# Designing A Framework For More Effective And Sustainable Land-Use Planning Decisions In Pastoral Areas Through Cost-Benefit Analysis

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## Acronyms

| | |
|---|---|
| ASAL | Arid and Semi-Arid Land |
| CBA | Cost-Benefit Analysis |
| FIRR | Financial internal rate of return |
| KIIs | Key Informants Interviews |
| LULC | Land Use and Land Cover |
| MATs | Mutually Agreed Terms |
| MoU | Memorandum of Understanding |
| NPV | Net Present Value |
| PDRA | Participatory disaster risk analysis |
| PIC | Prior Informed Consent |
| SSA | Sub-Saharan Africa |
| TEEB | The Economic of Ecosystems and Biodiversity |

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## 1. INTRODUCTION

Approximatively 54% of the Earth's total land area is covered by rangelands with the majority found in drylands (ILRI et al 2021), characterized by highly variable rainfall patterns (Fratkin, 2008) and therefore presenting mobile livestock production as the most practiced land use practice (Galvin, 2009).

Rangelands provide several ecosystem goods and services (Hobbs et al., 2008) (add figure/table 1) and it is estimated that they support one billion herds of cattle, sheep, camels, and goats and near to a billion people (McGahey et al. 2014).

Several factors of natural and anthropogenic origin are currently affecting/undermining rangelands (Lipper et al., 2010; Bedunah and Angerer, 2012). Climate change, drought, population growth, and policies mandating sedentary pastoral livelihoods are thought to be the major drivers of degradation. Sub-Saharan Africa has undergone rapid economic growth and environmental change over the last 30 years and use intensification was envisioned as support for the growing population. In addition, the rapid encroachment of grass species by woody species in the rangelands is reducing the availability of forage resources for pastoralists (Tsegaye et al., 2010). This has often translated into pastoralists shifting to small ruminants, such as sheep and goats, that feed on woody species and diversifying to non-livestock-based practices (Tsegaye et al., 2013).

Overall, it is estimated that about 20% of rangelands have been degraded by land uses (Reynolds et al., 2007). The Interg report highlights that "agriculture and clearing of land for food and wood products have been the main drivers of land degradation for millennia (high confidence)" (Olsson et al., 2019; Ordway et al., 2017; Xu et al., 2018). The conversion to cropland has led to the loss of about 4.7 million of grassland since 1850 worldwide. However, agriculture and forestry do not necessarily cause land degradation and sustainable management is possible though not always practiced for reasons that encompass economic, political, and social conditions.

The proliferation of crop farming in the rangelands of East Africa has been largely driven by policy and development agendas (Reid et al., 2004; Kuule et al., 2022), although the recent participation of pastoralists in non-pastoral activities, could be also the result of a cognitive response to the changing environment, or a result of natural response to new challenges or the realization of the opportunities in rangelands (Kuule et al., 2022). Pastoralism in Africa faces new challenges in an era of climate change, and there are concerns that pastoralism might not be sustainable in a climate-affected world. This has led to the return of policies to settle pastoralists and introduce modern cropping and is mostly due to the lack of understanding that pastoralism is a specialization to take advantage of instability and variability (Shine and Dunford, 2016).

The views on cropland expansion are polarized. Changes in land use will have implications on both social and environmental components and therefore affects on both components should be considered when changes in rangelands are to be promoted.

Livelihoods diversification for pastoral communities, which includes among others, crop cultivation, can contribute to reducing risk and stabilizing income flows and consumption, potentially improving the quality of life, wealth accumulation, and food security (Coppock et al., 2011) and overall enhance pastoral livelihoods. However, despite cropland expansion may result in improved food security, this could lead to substantial threats to the natural ecosystems, therefore calling on the need to address the trade-off between cropland expansion and food security (Delzelt et al., 2017; Liao et al., 2020). Diversification can bring about negative impacts on communities, especially in locations where the socio-environmental context strongly favours specialization in mobile livestock herding (Liao et al., 2020); it could also carry the threat of appropriation of communal lands and natural resources from pastoralists whose livelihoods depend on such assets, this raising significant concerns regarding social equity.

The potential negative effects of cropland expansion on the natural ecosystem point to the need for protecting other ecosystem services.
The aim of the current study is:

- to review studies assessing the ecological and economic implications of losing rangelands due to conversion in agricultural land.
- To consolidate pillars useful to design a framework for more effective and sustainable land-use planning decisions in pastoral areas through informed cost-benefit analysis.

In doing so, the current study will look into:

- Understanding drivers of land-use change, rangelands ecosystem goods and services, and impacts of land-use change in pastoral communities and beyond.
- Approaches to quantifying and estimating Land Use and Land Cover (LUCL) changes.
- Tools for analysis of monitoring spatial-temporal environmental changes.
- Tools for modelling and scenario analysis.
- Current frameworks for costs benefit analysis (CBA).
- The relevance of the policy and governance context.
- Qualitative tools to support CBA.
- The relevance of engaging users and decision-makers.

## 2. Understanding drivers of land-use change, ecosystem goods and services from rangelands and impacts of land-use change in pastoral communities and beyond

### 2.1 Drivers of land-use change

The perceived drivers of LULC changes in the rangelands can broadly be categorized as biophysical, demographic, economic, infrastructural, and technological.
Demographic/socio-cultural factors like human population growth come along with the increased demand for crop cultivation land which might lead to significant changes in LULC types in the rangelands and elsewhere (Abate and Angassa, 2016). Competition over scarce agricultural land is also mounting as the population grows.

Biophysical drivers of rangeland degradation include natural extreme events such as floods, droughts, soil erosion, and landslides. Removal of trees, overgrazing, and bushfires also play a major role in the degradation of rangelands. Drought has been linked with causing large-scale destruction of vegetation cover in rangelands (Kosonei et al., 2017; Shiferaw et al., 2014). During drought years farmers overexploit certain land cover types such as wetlands and forest areas by clearing them for the establishment of crop farming and sometimes for charcoal burking (Kosonei et al., 2017). During drought years, wetlands and woodland are also overgrazed with livestock, and overgrazing promotes bush encroachment and change in plant species composition in rangelands (Angassa and Oba, 2008; Bai et al., 2013).

The growing demand for renewable resources and the rising prices for agricultural commodities is other important factors beyond the conversion of rangeland into cropland.
Another major reason leading farmers to convert grassland to cropland is the economic profile linked with the low livestock productivity (Nkonya et al., 2016) and the need for diversification.
Table 1 summarizes the key drivers and shocks affecting rangeland management.

**Table 1**. **Key drivers and shocks affecting rangeland management** *(modified from Liniger et al., 2019).*

| | Global/International drivers | Shocks/extreme events | Local – national drivers |
|---|---|---|---|
| Biophysical | • claims on water (within transboundary watersheds)<br>• claims for land (acquisition/ grab, nature protection) | • droughts, water shortage, pollution, floods, extreme rainfall events, volcanic eruptions<br>• outbreaks of pests and diseases<br>• fires | • changes in quantity and quality of pasture biomass and quality<br>• changes in quantity and quality of water resources: rainfall, surface, groundwater<br>• climate change<br>• climate variability and change observed locally<br>• diseases/ pests<br>• wildlife interaction |

| | | | |
|---|---|---|---|
| | | | • changes in land quality (organic matter, N, P, K, etc. contents)<br>• changes in soil erosion<br>• changes in biodiversity<br>• changes in carrying capacity |
| Economic | • market for rangeland products<br>• market for tourism<br>• investments in research | • market crashes<br>• transfer of Technologies and innovations | • market and access<br>• alternative income (rangeland products, tourism/ wildlife)<br>• access to financial resources and services<br>• changes in economic opportunities |
| Political/ institutional | • transboundary policies<br>• transboundary conflicts<br>• land acquisition/ grab | • political instability<br>• insecurity, wars<br>• new laws, agreements | • legal framework: tenure, rights and land fragmentation<br>• authorities and institutional setting<br>• multiple claims<br>• local – national governance: rules, regulations<br>• conflicts and political unrest<br>• infrastructure and services<br>• interventions by development agencies |
| Socio-cultural | • transboundary migration of people and livestock | • outbreaks of ethnic and other clashes | • population changes and in/out-migration<br>• security and conflicts<br>• competition for resources<br>• livelihoods, poverty, and market orientation<br>• availability of manpower/ labour, and workload<br>• norms and values<br>• role of women, disadvantaged groups<br>• knowledge, management capacity, and skills<br>• collaboration and coordination of stakeholders |

## 2.2 RANGELANDS ECOSYSTEMS GOODS AND SERVICES

Land uses in the rangelands are forest, shrub land, woodland, grassland, wetland, cropland, settlements, barren lands and water bodies.

Rangelands and pastoralist areas produce a great variety of ecosystem services. The ecosystem services offered can be categorized:

- Provisioning services: food, fodder/forage (grasslands significantly contribute to food security through providing part of the feed requirements of ruminants used for meat and milk production), water availability for livestock, water quality for livestock, raw materials, non-wood forest products, animal/livestock production
- Regulating services: air quality regulation, climate regulation, disturbance moderation, regulation of water flows, waste treatment, carbon sequestration (emission in/from soil, and above and below ground forest/shrubs), soil erosion (wind and water) prevention, reduction in surface flow, nutrient cycling, pollination, and biological control
- Habitat services: nursery service (for example breeding habitat for wild ungulates) and genetic diversity, maintenance of biodiversity (conservation)
- Cultural services: aesthetic information (services), scenic beauty, recreation, inspiration, spiritual experience/enrichment, reflection, and cognitive development

## 2.2 IMPACTS OF LAND-USE CHANGE IN PASTORAL COMMUNITIES AND BEYOND

The conversion of rangelands into croplands is associated with several externalities, such as:

i) **Biodiversity loss**. The loss in plant and animal biodiversity might incur, which has a multitude of consequences relating to ecosystem functions (Fenta et al., 2020);

ii) **Pollution**. Pollutants might be released into the environment due to the use of agro-chemicals, which can harm ecosystem functions;

iii) **Reduction of carbon sequestration and emissions**. reduction of carbon sequestration potential and climate regulation (especially in a case when crop expansion includes deforestation), with knock-on effects on biodiversity and agricultural productivity; hydrological fluxes due to changes in some hydrological components like surface runoff, surface roughness, stream flow, and evapotranspiration (Kuule et al., 2022); Commercial farms with high stocking rates support lower rates of soil organic carbon compared to communal grazed farms with the same stocking rates.

iv) **Reduction of fodder resources**. Crop residues are used as fodder and are an important source of forage during the dry season, but arable farming only makes use of the soil on a seasonal basis. The conversion of rangelands to cropland affects forage provision and feed resource composition, and might result in feed deficits and changes in feeding management strategies since feed resources are no longer adequate to sustain a productive livestock population (Benin et al., 2022; Ellison et al., 2022);

v) **Limited mobility**. Cropland becomes off-limits to herds and herders during the cultivation period (Diogo et al., 2021), affecting the size of the transhuman corridors and, with landscape fragmentation, further limits the mobility of livestock and the access to spatially heterogenous vegetation resources (Hobbs et al., 2008). Mobility is among the most important strategies adopted by millions of pastoralists worldwide to survive and thrive in the drylands. Reduced mobility exacerbates bush encroachment and land degradation, as sedentarized pastoralists use the rangelands more recursively (Liao et al, 2020). Associated with declined mobility are livelihood intensification and diversification, but, such livelihood transitions may carry both socio-economic and environmental risks.

vi) **Reduced productivity** for pastoralists. there is a relationship between the heterogeneity of the vegetation and the carrying capacity of the land (Hobbs et al., 2008; Wang et al., 2006). This implies that rangelands transformation that limits livestock mobility can in turn constrain productivity unless herd sizes are reduced. The restricted mobility decreases pastoralist opportunities to optimize weight gain and milk production in the wet season and to limit weight loss in the dry season (Moritz, 2010; Krätli and Schareika 2010).

vii) **Conflict.** As access to suitable grazing areas and places where fodder can be gathered decreases, so the potential for conflict between pastoralist communities who move with the seasons and more sedentary farming communities in these areas increases. The ministry of Animal Resources in Burkina Faso, back in 2012, estimated that around 600 conflicts occur each year, between pastoralists and farmers. In Benin in 2017, 17 deaths were reported, resulting from conflicts between sedentary and transhumant people Ellison et al., (2022).

Conflict arises when farmers have encroached on transhumance paths, leading herders to move onto agricultural land to enable their animals to feed. The erosion of traditional transhumant corridors by sedentary people represents therefore a threat to peace.

viii) **Potential loss of indigenous knowledge**. Indigenous knowledge results from a blend of cultural and ecological diversity in specific contexts and has been recognized as crucial for future adaptation to achieve sustainability goals (Berkes, 1998; Kassam, 2009). Given their diversity and depth of knowledge on the rangelands, pastoralists can make novel contributions to rangeland management policy-making (Liao et al., 2020). Pastoralists might know when to increase their holdings of a specific species, according to the different plant cover composition (e.g. vegetation regime shifts towards denser woody plant cover in the East African drylands would negatively affect the production of cattle and sheep; however, goats would be largely unaffected by while camels could benefit from the ongoing regime shift). Pastoralists know about feeding livestock of different age groups in different patches of rangelands to better exploit the vegetation in their communities. This knowledge is functional to mitigate the impact of bush encroachment on pastoral food security and to facilitate adaptive management, therefore enhancing the resilience of dryland systems and pastoralist communities.

ix) **Increased rates of degradation and expansion onto less resilient lands**. Drivers of land use and cover change in rangelands interact with each other and with other factors, such as land tenure.

They can trigger a cycle of increased rates of degradation and expansion onto less resilient lands, even when demand stops increasing (Herrick et al., 2012).

**Box 1. Encroachment of crop production into pastoral land.**

Drivers of land use and cover change in rangelands interact with each other and with other factors, such as land tenure. They can trigger a cycle of increased rates of degradation and expansion onto less resilient lands, even when demand stops increasing (Herrick et al., 2012).

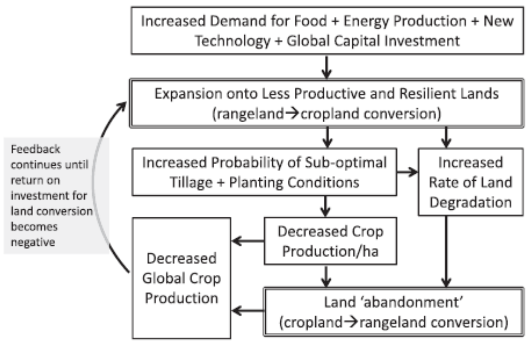


Figure X. Drivers of land use and cover change in rangelands and return on investments from land conversion. *Source: Herrick et al., 2012*.

The range management and pastoralism strategy of Kenya (Gov of Kenya, 2021) identifies challenges to rangelands productivity that include among others, the encroachment of crop production into pastoral land. Crop farming in the rangelands has led to increased opening up of the fragile rangeland ecosystems. In addition, rainfall scarcity results in crop failures that eventually make the productivity of land unviable.

## 3. QUANTIFY AND ESTIMATE LUCL CHANGES

Large parts of the populations of countries in the Global South, particularly of SSA, depend heavily on natural resources for their livelihoods (Egoh et al., 2012). SSA is one region potentially most vulnerable to the adverse effects of land cover change and land degradation. Communities living in rangelands in SSA are increasingly becoming exposed to the deteriorating quality and quantity of goods and services from rangelands (Mbolanyi et al., 2016). There is growing evidence showing there has been an extensive conversion of rangeland land cover types such as grasslands, woodlands, and wetlands into farmlands in Eastern Africa in the past three decades (Olson et al., 2004; Maitima et al., 2010).

Overall, cropland cover increased by about 20 million ha between 1992 and 2015 in SSA, with the largest crop expansion in West Africa (Egoh et al., 2012). In East Africa, farmlands increased for example by 171.2% in Ethiopia's Bale zone (Legese and Balew, 2021) and Borana rangelands of southern Ethiopia (Abate and Agassa, 2016). Cropland expansion took place mainly at the expense of shrubland and forest cover and to some extent grassland.

The estimation of the LULC changes is relevant in establishing the impact of anthropogenic activities on the ecological components of the rangelands such as water resources, plant structure, and diversity (Guuroh et al., 2018; Aghsaei et al., 2020). Estimating the economic and ecological implications of LULC is essential for the formulation of informed policies to support rangeland management and rehabilitation for natural resource protection and increasing resilience to climate change.In addition, valuing LULC changes has the potential to address trade-offs between competing needs and support better planning and decision-making relating to sustainable use and management of natural ecosystems.

Despite considerable efforts have been made to study land-cover change in SSA (e.g., Berihun et al., 2019a; Brink and Eva, 2009; Fenta et al., 2017a; Gibbs et al., 2010; Mayaux et al., 2013), only a few studies have estimated the effects of land cover change on ESV at the local scale (Kindu et al., 2016; Tolessa et al., 2017; Arowolo et al., 2018; Gashaw et al., 2018).

Fenta et al. (2020) estimate the ecosystem services value of different land cover types, based on the adoption of global value coefficients from the work of de Groot et al., (2012) and Costanza et al. (2014). The results from the assessment indicate that the contribution of provisioning services from cropland outweighs the same contribution from grasslands. The same applies to regulating services, such as climate regulation, erosion prevention, and nutrient cycling. Grassland scored high values in correspondence of habitat services, and cultural services. Overall, this study concludes that the total ESV has increased in SSA between 1992 and 2015, mainly due to cropland expansion; the study concludes that cropland expansion outweighs the monetary effect of the declining natural vegetation on ecosystem services in SSA. However, the authors noticed that it is worth considering the loss of ESV via the conversion of natural ecosystems to cropland and the fact that, conversion to cropland might result in the long-term decline of key ecosystem services, such as climate regulation and nursery services; therefore, the apparent gains from cropland expansion might be offset by the long-term losses of natural ecosystems and related ecosystem functions.

Other studies (Li et al., 2019), using a similar ESV assessment procedure to the one of Fenta et al., (2020), and applying valuation coefficients, have come to a different and opposite conclusion, having reported a decrease on ESV due to conversion to cropland of different ecosystems. There could be different reasons beyond these different results, including the application of different methodological approaches, such as a different number of biomes considered and the use of different valuation coefficients, for example, the application of Costanza et al. (1997) coefficients vs the combined coefficients of de Groot et al. (2012) and Costanza et al. (2014). The study of Fenta et al. (2020), however, presents the limitation of applying the value transfer methodology, assuming spatial homogeneity and could have led to an overestimation of the value associated with conversion to croplands. Non-market valuation methods are technically complex, costly, and time-consuming to implement. In the context of most CBA preparations, it is usually not feasible for an individual department to undertake its own non-market valuation study for an individual project or policy. Despite the shortcomings of the value transfer method, the approach is often the prominent option. A summary of key findings from studies assessing the implications for the conversion of rangelands is presented in table 2.

**Table 2. Implications from conversion of rangelands, a review of selected studies**

| Country | Period | Method | Results | Economic | Climate | Biodiversity | Other | Reference |
|---|---|---|---|---|---|---|---|---|
| Mauritania | 1999 - 2001 | Compared the returns, based on annual production values, from a system of intensive sorghum cultivation and a system that included pastoralism in seasonal wetlands in semi-arid eastern Mauritania. | Returns from pastoralism in seasonal wetlands in semi-arid were six to thirteen times greater than intensive sorghum cultivation.<br>Multiple-use systems (livestock rearing, arable agriculture, wild foods, and forestry products) out-perform single-use systems when the opportunity cost and the replacement costs of wetland resources are considered.<br>Multi-use systems are better adapted to a highly variable climate. | | | | | Shine and Dunford (2016) |
| Ethiopia (Awash River) | 1999-2009 Sugar cane<br>1980-1990 Cotton | Cost-Benefit Analysis (net returns based on benefits and costs of each production system) to estimate the economic contribution of pastoralism that is forgone with the conversion of a hectare of valley grazing to another land use compared with the return from conversion into different large-scale irrigated crop production systems (sugar cane and cotton).<br>Scenario analysis for livestock and | Livestock husbandry is more profitable than cotton farming and sugar cane cultivation. | | | | | Behnke and Kerven (2013) |

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| | | time-series data for cotton and sugar cane cultivation. | | | | | | |
| Nigeria (Hadejia-Jama’are River Basin) | 1998 | Economic and hydrological modelling of the impacts of upstream water diversion on downstream floodplain activities concerning the Hadejia-Jama’are River Basin in northern Nigeria. The losses are estimated in terms of net present value. | All scenarios, including the most conservative, show that the conversion of the upstream water diversion would be `uneconomic` and would lead to considerable losses. | | | | | Barbier (2004) and Barbier, R. and Thompson (1998) |
| Uganda (Nakasongola district) | 1985 - 2021 | Ex-post assessment combining remote sensing, to characterize the extent and drivers of land use and land cover (LULC) – satellite and qualitative tools (FGDs and KIIs) to capture perception from the local communities. | Gain in farmland (+28.6%), built-up (1.7%), central forest reserves (0.6%), and open water (0.1%)<br><br>Loss of woodland (5.2%), shrub and thicket (8.3%), grassland (13.3%), wetland cover (4.8%). Decline in forage diversity and shrinking of grazing land.<br>Marginalization of pastoral groups, reduction of heard size (a combination of shrunken grazing land due to LULC changes and increasing drought effects). | | | Qualitative | | Kuule et al., 2022 |
| Ethiopia (Borana) | 1985-2011 | The impact of the conversion of rangelands into cultivated land (sorghum, maize, haricot beans, teff, barley) was assessed through survey interviews from agro-pastoralists, participatory | Damages include: soil erosion, an increase of bare lands, loss of natural vegetation biomass (bushes and wood trees) and supply of fuelwood, fodder and non-timber forest product, and building material, reduction of soil organic carbon (due to slush and | | | | | Elias et al. 2015 |

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| | | appraisals, rainfall data, and remotely sensed satellite data. | burn), deterioration and fragmentation of rangelands, loss of dry season grazing reserves (constraint for browser animals, goats, sheep and other fame animals feeding on bushes)<br>Co-cause: degradation was worsened by application of not good agricultural practices | | | | | |
| Niger (Fakara) | 1998 - 2002 | Bio-economic model (from Barbier, 1998) was used with inputs from a household survey implemented in Fakara. A nutrient model too was used (Nutmon toolbox by Busqué 2002). | Shortage of seasonal availability because livestock have no access to croplands and reduction of shortage of quality grazing resources for livestock in the late dry and early wet season. The grazing pressure on the ranges during the growing season when livestock are excluded from croplands has increased considerably. | | | | | Hiernaux and Ayantunde, 2002 |
| Benin | 1986-2017 | Remote sensing analysis of the land cover evolution | A shift of shrub savannah to grass savannah, wood extraction, overgrazing, and bush burning, conversion to cropland<br><br>Croplands were less likely to be burned.<br><br>Reduction in shrub/grass savannah, and woodland savannah, open forests. Landscape fragmentation, with cropland interrupting the flow of common lands and riparian areas beginning to be farmed. Increase of | | | | | Ellison et al. 2022 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | conflicts between sedentary and transhumant people. | | | | | |
| Ethiopia | 2017-2020 | Qualitative tools (FGDs, KIIs) and field observations | The reported impact is the stop of traditional riverbank agriculture and reduction of crop production and hence threatening food security. In addition, traditional mobility routes were interrupted and a loss of biodiversity was registered. | | | | | Gebeyehu and Abbink (2022) |
| Ethiopia | 2013-2020 | Field work with qualitative tools (FGDs and KIIs). | The construction of the Gilgel Gibe III dam on the Omo River and the establishment of large-scale sugar estates. Food security results deteriorated and most individuals put in place coping strategies, such as selling animals | | | | | Gebresenbet, 2021 |

## 4. Frameworks for CBA analysis

Cost-benefit analysis provides a means to look into monetary incentives to preserve land.
The basic starting point for all CBAs is a determination of which and whose benefits and costs should count. The determination must be undertaken based on time and space. This is critical for ownership of polices that would be influenced by the CBA outputs. All CBAs must also specify the planning horizon over which benefits and costs count, and this issue can be important and consequential when it comes to long-term, intergenerational concerns like climate change (Joseph et al., 2021).

An applied example of cost-benefit analysis from the conversion of land used by pastoralists into irrigated land is included in the study of Behnke and Kerven (2013), see box 2, which demonstrates that livestock husbandry is more profitable than cotton farming and sugar cane cultivation.
Other studies that attempted to quantify the grazing-irrigation trade-off come to a similar conclusion. Shine (Shine, 2002; Shine and Dunford, 2016) compared the returns from a system of intensive sorghum cultivation to a system that included pastoralism in seasonal wetlands in semi-arid eastern Mauritania and the latter were six to thirteen times greater. Barbier and Thompson (1998) examined the costs and benefits of large-scale irrigation schemes in the Hadejia-Jama'are River Basin in northern Nigeria. these wetlands provide seasonal grazing for mobile pastoralists. Despite not accounting for the benefits of grazing, they found that gains in irrigation benefits accounted for about 15% of the losses from reduced floodplain inundation to existing production systems. Salem-Murdock and Horowitz (Horowitz 1995; Salem-Murdock and Horowitz 1991) looked at the downstream impact of Manantali Dam on a major tributary of the Senegal River and although irrigated agriculture offered higher returns per unit land area, there were lower returns to capital and labour than a pre-existing multi-use system that included livestock keeping.

**Box 2. Cost-benefit analysis of irrigated crop agriculture – the example of Awash River, Ethiopia**

Until the 1960s, Afar pastoralists were used to accessing the Awash River valley as a source of grazing for their livestock, benefiting, especially during the dry season, from the riparian grazing supported by the flood of the Awash River. Later, the flow of the river would have been regulated in support of agricultural companies, resulting in the loss of access to the riparian forest they were relying upon.
The authors quantified economic benefits generated by three alternative agricultural systems: pastoral livestock production versus cotton and sugar cane estate.

The authors estimated the gross value of livestock production, per hectare, for two stocking densities and collected information on production costs, to determine the annual net returns to Afar pastoralism per hectare. The opportunity cost per year of excluding pastoralism from a hectare of Awash valley grazing, i.e., the economic contribution of pastoralism that is forgone with the conversion of a hectare of valley grazing to another land use. At 2009 prices, this value was roughly 540 USD per year.

Cotton farming was assessed by assimilating seed cotton to live animals and milk production. The profitability of seed cotton spanned from 135 USD/ha to 616 USD/ha across different managements. Seed cotton was profitable, although profits from cotton farming mostly come from exporting ginned lint cotton.

Like cotton, sugar production begins with a raw agricultural commodity, sugar cane, comparable to live animals, and dairy produce sold by pastoralists. The estimates of returns to cane cultivation were based on a producer's price. Cane cultivation was roughly as profitable a livestock in two years, and less profitable in six out of the eight years. The real profit was made when an added value was created through refining and marketing raw sugar. However, the author notes that the profitability of farm sugar is site-specific, and the site analyzed was in a favourable area.

Cotton farming has radically changed the ecology, the agricultural production systems, and the ethnic background of the people that exploit the valley.
Having been forced to leave the valley, pastoralists have become more dependent on rain availability, forced their displacement into areas that became over-populated, with consequent overgrazing, livestock starvation, and diminishing herds and malnutrition.

Though these were not factored into the CBA, the authors underlined environmental hazards associated with each of the scenarios analyzed: pastoralism can lead to rangeland overgrazing and degradation; cotton is associated with deforestation, the introduction of invasive tree *Prosopis juliaflora*, and raised water levels; irrigation used in the sugar had increased the risk from malaria and schistosomiasis.

We present a few examples showing how the cost-benefit analysis was structured to assess the pros and cons of losing pastoral areas because of large-scale irrigated crop systems.

**Behnke and Kerven** (2013) structure the CBA around the economic contribution of pastoralism that is forgone with the conversion of a hectare of valley grazing to another land use compared with the return from conversion into different large-scale irrigated crop production systems in Ethiopia. Time-series data, with yields, revenues, and operating expenses, are considered for cotton and sugar cane production. For pastoralism, the amount of heard that could be supported by each hectare of the valley during a year is considered, based on the Afar heard composition and the feed requirements of each species. Cattle, camels, goats, and sheep are considered.

The production of milk and meat based on the number of animals is used to estimate the value of gross outputs. Husbandry costs for pastoralism included: security costs, and labour (transport and traction costs could not be determined).

Quantification of economic costs of hazards/externalities associated with the three systems is missing but mentioned as important.

**Shine and Dunford** (2016) compare the value of a single-use system, arable agriculture, with that of a multi-use system, wetlands, used by pastoralists. They calculate the value of pastoral production based on how many animals each day use the wetland and on average in a month. Cattle, camels, goats, and sheep are considered. The value of production of milk and meat is considered; wholesale market prices are used to calculate the value of annual off-take and the price of milk is used to estimate milk production value. Information on forestry products and wild foods is collected through household surveys, to estimate the value of botanical and natural resources, based on market prices. Revenue created from vegetable gardening is also considered.

For the single-use system, arable agriculture, harvest data were collected in the field on flood recession. Sorghum is the main cereal grown in flood recession conditions. A median figure of market price per kilogram was applied. Input costs were considered mainly in terms of fencing, levelling and digging, and agro-inputs and tools.

The replacement cost of a wetland converted from a multiple-system to a single-system is based on the loss of revenues from pastoral resources, wild foods, medicinal plants, construction material, and biodiversity. The loss of wetland resources to the pastoral sector is assessed by calculating the costs of well construction and labour needed for water extraction, intended as a proxy of the cost of replacing the wetland with wells. The number of wells needed is estimated based on the average number of animals that would have used the wetland.

**Barbier (2004) and Barbier, R., and Thompson** (1998) examined the economic and hydrological impacts of upstream water diversion on downstream floodplain activities in relation to the Hadejia-Jama'are River Basin in northern Nigeria and look into the economic gains of the upstream water projects compared to the resulting economic losses to downstream agricultural, fuelwood and fishing. These wetlands provide seasonal grazing for mobile pastoralists. Despite not accounting for the benefits of grazing, they found that gains in irrigation benefits accounted for about 15% of the losses from reduced floodplain inundation to existing production systems. The assessment is done comparing the total net benefits from downstream activities with the total net project benefits of irrigated crop production, and using different discount rates (8% and 12%), over 30 to 50 years. All scenarios led to the same conclusion, that the expansion of irrigation schemes within the river basin was `uneconomic`.

There are several lessons learned from this assessment, included the need to consider the forgone net benefits of disruption to the natural environment and degradation downstream, as part of the opportunity costs of the development investments. The authors underlined how this is important where substantial impacts on economic livelihoods will result from the hydrological and ecological impacts of upstream water diversion. There is a direct trade-off between increasing irrigation upstream and impacts on the floodplain downstream.

Other examples of cost-benefit analysis with application to different contexts are here presented since they can be useful to frame additional components to the analysis.

**Christo, *et al* 2001** present the application of a cost-benefit analysis framework for the national working for water programme***.*** This cost-benefit analysis framework was to address issues of alien infestation and provide an understanding of the cost implications for maintaining existing rangelands and water systems. The study relied on existing information on ecosystem functioning, economic values, and costs of clearing. The framework had five components. The first component was the ecological-economics components, which included the sub-components; the invasion of catchments by aliens, supply and value of water, and use and value of natural vegetation goods (products) & services (tourism). The second component was the management components which included clearing of alien vegetation, fire management, and links to the ecological components. The third component was the human development (training) component which included improved citizenship and improved earning potential. The fourth component was the secondary industries component. The fifth component was the cost-benefit analysis component, which aggregated the costs and benefits of each of the other four components.

The framework was mainly to establish the costs and benefits involved in restoration based on the eradication of alien infestations. The framework considered the economic impacts of reduced water supply, the supply and value of natural vegetation products and services,

Costs and benefits from the first four components were aggregated and transferred to the cost-benefit analysis component to generate values for decision-making. The decision values included net present value, benefit-cost ratio, and internal rate of return. The model does not include indirect, option, and existence values. The model is built in an MS Excel spreadsheet, which is not dynamic enough to address all ecosystem costs and benefits. The framework to be developed for the rangelands will include tailored aspects of the four components listed above with specific emphasis on rangelands maintenance and/or alternative uses.

**Verdone (2015)** presents a cost-Benefit Framework for Analyzing Forest Landscape Restoration Decisions. This is a cost-benefit framework for accounting for the ecosystem service and economic impacts of forest landscape restoration activities in a way that allows the results to be structured to inform multiple types of restoration decision-making that can help decision-makers understand the trade-offs of different restoration scenarios. The results can be used to set prices for payment for ecosystem services, identify sources of restoration finance, identify low-cost/high-benefit pathways towards carbon sequestration, and identify priority landscapes for restoration based on return on investment analysis.

Application of this framework involved these steps:

- Specify the set of restoration transitions: Define which degraded land uses will be restored and the activities that will be used to restore them.
- Define the stakeholders who will be affected by restoration: Define the groups of people who will be affected by the restoration transitions.
- Catalogue the impacts and define how they will be measured: Which impacts matter most to the stakeholders who will be affected by restoration and what units of measurement are most useful for measuring them?
- Predict the impacts quantitatively over the time horizon of the project: Use ecosystem service models, household surveys, stakeholder engagement, and other estimation methods to quantify the expected impacts of restoration activities.
- Monetize the impacts: Use appropriate direct and indirect methods to value the estimated impacts.
- Discount benefits and costs to obtain present values: Select discount rates to make streams of future benefits and costs comparable at the present moment.
- Calculate the net present value of each alternative: Subtract the discounted stream of implementation, transaction, and opportunity costs from the discounted stream of benefits.
- Perform sensitivity analysis: The results of the CBA depend on assumptions and the sensitivity of the results to changes in the underlying assumptions should be evaluated.
- Make policy recommendations: From a Pareto-efficiency perspective, the restoration activities with the largest NPV should be recommended.

This framework provides a clear procedure for executing the assessment of costs and benefits for restoration. However, it does not give attention to all costs and benefits of ecosystem services. An array of valuation methods are provided with general concepts on usage and it has no rigorous analytical model. This can be a starting point in the application of a CBA framework for rangelands and areas with recurrent conflicts but must be accompanied by a detailed and dynamic analytical model.

**Balmford et al.** (2011) provided an example of an operational framework for assessing the economic consequences of losing wild nature. This framework lays the basis for the assessment of the economics of losing biodiversity, on the premise that policy action to halt the global loss of biodiversity and ecosystems is hindered by the perception it would be so costly as to compromise economic development. This framework emphasizes contrasting counterfactual scenarios which differ solely in whether they include specific conservation policies; identifying non-overlapping benefits; modelling the production, flow, use, and value of benefits in a spatially-explicit way; and incorporating the likely costs and possible benefits of policy interventions. The framework hence quantifies how the loss of benefits derived from ecosystems and biodiversity compares with the costs incurred in retaining them.

The framework subscribes to the need to use different scenarios but settles on two scenarios. The first scenario reflecting continuing business-as-usual (with the associated loss of biodiversity and the benefits it bestows on people) and the second otherwise identical scenario, where policies to achieve particular conservation goals are in place. Those goals and policy actions must be defined explicitly—which requires understanding the causes of biodiversity and ecosystem loss.
The framework is based on two scenarios, but the development of the framework for rangelands and conflict areas will want to include scenario analysis with the number and type of scenarios deemed necessary by the appropriate stakeholders. A crucial aspect of applying the framework is identifying ecosystem services that can be evaluated in practice. The framework for rangelands and conflict areas will use ecosystem services already established to be useful for the environment and humans. Ecosystems services will be prioritized and evaluated for restoration and/or conservation and eventually depending on the economics of conversion to other uses.

The **TEEBAgriFood Evaluation framework** (https://teebweb.org) establishes what should be evaluated (TEEB. 2019). That is aspects of eco-agri-food systems are to be included in a holistic evaluation. However, it does not focus on how assessments should be undertaken, nor does it prescribe methods for assessments. Hence, it can be used as a starting point in establishing a rigorous cost-benefit analysis framework. Alisher et al. (2021) argue that the economics of ecosystems and biodiversity (TEEB) values of ecosystem services in the region are not enough for a detailed analysis. Figure 3 is a schematic flow of the TEEBAgriFood Evaluation Framework that can be adapted as appropriate for the cost-benefit analysis framework for rangelands and conflict areas. The choice of methods will depend on the focus and purpose of any assessment, the availability of data, and the scope of analysis.

### 3.2 WHAT COSTS AND WHAT BENEFITS TO ACCOUNT FOR

Recent studies on costs and benefits in the rangelands and pastoralist areas have not accounted for all costs and benefits. As a consequence, costs and benefits have been underestimated. This gives an incomplete assessment of the area especially when there is a need to change to different enterprises. This is, however, the result of the difficulties underneath the assessment, especially, of non-market use benefits.

Based on the literature review and Key Informant Interviews (KIIs) we provide a list of those costs and benefits associated with land use and land cover change that affect pastoral communities.

Given the need to restore/conserve the pastoral system or switch to different enterprises, costs will include the loss of the pastoral system. The costs focus on what benefits will be lost due to the proposed land-use change. Similarly, the benefits will include the gains from the system to which the land use will be changed. A comprehensive CBA framework is expected to use certain values in the processes of working towards generating key decision support values. Among the key values to be used are discount rates, the time horizon for interventions, elasticities for pastoralism, and different investment scenarios. The theoretical basis also needs to be identified. Studies need to be undertaken to get these values that will be representative and can be used in the analysis to generate good results to inform policy development and implementation.

A preliminary list of costs and benefits is provided below but this can be expanded and adjusted as appropriate. The plan is to create a list of all costs and benefits from current activities, irrigated farming, and nomadic livestock rearing.

*LISTING OF COSTS*

This involved identifying and estimating all direct and indirect costs in present value needed for each venture and the points in time at which it is expected that they will be incurred. A broad list of costs is stated in the table below:

| | **Direct costs** | **Indirect costs** |
|---|---|---|
| **Crop production** | o Loss of native tree species, grasslands and ecosystem services<br>o Cost of buying water<br>o Cost of water-trucking<br>o Administrative costs: typical administration, compliance promotion, monitoring and enforcement costs<br>o Compliance costs<br>o Capital and operating costs for industry to comply and generate credits<br>o Transaction costs<br>o Opportunity costs<br>o Implementation costs<br>o Voluntary credit-generating costs<br>o Compensation costs to affected parties for irrecoverable damage to the environment<br>o Resource costs<br>o Mitigation costs for both new and existing facilities/activities, like control of emissions, effluents and discharges<br>o Prevention costs incurred in operations that prevent | o Non-diversified food production for food security<br>o Future impact of relevant policies and measures taken<br>o Cost of regulatory services<br>o Awareness and capacity building of all stakeholders to understand and seek solutions to the degradation of natural resources, to generate collective action and respect for land ownership, settlement plans, livestock and grazing plans, by-laws, traditional knowledge and ecosystem functions<br>o Protecting wildlife habitats and threatened species |

| | | |
|---|---|---|
| | environmental impacts, i.e. tailings dams for mining operations<br>o Reclamation costs for returning the site of activity and surrounding affected areas to a state "agreed on"<br>o Compliance promotion, monitoring and enforcement costs<br>o Management of forest and wetland systems to stabilize, recover and sustain the forest and wetland resources | |
| **Pastoral systems** | o Replacement cost of buying hay<br>o Marketing e.g. transporting animal and their products to markets<br>o Safeguarding agreed rangelands management and rehabilitation plans and practices including household grass banks, clearing invasive species, warrior/herder forums, elder-endorsed enforcement plans, rangelands social clubs<br>o Re-seeding and fodder production<br>o Livestock feed<br>o Cost of livestock lost or reduced income due to weight loss<br>o Family separation (due to migration during drought)<br>o Breeding stock<br>o Health care and treatment: Veterinary and Medicine<br>o Health problems related to sand and dust storms<br>o Expenditure due to nature-based tourism<br>o Fire and soil protection/management<br>o Compliance promotion, monitoring and enforcement costs | o Future impact of relevant policies and measures taken<br>o Cost of regulatory services<br>o Resource use conflicts and cattle rustling<br>o Awareness and capacity building of all stakeholders to understand and seek solutions to the degradation of natural resources, to generate collective action and respect for land ownership, settlement plans, livestock and grazing plans, by-laws, traditional knowledge and ecosystem functions |

*LISTING OF BENEFITS*

Benefits to include span those that pertain to pastoral or agro-pastoral systems and large-scale irrigated crop systems.
Benefits from large-scale irrigated crop systems include mainly crop production.
Benefits from pastoral or agro-pastoral systems include:

Provisioning

- o Livestock and livestock products
- o Water supplied by the catchment
- o Value from harvesting natural resources such as flowers, medicinal plants
- o Livestock grazing grounds and hay

- Timber and non-timber forest product supplies
- Biomass for energy production

Regulating

- Incremental domestic GHG emissions reductions
- Pollination services provided to the fruit industry
- Climate stabilization
- Carbon sequestration
- Improved biodiversity
- Drinking water filtration
- Soil and water conservation
- Improved soil productivity
- Erosion control and improved biodiversity conservation
- Water use efficiency
- Nutrient cycling

Habitat

- Lifecycle maintenance (e.g. nursery services)
- Gene pool protection (conservation)

Cultural services

- Tourism and ecotourism
- Improved peace and security
- Recreation values such as hiking, horseback riding, swimming, skiing, and hunting

## 5. Tools for analysis and monitoring of spatial-temporal environmental changes

### 5.1 Remote sensing

Remote sensing work may be required where appropriate to generate data on historical forest and pasture biomass changes, and surface and base flow of water. Remote sensing can be a precious base for estimating parameters of spatial variables, through area frame sample designs (Carfagna Elisabetta, 2019). When an area frame with permanent physical boundaries is constructed, strata and counting units are drawn on remote sensing images, through a manual or computer-assisted procedure (FAO 1998). Land-use time-series and systematically produced datasets using similar methodologies and classification schemes should be used.

## 6. Tools for modelling and scenario analysis

The following session would need to be further explored and consolidated. From a preliminary review regarding specific modelling, consideration will be given to adapting ecosystem services modelling approaches like InVEST and ARIES. InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a suite of models used to map and value the goods and services from nature that sustain and fulfil human life. It helps explore how changes in ecosystems can lead to changes in the flow of many benefits to people. ARIES is an artificial intelligent modeller rather than a single model or collection of models. ARIES chooses ecological process models where appropriate, and turns to simpler models where process models do not exist or are inadequate.

### 6.1 Sensitivity analysis

Given the uncertainty of impact estimates, where possible, sensitivity analyses will be included in the CBA framework to assess the impact of changes to key parameters, which may be higher or lower than indicated by available evidence. To address these issues, the analysis will consider alternate scenarios (e.g., high, low) to assess the impacts under alternate conditions. Key parameters and uncertainties include, but are not limited to: price and production forecasts; and future policies. The analysis will assume that no other new policies will come into force before some time to be agreed upon (say before 2033).

This is based on the understanding that about 10 years are needed for the land restoration activities to reach positive benefit-cost ratios (or to breakeven) from the social perspective and about 20 years if only private benefits are considered, accounting for both market-priced and non-market ecosystem benefits (Alisher, et al 2021; Mirzabaev, et al 2021). A net cash flow for an irrigation scheme is usually calculated for 30 years.

Uncertainty in determining the viability of projects stems mainly from uncertainty about cost and revenue levels. This necessitates proper sensitivity analysis to test what happens to viability results when certain assumptions change. To perform a sensitivity analysis, first, a list of assumptions that may change will be drawn up. Then the implications of changing each of these assumptions (or a combination of them) for the financial estimates will be determined so the cost-benefit analysis can be revised with the new figures to determine a new net present value (NPV). In this way, alternative viability outcomes will be explored allowing for a more realistic analysis.

The assumptions that we suggest including are:

- Cost changes: expenditures tend to escalate as unforeseen difficulties arise. Consequently, we will make assumptions based on inflation rate changes and other economic factors.
- Revenue changes: revenue levels are usually difficult to estimate as they are based on sometimes tenuous assumptions about demand levels for products. We will make assumptions based on existing market conditions. In addition, the weather is an important source of variability that can affect crop yields and rangeland biomass productivity. We will make assumptions based on weather projections.
- Interest rate effects: interest rates are not stable over time making it important to check the effects of different rates on viability. Different interest rates will be considered based on base rates and projections.

## 7. Qualitative tools

Qualitative tools allow us to integrate local knowledge and perspective on landscape changes. An example of application is the study of Gebeyehu and Abbink (2022) that assesses the impact of a large, state-sponsored sugar plantation scheme on agro-pastoralist livelihoods and local land-use change in southern Ethiopia, in the lower Omo Valley. The study uses FGDs, KIIs, and field observations. The reported impact is the stop of traditional riverbank agriculture and reduction of crop production and hence threatening food security. In addition, traditional mobility routes were interrupted and a loss of biodiversity was registered.

The findings from the study are that understanding the views of agro-pastoral communities and their use of the environment and creating a broader consultation platform, might create opportunities for cooperation and synergies to optimize the benefits and sustainably adapt a development project to the local context.

## 8. Participatory development of CBA framework and scenarios

We suggest developing a participatory CBA framework using a scenario analysis (e.g assessing with and without investment scenarios).

The CBA framework is supposed to be used by stakeholders in decision-making. It is necessary to establish what the stakeholders understand about CBA framework regarding its use, what needs to be included in it, and expected outputs. This will help to identify the impacts and select measurement indicators and to decide whose costs and benefits count to guide the valuation methods to be used.

The possible users of the CBA framework are community, government experts, scientists in research, rangeland experts, ranchers, and large-scale farmers and development partners.
There is however very limited use of CBA frameworks although it is the case that CBA would have many uses if it were to be integrated into government and other stakeholder actions. Among the uses are placing value on the rangeland resources, informing resource allocation and helping prioritize investment opportunities, such as conservation interventions to be undertaken. Envisaged engagements could be through proposal development, research, agreements and protocols, MoU, MATs (mutually agreed terms), PICs (prior informed consent), awareness creation though conferences and workshops and dialogue. However, details on how to proceed are critical and more engaged approaches.

The CBA framework that will be selected for the analysis will include the baseline [business-as-usual]) scenario, and a scenario in which there are new actions, notably the conversion into cropland.

The net present value and the present value of benefits and costs will be based on a minimum forecast of ten years. To the extent possible, the benefits and costs will be quantified and monetized. In accordance with guidance regarding environmental and health regulatory analyses, monetized impacts will be analyzed in present value terms, applying a discount rate (to be agreed on; say 3%) for future years.

Impacts that cannot be quantified and monetized will be assessed qualitatively. We strongly suggest the inclusion of qualitative elements to complement the CBA and scenario analysis. The CBA framework will consider the degree to which the changes could incentivize the expansion of envisaged policy changes. A baseline of existing activities in the rangelands for a reference year (to be agreed upon) should be considered in the methodology for the calculations for benefits.
The CBA framework should provide some form of relative ranking of actions by the expected cost.
The CBA will attempt to establish a distinction between attributable and non-attributable impacts.
The modelling will be done to include natural capital valuation and valuing changes in social and human capital.

Examples in the current report can be used as guidance to establish what should be evaluated.
The data to be used for CBA assessments should therefore come from a mixture of primary and secondary sources depending on the required changes and the availability of data in the country.
These data will include: monetary/non-monetary, financial/ economic, social/environmental, and data on direct/indirect impacts as listed in the categories of cost and benefits.

The framework is expected to be structured as per these steps:

- Specify the set of scenarios to be considered: define which business-as-usual will be involved and the future changes as well as the activities to be undertaken.
- Define the stakeholders who will be affected by the changes: define the groups of people who will be affected by the transitions.
- Record the impacts and define how they will be measured: which impacts matter most to the stakeholders who will be affected by changes and what units of measurement are most useful for measuring them?
- Predict the impacts quantitatively over the time horizon of the project: use ecosystem service models, household surveys, stakeholder engagement, and other estimation methods to quantify the expected impacts of the changes/ activities.
- Monetize the impacts: use appropriate direct and indirect methods to value the estimated impacts. Parameters employed in the CBA should involve both market and non-market effects (e.g. environmental, health, social) associated with the proposed investment.
- Discount benefits and costs to obtain present values: select appropriate discount rates to make streams of future benefits and costs comparable at the present moment.
- Calculate the net present value (NPV) of each alternative: subtract the discounted stream of implementation, transaction, and opportunity costs from the discounted stream of benefits.

In addition, the financial internal rate of return (FIRR) could be calculated based on the prevailing financial discount rate. NPV and FIRR can complement each other, with FIRR giving a good proxy on profitability and return on investment, whereas the NPV sheds some light on the financial impact.
The computation of the respective economic rates of return (ERR) could be also used.

- Perform sensitivity analysis: The results of the CBA depend on assumptions and the sensitivity of the results to changes in the underlying assumptions should be evaluated. Hence sensitivity analysis is recommended to be part of the CAB framework.
- A participatory baseline survey should be part of the process and might be done through participatory disaster risk analysis (PDRA) and/or qualitative assessments (such as FGDs and KIIs). In addition, this participatory users assessment could be useful to validate the local interest in development and for the establishment of the prior agreement of beneficiaries' contributions and future maintenance expectations regarding water management for example.
- Make policy recommendations based on set out goals and objectives. Policy recommendations will be based on the net present value and cost-benefit ratios.

Based on expert opinion, several elements were identified that could feed into a scenario analysis: forage biomass availability and rehabilitation; livestock feed value chains; enhancement of livestock production parameters through the production of supplementary feeds primarily supplied from irrigation and/or high-yielding sites and other sources; implementation of rangelands improvement measures; construction of marketing infrastructures;

Scenario analysis is beyond the scope of the current study, however, it deserves to be further expanded and explored.

## 9. Communication of the outcomes

It is necessary to develop a range of outputs to suit different audiences including technical experts, politicians and business leaders, farmers and local communities and the media. There is a raft of content formats available to deliver communications of outcomes. These include peer-reviewed journals, conference publications, patents, press releases, question and answer, features, newsletters, case studies, podcasts and videos, events, brochures, leaflets, briefings and exhibitions. Communication of outcomes will be based on the type of audience and or outcome. For policy-level stakeholders we anticipate the use of policy briefs, the academia and research teams will get papers in referred journals, technical reports and occasional papers, and rangeland and pastoralist stakeholders will get newsletters. There will also be awareness creation through social media, Barazas, outreaches and community structures. A final approach to the communication of outcomes will be discussed and agreed upon with the advisory team, economists, rangeland experts and other stakeholders directly associated with the development of the CBA framework.

## 10. Conclusions and recommendations for implementing a sustainable and participatory CBA

The next steps should identify a pilot area and the adaptation of the theoretical framework, here developed, to a specific context. This implies that the adaptation should consider consultations with decision-makers to contextualize and align the components of the CBA and the associated scenarios with the specific policy and governance context and current and foresee investments (e.g. those in infrastructure development).

Guidance should be provided regarding the impacts of land use and land cover change that pastoralists and agricultural communities are likely to encounter to frame plausible scenarios. Competing land uses should be figured out, since they represent a source of conflict and might entail pastoralist and agricultural communities, irrigation, settlement, infrastructure development and oil and mineral exploration for example.

Scenarios developed should consider local needs and opportunities and be participatory, for example by gathering farmers and pastoralists to agree on transhumance paths together. According to what the specific scenarios will entail, market routes could be considered as well as migratory routes.

Water-wise, there should be consideration of scenarios with enhanced water availability through measures for groundwater and rainwater harvesting, and developing infrastructure for water capture, storage and distribution, and enhancing irrigation efficiencies. When simulating for water points establishment/rehabilitation one should consider “modelling” this aspect coupled with rangeland planning, to prevent overgrazing, erosion and uncontrolled settlements.

Consideration of land-use governance agreements will be relevant, such as access rights. Scenarios might require the addition of other elements, according to the potential foreseen impacts such as the identification of innovative ways to secure and increase livestock fodder resources through effective management and production, and/or those required for a gradual shift from traditional pastoralism to a more business and market-oriented livestock industry.

Scenarios developed should consider the positive elements of pastoralism, and in particular the capacity to better adapt to non-equilibrium dynamics characteristics of many ASAL rangelands. At the same time, they should consider the increased erratic climate variability, and drought and floods, that might undermine long-term development. In this sense, the scenarios proposed should consider sustainability and resilience, and account for water needs, water use efficiency, and rehabilitation of degraded land, while ensuring mainstreaming of drought risk reduction and climate change adaptation measures that can offset the worst drought impacts.

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