governing the weir must be able to link the micro-watershed within the weir to the macro-watershed beyond the cascade, to ensure there are participatory mechanisms for secondary land users and downstream stakeholders to deal with unanticipated impacts.

5 Conclusion

The cost-benefit analysis reveals that a cascade of weirs *does* provide a net benefit to society, provided that there is not a major flood event that destroys much of the weir and badly affects crops and livestock. The net benefit is significantly larger when the weirs are further developed to also provide water benefits for people (i.e. hand dug wells are installed close to weirs to take advantage of increased groundwater recharge). When access to domestic water is provided in addition to the weir, for every $1 invested the intervention provides $2.17 in benefits; when access to safe domestic water is not provided, for every $1 the weirs provide $1.18 in benefits. Compared to a counterfactual scenario, however, the weirs are only a sensible investment if they are accompanied by the installation of water points, which create a positive NVP result.

If accompanied by water points, the weirs can sustain benefits in the face of drought, indicating that weirs can enhance people's resilience. When a drought affects crops and livestock in the CBA model, the intervention provides $1.70 in benefits for every $1 invested. If the weirs are not accompanied by water points, and crops and livestock are affected by a drought, the weirs still provide $1.10 for every dollar invested. For people struggling to recover livelihoods after recurrent droughts, this indicates that weirs could be a way of bouncing back faster – or at least mitigating the damage and asset loss caused by the drought.

Yet these positive NPV results are not robust to changes in the amount of land that the weir inundates – if all the weirs in the cascade can only rehabilitate 20 ha of land each, then the NVP becomes negative, indicating that the intervention is too costly to be worthwhile unless additional time savings and health benefits can also be accrued from access to safe domestic water. Equally, if weirs are able to rehabilitate an area of up to 50 ha each, then investments in weirs are more attractive compared to not investing in weirs in all but one situation (see Figures 13 and 14). The land area rehabilitated has a multiplier effect on other benefits, but it reveals that the value of weirs depends enormously on the size of area they are able to influence.

Most of the costs of the weir do not fall on the people living near the weir who reap the benefits that the rehabilitated land provides. As a result, beneficiaries' perceptions of the weir are likely to be positive – a sentiment that was often confirmed during discussions with beneficiaries during fieldwork in Afar. Yet beneficiaries also had very high hopes about what the weirs *could* provide, which were out of step with the reality of agro-pastoral life in Afar. Weirs cannot single-handedly combat threats of invasive species, worsening drought, and population growth, all of which play a role in pastoral poverty. Equally, weirs are dependent on run-off from the highlands, which is not a *fait accompli.* With climate change shifting precipitation patterns, and people implementing conservation measures in the highlands through the GoE's Productive Safety Net Programme, the assumption that floods will continue rushing down from the highlands unchanged may be in question in future. Being honest about what the weirs can do is important to keep people's assumptions and expectations tethered to reality.

Lastly, a cascade management committee that is capable of assuring that benefits are spread equitably, and grievances can be dealt with appropriately, is vital to the long-term sustainability of the intervention. Though issues of land tenure and changing livelihood patterns in Afar are sensitive, development practitioners like GIZ would do well to engage directly with these issues when

attempting to improve the natural resource base. This is not to say that GIZ should promote a specific land tenure regime over another, or encourage livelihood changes that people have not chosen themselves. Rather, GIZ staff should be aware that WSWs and increasing sedentarisation may result in land disputes and social conflict. To prepare for this possibility, GIZ should ensure that there is a mechanism to resolve land disputes that is acceptable to the first and second-degree land users that access the land around the weirs. Much like traditional conflict resolution mechanisms, this mechanism should specify who is entitled to make decisions and how decisions are enforced. Unlike customary methods, however, women should also have a seat at the table to participate in conflict resolution.

Though Ostrom's design principles are a useful guide for distributing costs and benefits more equitably, as Behnke explains, "*much of the solution comes down to local-level community organising and negotiation to share costs and benefits*" (Behnke R. , 2013). For any participatory land use planning exercises, extra care should be taken to ensure the process is truly inclusive, so that people do not inadvertently or purposefully exclude competing land users. Sharing costs and benefits equitably is a matter of institution building at the local level; this 'soft' infrastructure deserves as much investment and attention as the physical weirs themselves. As the gender study emphasizes (Imburgia, 2016), simplifying the complexity of social relations by treating a community as a homogeneous entity will only mask people's different vulnerabilities, motives and needs. A fair and transparent governance system that allows different people – within the same community, and living upstream and downstream of the weir - to claim rights to resources is key to distributing costs and benefits in a way that is perceived as acceptable.

For those pastoralists who have "dropped out" or are already voluntarily shifting towards sedentary lives, interventions like those supported by GIZ can support other types of skill trainings that can make newly settled people more competitive in the wage labour market. A successful transition from a pastoral life to a more sedentary one requires former pastoralists to be equipped with a range of skills that may be entirely new to them. Complementing support for small-scale agriculture or fodder production with other skills and trainings, such as the masonry training currently provided through the GIZ supported programme to strengthen the drought resilience of pastoral and agro-pastoral populations in the lowlands of Ethiopia, could improve people's adaptive capacity. For pastoralists who have lost most of their animals, gaining new skills is essential to forge a life in a world with more climate, demographic, and economic pressures than ever before.

Initial experiences with water spreading weirs in Afar Region have been positive – more water has been available for different purposes, not least for improved crop and pasture production, both of which have been seriously impacted by the recent droughts. It is thus not surprising that there are calls to scale up efforts and build many more water spreading weirs across the parched Afar landscape. As experiences with pilots supported by external agencies across Africa have demonstrated time and again, however, successfully scaling up depends on the required financial resources, skills and institutional arrangements being in place. Without these and the ability to manage the social, economic and environmental consequences of technical interventions, attempts to "green" Afar will not be sustainable.

6 References

Ackermann, K., Nill, D., Schoening, A., Trux A, van den Akker, E., Wegner, M., & Gerhartsreiter, T. (2014). Water and soil conservation practices in the Sahel: an analysis of their potential to increase resilience of rural livelihoods. *Planet @ Risk*, 14-20.

AHT Group, ICON Institut, Veterinaires sans Frontieres Germany. (2016). *Final Baseline Report - Soil Conservation and Rehabilitation for Food Security.* Addis Abeba: GIZ.

Albon, S., Balmford, A., Brown, C., Church, A., Haines-Young, R., Pretty, J., . . . Winn, J. (2011). Conceptual framework and methodology. In *UK National Ecosystem Assessment. Understanding nature's value to society.* (pp. 12-24). Cambridge: UNEP-WCMC.

ANRS - Afar National Regional State. (2010). *Programme of Plan on Adaptation to Climate Change.* Semera: ANRS.

Behnke, R. (2010). *The contribution of livestock to the economies of IGAD Member States.* Nairobi: IGAD Livestock Policy Initiative.

Behnke, R. (2013). *Pastoral Land Rights and Resource Governance.* Washington DC: USAID Issue Brief.

Behnke, R., & Kerven, C. (2013). *Counting the costs: replacing pastoralism with irrigated agriculture in the Awash Valley, north-eastern Ethiopia.* London: IIED.

Biratu, A., & Asmamaw, D. (2016). Farmers' perception of soil erosion and participation in SWC activities in the Gusha Temela watershed, Arsi, Ethiopia. *International Journal of River Basin Management, 14*(3), 329-335.

BMZ. (2012). *Water-spreading weirs for the development of degraded dry river valleys. Experiences from the Sahel.* Eshborn: Federal Minisrty for Economic Development and Cooperation.

Bolwig, S., Cold-Ravnkilde, S., Rasmussen, K., Breinholt, I., & Mortimore, M. (2009). *Achieving sustainable natural resource management in the Sahel after the era of desertification.* Copenhagen: Danish Institute for International Studies.

Buse, K., Ludi, E., & Vigneri, M. (2008). *Beyond the village: The transition from rural investments to national plans to reach the MDGs: Sustaining and scaling up the Millennium Villages.* London: ODI.

Calder, I. (1998). *Water Resource and Land-Use Issues.* Colombo: IWMI.

Carabine, E., Jouanjean, M.-A., & Tsui, J. (2015). *Kenya Ending Drought Emergencies Policy Review: Scenarios for building resilience in the ASALs. .* Nairobi: ILRI.

Conway, D., & Schipper, E. (2011). Adaptation to cllimate change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environmental Change*(21), 227-237.

Creswell, J., & Clark, V. (2007). *Designing and conducting mixed methods research.*

Darghouth, S., Ward, C., Gambarelli, G., Styger, E., & Roux, J. (2008). *Watershed Management Approaches, Policies and Operations: Lessons for Scaling Up.* Washington DC: World Bank.

de Graaff, J. (1996). *The Price of Soil Erosion. An economic evaluation of soil conservation and watershed development.* Wageningen: Wageningen Agricultural University.

Dereje, G., & Hailemariam, M. (2017). *Assessment of water availability, access and utilization at Chifra and Kalkalsa aarea of Afar Regional State, Ethiopia.* Samara: Samara University.

Dlamini, C. S. (2012). Types and values and valuation methods for environmental resources: Highlights of key aspects, concepts, and approaches in the economic valuation of forest goods and services. *Journal of Horticulture and Forestry, 4*(12), 181 - 189.

ELD Initiative. (2013). *The reward of investing in sustainable land management. Interim Report fot the Economics of Land Degradation Initiative: A global strategy for sustainable land management. .* Bonn: ELD Secretariat.

Ellis-Jones, J., & Mason, T. (1999). Livelihood strategies and assets of small farmers in the evaluation of soil and water management practices in the temperate Inter-Andean valleys of Bolivia. . *Mountain Research and Development, 19*(3), 221-234.

Erdogan, R. (2013). Stakeholder Involvement in Sustainable Watershed MAnagement. In M. Özyavuz (Ed.), *Advances in LAndscape Archgitecture* (pp. 131-168). InTech.

FAO. (2006). *The new generation of watershed management programmes and projects.* Rome: FAO.

FAO. (2017). *Ethiopia - Drought response plan and priorities 2017.* Rome: FAO.

Funnell, S., & Rogers, P. (2011). *Purposeful Program Theory: Effective use of theories of change and logic models.* San Francisco: Jossey-Bass & Wiley.

Gale, I., MacDonald, D., Calow, R., Neumann, I., Moench, M., Kulkarni, H., & Palanisami, K. (2006). *Managed aquifer recharge: An assessment of its role and effectiveness in watershed management.* Wallingford: British Geological Survey.

Gebrehaweria, K., Aregaw, A., Abdelah, A., & Bushra, B. (2017). *The status of livestock production and rangeland resources in GIZ natural resources management intervention project areas of Chifra and Kalkalsa areas of Afar Regional State, Ethiopia.* Samara: Samara University.

GIZ. (2017, 11 29). Retrieved from Measures to fight drought in the lowlands of Ethiopia: https://www.giz.de/en/worldwide/23119.html

Hanley, N., & Spash, C. (1993). *Cost-benefit analysis and the environment.* Cheltenham: E. Elgar Publishing.

Hayward, B. (2005). *From the Mountain to the Tap: How land use and water management can work for the rural poor.* London: DFID.

HM Treasury. (2011). *The Green Book. Appraisal and Evaluation in Central Government.* London: UK Government.

Hope, R., Gowing, J., & Jewitt, G. (2008). The contested future of irrigation in African rural livelihoods - analysis from a water scarce catchment in South Africa. . *Water Policy, 10*, 173-192.

Hundie, B. (2008). *Property Rights among Afar Pastoralists of Northeastern Ethiopia: Forms, Changes, and Conflicts.* Humbolt University of Berlin.

Hundie, B., & Padmanabham, M. (2011). The Transformation of the Afar Commons in Ethiopia: State coercion, diversification, and property rights change among pastoralists. In H. M.-D. Esther Mwangi (Ed.), *Collective action and property rights for poverty reduction: Insights from Africa and Asia* (pp. Chapter 9: Pp 270 - 303). Philadelphia, Pennsylvania: University of Pennsylvania Press.

Hurni, K., Zeleke, G., Kassie, M., Tegegne, B., Kassawmar, T., Teferi, E., . . . Hurni, H. (2015). *Economics of Land Degradation (ELD) Ethiopia case study. Soil degradation and sustainable land management in the rainfed agricultural areas of Ethiopia. An assessment of the economic implications.* Bonn: ELD.

Hutton, G., Haller, L., & Jamie, B. (2007). Global cost-benefit analysis of water supply and sanitation inventions. *Journal of Water and Health, 5*(4), 481-502.

IGAD Centre for Pastoral Areas and Livestock Development (ICPALD). (2013). *The Contribution of Livestock to the Ethiopian Economy.* Nairobi: IGAD.

IHME. (2017). *GBD Compare Data Visualization.* (Available from http://vizhub.healthdata.org/gbd-compare. (Accessed 3 November 2017) ed.). Seattle, WA: IHME, University of Washington.

Imburgia, L. (2016). *Gender and livelihood analysis: Implementation level. .* n.a.: n.a.

IPCC. (2014). *Climate Change 2014: Impacts, Adaptation and Vulnerability. Contribution of the Working Group II to the 5th Assessment Report of the IPCC. .* Cambridge, UK and New York, USA: Cambridge University Press.

Kebede, G., Feyissa, F., Assefa, G., Alemayehu, M., Mengistu, A., Kehaliew, A., . . . Abera, M. (2017). Agronomic performance, dry matter yield stability and herbage quality of Napier grass (Pennisetum purpureum (L) Schumach) accessions in different agro-ecological zones of Ethiopia. *Journal of Agricultural Crop Research, 5*(4), 49-65.

Kerr, J., & Chung, K. (2002). Evaluationg Watershed Management Projects. *Water Policy, 3*(6), 537-554.

Kerr, J., Milne, G., Chhotray, V., Baumann, P., & James, A. (2007). Manging Watershed Externalities in India: Theory and Practice. *Environment, Development and Sustainability, 9*(3), 263-281.

Kerr, J., Pangare, G., & Pangare, V. (2002). *Watershed Development Projects in India. An Evaluation.* Washington DC: IFPRI.

Lind, J., Sabates-Wheeler, R., & Kohnstamm, S. (2016). *Changes in the drylands of Eastern Africa: implications for resilience-strengthening efforts.* Brighton: Institute of Development Studies.

Ludi, E. (2003). *Economic Analysis of Soil Conservation. Case studies from the Highlands of Amhara Region, Ethiopia.* Bern: University of Bern.

Ludi, E. (2009). *Climate change, water and food security.* London: ODI.

Ludi, E. (2017). *Water for Food Security. Lessons learned from a review of water-related interventions.* London: ODI.

Ludi, E., Levine, S., McCord, A., Duvendack, M., Agol, D., Njigua, J., . . . Tefera, M. (2018 (forthcoming)). *Approaches to evaluating the impacts of public works assets on livelihoods. A case study of natural resource management assets.* London: ODI.

Maxwell, D., & Caldwell, R. (2008). *The Coping Strategy Index. Field Methods Manual, 2nd edition.* London: CARE.

McCord, A., Ludi, E., & Levine, S. (2015). Developing Practical Methodologies to Assess the Spatial, Temporal and Socio-economic Distribution of the Impacts of Public Works Programme Assets. Bonn.

McKenney, D., & Sarker, R. (1994). An overview of non-wood valuation efforts in Ontario. *The Forestry Chronicle, 70*(1), 47 - 51.

Moges, D., & Taye, A. (2017). Determinants of farmers' perception to invest in SWC technologies in the North-Western Highlands of Ethiopia. *International SWC Research, 5*(1), 56-61.

Mussa, M. (2004). *A comparative study of pastoralist parliamentary groups: Case study on the Pastoral Affairs Standing Committee of Ethiopia.* NRI/PENHA.

Nicol, A., & Otulana, M. (2014). *Complex Pathways: The Afar Triangle in the Horn of Africa.* Brighton: Future Agricultures.

Oosterbaan, R., & Nijland, H. (1994). Determining the saturated hydraulic conductivity. In H. Ritzema, *Drainage Principles and Applications.* (pp. 435-456). Wageningen: Alterra.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action.* Cambridge & New York: Cambridge University Press.

Pascual, U., & Muradian, R. (2010). The economics of valuing ecosystem services and biodiversity. In P. Kumar (Ed.), *The Economics of Ecosystems and Biodiversity (TEEB). Ecological and Economic Foundations.* London and Washington: Earthscan.

Pearce, D., Atkinson, G., & Mourato., S. (2006). *Cost-benefit analysis and the environment: recent developments.* Organisation for Economic Cooperation and development.

Piguet, F. (2007). Complex Development-Induced Migration in the Afar Pastoral Area (North-East Ethiopia). *Migration and Refugee Movements in the Middle East and North Africa . .* Cairo: The Forced Migration & Refugee Studies Program, The American University in Cairo.

PRISE. (2017). *Challenging the myths around semi-arid lands.* London: ODI.

Prizzon, A., & Rogerson, A. (2013). *The age of choice: Ethiopia in the new aid landscape.* London: ODI.

Rauch, T., Beckmann, G., Neubert, S., & Rettberg, S. (2017). *Rural transformation in sub-saharan Africa. A conceptual study.* Berlin: Centre for Rural Development (SLE).

Reed, D. (2001). The rural poor and their natural resources. Understanding the link between poverty and the environment in a globalised economy. *the Courier ACP-EU, November-December*, 30-13.

Rettberg, S. (2010). Contested Narratives of Pastoral Vulnerability and Risk in Ethiopia's Afar Region. *Pastoralism, 1*(2), 248 - 273.

Sharma, B., & Scott, C. (2005). Watershe management challenges: Introduction and Overview. In B. Sharma, J. Samra, C. Scott, & S. Wani (Eds.), *Watershed Management Challenges: Improving productivity, resources and livelihoods.* (pp. 1-21). Colombo: IWMI.

Sileshi, A., & Habtamu, D. (2017). *Investigating selected soil physicochemical properties, status of soil fertility and salinity at Gariro, Shakayboru and Kalkalsa watersheds in Chifra District and its vicinity, Afar National Regional State, Ethiopia.* Samara: Samare University.

Spradley, J. (2016). *Participant Observation.* Waveland Press.

Stern, P., Dietz, T., Ostrom, E., & Stonich, S. (2002). The Drama of the Commons. In *Knowledge and Questions after 15 Years of Research* (pp. 445 - 90). Washington DC: National Academy Press.

Storck, H., Bezabih, E., Berhanu, A., Borowiecki, A., & Shimelis, W. (1991). *Farming systems and farm management practices of smallholders in the Hararghe Highlands - A baseline survey.* Kiel: Wissenschaftsverlag Vauk.

Tafere Reda, K. (2014). Formal and informal land tenure systems in Afar region, Ethiopia: perceptions, attitudes, and implications for land use disputes. *African journal on conflict resolution, 14*(2), 41 - 62.

Tilahun Amede. (2016). *Rebuilding Livelihoods of (Agro-)Pastoral Communities in Chifra District of Afar National Regional State. Annual Progress Report.* Addis Abeba: ICRISAT.

Turton, C., Warner, M., & Groom, B. (1998). *Scaling up participatory watershed development in India: A review of the literature.* London: ODI.

United Nations. (1992). *Rio Declaration on Environment and Development.* Rio de Janiero: United Nations.

USAID. (2006). *Issues in Poverty Reduction and Natural Resource Managment.* Washington DC: USAID.

Vaitla, B., Coates, J., & Maxwell, D. (2015). *Comparing Household Food Consumption Indicators to Inform Acutr Food Insecurity Phase Classification.* Washington DC: FHI 360 / Food and Nutrition Technical Assistance III Project (FANTA).

Wakie, T., Evangelista, P., Jarnevich, C., & Laituri, M. (2014). Mapping current and potential distribution of non-native Prosopis juliflora in the Afar Region of Ethiopia. *PLOS ONE*, 1-9.

White, H. (2009). *Theory-based Impact Evaluation: Principles and Practice.* New Delhi: 3iE.

WOCAT. (2017, 11 24). *WOCAT SLM Database*. Retrieved from WOCAT: https://qcat.wocat.net/en/wocat/technologies/view/technologies_1536/

Yin, R. (2009). *Case study research: design and methods. Essential guide to qualitative methods in organisational research.* (4th ed.). Thousand Oaks, CA: SAGE.