CHAPTER 5

Vulnerability and Resilience in Livestock Systems in the Drylands of Sub-Saharan Africa[1]

Cornelis de Haan and Raffaello Cervigni with Anne Mottet, Giulia Conchedda, Pierre Gerber, Siwa Msangi, Matthieu Lesnoff, Frederic Ham, Erwan Fillol, and Kidus Nigussie

Introduction

Chapters 1–4 clearly showed an urgent need to move the African drylands livestock sector from emergency aid-dependence to a state characterized by more resilience. This chapter seeks to inform policy makers on desirable policy and investment options to enhance the resilience of drylands livestock production systems (LPS) and livestock keepers.

Identification of policy and investment options for livestock systems in dryland regions of Africa is constrained by the lack of analytical framework, as little work has been done to model livestock production, combining the physical (vegetation, feed resources, animal production) and economic (market integration, income, and livelihoods effects) factors associated with these arid environments. This chapter reports on a first attempt to develop and apply such an analytical framework. Its novelty is that it incorporates several modeling tools never before used in an integrated, interactive manner to provide, for a small number of climate and intervention scenarios, quantitative information on feed availability, meat and milk production, household income, and vulnerability in select drylands countries.[2] More specifically for three climate and two intervention scenarios, the analytical framework is used to estimate the number of livestock-dependent households that could be lifted out of poverty by 2030. This analysis therefore consists of three complementary parts and corresponding estimates:

- The livestock population (numbers of cattle, sheep, goats, and camels) that can be fed on available feed resources on a year-round basis with and without mobility;

- The impact of different interventions and climate scenarios on production and greenhouse gas emissions (GHG); and
- Under different scenarios, the number of households that can be expected to meet the resilience level, or conversely, the number of households for which additional (for those who can stay) or alternative (for those are probably exiting or remain extreme poor) sources of income are needed.

Setting the Scene

Models Used

Five simulation models were used to estimate the impacts of the selected climate patterns and interventions on feed balances, livestock production, and household income resilience.

- The *BIOGENERATOR model* developed by *Action Contre la Faim* (ACF) uses the NDVI (Normalized Difference Vegetation Index) and DMP (Dry Matter Productivity) data products collected from Spot 4 and 5 satellites since 1998 (Ham and Filiol 2011). In this modeling exercise the model provides, on a pixel basis, the usable (that is, edible by livestock) biomass data of the natural vegetation of drylands;
- The *Global Livestock Environmental Assessment Model—GLEAM* developed by Gerber et al. (2013) calculates at pixel and aggregate level: (i) data on crop byproducts and crop residues' usability; (ii) livestock rations for the different types of animals and production systems, assuming animal requirements are first met by high-value feed components (crop byproducts if given, and crop residues), and then by natural vegetation; (iii) feed balances at pixel and aggregate level, assuming no mobility at pixel level and full mobility at grazing shed level; and (iv) GHG intensity;
- On the basis of the feed rations provided by GLEAM, the *IFPRI/IMPACT model*[3] developed by IFPRI calculates (in this exercise) the drylands' production of meat and milk and how they will affect overall supply of and demand for these products in the region. By taking the sum of animal production at the national level, the IMPACT model conforms with the boundaries of market exchange and price formation, normally harmonized with the Food and Agriculture Organization of the United Nations (FAO) food production and consumption balances;
- The *CIRAD/MMAGE model*[4] consists of a set of functions for simulating dynamics of animal populations that are categorized by sex and age class. In this exercise, it calculates the sex/age distribution of the four prevailing ruminant species (that is, cattle, camels, sheep, and goats), the feed requirements in dry matter, and milk and meat production; and
- The *ECO-RUM model*, developed by Centre de coopération internationale en recherche agronomique pour le développement, France (CIRAD) under

the umbrella of the African Livestock Platform (ALive), is an Excel-supported herd dynamic model based on the earlier International Livestock Research Institute (ILRI)/CIRAD DYNMOD.[5] The expansion concerns the socioeconomic effects of changes in the herd/flock's technical parameters (return on investments, herder household income, and contribution to its food security).

In addition, the modeling exercise benefitted from the outputs of the *FAO supply/demand* model[6] reported in Robinson and Pozzi (2011) and the livestock distribution data from the Gridded Livestock of the World (GLW) (Wint and Robinson 2007) and its most recent update GLW 2.0 (Robinson et al. 2014).

Figure 5.1 and table 5.1 illustrate how the various simulation models were applied. The top of the diagram shows how feed availability and feed requirements for the animals were assessed—with the combination of the BIOGENERATOR, GLEAM, and MMAGE models and various key datasets. For feed availability, the BIOGENERATOR model evaluated the total biomass from natural vegetative cover on the landscape of the drylands regions, and the

Figure 5.1 Models Used for the Livestock Systems Analysis

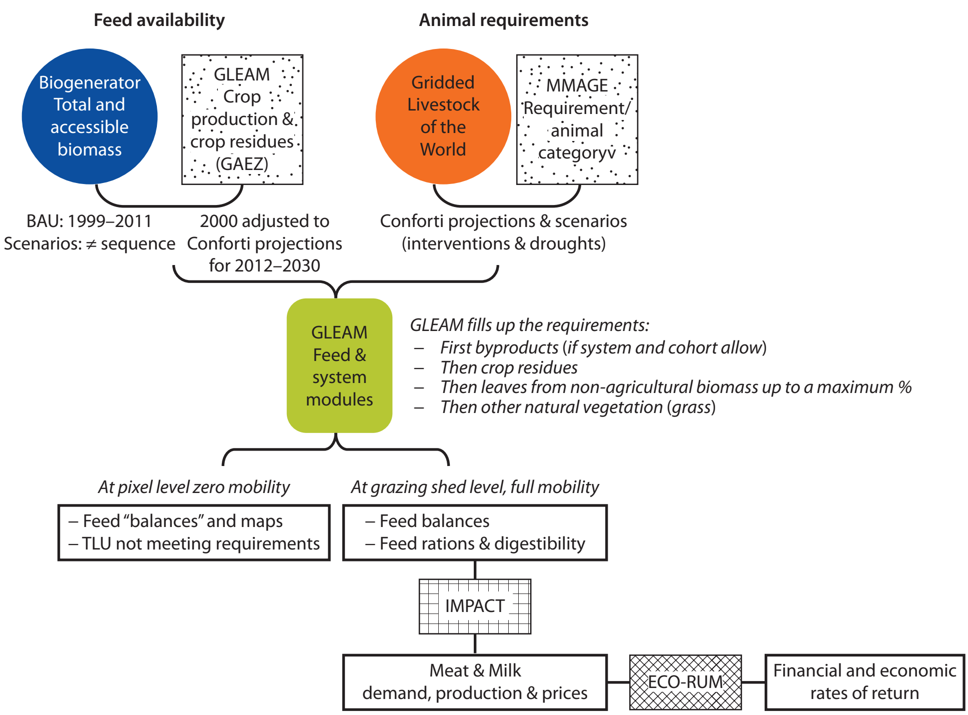


Table 5.1 Outputs of the Models Used in this Analysis

Model	*Feed Availability*	*Feed Requirements*	*Feed Balances and Feed Rations*	*Herd Performance and Animal Production*	*Income, Livelihoods Impacts (Costs and Benefits)*	*Supply, Demand, and Trade of Animal Products*	*GHG Intensities*
BIOGENERATOR	X						
GLEAM	X	X	X	X			X
MMAGE		X		X			
ECO-RUM		X		X	X		
IMPACT						X	

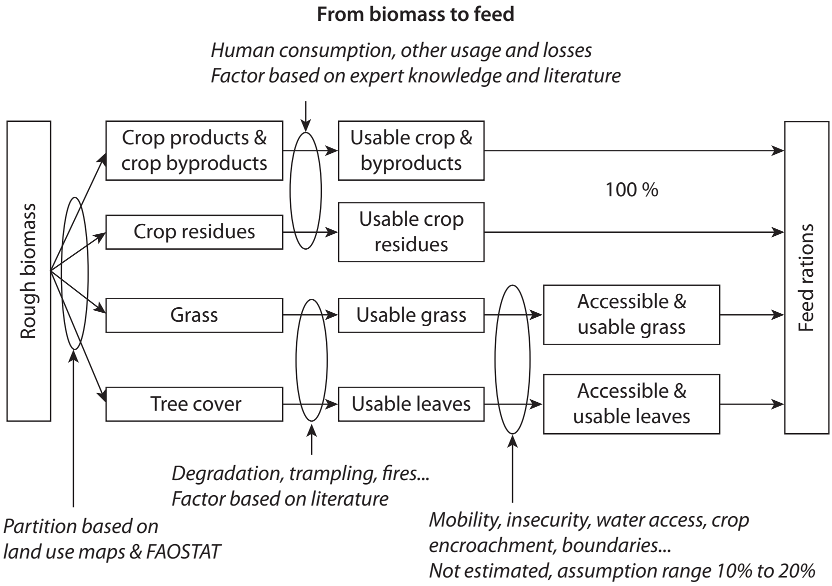
Notes: Cells marked with X show where a particular modeling tool generated an output used in the analysis. BIOGENERATOR provides biomass from vegetative cover. GLEAM provides agricultural biomass and what is usable from crop byproducts and crop residues. GLEAM calculates a feed "basket" for each animal species and category that is consistent with the livestock system type and what is available. GLEAM computes emission intensities within species, systems, and regions for the main sources of GHG along livestock supply chains. MMAGE projects the animal requirements implied by projected herd growth. MMAGE uses production projections to give demographic projections of the herd (age/sex breakdown), and both the implied feed requirements and meat/milk production. ECO-RUM is calibrated to match the herd performance and production trajectory of MMAGE. In addition, it calculates incomes at household level and the costs and benefits of various interventions. IMPACT reconciles supply with country-level demand to generate prices and trade. The results of FAO's Global Prospective Group (Conforti et al. 2011) are used as comparators. GHG = greenhouse gas emissions; GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations.

quantity of the overall total that is usable (that is, edible) to the ruminant animals in those regions. This assessment of feed availability from natural vegetative cover was complemented by the GLEAM model's assessment of feed available from crop residues, grain, and concentrates. These two sources combined were then compared with the assessment of animal feed requirements across the various livestock systems in the dryland region generated by the MMAGE model, as shown on the right-hand side of figure 5.1. The MMAGE model generated a forward-looking projection of animal numbers and production growth that was initially calibrated to FAO's long-term agricultural projections baseline to 2030, generated by Conforti (2011) and Alexandratos and Bruinsma (2012). This baseline was then modified according to the "best bet" intervention scenarios for the livestock sector—that is, improving animal health and adjusting herd demographics (through early offtake of male cattle for fattening in higher-rainfall areas).

Data Sources

Because of its importance in determining the viability of maintaining livestock production in dryland regions over time, major attention is paid to simulating on an annual basis for the 2012–30 period the volume and quality of local feed supplies and the degree to which they are expected to meet animals' requirements under different climatic and investment scenarios. Figure 5.2 provides a flow chart of the conversion of grass, trees, and crop biomass to usable and accessible feed for animals, including:

Figure 5.2 Stages in the Conversion of Drylands Vegetation to Livestock Feed Rations



- *From crops to crop byproducts* (such as cottonseed cake and brans*) and crop residues* (such as straw and stovers). Factors used are provided by GLEAM: the Mass Fraction Allocation and the feed use efficiency provide information for each feed component on the share of dry matter produced that is used for animal feed. Factors for the most common feeds are provided in appendix C.
- *From natural vegetation (trees and grass) to usable feed*, adjusting for losses due to trampling, fire, and poor palatability of standing vegetation. For this study, the usability factor used varied from 50 percent under Sahelian climate (north of 400 millimeter isohyets) to 30 percent under Sudanese climate (south of 600 millimeter isohyets). A progressive variation is set between 400–600 millimeter isohyets, following the annual rainfall quantity. These factors are based on data from the literature (de Ridder 1991; Toutain and Lhoste 1978).
- *From usable to accessible feed*, adjusting the usable feed quantity and quality to the inaccessibility of certain feed resources due to distance to water, conflicts, borders, and the heavy density of crop farms, all of which preclude passage. For example, the maximum distance that cattle can trek to a water point under an every second day watering regime in the dry season is about 25 kilometers (King 1983); any feed beyond this radius has to be excluded from the available feedstock. No data are available, however, on the share of drylands' natural rangelands that are out of this range. Regarding the water constraint, lacking are both a comprehensive overview of underground water sources (boreholes) and quantitative data on the period animals stay in a

particular area (at the pixel level) in the rainy season before they move towards higher rainfall areas. Given this lack of data on the degree of herd/flock mobility (that is, the share of the total year that animals are in any particular pixel), feed balances cannot be calculated at pixel level. Comparing the availability of local feed resources to animal requirements assuming—incorrectly—a complete absence of mobility can, however, highlight the extreme importance of mobility in the arid areas, as nowhere in these areas are local feed resources shown to be sufficient to feed the local animal stocks on a year-round basis. More research is required on the importance of the constraining factors to access eventual unused feed and the amounts available.

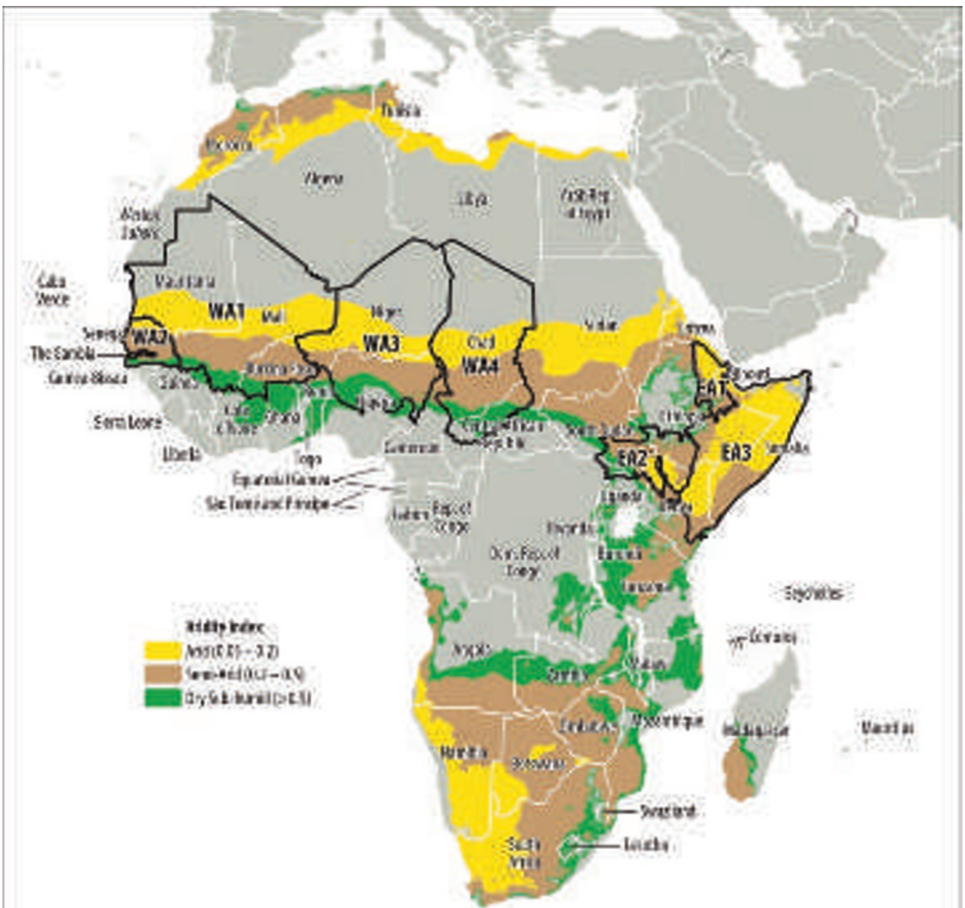
The modeling exercise used the following data:

- A time series of biomass availability was extracted from BIOGENERATOR at pixel level over the period 1998–2013;
- Livestock numbers per pixel assuming no movement outside that pixel were calculated using the GLW;[7]
- Livestock population dynamics for the different species and cohorts (adults, replacement, juveniles) were calculated using MMAGE for the period 1998–2011, using key technical performance parameters (fertility, mortality, milk yields, live-weight, offtake for the different age classes) collected through a major literature review and expert opinions at the Dakar experts' consultation;
- Scenarios for the assessment of future trends (2012–30) were defined as a combination of climatic patterns (no drought, mild drought, and severe drought) and management interventions (health improvement and early off-take of young bulls). The impact of these scenarios on livestock population dynamics was calculated by MMAGE;
- Using MMAGE animal numbers and requirements and BIOGENERATOR biomass availability, GLEAM computed feed requirements and agricultural and natural vegetation per pixel. Assuming no mobility, GLEAM estimates for each scenario the number of tropical livestock unit (TLU) per pixel and livestock production system for which local resources are not sufficient;
- Assuming full mobility of animals and feed resources within each grazing shed, feed rations and feed balances are calculated in GLEAM for each scenario and each production system. Animal requirements are met first by high-value feed components (crop byproducts if given, and crop residues), then by natural vegetation. Feed balances are calculated first in relative terms, using as reference the past sequence 1998–2011, and then in absolute terms assuming a range of 10–30 percent accessibility to natural vegetation[8,9];
- Production, demand, and price estimates for each scenario are provided by IMPACT; and
- ECO-RUM, using the MMAGE livestock numbers, validated with IMPACT outputs and projected meat and milk prices, calculates the financial and economic rates of return.

Level of Analysis

For the calculation of feed balances and feed rations, the definition of a geographical unit to aggregate the pixel-level information on feed availability and requirements received considerable attention. The geographical unit definition was based on animal mobility patterns (transhumance) (SIPSA 2012 and experts' consultation) and consisted of an area that would be self-contained in mobility to a significant degree; that is, used predominantly for transhumance by the same population and herds/flocks each year. These areas were named "grazing sheds" (map 5.1). They exist in a single country or a group of countries, or, where a particular country also covers non-drylands (Nigeria, Ethiopia, Kenya) they are defined by the limits of the sub-humid zones or the highlands. This

Map 5.1 Map of Grazing Sheds in the Drylands of West and East Africa



Source: World Bank based on data from HarvestChoice, IFPRI (2013).
Note: IFPRI = International Food Policy Research Institute; AI = aridity index.

approach enables presentation of areas where, without mobility, large feed deficits occur, whereas towards the higher-potential areas surpluses exists, even under severe drought conditions, thus highlighting the need for mobility or feed transport. Contrary to pixel level, feed balances at grazing shed level assume full mobility of feed resources and animals within each grazing shed.

Scenarios

Climatic Zones and Livestock Systems

As indicated in chapter 2, the Global AI[10] is adopted for the classification of climatic zones.[11] The limits of the different climatic zones are provided in table 5.2.

Livestock production is disaggregated into two main production systems in GLEAM, using the Sere and Steinfeld (1996) classification:

- Pastoral systems correspond to grassland-based systems (more than 90 percent of dry matter fed to animals comes from grasslands and rangelands, and more than 50 percent of household income is from livestock); and
- Agro-pastoral systems correspond to mixed systems (more than 10 percent of the dry matter fed to animals comes from crop byproducts or stubble and more than 10 percent of the total-value of production comes from non-livestock farming activities).

In 2002, Thornton and colleagues spatialized the Seré and Steinfeld classification and produced the first map of LPS for developing countries (Thornton et al. 2002). Land cover and agro-ecological parameters were used as proxy variables due to significant data limitations on the contribution made by livestock to incomes and rural livelihoods at a global scale. In essence, the presence of agriculture from land cover maps is associated with mixed crop-livestock systems, whereas land cover categories such as grasslands and shrub lands are called livestock-only systems.[12]

It is acknowledged that the land cover and climate disaggregation do not fully explain the functional interplay of the systems and actual land uses. In drylands, even otherwise "pure" pastoralists might engage in opportunistic cropping. The analysis at pixel level provides little information on the actual interrelationships

Table 5.2 AI Limits of the Climatic Zones Used in This Analysis

Zone	*AI Limits*
Hyper-arid	< 0.03
Arid	0.031–0.2
Semi-arid	0.21–0.5
Dry sub-humid	0.51–0.65

AI = (Global) Aridity Index.

between cropping and farming activities, for instance on the use of crop residues. However, at the larger scale used for this report, this classification and its spatial representation are considered adequate.

Climate Scenarios

The three different climate scenarios are defined on the basis of the standard deviation in NDVI, used as main proxy for variability in rainfall (Kawabata, Ichii, and Yamaguchi 2001). A simulated vegetation and associated rainfall pattern over the 2012–30 period (figure 5.3) was drawn from standard deviation intervals of the NDVI distribution over the period 1998–2013 as derived from remotely sensed data.[13] Table 5.3 gives the standard deviation intervals of the drought classification used in this analysis.

The three climate scenarios adopted for the livestock modeling exercise are:

- *Stable climate*, extending the known average weather pattern of 1998–2011 to the 2012–30 period;
- *Mild drought*, with 10 years of mild drought, 3 years of average rainfall, and 7 years of good rainfall; and
- *Severe drought*, with 3 years of severe drought, 7 years of mild drought, 3 years of average rainfall, and 7 years of good rainfall.

The health intervention simulates improved access to veterinary and vaccine services for all species and is modeled through changes in the main herd

Figure 5.3 Simulated Precipitation Patterns Used in This Analysis (Severe Drought Scenario)

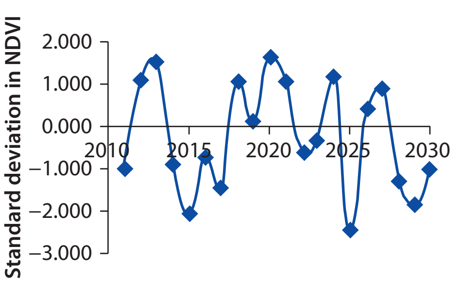
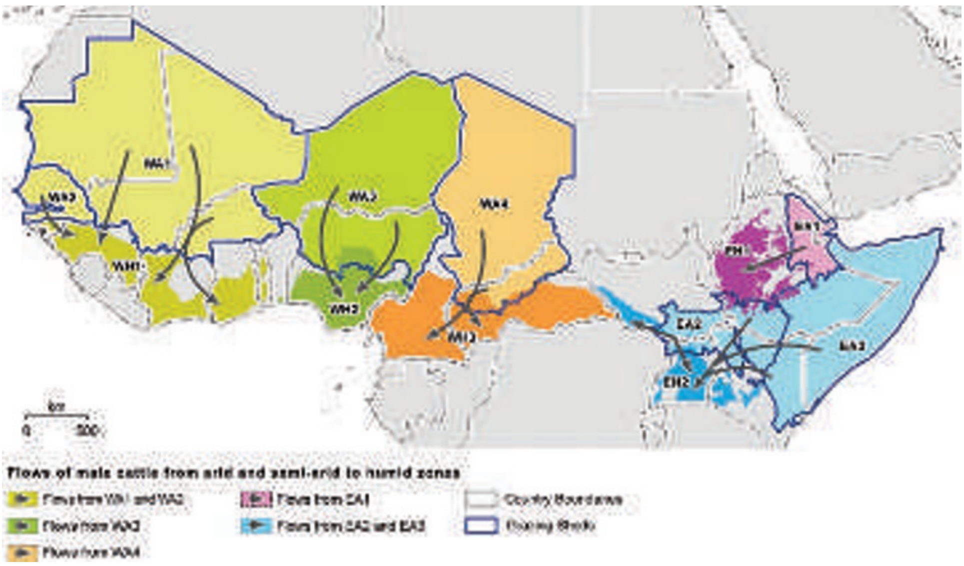


Table 5.3 Standard Deviation Intervals of the Drought Classification Used in This Analysis

Classification	*Sigma Lower End*	*Sigma Higher End*
Very good	2	+ ∞
Good	0.5	2
Average	–0.5	0.5
Mild	–2	–0.5
Severe	– ∞	–2

parameters (fertility and mortality rates). The early offtake models the early exit of young bulls (up to four years old) from herds in arid and semi-arid zones for fattening in areas with higher feed availability (humid areas in West Africa and highlands in East Africa). Based on the Information System on Pastoralism in the Sahel (SIPSA) Atlas and the Dakar workshop, movements were assumed to be as summarized in map 5.2:

Map 5.2 Simulated Movements of Male Cattle from Drylands to Humid Areas for Fattening



Source: FAO. Used with permission; further permission required for reuse.

Note: Simplified from SIPSA Atlas. SIPSA = Information System on Pastoralism in the Sahel.

Table 5.4 MMAGE Results for Animal Population Dynamics (Stock Variation + Offtake) Under Different Scenarios, 2011–30

	West Africa			*East Africa*		
	Cattle	*Goats*	*Sheep*	*Cattle*	*Goats*	*Sheep*
Climate scenario	(%)	(%)	(%)	(%)	(%)	(%)
Baseline	23	42	43	10	34	34
Mild drought	7	11	13	–5	10	10
Severe drought	–7	11	10	–17	9	7
Health intervention production	9	36	29	10	20	12
Impact of early offtake on production within drylands area *(Modeled for cattle only. Early offtake and fattening of sheep and goats in the higher potential area is technically not feasible.)*	3	n.a.	n.a.	6	n.a.	n.a.

Source: Dakar Consultation CIRAD Mega Literature Review.
Note: n.a. = not applicable. Above inputs specifically prepared for this study and are unpublished. Results on increased production in higher-potential areas (humid areas and highlands) due to fattening of additional young bulls are in table 5.8 and section Macroeconomic Implications. CIRAD = Centre de coopération internationale en recherche agronomique pour le développement (France).

Biophysical Modeling

Livestock Population Dynamics

Results of population dynamics from MMAGE are presented in table 5.4. Cattle population growth rates are significantly affected by severe drought (–7 percent and –17 percent, respectively, in West Africa and East Africa) and by mild drought (–7 percent and –5 percent), though to a lesser extent. Small ruminants appear to be less affected by drought in both regions.

Health interventions result in increased animal numbers for production (stock variation + offtake) in both regions, and are more efficient for small ruminants. These results are consistent with the greater prevalence of animal health improvement campaigns for small ruminants (sheep deworming, for example) than for cattle.

Feed Availability, Animal Requirements, and the Need for Animal Mobility

The main results on the variability of feed availability and animal requirements are summarized in table 5.5 and in Tables F.1–F.3 in appendix F. The baseline is illustrated in map 5.3. Maps for other scenarios can be found in appendix D.

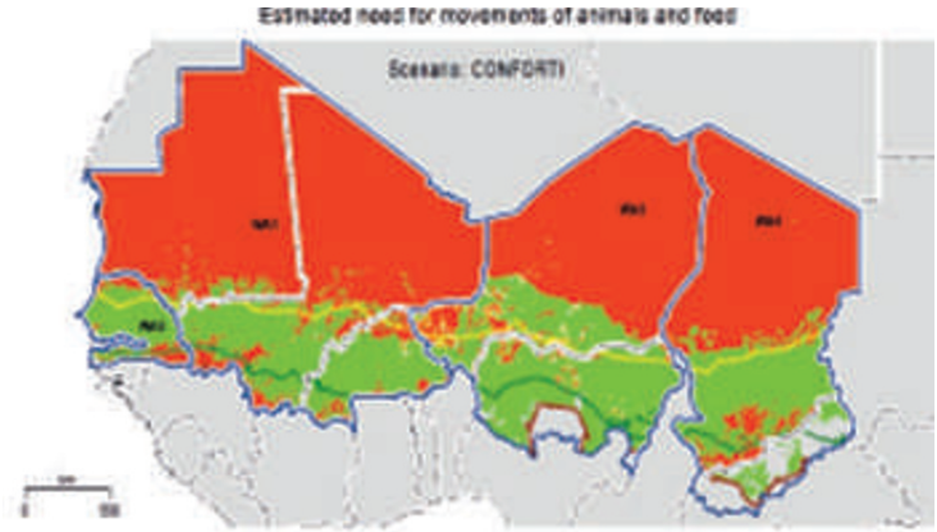
As expected, drought events increase the proportion of animals located in areas where local resources are insufficient to meet their requirements. Likewise, the share of TLU for which local feed resources are insufficient to meet the animal

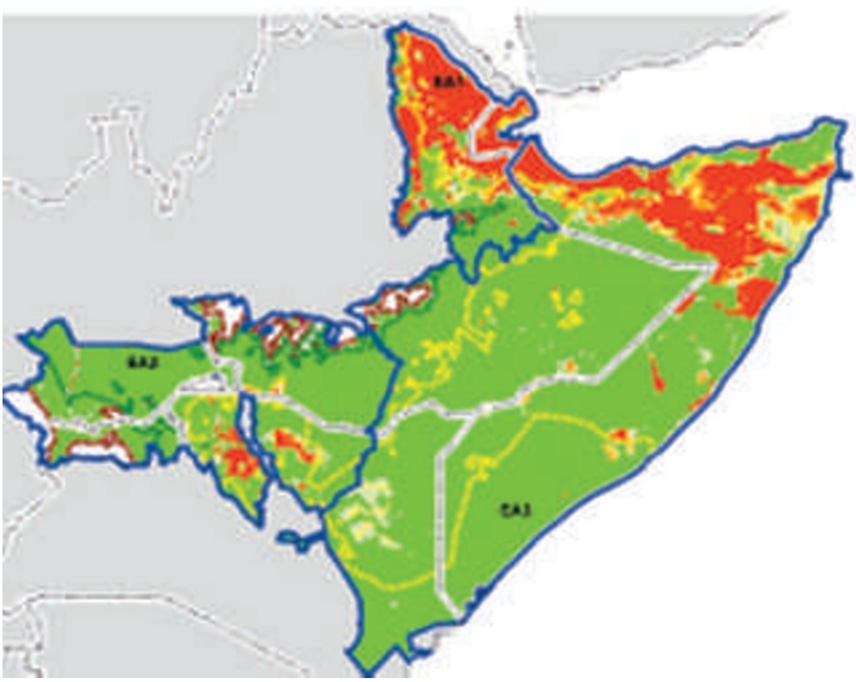
Table 5.5 Effects of Droughts and Interventions on Feed Availability and Animal Requirements, No Movement of Animal or Feed, 2012–30

	Past Sequence	*Baseline*	*Mild Drought*	*Severe Drought*	*Mild Drought Plus Health*	*Severe Drought Plus Health*	*Severe Drought Plus Health Plus Early Offtake of Males*
West Africa arid (AI 0.03–0.2)							
TLU (million)	20.5	27.9	26.6	24.4	28.7	26.2	24.8
TLU in deficit area (%)	2.7	20.2	22.9	22.5	23.5	23.8	24.3
West Africa semi-arid (AI 0.21–0.5)							
TLU (million)	24.1	31.9	30.3	27.5	33.0	30.1	28.0
TLU in deficit area (%)	2.7	6.6	9.3	11.0	13.1	16.2	13.0
East Africa arid (AI 0.03–0.2)							
TLU (million)	32.3	39.6	37.9	35.9	40.9	38.7	37.6
TLU in deficit area (%)	14.6	18.9	20.9	25.3	22.1	26.9	28.3
East Africa semi-arid (AI 0.21–0.5)							
TLU (million)	42.1	49.3	47.1	43.3	49.9	45.9	43.5
TLU in deficit area (%)	9.4	10.4	10.0	12.2	10.7	12.5	10.9

Source: Based on data from FAO/GLEAM.
Note: GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations; TLU = tropical livestock unit; AI = (Global) Aridity Index.

Map 5.3 Spatial Modeling of the Estimated Need for Movement of Animals and Feed in the Baseline and the Drought + Health + Offtake Scenarios in West African Grazing Sheds





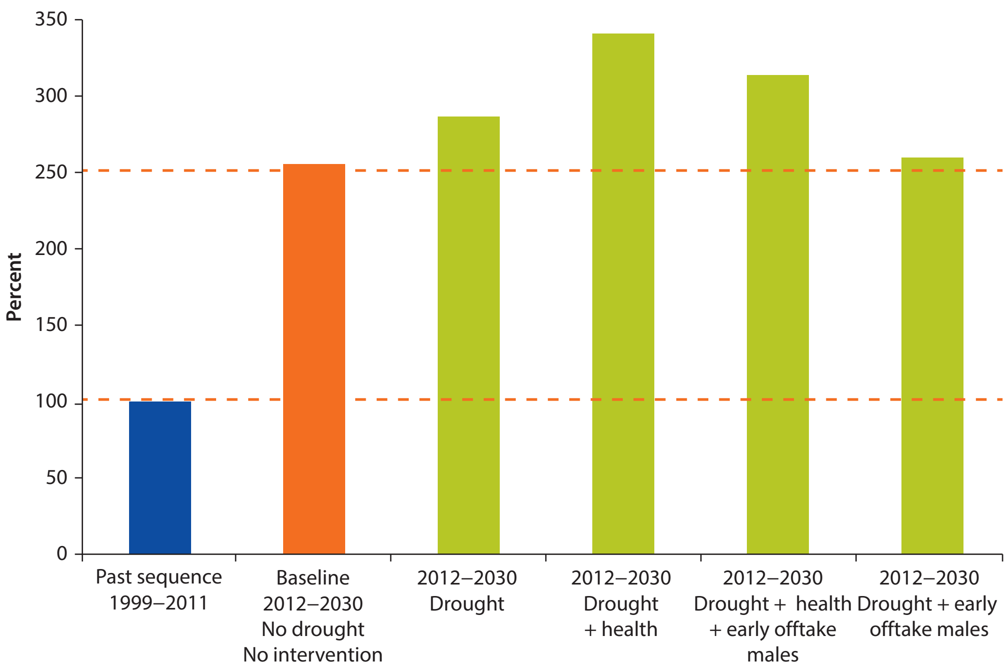
Source: FAO/GLEAM.
Note: GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations.

requirements increase with health interventions due to the relative improvement in fertility and mortality rates and thus in overall animal numbers compared to the same climatic scenarios without intervention. In West Africa, health interventions increase the share of TLU for which local resources cannot meet requirements without mobility of animals or feed by 4 percent in arid zones and 20 percent in semi-arid zones. A similar decrease is observed in East African drylands. There is little difference between the zones in the health intervention effect.

Map 5.3 reveals specific areas where local resources do not meet animal requirements, that is, where there is a need for mobility of animal or feed, for the baseline and for the drought plus health plus early offtake scenario. This can support the targeting of intervention for increased feed accessibility. Maps for the other scenarios can be found in the technical report.

The relative merits of the different policies to reduce feed deficit are summarized in figure 5.4 for the drylands of West Africa and East Africa. The index of animals in deficit of local resources (on average for 2012–30) measures the TLU located in areas where feed resources are insufficient, using the sequence 1998–2011 as the baseline (=100). Values above 100 indicate an increased need for mobility compared to the past sequence to close the feed gap. In case of a severe drought in the future, early offtake of male cattle would bring the index of animals in deficit close to a "no intervention" scenario, whereas adding health improvements would only worsen the feed deficit.

Figure 5.4 Index of Animals in Deficit of Local Resources, West and East Africa, 2012–30



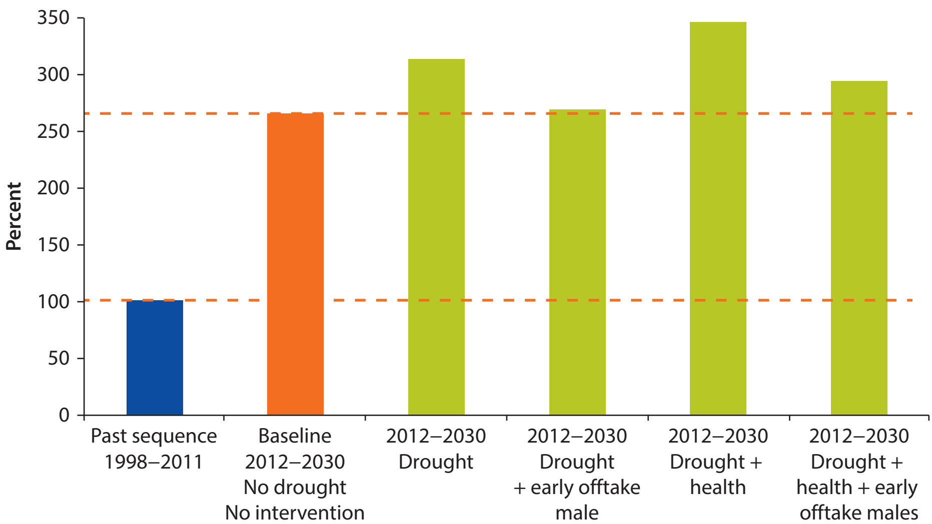
Feed Balances and Feed Rations at Grazing Shed Level

Feed balances were calculated assuming full mobility of animal and feed within grazing sheds. Since little information is available on natural vegetation accessibility, the results are expressed: (i) in relative terms by comparing the average annual balance of each 2012–30 scenario to the balance of the past sequence of 1998–2011; and (ii) in absolute terms by assuming a range of 10–30 percent accessibility to natural vegetation. Relative balances per grazing shed and feed component are presented in appendix E and summarized in figure 5.5.

In the whole of the drylands, the feed balance assuming full animal and feed mobility within each grazing shed would increase from 6 percent of the usable biomass under the past sequence to 15 percent under the future baseline scenario; that is, a 2.5-fold increase. These projections of animal populations and crop production, without drought or interventions, predict the use of about 2.5 times more usable biomass than in the past.

In the severe drought scenario, livestock would use three times as much usable biomass as in the past, whereas adding an early offtake of males results in the same balance as in the baseline without drought. The highest balance is with drought + health intervention, which results in both a decreased amount of usable biomass and an increased number of animals compared to drought only: this scenario results in a use of 3.5 times as much usable biomass than in the past.

Figure 5.5 Feed Deficit Assuming Full Animal and Feed Mobility within Grazing Sheds, East and West Africa Drylands, 2012–30



Source: FAO/GLEAM.
Note: GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations.

Results of absolute feed balances (summarized in table 5.7; details per grazing shed are in appendix F) indicate that resources seem to be sufficient in all scenarios starting with 20 percent accessibility to natural vegetation. With only 10 percent accessibility to natural vegetation, the deficit in feed reaches 4 percent in the drought + early male offtake scenario. Given the assumptions on feed baskets, the absolute feed balances also seem to reveal an excess of crop byproducts in West Africa. This reflects the fact that a significant share of usable byproducts produced in the area is exported to peri-urban areas, as confirmed during the Dakar workshop.

Results also indicate that the earlier assumptions on the contribution of crop residues to the feed baskets in West Africa may have been too low, since an excess of crop residues was observed in most grazing sheds of West Africa. This was corrected and all crop residues accessible were modeled as consumed, as reported in table 5.6.

Table 5.6 Feed Balances Assuming Full Mobility and 10–30 percent Accessibility to Natural Vegetation

		Balance Accessibility 10%	*Balance Accessibility 20%*	*Balance Accessibility 30%*
Past reference	Crops + byproducts	100	100	100
	Crop residues	100	100	100
	Natural vegetation	95	85	75
	Total	95	85	74
Baseline	Crops + byproducts	46	46	46
	Crop residues	100	100	100
	Natural vegetation	106	96	86
	Total	101	91	82
Drought	Crops + byproducts	56	56	56
	Crop residues	100	100	100
	Natural vegetation	109	99	89
	Total	102	93	83
Drought plus male offtake	Crops + byproducts	39	39	39
	Crop residues	100	100	100
	Natural vegetation	108	98	88
	Total	99	90	81
Drought plus health	Crops + byproducts	62	62	62
	Crop residues	100	100	100
	Natural vegetation	111	101	91
	Total	104	95	85
Drought plus health plus male offtake	Crops + byproducts	39	39	39
	Crop residues	100	100	100
	Natural vegetation	109	99	89
	Total	101	91	82

table continues next page

Table 5.6 Feed Balances Assuming Full Mobility and 10–30 percent Accessibility to Natural Vegetation *(continued)*

		Balance Accessibility 10%	*Balance Accessibility 20%*	*Balance Accessibility 30%*
Mild drought	Crops + byproducts	61	61	61
	Crop residues	100	100	100
	Natural vegetation	109	99	89
	Total	102	93	84
Mild drought plus health	Crops + byproducts	68	68	68
	Crop residues	100	100	100
	Natural vegetation	111	101	91
	Total	105	95	86

Source: FAO/GLEAM.
Note: When there are not enough usable crop byproducts, the balance is 100 percent and the remaining requirements are added to those in crop residues. When there are not enough usable crop residues, the balance is 100 percent and the remaining requirements are added to those in natural vegetation. When there is not enough natural vegetation, the balance is > 100 percent, indicating a deficit in feed. GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations.

The detailed balances per grazing shed (appendix F) indicate that WA1[14] (Mali, Mauritania, and western Burkina Faso) and EA1&3 ((northern) Ethiopia and Somalia) are the areas where most deficit can be found.

In the early-offtake-of-males scenarios, male cattle were modeled to be fattened for approximately four months on a basic feed ration of brans, cakes, molasses, and crop residues. In West Africa, the modeled ration was 75 percent crop residues and 25 percent byproducts and fodder crops. In East Africa, the modeled ration was 50 percent crop residues and 50 percent byproducts and fodder crops (Abate et al. 2012; Drabo 2011; Sidibé 2006; Mlote et al. 2012). Table 5.7 presents the summary of outputs by grazing shed.

Though the early offtake of males significantly reduces the pressure on feed resources within drylands, the impact on humid areas is quite high. It results in additional requirements ranging from 4 to 7 percent in most fattening areas, given the assumptions made on the animals' fattening rations. The impact on crop byproducts is higher, around 15 percent of availability in the humid zones. In fattening area EH2 (humid areas of South Sudan and Kenya), fattening bulls from the drylands of East Africa would use about one-quarter of local agricultural biomass.

Total meat production and dry matter requirements for the different scenarios are presented in table 5.8 for all species, including the increase in meat supply due to males fattening in humid areas. Whereas drought reduces average annual meat production by 14 percent in drylands, health interventions seem to restore the baseline level of production while early offtake of males increases production by 5 percent. Coupling male early offtake and health intervention results in a 20 percent increase in average annual meat output. But this scenario requires an additional 7.1 million metric tons (MT) of biomass from humid areas, as modeled in this study.

Table 5.7 Outputs by Grazing Shed for Early Offtake Scenarios

	Drought + Male					*Drought + Health + Male*				
	WH1	*WH2*	*WH3*	*EH1*	*EH2*	*WH1*	*WH2*	*WH3*	*EH1*	*EH2*
Extra male cattle (1,000 head)	1,473	1,621	515	950	2,703	1,541	1,713	549	1,005	2,883
Initial live weight (kg)	297	297	297	264	264	297	297	297	264	264
Daily intake crops + byproducts (kg DM)	2.0	2.0	2.0	3.7	3.7	2.0	2.0	2.0	3.7	3.7
Daily intake crop residues (kg DM)	6.1	6.1	6.1	3.7	3.7	6.1	6.1	6.1	3.7	3.7
Use of usable agricultural biomass	5%	4%	6%	7%	24%	5%	4%	6%	7%	23%
of which crops + byproducts	16%	14%	14%	17%	67%	17%	14%	15%	16%	63%
of which crop residues	4%	3%	5%	4%	8%	4%	3%	5%	4%	14%
Modeled Daily Weight Gain (DWG)(kg/day)	1.0	1.0	1.0	0.6	0.9	1.0	1.0	1.0	0.6	0.9
Modeled live exit weight (kg)	415	416	415	338	376	415	416	415	338	376
Modeled extra meat (1,000 MT carcass weight)	287	317	100	151	478	301	335	107	160	510

Source: Based on data from FAO/GLEAM.
Note: GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations; MT = metric ton; DM = dry matter.

Table 5.8 Outputs for the Different Intervention Scenarios Compared to Baseline

Scenarios	*Production*	*Fattened Males*	*Productivity (Animals Sold per 1000 TLU)*	*Dry Matter Requirement Drylands*	*Extra Dry Matter Requirements Humid Areas*	*Total Meat Production Drylands*	*Total Meat Production Incl. Fattened Males*
Baseline (Conforti 2011)	37 million TLU	–	25%	428 million t	–	4.4 million tcw	4.4 million tcw
Drought	−14%	–	−2%	−26%	–	−14%	−14%
Drought plus health	1%	–	6%	−4%	–	1%	1%
Drought plus male offtake	−26%	7.7 million TLU	13%	−27%	6.8 million MT	−26%	5%
Drought plus health plus male offtake	−12%	9.3 million TLU	25%	−21%	7.1 million MT	−12%	20%
Mild drought	−8%	n.a.	−3%	−4%	n.a.	−8%	−8%
Mild drought plus health	7%	n.a.	4%	3%	n.a.	7%	7%

Source: Based on data from FAO/GLEAM.
Note: n.a. = not applicable. GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations; TLU = tropical livestock unit; MT = metric ton; tcw = ton carcass weight.

These results indicate that at the grazing shed level, there seems to be enough biomass to enable livestock sector growth (independent of the livelihood criteria introduced in section Macroeconomic Implications)—about 60 percent compared to the past sequence in the drought + health + early offtake of males scenario—if it can be made accessible to livestock. Nevertheless, the situation appears more critical in three of the seven grazing sheds: Mauritania and Mali (WA1), northern Ethiopia (EA1), and Somalia (EA3).

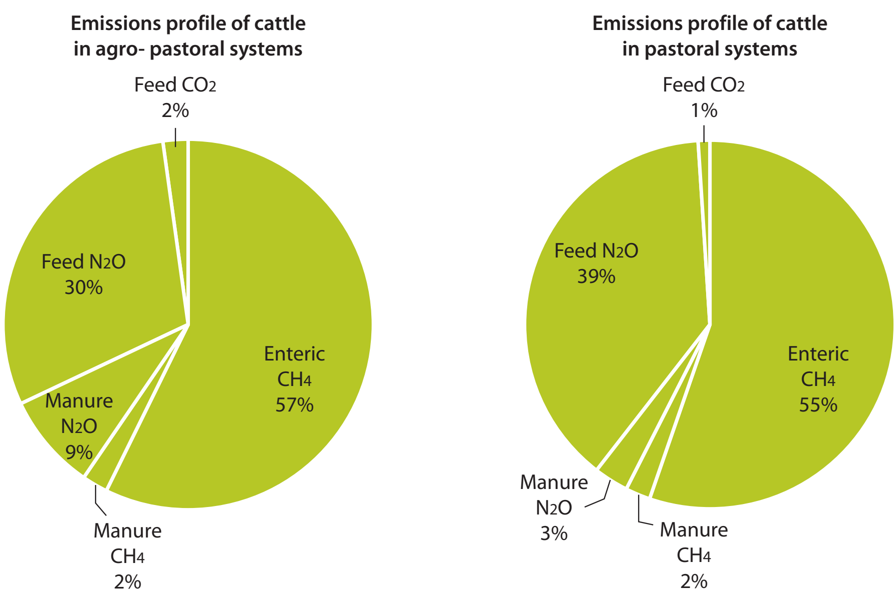
GHG Intensities

Greenhouse gas emissions from livestock production in the drylands were computed in GLEAM. GLEAM uses IPCC (2006) Tier 2 methodology to calculate emissions from enteric fermentation and manure management. In this assessment, using a lifecycle assessment approach, GLEAM considered two main groups of emissions along production chains. Upstream emissions include those related to feed production, processing, and transportation. Animal production emissions comprise emissions from enteric fermentation, manure management, and on-farm energy use. The model covers emissions of methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O). GLEAM's structure consists of five main modules: herd, manure, feed, system, and allocation.

Total GHG from ruminants in African drylands are estimated to reach 1.15 million MT per year as an average over the baseline scenario. Emissions from cattle represent 90 percent of the total (from 78 percent in the grazing shed of Somalia and southern Ethiopia to 97 percent in the grazing shed of Chad).

Enteric methane is the most important source of GHG, accounting for 55 percent of total emissions in pastoral systems and 55 percent in agro-pastoral systems (figure 5.6). This share reaches 66 percent in the pastoral systems of Somalia, Ethiopia, and South Sudan. The second most important source of emissions is N_2O from feed production (deposition or application of manure on crop fields and pastures and crop residue decomposition). It accounts for 41 percent of emissions in pastoral systems and 32 percent in agro-pastoral systems.

Figure 5.6 GHG Profiles for Cattle by Production System, SSA Drylands



Source: Based on data from FAO/GLEAM.
Note: SSA = Sub-Saharan Africa; GHG = greenhouse gas emissions; GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations.

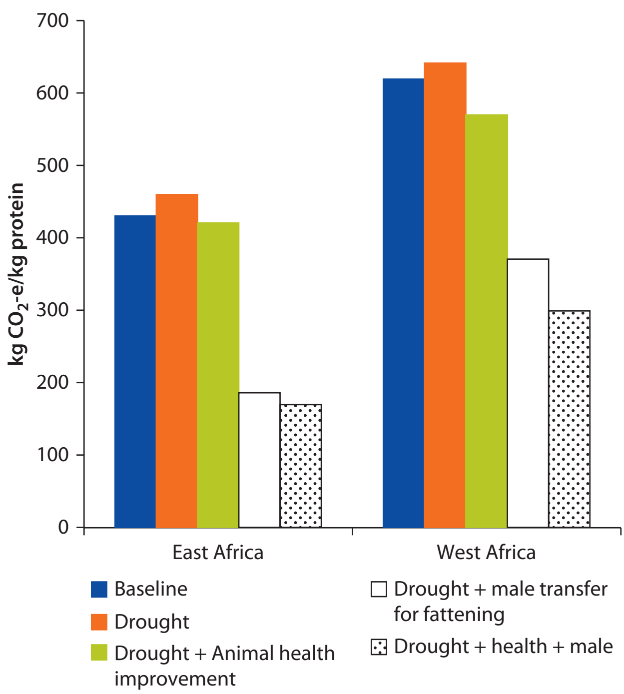
In the baseline scenario, emission intensities range from 423 to 667 kilograms CO_2-e per kilogram protein (figure 5.7). This variability reflects the composition of the ruminant herd and the different levels of milk production: in grazing sheds where milk production is important, total emissions are allocated to a higher amount of protein produced (in Ethiopia but also in Senegal, for example).

Emission intensities are increased by drought. Health interventions tend to reduce emission intensities in all grazing sheds since they reduce mortality rates and therefore the unproductive overhead feed consumption of the herd. But the most significant scenario in terms of GHG reduction is from early offtake of males: males fattened in higher-potential areas have a lower emission intensity than those in drylands since they receive higher-quality feed and are slaughtered at a heavier weight.

Macroeconomic Implications

Supply and demand of meat and milk produced in the drylands of Africa, as well as their prices, differ under the various scenarios. The IMPACT model was used to explore the likely impacts of some of the scenarios on key macroeconomic

Figure 5.7 GHG Profiles for Cattle by Intervention Scenario, SSA Drylands



Source: FAO/GLEAM.
Note: SSA = Sub-Saharan Africa; GHG = greenhouse gas emissions; GLEAM = Global Livestock Environmental Assessment Model; FAO = Food and Agriculture Organization of the United Nations.

parameters. The IMPACT model is a global model that calculates supply, demand, and trade at the national level. As such, it aggregates over some of the subregions of the West and East African countries that fall into the "dryland" categories to calculate the overall country-level market balance and trade with the rest of the world. In the case of Africa, each country is individually represented in the model, with some subnational disaggregation—although this does not necessarily coincide with the drylands boundaries.[15] For the purposes of this study, the definition of LPS was aligned to match those used by the other models, such as GLEAM.[16] IMPACT uses the changes in livestock numbers simulated by the MMAGE model and calculates the corresponding changes in per animal productivity according to the variation in feed availability calculated by GLEAM. The resulting changes in prices, country-level trade, and country-level demand for livestock products are therefore affected by these scenario-based changes in supply, as shown below. Results for meat supply, demand, and prices are shown in table 5.9. Results for milk are shown in table 5.10. The results are reported in terms of five-year averages taken over the yearly simulation results of the model.

These results show that drought has the expected effect of dampening the supply of both meat and milk in West and East Africa. The resulting price changes are quite small under these scenarios—making the changes in demand seem much smaller than the changes occurring on the supply side. This is due to the fact that all livestock products are modeled as being tradable on the international market, which makes the effects observed at the country level relatively small with respect to the size of the wider market. Therefore, the scenario-driven changes in supply are mostly translated into changes in the net balance of supply over demand (that is, net exports) in each region. This means that trade dampens the impacts of these scenarios, which is not always applicable to subregions of the countries where drylands are found. This points to an aspect of IMPACT's structure (as a global rather than a regional model) that may understate the real impact of these scenarios.

Both West and East Africa have a negative net balance (deficit) for meat that increases under the drought scenario and returns closer to the baseline with the health intervention. In the case of milk, East Africa has a positive net balance (that is, a surplus) that decreases under the severe drought scenario, but still remains positive overall. West Africa, by contrast, maintains a net negative balance of milk that becomes slightly more negative under the drought scenario. While in principle East Africa could supply West Africa in dairy, transport and technical barriers probably mean that both regions will have to continue to rely on external suppliers.

In these scenarios, growth in population and income, the main drivers of demand for livestock products, are held constant, so all of the impacts shown are driven by supply-side shocks.

Table 5.9 Impact of Different Scenarios on Meat Supply/Demand, 2006–11 and 2026–30

	Average Annual Red Meat Demand 2006–11 (Million MT)	*Average Annual Red Meat Supply 2006–11 (Million MT)*	*Net Annual Average Balance 2006–11 (Million MT)*	*Average Meat Price 2006–11 ($/MT)*	*Average Annual Red Meat Demand 2026–30 (Million MT)*	*Average Annual Red Meat Supply 2026–30 (Million MT)*	*Net Annual Average Balance 2026–30 (Million MT)*	*Average Meat Price 2026–30 ($/MT)*
West Africa drylands areas								
Baseline	1.57	1.30	–0.27	1,685	3.58	2.82	–0.76	2,133
Severe drought	1.57	1.29	–0.28	1,685	3.57	2.64	–0.93	2,140
Severe drought plus health intervention	1.57	1.29	–0.27	1,686	3.57	2.65	–0.92	2,143
East Africa drylands areas								
Baseline	1.92	1.54	–0.37	1,622	4.23	3.28	–0.95	2,043
Severe drought	1.92	1.56	–0.36	1,623	4.22	3.20	–1.02	2,049

Source: IMPACT model.
Note: MT = metric ton.

Table 5.10 Impact of Different Scenarios on Milk Supply/Demand, 2006–11 and 2026–30

	Average Annual Milk Demand 2006–11 (Million MT)	*Average Annual Milk Supply 2006–11 (Million MT)*	*Net Annual Average Balance 2006–11 (Million MT)*	*Average Milk Price 2006–11 ($/MT)*	*Average Annual Milk Demand 2026–30 (Million MT)*	*Average Annual Milk Supply 2026–30 (Million MT)*	*Net Annual Average Balance 2026–30 (Million MT)*	*Average Milk Price 2026–30 ($/MT)*
West Africa drylands areas								
Baseline	3.54	2.5	–1.04	153	7.22	4.41	–2.81	159
Severe drought	3.54	2.44	–1.1	153	7.21	4.1	–3.11	159
Severe drought + health intervention	3.54	2.46	–1.07	153	7.21	4.11	–3.1	159
East Africa drylands areas								
Baseline	12.17	16	3.84	149	19.57	24.18	4.62	154
Severe drought	12.16	15.74	3.59	149	19.52	23.25	3.73	154
Severe drought + health intervention	12.16	15.79	3.63	149	19.52	23.24	3.72	154

Source: IMPACT model.
Note: MT = metric ton.

Table 5.11 Summary of Definitions and Assumptions Used in the Livelihoods Modeling

	Definitions		
	Source	*Values Used*	*Comments*
Resilience level		Average US$1.25 per capita per day over 2011–30 period	
Income from livestock		70% in pastoral households; 35% in agro-pastoral households	Outside source of income in line with literature
Interventions tested		Health improvement of all stock except camels and early offtake for fattening of male cattle outside drylands	
Climate scenarios included		Baseline (no drought) and severe drought (3 years with –2 times standard deviation (Δ and 7 years with –1 Δ precipitation)	
Countries covered		Burkina Faso, Chad, Ethiopia, Kenya, Mali, Mauritania, Niger, northern Nigeria, Senegal, and Uganda	Selection based on data availability
Livestock systems and agro-ecological zones		Arid equals pastoral system (more than 50% income from livestock and 90% of feed from range) and semi-arid and sub-humid equal agro-pastoralism (less than 50% income from livestock and at least 10% of feed from crop residues)	
Drivers, assumptions, and values used			
Population growth	UN and World Bank	3% per year pastoral population and 2.5% per year for agro-pastoralists; household size of 6	Driven by fertility and GDP growth/exit correlation
Minimum livestock ownership to reach resilience level	ECO-RUM model	**Baseline weather scenario (TLU)** Intervention: None / Health improvement / Health improvement plus early offtake of male cattle Pastoralists: 14.8 / 11.5 / 11.0 Agro-pastoralists: 9.0 / 5.3 / 5.2	Based on technical parameters and incremental costs and benefits for interventions tested as defined by scientific consultation. Assumes on a TLU basis a 50% cattle–25% sheep–25% goat herd composition. TLU is defined as a camel equivalent of 0.7, cattle 0.6, and shoats 0.1

The nested values in the last row are set out here as a separate table:

Intervention	None	Health improvement	Health improvement plus early offtake of male cattle
Pastoralists	14.8	11.5	11.0
Agro-pastoralists	9.0	5.3	5.2

table continues next page

Table 5.11 Summary of Definitions and Assumptions Used in the Livelihoods Modeling *(continued)*

	Definitions						
	Source	*Values Used*					*Comments*
		Severe drought scenario (TLU)					
		Pastoralists	17.4	13.6		13.1	
		Agro-pastoralists	10.7	6.0		6.0	
		Livestock ownership top 1% (in TLU) of livestock-keeping households (%)					
Asset distribution	SHIP survey and rural Gini's and MMAGE for 2030	Burkina Faso	9	Mauritania	17		Countries covered by SHIP: Burkina Faso (2003), Niger (2007), Nigeria (2004), Ethiopia (2011), and Kenya (2005). Asset distribution follows log normal. Assumes that 2030 asset distribution equals 2010 figures
		Chad	23	Niger	17		
		Ethiopia	11	Nigeria	26		
		Kenya	28	Senegal	25		
		Mali	12	Uganda	10		
Feed availability	BIOGENERATOR and GLEAM	Usable (edible) biomass from satellite data (1998–2011), ground truth, and BIOGENERATOR model accessible equals 30 percent of accessible. Severe drought is 90% of mild drought satellite data. Average consumption 2.3 MT/TLU/year					

Note: TLU = tropical livestock unit; MT = metric ton. Δ = standard deviation.

Livelihoods

Introduction and Overview of the Approach

This section provides estimates of vulnerability levels of the livestock-keeping population under different climate, technology, and policy assumptions, one of the key aims of this study. Table 5.11 summarizes the main definitions and assumptions used in these calculations.

Initial calculations clearly show that the feed resources are insufficient to sustain the number of livestock needed to provide all households in 2030 with holdings above the resilience level. Assuming that only households with stock numbers above the resilience level would remain means that large numbers of households would have zero feed resources. Therefore, three groups were distinguished in the modeling:

- "Resilient" households: those households fully meeting the resilience level;
- "Vulnerable" households: those remaining below the income poverty line but with enough livestock to at least meet about half the resilience level. This group would remain vulnerable, but would have at least some assets to buffer shocks. To be fully resilient, this group will require *additional* sources of income; and
- "Potential exits or extremely poor (pushed out in the graphs)": those households with such limited livestock resources that they will be pushed out of the sector and will either find *alternative* sources of income or become permanently food aid-dependent.

The calculations then seek to balance feed and animal resources with income requirements, as demonstrated in table 5.12 for the pastoral system in Burkina Faso.

Results for 2010

Figures 5.8 and 5.9 illustrate the results for 2010. They show that only 23 percent of pastoral households and 34 percent of agro-pastoral households have livestock holdings that provide an income above the poverty line (assuming that 70 percent and 35 percent of income comes from livestock in the respective systems).

The differences between regions and countries are striking: the East African countries are generally better off; in West Africa, Burkina Faso, Mauritania, and Niger have a particularly high incidence of households with livestock holdings below the resilience threshold.

Figure 5.9 demonstrates for 2010 the shares of resilient, vulnerable, and potential exits households under different exit threshold scenarios. If the exit threshold increases from 1 TLU to 5 TLU per family, the number of vulnerable households decreases from 55 to 27 percent, whereas the number of pushed out households more than triples, from 12 to 40 percent. The exact exit threshold to

Table 5.12 Feed Ceilings Under Different Climatic Conditions, Burkina Faso, 2011 and 2030

2011		*2030*		
	Baseline Weather		*Baseline Weather*	*Severe Drought*
Total households	26,324	**Total households**	38,501	38,051
Resilient share	18%	**Resilient share**	10%	2%
Total households resilient	4,641	**Total households resilient**	3,697	691
Total biomass	582,000	**Total biomass**	582,000	308,735
Total TLU based on average feed for 2011–30	407,008	**Total TLU based on average feed for 2011–30**	253,043	134,233
TLU share in resilient households	53%	**TLU share in resilient households**	38%	14%
TLU in resilient households	214,991	**TLU in resilient households**	96,927	18,423
Biomass equivalent	494,480	**Biomass equivalent**	222,931	42,373
Remaining biomass	87,520	**Remaining biomass**	359,069	266,362
TLU supported by remaining biomass	38,052	**TLU supported by remaining biomass**	156,117	115,810
Average TLU of remaining vulnerable households	14.77	**Average TLU of remaining vulnerable households**	4.544	3.100
Household equivalents	2,576	**Exit TLU threshold**	5	3.63
Households that can be maintained above resilience level	7,217 (27%)	**Share of households below exit threshold**	72.4%	87.3%
Households with zero feed	19,106 (73%)	**Households pushed out**	24,883 (65%)	32,606 (86%)
Share of households below exit threshold	44%	**Final remaining vulnerable households**	9,471 (25%)	4,753 (12%)
Resilient households	4,640	**Resilient households**	3,697 (25%)	691 (2%)
Dropout households	11,599	**Dropout households**		
Vulnerable households	10,124	**Vulnerable households**		

Note: TLU = tropical livestock unit.

aim for will depend largely on country-specific conditions, whereby the existing ratio among the three groups, the expected absorptive capacity of the manufacturing and service sectors, and available funds to provide additional income sources for vulnerable households are important criteria.

Results for 2030

The key message for 2030 is that given the major population growth occurring across Africa, a "business as usual" approach will lead to large numbers of "likely dropouts;" that is, those households with fewer than 5 TLU. As shown in figure 5.10, the risk of this is particularly high in pastoral systems (77 percent),

Figure 5.8 Share of Households Above the Resilience Threshold, 2010

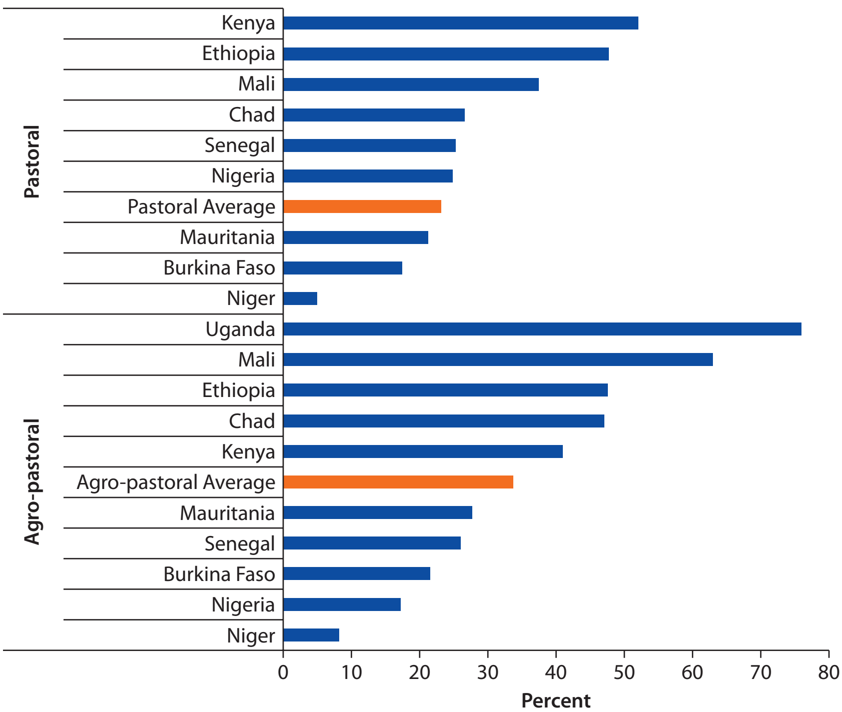
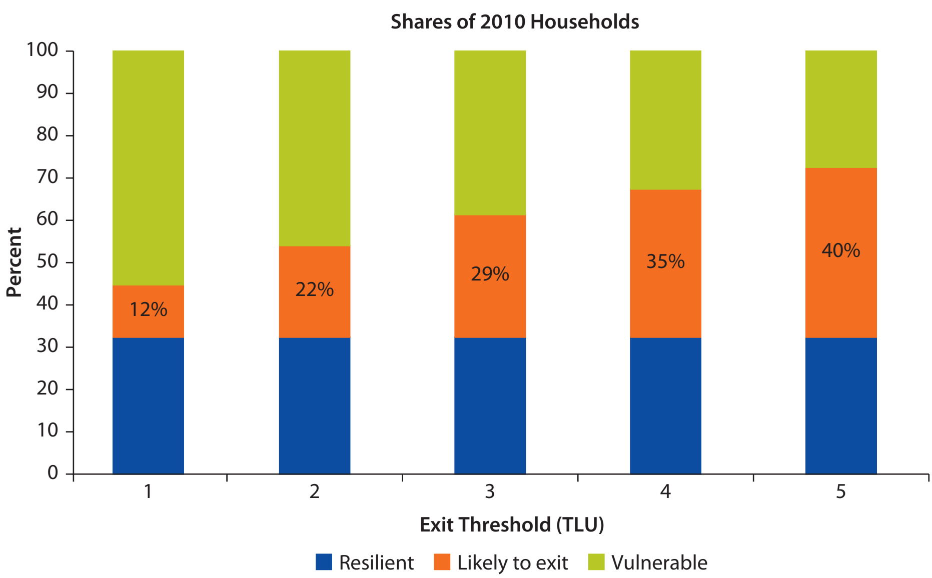
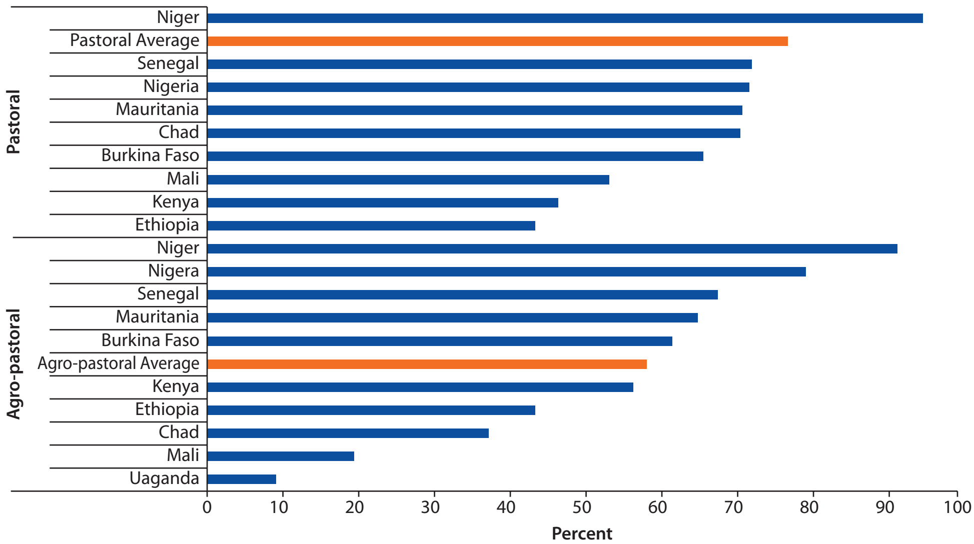


Figure 5.9 Share of Households Likely to be Pushed Out Under Different TLU Exit Thresholds



Note: TLU = tropical livestock unit.

Figure 5.10 Share of Household Dropouts under a Baseline Climate Scenario and No Interventions, 2030



although the figures from Niger strongly affect the average. In addition to this high share of "dropouts," 12 percent of households remain vulnerable.

So without action, an extremely poor and vulnerable population will either remain in drylands and become food aid-dependent and conflict-prone, or it will flood the already overpopulated slums of urban centers. Interventions to manage this essential transition to avoid those outcomes are envisaged in three areas:

1. *Promoting technological change to increase productivity*. In this study, the options assessed include: improvement of animal health (vaccinations, clinical services); closer integration in the market chain (promoting the offtake of bulls at an earlier age for fattening); and finding additional feed, either by identifying un- or underused areas or by increasing on-farm feed production in semi-arid and sub-humid areas;
2. *Promoting structural change in asset distribution*. The options explored in this study are: encouragement of herd consolidation, particularly for the current "vulnerable households"; and redistribution of wealth more generally;
3. *Generating other sources of income from outside the livestock production system*. This could be explored by increasing the percentage of non-livestock income (now at 30 percent for pastoralists and 15 percent for agro-pastoralists). Additional sources of income could cover dryland-related activities (such as processing of livestock products and collection of medical plants and firewood from rangelands), provision of incentives for increasing carbon sequestration, and PES for enhancing rangeland biodiversity. Other sources of income should also be sought from employment generation outside the livestock sector and drylands.

Technological Change

The effects of technological interventions are illustrated in figures 5.11 and 5.12. The relative gains associated with technological change seem rather low. In pastoral systems, the improvements lead to only a 5 percentage point decrease in the number of pushed out households, compensated by an increase in the share of resilient households. In agro-pastoral systems, the decrease in the number of dropout households is more significant (12 percent).

The percentages vary greatly by country and production system and are mainly a function of the feed availability and the percentage of small ruminants in the total herd, as the initial mortality, particularly in the more humid agro-pastoral systems, is higher, and the improvement larger because of the health intervention.

While the improvement in relative terms seems somewhat disappointing, in absolute numbers it is highly significant (table 5.13). The interventions are estimated to increase the number of resilient households by more than 3 million, mostly by reducing the number of likely pushed out households.

As seen in figure 5.13, the share of resilient households decreases slightly under the drought scenario, probably because the already large herds in times of a drought crowd out the smaller livestock-keeping households.

Although a major constraint, in this modeling exercise feed does not seem to make a major impact beyond the 35 percent accessibility level (which already assumes a high level of mobility), but if more feed were made available, it would

Figure 5.11 Effect of Technological Interventions on the Shares of Resilient, Vulnerable, and Likely Exits Households, by Production System

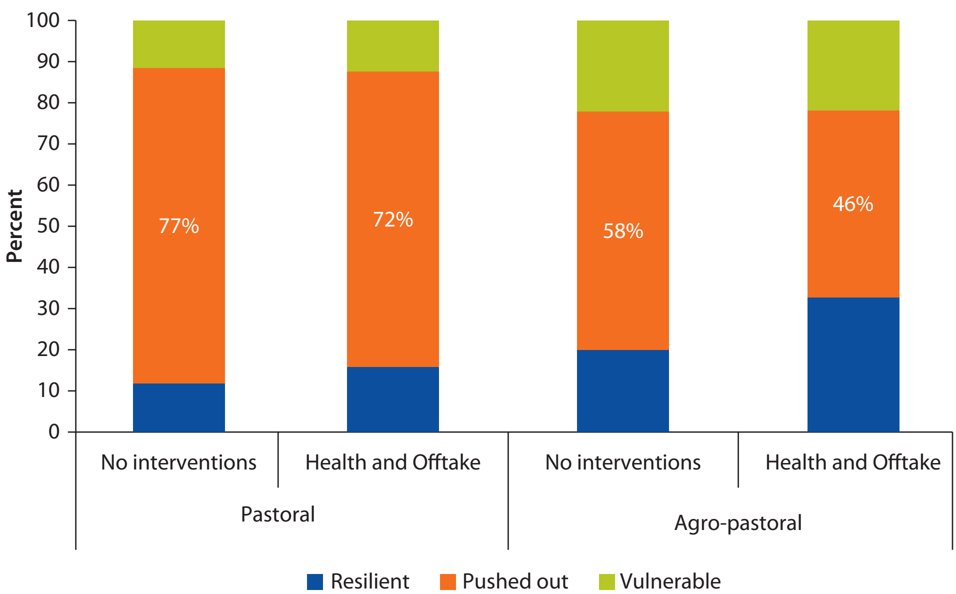


Figure 5.12 Percentage of Avoided Exits due to Interventions in Health Plus Early Offtake

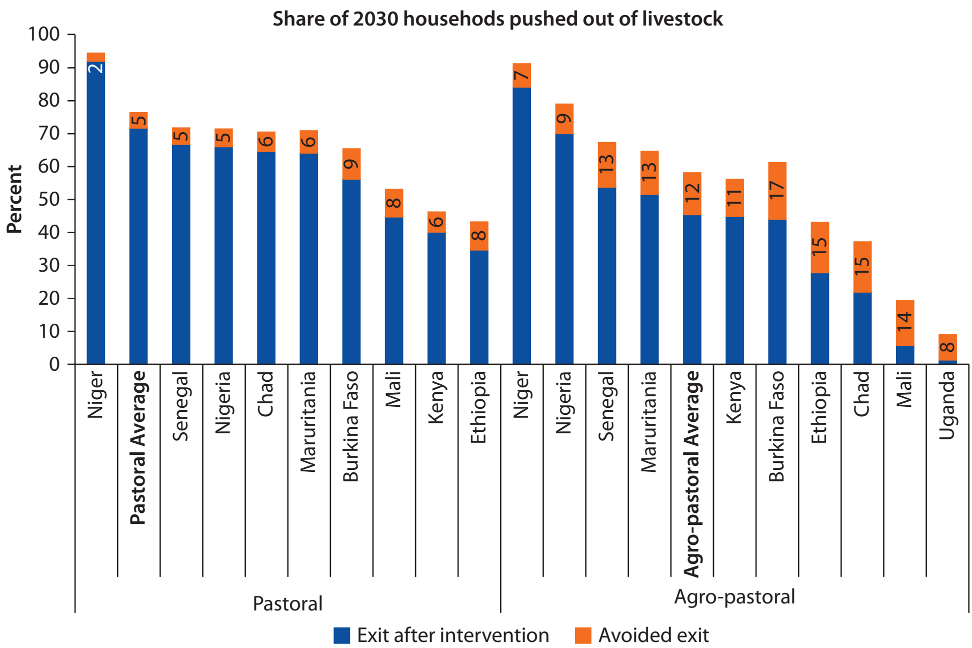


Table 5.13 Impact of Interventions, Baseline Climate Scenario

	Pastoral			*Agro-pastoral*		
Intervention	*Resilient*	*Vulnerable*	*Potential Exits*	*Resilient*	*Vulnerable*	*Potential Exits*
None	543,954	525,953	3,500,828	4,700,649	5,186,613	13,640,662
Health plus offtake	721,916	563,322	3,285,497	7,694,339	5,126,524	10,707,060
Difference	177,963	37,369	(215,331)	2,993,689	(60,088)	(2,933,601)

significantly facilitate the transition of extremely poor dropout households to the vulnerable category (figure 5.14).

Other Structural Changes

Highly inequitable livestock ownership is a root cause of the high shares of vulnerable and pushed out households in the drylands livestock-keeping population. The ongoing transformation of the sector, as described in chapter 3, will exacerbate this inequality and increase the share of vulnerable and dropout households. However, changes in asset distribution are highly sensitive, so the modeling results provided below are mainly meant to stimulate dialogue.

Figure 5.13 Impact of Interventions, Different Climate Scenarios, 2030

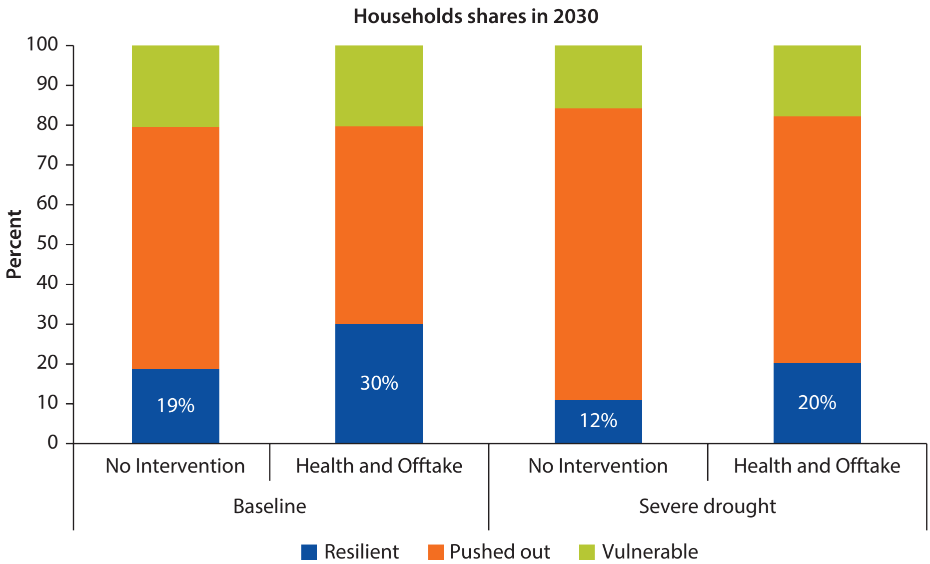


Figure 5.14 Relative Shares of Resilient, Vulnerable, and Likely-to-Exit Households as Affected by Feed Accessibility, Baseline Climate and No Interventions Scenario, 2030

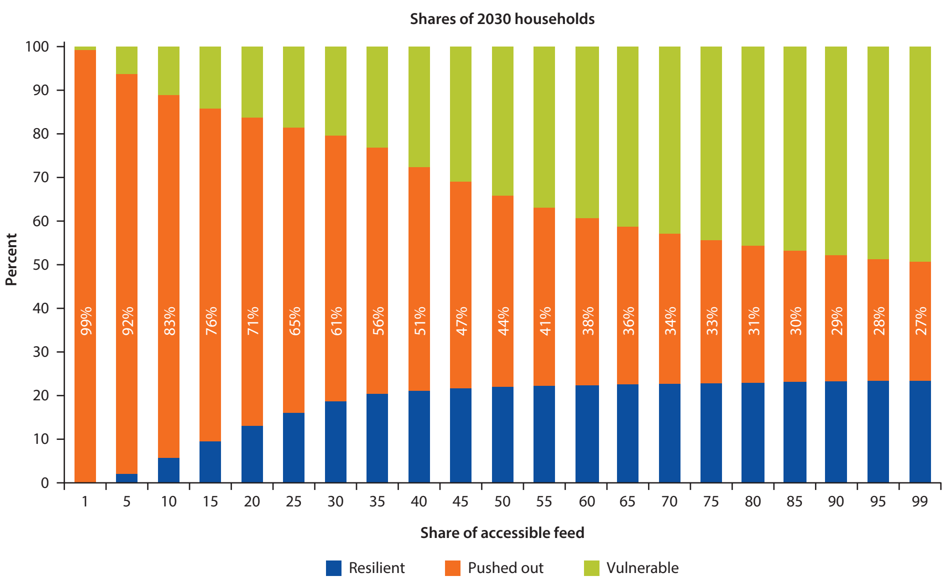


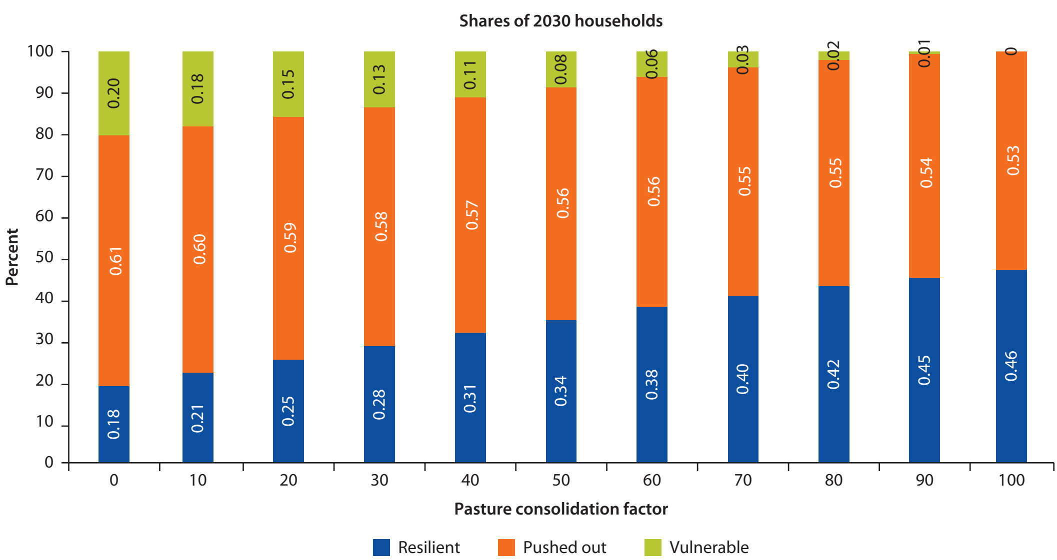
Figure 5.15 shows the effect of consolidation of pasture land by: (i) maintaining the area allocated to resilient households constant at the expected 2030 level; and (ii) allocating different shares (the consolidation factor in figure 5.15) of the remaining area exclusively to vulnerable households (that is, seeking to consolidate vulnerable and likely dropout households). It shows that under such a land consolidation policy, the number of potential exits is reduced to nil, and there is also a slight reduction in the share of vulnerable households.

Allocation of exclusive land and water access rights to vulnerable households at the exclusion of large herd owners will be challenging under the open access system of the drylands. Policies to promote consolidation include:

- Stopping land grabbing by large herd owners, and enhancing mobility;
- Allocating exclusive water and grazing rights for the wet and dry season to groups of smallholder livestock keepers (although this is difficult and has shown disappointing results in the past); and
- Giving a high priority to small ruminants' improvement, as these are the main source of income for the poor.

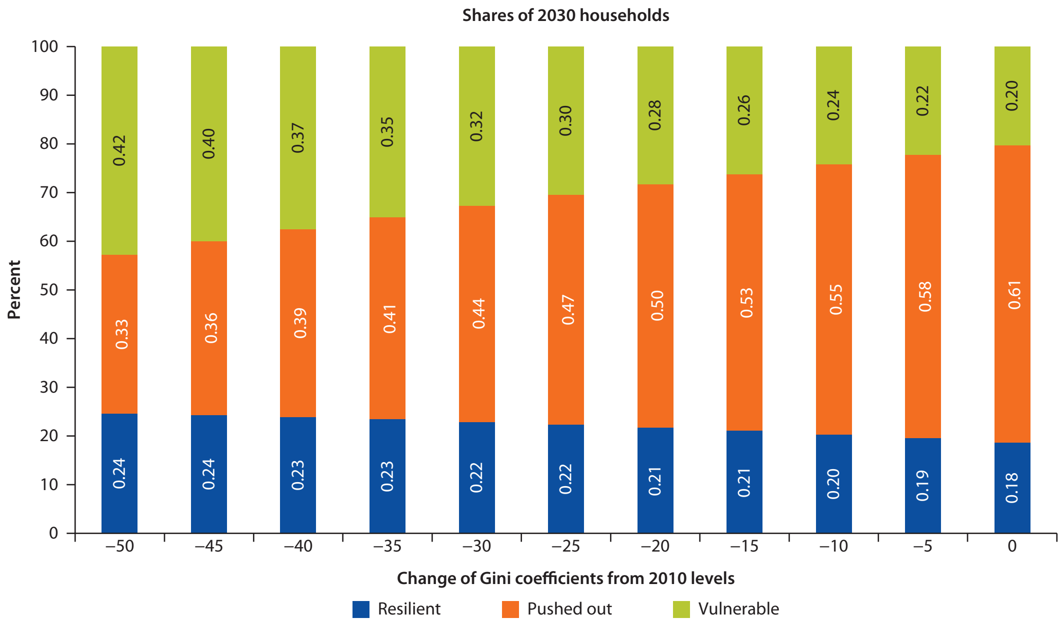
In line with such a consolidation program, the possibility of redistributing livestock wealth could be explored. Figure 5.16 provides an estimate of the

Figure 5.15 Effect of Different Degrees of Consolidation of Feed (Pasture) Resources to Vulnerable Households (Over 5 TLU/Family), Baseline Climate and No Intervention Scenario, 2030



Note: TLU = tropical livestock unit.

Figure 5.16 Effect of Changes in the Gini Coefficient on the Share of Resilient, Vulnerable, and Potential Exits Households, Baseline Climate and No Intervention Scenario, 2030



impact of a change in the Gini coefficient as a proxy for asset distribution: an increase in pasture consolidation of 50 percent from the 2010 level (no consolidation) would halve the number of pushed out households.

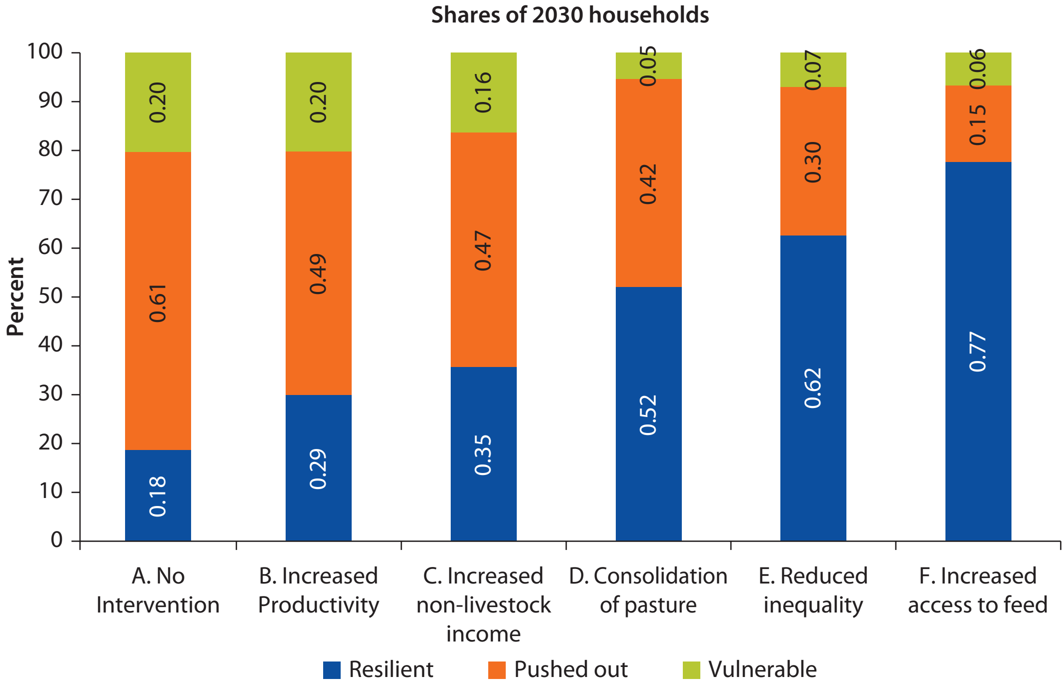
Policies to bring about such a change in the Gini coefficient include:

- Progressive taxation of large herd owners, either through a direct tax per head or progressive grazing and watering fees;
- Differential service fees (such as for vaccination) for large herd owners; and
- Introduction of or an increase in the export tax, as the large herd owners supply more animals for export.

Individually introduced, none of the above measures would make a major dent in the share of vulnerable households. The final model therefore sequentially combines all of the above policies and investments, as shown in figure 5.17. If all interventions are combined, major reductions in the share of vulnerable and dropout households can be gained.

Although admittedly based on a large number of assumptions, the model shows that livelihoods in drylands can be substantially improved, vulnerability

Figure 5.17 Impact of Sequentially Combining Different Policy and Investment Options on Resilient, Vulnerable, and Potential Exits Households, 2030



reduced, and the rural to urban flow diminished when aggressive policies and interventions are taken in combination. It would be wrong, however, to adopt an "all or nothing policy." Individual interventions such as enhancing mobility would make a difference

Summary and Conclusions

These results are based on a large number of assumptions and significant levels of underlying uncertainty. The conclusions should thus be interpreted as indicative only. However, the overall picture is rather clear:

On feed resources:

- The GLEAM/BIOGENERATOR models show that, depending on the climate and interventions, on average for the period 2011–30, 19–29 percent of TLU in arid areas and 9–16 percent in semi-arid areas would have insufficient local feed resources to meet their nutritional requirements without mobility.
- With full mobility of animals and feed within grazing sheds, 2.5 times more usable biomass would be required than in the past. In the scenario of a severe

drought and animal health interventions, biomass use increases 3.5-fold compared to the past sequence.

- Results regarding absolute feed balances indicate that resources seem to be sufficient in all scenarios, starting with an assumption of 20 percent accessibility to natural vegetation. With only 10 percent accessibility to natural vegetation, the deficit in feed reaches 4 percent in the 2011–30 drought + male early offtake scenario, enabling about 60 percent growth compared to the past sequence (1998–2010) in the drought + health + early offtake of males scenario.
- Some grazing sheds appear to have greater feed deficits than others, across scenarios. Mali, Mauritania, and western Burkina Faso (WA1) and northern Ethiopia and Somalia (EA1&3) are the areas where the greatest deficit is found.
- Whereas drought reduces average annual meat production by 14 percent in drylands compared to the baseline, health interventions seem to restore the baseline level of production while early offtake of males increases production by 5 percent. Coupling male early offtake and health interventions even results in a 20 percent increase in average annual Sub-Saharan African (SSA) meat output. But this scenario requires an additional 7.1 million MT of biomass from humid areas.

Therefore, to sustain growth in the sector, policies and investments need to aim at:

- Maintaining and probably even expanding pastoralists' possibilities for seasonal herd/flock mobility to higher-potential areas through interventions in territorial organization (corridors, security, border regulations, water development, allocation of dry season grazing areas);
- Enhancing feed marketing possibilities (storage, processing, transport);
- Supporting market integration through stratification of arid and semi-arid areas (early male offtake) to reduce grazing pressure in arid areas and increase overall meat production; and
- Combining animal health interventions with interventions that increase access to feed. Unconstrained growth of livestock numbers without increased access to additional feed resources will most likely lead to resource degradation and increased conflicts over resources.

On macroeconomic aspects:

- There is potential for growth. The GLEAM/IMPACT modeling shows that health improvement and stratification/closer market integration through fattening outside the region. The combined package could halve the projected meat deficit by 2030.

On livelihoods:

- Livestock ownership in the drylands is highly skewed: the wealthiest 1 percent own 9–26 percent of the livestock (expressed in TLU). Cattle ownership is particularly vested in the better-off groups.
- Currently, about 23 percent of pastoralist and 34 percent of agro-pastoralist households are resilient; about 40 percent have livestock holdings that place them in extreme poverty, probably forcing them out of the system. Under a "business as usual" approach, the shares of resilient pastoralist and agro-pastoralist households are projected to decrease in 2030 to 10 percent and 20 percent, respectively, and 77 and 58 percent, respectively, will be forced to drop out.
- Urgent and concerted action is therefore required; although feed and animal resources will not be sufficient to provide a livelihood for all drylands livestock keepers, several measures are possible, including:
- Introducing improved health care and market integration by inducing offtake at an earlier stage than is now practiced, and fattening these animals in areas of higher potential. In the pastoral zone this will increase the share of resilient households from 10 percent to 15 percent and decrease the share of pushed out households from 77 to 72 percent. In the agro-pastoral zone, comparable figures are from 20 to 30 percent for resilient households, and from 58 to 46 percent for pushed out households. Additionally, the total production of red meat would increase by about 20 percent (although drylands red meat production would reduce by 12 percent).
- Finally, GHG per kg animal protein produced would reduce by about 10 percent;
  - Increasing non-livestock income, in addition to increased productivity, would further increase the share of resilient households from 30 to 36 percent and reduce the share of pushed/dropout households from 50 to 48 percent;
  - Ensuring greater access to feed resources (through water development and opening of feed markets) from 15 to 30 percent accessibility would increase the share of resilient households from 7 to 18 percent and reduce the share of pushed/dropout households from 71 to 61 percent;
  - Redressing inequity through preferential allocation of grazing rights to the vulnerable part of the population would increase the share of resilient households from 18 to 40 percent and reduce the share of households likely to be pushed out from 61 to 53 percent. Similarly, changing the Gini coefficient through, for example, progressive taxation could theoretically reduce the share of families pushed out from 61 to 33 percent; and
  - Implementing all measures combined—this would result in resiliency for 78 percent of households, while only 15 percent of households would be pushed out.

In view of the above analysis, recommended policies would:

- Be country specific;
- Establish the enabling environment for technological change (extension, infrastructure; credit) to: (i) strengthen animal health services; and (ii) increase early offtake of male animals. The specific policies would cover for both interventions an appropriate distribution of responsibilities between the public and private sectors, and for incentives for early destocking, such as the introduction of grazing and watering fees and facilitating market integration (enabling the private sector to develop the value chains, infrastructure, credit, support for standard setting, including harmonization of international standards);
- Be pro-poor in its allocation of grazing rights and taxation, and focus on small ruminants;
- Develop institutions that help the poor with early destocking and restocking (subsidized transport, livestock insurance);
- Seek additional (such as PES) and alternative (such as crop farming and employment generation within or outside the value chain) income sources for drylands populations; and
- Focus on intensification of land use in semi-arid and sub-humid areas.

Data Gaps

Serious gaps exist in practically all categories of data needed for this analysis. Future investments need therefore to give priority to the following issues:

- Livestock technical performance data are scarce and mostly come from experimental stations under conditions quite different from those prevailing in practice. They are mostly collected over a very short period (1–2 years) and lack the long-term time series needed to capture the climate variability in drylands;
- Information on feed availability from natural vegetation is overestimated, as the critical accessibility factor is unknown;
- Livestock ownership data, in particular per wealth category, are scarce and normally suffer from underreporting. Poverty rates from ILRI are based on some rather bold assumptions by Livestock in Development (LID) dating back to 1999;
- Livestock numbers come almost uniquely from FAOSTAT, with known bureaucratic weaknesses;
- Data on human demographics, particularly differentiating between pastoral, agro-pastoral, and crop farmers, are critical for future projections regarding conflict situations but are essentially unavailable;
- Income and expenditure data at the household level, especially for revenues from non-livestock outside sources, are only available for a very limited number of sites; further, pastoral groups are often missed in household surveys;
- Crop projections used in the modeling to account for trends in land cover and land use changes and changes in the spatial distribution of cropped area are scarce; and

- More data are needed on actual growth rates using crop byproducts and residues for fattening, as significant differences exist between the GLEAM projections and those identified at the experts' consultation held in Dakar.

Financial and Economic Returns

This section provides an overview of: (i) the wider macroeconomics of resilience in the livestock sector, mainly based on a literature review heavily reliant on Venton et al. (2013); and (ii) the costs of and returns to investments of the interventions described above.

Macroeconomic Aspects: Wider Dimensions of Resilience

The main macroeconomic issue concerns the comparison of the costs of emergency aid and other humanitarian support with the total package of investments to reduce livestock-keeping households' exposure and sensitivity to shocks and enhance their capacity to cope. As shown below, the costs of the former are generally higher than the cost of drought preparedness. Most of the work in this area has been done in East Africa, and has been based on modeling, as "with/without" field assessments are not feasible in the highly variable SSA environment.

Venton et al. (2013) compare the cost and benefits of late and early responses with those of building livestock keepers' resilience. They make the point that under a late response/emergency scenario, while it helps to ensure that people and livestock stay alive, asset depletion is often the result, and when the next drought hits, people often have not recovered their asset levels, falling into a downward spiral of emergency aid dependency. Under an early intervention scenario, per capita intervention costs are generally lower and a significant share of livestock (estimated at 50 percent by the authors) can still be commercially destocked and valued. The resilience-building scenario prepares communities to cope without external support, and depending on the severity of subsequent shocks, to continue to build their assets.

For the Wajir grasslands in Kenya (with 367,000 inhabitants), the main results from Venton et al. (2013) are presented in table 5.14 as an example.

This estimate shows that a commercial destocking (as described in chapter 4) would yield a benefit of about US$250 million over a 20-year period. The total resilience package C even has a positive return, with a cost-benefit ratio of 1:5.5 resulting from a reduction in food aid and livestock losses.

Other interventions for this area such as water development would result in a cost-benefit ratio varying from 1:26 for a shallow well, to 1:6 for a drilled well for 5,000 people, to 1:1.1 for a drilled well for only 1,000 people.

Also at the national level, early intervention and resilience building yields positive returns. For example, discounted over a 20-year period for the arid and semi-arid areas of Kenya, a late response would cost US$29 billion; with an early response this would go down to US$22 billion; and with the resil-

Table 5.14 Costs (US$ Million) of Various Response Scenarios—Wajir Grasslands, Kenya

Intervention/ Outcome	*A: Late Humanitarian Response (US$ Million)*	*B1: Early Response: Destocking (US$ Million)*	*B2: Early Response: Destocking Plus Improved Animal Condition (US$ Million)*	*C: Resilience Building*
Aid costs assumed every fifth year	176	88	66	Residual risk: Full costs under B2 in year 0, decreased by 50% year 5, 25% carries on every event thereafter
Losses (animal deaths)—assumed every fifth year	81	62	19	Residual risk: Full costs under B2 in year 0, decreased by 50% year 5, 25% carries on every event thereafter
Cost of program assumed every fifth year		0.28	5.8	US$50 million annually (US$137 per capita for beneficiary population) [a]
Net cost over 20 years, discounted at 10%	606	354	214	Pos. balance US$54 million[b]

Source: Adapted from Venton et al. (2013).
Note:
a. Broken down as follows: Livestock interventions US$24; Water and sanitation interventions US$25; Livelihood interventions US$60; Road interventions US$11; and Education support US$17.
b. Assuming a conservative benefit of US$1.1 for every US$1 invested.

ience-building package, to US$9 billion. The same work in Ethiopia showed similar results.

All indications are that early intervention and a resilience package will provide positive returns, reducing losses and human suffering, and should thus be the direction of future development.

Cost of Interventions

For the economic assessment, a cost estimate was first prepared. In the absence of data in the literature, cost estimates were based on cost projections from five recently started, major internationally funded projects dealing with pastoral areas[17] and on a further literature review. Table 5.15 provides a summary of the cost per pastoral/agro-pastoral person associated with these projects.

The range of values is significant, particularly for health improvement. However, the average is in line with the estimates of the OIE-sponsored study (CIVIC Consulting 2007) for Uganda.

For development decision making, it is important to know the distribution between technology adoption-related and non-adoption-related costs, as well as between investment and recurrent costs. Based on the projects analyzed, and the authors' experience, the assumptions used are provided in table 5.16.

Table 5.15 Average Cost/Person/Year of the Main Interventions in Five Drylands Livestock Development Projects

Intervention	*Average Cost/Person/Year (US$)*	*Number of Projects/Sources*	*Range (US$)*
Health improvement	3.95	3	3.37–20.12
Market improvement (early offtake of bulls)	6.00	3	3.67–8.33
EWS	3.72	2	1.79–2.09
Social services, etc.	5.30	2	2.39–5.82

Table 5.16 Assumptions About the Allocation of Adoption- and Non-Adoption-Related Costs and of Investments and Recurrent Costs for Animal Health and Early Offtake Interventions

Item	*Allocation*
Animal health non-adoption-related	Of total health improvement budget, 20% in investments and 25% in recurrent costs
Animal health adoption-related	Of total health improvement budget, 25% in investment and 30% in recurrent costs
Animal health improvement adoption-related by livestock system	10% higher/person (higher delivery costs) in pastoral systems
Early offtake (market integration)	Of total budget, 70% in investment and 30% in recurrent costs (high capital investment needed in infrastructure such as transport, processing facilities).
Early offtake non-adoption-related costs	Nil, because of its currently nascent character
Adoption rate	70% for pastoral and 80% for agro-pastoral households for health improvement and 60% and 70%, respectively, for early offtake
Public and private sector contribution	Public sector: 80% for cross-cutting costs, 60% for adoption costs in animal health improvement, and 20% for early offtake; the remainder belongs in the private sector

With these very hypothetical assumptions, the costs per household for the different interventions can be calculated on a country basis[18] (table 5.17).

The distribution of costs between public agencies and livestock owners (private sector) can also be estimated (table 5.18).

In aggregate, these figures seem high at a total of about US$ 10 billion over the 20 year period or about US$500 million per year (about US$200 million per year for the public sector. They look more reasonable when calculated per beneficiary (number of people made resilient), as shown in figure 5.18.

Figure 5.18 shows that with the exception of Niger, the costs per person made resilient are significantly below the US$100–135 normally calculated for food aid. As expected, the annual cost per person made resilient is higher in

Table 5.17 Costs of the Health Improvement Intervention in Pastoral and Agro-pastoral Systems for the Drylands Countries Analyzed, 2011–30

	System	*Total Crosscutting Costs (US$)*	*Animal Health Costs Related to Adoption (US$)*	*Early Offtake Cost Related to Adoption (US$)*
Burkina Faso	Pastoral	2,001,340	4,375,668	8,761,819
	Agro-pastoral	146,411,191	296,312,335	611,860,734
Chad	Pastoral	22,269,103	46,248,843	94,322,021
	Agro-pastoral	80,355,873	153,572,465	325,511,901
Ethiopia	Pastoral	40,450,812	84,084,728	200,001,914
	Agro-pastoral	215,420,784	475,994,713	945,777,249
Kenya	Pastoral	11,639,980	24,028,169	57,297,407
	Agro-pastoral	100,380,624	190,548,382	405,157,258
Mali	Pastoral	18,237,102	35,108,525	73,647,630
	Agro-pastoral	108,214,483	189,929,255	419,156,401
Mauritania	Pastoral	22,825,513	47,451,895	96,740,466
	Agro-pastoral	1,022,503	1,956,348	4,144,523
Niger	Pastoral	110,077,554	214,747,897	448,217,398
	Agro-pastoral	30,208,044	67,968,123	134,012,642
Nigeria	Pastoral	6,708,289	13,742,922	28,167,673
	Agro-pastoral	403,725,668	759,884,598	1,622,137,722
Senegal	Pastoral	6,713,968	14,168,716	33,518,259
	Agro-pastoral	64,583,740	125,656,019	308,179,228
Uganda	Agro-pastoral	38,844,123	77,107,686	160,618,168
Total		1,430,090,694	2,822,887,289	5,884,440,004

Table 5.18 Summary of Costs (2011–14 Prices) of Health and Early Offtake Interventions and Their Distribution between the Public and Private Sectors (2011–30)

	Cross-Cutting Cost (US$)	*Adoption Costs Animal Health (US$)*	*Early Offtake Costs (US$)*	*Total (US$)*
Public sector	1,144,072,555	1,693,732,373	1,176,888,001	4,014,692,929
Private sector	286,018,139	1,129,154,916	4,707,552,003	6,122,725,057
Total	1,430,090,694	2,822,887,289	5,884,440,004	10,137,417,987

pastoral areas. In general, the costs in East Africa seem to be lower than in the Sahel. At an average cost of US$27 per person per year, they are half the US$65 per person per year estimated by Venton et al. 2013.[19]

Micro-Economic and Financial Returns

The financial and economic rates of return were determined for the interventions based on the ECO-RUM projections, using the parameters in appendix A (table 5.19).

Figure 5.18 Estimated Unit Cost (US$/Person/Year) Made Resilient (Presented at Log Scale) Under Baseline Climate and Health and Early Offtake Scenarios

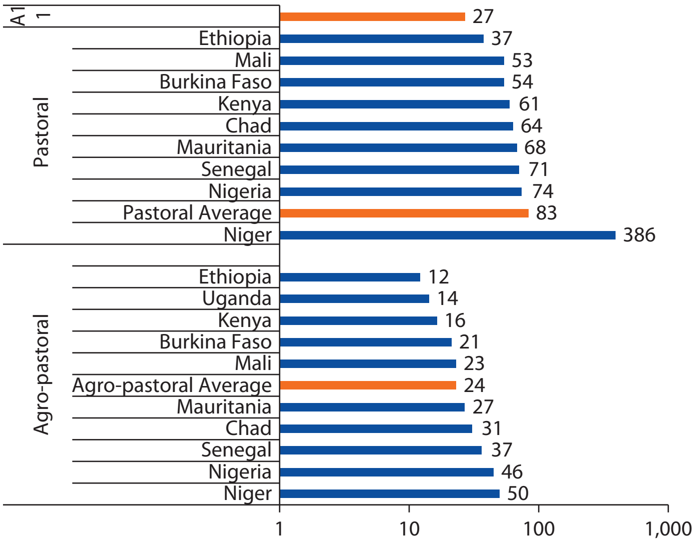


Table 5.19 Financial Rates of Returns (%) of Different Interventions at Household Level for Different Species

	Baseline Plus Health Intervention	*Mild Drought Plus Health Intervention*	*Severe Drought Plus Health Intervention*	*Baseline, Health Plus Early Offtake*	*Mild Drought Plus Health Plus Early Offtake*	*Severe Drought Plus Health Intervention Plus Early Offtake*
Pastoral households						
Cattle	11	11	2	29	16	4
Sheep	26	31	42	NA	NA	NA
Goats	29	41	65	NA	NA	NA
Camels	21	31′	57	NA	NA	NA
Agro-pastoral households						
Cattle	Neg.	Neg.	Neg.	14	15	22
Sheep	High	36	36	NA	NA	NA
Goats	High	46	53	NA	NA	NA

As in the earlier modeling results, because of the paucity of data and the wide variation in environments under which these systems and species function, the results from table 5.19 should be evaluated based on their order of magnitude, rather than taken as precise data on the rates of returns of these interventions. However, it can be concluded that:

- Health interventions for small ruminants and camels seem highly remunerative;
- In pastoral areas, the rate of return of animal health improvements for small ruminants and camels increases in drought situations;
- For cattle, the situation is less clear-cut. With the existing technical and financial data provided at the experts' consultation in Dakar, health improvement on its own is only marginally remunerative in pastoral areas, and even yields a negative rate of return in agro-pastoral areas. Early offtake of young males increases the rate of return.

The policy implications are that:

- In animal health improvement, attention should be paid particularly to small ruminants, which are normally neglected. This would also address inequity; and
- Health improvement for cattle should be accompanied by further intensification through early offtake of young males or through other husbandry improvement (genetics, feeds) to be financially attractive. This supports the earlier results of the feed balance modeling.

Notes

1. A more detailed technical paper is being prepared.
2. Unless otherwise reported, the countries covered include: in the Sahel—Burkina Faso, Chad, Mali, Mauritania, Niger, Nigeria, and Senegal; in the Horn of Africa—the countries included are different from those used in chapter 2 as they cover only Ethiopia, Kenya, Tanzania, and Uganda. The feed balance work with Global Livestock Environmental Assessment Model (GLEAM) also includes Djibouti and Sudan (statistics from the former Sudan) and Somalia.
3. http://www.ifpri.org/book-751/ourwork/program/impact-model.
4. http://livtools.cirad.fr/mmage
5. http://livtools.cirad.fr/dynmod
6. www.fao.org/docrep/014/i2425e/i2425e00.pdf
7. The spatial distribution used 2010 as reference year.
8. No estimates could be found in the literature on the share of natural vegetation accessible to livestock. The authors' estimate is based on the initial estimates from the ACF work with BIOGENERATOR, also discussed at the Dakar workshop, of 30 percent for water only. A further reduction to 10–20 percent was assumed because of other movement constraints (insecurity, high crop intensity, constructed areas, etc.).
9. The results of the additional scenario of 30 percent accessibility are the basis of the livelihood analysis (see section Macroeconomic Implications).
10. The (Global) Aridity Index (AI) is calculated from MAP/MAE, where MAP is the Mean Annual Precipitation and MAE is the Mean Annual Potential Evapotranspiration.
11. http://www.cgiar-csi.org/data/global-aridity-and-pet-database

12. This differs from the classification used in the subsection on livelihoods modeling, where agro-ecological zones were used assumed to represent the systems (that is, arid equals pastoral and semi-arid and sub-humid equal agro-pastoral).
13. See description below of the BIOGENERATOR data and model.
14. The geographical limits of the different grazing sheds are depicted in map 5.3.
15. In IMPACT, the subnational spatial units are defined according to how certain key river basins intersect with national boundaries, rather than with the aridity zones used in this study.
16. In GLEAM, the distribution of animals is highly disaggregated on a spatial scale, so that the production systems are delineated by their feed characteristics and the aridity zones in which they are located.
17. The Ethiopia-Drought Resilience & Sustainable Livelihood Program in the Horn of Africa (PHASE I), funded by the African Development Bank (US$48.5 million, 2012); the IFAD- and World Bank-funded Regional Pastoral Livelihoods Resilience Project for Kenya and Uganda (US$132 million, 2014); the World Bank-funded Regional Sahel Pastoralism Support Project (US$250 million, under preparation); the WB/IFAD-funded Ethiopia Pastoral Community Development Project—Phase II (US$133 million, 2013); and the IFAD-funded Sudan Livestock Marketing and Resilience Program (US$ 119 million under preparation).
18. A detailed worksheet is available from the authors upon request.
19. US$54/person/year for Kenya and US$77/person/year for Ethiopia. No data are available for the Sahel.