IMPROVING THE RESILIENCE OF PASTORAL CATTLE PRODUCTION IN SOUTHERN ETHIOPIA

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IMPROVING THE RESILIENCE OF PASTORAL CATTLE PRODUCTION IN SOUTHERN ETHIOPIA

Background paper to the preparation of the Strategy:
"Sustainable and Resilient Livestock Development in view of Climate Change in the IGAD Region"

SEPTEMBER 2022

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TABLE OF CONTENTS

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ACRONYMS

AP	Agro-pastoral
DI	Drought index
DM	Dry matter
DMI	Dry matter intake
ETB	Ethiopian birr
EWS	(Destocking with an) early warning system
FAO	Food and Agriculture Organization of the United Nations
FP	Fodder planting
GCM	Global circulation model
HH	Household
IBLI	Index-based livestock insurance
IGAD	Intergovernmental Authority on Development
LW	Live weight
LWG	Live weight gain
MODIS	Moderate resolution imaging spectroradiometer
MP	Multipurpose
NDVI	Normalised difference vegetation index
P	Pastoral
PAP	Pastoral/agro-pastoral
RCP	Representative concentration pathway
RR	Rangeland restoration
RRSR	Real regional stocking rate
SR	Stocking rate
TLU	Tropical livestock unit
USD	US dollars
WB	World Bank

EXECUTIVE SUMMARY

Background

Climate change is one of the main challenges for pastoralists. Studies have found statistically significant links between climate (particularly rainfall and drought incidence) and cattle populations. Pastoralism is becoming an increasingly precarious livelihood. The World Bank and the Intergovernmental Authority on Development (IGAD) have developed a strategy to improve the resilience and sustainability of livestock production in the IGAD region of Africa. The focus is on ruminants (cattle, sheep and goats) and camels in pastoralist and agro-pastoralist (PAP) production systems because of their particular vulnerability to climate change. The strategy is based on a wide range of information sources, including modelling of the resilience of pastoral livestock systems.

Scope and purpose

This publication summarises the findings of the modelling undertaken for PAP cattle systems in Oromia, southern Ethiopia. The resilience of some PAP systems to drought has been eroded in recent years due to three underlying causes: natural factors, resource expropriations, and poor infrastructure and capacity. There is also evidence of a widening gap between feed demand and feed supply in Oromia. This work looks in detail at four measures to improve resilience:

- Index-based livestock insurance (IBLI)
- Commercial destocking with an early warning system (EWS)
- Rangeland restoration (RR)
- Fodder planting (FP)

Specifically, the study quantifies the effect that droughts have on cattle populations, their productivity and profitability. The findings will be of interest to those developing policies in Oromia and other pastoral areas, as well as to a wider audience with an interest in the resilience of livestock in the IGAD region. The modelling approach developed for this work provides a coherent framework for evaluating policies that could be further developed and deployed in the future.

Method

A dynamic model of the Oromia pastoral cattle system was developed for the analysis with, at its core, a herd model that calculates the cattle population each month for a specified period of time. The population is divided into 9 categories of animals (or *cohorts*) defined by age, sex, function and finishing system. An initial value (month 1) is assumed for the population in each of these cohorts, the herd model then calculates the population in subsequent months based on the values specified for parameters such as fertility, mortality, and replacement rates. The model was parameterised using a combination of published data and calibration. In the latter, relationships between key parameters (such as drought index, fertility and mortality) were varied until a good match was achieved between the modelled and reported population trends.

Drought is represented in the model using a drought index based on the Normalized Difference Vegetation Index – NDVI (based on satellite imagery), which is a standardised way to measure vegetation reflectance that can be used to estimate vegetation condition. The drought index for 2000-2020 was used to calibrate the model. Rainfall and temperature projections from three different global circulation models (GCMs) were used to estimate the NDVI trends in Oromia for the 2021-2100 period. The results indicate that drought events will continue to pose serious challenges to the resilience of pastoralists in the future. The effects of the resilience measures were analysed using a representative drought scenario that includes two severe droughts, two moderate ones and four mild droughts over a twenty-year period.

Findings

IBLI enhances resilience by enabling farmers to secure the resources to feed their cattle during droughts, thereby reducing the impacts on mortality and fertility. Overall, it has little effect on milk production but leads to a consistent, moderate increase (relative to the no-measure situation) in meat production. IBLI has little effect on profit because the financial benefits of reduced drought losses are largely offset by the costs of insurance premiums. However, the protection provided by IBLI may encourage farmers to shift over time, from decision making based on risk minimisation, to productivity-enhancement, thus increasing income. Obstacles to uptake include the cost of insurance premiums, relative to anticipated benefits, and the technical requirements of IBLI that mean it is better suited to locations with rangeland dominance and adequate forage production and seasonality. Subsidising the cost of IBLI in the start-up phase and dynamically adjusting premium rates have been suggested as ways of encouraging uptake.

Destocking with an EWS reduces cattle mortality and enables animals to be sold in better condition, giving farmers the means to maintain more of their breeding herd and to restock more rapidly after a drought. EWS leads to large increases in meat and milk production and, consequently, profit. This is due to the way in which the measure changes the herd structure; adult males are sold off, and the revenue is used to maintain calves and females, leading to a greater proportion of cows in the herd. Implementation of this measure may be hampered by inadequate transport infrastructure and lack of holding grounds for cattle. Perceived benefits of large herds (in conferring social status and providing a stock reserve for post-drought recovery) may make some farmers reluctant to destock, while the existence of a strong livestock export system facilitates destocking for those prepared to sell.

While IBLI and EWS seek to reduce the impacts of acute drought events, fodder planting and rangeland restoration both seek to address the chronic (drought-exacerbated) problem of feed shortage in Oromia by increasing the feed supply. Fodder planting entails growing crops on under-used land while rangeland restoration involves a combination of reducing grazing pressure (facilitated by supplementary feeding of purchased feed) and planting herbaceous species. Both measures lead to significant improvements in cattle performance, specifically increased cow fertility, increased growth rates and increased offtake rates (for mature male cattle). In theory, both measures could lead to significant increases in production. However, both require that farmers have the money to pay for the costs of implementing the measure, thus long-term loans may be necessary to enable adoption. Both measures also assume that adequate land can be made available: "under-used" land, for fodder planting, and land to grow feed for rangeland restoration. Further investigation is required to establish such availability. Even if it is available, these measures face further challenges as farmers may not be willing to make long-term investments to improve land over which they have limited property rights.

The measures in this study have been assumed to be implemented individually. In practice, measures may be more effective when implemented as part of co-ordinated packages of interventions. In some cases, realising the benefits of the measures may be contingent on other actions. For example, widespread adoption of measures that significantly increase milk production may require the development of milk producer groups and improvements in transport infrastructure. In the absence of coordinated improvements to supply chains, increasing production may lead to local oversupply and depressed prices.

Ultimately, the heterogeneity of the pastoralist sector means that a range of measures are needed to improve resilience; what works best in one context may be inappropriate in another. It is likely that all of the measures in this report have a role to play in the future.

1. INTRODUCTION

1.1 Context

Pastoralism has been defined as "a complex interaction of people, natural resources, and livestock, predominantly practiced in arid and semi-arid lowlands" in which herders "derive most of their income or sustenance from keeping domestic livestock reared in conditions where most of the feed is natural rather than cultivated" (Gebremeskel et al. 2019, p1). Climate variability is one of the main challenges for pastoralists in Eastern Africa. Studies have found statistically significant links between climate (particularly rainfall and drought incidence) and cattle populations (Megersa *et al.* 2014; Kimaro *et al.* 2018; Araro 2019). It has been argued that "As climate change advances, the downward trend in cattle numbers is expected to persist, implying that the centuries-old cattle pastoralism is likely to become a precarious livelihood option" (Megersa *et al.* 2014). While it is recognised that pastoralism is designed to deal with uncertainty, "it is unclear if current practices will suffice under changing environmental conditions. (McPeak et al. 2012, p169)".

This background paper summarises analytical work undertaken in the context of the Program on Climate Smart livestock Systems in Africa (GIZ 2018) as part of a WB/IGAD activity aiming to develop a Strategy towards a "Sustainable and Resilient Livestock Development in view of Climate Change in the IGAD Region" (hereafter "the IGAD resilient livestock strategy"). The IGAD region covers Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda. The focus in this report is on resilience as measured in terms of changes in production and profit. A scientific paper (MacLeod *et al.* 2022) is in preparation that covers the greenhouse gas implications of improving resilience.

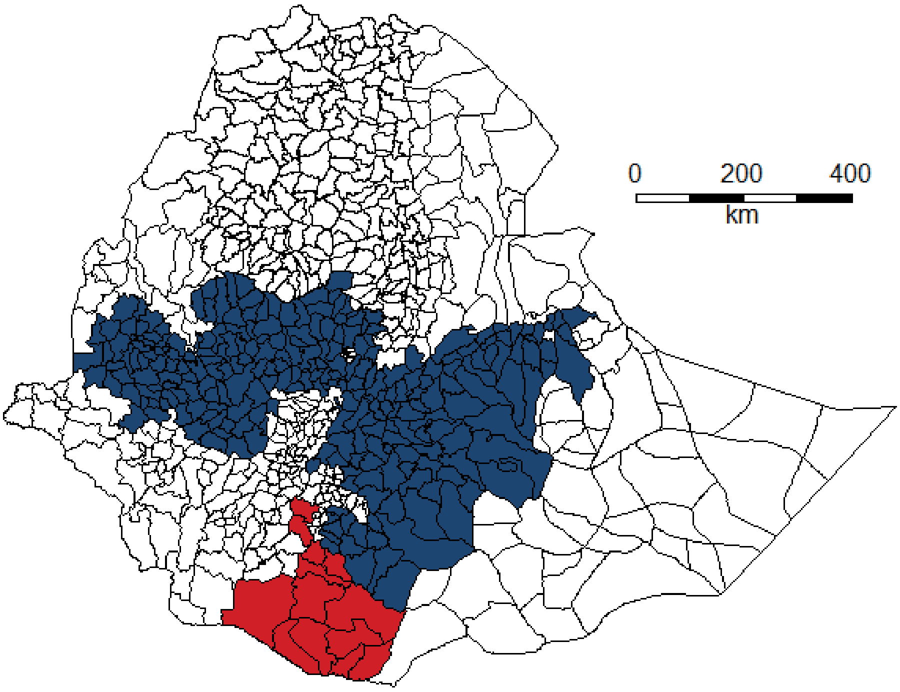
The IGAD resilient livestock strategy is based on a wide range of inputs, including literature reviews, consultation with stakeholders in the IGAD region, primary data collection and modelling of climate change impacts on the livestock sector's resilience. This background paper summarises the findings of this last activity. The modelling is intended to complement the other activities by providing insights into how the scale and performance of livestock production changes in response to drought events. It enables aspects of livestock production (such as herd size, productivity and farm income) to be quantified and the effects of measures estimated.

While the IGAD resilient livestock strategy covers a wider range of livestock systems, this background paper focuses on cattle in pastoral/agro-pastoral (PAP) systems in southern Ethiopia, specifically, in the Oromia region (Figure 1.1). This system/location was chosen due to its (social and economic) importance and vulnerability to the effects of drought, as well as the availability of data in the region.

Pastoral systems originated in response to environmental constraints, but their resilience has been eroded in recent decades by a range of pressures. The unpredictable nature of drought presents a particular problem to pastoralists, given their dependence on natural rain-fed feed. However, several measures to improve their resilience have been proposed. This work looks in detail at four of them:

- Index-based livestock insurance (IBLI),
- Commercial destocking with an early warning system (EWS),
- Rangeland restoration (RR), and
- Fodder planting (FP).

Figure 1.1: Map of Ethiopia's woredas (administrative units).



Coloured woredas = Oromia region, red = Borena zone, blue = rest of Oromia. Most of the PAP cattle in Oromia are located in the red zone.

These measures were chosen based on a combination of literature reviews and consultations with experts and representatives from IGAD and IGAD's member states. These four measures are not to be thought of as the only or best ways of improving the resilience of PAP systems in Oromia, rather they have been selected to illustrate different approaches to improving resilience. The results for Oromia do not necessarily hold for the entire IGAD region.

1.2. The response of pastoral and agro-pastoral systems to drought

Pastoralism has evolved over time to be resilient to droughts. However, this resilience has been eroded in recent years (Megersa et al. 2014, Gebremeskel et al. 2019). Inter-Africa Group (IAG 2010, p76) identified three underlying causes of increased vulnerability of pastoralists: natural factors, resource expropriations, and poor infrastructure and capacity. *Natural factors* (possibly a misnomer given the underlying human causes) include droughts and degradation of rangelands. These natural factors have been exacerbated in Ethiopia by "extensive land *expropriation* (italics added) by the state particularly since the 1960s" (IAG 2010, p79) to make way for state farms and national parks. This has led to increased stocking rates and rangeland degradation. Finally, *infrastructural* problems, such as lack of roads and markets, have "created difficulty to destock animals during drought seasons" (IAG 2010, p81) and lower cattle prices in some areas. McPeak et al. (2012, p66) noted that "Borana herders are poorly informed about prices in Nairobi and highly dependent on selling to Burji traders" who are "constrained in the level of prices that they can pay herders in the border areas." Inadequate soft infrastructure (e.g. financial and legal institutions) makes it difficult for markets to function properly and renders conflict resolution expensive.

PAP systems can respond to droughts in a variety of ways depending on their starting point (i.e. their access to resources and markets), and the severity of the drought. Figure 1.2 illustrates the chain of events that can be initiated by a drought, leading ultimately to PAPs:

1. moving animals beyond their normal range;
2. remaining *in situ* but seeking additional feed and water;
3. selling cattle (early or during the drought) and restocking post drought; or
4. selling cattle and exiting the sector.

The implications of these responses for resilience are discussed below.

Increased movement

Movement is one of the traditional responses of PAP systems to drought, but mobility has been hampered by policy, rangeland degradation and conflict. For example, Bekele and Abera (2008, p15) reported that mobility has been undermined by “The conversion of dry season pasture into farmland and the establishment of year-round water facilities in traditional wet season grazing areas. Previously, wet season pasture was exploited as a source of feed during critical periods, but year round grazing has left the pasture degraded and no longer an asset in a drought situation”. Where increased movement is possible, it can reduce the immediate impacts of drought, but has associated costs such as additional time (Smith *et al.* 2019, p53) and energy expenditures. Increased movement can increase the risk of conflict and disease transmission.

Likely outcome: Adopters remain in mobile pastoralism but are less resilient due to the costs and risks associated with movement and increased constraints on mobility.

Increased grass offtake

Increasing grass offtake beyond a sustainable yield leads to overgrazing and depletion of soils. It is likely to lead to rangeland degradation and a gradual diminution of the forage resource, with consequent impacts on forage quality and cattle performance. There may also be increased risk to cattle health via plant poisoning as scope for selective grazing is reduced.

Likely outcome: Adopters remain in mobile pastoralism in the short term, but less resilient in the medium-long term due to land degradation.

Obtaining extra feed through feed purchase

The impacts depend on how the purchase of extra feed is funded. In the absence of savings (or an insurance payment), feed purchase may be funded via coping strategies such as: eating less, borrowing, food aid, selling livestock, wage labour, taking children out of school, eating next season’s seeds (Smith *et al.* 2019, pp xiv, 95-97). Livestock will typically be sold during droughts under poor terms of trade (i.e. low livestock prices and high feed prices). The health and performance of remaining stock are protected, but the asset base is depleted.

Likely outcome: Adopters remain in mobile pastoralism, but are becoming less resilient due to asset depletion.

Obtaining extra feed through feed production

The implications depend how the increase in feed production is achieved. It can entail sedenterisation and the conversion of good quality grazing land to crop production, impacting on those remaining in mobile pastoralism by reducing the forage resource. Questions arise regarding how sufficient land can be obtained given the apparent feed deficit in pastoral areas, and the challenges of large-scale fodder production in drylands.

Likely outcome: Effectively a transition from pastoral to agro-pastoral i.e., adopters are moving out of mobile pastoralism.

Post-drought restocking

The extent to which livestock lost (sold, dying, or not born) through drought can be replaced depends on the revenue received for those that are sold, (and the proportion of the revenue that can be made available for restocking), and/or the ability to regrow naturally (which depends on factors such as herd size and the extent to which neighbours are able to share new cattle). Sales revenue depends on the prices obtained for the livestock, which is a function of their physical condition at sale and the prevailing market conditions – buyers have been reported to wait for prices to drop before purchasing animals. Livestock sold early, before their physical condition has deteriorated and supply has increased, will obtain higher prices than later distress sales of animals in poor condition. Early sales (of mature males) also enable more breeding stock to be maintained, thus enabling faster replenishment of the herd post-drought and maintenance of the genetic integrity of the pastoralist cattle breeds: "During post-drought restocking, herders often are forced to buy poor breeds of cattle from the highland communities that further contribute to the genetic dilution of the Borana breed." (Angassa and Oba 2007). Not all the revenue from sales will be available for restocking; some will be used to purchase food (to make up for reduced milk production) and increased veterinary costs post-drought etc. (Catley *et al.*2014).

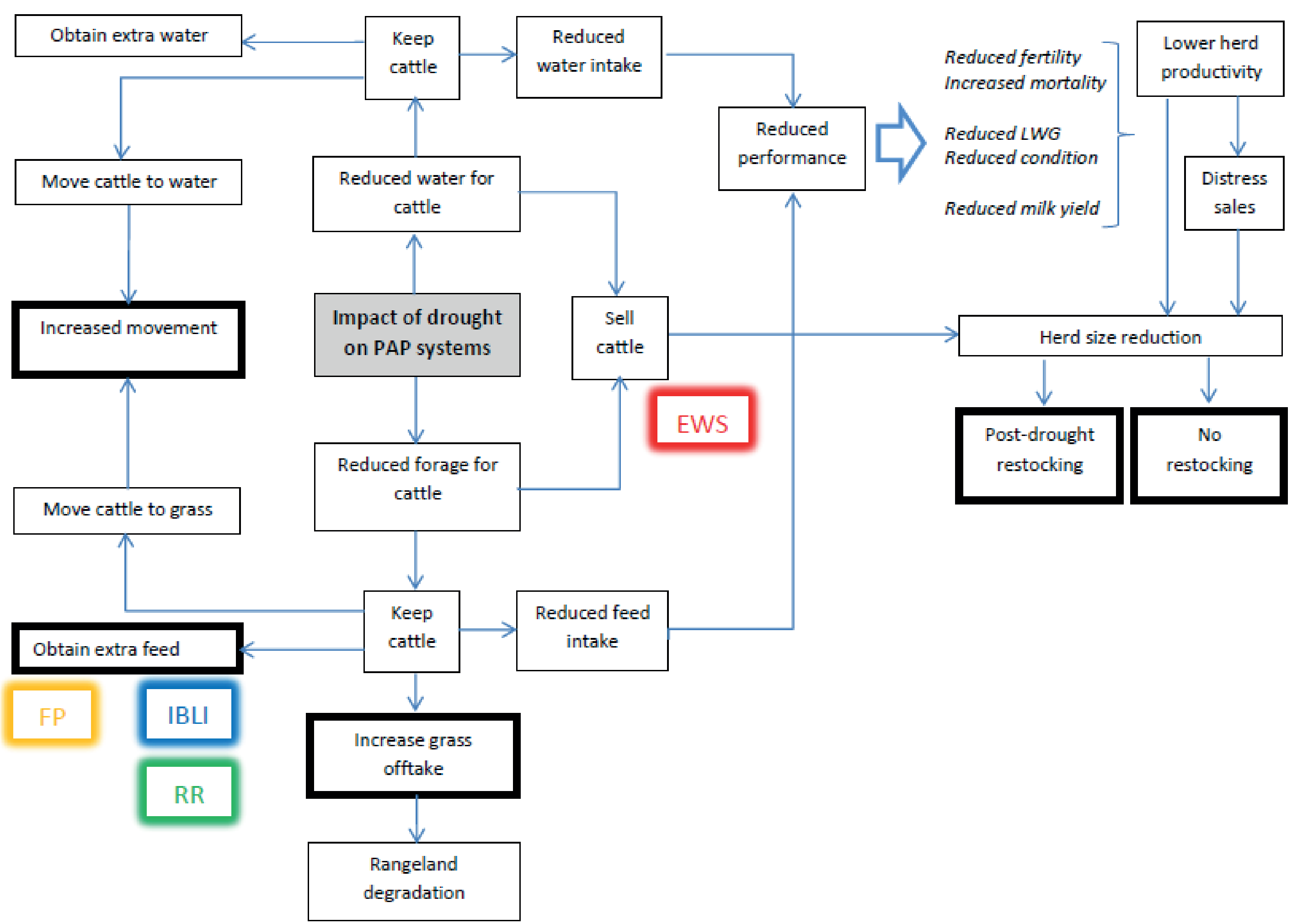
Likely outcome: Those restocking recover and remain in mobile pastoralism, with resilience maintained if stock are sold early. Recovery is slower and resilience reduced if stock are sold later.

No restocking after drought

Revenue received for sold animals does not have to be spent on restocking. Catley and Cullis (2012) have questioned "whether a return to pastoralism is really viable for many poorer households given the competition they will face from a commercializing, wealthy and well connected sector within pastoral areas." This is particularly the case with those who have sold animals late, and lost part of their breeding herd. Gebremeskel *et al.* (2019, p30) suggest that pastoralists with low resource and market access may be better seeking alternative livelihoods, with the support of measures that "facilitate positive diversification and their safe and smooth landing into the new livelihood."

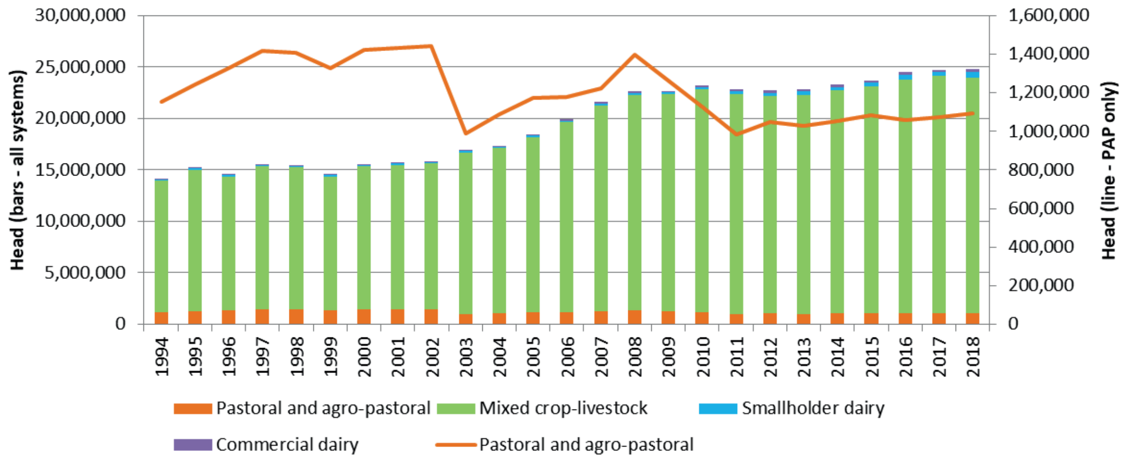
Likely outcome: Exits and alternative livelihoods.

Figure 1.2: Schematic diagram of PAP systems responses to drought impacts, and the points at which the four measures act.



IBLI: Index-based livestock insurance. EWS: Drought early warning system and destocking. RR: Rangeland restoration. FP: Fodder planting.

Figure 1.3: Cattle populations in Oromia by system (based on Wilkes et al. 2020)



1.3 Cattle and drought in Oromia

Cattle production systems

As part of an inventory of greenhouse gas (GHG) emissions from cattle in Oromia, Wilkes *et al.* (2020) divided cattle into four production systems, based on their purpose, agro-ecology and management: (i) commercial dairy cattle, (ii) smallholder dairy cattle, (iii) dual purpose cattle in the mixed crop-livestock system and (iv) dual purpose cattle in the pastoral/agro-pastoral system (PAP). They estimated the population in each system using the annual livestock sample surveys reported by the Central Statistical Agency of Ethiopia (Figure 1.3). The mixed crop-livestock system predominates and increased by 66% between 1998 and 2018. The smallholder and commercial dairy populations are small but also increasing, while the PAP population is somewhat erratic but still accounts for over 1 million animals.

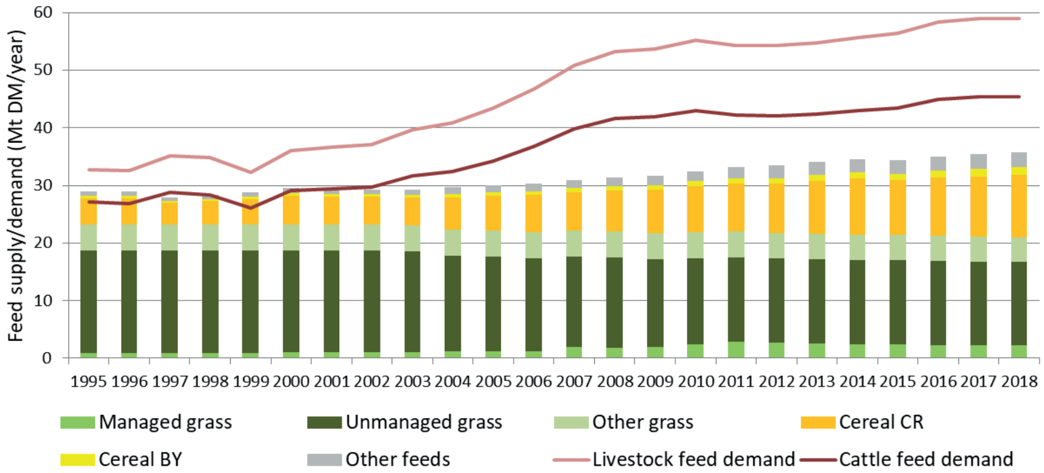
The feed balance in Oromia

The performance of cattle (e.g. their milk yields, growth rates and reproductive performance) is dependent on their nutritional status. If the diet provides inadequate macronutrients (protein, fat carbohydrates and metabolizable energy) or micronutrients the animals will only achieve a fraction of their full genetic potential. To understand the feed balance in Oromia better, a method for quantifying feed demand and supply was developed (Appendix A). The feed supply and demand for the period 1995-2018 were estimated (Figure 1.4). The results suggest that there was usually a small feed deficit in the 1990s, which has gradually widened since 2002 as livestock populations have increased more rapidly than feed supply. The feed deficit leads to many cattle suffering from chronic malnutrition and acute mortality during droughts, which is a particular challenge for PAP systems largely dependent on grasslands and with limited capacity to purchase additional feed. The vulnerability of PAP systems to drought is reflected in the erratic population (Figure 1.3) and is one of the reasons why this study focuses on these systems, and, in particular, on ways of reducing the feed deficit within them (Section 1.5).

1.4 Drought trends and projections

Several factors can explain the higher mortality of cattle during drought (e.g., forage or water scarcity, heat stress, higher vulnerability to diseases or predation) and they are not easily disentangled (Catley *et al.* 2014). Proxy drought indicators have been used to aggregate the multiple and inter-related factors of cattle mortality; for instance, Normalized Difference Vegetation Index (NDVI)-based indicators in the context of Index-Based Livestock Insurance (IBLI) (Chantarat *et al.* 2013). NDVI is calculated from satellite images and reflects vegetation

Figure 1.4: Estimated feed supply (bars – supply of these feed materials available for all livestock) and demand (lines – all livestock and cattle only) in Oromia from 1995 to 2018. CR: cereal crop residues; BY: cereal processing by-products; Other feeds: mainly non-cereal CRs and pulse by-products.



growth (including inedible forages such as Prosopis juliflora; an invasive plant species). In this study, the latest IBLI methodology (Fava *et al.* 2021) was used to build a NDVI-based drought index reflecting forage scarcity and influencing herd dynamics (see Section 2.3). The drought index was calculated from both historical NDVI time series (2000-2020) and projected NDVI values derived from temperature and rainfall predicted by three Global Circulation Models (GCMs).

Monthly satellite NDVI data for 2000-2020 show the seasonal dynamics of forage productivity, with growth periods occurring in the long (March-June) and short (October-December) rainy seasons (Figure 1.5). The drought index reflects anomalies in rainy seasons' NDVI compared to its historical distribution, i.e., lower than usual forage productivity. Cut-off percentiles in the historical distribution are used to determine drought severity. According to this method, 8 significant droughts (i.e. rainy seasons with low rainfall and forage growth) are recorded in the 2000-2020 period, respectively 4, 2 and 2 low-, medium- and high-intensity droughts.

Rainfall and temperature projections were used to estimate the evolution of NDVI and of the drought index in Oromia for the 2021-2100 period (Table 1.1). Projections varied across models but none of them predicted a radical change in average NDVI, even under the most pessimistic Representative Concentration Pathway (RCP 8.5) of the Intergovernmental

Figure 1.5: Historical NDVI (grey) and drought index (red) data in pastoral areas of Oromia (Borena zone)

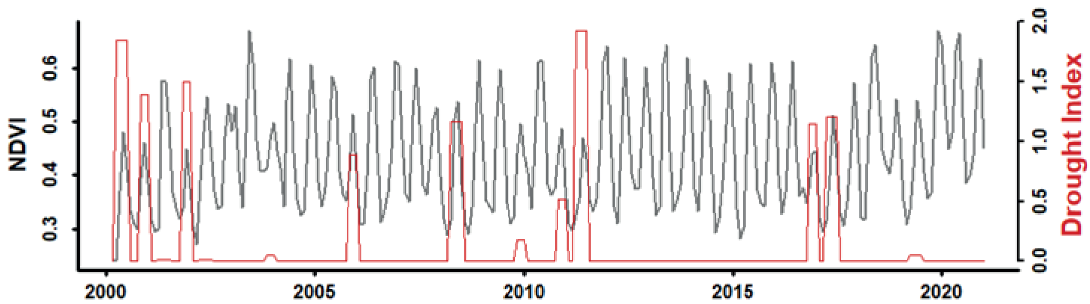


Table 1.1: Summary of NDVI evolution estimated with linear regression from temperature and rainfall projections of three global circulation models[1], and consequence for drought frequency.

	BGC[2] model	CM[3] model	MIR[4] model
Average NDVI in 2021-2060 period compared to 2000-2021	+0.2%	-1.7%	-4.1%
Average NDVI in 2061-2100 period compared to 2000-2021	-1.7%	-7.5%	-8.0%

[1] *Source:* Karger et al. (2020). Projections for the Representative Concentration Pathway 8.5 were used.
[2] CESM1-BGC run by National Center for Atmospheric Research (NCAR).
[3] CMCC-CM run by the Centro Euro-Mediterraneo per I Cambiamenti Climatici (CMCC).
[4] MIROC5 run by the University of Tokyo.

Panel on Climate Change (IPCC). In the 2021-2060 period, a very slightly positive (+0.2%) to slightly negative (-4.1%) change in average NDVI compared to the historical period (2000-2020) was found. Changes in average NDVI were negative for all models in the later period (2061-2100). Projected drought frequency was lower than in the historical period for all models, but the relative number of medium-intensity droughts and the maximum drought index values were higher. This can be related to the "East African Climate Paradox" (Rowell *et al.* 2015), predicting higher average rainfall in the region for the future, but also more extreme rainfall events and more variable rainfall. Higher average rainfall could have a positive impact on average NDVI, although it could be progressively counterbalanced by the strong increase in temperature predicted towards the end of the century. Despite these complexities, it is clear that drought events will continue to pose serious challenges to the resilience of pastoralists in Oromia.

1.5 Improving resilience

"Resilience" is defined in this report as: *the capacity of livestock production systems to either maintain or quickly restore production and income in the face of disturbances and shocks associated with or worsened by climate change.* This definition, adopted from the IGAD resilient livestock strategy, is an adaptation of the definition presented in IPCC (2014). While we recognise that the ultimate goal should be to improve the resilience of people's livelihoods, a more (production system) focussed definition is adopted because one of the main coping mechanisms for dealing with drought is to sell livestock (Smith *et al.* 2019, p97). Measures that improve the resilience of livestock production, therefore, enable households to avoid being forced to sell their livestock during droughts when the terms of trade are poor. People should be free to choose whether to undertake livestock production or not. If they decide to withdraw from the sector, it should be for positive reasons, i.e. they should be pulled out of the sector by better opportunities outside it, rather than pushed out by lack of resilience within it. Change should be driven by properly functioning markets, rather than by drought-induced desperation.

The following indicators for measuring resilience were discussed with member states and IGAD in the context of preparations for the IGAD resilient livestock strategy:

1. The length of time from the onset of a disturbance or shock to the loss of livestock numbers, production, and income.
2. The length of time during which livestock numbers, production and income are compromised due to the shock or disturbance.
3. Total losses of livestock numbers, production, and income due to the shock or disturbance.
4. The extent to which livestock numbers, production, and income recover to previous levels.

Table 1.2: Indicators used to estimate the effect of each measure on resilience

	Livestock production*	Income**
Time to impact	Time between start of drought and 20% reduction in meat and milk production	Time between start of drought and 20% reduction in household income
Duration of impact	Time taken (from start of drought) to return to 90% of pre-drought production levels	Time taken to return to 90% of pre-drought household income
Change in output	Change in production with the measure over the 1 and 5 year periods after the start of the drought compared to production without the measure	Change in income with the measure over the 1 and 5 year periods after the start of the drought compared to income without the measure
Extent of recovery	Production 1 year and 5 years after the start of the drought as a % of pre-drought production	Income 1 year and 5 years after the start of the drought as a % of pre-drought income

**production measured in terms of mass of meat or milk. **income in terms of operating profit per household (HH)*

To measure changes in resilience consistent with these indicators, a series of indicators were used in the modelling work (Table 1.2).

Measures chosen for analysis

There are many ways in which the resilience of pastoralists in the IGAD region can be improved. The most appropriate set of measures will vary depending on where the particular farmer is starting from, and the pathway they are on, which, in turn, depends largely on their market and resource access. In this study, four measures were chosen that seek to improve resilience in different ways (thereby making the analysis relevant to a wide range of pastoralists). The point at which they act is shown in Figure 1.1. The measures chosen for analysis are:

1. Index-based livestock insurance (IBLI);
2. Drought early warning system and destocking (EWS);
3. Rangeland restoration (RR); and
4. Fodder planting (FP).

The measures target nutrition in different ways. Insurance enables the purchase of feed (and other inputs) in drought years to prevent livestock losses. The early warning system plus destocking reduces feed demand in years when feed supply is predicted to be low, while rangeland restoration and fodder planting seek to increase feed supply by increasing the production of grass and crop feed materials.

Measures targeting cattle nutrition were chosen because of its fundamental importance to resilience and because there is evidence of increasing feed scarcity in Oromia (Figure 1.3). Adequate nutrition is also a prerequisite for other measures (Gebremeskel *et al.* 2019, p36). However, other approaches are also important, such as those identified by de Haan (2016):

- Enhancing mobility through water resource development and land use planning.
- Integration of PAP systems with more intensive fattening/finishing operations.
- Livelihood diversification.
- Strengthening clinical veterinary services.

2. METHODS

2.1 Overview of the model

A dynamic model of the Oromia pastoral cattle system was developed to quantify how the population and (meat and milk) production changes over time in response to droughts. At its core is a herd model that calculates the cattle population each month for a specified period. As Tuffa *et al*. (2017) noted, population models are useful planning tools that can support management decisions. In this model, the herd is comprised of 8 categories of animals (or *cohorts*) defined by age, sex, function and finishing system, i.e.: calves, weaner males/females, growing males/females, adult females and adult males (draught and non-draught). An initial value (month 1) is assumed for the population in each of these cohorts, then the herd model calculates the population in subsequent months based on the values specified for parameters such as fertility, mortality and replacement rates.

The theoretical behaviour of the population under three scenarios is shown in Figure 2.1. With no droughts (Scenario A), the population increases until it is constrained by feed availability. For pastoral systems the feed availability can be expressed using the number of cattle per hectare of grassland, i.e. the stocking rate. As the population increases, the stocking rate increases and the fertility rate decreases (and at high stocking rates, mortality increases) until the births are equal to the deaths, i.e. the herd reaches its equilibrium population. In Scenario B (droughts but no measures) the population is reduced when drought 1 occurs (due to increased mortality and sales, and decreased fertility). This also lowers the stocking rate, which leads to a higher fertility rate post-drought. The population grows until a second drought occurs in year 15. Implementing a measure (Scenario C) reduces the impact of drought, enabling smaller reductions in population and/or more rapid recovery post-drought.

Figure 2.1: The theoretical behaviour of the cattle population under three scenarios.

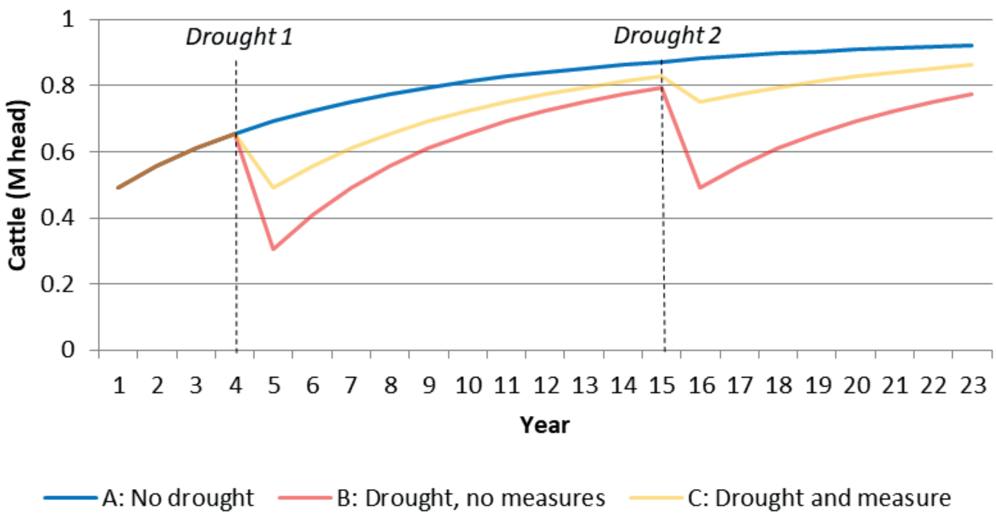


Table 2.1: Summary of the model views

View	Function
Herd model	Calculates the herd structure and dynamics (see Figure 2.3)
Policy switches and adoption rates	Turns policies off and on, specifies the start and end times
Policy 1: IBLI	Formulae for index-based livestock insurance
Policy 2: EWS	Formulae for destocking with an early warning system
Policy 3-4: Land feed	Formulae for rangeland restoration and fodder planting
Economics	Meat and milk production and revenue
Calibration check	Graph of modelled population against the real population
Herd performance metrics	Metrics summarising performance, e.g. total sales and deaths

2.2 Model platform and elements

The model was created using Vensim Professional (version 8.2.1) simulation software (https://vensim.com/vensim-software/). The model consists of eight sheets or "views". The names and contents of each view are given in Table 2.1. The herd model consists of stocks (called *levels* in Vensim) and flows (called *rates*). *Levels* adjust their values by accumulating rates and change continuously over time. *Rates* are determined by the levels and other factors. Intermediate calculations are known as *auxiliaries*. Figure 2.2 shows part of the herd model. The level **MP cows** (MP cows are adult females older than the age at first calving) is the population of cows, and its value changes each month depending on three rates (the arrows with valve symbols): **MP cow entries**, **cow sales** and **MP cows dying**. Figure 2.2 contains three auxiliaries (**adult mortality rate**, **cows maintained** and **actual cows maintained IBLI**) for which the values are calculated within the model, but which do not directly change the level, and two constants (**Cow service life** and **Initial MP cows**) for which the values are derived outside the model.

The values for some exogenous parameters (such as the initial number of cows) are defined within the model (for example, see

Figure 2.2: Part of the model showing key elements

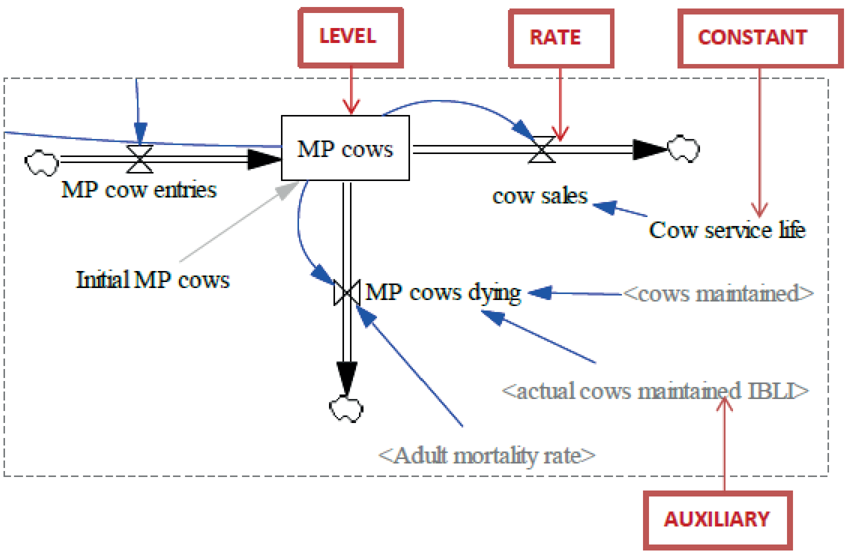
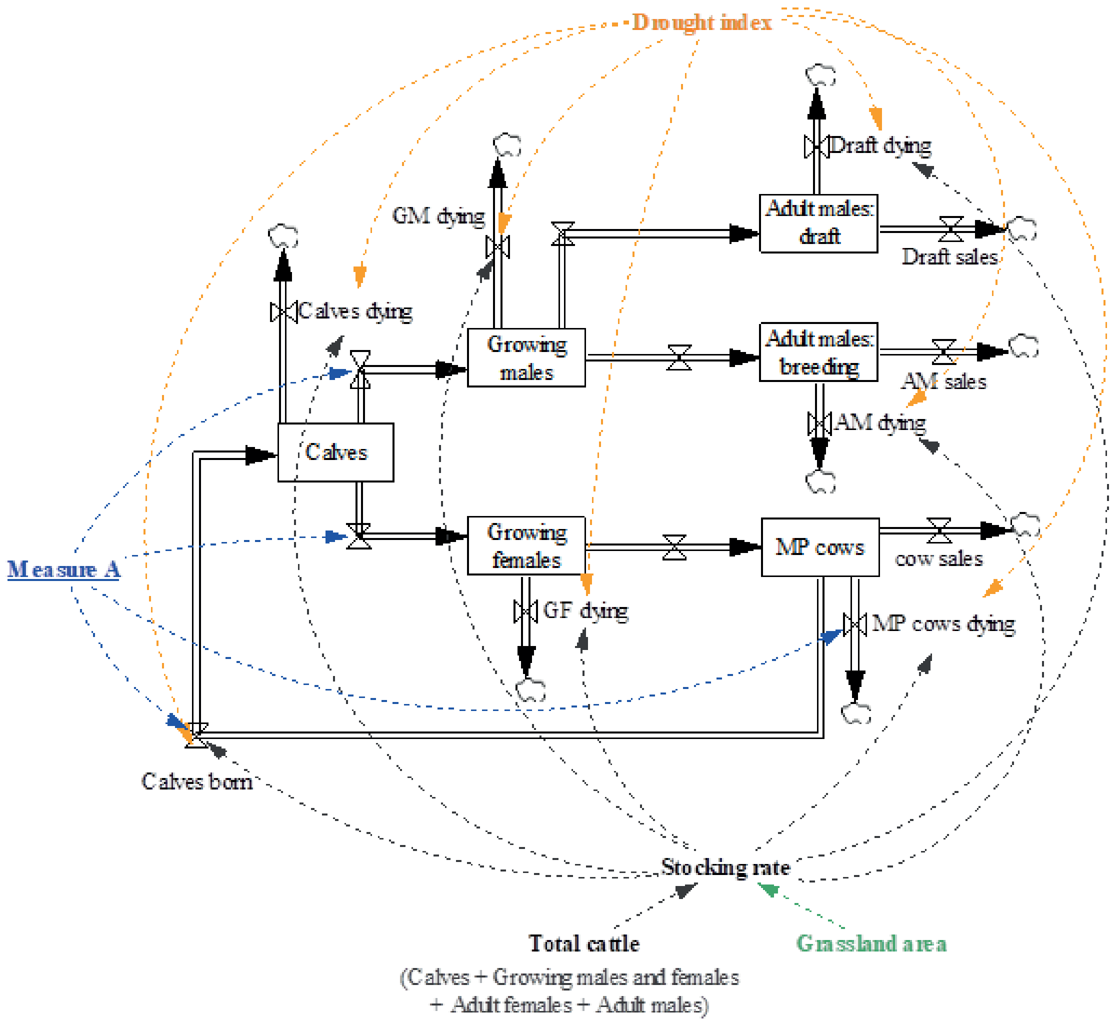


Figure 2.3: A schematic diagram of the Herd model



the variable "Initial MP cows"). However, some parameters (such as the drought index or the hectares of grazing land) have values that change each month and are stored outside the model. These values are imported into the model using the GET XLS DATA function.

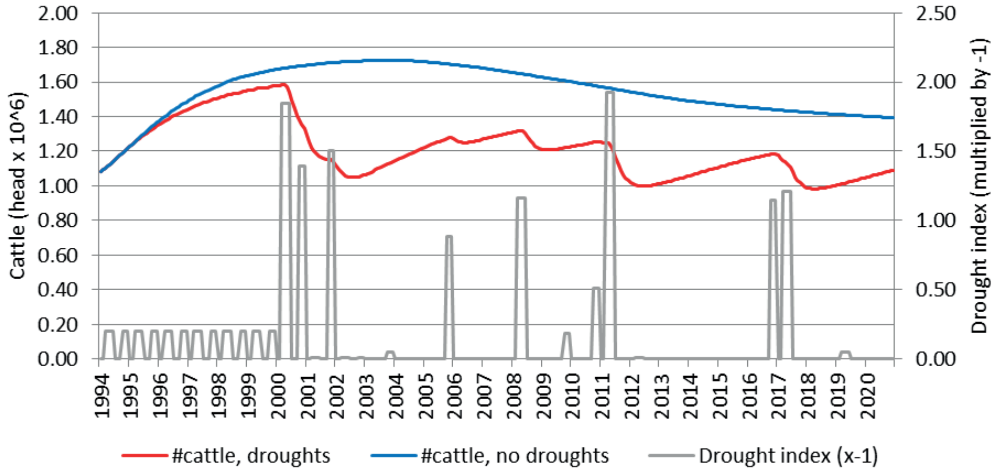
Figure 2.3 provides a simplified overview of the Herd model. Each month new-born calves enter the herd and other cattle exit the herd via sales and deaths. The herd size can increase or decrease each month, depending on the cow fertility rate, the mortality rates and the offtake rates (the proportion of cattle sold). With a constant grassland area and no droughts, the herd reaches equilibrium. However, when a drought occurs or the grassland area changes, the fertility and mortality rates change (dashed arrows in Figure 2.3) and the equilibrium is disturbed. The implementation of a resilience measure can also change the equilibrium; in Figure 2.3 Measure A (which targets cow health and nutrition) increases the fertility rate and decrease the mortality rates of cows and calves.

2.3 Effect of drought on the cattle population

Drought index

Drought is represented in the model using the parameter **drought index**. Three different drought index series are employed in this study:

Figure 2.4: Modelled cattle population with and without droughts (DI = 0).



1. A series for 2000-2020, based on historic NDVI, is used to calibrate the model (Section 2.7).
2. A series for 2021-2100, calculated using rainfall and temperature predictions from three GCMs, is used to provide context, but is not used in the calculations (Section 1.4).
3. A series constituting a representative drought scenario (Section 2.8) is used to calculate cattle population, production and profit with the resilience measures (Section 3).

The historic drought index (1) is derived from NDVI satellite images and thus reflects forage scarcity. The main steps in calculating the index are the following:

- Retrieving and combining NDVI data from two different products (eMODISc6 and MOD13C2) to construct a monthly NDVI time series covering the 2000-2020 period for the entire Oromia region (with a 5km resolution).
- Applying temporal and spatial averages. Temporal averages lead to NDVI values for the long (March-June) and short (October-December) rainy seasons. Spatial averages lead to NDVI values at the level of woreda administrative units and Borena zone (13 woredas where PAP systems are located in Oromia).
- Calculating the drought index as the number of standard deviations below the historic mean for the rainy season that the NDVI is for a given month, i.e. if it equals -1, then the NDVI is 1SD below, or in the bottom ~16% of the historic NDVI range.

The drought index is, therefore, a measure of drought severity and is usually in the range 0 to -2, where 0 indicates no drought and -2 a severe drought.

Effect of drought

The drought index affects mortality and fertility, specifically in the expressions for **drought mortality function** and **drought fertility impact**. The mortality rate is multiplied by the drought index, -1 and the **drought mortality multiplier** (11.5). For example, during a drought where the drought index is equal to -1, the mortality rate is multiplied by 11.5, increasing from 0.3% to 3.6% per month. During a drought the fertility rate is changed by the product of the drought index and the **drought fertility multiplier** (0.2), e.g., when the drought index is -1, the fertility rate is reduced from 0.55 to 0.35. Figure 2.4 shows the trends in the modelled population (i.e. the population estimated using the model, rather than the actual population) for the Oromia pastoral system with and without droughts (DI = 0). In the absence of droughts, the population grows until it is constrained by the effect of increased stocking rate (see the next section) and reaches just over 1.7million head, then declines as the grassland area changes. With droughts, the population varies (in response to the drought index and the grassland area) between 1.0 and 1.3 million head.

2.4 Effect of stocking rate on the cattle population

The stocking rate (in head of cattle per hectare of grassland) is given by the parameter **Real regional stocking rate (RRSR)**, which is the total cattle population divided by the hectares of grazing land. The total cattle population is calculated in the model and hectares of grazing land is estimated outside the model (see 1.3 and Appendix A) and imported. RRSR impacts on fertility, mortality and growth rates thus:

- The base fertility rate is divided by the RRSR multiplied by 0.97, e.g., if the RRSR = 1.1 then the base fertility rate is divided by 1.1x0.97=1.07, i.e., changes from 0.45 to 0.42.
- If the RRSR is <=1 the mortality rates are unaffected by the stocking rate; if RRSR is >1, then the mortality rates are increased by the RRSR x 1.2, e.g., if the RRSR is 1.1 then the mortality rate is multiplied by 1.1x1.2=1.32, i.e., it increases by 32%.
- If the RRSR is <=1 the growth rates are unaffected by the stocking rate; if RRSR is >1, then the growth rates are decreased, by multiplying the time taken for yearlings to become adult cattle by the RRSR.

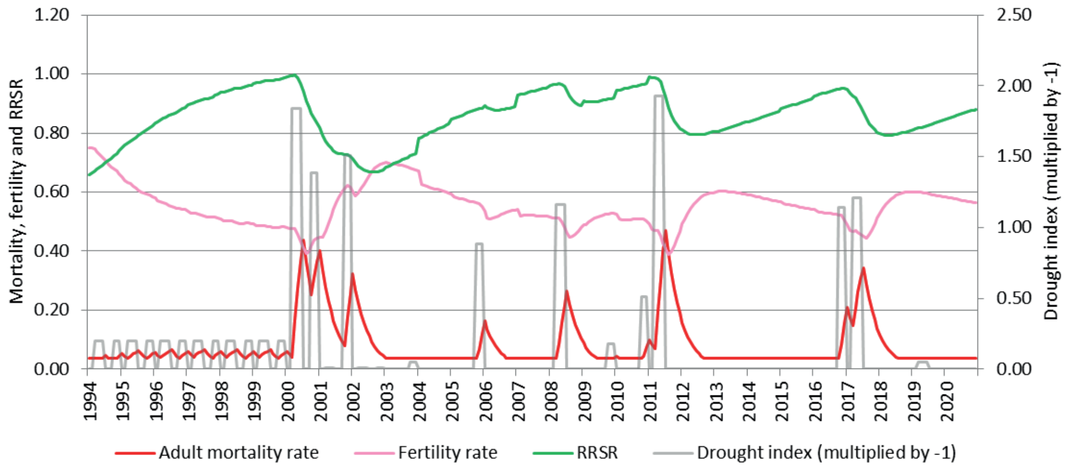
In practice, the RRSR is usually in the range 0.5 to 1.0 in the Oromia pastoral systems, so the stocking rate has a more limited effect on mortality and growth, compared to its effect on fertility.

Illustration of the relationships between drought, stocking rate, mortality and fertility

Figure 2.5 shows the drought index and the modelled trends in adult mortality rate, fertility rate and stocking rate (RRSR). The fertility rate starts off high in 1994, and gradually declines as the cattle population and stocking rates increase. With no drought, the population (and stocking rate) would increase until the fertility rate decreases to the point at which the births are equal to the deaths plus offtake, i.e., the herd is in equilibrium. However, when droughts occur there is an immediate reduction in the fertility rate and a reduction in the stocking rate, caused by the cattle mortalities during the drought (Figure 2.5). In response to the reduction in stocking rate, the fertility rate increases, and the cattle population increases (assuming offtake rates remain constant) until the equilibrium population is reached, or another drought occurs.

There is evidence that the grassland area is changing over time (Abate and Angassa 2016; Urgessa and Lemessa 2020; Ogato *et al.* 2021; Mahamued *et al.* 2021; Regasa *et al.* 2021).

Figure 2.5: Trends in drought index and modelled adult mortality rate, fertility rate and stocking rate (RRSR) for the Oromia pastoral system.



Hence, the stocking rate (and with it the fertility rate) varies over time with the cattle population and the grassland area. A method for quantifying grassland areas based on empirical evidence was developed (Appendix A) and the calculated areas imported into the model.

2.5 Derivation of key assumptions

The sources and methods used to derive the values for parameters are summarised in Table 2.2 and 2.3. A process of calibration was undertaken for selected parameters to refine the values (see Section 2.7).

Table 2.2: Summary of how key assumptions and values were derived for baseline scenario

Element	Derivation
Cattle populations	
Cattle systems	Wilkes et al. (2020)
Real cattle population 1994-2018	Ethiopian CSA (Bachewe 2021 and Wilkes et al. 2020), assuming that the PAP cattle population in Oromia is equal to the “Other cattle” in the Borena Zone of Oromia.
Initial cattle population by system	Combination of the two above
Feed availability	
Grassland area	Estimated in this study, see (Appendix A)
Drought severity	
Drought index	Estimated in this study, see Section 1.4 and 2.3
Baseline cattle performance	
Fertility	The base fertility rate and the effects of drought and stocking rate on fertility were determined via calibration, (Section 2.7) and checked against other studies (Appendix B)
Mortality	The base mortality rate and the effects of drought and stocking rate on mortality were determined via calibration, (Section 2.7) and checked against other studies (Appendix B)
Time in each cohort	The amount of time spent in each cohort was determined via reported values (see Appendix B)
Weights	Based on Wilkes et al. (2020)
Growth rates	Baseline value calculated using the weight and times in cohorts above. Adjusted in response to SR, FP and RR
Milk secreted	Taken from Wilkes et al. (2020, p91), who based their estimates on CSA reported milk yields.
Milk consumed by calves	Milk suckled - calculated, assuming 8.7kg of milk per kg of LW gain when suckling (Ezanno 2005, p294)
Milk available for human consumption	Milk secreted minus the milk consumed by calves. Assumes no wastage of milk.
Prices	
Meat and milk prices	Expressed in constant (2010) prices. Price of meat and milk in Ethiopia from FAOstat (see Appendix C).
Effect of milk and meat production on prices	No effect; it is assumed that the production-enhancing measures are accompanied by supply-chain development that avoids local oversupply.
Effect of feed demand on feed price	Increased feed demand may lead to feed prices and increased grazing time spent per kg of feed obtained, but these effects are not captured in the model.

Table 2.3: Summary of how key assumptions and values were derived for measure scenarios

Element	Derivation
Index-based livestock insurance	
20% of cattle are insured	Assumption.
Use of insurance pay out	Assumption that 100% is spent on cattle maintenance, reflecting the purpose of the scheme, i.e., asset protection.
Insurance premium of 7.5%	Premium rate that maintains the insurance fund over time, without it growing excessively or falling into debt.
Insured value of cattle	Based on a cost of maintaining cattle during a drought of 1527 ETB per Tropical Livestock Unit (TLU) per year (2010 prices), source: Fava (personal communication) 2020.
Pay out percentage	Based on the formula in use in current Ethiopia IBLI scheme.
Effect of IBLI on mortality	Based on the insurance pay out and the Insured value of cattle (which is the cost of maintaining a TLU of cattle during a drought). Drought deaths and fertility impacts are reduced by 100% when there is sufficient revenue from insurance, but the effect reduces as the revenue becomes insufficient to maintain all cattle, until the measure has no effect once the revenue is exhausted.
Effect of IBLI on fertility	
Destocking with an EWS	
20% adoption rate	Assumption.
Sale price of destocked cattle	Assumed to be sold for 90% of their normal value.
% cattle sold during drought	Based on the product of the drought index and a constant (Effect of drought on EWS destock) determined via calibration.
Cost of running the EWS	Not currently included.
Effect of EWS on mortality	See the effect of IBLI on mortality/fertility, i.e. it is assumed that EWS fully negates the effects of drought on mortality and fertility until the sales revenue is exhausted.
Effect of EWS on fertility	
Fodder planting	
20% of farmers adopt	Assumption, based on Ng'ang'a et al. (2020) who estimated the 25-50% of the total arid and semi-arid grazing land could be used for fodder planting and rangeland restoration.
Cow fertility increased by 25%	Ng'ang'a et al. (2020)
Male offtake rate increased by 25%	Ng'ang'a et al. (2020)
LWG increased by 25%	Ng'ang'a et al. (2020)
Cost of measure	Based on Ng'ang'a et al. (2020). Note that the opportunity cost of land used for fodder planting is assumed to be zero.
Rangeland restoration	
20% of farmers adopt	See fodder planting.
Cow fertility increased by 25%	Ng'ang'a et al. (2020)
Male offtake rate increased by 25%	Ng'ang'a et al. (2020)
LWG increased by 25%	Ng'ang'a et al. (2020)
Cost of measure	Based on Ng'ang'a et al. (2020). Note that the cost of purchasing hay may be underestimated.

2.6 Costs and benefits included in calculating profit

The costs included and excluded from the calculations are summarised in Table 2.4. Some costs were not included, i.e., the cost of setting up and running an EWS, and of organising sales and transporting cattle during destocking (Table 2.4). Catley and Cullis (2012, p5) reported a cost of US$4.53 (2006) per household for organizing commercial destocking in Ethiopia, with the costs of animal transport being shared between the organising agency and the livestock traders. The cost of an EWS has been estimated to be US$3.72 (year not stated) per person per year (de Haan 2016, p118; costs expressed "per pastoral/agro-pastoral person associated with these projects"). The missing costs seem modest, relative to the typical household's operating profit of around ETB7,000 in 2010 (equivalent to about US$500 (Table D1).

It is assumed (based on Ng'ang'a et al. 2020) that the land converted to fodder planting had no opportunity cost; further work is required to verify this assumption.

Table 2.4: Summary of the main financial costs and benefits of the measures included in the current analysis

		Included		**Not included**	
		One-off	*Recurring*	*One-off*	*Recurring*
Index-based livestock insurance	Costs		Insurance premium.	None - assuming the costs of establishing and maintaining the IBLI scheme are included in the premiums.	
	Benefits		Avoided losses of meat and milk.		
Destocking with an EWS	Costs		Selling male cattle to fund maintenance of calves and cows.	Establishing the EWS.	Maintaining the EWS. Organising sales and transporting cattle.
	Benefits		Avoided losses of meat and milk.		
Fodder planting	Costs	Opening new land, weeding etc.	Mainly labour for fodder production.		Foregone income from land converted to fodder production.
	Benefits		Increased meat and milk sales.		
Rangeland restoration	Costs	Labour for land preparation, fencing etc.	Mainly purchasing feed, plus some labour costs.		
	Benefits		Increased meat and milk sales.		

2.7 Model calibration and validation

There is evidence that droughts lead to decline in cattle populations by reducing fertility rates and increasing mortality rates (Angassa and Oba 2007, Tuffa and Treydte 2017). To determine realistic fertility and mortality rates, a process of calibration was undertaken where the values of parameters with a strong influence on population were varied until the best fit between the modelled cattle population and the real population was obtained. The following "optimisation" parameters were varied:

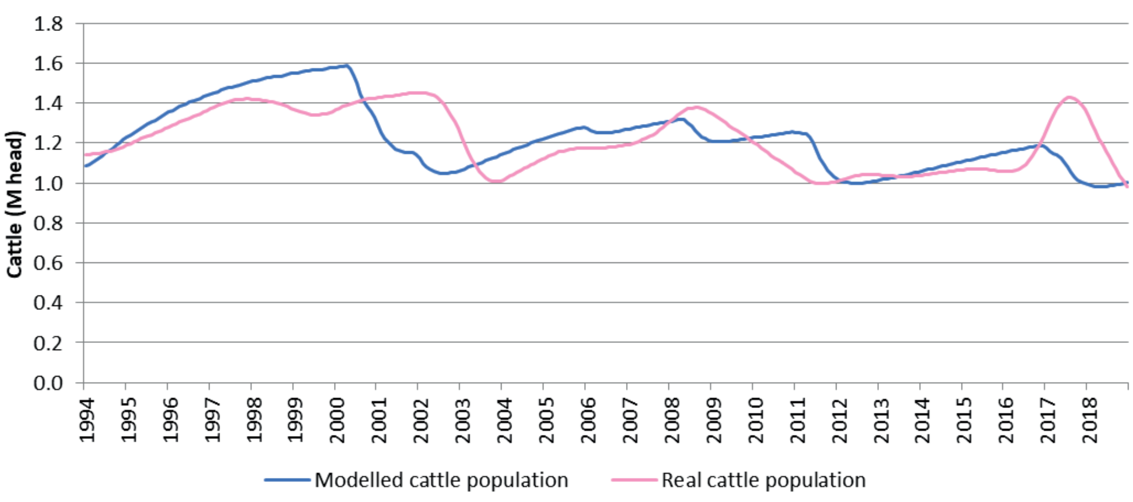
- Base fertility rate;
- Drought fertility multiplier;
- Stocking rate fertility multiplier;
- Base adult mortality rate;
- Base calf mortality rate; and
- Drought mortality multiplier.

The real population for the period 1994-2018 was derived from data provided by the Ethiopian Central Statistical Agency for 2005-2017 (Bachewe 2021) and from Wilkes et al. (2020) for 1994-2004 and 2018. In both cases the results were based on the Ethiopian Central Statistical Agency Agricultural Sample Survey (e.g., CSA 2018).

The drought index for Oromia was calculated using the woreda level DI for each pastoral woreda and assigning weights to obtain the weighted average DI (Section 2.3). In the absence of cattle population data for each woreda, this procedure was initially conducted while using the land areas as weights to combine the NDVI data that was prepared for each woreda. Following this, a further calibration step was used to fine tune the woreda weights.

Calibration was performed using the Model Calibration process in Vensim. Ranges were estimated for each optimisation parameter, based on reported values. The Total cattle population was set as the "payoff", i.e. the parameter matched to the real cattle population. Vensim then found the best fit that could be achieved between the modelled and real cattle population (Figure 2.6).

Figure 2.6: Comparison of the best fit achieved via calibration between the modelled Total cattle population in Oromia and the Real population reported in government statistics.



The fit between the modelled and real populations is considered to be satisfactory, given that cattle populations are influenced by a wide range of factors, only some of which were included in the model. Other factors that can influence cattle populations include policy interventions and pest or disease outbreaks. For example, the apparent delayed impact of the 2000 drought could be because the real cattle population was somewhat lower than the modelled population prior to the, or because of emergency relief efforts in 2000/2001 that delayed its impact.

The modelled and real post-drought herd growth rates are generally similar, the main difference being the spike in the real cattle population in 2017. It is not clear how this rapid increase in population was achieved given the low fertility rates of cattle. The spike may be an artefact of the method used to estimate the "real" population, i.e., it could reflect sampling error or change in survey method. Ultimately both modelled and "real" populations are estimates – imperfect but useful if interpreted appropriately.

The values for the optimisation parameters that achieved the best fit were then used in the model. The values for selected intermediate parameters (fertility rate, mortality rates, age at first calving, growth rates and milk yields) were compared against other studies and found to be in the reported ranges (see Appendix B).

2.8 Representative drought scenario

The effect of the measures in reducing drought impacts depends in part on the intensity and frequency of the drought events. In order to create a baseline that captured typical drought occurrence, a representative drought scenario was developed with a combination of droughts of varying intensity and frequency, i.e. 2 severe, 2 moderate and 4 mild droughts occurring over a twenty year period (Table 2.5). This is consistent with the observed drought patterns over the period 2000-2020 (see Section 1.4). The droughts were defined by their probability of occurrence; severe drought has a drought index value equivalent to the 5th percentile, moderate the 10th percentile and mild the 20th percentile.

Table 2.5: Drought frequency and severity in the representative drought scenario.

DI	Description	Drought frequency			Occurrence
		<-1.65	<-1.28	<-0.84	
<-1.65	Severe	2	2	2	1 LR and 1 SR in y1
-1.65 to <-1.28	Moderate		2	2	1 LR and 1 SR in y11
-1.28 to <-0.84	Mild			4	1 LR and 1 SR in y6 and y16
Total droughts over 20 years		2	4	8	

LR: long rains, SR: short rains

3. RESULTS AND DISCUSSION

The modelled cattle population with the representative drought scenario and no measures is shown in Figure 3.1. This figure also shows the timing of the eight droughts that occur over the 20-year period.

Four policies are modelled that reduce the impact of drought on cattle farmers:

1. Index-based livestock insurance (IBLI);
2. Destocking with a drought early warning system (EWS);
3. Rangeland restoration (RR); and
4. Fodder planting (FP).

The direct effects of the policies are summarised in Table 3.1. As all the policies affect fertility rates, they can all lead to changes in population and stocking rates. Therefore, all the policies can lead to changes in mortality, fertility and growth rates, either directly or indirectly.

Figure 3.1: Modelled cattle population with the representative drought scenario and no measures

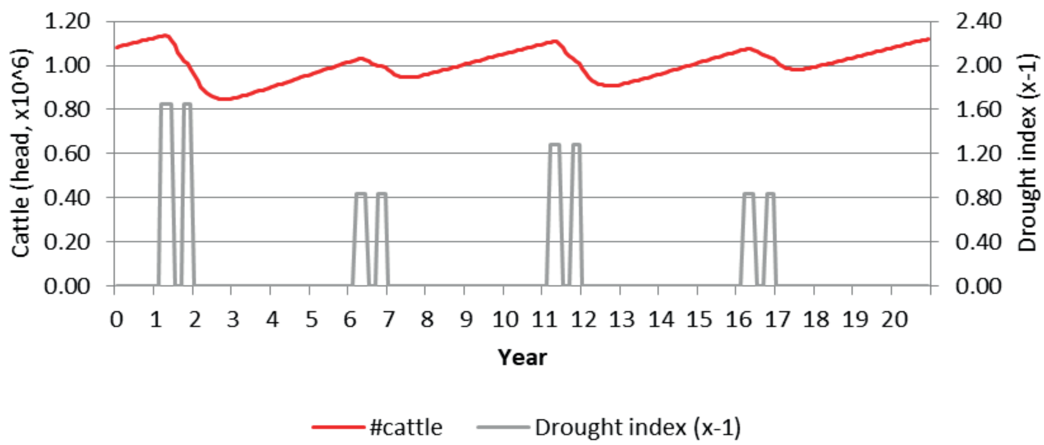


Table 3.1: Summary of the parameters affected by the policies

	Mortality rates	Fertility rates	Growth rates	Offtake rates
	Direct effects			
Index-based livestock insurance	Pay outs are used to maintain all cattle during droughts, reducing the impacts on mortality and fertility			
Drought early warning system	Adult male sales revenue is used to maintain calves and adult females			Adult males are sold early
Rangeland restoration		Increased feed availability increases growth rates and cow fertility		Adult male offtake rate increased
Fodder planting				
	Indirect effects of policy			
Stocking rate	Increasing fertility increases the population and stocking rate, which in turn can increase mortality and reduce fertility and growth rates (Section 2.4)			

3.1 Index-based livestock insurance (IBLI)

Background

What is it and how does it improve resilience? IBLI is a type of risk financing that provides farmers with money to maintain their livestock during droughts. A key feature of IBLI is that it triggers payments to farmers when a predetermined and objectively measured value of an indicator (such as NDVI) is met. These payments enable farmers to adopt measures to mitigate the drought impacts, such as purchasing feed and water. IBLI represents a shift from traditional livestock mortality asset-replacement insurance to an asset-protection approach. The insured value is, therefore, based on the cost of maintaining animals, rather than replacing them.

Evidence of effect

Jensen *et al.* (2015) found that (in northern Kenya and southern Ethiopia) IBLI reduced cattle mortality and meant that insured households were 36% less likely to rely on distress sales of livestock or to reduce meals to cope with droughts. Matsuda *et al.* (2019) also found that IBLI led to an "increase (in) household income and milk production during drought years" in Southern Ethiopia. Norimoto and Takahashi (2020) undertook randomised experiments in northern Kenya and found that index-based insurance can help reduce the probability of distress sales and slaughter of livestock

Obstacles

Obstacles to IBLI include the cost of insurance premiums, relative to anticipated benefits, and the technical feasibility of IBLI - rangeland dominance and adequate forage production and seasonality are required for NDVI-based IBLI (Kahiu *et al.* 2021).

Enabling factors

Taye and Mude (2018) reported that the IBLI program in Oromia has steadily gained momentum since it was launched in 2012, "accelerating in 2017 and 2018 as record indemnities offered clients a clear demonstration of the value of IBLI". Takahashi *et al.* (2020) reported drivers of uptake to be: reduced premiums and (increased) drought risk. They suggested "distributing discount coupons to trigger initial uptake and adjusting premium rates dynamically to avoid spatiotemporal adverse selection"

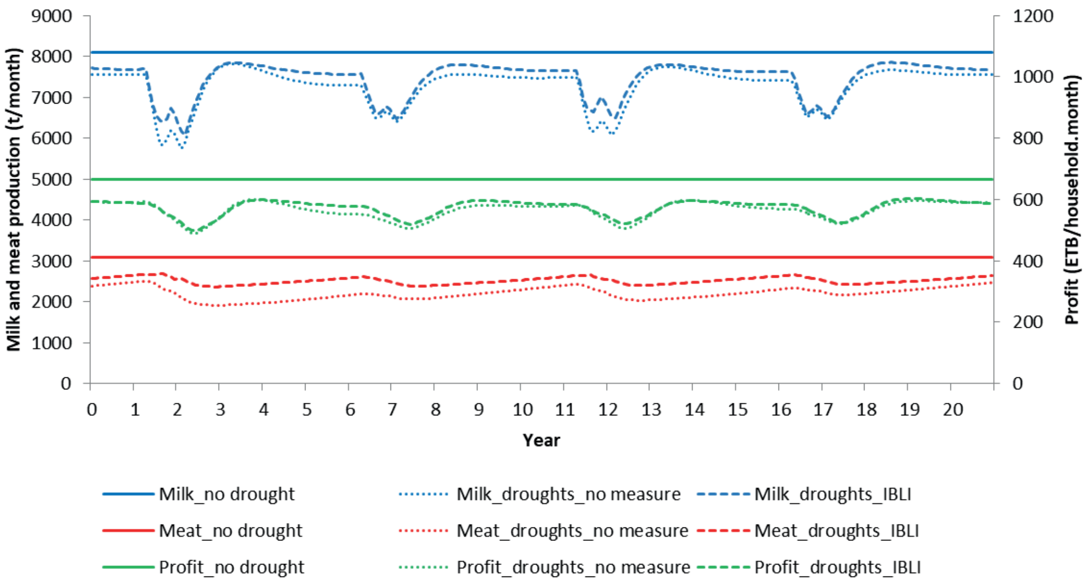
Modelling approach

It is assumed that having insurance enables farmers to secure the resources (either in terms of savings or credit) to feed their cattle during the drought, in anticipation of receiving the insurance pay out post-drought. As Taye and Mude (2019) note "The promise and anticipation of indemnity payments during droughts can influence the way households respond to risk and drought long before payouts are triggered". This has the effect of reducing the impact that drought has on mortality and fertility, increasing the cattle population, and meat and milk production. Over time this increases the stocking rate, reducing the fertility rate until an equilibrium population is reached, or another drought occurs. While it is assumed that 100% of the insurance pay out is spent on maintaining the herd, this is a simplification; in practice some of the pay out would be used for non-livestock expenditures such as food and education (Taye and Mude 2019). However, quantifying the effect of the non-livestock expenditure on production and profit is complicated and beyond the scope of the model.

Key assumptions

1. 20% of cattle are insured;
2. 100% of the insurance pay out is spent on maintaining the herd;
3. The insurance premium is 7.5%;
4. Unsubsidized premium rate = Insurance premium, i.e., no overhead is applied, the policy is sold at cost price; and
5. The cost of maintaining cattle during a drought is ETB 1,527 per Tropical Livestock Unit (TLU) per year (2010 prices).

Figure 3.2: Production and profit for all PAP cattle in Oromia with (a) no droughts, (b) droughts but no measure and (c) droughts and 20% adoption of IBLI.



Results

IBLI has a small effect on milk production but leads to a consistent moderate increase (relative to the no-measure situation) in meat production (Figure 3.2). Milk production does not increase as much because IBLI increases the cattle population and, hence, the stocking rate. The negative effect of the increase in stocking rate on fertility is greater than the short-term positive effect of IBLI on fertility. Despite the lower fertility rate with IBLI, the population remains higher than with no measure due to reduced mortality. Effectively, IBLI reduces the milk yield per cow, but increases the number of cows, leaving the milk production similar to the no-measure situation.

Profit is only marginally improved by IBLI as the increased revenue from meat production is offset by the cost of purchasing insurance – assumed here to be fully carried by cattle owners.

IBLI increases the length of time between the drought occurring and production impacts arising, and shortens the duration of the impacts. Post drought recovery rate is largely unaffected by IBLI.

3.2 Destocking with an early warning system (EWS)

Background

What is it and how does it improve resilience?

Cattle physical condition declines during a drought, until they become too weak for transport and commercial sale. This leads to emergency slaughter and meat distribution. This measure improves resilience by using an EWS to predict when and where drought is likely to occur. It enables action to be taken to facilitate the orderly sale of livestock (offtake), thereby allowing animals to be sold in better condition, and providing more time to arrange sales and (if needed) loans to traders. Mortalities are reduced and better prices are achieved for cattle sold, giving farmers the means to maintain more of their breeding herd and restock more rapidly after the drought.

Evidence of effect

Abebe *et al.* (2008, p16) found that with early destocking in Ethiopia "pastoralists might have received twice the amount for their cattle" (p16). More recently Matere *et al.* (2020) argued that early intervention can "strengthen the resilience of at-risk populations, mitigate disaster impacts and prepare communities and global actors to plan and mitigate rather than respond."

Obstacles

1. Poor roads and limited infrastructure (including markets) in pastoralist areas (Abebe *et al.* 2008);
2. Limited holding grounds for cattle (Abebe *et al.* 2008);
3. Unwillingness to destock as herd size signifies social status (Smith *et al.* 2019);
4. Doesn't prevent livestock price drop if buyers also anticipate drought.

Enabling factors

1. Robust livestock marketing system, and export trade. (Abebe *et al.* 2008);
2. Network of primary veterinary service delivery. (Abebe *et al.* 2008).

Modelling approach

In the model, the EWS is assumed to enable managed destocking, i.e., male cattle are sold prior to drought-induced feed shortage, albeit at a 10% discount (see **Quality discount for destocked animals**), rather than dying during the feed shortage. The revenue from destocking is used to maintain calves and female cattle, thereby reducing the impacts of drought on mortality and fertility.

The costs to each adopter of setting up and running an EWS depends on the number of people using the EWS and the effort required to obtain the necessary data (it may be possible to make use of pre-existing data). These costs were excluded from the calculation due to lack of robust information on them. However, there is evidence that these costs would be low (Section 2.6). The cost of organising sales and transporting cattle during destocking are also not included but assumed to be low, based on the available data (Section 2.6).

Key assumptions

1. 20% adopt EWS.
2. With EWS, destocked cattle are sold for 90% of their normal value (i.e., the value during a non-drought period), without the measure they are sold at 50% of their normal value.
3. The destocking revenue is used to maintain calves and female cattle.
4. Destocking only occurs in the Oromia pastoral system when the EWS measure is active.
5. EWS is provided for free to cattle owners.
6. The costs of setting up and running an EWS, and of organising sales and transporting cattle during destocking, are not included.

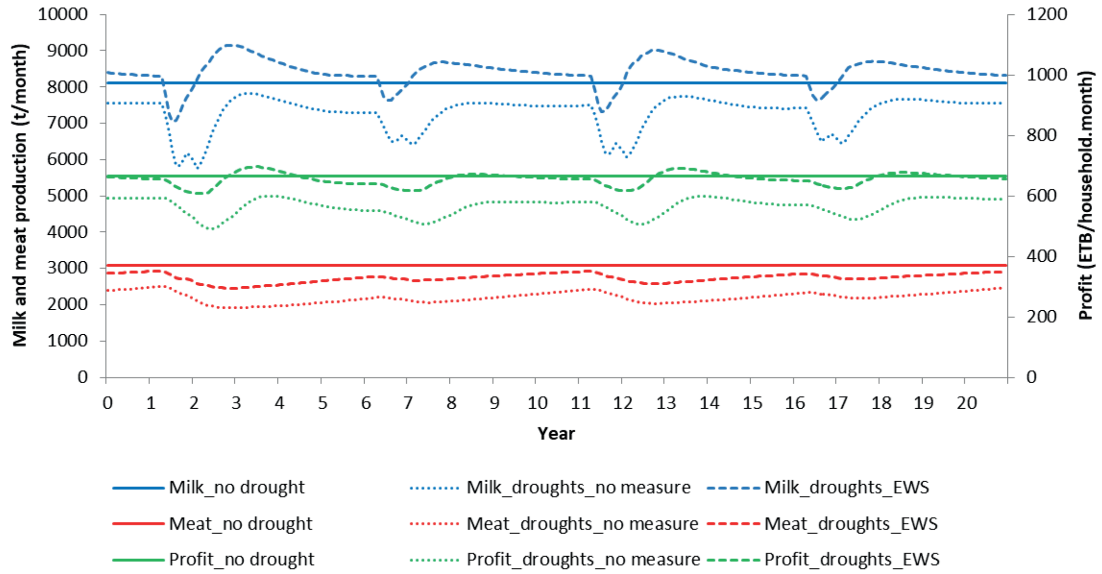
Results

Compared to the no-measure situation, EWS leads to large increases in meat and milk production and, consequently, profit (Figure 3.3). This is due to the way in which the measure changes the herd structure; adult males are sold off, and the revenue is used to maintain calves and females, leading to a greater proportion of cows in the herd, which enables a larger population to be sustained (Figure 3.8). Note that the second (short rains) drought in each pair has little effect as some money remains at the start of the short rains drought from sales during the preceding long rains drought.

EWS increases the length of time between the drought occurring and production impacts arising, and shortens the duration of the impacts. It also speeds up the immediate post drought recovery.

EWS leads to a larger herd, with a greater proportion of breeding females and more calves being born each year. However, these desirable changes in herd structure are achieved in a somewhat reactive manner, only occurring in response to droughts. Furthermore, the effects are temporary, and fertility rates are lowered (and mortality rates increased) by the underlying feed constraint once the revenue from the sales is spent. While EWS is successful in making the systems more resilient to drought, the benefits could be increased if the change in herd structure was achieved in a more proactive way. Appendix D further explores the effects of changing herd structure and how this might be achieved.

Figure 3.3: Production and profit for all PAP cattle in Oromia with (a) no droughts, (b) droughts but no measure and (c) droughts and 20% adoption of EWS.



3.3 Fodder planting (FP)

Background

What is it and how does it improve resilience?

The measure entails agro-pastoral farmers' planting crops on land that is currently unused or under-used, thereby achieving increases in feed availability and cattle performance.

Evidence of effect

Pilot studies of fodder planting in Oromia were undertaken in 2015, and a survey undertaken in 2018 in which pilot study participants were asked "to recall information for the five years before the pilot tests and the five years after." Ng'ang'a *et al.* (2020, p8).

Obstacles

1. Availability of suitable land.
2. Willingness/ability of farmers to adopt.
3. Money to pay for the measure implementation: "Some interviewees who had not participated in these pilot tests noted that they would need financing to adopt these practices." (Ng'ang'a *et al.* 2020, p34)

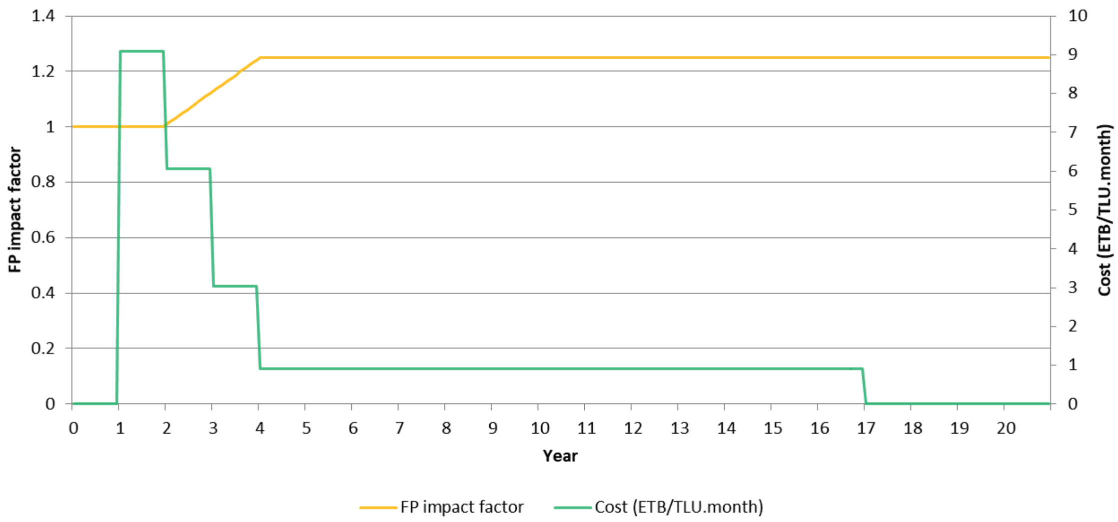
Enabling factors

Access to long-term loans: "The high transaction costs and risks of providing individual loans to low-income farmers can be reduced by providing loans to farmer groups or associations." (Ng'ang'a *et al.* 2020, p34).

Modelling approach

The measure increases cattle growth rates, cow fertility and the offtake rate of adult male cattle (both bulls and animals used for draught). The measure commences at the start of year 1 with the planting of crops. It starts to have an effect on cattle performance at the start of year 2, after which the effects increase linearly over the following 2 years, reach a maximum at the start of year 4 then remain constant after that (as long as the measure remain in place, Figure 3.4). Costs are incurred from the start of year 1 and are higher in the first 3 years, during the implementation phase, when additional labour is required to make the land suitable for crop production. The cost cycle repeats every 20 years.

Figure 3.4: The cost and effect of FP over 20 years. The FP impact factor increases the fertility rate, growth rates and the offtake rates for bulls/draught males.



Key assumptions

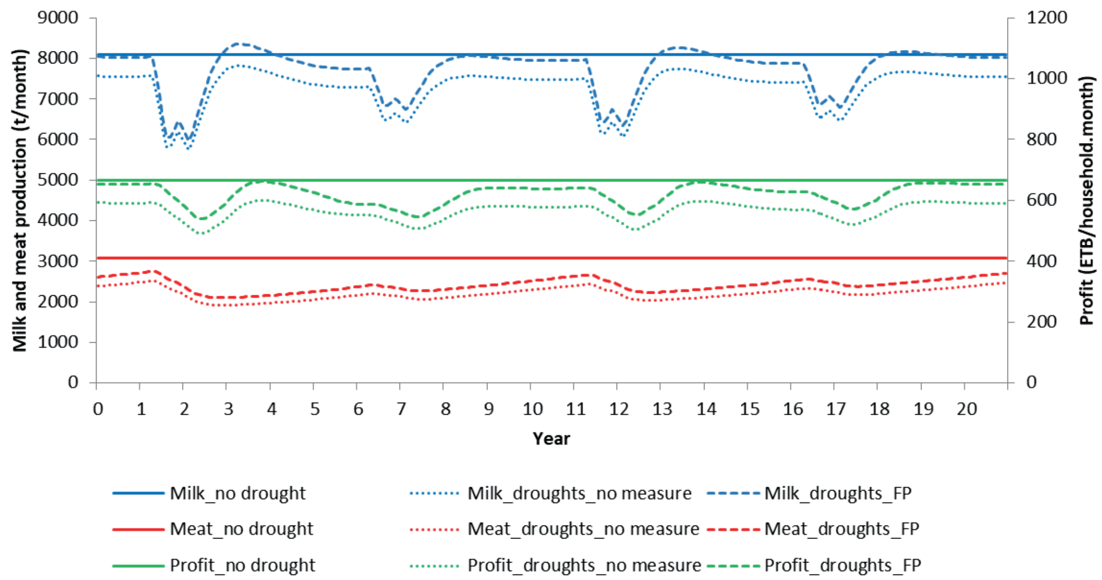
1. 20% of farmers adopt.
2. The main implementation costs are associated with opening new land to enable crop planting (on 1.4ha per household, or 0.1ha per TLU).
3. Recurring costs arise from additional labour required to cut and carry fodder, and weeding.
4. Total costs per TLU (ETB 2010 per month) are shown in Figure 3.4.
5. 3 years after the commencement of the measure the cow fertility rate and the number of bulls/draught males sold are increased by 25%, and the growth rates of immature cattle are increased by 25%.

Results

Compared to the no-measure situation, fodder planting leads to moderate increases in meat and milk production and, consequently, profit (Figure 3.5). This arises from a combination of the FP-induced increase in fertility rate (which increases both the population size and the proportion of lactating females), and the increased offtake rate for mature male cattle.

Fodder planting has little effect on the length of time between the drought occurring and production impacts arising, or on the duration of impacts. Post drought recovery rate is also largely unaffected by the measure.

Figure 3.5: Production and profit for all PAP cattle in Oromia with (a) no droughts, (b) droughts but no measure and (c) droughts and 20% adoption of fodder planting.



3.4 Rangeland restoration (RR)

Background

What is it and how does it improve resilience?

This measure refers to *active* restoration, i.e., planting desired herbaceous plant species and removal of woody plants as well as invasive plant species to restore productivity for grazing, rather than *passive* restoration that implies merely resting rangeland. It also entails supplementary feeding with purchased hay to allow a reduction in grazing pressure.

Evidence of effect

As with fodder planting, pilot studies of rangeland restoration in Oromia were undertaken in 2015 (Ng'ang'a *et al*. 2020). IAG (2010, p123) found rehabilitation of rangeland via enclosure (sometimes accompanied by enrichment plantation) to be successful in Borana "because it was participatory and included the stakeholders which were organized by the administration and development agents and the advantage and disadvantage was discussed with the end users".

Obstacles

1. Costs – the measure has a long break-even period (6 years) and farmers may not be willing to make long-term investments to improve land they do not own and over which they have limited rights "farmers cannot sell land or use it as collateral for a loan and are uncertain about their ability to obtain long-term financial benefits from any land improvements" (Ng'ang'a *et al.* 2020, p6).
2. There may be a lack of interest in increased production due to non-market orientation amongst some farmers (also applies to FP) (Ng'ang'a *et al.* 2020, p34).

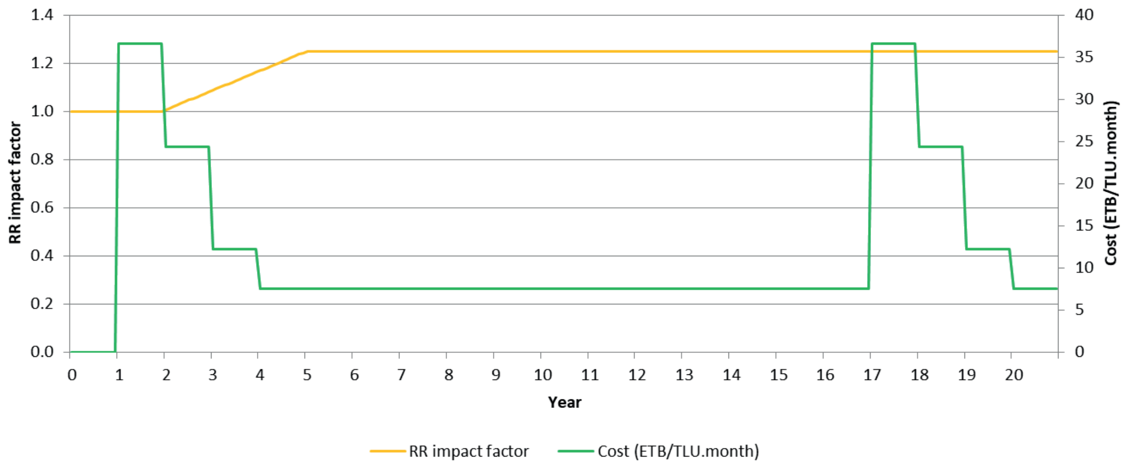
Enabling factors

As with fodder planting, uptake may be facilitated by providing access to long-term loans and suitable land.

Modelling approach

The measure increases cattle growth rates, cow fertility and the offtake rate of adult male cattle (both bulls and animals used for draught) in a similar way to fodder planting. The measure commences at the start of year 1 with the removal of scrub, planting of desired

Figure 3.6: The cost and impact of RR over 20 years. The RR impact factor increases the fertility rate, growth rates and the offtake rates for bulls/draught males.



herbaceous species and supplementation of the ration with hay. It starts to have an effect on cattle performance at the start of year 2, after which the effects increase linearly over the following 3 years, reach a maximum at the start of year 5 then remain constant after that (as long as the measure remain in place, Figure 3.6). The cost cycle repeats every 17 years.

Key assumptions

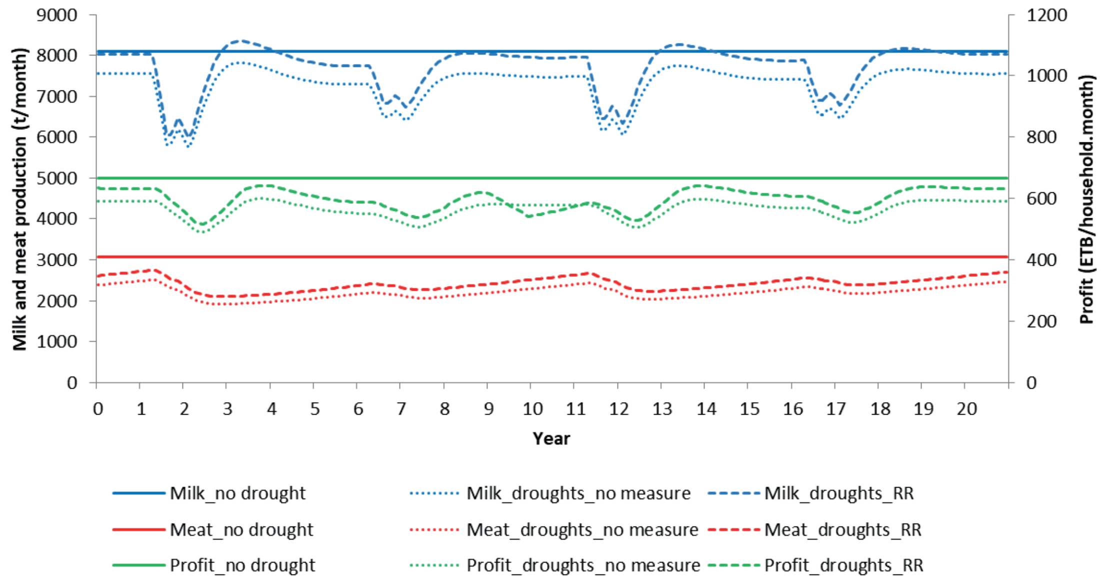
1. 20% of farmers adopt. In scaling up to the national scale, Ng'ang'a *et al*. (2020, p30) assume that 25-50% of arid and semi-arid grazing could be restored; 20% is, therefore, a conservative estimate, consistent with the adoption assumptions for the other measures.
2. The main implementation costs are associated with purchasing hay and labour for various activities, such as land opening/preparation/fencing and harvesting feed (Figure 3.6, y 1-3).
3. Recurring costs mainly arise from purchasing hay; increased labour costs arise from maintaining fencing etc. but these are largely offset by reductions in the labour required for other activities (e.g., herding and watering cattle, see Figure 3.6, y4-16).
4. Total costs per TLU (ETB 2010 per month) are shown in Figure 3.6.
5. Four years after the commencement of the measure the cow fertility rate and the number of bulls/draught males sold are increased by 25%, and the growth rates of immature cattle are increased by 25%.

Results

The effect of rangeland restoration on meat and milk production are the same as fodder planting, i.e. it leads to moderate increases, relative to the no-measure situation (Figure 3.7). The increase in profit is smaller than with fodder planting, due to the higher costs of this measure, and the extra year taken for the measure to reach its full effect.

As with fodder planting, rangeland restoration has little effect on the length of time between the drought occurring and production impacts arising, or on the duration of impacts. The post-drought recovery rate is also largely unaffected by the measure.

Figure 3.7: Production and profit for all PAP cattle in Oromia with (a) no droughts, (b) droughts but no measure and (c) droughts and 20% adoption of rangeland restoration.



3.5 Synthesis and SWOT analysis

The trends in cattle population are shown in Figure 3.8 and changes in output are shown in Figures 3.9-3.11. Over the three time periods, EWS provides the biggest increases (or smallest decreases) in production and profit, due to the way in which it leads to changes the herd size and structure. EWS maintains a larger herd than any of the other measures, and a greater proportion of the herd are cows. Combined, these mean that the cow population with EWS is as large as it is in the no drought situation (Figure 3.8).

Fodder planting and rangeland restoration provide moderate increases in production and profit (relative to the no-measure situation); in practice the different characteristics of these measures could lead to different levels of uptake and impact. IBLI provides moderate increases in meat production, but has a small

Figure 3.8: Total PAP cattle population and adult female cow population in Oromia with no droughts, with droughts but no measure, and with droughts plus each of the measures adopted by 20% of the PAP cattle.

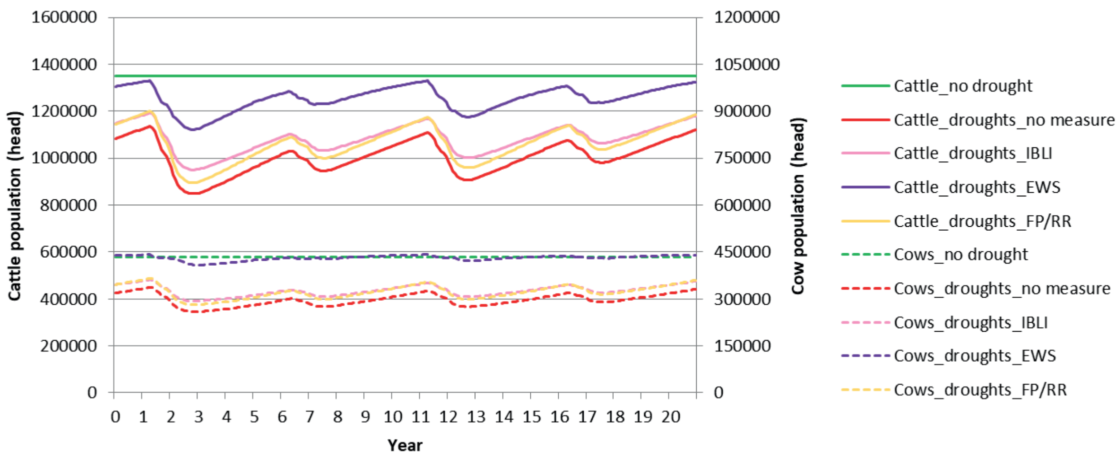


Figure 3.9: Change in meat and milk production and household profit, i.e., total production/profit with the measure for the year after the start of the drought in year 1, divided by the production/profit with no drought. Changes across all PAP cattle in Oromia with 20% adoption of each measure.

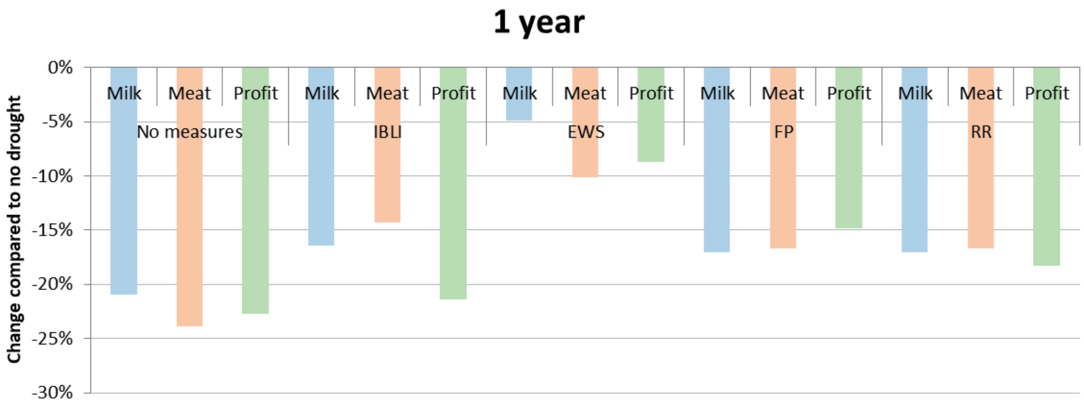
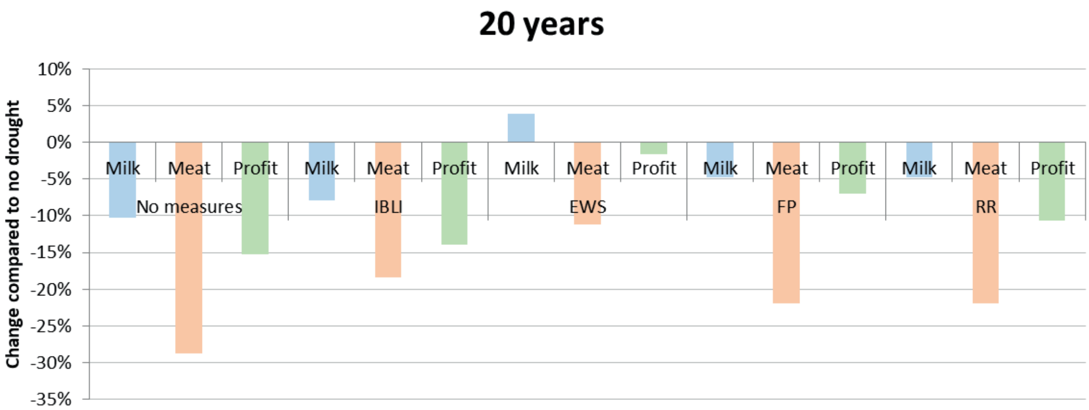


Figure 3.10: Change in meat and milk production and household profit, i.e. total production/profit with the measure for the 5 years after the start of the drought in year 1, divided by the production/profit with no drought. Changes across all PAP cattle in Oromia with 20% adoption of each measure.

Figure 3.11: Change in meat and milk production and household profit, i.e. total production/profit with the measure for the 20 years after the start of the drought in year 1, divided by the production/profit with no drought. Changes across all PAP cattle in Oromia with 20% adoption of each measure.



effect on milk production and no effect on profit. IBLI has no effect on profit because it is designed to reduce risk rather than increase productivity or profit, at least in the short term.

Uptake rates depend partly on the private costs and benefits of the measure, i.e., the net cost or benefit to the farmer. Some measures are likely to receive an element of external support, which can be explicit (e.g., subsidising insurance premiums) or implicit (e.g., paying for the setting up and maintenance of an EWS). Such support does not eliminate costs, it simply transfers them from the individual to society. In the short-term, these transfers do not change the balance of costs and benefits (although the costs of administering the transfers do). However, such external support may be instrumental in initiating change that leads to more resilient and productive PAP systems (Figure D2).

Other indicators of resilience

In addition to changes in output shown in Figure 3.9-3.11, the model can also be used to estimate how the measures affect the **time drought takes to have an impact**, the **duration of the impact** and the **extent of recovery**. Results for these indicators are given in Tables 3.2-3.4, and summarised below:

- Relative to the no-measure scenario, IBLI and EWS delay the time to impact significantly. FP and RR have no impact on the time to impact (Table 3.2).
- As with the time to impact, IBLI and EWS both reduce the duration of the drought impact, while FP and RR have no effect (Table 3.3).
- In terms of the extent of recovery IBLI has little effect on milk but increases meat production. In contrast, EWS enables rapid recovery in milk production, due to the way that income from destocking is used to maintain cows, while FP and RR have little effect (Table 3.4).

It should be noted that while FP and RR do not seem to improve resilience, this is because these results measure changes before and after a drought, rather than with and without a measure. In fact, FP and RR lead to increases in production and profit, relative to the no-measure situation, which, in turn, provides scope for improving resilience.

The measures in this study have been assumed to be implemented individually. In practice, measures may be more effective when implemented as part of co-ordinated packages of interventions. For example, Shapiro et al. (2017, p51) identified a package of measures

Table 3.2: Time to impact, i.e. time (in months) between start of drought and 20% reduction in production or profit. “>80%” indicates that production/profit does not go below 80%.

	Milk production	Meat production	Operating profit
No measure	5	15	>80%
IBLI	12	>80%	>80%
EWS	>80%	>80%	>80%
FP	5	15	>80%
RR	5	15	>80%

Table 3.3: Duration of impact, i.e. time taken (in months) from the start of drought to return to 90% of pre-drought production levels. “>90%” indicates that production/profit does not go below 90% “<90%” indicates that production/profit remains below 90% for 60 months.

	Milk production	Meat production	Operating profit
No measure	16	<90%	20
IBLI	15	25	21
EWS	7	40	>90%
FP	16	<90%	21
RR	16	<90%	21

Table 3.4: Extent of recovery, i.e. production/profit 1 year and 5 years after the start of the drought as a % of pre-drought production.

		Milk production	Meat production	Operating profit
No measure	1 year	78%	82%	85%
IBLI	1 year	79%	95%	87%
EWS	1 year	102%	88%	93%
FP	1 year	77%	82%	85%
RR	1 year	77%	82%	84%
No measure	5 years	96%	87%	93%
IBLI	5 years	98%	98%	98%
EWS	5 years	100%	95%	98%
FP	5 years	96%	87%	90%
RR	5 years	96%	87%	93%

to reduce cattle mortality comprised of “vaccinations and deworming, plus mineral supplementation, combined with better management practices (improved feeding, housing, and sanitation) and annual disease surveillance.”

While the indicators used in this report tell us something about how measures might perform in theory, in practice their uptake and impact depend on a range of factors. A SWOT analysis (Table 3.5) was carried out in order to elucidate the wider advantages and disadvantages of the measures.

Table 3.5: SWOT analysis of the four resilience measures

	Strengths	Weaknesses	Opportunities	Threats
Index based livestock insurance	• Reduces impact of drought on meat production • Proven approach • Theoretically financially self-sustaining • Avoids costs of disaster relief • May encourage a transition from risk minimisation to productivity-enhancement • Insurance firms are available	• Cost of insurance premiums • Doesn't increase profit (cost of premium) • Assumes adequate feed can be sourced during droughts when IBLI is scaled up • NDVI-based IBLI has certain technical requirements, so not applicable everywhere • Unwillingness of vulnerable households to take it (cost of premium) • Need to combine IBLI with other tools, or limit payments in case of major impact to prevent insurance company default	• Build on existing schemes • Use discounts to trigger initial uptake, and adjust premiums • Large livestock resource • New data acquisition and management tools to compute and monitor index at fine temporal and geographical resolutions • Promotion of IBLI to target groups	• "challenges in implementing sales of the product at sustainable levels" de Haan (2016, p71) • May threaten informal risk-sharing between smallholders. • Insurance may invite overstocking (Bulte and Haagsma 2021)
Destocking with an early warning system	• Increases production and profits • Encourages proactive behaviour and orderly destocking • Enables maintenance of the breeding herd • Likely to be economically justifiable (de Haan, 2016, p69) • Avoids costs of disaster relief • EWS institutions already in place	• Operationally complex (de Haan, 2016, p69) • Requires adequate transport infrastructure and holding grounds for cattle (Abebe et al. 2008) • Requires resources to establish and maintain an EWS • Some farmers may be reluctant to destock (Smith et al. 2019) • Lack of farmers confidence in EWS due to occasional false alerts • Inadequate dissemination of EWS messages • Doesn't necessarily prevent livestock price drop since both buyers and sellers anticipate drought	• Strengthen infrastructure and livestock export system (Abebe *et al.* 2008) • Allocate holding zones prior to the onset of drought. Abebe et al. (2008) • Use EWS data for other purposes, e.g., emergency interventions, IBLI system, extension work	• Increasingly erratic climate changes may be a challenge for EWS

	Strengths	Weaknesses	Opportunities	Threats
Fodder planting	• Increases production and profit • Avoids costs of disaster relief (if some income is saved)? • High demand due to increased frequency of drought • Support from government and development partners	• Dependent on availability of suitable land at low/no opportunity cost, may only be feasible on private enclosures • Time taken to recoup initial costs • Willingness/ability of farmers to adopt at scale • Inability to irrigate fodder, and more generally to maintain productivity • Insufficient storage facilities contributing to wastage • Occasionally inadequate demand	• Supply chain development to enable milk and meat to reach consumers • Breed and health improvement to take advantage of higher quality feed • Further investigation is required to establish if adequate land is available • Provide loans to farmer groups to cover initial costs • Participatory approach including all stakeholders? • Donor and government support for commercial fodder production	• Transaction costs and lender risks (Ng'ang'a *et al.* 2020, p34) • Conflict? May further marginalise pastoralists without access to land? • Impact of land use change, e.g. on GHG emissions, biodiversity and water cycles • Increasing frequency of drought due to climate change • Outbreak of desert locusts • Potential land degradation on planted areas, and losses of soil organic carbon
Rangeland Restoration	• Increases production and profit • Only way to restore severely degraded rangelands? (Ng'ang'a et al. 2020, p4) • Avoids costs of disaster relief (if some income is saved)? • Theoretically applicable to a large area of rangeland	• Dependent on the availability and cost of supplementary feed • Time taken to recoup initial costs • Limited property rights discourage investment required (Ng'ang'a *et al.* 2020, p6) • Unregulated deforestation and land degradation in some areas	• Co-ordinate RR with a strategy to increase feed supply? • Provide loans to farmer groups to cover initial costs • Participatory approach including all stakeholders? (IAG 2010, p123) • Payment for Environmental Services for rangeland restoration? • Willingness of government and development partners to support rehabilitation efforts • Co-benefits in terms of carbon sequestration, biodiversity, and water cycles	• Widespread adoption could lead to increased feed prices as this measure entails supplementary feeding • Cattle population increase could result in less productive animals (Ng'ang'a et al. 2020, p35) • Transaction costs and lender risks (Ng'ang'a *et al.* 2020, p34) • Conflict arising from private management of a common asset? • Increasing aridity due to climate change

4. CONCLUSIONS

Effects on production and resilience

IBLI enhances resilience by enabling farmers to secure the resources to feed their cattle during droughts, thereby reducing the impact that drought has on mortality and fertility. IBLI has little effect on milk production but leads to a consistent moderate increase (relative to the no-measure situation) in meat production. Milk production does not increase because IBLI increases the cattle population and hence the stocking rate. IBLI has little effect on profit as the financial benefits of reduced drought losses are largely offset by the costs of insurance premiums. However, the protection provided by IBLI may encourage farmers to shift over time from decision-making focussed on risk minimisation to productivity-enhancement, thereby increasing income. Obstacles to uptake include the cost of insurance premiums, relative to anticipated benefits and the technical requirements of IBLI, which mean it is better suited to locations with rangeland dominance and adequate forage production and seasonality. Subsidising the cost of IBLI in the start-up phase and dynamically adjusting premium rates have been suggested as ways of encouraging uptake.

Destocking with an EWS reduces cattle mortality and enables animals to be sold in better condition, giving farmers the means to maintain more of their breeding herd and restock more rapidly after a drought. It leads to large increases in meat and milk production and, consequently, profit. This is due to the way in which the measure changes the herd structure; adult males are sold off, and the revenue is used to maintain calves and females, leading to a greater proportion of cows in the herd. Implementation of this measure may be hampered by inadequate transport infrastructure and lack of holding grounds for cattle. The perceived benefits of large herds may make some farmers reluctant to destock, while the existence of a strong livestock export system facilitates destocking for those that are prepared to sell.

While IBLI and EWS seek to reduce the impacts of acute drought events, fodder planting and rangeland restoration both seek to address the chronic (drought-exacerbated) problem of feed shortage in Oromia by increasing feed supply. FP entails planting grains (or other crops such as Rhodes grass, Guinea grass, signal grass and Green leaf desmodium) on under-used land while RR involves a combination of reducing grazing pressure, planting herbaceous species and supplementary feeding (to facilitate long-term reductions in grazing pressure). Both measures lead to significant improvements in cattle performance, specifically increased cow fertility, increased growth rates and increased offtake rates (for mature male cattle). In theory these measures should lead to significant increases in production. However, both require that farmers have the money to pay for the costs of implementing the measure. Long-terms loans may be required to enable adoption. Both measures also assume that adequate land can be made available: “under-used” land for FP and land to grow feed for RR. Further investigation is required to establish the availability of such land. Even if land is available, these measures face further challenges as farmers may not be willing to make long-term investments to improve land over which they have limited property rights.

Farmers’ willingness to adopt measures depends partly on their net benefit. Some measures are likely to receive an element of external support, which can be explicit (e.g., subsidising insurance premiums) or implicit (e.g., paying for the setting up and maintenance of an EWS). While such support does not change the balance of costs and benefits to society in the short term, it may be instrumental in initiating change that leads to more resilient and productive systems.

Optimising the benefits of resilience measures

The measures in this study have been assumed to be implemented individually. In practice measures may be more effective when implemented as part of co-ordinated packages of interventions; as Smith *et al*. (2019, p xviii) noted "Greater impacts are achieved when interventions from multiple sectors are combined than when they are implemented separately. Comprehensive, multi-sectoral programming optimizes resilience impacts". In some cases, realising the benefits of the measures discussed in this study may be contingent on other actions. For example, widespread adoption of measures that significantly increase milk production may require the development of milk producer groups (to co-ordinate the collection, processing and marketing of milk) improvements in transport infrastructure and improved access to water for cattle. In their absence, increasing production may lead to local oversupply and depressed prices, as it is currently "too expensive for livestock farmers in the Oromia lowlands to transport milk to urban and peri-urban markets." Ng'ang'a *et al.* (2020, p3).

Previous experience of technically-driven development programmes in pastoralist areas suggests that, unless they are based on a thorough understanding of the socio-economic-ecological-institutional aspects of the pastoralist system as a whole, they tend to be unsustainable. Instead of implementing programmes of pre-defined measures, efforts could be made to identify the key risks in a particular location and provide targeted measures to reduce risk (although as McPeak et al. (2009) note, identifying priorities within pastoral communities is complicated by spatial and temporal heterogeneity). This would provide farmers with a window of opportunity to shift focus from risk-minimisation to increasing profits, which could then be reinvested in further measures, according to the farmers' priorities.

Improving the analysis

The model assumes that the cattle population will respond in broadly the same way to the same pattern of drought events at different points in time, and seek to return to the equilibrium population. However, in response to repeated droughts, farmers' behaviour may eventually change in ways not predicted by the model i.e., more vulnerable pastoralists may exit the sector leading to restructuring and fundamental changes in the way pastoralists respond to droughts. Catley (2017) noted a trend over time of the commercialisation of pastoralist production and the privatisation of commonly owned rangelands, leading to increasing divergence in the impacts of drought on rich and poor pastoralists.

The model, by necessity, simplifies a complex situation. In reality, there is variation within PAP systems in Oromia in terms of their exposure to droughts and ability to respond. The analysis could be refined by undertaking the modelling at a sub-regional scale and better reflecting the spatial variation in drought impact and access to markets/resources, thus enabling targeting of measures on specific systems and locations. For example, successful fodder production requires a combination of land, water resources, labour and skills that will only be present at some locations. For other locations a more feasible alternative may be to develop the supply of fodder from areas better suited to its cultivation.

Ultimately, the heterogeneity of the pastoralist sector, and of the impacts drought has upon it, means that a range of measures are needed to improve resilience; what works best in one context may be inappropriate in another. It is likely that all of the measures in this report have a role to play in the future.

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Appendix A.
Estimating the grassland area and feed balance in Oromia

Estimating feed supply

Estimating the grassland area

CSA surveys of land utilization (CSA 2021a, b, and previous years) provide estimates of grazing areas that appear to be the areas of managed grassland used by sedentary farmers. CSA also provides estimates of the areas of cropland cultivated by commercial (CSA 2021c) and peasant farmers (CSA 2021d).

BioCarbon Fund (2019) provides estimates of the areas of cropland and grassland; however, their categories differ from the CSA ones. Cropland includes land used for hay and pastures included in crop rotations, while grassland comprises all rangelands and pasturelands not considered cropland, including land with low woody plant communities not meeting the criteria for Forest Land (p235).

If we assume that (A) the total cropland and grassland areas in BioCarbon (2019) and (B) the cropland and managed grassland areas in CSA are correct, then the unmanaged grassland can be estimated by subtracting (B) from (A). This approach gives us the land use trends in Figure A1, i.e. cropland increasing at the expense of grassland, and, to a lesser extent, forest. This is in line with the findings of Regasa et al. (2021) who reviewed 25 studies of land use change in Ethiopia (15 in Oromia). For the 12 studies reporting grassland areas in Oromia, 10 reported decreases and 2 (studies 6 and 13) reported increases. For the 14 studies reporting forest areas in Oromia, 13 reported decreases and 1 (study 5) reported an increase.

Grassland yields

Grassland yields vary depending on factors such as agro-ecological zone and weather conditions. Table A1 gives estimates of yield (more accurately biomass availability) from Ethiopian grasslands. In this study we assumed that unmanaged grassland has a biomass availability of 0.99 tonnes of dry matter per hectare (tDM/ha) (this is the total available biomass from grazing divided by the total area grazed in FAO (2018, p34)). Managed grassland was assumed to have a biomass availability of 2.25tDM/ha (based on the MRS average yield

Figure A1: Land use trends in Oromia. Managed grass, cereals and other crops based on CSA survey reports. Unmanaged grass estimated using approach outlined above. Forest area from BioCarbon Fund (2019).

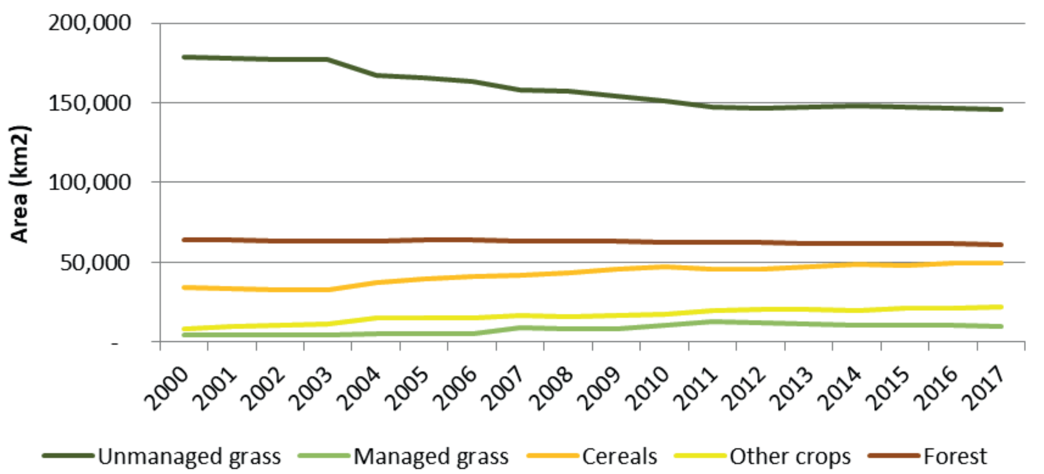

Table A1: Grassland yields in Ethiopia in tDM/ha of "usable biomass" (Shapiro et al. 2017, p38) or "grazing biomass availability" (FAO (2018, p34)/ P/AP: pastoral/agro-pastoral. MRD: mixed rainfall deficient. MRS: mixed rainfall sufficient

	Shapiro et al. (2017)	**FAO (2018)**	**Shapiro et al. (2017)**	**Shapiro et al. (2017)**	**FAO (2018)**
Weather:	Lowland P/AP	Lowland	MRD	MRS	Mid/highland
Good	1.00		2.11	2.45	
Average	0.75	0.56	1.46	1.88	2.00
Bad	0.45		1.14	1.50	

of 2.5tDM/ha reported in Shapiro, multiplied by a use rate of 90%).

Table A1. Grassland yields in Ethiopia in tDM/ha of “usable biomass” (Shapiro et al. 2017, p38) or “grazing biomass availability” (FAO (2018, p34)/ P/AP: pastoral/agro-pastoral. MRD: mixed rainfall deficient. MRS: mixed rainfall sufficient

Feed from cereal crops

Two cereal-derived feeds were included: crop residues (CR) and the by-products (BY, i.e. brans) from cereal processing. The yield of CR was calculated using the CR formula for sorghum from IPCC (2006, p11-17). Sorghum was used as it gives a CR yield close to the average for maize, wheat and sorghum at the low yields found in Oromia. It was assumed that 60% of the CR would be available as feed (the remainder being used for other purposes or unharvested).

It was assumed that for every 1kg of cereal grain, 0.1kg of BY would be produced, based on an average extraction rate across all cereals of 90% (FAO 1953). It was assumed that 100% of the BY would be available as feed.

Cereal areas, production and yield were based on data provided in the Ethiopian Central Statistics Agency survey report, i.e. CSA (2021g, p47), and CSA (2021d, p37) and previous years.

Estimating feed demand

The cattle populations reported in Wilkes et al. (2020) (which are based on CSA reports) were used.

The feed intake per head of cattle was calculated using the IPCC (2006, 2019) tier 2 formula as follows. The net and gross energy requirements were calculated for each cohort (calves, male and female weaners etc.) then converted to the dry matter intake (DMI). The DMI for each cohort was multiplied by the number animals in each cohort to arrive at the herd DMI each year.

The feed demand for other livestock was estimated by assuming the DMI intake per TLU for other livestock was the same as for cattle, and converting the livestock populations reported by the CSA (CSA 2021a and previous years) to tropical livestock units (TLUs).

Refining the approach

The feed balance for Oromia in 2016 was calculated and compared with the results in FAO (2018). In the light of this comparison, the following changes were made to the method:

- Daily DMI was reduced by 25% to reflect the lighter cattle weights in FAO (2018).
- The grazing supply was increased to be equal to the FAO (2018) supply, to capture the grazing available in forests and wetlands.
- A category of “Other feed” was added, which includes the feed available from non-cereal CRs, pulse milling BY, oilseed cake, and permanent crops (based on the amounts reported in FAO (2018).
- Brewery by-products were added to the “Other feed” category, based on the availability reported in FAO (2019).

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Appendix B.
Comparison of model values for key parameters with other studies

Fertility rates

Figure B1 shows the fertility rates calculated in the model along with those reported in Angassa and Oba (2007) and Wilkes et al. (2020).

The modelled fertility rate matches Angassa and Oba (2007) well, apart from in 1999 and 2000, where the latter estimate has very low values. There is a good match between the modelled fertility rate and Wilkes et al. (2020) from 2002 to 2006, but after that the modelled values are lower. Wilkes et al. (2020) report very high (>80%) fertility rates in some years, however this may be due to the way in which they estimate fertility rate: they took the reported number of calves born from CSA, then adjusted it (assuming that CSA calf numbers do not include any of the mortalities from birth to 6 months old, i.e. they are the number of calves surviving beyond 6 months of age) by adding the % of liveborn calves (i.e. not including stillborn/abortions) dying between birth and weaning (assuming that 27.6% die between birth and weaning, the average of the Afar and Somali pastoral systems reported in Fentie et al. 2016, p35) to arrive at the number of calves born alive. The percentage of cows giving birth to a live calf is then calculated by dividing the number of calves born alive by the "number of cows in milk" reported in CSA.

In the model, the fertility rates do not include abortions/stillbirths or perinatal mortality, i.e. it is the % of cows that give birth to a calf surviving beyond the perinatal period (the first 48 hours after birth). The modelled post-perinatal calf mortality varies between 10% and 66%, with a mean of 22%, while the average post-perinatal calf mortality for pastoral systems in Afar and Somali is 22% (Fentie et al. (2016). The same study estimated perinatal deaths rates in pastoral systems to be 0.5% in Afar and 10.3% in Somali, giving an average of 5.5%. Adjusting Wilkes et al. (2020) fertility rate so that it excludes perinatal mortality leads to a better match (Figure B1, Wilkes et al. (2020) B), but the fertility rates are still high in some years. It could be that the CSA calf numbers include some of the calves dying between birth and 6 months.

Figure B1: Annual average fertility rate for pastoral cattle in Oromia, and drought index. Wilkes et al. (2020) A: % cows giving birth to a live calf; Wilkes et al. (2020) B: % cows giving birth to a calf surviving beyond 48 hours.

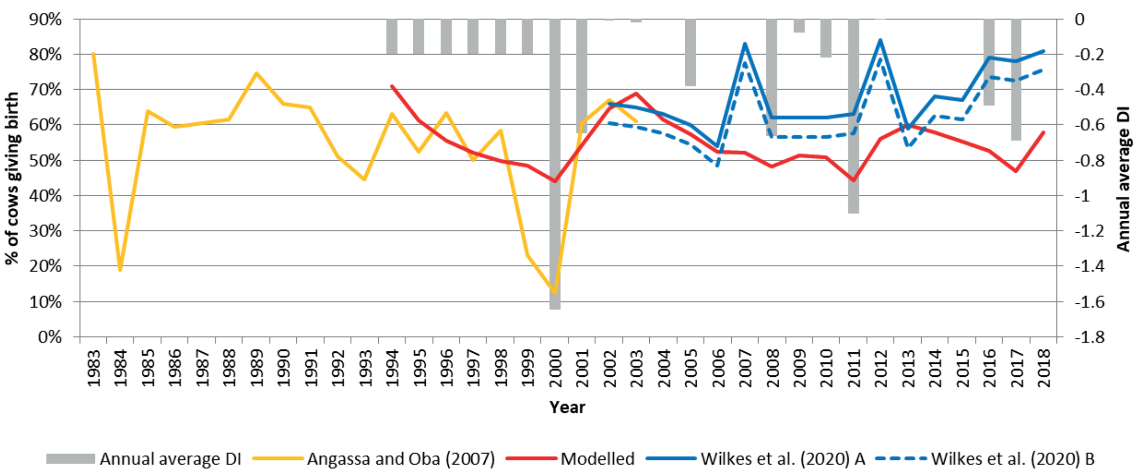


Table B1: Summary of reported average fertility rates for cows in pastoral systems

Study	Period	Area	Calving rate	Fertility rate
Coppock (1994)	1980-1991	Borana	70%	
Angassa and Oba (2007)	1983-1991	Borana	61%	
Angassa and Oba (2007)	1994-2003	Borana	51%	
This study	1994-2003	Oromia	62-67%*	57%
Wilkes et al. (2020)	2002-2018	Oromia	68%	
This study	2002-2018	Oromia	60-65%*	55%
Wario et al. (2017)	2003-2013	Borana	70%	
This study	2003-2013	Oromia	60-65%*	55%
Otte and Chilonda (2002)	1973-2000	Sub-Saharan Africa	61%	

*Assuming the calving rate is 10% higher than the fertility rate used in the model.

Table B1 summarises the average fertility rates for different periods. Comparing studies is complicated by the ambiguity in the units used to measure fertility. Fertility can measured in terms of the number of cows getting pregnant, giving birth, giving birth to a live calf or giving birth to a calf that survives beyond a certain period (such as the perinatal or neonatal period). Coppock (1994), Otte and Chilonda (2002), Angassa and Oba (2007) and Wario et al. (2017) report calving rates, but it is not clear whether they include stillbirth, perinatal or neonatal mortalities. The fertility rate in the model does not include stillbirths or perinatal mortality, so the calving rate (assuming including all living calves born) is likely to be 5-10% higher than the fertility rate.

Coppock (1994, p137) reported that "annual calving rates average around 70%", which is somewhat higher than the fertility rate reported by Angassa and Oba (2007), who attributed the difference to the timing of the studies; the study period for Coppock (1994) was 1980-1991, a period which "experienced a single drought, while in our case the lower calving rate probably reflected the effects of multiple droughts."

Summary

The average fertility rates calculated in the model are within the range reported in other studies for comparable systems, locations and time periods.

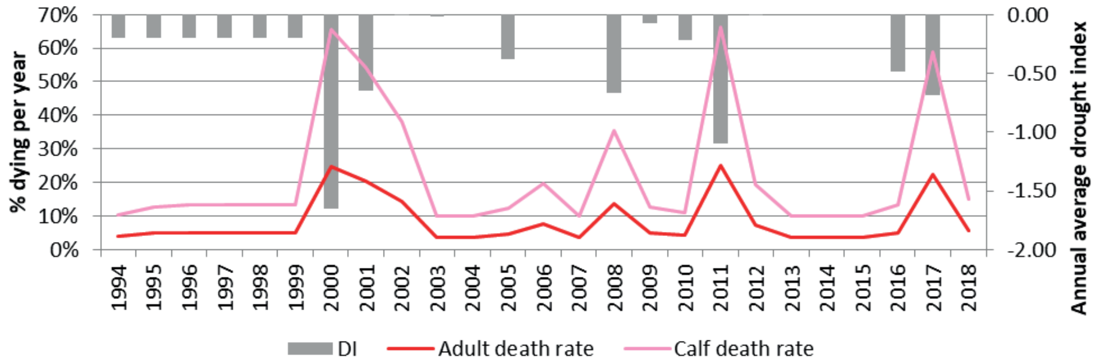
The variation in the modelled fertility rate over time matches the trends in Angassa and Oba (2007) in most years, and the trends in Wilkes et al. (2020) in some years. It is not clear whether the sudden increases in fertility reported in the latter in 2007 and 2012 are real or an artefact of how they were derived.

Mortality rates

Comparison of model mortality rates with reported mortality rates

A strong link between drought and mortality has been observed (Angassa and Oba (2007). For example, Mulugeta Assefa (1990) reported that the average calf mortality of 24%, rose to 69% during drought years, while Wario et al. (2017) concluded that "Young stock mortality was mainly attributed to malnutrition during periods of limited fodder availability resulting from extended dry conditions." Adult and calf mortality varies with drought in the model via

Figure B2: Modelled death rates for adult cattle and calves



the drought mortality function. The annual death rates in the model can increase five or six-fold during a severe drought such as in 2000 (Figure B2). The death rates are in the ranges reported in other studies and the long-term averages are consistent with those reported by Otte and Chilonda (2002) (Table B2).

Time in each cohort

The amount of time cattle spend in each cohort are summarised in Table B3. Note that some of these times are adjusted for high stocking rates or if certain measures (FP or RR) are implemented. When SR is >1, the Time to become AF or AM increases, reflecting the impact that feed scarcity has on growth rates. Implementation of FP or RR has the opposite effect, increasing feed availability and growth rates, while leading to an increase in the offtake rates of adult male cattle, reflected in their reduced service life.

Table B2: Adult and calf death rates for adult cattle and calves in pastoral systems

Study	Period	Area	Annual death rate		Notes
			Adult	Calf	
Cossins and Upton (1987)	1982-84	Borana	3%	25%	
Mulugeta Assefa (1990)	1985-89	Borana		24%	69% during drought years
Angassa and Oba (2007)	1983-4	Borana	55%	56%	During a major drought
Angassa and Oba (2007)	1992-3	Borana	37%	38%	During a major drought
Angassa and Oba (2007)	1999-2000	Borana	54%	53%	During a major drought
Wario et al. (2017)	2003-2013	Borana		18%	
This study	2003-2013	Oromia	7%	20%	
Catley et al. (2014)	2002-03	Borana	19%		ALL cattle, normal year
Catley et al. (2014)	2005-06	Borana	44%		ALL cattle, drought year
Fentie et al. (2016)	2014-2015	Afar and Somali		22%	Not including deaths in the first 48 hours
This study	1994-2018	Oromia	8%	22%	
This study	2000	Oromia	25%	65%	Drought year
This study	2003	Oromia	4%	10%	Non-drought year
Otte and Chilonda (2002)	1973-2000	SSA	8%	23%	

Table B3: Time in each cohort

Period	Duration (months)
Weaning time	6
Growing time	6, adjusted if FP or RR are implemented – see below
Time to become AF or AM	30, adjusted for SR and if FP or RR are implemented – see below
AF service life	90
Bull service life	66, adjusted if FP or RR are implemented – see below
Draft (male) service life	66, adjusted if FP or RR are implemented – see below

Growing time

= 6/(range restoration impact factor + fodder planting impact factor-1)

Bull service life (adjusted)

= Bull service life/(range restoration impact factor + fodder planting impact factor-1)

The same formula is used for draft males

Time to become AF

= (Base time to become AF*impact of SR on growth)/ (range restoration impact factor + fodder planting impact factor-1)

The same formula is used for AM

Impact of SR on growth

= IF THEN ELSE(real regional stocking rate>1 , real regional stocking rate, 1)*SR growth multiplier

SR growth multiplier=1

The weaning time, growing time and time to become an adult female were checked by calculating the age at first calving arising from these times and comparing it with values reported in other studies (see next section).

The offtake rate for adult male cattle was assumed to be 18%, which is within the range reported in Tuff and Treydte (2017) of 9-35%. For adult females the offtake rate was assumed to be 13%, which is higher than the 4-5% reported in Tuffa and Treydte (2017). Wario et al. (2017) noted that cow numbers decline sharply in the age class 12-13, suggesting that most cows are kept for ~11 years, i.e. have a breeding life of 7 years, or an offtake rate of about 14%.

Age at first calving

When the SR is <=1, and no measures are implemented cattle become adults at 42 months, i.e. the AFC for fertile cows is 42

Table B4: The number of cows calving at different ages (with a calving rate of 62% per annum), and the average age at first calving. Cohort size is 100 cows

AFC (months)	# calving	# not calving
42	62	38
54	24	14
66	9	6
78	3	2
	Average AFC (%)	
Infertile cows culled after 4 years	48.3	
Infertile cows culled after 3 years	47.3	
Infertile cows culled after 2 years	45.3	

Table B5: Age at first calving in the model and reported in other studies

Study	Period	Area	AFC (months)	Notes
Cossins and Upton (1987)	1982-84	Borana	48	
Coppock (1994)	1980-1991	Borana	48-54	Single drought during this period.
Wario et al. (2017)	2003-2013	Borana	54	
This study	1994-2018	Oromia	45-48	See Table B4, assuming SR is <=1
Bayssa et al. (2021)	1985-2019	Borana	44	Meta-analysis
Haile et al. (2011a)	1990-2004	Borana	44	
Otte and Chilonda (2002)	1973-2000	SSA	48	

months. With a calving rate of 62% (Table B1), the average AFC will be between 45 and 48 months, depending on how long infertile cows are kept for (Table B4).

Comparison of model age at first calving with reported ages at first calving

The AFC in the model is consistent with those reported elsewhere.

Weights and growth rates

The weights of adult cattle are taken from Wilkes et al. (2020, p20), i.e. 322kg LW for adult males and draft males, and 290kg LW for adult females. Calf weight at birth was assumed to be 7% of adult female weight, i.e. 20kg. Based on these assumptions, the average baseline (i.e. unadjusted for SR, FP or RR) growth rates from birth to becoming adult are: 0.214kgLW/day (female) and 0.239kgLW/day (male). The average weight in each cohort was calculated (Table B7), assuming a constant growth rate from birth to becoming adult and no growth afterwards

Table B6: Unadjusted live weights by cohort

		Average LW (kg)	
Cohort	**Age (months)**	Male	Female
Calves	0-6	49	49
Weaners	6-12	111	101
Growers	12-42	231	209
Adult	>42	322	290

Comparison of model growth rates with rates reported in other studies

The modelled growth rates are similar to those reported in other studies (Table B7).

Effect of drought and stocking rates on growth rates

Drought has no effect on growth rates in the model (but stocking rate does). The assumption is that the transient effects of drought lead to short term reductions in growth rates (or even wasting) but that over their lifespan (the typical lifespan of cattle that are culled rather than dying is 10 years for female cattle, and 8 years

Table B7: Growth rates from birth to first calving/adulthood. Rates for this study are for when the stocking rate is <=1TLU/hectare

	Study period	Growth period (months)	Weight gain (kgLW)	Growth rate (kgLW/day)
Bayssa et al. (2021), male and female, birth to adulthood	1985-2019	44.0	331	0.250
Haile et al. (2011a) female, birth to first calving	1990-2004	43.5	281	0.215
This study, female, birth to first calving	1994-2018	42	270	0.214
This study, male, birth to adulthood	1994-2018	42	302	0.239

Table B8: Milk yields used in the model and reported in other studies

	Lactation yield (kg)	Lactation length (days)	Milk yield (kg/day) during lactation
This study	505	248	2.0
Haile et al. (2011, Table 4)	507	240	2.1
Bayssa et al. (2021, Table 3)	596	231	2.6

*Not including milk suckled by calves

for male cattle) the effect on lifetime average growth rates is small as emaciated animals can grow faster post-drought once feed is available (see Angassa and Oba (2007, p724). However, chronic lack of feed quantity/quality caused by high stocking rates does lead to reduced growth. See also Coppock (1994, p137) for the effect of watering on compensatory growth.

Milk production

The milk secreted per cow was taken from Wilkes et al. (2020, p92), who based their estimates on CSA reported milk yields. The amount of milk available for human consumption was then calculated by subtracting the milk suckled by calves from the milk secreted. The amount of milk suckled by calves was calculated, assuming 8.7kg of milk per kg of LW gain when suckling (Ezanno 2005, p294).

Comparison of model milk yield with rates reported in other studies

In order to compare the milk yield used in the model with other studies, the milk yield was converted into the yield per lactation, not including milk suckled by calves. Expressed in these units, the model milk yield is somewhat (20%) lower than Bayssa et al. (2021) but very similar to the yield reported in Haile et al. (2011).

In the model the milk yield per lactating cow is not directly affected by drought, stocking rate or policies. Instead, the effects on milk production are captured in the model via changes in fertility rate.

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Appendix C.
Costs, revenues and profits

Table C1: Twenty-year regional average costs, revenues and profits for each of the measures when they are adopted by 20% of households. Prices in ETB 2010.

Parameter	Units	No measures	IBLI	EWS	FP	RR
Cattle population	M TLU	0.94	1.02	1.17	1.00	1.00
Baseline costs	ETB/TLU.year	600	600	600	600	600
Measure costs	ETB/TLU.year	0	23	0	4	26
Total costs	ETB/TLU.year	600	623	600	604	626
Milk revenue	ETB/TLU.year	480	449	444	482	482
Meat revenue	ETB/TLU.year	656	666	655	680	680
Total revenue	ETB/TLU.year	1136	1115	1099	1161	1161
Operating profit	ETB/TLU.year	536	492	499	557	535
Operating profit	ETB/household.year	6722	6701	7831	7393	7097

The costs and revenues for each of the measures is summarised in Table C1. The average over 20 years has been used to capture the variation in revenue and costs that occurs in the short-medium term.

Baseline costs

The baseline cost of maintaining cattle is assumed to be 600ETB/TLU/year based on Ng'ang'a et al. (2020).

Measure costs

IBLI

The insured value of cattle is based on a cost of maintaining cattle during a drought of ETB 1,527 per TLU per year (2010 prices), source: Fava (personal communication) 2020.

The insurance premium is set at 7.5%.

EWS

The costs of establishing/maintaining the EWS and of organising sales and transporting cattle are not included, but these could be quite modest on a per-household basis (Section 2.6).

Fodder planting and rangeland restoration

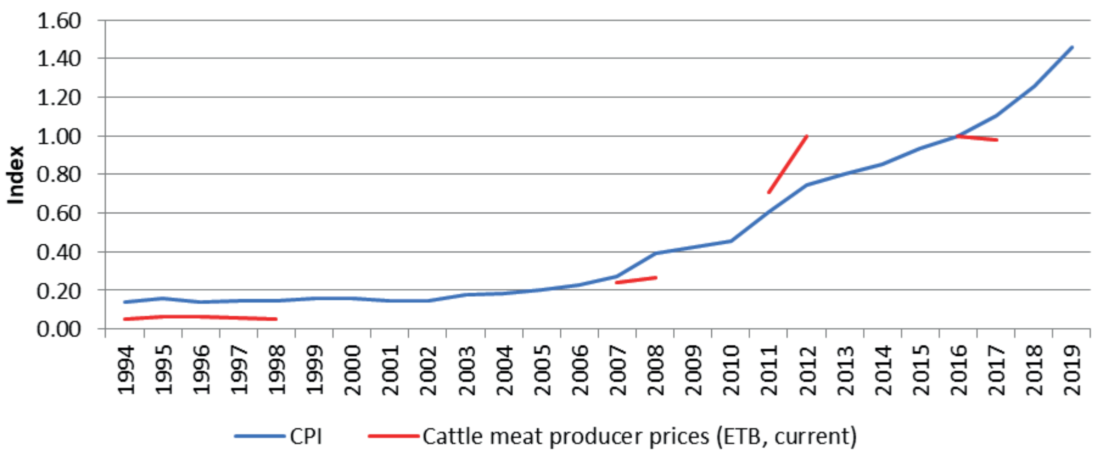
Costs are based on Ng'ang'a et al. (2020) and vary according to the year of the measure – see Figures 3.4 and 3.6. Note that the opportunity cost of land used for fodder planting is assumed to be zero.

Milk and meat revenue

Revenue is determined by multiplying the amount of meat and milk produced by the unit price. Estimating commodity prices is complicated by rapidly changing prices in Ethiopia. Figure C1 gives the consumer price index (CPI) and cattle prices, expressed relative to the prices in 2016.

The implied sale price currently used in the model (i.e. the meat price per kg multiplied by the average LW per TLU sold) is shown in Table C2, along with estimates of cattle sale prices from other studies. The sale price in Catley and Cullis (2012) is much lower, but this is the price during a drought (with commercial destocking, but no EWS) and the authors recognise that "the prices are not high relative to the best market values in a good year". The sale prices reported in Ng'ang'a et al. (2020) and Bachewe et al. (2017a) are consistent, and lower that the FAOstat price.

Figure C1: Relative consumer price index and cattle meat prices for Ethiopia (2016 = 1). Sources: CPI – World Bank 2022; meat prices – FAOstat 2022a.



Changing the meat price changes profits for all scenarios, but only changes production with the EWS measure (Table C3). With EWS, doubling the meat price increases meat and milk production by 2-3% while halving the price reduces production by 5% (with 20% uptake of the measure). Increasing the meat price has a smaller effect than decreasing it as there is a limit to the number of animals that can be maintained via destocking revenue.

The FAOstat milk price is used in the study, which is in the range for prices reported in other studies (Table C4).

Table C2: Cattle prices used in this study, and reported in other studies.

Parameter	Value	Units	Notes
Sale price per TLU	6,395	ETB (2010) per TLU	This study
Sale price	6,048	ETB (2010)/TLU	FAOstat (2022a)*
Sale price of destocked cattle	876	ETB (2010)	Catley and Cullis (2012, Box 2)
Sale price	3,855	ETB (2010)	Ng'ang'a et al. (2020, p19)
Cow (4+ years)	2,110	ETB (2010)	Oromia, Bachewe et al. (2017a, p11)
Ox (4+)	3,726	ETB (2010)	“”

*Based on FAOstat cattle meat producer prices and assuming an average LW per animal sold of 270kg

Table C3: The effect of varying meat price (0 no effect; + increase; - decrease)

	Increasing meat price			Decreasing meat price		
	Meat prod.	Milk prod.	Profit	Meat prod.	Milk prod.	Profit
No measure	0	0	+	0	0	-
IBLI	0	0	+	0	0	-
EWS	+	+	+	-	-	-
FP	0	0	+	0	0	-
RR	0	0	+	0	0	-

Table C4: Milk prices used in this study, and reported in other studies.

Parameter	Value	Units	Notes
Milk price per t	5,170	ETB (2010)/t	This study
Whole milk, producer price	5,170	ETB (2010)/t	FAOstat (2022b)
Milk price (assumed producer price)	4,183	ETB(2010)/t	Ng'ang'a et al. (2020, p19)
Unpasteurised milk	6,618	ETB (2010)/t	Oromia, Bachewe et al. (2017a)

Meat and milk price summary

- The baseline milk price is consistent with other studies.
- The baseline meat price may be overestimated in the model.
- Varying meat or milk price affects revenue and profit, but has no effect on production, except with EWS, where changes in the meat price lead to small changes in population and production.
- The meat prices during a drought may be reduced by more than 10% (Bachewe 2017b, Catley and Cullis 2012)

Operating profit

The operating profit is the total revenue minus the total costs and varies between 492 and 557 ETB/TLU/year. These values are consistent with the net incomes reported for pastoral systems in Shapiro et al. (2017, p14) of 767-811ETB/TLU (assuming the latter data is in ETB 2012 or 2013).

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Appendix D.
Exploring the effect of herd structure on resilience

The model was run with increased offtake rates for adult male cattle (the adult male service life was reduced from the baseline value of 66 months to 54 months for 100% of the Oromia herd) to explore the effect of a proactive change in herd structure. Increasing adult male offtake increases the proportion of adult females in the herd, the number of cattle sold, and the number of calves born each year, leading to increases in meat and milk production, and profits (Figure D1). At the household level, the increased offtake increases the annual profit by ETB 873 or 13% (Table D1).

Increasing the offtake rate will not, in itself, increase resilience to drought. However, the increase in profits provides opportunities to improve resilience. For example, it could be used to purchase livestock insurance. The full premium per household for IBLI would be in the order of ETB 1,400 per year, so the increase would cover more than half of the cost. Or it could be used to improve cattle performance during inter-drought periods via investment in cattle nutrition, genetics and access to veterinary services.

Figure D1: Total PAP meat and milk production in Oromia, and household profit, with an adult male service life of 66 months ("No measure") and 54 months ("Offtake+").

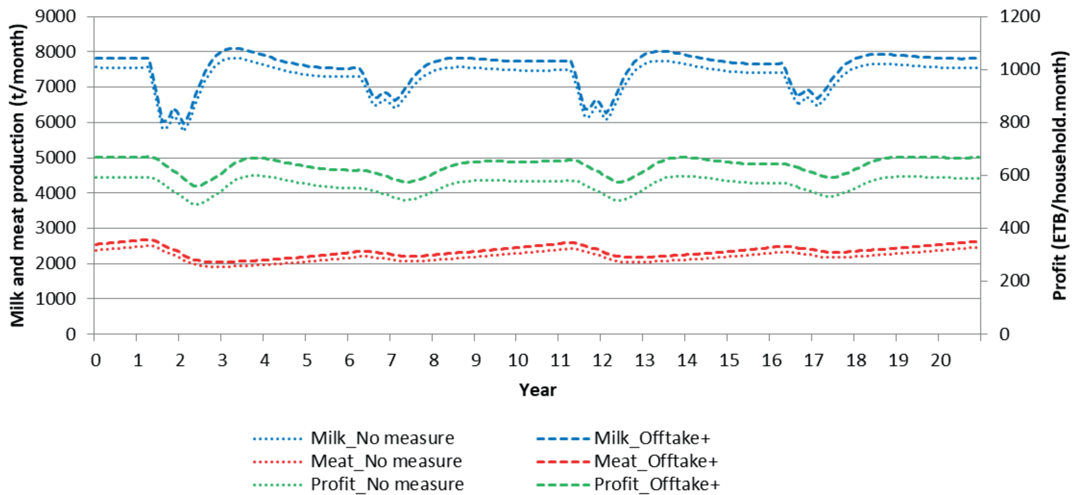
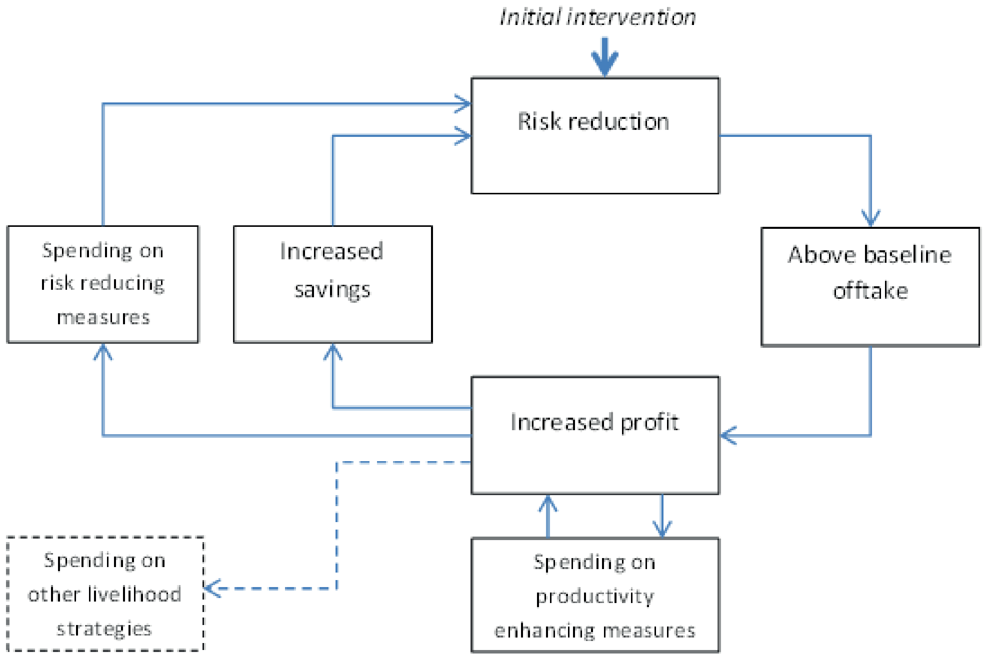


Table D1: Average annual production and profit per household in the baseline (no-measure) situation and with the offtake rate of male cattle increased (Offtake+). Values are for a 20-year period. Prices expressed in ETB 2010.

	No measure	Offtake+
Total cattle (TLU)	12.6	12.5
Milk production (kg/year)	351	375
Cattle sales (TLU/year)	1.30	1.39
Cattle sales revenue (ETB/year)	8291	8872
Milk sales revenue (ETB/year)	6048	6256
Baseline operational costs (ETB/year)	7560	7476
Profit (ETB/year)	6779	7652
Change in profit relative to no-measure (ETB/year)		873

Figure D2: Illustration of the potential impact of a risk reduction intervention



In practice farmers may be reluctant to increase offtake rates for fear of losing animals to drought and disease; low offtake rates are partly a way of managing risk. An external intervention to reduce risk may be required to initiate an increase in offtake. Once initiated, the increased profit should be sufficient to sustain the above-baseline offtake (Figure D2), via increased savings or spending on risk reducing measures (e.g., livestock insurance or vaccination…) or productivity-enhancing measures (e.g., feed supplementation, parasite treatment or improved genetics).

This analysis assumes that the increased supply of meat and milk does not lead to price reductions, and that increased demand for feed resources and veterinary and genetic services can be met. This is not currently the case; rather, there is a feed deficit in Oromia and a lack of veterinary services in rural areas (Shapiro et al. 2017, p49). However, increases in demand for inputs and the supply of outputs could help develop supply chains for feed and veterinary services, as well as for the sale of cattle.

References for Appendix D

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