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Optimizing Livelihood and Environmental Benefits from Crop Residues in Smallholder Crop-Livestock Systems in Southern Africa

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Abstract

Sustainable forms of intensification are needed to address the low and stagnant production of farming systems in southern Africa. More efficient use of crop-livestock interactions can contribute to this; in this context the effective use of crop residues is becoming increasingly important and also contested. Crop residues left on the field for mulching are expected to bring long-term environmental benefits but when fed to livestock they provide farmers with short-term livelihood benefits. This study aims at better understanding the diversity of farming systems and uses of crop residues, in particular the trade-offs in using the residues for soil amendment versus livestock feed. It is part of a global comparison with sites along a human and livestock population density gradient across sub-Saharan Africa and South Asia. This southern Africa study represents the most extensive case of semi-arid areas with lowest biomass production. Three sites were compared, at different levels of agricultural intensification, extent of crop-livestock integration and use of crop residues. 1. Mzimba in Northern Malawi – intensified crop oriented production. 2. Nkayi in southwest Zimbabwe – integrated crop-livestock systems. 3. Changara in Tete province in Central Mozambique – extensive crop-livestock farming. Across the three sites, crop residues are clearly needed as livestock feed. In Nkayi and Changara low crop yields and low biomass production against the existing demand from livestock prevents farmers from using residues for purposes other than livestock feed. The practice of collecting and kraal feeding residues in Nkayi illustrates that the pressure on residues is at a level where farmers start privatizing residues in order to ensure their individual benefits. When feeding crop residues in the kraal, farmers also increase the amount of manure for soil fertility improvement. Even in Mzimba, with higher residue production and lower livestock ownership, very few farmers retain the residues to achieve real impact on soil health. Although farmers see soil fertility as a critical constraint, they have limited residues to spare for mulching. The trade-offs of reallocating crop residues from livestock feed to mulching for soil amendment will be high as long as alternative feed technologies and access to input and output markets are not developed. The trade-offs will be lower in areas with higher biomass production and less competition with livestock. Technical options need to increase biomass on existing croplands, addressing feed shortages and the need for soil amendment concurrently. Viable institutional structures and appropriate policies need to support this intensification processes through better access to inputs, knowledge and markets. The pathways for sustainable intensification and more efficient crop residue utilization need to be developed within the local context. We found strong growth potential for livestock-oriented agricultural development in extensive areas (Changara), strengthening crop and livestock integration to support intensification in areas like Nkayi, and enhancing crop-livestock integration for more efficient resource utilization where biomass is less limiting (Mzimba).

Keywords:
Mixed crop-livestock systems, Crop residues, Trade-offs, Sustainable intensification, Southern Africa.
JEL classification: Q01, Q16

Contents

1 Introduction

1.1 Crop residue trade-offs in mixed systems

Mixed crop-livestock systems are the predominant form of land use and main source of income for smallholder farmers in southern Africa. Most of these systems are in semi-arid areas with low rainfall and poor inherent soil fertility. Farming systems are extensive, characterized by relatively low human and livestock population densities. Investments in agricultural production are generally low. Stagnant or declining agricultural productivity are major constraints.

In these high-risk environments with typically low biomass production and increasing demand for food and feed, the use of crop residues is becoming increasingly contested. The use of crop residues as feed is becoming more important due to the expansion of croplands and degradation of the remaining rangelands (Alkemade *et al*., 2012). Especially where food and feed shortages are common, feeding crop residues to livestock provides benefits to farmers within a given production year (FAO, 2001). Farmers use animal traction for draft power and manure as a soil amendment as inputs to crop production. Selling livestock enables farmers to purchase food when crop harvests fail, pay for education and human health (Moll, 2005; van Rooyen and Homann, 2009). Farmers also use the cash to purchase crop and livestock inputs, which contributes to enhance overall farming systems productivity.

On the other hand, Conservation Agriculture (CA) practices are promoted to intensify crop production, emphasizing the retention of crop residues as mulch to improve water use, soil fertility and crop yields (Mazvimavi and Twomlow, 2009). The benefits of CA technologies however materialize only after a relatively long time, approximately after 10 years (Wall, 2007; FAO, 2009). The trade-offs in using the residues for these longer-term benefits from soil amendment are high in areas with low levels of biomass production and where livestock keeping is an important livelihood activity (Valbuena *et al.,* 2013).

Greater crop-livestock integration can create resource competition over the uses of crop residues for soil amendment or livestock feed. Using crop residues to feed livestock during the long dry season implies substantial opportunity costs to their use as mulch (Giller *et al.*, 2009). The form and pressure of such trade-offs depends on the local bio-physical and socio-economic farming characteristics and context.

1.2 Opportunities for sustainable intensification

Despite challenges, substantial growth potential has been projected from sustainable intensification of the extensive mixed farming systems, such as those in southern Africa (Herrero *et al*., 2010; Tarawali *et al.,* 2011). Sustainable intensification aims at increasing production levels in two ways: (i) optimizing the use of available resources, including a more efficient use of the crop-livestock interactions; (ii) intensifying production per unit land through modern technologies in an environmentally sound manner (The Montpellier panel, 2013).

Crop residues are one of the important resources available to farmers to promote sustainable intensification. The opportunities to make better use of the crop residues differ among the research sites (Figure 1). They are a function of the interplay between agro-ecological conditions, human population densities, national and local drivers (Figure 1).

The sites in Zimbabwe and Mozambique represent the more extensive mixed farming systems and show a strong growth potential in livestock. In Nkayi, Zimbabwe, farmers use integrated crop-livestock farming technologies and crop residues are an important dry season feed. By strengthening this integration the productivity of the system could be substantially enhanced. Cost-effective availability of crop and livestock inputs and services are of first priority. In particular, investments in fodder technologies, which would at the same time set residues free for mulching, can contribute to increase farming systems productivity. Crop and livestock market development are expected to provide the incentives for uptake of such technologies.

In Changara, Mozambique, land use is even more extensive than in Zimbabwe, access to farming inputs more difficult. Livestock has a greater potential than crop production to attract investments and market orientation. Despite high participation in markets, the livestock markets are still largely informal. Farmers practice subsistence crop production and could increase yields tremendously through better crop management. National programs are required to set up required infrastructure and services for crop and livestock production.

The Malawian case represents higher intensification levels. Government investments are primarily through the crop input subsidy programme. Farmers responded by intensifying crop production. Farmers produce higher crop yields and surplus residue biomass available for mulching and feeding livestock. The potential role of livestock production and market development is however not yet exploited. Farmers could gain more from their enterprises through greater crop-livestock integration and cross-subsidization.

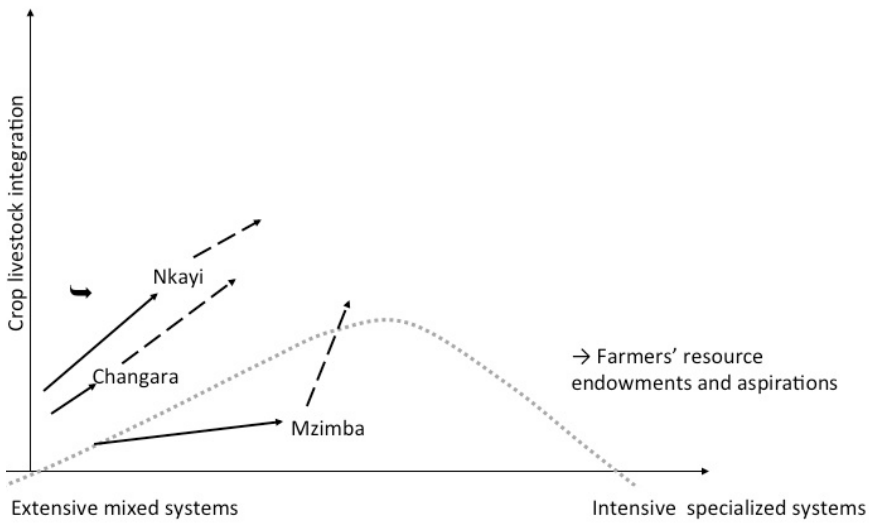

Figure 1: Current levels of agricultural intensification and crop-livestock integration at the study sites (adapted from McIntire *et al*., 1992).
Notes: Solid lines: recent trends; dashed lines: potential directions through better crop-livestock integration; grey dotted line: role of crop-livestock integration from extensive mixed to intensive specialized systems.

1.3 Trends, drivers and dynamics

There is an urgent need for sustainable intensification options for smallholder farmers given that agricultural production in the three countries is almost entirely handled by smallholder farmers and almost entirely rainfed. Agricultural production levels have been stagnant over years, and per capita agricultural production has been on the decline (Chilonda and Minde, 2008). Smallholder farmers have been responding to the increasing demand for food mainly by expanding or shifting crop fields or increasing herd sizes. In most countries fallow land has almost disappeared and continuous cropping is the norm (Twomlow *et al.*, 2006). Marginal lands are being cultivated and remaining grazing areas and woodlands are over-exploited (Lal, 1998).

Maize (*Zea mays L*.) is the major crop and staple food. Maize has replaced the traditionally grown small grains such as finger millet (*Eleusine coracana L.*), pearl millet (*Pennisetum glaucum L.*,) and sorghum (*Sorghum bicolor Moench*) as well as cassava (*Manihot esculenta* Crantz). Consumers have a strong taste preference for maize and support systems have been focusing more on maize. For instance in Zimbabwe, Sorghum is the second most prevalent crop; although more drought tolerant than maize, it is grown on only about 10% on the cropped area. Groundnuts are the most important legume crop, planted on about 10% of the cropped area (Twomlow *et al.*, 2006). Enhancing maize production is however cost intensive and implies high risk in semi-arid areas.

Livestock production is a major income generating activity and has the potential for higher value and more consistent returns to investment than crops (Ryan and Spencer, 2001). Cattle play a predominant role, but the per capita ownership is dwindling in many parts of southern Africa. Small stock numbers, on the other hand, are steadily increasing in most countries most probably because of their high intrinsic rate of increase, adaptability to various habitats and their relatively low purchasing prices compared to cattle (Van Rooyen and Homann, 2009).

To achieve agricultural productivity growth, southern Africa aims at least at 7% increase in agricultural GDP by increasing fertilizer use to 65 kg/ha, crop yields to 2 t/ha and livestock production by 4% annually (SADC RISDP, 2006). Recent studies have demonstrated that productivity growth in the low-income countries' grain and livestock sectors can generate more growth in GDP and food consumption than growth in non-traditional export crops (Nin Pratt and Diao, 2008). Current investments are directed towards increasing the competitiveness of smallholder farmers, and thereby to also reduce negative impacts on the environment. While in the past support to agricultural development has focused primarily on crop production, there is now a growing recognition of the livestock sector and greater attention on enhancing integrated crop-livestock systems (FARA, 2006; ASWAP, 2011).

Changes in agricultural production systems are a result of the diverse and interacting nature of drivers. These are the major socio-economic and bio-physical factors that shape the context of agricultural production at the research sites.

1.3.1 Socio-economic factors

- Economic development: Agriculture is the primary source of employment and income in the low-income countries. Malawi is among the countries with lowest GDP but highest share in agriculture, mainly through crop production (Table 1). Mozambique has large potential for increasing agricultural development and growth with large acres of land still uncultivated, representing an underexploited potential for livestock production. Zimbabwe's agricultural sector performed the worst since 2000, with negative growth due to political and economic instability. The livestock sector plays an important role and contributes substantially to the national agricultural income.

- Agricultural policies and investments: Government investments in agriculture tend to be low considering the many people depending on agriculture. Malawi started early to increase government investments in agriculture to about 10%, mainly in crop production. Mozambique recently increased these investments to 10%. Both countries achieved the targeted GDP growth in agriculture of 7% (Benin *et al.,* 2010). In Zimbabwe the livestock sector contributes substantially to national agricultural income (Chilonda and Minde, 2008). Agricultural policies should take cognizance of integrated crop-livestock systems.
- Market development: There is a trend towards more market integration and greater demand for higher quality and more processed food, especially livestock products (Delgado *et al.*, 1999). Sharing boundaries with middle-income countries provides additional demand for grain and livestock products. South Africa has the largest market and could be used as engine of growth for the region. Engaging smallholder farmers to increasing supply to domestic and regional markets is an important opportunity; regional integration should facilitate market linkages to South Africa (Scoones *et al.*, 2010).
- Land tenure: Most countries face high pressure for redistribution of land, but appropriate mechanisms are lacking. Smallholder farmers are traditionally on the less fertile communal lands, which are state owned and imply insecurity of property rights. Land tenure is more commercially oriented and with foreign interests in Malawi (tobacco, dairy estates) and Mozambique (Cane sugar, cotton, coconut, tobacco and bio-fuels) (Quan, 2005; van den Brink *et al.* 2006).
- HIV/AIDS: Estimated 25% of the adult population living with HIV/AIDS has dramatic impacts on agricultural labor force, assets and incomes, and leaves people more vulnerable (de Waal and Whiteside, 2003; Jayne *et al*., 2006).
- Out-migration: High labor out-migration, particularly by the young generation, results in dependence on relatively old farming population, which also affects livelihoods and food security (Jayne *et al.,* 2006).
- Gender: About a quarter of households are female headed and women take great responsibilities in farming. *De jure* female-headed households, where men are absent, are more vulnerable, as compared to *de facto* female-headed households where men send remittances (Rohrbach and Alumira, 2002).

1.3.2 Bio-physical factors

- Climate variability and change: Recurrent droughts and annual dry spells constrain crop production. Climate change, through increasing temperature, reduction of length of growing period and higher rainfall variability, was projected to affect large parts of southern Africa (Thornton *et al.*, 2007). A greater shift towards livestock production is expected (Kandji *et al.*, 2006).
- Poor inherent and declining soil fertility: Soils are predominantly sandy, poorly buffered and acidic, with P, N and S as most limiting nutrients. Fertilizer use is extremely low and less than average of sub-Saharan Africa. Widespread re-introduction of fertilizer subsidies and micro-dosing technologies are being advertised (Twomlow *et al.*, 2006). Conservation agriculture technologies are promoted to link yield increases with improved soil, water and nutrient balances (Morris *et al.*, 2007).

Table 1. Indicators for major socio-economic drivers at national scale

	Mozambique	Zimbabwe	Malawi
GDP/capita (average USD, 2003-09) [1]	324.6	422.3	145.5
Annual GDP growth (av. %, 2003-09) [1]	7.3	-6.4	7.0
Livestock (% agric. gross production, 2009) [2]	15.7	44.8	9.9
Public spend. on agriculture (av. %, 2003-09) [1]	4.5	8.6	9.8
Rural population (%, 2009) [2,3]	62.4	62.2	80.7

Source: [1]Benin *et al.*, 2010;[2]www.FAOstat.fao.org; [3] NSO (2010)

1.4 Conceptual framework

This study draws on a framework that was developed for comparing crop residue uses, trade-offs and determinants across four contrasting regional case studies - three in sub-Saharan Africa and one South Asia. It dissects three nested levels (Figure 2):

- Context: Diverse socio-economic and bio-physical factors influence farmers' livelihood strategies and current levels of agricultural production and crop-livestock integration. The analysis employs a historical perspective to understand how systems have evolved and what conditioning factors have shaped farmers' livelihood strategies.
- Systems level: Three factors were used as key criteria for selecting the target farming systems:
  - 1. Market access: Market arrangements that enhance benefits for smallholder farmers from market participation;
  - 2. Intensity: Human and livestock population densities as proxy for land use intensity;
  - 3 Agro-ecology: Natural production potential and constraints and negative impacts on the environment
- Household level: Decisions at farm level and household-specific resource endowments will influence farmers' choices on how they intensify. This will, in turn, depend on farmers' preferences, product uses (domestic or for market) or feed value.

Using this conceptual framework, study sites were selected with different market accessibility, intensification and agro-ecologies. Sites in southern Africa are Mzimba in Northern Malawi, Changara in Central Mozambique and Nkayi in West Zimbabwe. Southern and Western Africa are the regions to represent the more extensive systems as compared to intensive systems in Eastern Africa and South Asia.

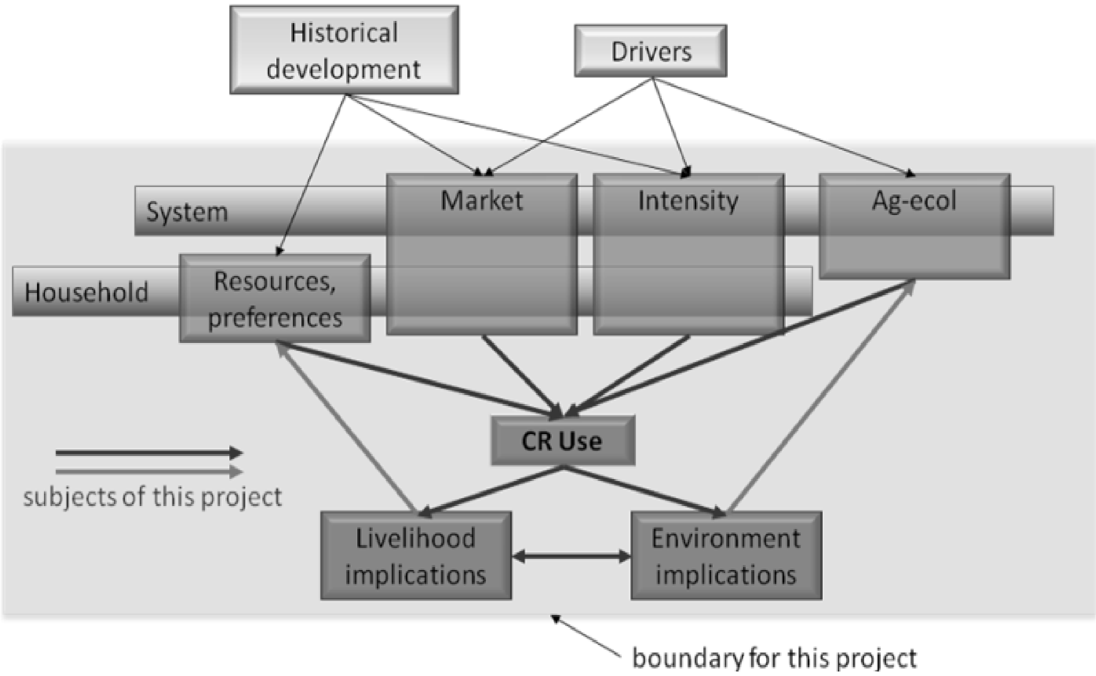

Figure 2: Conceptual framework for scoping study on crop residue uses and trade-offs (SLP).

1.5 Objectives

The study aims at better understanding the diversity of livelihood systems, current crop residue availability and uses of crop residues in order to improve the understanding of the trade-offs that increase total livelihood and environmental benefits for mixed farming systems in southern Africa. This will be helpful to better target technical, institutional and policy (TIP) options for improving livelihoods without compromising long-term system sustainability.

The specific research objectives are to:

1. Characterize livelihood and crop-livestock farming systems, production practices, market access and institutional support
2. Characterize crop-livestock interactions, crop residue production and uses and recent changes in crop residue allocations
3. Evaluate major determinants that influence farmers' decisions on the use of crop residues at household level
4. Identify possible TIP options that could influence the greater availability of crop residues and reduce trade-offs.

2 Methods

2.1 Study sites

The study was carried out at three contrasting sites in southern Africa: Changara district in Tete Province, central Mozambique, represents the most extensive case; Nkayi district in Matabeleland North, southwest Zimbabwe, more intensified land use, greater crop-livestock integration and better market access; Mzimba district in northern Malawi has the highest annual rainfall, human population densities and more intensified cropping activities (Figure 3).

Figure 3: Study sites in Malawi, Mozambique and Zimbabwe (ICRISAT).

2.1.1 Agro-ecology

Changara and Nkayi have low rainfalls with severe dry spells during the rainy season, restricting water for crops and livestock (Table 2). Mzimba has higher agro-ecological potential and biomass production. All sites share mono-modal rainfall regime, with the rainy season between November and April, followed by long dry season with highest temperatures in October.

Soils in Changara and Nkayi are predominantly sands of typically low mineral content, due to low clay and organic matter contents (FAO, 2006). Soils in Mzimba are well drained latosols on the higher parts, and poorly drained sand and clay in the hollows (Reynolds, 2006).

The typical natural vegetation is savannah woodlands and natural grasses at all three sites. Rangeland degradation, soil erosion and nutrient mining affects especially Nkayi, and Changara to lesser extent. In Mzimba the farm input subsidy program encourages inorganic fertilizer application, but without increasing soil organic substance soils risk becoming more acidic.

2.1.2 Socio-economic context

Human population and livestock densities are considered to be the main factors that determine the local demand and management of crop residues. Mzimba has three times the human population densities than Nkayi and Changara, and at district level the livestock densities are also higher (Table 3). This suggests high availability of crop residues and high demand for the residues as livestock feed in Mzimba. In Nkayi we expect a lower supply of residues, lower demand as livestock feed. Changara represents the most extensive site, with lowest human and livestock population densities and less cultivated area.

Access to extension services has influenced crop production. Public support focuses on maize as food security crop. Zimbabwe was among the first countries with a maize-based green revolution. Through input subsidies and market support farmers doubled maize production in few years and Zimbabwe exported large volumes of maize (Eicher, 1995). In Malawi the farm input subsidy program started 2004/05 and also resulted in surplus production for exports (Chibwana *et al.*, 2012). In Mozambique large areas are under-utilized. Extension support is often not functional, particularly in remote areas like Changara (Hagbladde and Nielson, 2007).

The livestock sub-sector has received less governmental support despite the growing demand for livestock products. In Zimbabwe livestock production plays an important role in livelihoods, with support structures adopted from the commercial farming sector, focusing on cattle production for beef and dairy. The attention has been mostly on animal health control. Small stock and fodder supply has only recently received attention (Van Rooyen and Homann, 2009).

Markets for agricultural inputs and outputs are generally poorly developed. In Malawi, deficient markets are a major constraint for income generation from crop and livestock sales, despite the input program (ASWAP, 2011). In Zimbabwe crop and livestock market structures existed in the commercial sector and needs to be adjusted to the needs of smallholder farmers (Hargreaves *et al*., 2005). In Mozambique crop and livestock markets for smallholders are largely informal.

Table 2. Bio-physical and socio-economic indicators at the project sites

	Changara–Mozambique	Nkayi–Zimbabwe	Mzimba - Malawi
Rainfall (mm annual)[1]	650	600	700
District size (km^2)[1]	8,660	5,300	10,382
Densities			
- Human (pers/km^2)[2]	19	23	57
- Livestock (head/km^2)[3]	5.7	5.9	9.6
Net Prim. Production (t ha^{-2})[4]	5.5-6.2	4.8-5.5	6.2-6.8
Extension services[5]	Poor	Limited	Limited
Market access[5]	Poor	Limited	Limited

Sources: [1]District government statistics (2008); [2]CIESIN *et al.*(2004); [3] Robinson *et al*. 2011; [4]Imhoff *et al*. (2004); [5]Expert knowledge

2.2 Data collection

A multi-disciplinary team of researchers working in the study regions, including socio-economists, crop and livestock scientists, developed three research tools.

1. Quantitative focus group discussions at village level, using a structured questionnaire to understand local land use, farming systems and crop residue management.
2. Quantitative household surveys to assess livelihood strategies, agricultural production levels and determinants of crop residues uses.
3. Feedback and solutions workshops: Research results were verified through a series of one-day workshops. Possible TIP options were identified for improving farming systems.

2.2.1 Village and household selection, stakeholder involvement

A central market place was selected at each site, and eight villages of different distances to the market and major roads (n=8 per site). The village level focus group discussions were conducted at the end of 2010 and early 2011. At each village about 15 farmers of different age, gender, land and livestock ownership were invited to participate in the discussions.

The household surveys were conducted at the same time. Twenty households were selected in each village using stratified random sampling by four wealth categories, derived from preceding village census lists (n=160 per site).

Feedback and solutions workshops were held at village and district level. Three villages were selected, with most contrasting conditions in terms of market distance, crop and livestock density and pressure on crop residues (Table 3). Around 20 farmers and local extension officers attended the village-level workshops. Invited farmers ideally had different herd sizes, ages and gender. The following district-level stakeholder workshops were attended by about 30 participants, including farmers, extension, NGOs, local government and authorities.

Table 3. Characteristics of the selected villages for feedback and solutions workshops

Site	**Village**	**Market distance**	**Cultiv. Land**	**Cultiv. land**	**Maize yield**	**Fertil. on maize**	**Herd size**	**Press. on CR**
		Far/near center /road	% of total land	ha/HH	kg/ha	kg/ha	TLU /HH	TLU/ha cult. land
Changara-Mozamb.	1	FN	53.0	1.1	228	0.0	2.1	0.1
	2	NF	35.9	1.0	n.a.	0.0	4.2	0.4
	3	NN	26.6	1.3	393	0.0	1.4	0.2
Nkayi - Zimbabwe	1	FN	70.0	2.4	869	2.1	2.5	0.2
	2	NN	37.7	2.0	448	13.9	1.8	0.2
	3	NN	37.6	1.9	636	13.3	4.4	0.5
Mzimba – Malawi	1	NF	49.9	1.3	1524	139.0	0.8	0.2
	2	NN	60.2	1.3	1637	115.5	1.2	0.1
	3	FN	45.4	1.0	1800	108.5	0.8	0.2

2.2.2 Village and household data collection and analyses

The village questionnaire assessed (i) village location and population; (ii) land use, cultivated area, grasslands and irrigated area; (iii) crop growing seasons, main crops, use of crops and residues; (iv) herd composition, feeding strategies, feed shortages and use of manure; (v) income composition per household wealth classes; and (vi) livelihood indicators such as literacy, access to different services and input/output prices. Selected results were averaged for comparison across the research sites.

The household questionnaire was more detailed about: (i) livelihood assets including incomes, expenditures, food security status, labor allocation, access to markets and services; (ii) land use, crop production and product uses; (iii), crop residue management; (iv) livestock production, performance and herd dynamics; (v) perceptions on crops, residues and livestock; (vi) constraints to crop and livestock production and future priorities. Retrospective components were included in village and household-level surveys to assess changes in farming context and management practices.

The household data were analyzed in SPSS using descriptive statistics to characterize the household assets, crop and livestock production and crop residue uses. Crop residue yields were derived from crop yields using Harvesting Index 0.3 for cereals in Changara and Nkayi, and 0.4 for Maize in Mzimba, and 0.4 for legume residues across the sites. The formula for converting crops into residue yields was: Residues (kg)= Grain yield (kg) * (1-HI)/HI.

The determinants of crop residue uses were identified using the three stage least squares (TSLS) econometric model, applied for the following three crop groups: i) maize, ii) small grains (sorghum and millet), and iii) legumes (groundnuts, cowpeas, beans and roundnuts). Three types of residue uses were considered: i) mulching or residues left on the field, ii) residues grazed by own or others' livestock, and iii) residues used as kraal feed.

2.2.3 Workshop structure, process and analyses

Feedback and consultation with farmers, extension services, development organizations, policy-makers and private sector was to ensure that TIP options will respond to the context-specific situations and take into account local stakeholders priorities for agricultural development.

The workshops were structured as follows, same process for village-level and stakeholder workshops, and across the three sites (Photo series 1):

Introductions, presentations and feedback

First 1-day village-level workshops were held to review the research results with farmers and capture farmers' perceptions and priorities. Farmers were requested split into two groups based on livestock holdings (those with more and those with less), and defined the cut-off points themselves. In each group one participant volunteered to document and report the highlights to the other group. The two groups shared the highlights in plenary.

At the beginning of the village-level workshops, most relevant survey results were presented and discussed, using graphs in poster format. They included:

- Use of crop residues and recent changes, access to information on crop residue uses

- Cropping practices, proportion of legumes in crop mix, yields and levels of mechanization
- Livestock production, feed shortages and herd outflows
- Income generation from agriculture and off-farm activities

Visions, challenges and solutions

Farmers were asked to explain their priorities for investments in crops and livestock. Second, they were asked to choose future options for improving their farms: intensification, diversification, specialization, or moving out of farming. Farmers voted for the most realistic option, i.e., where they see themselves in the next 5 to 10 years. The votes were counted and few farmers explained their vision.

Third, farmers brainstormed the major challenges they face in achieving their visions. The challenges were listed on flip charts and ranked. The top three challenges were allocated to different groups. For each challenge farmers identified the major root causes and identified solutions for each of the root causes. Farmers differentiated whether they could undertake these solutions alone or whether they would require institutional or policy support, and from whom.

Technical, institutional and policy options

The stakeholder workshops focused more on developing TIP options. Feedback on research results and three key challenges identified at the village-level workshops were presented to stakeholders for discussion and further analysis. Stakeholders split into three mixed groups to ensure variety of views. Each group identified the root causes for each challenge and then TIP options to address each challenge. The results were noted on flip charts, presented and discussed with the audience.



Figure 4: Engagement of farmers and other stakeholders in workshops. A. Village focus group discussion in Mzimba. B. Village feedback workshop in Changara. C. Stakeholder solutions workshop in Nkayi.

3 Results

3.1 Farming systems description

3.1.1 Land use and history

Land use is predominantly croplands and rangelands (including grass and woodlands). In Mzimba and Nkayi almost half the village land is cultivated. In Mzimba uncultivated land is scattered reflecting the higher human population density and expanded human settlements. In Nkayi also about half of the village land is cultivated, but large sections of uncultivated rangelands and forests intersect villages. In Changara only about a third of the village land is cultivated, with large areas of uncultivated shrub land between villages. According to farmers observations, human settlements and associated cropland have expanded drastically in Mzimba' and Nkayi, and less in Changara.

Crop production is mainly rainfed, less than 5% of the cultivated land is irrigated. About a fifth of the cultivated land is fallow land, mainly because of short-term constraints to cultivation but not an intention to improve soil fertility. Fodder crop production is not developed.

Feed resources in rangelands and croplands after harvest are usually common property. Fences around crop fields serve mostly to protect the growing crops from livestock. While the crops are individually owned, the cropland will be opened for grazing to the community after harvest. In Nkayi local authorities have developed bylaws that define dates for opening crop fields to communal grazing. Local arrangements are in place that farmers can enclose maximum 0.4 ha cropland to protect the crop residues from communal grazing.

The relative availability of crop residues is expected to influence the site-specific allocation of residues. With expanding croplands, crop residues are becoming more important as livestock feed. Grazing pressure on crop residues is highest in Nkayi, where croplands and herd sizes are large and livestock densities relatively high (Figure 3). Pressure on crop residues for feeding livestock is less in Changara where there is still more rangeland available. In Mzimba cropland is more limited and livestock per person drastically less. As a result of smaller herd sizes, farmers have more crop residues available per unit livestock (1.2 ha cropland TLU^{-1}) as compared to Nkayi (0.6 ha TLU^{-1}) and Changara (0.7 ha TLU^{-1}).

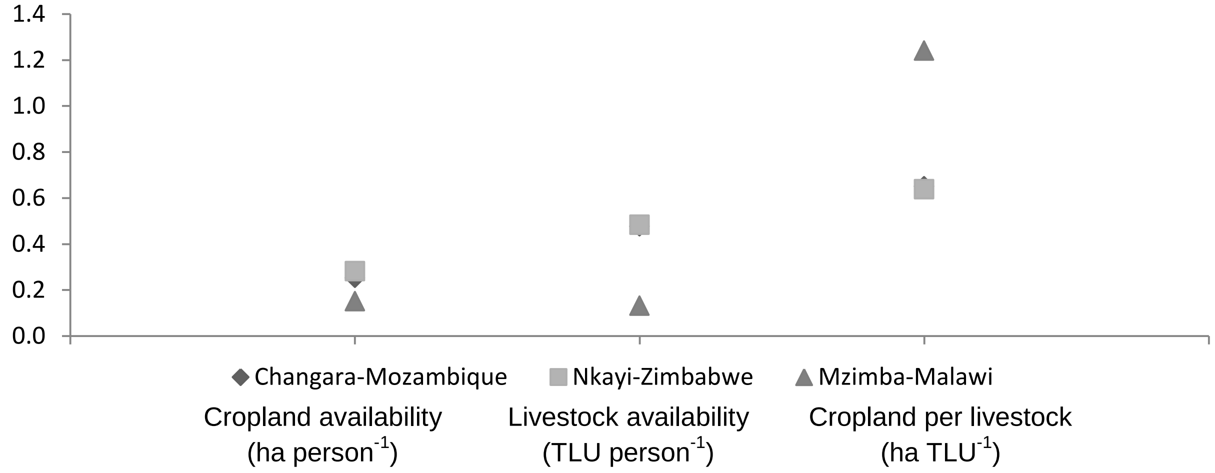

Figure 5. Indicators for cropland and livestock availability at village level at the project sites (source: village survey).

3.1.2 Livelihood situation

Livelihood capitals (physical, social, financial and human) influence farmers' choices on intensification options and crop residue use. Although livelihood capitals are diversely distributed across and within the sites, there is a general tendency that farm households are poorly equipped. Limited capital restricts farmers' options to improve their own livelihoods. Farmers' investments are primarily towards ensuring food security, implying a strong preference for short-term livelihood benefits. This section provides an overview on the livelihood capitals and food security situation.

Natural capital

The distributions of cropland and livestock illustrate different orientations of farming systems (Table 4). In Mzimba, the site with higher agro-ecological potential and higher human population density, the households' cropland sizes are relatively small; less than half of the household's own ruminants. Yet, at landscape level, along with the high human population densities, livestock densities are relatively high. In Nkayi and Changara the farming conditions are more extensive; farm sizes are larger, more households keep ruminants and herd sizes are also larger. The households' ownership of cultivated land and livestock varies largely (standard deviation > 50% of the means), suggesting substantial heterogeneity within the communities.

Table 4: Natural capital indicators

	Changara - Mozambique		Nkayi – Zimbabwe		Mzimba – Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
Cultivated land (ha)	1.5	1.1	1.9	1.3	1.3	1.0
Livestock						
HH with ruminants (%)	53.1		74.4		45.0	
Herd size (TLU)	6.5	7.5	5.1	5.9	3.5	4.1

Physical capital

All three sites are poorly connected to infrastructure and services (Figure 5). Access to electricity is extremely poor. Farmers in Mzimba have better coverage of communication facilities; about half the households have a radio and/or mobile phone. Transport seems better in Nkayi; almost half of the households use public transport; about a third have oxcarts for local transport. In Mzimba and Changara few farmers have a bicycle. Mechanization is extremely limited; tractors or mechanized harvesters are not available. Ploughing is the most common labor saving land preparation technology in Nkayi; few farmers in Changara own a plough. Across sites, the better off households are generally better equipped in communication and transport (phone, radio, bike, oxcart).

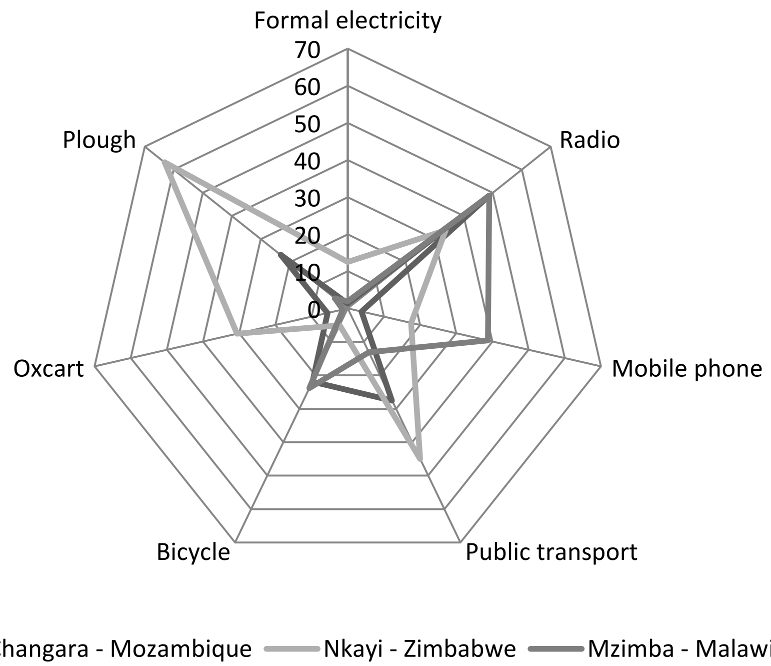

Figure 5: General physical capital indicators

Market access varies across sites. In Mzimba most farmers use crop markets but few use livestock markets (Figure 6 and 7). Almost all households buy crop inputs and the majority sell crop outputs. Main market channels are local shops and village places. Although farmers seems to have access to basic crop market infrastructure, many farmers complained that subsidized inputs are not available and that input prices are too high relative to the low output prices. In Nkayi and Changara more farmers engage in livestock markets than in crop markets. Livestock markets are better developed in Nkayi; many households engage in cattle auctions and they also purchase inputs for livestock. In Changara fewer households engage in markets. Across sites many farmers sell at the farm gate, also to reduce the transport cost.

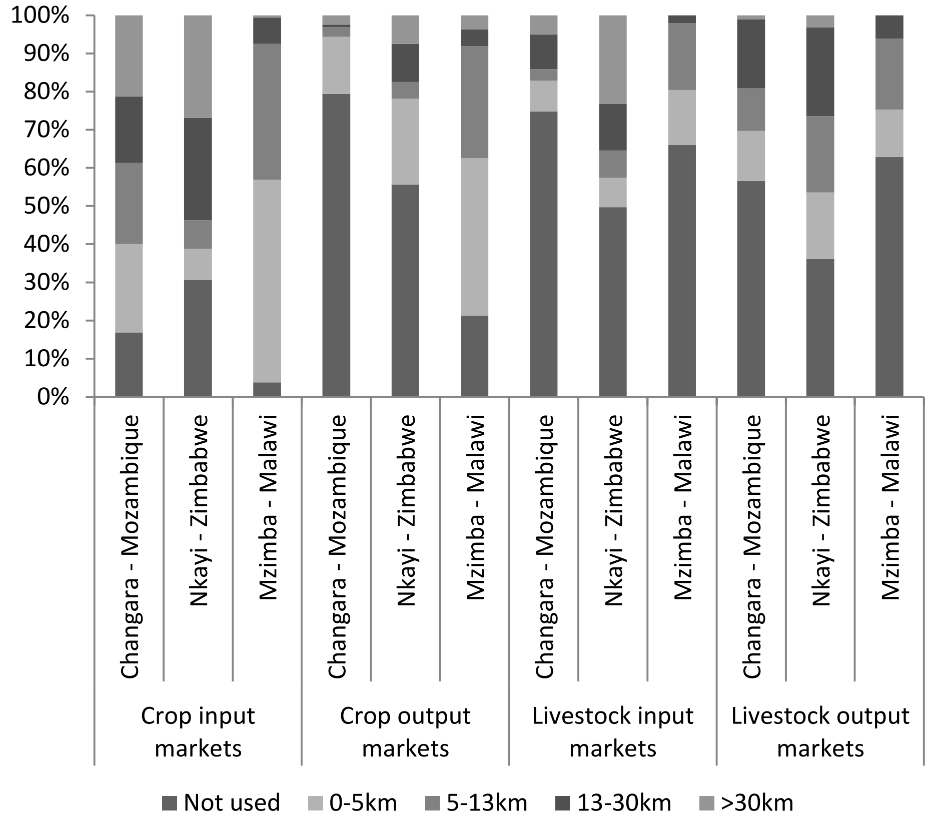

Figure 6. Households using crop and livestock markets (use and distance categories)

Figure 7: Typical livestock markets in A. Mozambique, B. Zimbabwe, C. Malawi.

Human capital

The age structure is relatively old with most household heads older than 50years in Nkayi and around 45 years in Changara and Mzimba. In Nkayi and Mzimba older household heads, in family maturity phase and with more accumulated local knowledge, tend to have larger families, keep more livestock and are better off.

The rate of female-headed households is high, typically for areas with high labor emigration, particularly in Changara, and also in Nkayi and Mzimba (Table 5). Male-headed households tend to be larger, and in Mzimba and Changara they have received more formal education. They seem to cultivate larger land in Nkayi and Changara, especially small grains, suggesting labor constraints. De jure female-headed households seem older in Changara and Nkayi, reflecting that these households are often widowed. In Changara male-headed households tend to be wealthier, and female headed households more among the poor. Cattle herd sizes do not differ by gender, but in Mzimba and Nkayi female-headed households seem to own fewer goats than families in Changara. The fact that agricultural production levels do not differ much between male- and female-headed households suggests that men and women face similar challenges in agricultural production.

Literacy levels are very poor in Changara, partly caused by the displacements during the liberation war until the 1990s; current children's school enrolment has improved through government education programs. Education is largely accessible in Mzimba (3% illiterate) and Nkayi (9% illiterate). Family sizes are larger in Nkayi, but considering the larger croplands and herds, the potentially available family labor is similar across the sites.

Table 5: Selected human capital indicators

	Changara - Mozambique		Nkayi-Zimbabwe		Mzimba – Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
Fem. head. HH (%)						
De jure	25		18.8		10.6	
De facto	10		9.4		13.1	
Age of HH head (yrs)	44.6	16.1	51.8	15.5	45.4	19.1
Education (yrs)						
Head of HH	3.1	3.0	6.4	3.2	6.8	3.1
Spouse	2.6	2.6	6.7	2.7	6.3	3.2
Family size (no/HH)	5.2	2.7	6.7	2.8	5.0	2.3

Social capital and financial resources

Access to extension service is important for broad based knowledge, technology and market information. Although the study could not assess the quality of information provided by extension services, the frequency of extension services as source of information may indicate farmers' access to modern technologies and market support. In Mzimba and Nkayi extension services focus primarily on crop production, and provide less information on market aspects. Livestock extension services are predominantly on animal health, but less on feeding and marketing. Extension services for both crops and livestock are most limited in Changara.

Through associations farmers can develop local strategies for enhancing agricultural production, e.g., cost effectively sourcing inputs and services, joint learning and experimentation programs and gaining a stronger position in market processes. Membership in associations is however generally very low. More farmers in Nkayi are members of farmers associations, which is probably related to farming support through NGOs.

Financial resources, other than that stored in natural capital, are limited at all sites (Table 6). In Mzimba few households have access to credit. In Nkayi some households have savings.

Table 6. Selected social and financial capital indicators

	Changara - Mozambique	Nkayi - Zimbabwe	Mzimba – Malawi
Access to credit (% HH)	5	2.5	11.9
Access to savings (% HH)	5.6	27.5	18.1
With extension on (% HH)			
New crop technologies	8.1	75.6	80.0
Crop market information	10.6	55.0	65.5
Livestock feeding	23.2	46.5	62.9
Livestock health	27.3	80.0	68.0
Livestock marketing	22.2	41.9	67.0
Member of association (% HH)	1.3	20.6	8.1

Food security situation

With the above listed capitals, most farmers do not produce enough to sustain their households' food requirements from own production throughout the year (Table 7). Farmers are net buyers of food for at least two months per year. In low rainfall years, farmers in Changara and Nkayi have to supplement food for 8 to 9 months. Nkayi has received more food aid as compared to Changara and Mzimba.

Table 7. Food availability indicators

	Changara– Mozambique		Nkayi– Zimbabwe		Mzimba– Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
Enough food average rain year (months)	10.4	2.3	9.5	2.9	10.8	1.5
Enough food low rain year (months)	3.6	1.8	3.2	2.2	6.2	2.5
Years of food aid past 5 years	0.7	1.3	2.5	1.2	0.1	0.3

Household expenditure profiles illustrate farmers' investment priorities. Across the sites, households spend most of their expenditures on food (Figure 8). This confirms that most farm households are net buyers of food. Unexpectedly, households in Mzimba spend large parts of their expenditure on crop inputs, despite the farm input subsidy program. The subsidies might not reach all farmers and might not be sufficient to cover farmers' requirements. In Nkayi better off households invest more in crop inputs, with access to cash serving as a constraint for investments. All farmers in Nkayi invest large shares in education, ways out of agriculture. In Mzimba the better off-farmers invest more in education. Expenses on livestock inputs are insignificant; better off households invest slightly more in livestock inputs.

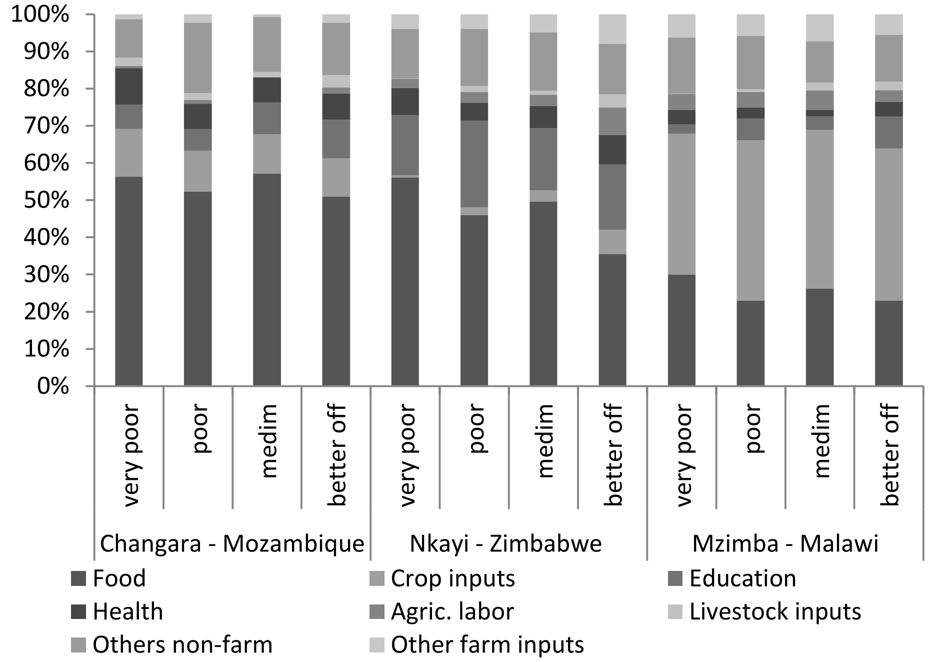

Figure 8: Proportions of expenditures by wealth classes

As the income portfolios illustrate, farmers at all sites derive large parts of their income from off-farm income, especially at the higher risk areas Changara and Nkayi (Figure 9). The contribution of off-farm income declines and agriculture increases with higher wealth levels, off-farm income is thus a strategy to complement the limited income from agriculture. In Changara and Nkayi medium and better off farmers have more livestock and derive substantially more income from livestock. In Mzimba income from crops is more important.

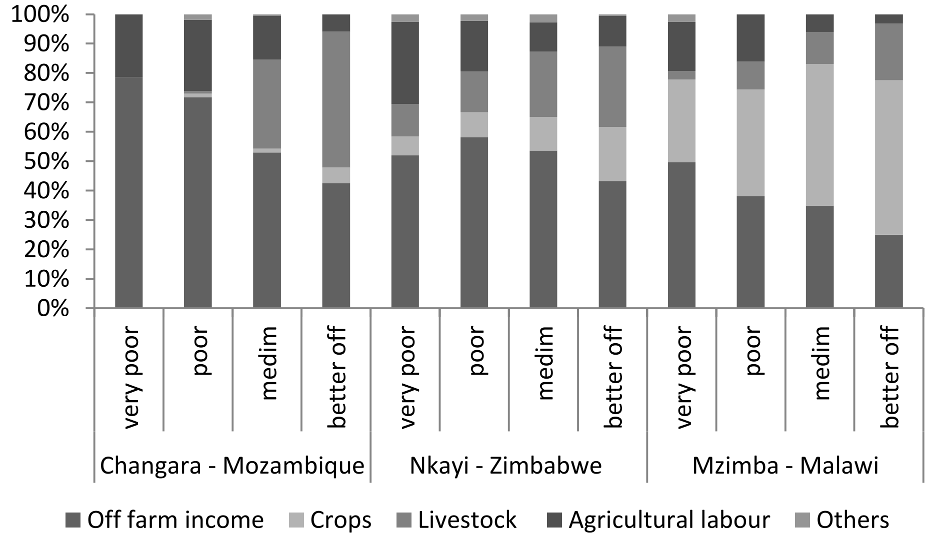

Figure 9: Proportions of incomes by wealth classes

3.2 Crop and livestock production

A closer look at the distribution and management of croplands and livestock illustrates farming systems at different levels of agricultural intensification. This affects the availability and allocation of crop residues.

3.2.1 Crop production

Crop production is mainly for subsistence; few farmers in Mzimba and Nkayi produce cash crops (Table 8; Figure 10). The importance and performance of the different crops varies within and between the sites:

- Maize and groundnut farming in Mzimba: All households produce maize and about half the households produce groundnuts. The legume to cereal ratio is higher than at the other sites (0.28). About a third of the households engage in tobacco production. Higher rainfall and massive government support and private sector investment favor the production of these crops. Few farmers also grow roots and tubers.
- Maize dominated crop farming in Nkayi: Maize production also predominates here, promoted by government extension and NGOs. The area under small grains and legumes is comparatively small (legumes to cereal ratio 0.11), about a third of the households grow these crops. Few farmers grow cotton as cash crop.
- Small grain oriented crop farming in Changara: Small grains are most common, in adaptation to the lower and more erratic rainfalls, and absence of maize promotion. About 40% of the households also grow maize. Fewer households cultivate legumes and the area under legumes is also limited (legume to cereal ratio 0.14).

Table 8: Households growing crop types and area sizes

	Changara - Mozambique			Nkayi - Zimbabwe			Mzimba - Malawi		
	% HH growing	Area size (ha/hh)		% HH growing	Area size (ha/hh)		% HH growing	Area size (ha/hh)	
		Mean	StDev		Mean	StDev		Mean	StDev
Maize	41.3	0.7	0.6	99.4	1.4	1.1	100	0.8	0.5
Small grain	96.9	0.9	0.7	30.6	0.8	0.8	3.1	0.3	0.3
Groundnut	13.1	0.5	0.3	38.8	0.3	0.3	56.3	0.4	0.2
Oth.legume	20	0.5	0.3	16.9	0.2	0.2	10.6	0.3	0.3
Cash crop	0	0	0	3.1	1.4	1.4	32.5	0.6	0.5
Roots/tuber	0	0	0	0	0	0	10	0.5	0.6

Figure 10:.Crop fields. A. Small grains in Changara, B. Groundnuts in Nkayi, C. Maize in Mzimba.

Men and women make most of the decisions about crop production and crop residue management together (Figure 11). Male dominated decisions are mainly in Changara.

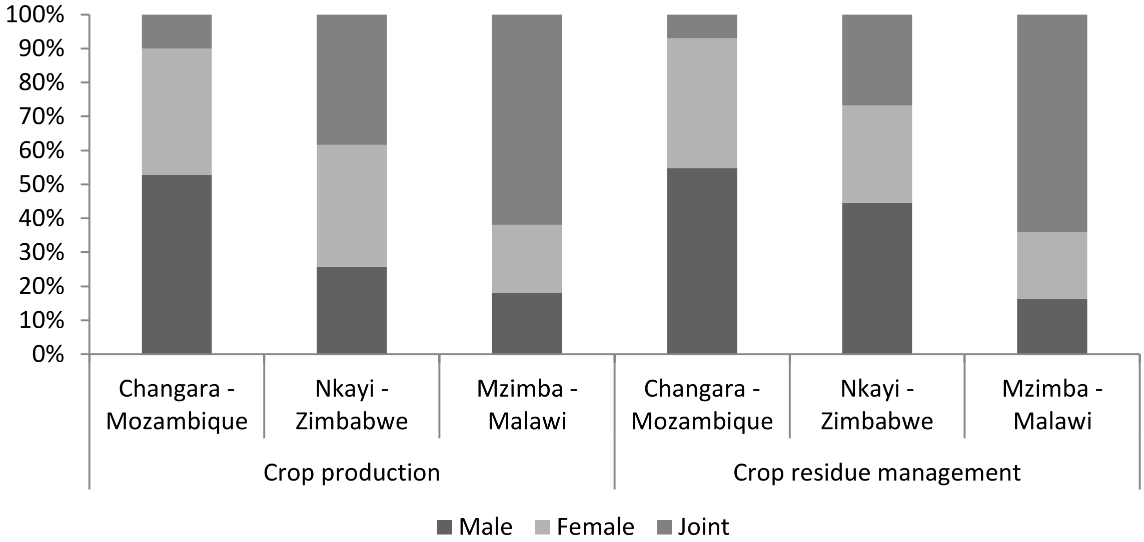

Figure 11: Decisions on crop production and crop residue management by gender

Levels of crop intensification, by use of external inputs and use of crop-livestock integration, differ across the sites (Table 9). Farmers invest more in maize as compared to other crops.

- Intensified crop production in Mzimba: Farmers invest in maize production through use of external inputs: almost all farmers apply inorganic fertilizer and the rates are relatively high (118kg/ha); almost half of the farmers use hybrid seeds (43% of the area). Use of draft power and manure seem however insignificant. Farmers invest less in other crops, apart from hybrid seeds.
- Crop-livestock integration in Nkayi: Investments are also predominantly in maize production, but in the form of inputs from livestock. Although only about 60% of the households have cattle, almost all use animal draft power (96%), through share cropping arrangements. About a third of the farmers apply manure (479kg/ha). Farmers try to combine the use of manure with inorganic fertilizer, but only about a fifth apply inorganic fertilizer. About 42% use hybrid seeds. Few farmers engage in conservation agriculture (9%). Investments in other crops are limited, apart from animal draft power.

- Extensive crop production in Changara: About half the households use animal draft power, but other investments in crop production seem extremely limited. Farmers seem to prioritize their limited manure to legumes and small grains, but not to maize.

Table 9. Intensification levels in crop production

	Changara - Mozambique		Nkayi – Zimbabwe		Mzimba – Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
Maize						
Tillage by animal (% area)	50		96.2		3.8	
CA (% HH)	0		9.4		0	
Seed rate (kg/ha)	19.7	10.6	22.9	8.4	23.0	8.6
Hybrid seed (% area)	13.6		41.5		42.5	
Manure (kg/ha)	0	0	479.3	1170.3	63.4	149.6
Chemical fertilizer (kg/ha)	0	0	9.7	29.3	117.9	60.9
Small grains						
Tillage by animal (% area)	45.8		100			
CA (% of area)	0		0		0	
Seed rate (kg/ha)	12.7	16.4	9.0	10.0	2.4	2.5
Hybrid seed (% area)	1.3		4.1		60	
Manure (kg/ha)	5.9	37.9	33.2	185.4	0	0
Chemical fertilizer (kg/ha)	0	0	0	0	0	0
Groundnuts						
Tillage by animal (% area)	47.6		95.2		5.6	
CA (% of area)	0		4.8		0	
Seed rate (kg/ha)	22.2	21.2	20.1	15.4	15.5	6.6
Hybrid seed (% area)	4.8		8.1		71.1	
Manure (kg/ha)	16.7	53.2	30.3	238.8	8.4	79.5
Chemical fertilizer (kg/ha)	0	0	0.3	2.5	0	0

Yield analysis of the major crops illustrates large variations. Yield gaps are considerable for all major crops (Figure 12). Mzimba has higher maize and groundnut yields (1.5 and 0.6t/ha respectively), a function of higher rainfall and access to fertilizer and seeds through the farm input subsidy scheme. There are farmers who achieve yields of more than threefold the average yields, illustrating a large potential for improvement. In Nkayi and Changara, with lower rainfall and poor access to inputs, maize yields are on average 0.7 and 0.3 t/ha, respectively. Groundnut yields are higher in Nkayi than in Changara (0.4 and 0.2 t/ha respectively). Maximum yields confirm that production can at least be doubled in these areas.

Small grain yields are the lowest, although they are drought tolerant and commended as appropriate crops for the semi-arid areas. In Nkayi, where small grains are traditional crop, average yields are as low as 0.4 t/ha. Small grain yields are extremely low in Changara, despite being the main crop (0.1 t/ha). Low small grain yields reflect the lack of attention and investments in these crops.

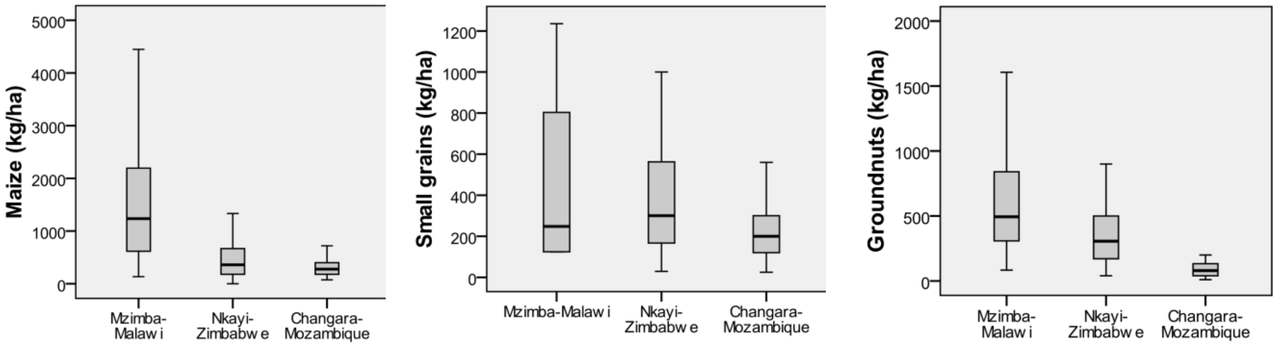

Figure 12. Crop yields at the project sites

Note: Yield outliers removed: Maize 6.4%, small grains 9.7% and groundnuts 15.0% of the cases.

Farmers tend to consume the largest proportion of crops and retain a small share for their own seeds, confirming that crop production is oriented towards subsistence (Table 10). In Mzimba, farmers sell a small proportion of their maize, and about a quarter of their groundnut harvests. Crop sales are insignificant in Nkayi and Changara.

Table 10. Estimated proportion of crop harvest being sold (%).

	Changara - Mozambique		Nkayi – Zimbabwe		Mzimba – Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
Maize	2.1	7.8	6.7	13.7	10.2	14.4
Small grains	0.8	5.1	6.9	19.0	27.9	40.5
Groundnuts	1.9	7.9	7.6	21.0	23.0	26.8

When asked about their perception of future trends farmers see a strong expansion and intensification of crop production, associated with human population growth and existing support programs. The growth projections differ across the sites:

- Mzimba: Strong growth for maize, roots and tubers, but negative trends for small grains and other legumes than groundnuts. Small grains were mainly produced as livestock feed, which might become more restricted under the limited land per household.
- Nkayi: Strong growth for maize and groundnuts, but negative trends for cotton associated with volatile prices and uncertain markets, and for sorghum and millet with high labour for processing and standing crops often attacked by birds.
- Changara: Strong growth for all major crops, despite the identified challenges.

3.2.2 Livestock production

Cattle and goats provide multiple benefits. Draft power and cash income are the most important functions. Milk production is limited and mainly used for home consumption. The role of livestock and livestock performance varies across the sites (Table 11):

- Diverse herds in Mzimba: About a quarter of the households keep cattle, on average seven heads. About a third of the households keep small ruminants, on average eight goats (small ruminants to cattle ratio 0.22). Farmers keep cattle for multiple purposes, cash income, milk and draft power seem of similar importance. They keep small ruminants mainly for cash income and home consumption. More households here than at the other sites keep pigs.

- Cattle dominated production in Nkayi: Cattle dominate livestock production (small ruminants to cattle ratio 0.12). More than 50% of the households own cattle and goats; herd sizes are similar to those in Mzimba. Draft power is the most important cattle function, illustrating crop-livestock integration. Cash income and milk are important to a lesser extent. Small ruminants are for cash income and home consumption.
- Diverse herds in Changara: Cattle and small ruminant herd sizes are larger than at the other sites (small ruminants to cattle ratio 0.27). However, only about a third of the households keep cattle and half of the households keep small ruminants. The cash income function is the most important function of cattle and small ruminants and seems to be of higher priority than keeping the animals for their inputs to crop production.

Table 11. Households with livestock and herd sizes

	Changara - Mozambique			Nkayi - Zimbabwe			Mzimba - Malawi		
	% HH owning	Herd size (n/hh)		% HH owning	Herd size (n/hh)		% HH owning	Herd size (n/hh)	
		Mean	StDev		Mean	StDev		Mean	StDev
Cattle	34.4	11.3	9.5	57.5	7.7	7.2	26.3	7	6.0
Goats	45.6	15.4	14.8	56.9	6.1	7.9	33.1	8.3	6.3
Sheep	1.3	14.0	5.7	2.5	5	3.1	0.6	3	n.a.
Donkeys	0	0	0	15.6	4.4	2.7	0	0	0
Pigs	15.6	2.8	2.6	5.6	7.2	4.4	25.6	4.7	4.1
Chicken	30	15.0	14.7	85.9	13.3	8.2	63.8	10.1	7.5

Men seem to play a stronger role in decision-making about livestock production (Figure 13). Women have more decision-making authority over small stock than large stock. More joint decision-making was found in Mzimba as compared to Changara or Nkayi.

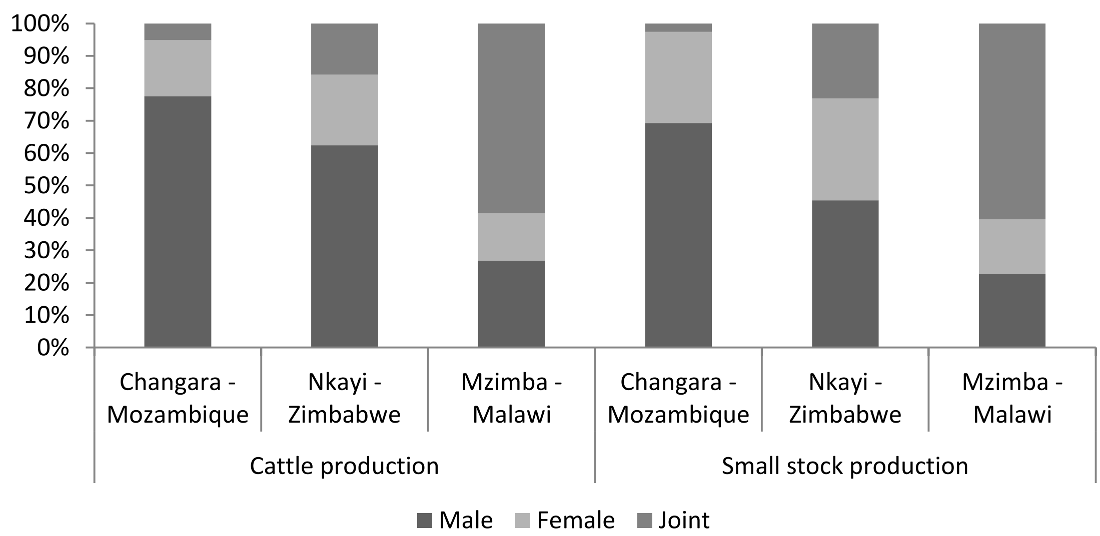

Figure 13: Decisions on cattle and small stock management

Despite their important functions, herd productivity is low (Table 12). Losses through mortality outweigh productive uses. Average cattle mortalities vary around 10%, as compared to sales less than 1%. Low off-take confirms the main function of cattle as farm input or wealth storage.

Lowest herd productivity is in Nkayi, 15% cattle and 27% goat mortality. High livestock densities against limited feed resources might be a major factor. Goat sales are also lowest in Nkayi, reflecting limited attention attributed to goats, since farmers focus more on cattle. Although farming in Mzimba is crop oriented, herd productivity is higher. Higher rainfall and abundant feed resources might explain this. More households use cattle for consumption ($p<0.01$). Goat off-takes are high in Changara (>25%), confirming goats as important income generation strategy ($p<0.01$).

Table 12. Cattle and goat outflows at the project sites

	Changara - Mozambique		Nkayi - Zimbabwe		Mzimba - Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
			Cattle			
Mortalities	12.9	19.5	14.6	19.3	9.7	20.1
Sales	0	0	0.4	2.7	0	0
Consumed	0	0	1.1	3.8	2.9	7.3
			Goats			
Mortalities	13.9	18.1	26.9	25.6	5.6	12.1
Sales	19.9	19.4	4.7	13.3	10.4	14.6
Consumed	5.8	7.8	8.5	12.7	9.9	14.5

Milk yields and reproductive performances are also low (Table 13). Cattle milk yields vary between one and two liters per day and the lactation period is around 10 months. Intercalving periods and age at first calving seem higher in Nkayi, contributing to low herd productivity.

Goats are often not milked for human consumption, but the milk is kept for their kids. Inter-calving period and age at first calving ranged around 7-8 months and 10-15 months respectively, and were also lower in Nkayi.

Table 13. Cattle and goat milk performance and fertility estimated by farmers

	Changara - Mozambique		Nkayi - Zimbabwe		Mzimba - Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
Cattle						
Milk yields (l/day)	1.5	0.7	1.3	0.6	1.3	0.6
Lactation period (months)	10.0	4.0	11.0	4.4	9.0	3.2
Inter-calving period (months)	14.9	6.2	18.0	8.0	15.4	4.1
Age first calving (months)	36.7	9.4	39.4	9.0	24.4	11.9
Goats						
Milk yields (l/day)	0.4	0.3	0.4	0.2	n.a.	n.a.
Lactation period (months)	4.9	1.8	4.6	1.6	n.a.	n.a.
Inter-calving period (months)	6.8	1.1	8.1	2.1	8.6	2.0
Age first calving (months)	10.8	4.5	15.1	7.8	9.8	3.2

As the above figures reflect, current livestock output levels are low, but individual households demonstrate the possibility of achieving higher outputs. Given the fact that the levels of input use are also low, a strong potential for increasing livestock production can be expected. Farmers however are uncertain about the growth potential of livestock. Especially for large ruminants the projections are negative, associated with feed shortages and diseases, and reflecting management challenges:

- Mzimba: Negative trends for most livestock species except for goats and pigs. Goats and pigs are easier accessible to households, and associated with low investment costs. Negative trends for poultry are associated with disease outbreaks.
- Nkayi: Negative trends for most livestock species except poultry. Farmers realize declining herd sizes per households. They see greater challenges to feed livestock as well as to deal with the prevalent diseases.
- Changara: Strong growth potential for goat production, reflecting a strong market demand by goats but also goats' hardiness to live in the harsh environment. Farmers see a potential for keeping more cattle and poultry but not as strong as for goats.

3.2.3 Crop-livestock integration

Levels of crop-livestock integration, measured in livestock contributions to crop production and vice versa, vary across the sites. Farmers in Nkayi, as well as those in Changara to some extent, make great use of draft power to sustain crop production. In both countries however feed shortages peak when these services are needed.

Farmers in Nkayi also make greater use of manure for crop production (Table 14). Lowest manure use of manure in Changara, where farmers also do not use inorganic fertilizer, confirms high risk of soil nutrient mining.

Table 14. Estimated use of manure during peak planting season (%)

	Changara - Mozambique		Nkayi - Zimbabwe		Mzimba – Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
Manure/organic fertilizer	6.8	23.8	34.7	45.5	20.7	38.2
Not used	93.2	23.8	61.9	45.5	78.9	39.3
Others	0	0	3.5	12.4	1.1	12.7

Despite feed shortages restricting livestock production, farmers invest little in feed technologies. Rangelands are still the major feed resource throughout the year. In Nkayi and Mzimba crop residue grazing and collected crop residues provide up to 40% of the cattle and goats feed intake during the dry season (Table 15). Forages and commercial stockfeeds are insignificant.

Apart from the limited biomass, feed quality is a serious constraint to livestock nutrition. The nutritional value of the mostly available maize residues is low (6-7% crude protein and 7.5 MJ/kg DM). Small grain stover is less preferred as livestock feed, and also has low feed value. Legumes provide the best crop residue quality, ranging around 10% crude protein, and 8 MJ/kg DM. The areas cultivated to legumes are however small.

Table 15: Estimated feed contribution (%) to cattle and goat nutrition during dry season

	Changara - Mozambique		Nkayi - Zimbabwe		Mzimba - Malawi	
	Mean	StDev	Mean	StDev	Mean	StDev
			Cattle			
Rangelands	75.5	11.2	61.1	24.3	60.3	22.1
Crop residue grazing	22.2	10.9	15.7	20.3	24.6	22.5
Dry fodder	2.3	5.7	23.3	24.7	12.1	22.4
Green fodder	0	0	0	0	3.0	8.8
			Goats			
Rangelands	76.7	12.6	63.6	22.1	62.3	25.0
Crop residue grazing	22.2	11.9	28.2	22.8	25.1	25.6
Dry fodder	1.1	5.1	7.8	13.3	10.2	17.4
Green fodder	0	0	0.4	3.0	2.3	7.8

The study results illustrate sites at different levels of intensification and crop-livestock integration (Table 16). Given Nkayi and Changara's limited access to external resources, crop-livestock integration is important. Farmers in Nkayi already use the complementarities between crops and livestock. Improved use of crop residues strengthens livestock functions, especially the timely availability of draft power. Manure application and draft power use enable farmers to increase crop grain and residue yields. In Changara, the links between crops and livestock are less developed. In Mzimba the benefits of crop-livestock integration could be better utilized, e.g. dairy production to make use of available feed resources, manure application complementary to inorganic fertilizer use, as well as draft power for saving human labor.

Table 16: Summary of indicators for crop and livestock integration

	Changara - Mozambique	Nkayi - Zimbabwe	Mzimba - Malawi
	Crop contributions to livestock production		
Crop residues	++	+++	+
	Livestock contributions to crop production		
Draft power	++	+++	+
Manure use	+	+++	++

3.3 Crop residue uses and determinants

The relative availability of crop residues (supply of residues for feeding and available alternative feed biomass) and livestock holdings (demand for residues as feed) are key factors expected to influence the site-specific allocation of residues towards livelihood and environmental benefits.

3.3.1 Current and past crop residue uses

Crop residues are mostly used as livestock feed, predominantly grazing. The case of Nkayi illustrates the importance of crop residues where feed is limited: Local by-laws exist that define cropland after grain harvest as common property, and thereby sustain access to the residues for all households. Many farmers collect and store the residues after harvest for kraal feeding, appropriating the residues for individual use. Kraal feeding allows farmers to support draft animals for ploughing, which coincides with the period of peak feed shortages. Through kraal feeding farmers also increase the availability of manure for soil fertility improvement.

Farmers leave residues on the fields, but not necessarily as a deliberate effort for soil amendment. In fact, only very few farmers produce sufficient residues to achieve a positive effect on soil amendment. Farmers would need to retain about 1 t crop residues per ha, assuming a recommended minimum of 30% soil cover (Naudin *et al.*, 2011). It is only in Mzimba that most farmers (92%) produce this amount. Very few farmers in Nkayi (48%) and Changara (26%) produce 1 t of crop residues per ha. Considering that most residues are used as feed, actually only 17% farmers in Mzimba and less than 2% in Nkayi and Changara retain sufficient residues to achieve an impact on soil health.

More than 50% of the crop residues are fed to livestock across all sites. Other uses of crop residues vary across sites and by types of crops (Figure 14 and 15).

- Most extensive crop residue use in Mzimba: Large shares of maize residues are mulched (19%) and burnt (18%). Groundnut stover, although recognized as a high protein feed, is also mulched (17%) and burnt (6%). Farmers observe increasing use of mulching and kraal feeding maize residues. They seem to realize the value of residues for soil health and livestock feed.
- Most intensive use in Nkayi: Farmers collect a substantial share of groundnut (34%) and maize (20%) residues for kraal feeding; kraal feeding is being practiced by 42.1% of the households. Farmers' burn small grain residues (13%), mainly millet, as

they are less appreciated as livestock feed. Very few residues are left for mulching. Farmers do not see a change in the use of crop residues.

- Emerging intensification in Changara: Groundnut (50%) and small grain (22%) residues are largely mulched. These residues are left on the field, reflecting a lack of awareness of the feed value of residues or less appreciation as livestock feed. Few farmers in Changara see an increasing use of residues for kraal feeding,suggesting that farmers do realize crop residues as valuable feed resource and start intensifying its use.

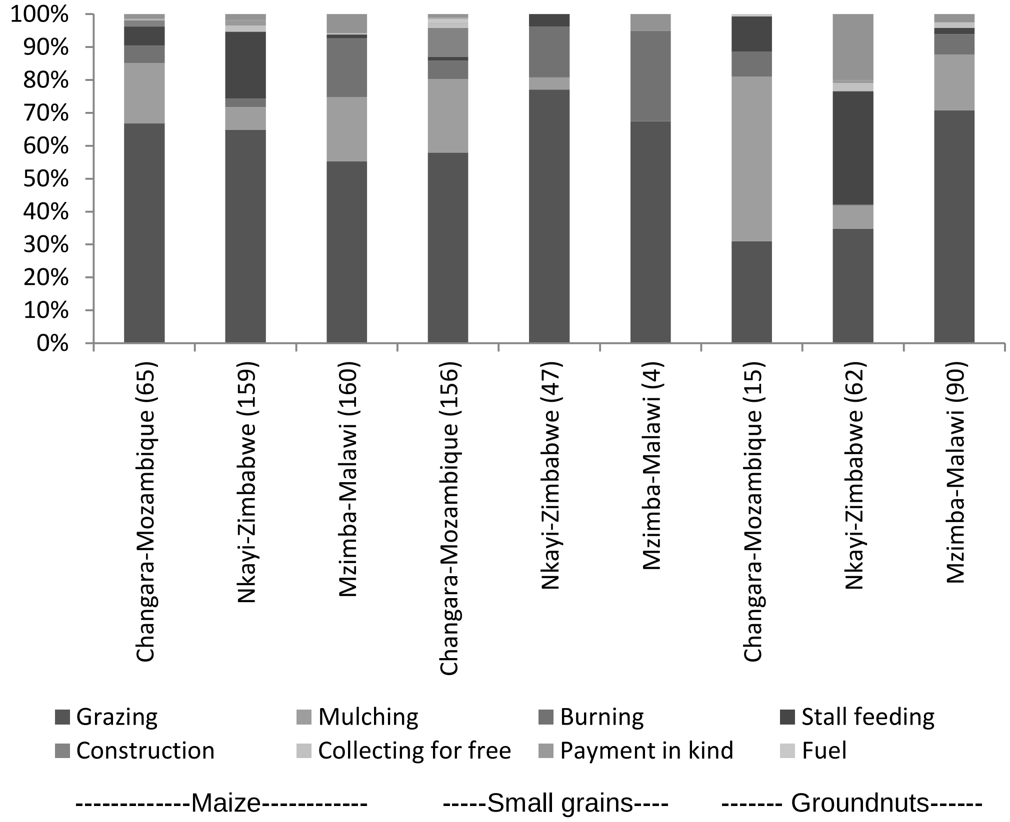

Figure 14: Proportion of crop residue uses of major crops at the study sites

Figure 15: Alternative crop residue uses. A. Grazing in Changara, B. Storage for feeding in Nkayi, C. Burning in Mzimba, D. Mulching in Nkayi

3.3.2 Determinants of crop residue uses

The econometric analysis of determinants of households' residue uses identified several factors that help explain the allocation of crop residues for feed or mulch. We summarize results for the aggregate data on maize, small grains and groundnuts residues, and refer to crop and site-specific implications. Appendix A to F list the econometric outputs.

Socio-economic factors

- Self-sustained food security: The more food secure households, those with more livestock and better resource endowment, use maize residues more for kraal feeding and grazing to support livestock, rather than for mulching. Households with livestock tend to be more food secure.
- Age and education of heads of households: Older and more educated heads of households use more residues for grazing and leave fewer residues on the soil for mulching. They often have larger herds and might have accumulated more experience and knowledge on livestock production. They tend to better understand the nutritional requirements of livestock.
- Women involvement in decision-making: Where women are more involved in decision-making, kraal feeding maize residues declines, but grazing the residues increases. This might reflect labour shortages.
- Off-farm income: Households with higher proportion of off-farm income use more legume residues for grazing. In the absence of feed markets, purchase of higher quality feed and thereby substituting crop residues as feed is limited.

Crop production related factors

- Farmers' perception on mulching: Farmers who believe that mulching is vital for soil health used more residues for mulching and less for grazing. This confirms farmers' perceptions as an important indicator on decisions made on the allocation of crop residues.
- Information on crop production: Households with access to external information on crop production use more residues for mulching. Crop extension services emphasize soil amendment, e.g. through the promotion of conservation agriculture.
- Cropland size: Access to larger cropland and more residue biomass was expected to result in fewer residues for feed and more for mulching. This pattern was however only found in Changara. It confirms that more alternative biomass is required for providing more residues for soil amendment.
- Use of draft power: Households that use animal draft power to till their fields use the residues as feed rather than leaving them on soil as mulch. Especially in Nkayi farmers feed residues to draft animals in their kraal, to sustain draft power for cropland preparation.
- Fertilizer application: Farmers who use inorganic fertilizer tend to increase the proportion of crop residues for mulching, enhancing the effect of fertilizer on crop growth. Yet, there is no consistency between inorganic and organic fertilizer and crop residue uses.
- Access to crop markets: The effects of participation in crop markets were less clear. It confirms the role of crop production for subsistence and limited market orientation.

Livestock production related factors

- Farmers' perception on feeding: Farmers who see crop residues as vital feed applied more maize residues for kraal feeding. They also used fewer small grain and legume residues for mulching. Once more, farmers' perceptions match well with crop residue uses.
- Herd size: Against our expectations, the effect of livestock numbers, measuring the demand for crop residues, is not strong. Farmers with more livestock tend to use more legume residues for kraal feeding.
- Access to livestock markets: In line with the limited effects of crop markets, effects of livestock markets on crop residue uses were also limited, indicating that farmers are pre-occupied with subsistence needs and market oriented investments not yet evolved.
- Information on livestock production: Contrary to crops, access to information on livestock production did not influence the use of crop residues. This might confirm limited outreach of livestock extension services and lack of awareness of livestock nutrition.

3.4 Feedback and solutions workshops

3.4.1 Visions, challenges and solutions

Based on the site-specific situation analysis of crop and livestock activities, farmers and extension officers, at village-level workshops, delineated local pathways for agricultural development, including the implications on crop residue uses. Across the sites there was a unified opinion that the future for farmers is in agriculture. Moving out of agriculture seems unrealistic. Crop and livestock production are however at very low states, far below their potential.

- Mzimba - intensification and specialization of crop and livestock activities: Farmers already operate at higher levels of crop intensification. With higher crop and biomass production farmers have more choices on how to allocate their crop residues. The challenge for them is to operate more efficiently on limited land and preserve the natural resource base. Most farmers opted for intensification since they realized that there is substantial scope for improved crop management and better integration of crops and livestock. Important entry points are new crop varieties, pest and disease control, complementing inorganic fertilizer with manure, mulching crop residues for soil amendment, as well as feeding crop residues to livestock and improve housing of livestock. Few farmers opted for specialization into cash crop production, e.g. tobacco, where they already use crop residues for mulching. Those who would venture into dairy production need to improve feed quality and management. Policy support is needed to expand existing input and service delivery and include livestock as well, and support the exploration of special markets.

- Nkayi - intensification through enhanced crop-livestock integration: Most farmers are confident that application of external resources (seeds, fertilizer, forages), improved rangeland management as well as better integration of crop and livestock activities will allow them to move farming systems to higher states. Farmers invest in and value livestock more here, especially as a necessary precondition to increase crop production. Apart from readily available draft power, cash from livestock sales will enable them to re-invest in crop production. The major constraints across villages are the lack of access to water (rain, natural, constructed) and maintenance of existing water sources. Limited capital equipment, direct consequence of poor management, prevents farmers' from investing in improved production technologies. This was further restricted through poor access to inputs and relevant knowledge about crop and livestock production. More integrated crop-livestock extension services are required to assist farmers in building their crop and livestock assets. Developing existing market structures for crop and livestock, input and output markets are seen as opportunities. Cost-effective linkages and better coordination between farming communities, government, NGOs and private actors are seen as key for addressing the constraints.

- Changara - diversification through livestock as a risk minimizing strategy: Livestock plays the most critical role, mainly to generate cash income but also for providing inputs to crop production. Better access to livestock markets seems to stimulate higher off-takes. Despite extremely low crop yields all farmers highlighted that investments in crop production are critical for providing households with basic food security. For their future most farmers opted for diversification, notably those without livestock wanted to start livestock production in order to generate more income. Reinvestments from livestock into crop production will allow farmers to achieve higher states of agricultural production. The main constraint to diversification of the farming systems is also related to limited water, due to low and erratic rainfall, degradation of natural water sources and lack of alternative water sources. Difficult access to appropriate production enhancing technologies, inputs and credit further restricts agricultural production. Theft of livestock delineates the most important productive assets. Farmers see better collaboration between communities, provincial/district level authorities and the private sector as critical to facilitate development. They request local allocation of extension services to promote improved technical options. National programs and investments in basic infrastructure and services for crop and livestock production with incentives for private sector investments are required to develop the remote area.

3.4.2 Technical, institutional and policy options

At stakeholder workshops feedback was given on the situation analysis, future visions and major challenges for transforming agriculture. Stakeholders defined TIP options for the site-specific agricultural development pathways, addressing the major challenges while also taking into consideration the livelihood and environmental benefits from crop residues. The major agricultural challenges are surprisingly similar across the three sites:

- Poor water availability, largely a consequence of human made degradation.
- Poor access to inputs and services, lack of investment, coordination and incentives,
- Limited capital assets, result of poor crop and livestock management and lack of appropriate support structures.

The site-specific TIP options reflect the different development pathways. All three sites highlight the need for consultative processes through which stakeholders can contribute to adjust the development pathways (Table 17):

- Mzimba: Greater attention was given towards enhancing sustainable utilization of soils and land and using the available resources more efficiently. Stakeholders emphasized the need to improve support for crop production and create adequate support for livestock as well. Policies should provide incentives for private sector investment in rural areas.
- Nkayi: Stakeholders prioritized strengthening crop-livestock integration and intensification. The emphasis was on stakeholder-driven processes that can play a much greater role for directing interventions towards market-oriented crop-livestock farming systems. Policy makers should strengthen stakeholder networks as effective tools to link farmers to markets.
- Changara: A very strong role was attributed to government-driven support programs for facilitating basic infrastructure, services and capacity strengthening. Policy makers need to be informed and involved in the design of programs and legislation that support investments in crop and livestock production.

Table 17: Summary of challenges, root causes and TIP options identified at stakeholder workshops by project sites

Root causes	Technical options	Institutional options	Policy options
	Mzimba in Northern Malawi		
1.Pooraccess to water			
Declining and more erratic rainfall. Deforestation and bush fires. Poor crop management practices, cultivation on steep slopes, poor soil fertility management.	Agro forestry, prevention of deforestation, CR burning and bush fires. Promotion of good crop management, incl. CA practices, early-maturing varieties, early planting. Crop cultivation in wetlands. Irrigation agriculture.	Community participation and involvement of traditional leaders to design rules and regulations for sustainable land management. Allocation of adequate extension officers to rural areas, and strengthening their cooperation with NGOs and private sector. Better coordination of development programs and actors based on community needs.	Government to expand agricultural support programs in Mzimba by increasing extension staff numbers and resources allocated to them. Better integration and coordination of NGOs with ongoing programs.
2. Limited assets and capital			
Pests and diseases decimating crops and livestock. Lack of knowledge and poor management of crops and livestock. Lack of support	Effective pest prevention through crop rotation, agroforestry, chemical treatments, disease resistant varieties. Effective disease prevention through improved animal health management, incl. dipping, vaccination, de-worming, improved housing and improved	Stronger links between agricultural research and extension, agro-industries, agro-dealers and local communities to develop area-specific pest and disease control. Extension workers and lead farmers to cooperate to raise communities' awareness on	Government to employ and empower more extension officers for crop and livestock production and marketing through adequate equipment and budgets. Government to encourage local manufacturing and sale of inputs to prevent crop and livestock

services, especially for livestock production, veterinary care, grazing and feed management. Poorly developed output markets for crops and livestock.	grazing management.	livestock health management. Veterinary inputs to be made easily accessed locally for farmers.	pests and diseases Collaborative support to crop and livestock market development.
3. Poor access to agricultural inputs and services			
Limited access to inputs and services despite the crop input subsidy program. High input prices. Lack of information on appropriate input use.	Technical trainings on cost-saving soil fertility technologies (mulching, manure, compost). Practical trainings on basic livestock husbandry, esp. feeding, health, housing. Enhance farmers' participation in knowledge sharing events (farmer days, agricultural shows, demonstrations). Promote simple and locally accessible information sharing technologies, e.g. SMS or radio voice systems.	Private sector to invest in rural input markets and services, incl. agro-dealers, seed-, fertilizer- and pesticide industries. Banks to provide alternative locally accessible loan mechanisms. Involve NGOs to support the trainings and knowledge sharing mechanisms.	Government to provide the incentives for private sector investments in rural areas. Maintain and expand subsidized inputs to include livestock as well. Support district level input market information centers (prices, availability, technical information).

Nkayi in West Zimbabwe

1. Poor access to water

Low, declining and more erratic rainfall. Land degradation, deforestation, bush fires. Insufficient investments in and maintenance of water sources, incl. siltation of dams and rivers, gold panning. Incomplete irrigation infrastructure.	Investment in water sources, incl. sand abstraction at rivers and dams, boreholes. Promotion of crop intensification and diversification, incl. fertilizer application, drought tolerant and early maturing varieties, early planting, CA and improved tillage. Improved land use planning, incl. forage production, reclamation of degraded land, grazing schemes. Revitalization of incomplete irrigation projects.	Better coordination of investments in water infrastructure and natural resource management by government technical departments, local government, international funding and NGO's. Consultation with local leaders on infrastructure development, land use planning and controlled land use (cropping, grazing and forest use).	Government water and sanitation departments to facilitate water supply and quality testing. Strict enforcement of the environment management act and local by-laws, e.g. against gold panning, veld fires, cutting trees, uncontrolled grazing. National government budgets to prioritize irrigation development; local governments to develop strategic plans for irrigation facilities.

2. Limited assets and capital

Low livestock production due to dry season feed shortages and diseases, limited access to and use of inputs, incl. draft power and credit. Low crop yields due to low rainfall, poor	Most technical options are available (e.g. CA, crop management, post harvest management, fodder production, feed formulations, grazing reserves, animal health, quality control) but better outreach and integrated trainings are required. Revolving funds / community trust schemes for farmers to access	Models for effectively linking crop and livestock input and output markets, set up with farmer associations, extension services, local government, private and para-statal sectors, NGOs. Develop and promote new markets for small stock, groundnuts and tomatoes, incl. local value addition like peanut	Promotion of more integrated crop-livestock and market oriented approaches, rather than segregated extension messages. Farmer-needs driven policies that enable access to equipment and inputs for crop and livestock production, post-harvest technologies and quality control,

management and limited input use. Poor post-harvest management and product quality control for crop and livestock products. Limited surplus of crop and livestock products for sale	farm equipment and inputs. Access to credit through small enterprise development corporations.	butter processing. Engage private companies more pro-actively in outreach and trainings, e.g.at agricultural shows, field days, market days.	livestock as collateral.
3. Poor access to agricultural inputs and services			
Late delivery of crop inputs and not aligned with the agricultural calendar. Labor shortages during peak planting and harvesting time. Lack of stock feed at local level. Far distance to livestock extension services. Local agro-dealer networks disrupted	Timely delivery of inputs by seed houses and fertilizer suppliers. Supply of stockfeed by manufacturers and para-statals to agro-dealers, or directly at business centers. Practical training on labor saving technologies, input sourcing and uses, aligned with agricultural calendar. Effective communication channels, incl. cell network expansion; information transfer through public transporters.	Improved coordination and new linkages among farmer associations, extension services, local government, private and para-statal sectors, NGOs, to avail inputs cost effectively. Contract arrangements between input manufacturers, para-statals and agro-dealers, also to include barter trade options and loans. Formation of commodity specific farmer associations/ unions for cost effective access to inputs, knowledge and markets. Engage private	Government to provide strong support for the development of stakeholder driven networks and multiple direction communication channels for timely and effective dissemination of inputs and information. Mandate para-statals to manufacture and sell crop and livestock inputs and products. Provide incentives for joint projects by private sector and government, e.g. in agro-dealership, telecommunications.

and farmer dependency syndrome after free input distribution. Limited cash in local economies, forcing farmers to rely on barter trade. Poor communication networks.		telecommunication and network providers.	
Changara in Central Mozambique			
1.Lack of access to water			
Low, erratic and declining rainfall Unsustainable uses of croplands, rangelands and forests Wild fires reduce the water holding capacity of the rangelands	Investment in water sourcing equipment, incl. boreholes, dams and wells Promotion of good crop and feed production practices, incl. drought tolerant and dual-purpose crop varieties.	Provincial government should facilitate collaborative initiatives and investments in water sources, crop input supply and sustainable natural resource management, implemented by communities, district extension, private sector. Activities of non-governmental organizations need to be better integrated into agricultural development plans.	Enabling legislation for water infrastructure development and sustainable natural resource management. Establishment of natural resources management committees and reforestation programs.

2. Poor access to agricultural inputs and services

Lack of access to crop and livestock inputs, information services and markets. Late arrival of inputs for crop and livestock production. Lack of locally accessible extension officers on crop and livestock production. Livestock services are mainly for veterinary campaigns. Poorly implemented technology dissemination programs. Input prices are not transparent. Animal draft power limited to few households.	Private sector investments in input markets (local stores, fairs). Promotion of robust feed and fodder production technologies incl. dual purpose crops, crop residues, fodder banks. Local seed production (drought and disease tolerant cereals and legumes) and multiplication by producers. Information dissemination at public places and broadcasting through community radio, text messages, incl. early price dissemination. Draft power programs, to avail draft power to more households.	Provincial agricultural services in collaboration with district services to facilitate more effective coordination between government services, communities and private sector for dissemination of inputs and information at local seed fairs and stores. Awareness creation on soil fertility management (manure, fertilizer, compost, legumes, mulching)	National and provincial legislation to support new dissemination channels for inputs, including seeds. Adequate allocation and capacity development of crop and livestock extension services.

Labor shortages during peak land preparation and planting times.			
3. Limited assets and capital			
Herd depletion due to theft especially during the dry season. Poor registration and control of herd movements and slaughter processes between communities, police and courts. Illegal slaughtering and trade of livestock. Lack of access to credit. Programs exist but most farmers fail to enroll.	Strict implementation of movement licenses and slaughter control through close collaboration between community leadership, local police and clearing administration.	District services to record cattle and control movement through the emission of transit licenses; consequent enforcement of laws against cattle theft. District services to advertise and assist the application procedures for application to local development and credit programs.	Formalization of herd movement control and slaughter processes at national level.

4 Recommendations and conclusions

This study has presented crop residue uses for three sites in southern Africa, the region with most extensive land use and lowest biomass production in the global comparison. Even though the demand for crop residues compared to the other SLP sites around the world is low, the pressure on crop residues and thus trade-offs are high and increasing.

4.1 Crop residue uses and determinants

In the context of smallholder farming systems characterized by limited biomass and with livestock as important livelihood activity, most farmers choose to feed residues to livestock and generate short-term livelihood benefits. Across the three sites farmers use more than 50% of the residues as livestock feed and retain less than 20% for soil amendment. More intensive forms of crop residue utilization emerged in areas such as Nkayi, where a strong expansion of croplands has contributed to shrinkage and degradation of rangelands. Farmers have started collecting and storing the residues for kraal feeding, supplementary dry season feed. Research and development have promoted crop residues as dry season feed since the 1980s. Even though of low nutritional quality, crop residues can provide up to 50-80% feed intake and sustain livestock survival when alternative feed is not available (Reed *et al*., 1988; Renard, 1997; Holness *et al.,* 1998).

In comparison, retaining crop residues for mulching has a limited impact on crop yields and environmental benefits are long term. Few farmers, mainly those in Mzimba, produced sufficient residue biomass required to achieve positive effects on soil health (Goovaerts *et al*., 2009; Naudin *et al*., 2011). Evaporation might also reduce the effects of mulching on soil water conservation (soil run off, rain water infiltration) (Rusinamhodzi *et al.*, 2011). Furthermore, building up organic material is a challenge on sandy soils of low soil fertility. In particular, cereal residues with high C/N ratios bear the risk of nitrogen immobilization. High application of inorganic nitrogen fertilizer would be required on these soils when low quality residues are applied as mulch (Giller *et al.*, 2011).

In this regard, the trade-offs for reallocating crop residues from livestock feed to mulch for soil amendment are highest in areas such as Nkayi and Changara, especially when alternative biomass is not available and access to input and output markets also limited. The trade-offs for retaining more crop residues as mulch are lower in areas with more biomass and less competition with livestock, like in Mzimba.

At household level, several factors that help to better understand farmers' choices for crop residue use were identified. A households' food security status was most important for allocating crop residues for feed. This supports the importance of livestock in areas of low rainfall and high risk, where crop production often fails to sustain households' food requirements. Selling livestock enables households to buy food when crop harvests are depleted (Van Rooyen and Homann, 2009). Another important factor was access to draft power. Farmers feed crop residues specifically to draft power animals. Intensifying crop residue uses to increase the livestock input functions is a smart strategy for raising agricultural production levels, especially in areas where access to external farm inputs is limited. It is also important to note the effects of access to external information and formal education on crop residue allocation. Information services on crop production led farmers to use more residues for mulching, while the effects of livestock production services were not strong. More educated households however allocated more residues to feed livestock. It reflects that agricultural extension and development services focus more on crop production, but outreach of livestock services has generally been poor. Farmers might be aware of feed shortages, but few have information about alternative feed technologies. Farmers' perceptions substantiate these results, whereby farmers who believe in mulching for soil health leave more crop residues on the soil, whereas those who see crop residues as vital for livestock feed intensify crop residue uses for kraal feeding. These results emphasize the need for integrated extension services, which consider the requirements for soil health and livestock nutrition, and promote technologies that can reduce the trade-offs.

Against expectations, the effects of other factors were not strong. Households with more livestock did not necessarily use more crop residues as feed. Extensive land use and crop residues kept as common property might explain this. Similarly, households that produced more biomass did not necessarily retain more crop resides on the soil for mulching. Crop and livestock markets did not affect the uses of crop residues, confirming that the selected sites are at the lower end of intensification processes with limited market orientation, and farmers being preoccupied with subsistence needs. Limited resources (land, labor, capital) might restrict farmers' from investing in crops other than for staple food.

The site- and household-specific uses of crop residues can change over time and in reaction to internal and external factors. For instance, mechanization and the supply of chemical fertilizer such as in Malawi might reduce crop-livestock integration and provide more crop residues for mulching. Conservation Agriculture, promoting crop residue retention for mulching and minimum tillage might also reduce the integration. In contrast, livestock market development, especially in areas like Nkayi or Changara, might enhance the use of crop residues as feed. The financial transactions between crops and livestock were not analysed in this study. This is an important aspect of crop-livestock integration and can support long-term economic and ecological sustainability.

Future trends at the study sites point to further expansion of croplands to sustain the food requirements of growing populations. This will be at the expense of feed resources for livestock. If not controlled, the conversion of rangelands into croplands will increase the pressure on crop residues for feeding livestock. However, given the low levels of crop production and high risk of crop failure, greater investments in livestock production might lead to more profitable development pathways. The demand for livestock products, notably by growing urban populations, is increasing. Feeding livestock without compromising the human need for food will become an important area for future investigations, also in areas like Mzimba, when farmers start responding to the high demand for livestock products (Thornton *et al.*, 2007). Current and future trade-offs for using residues for purposes other than to feed livestock are therefore high. We conclude that drastically more alternative biomass would be required if farmers in low rainfall areas were to retain crop residues for mulching.

4.2 Options for alternative crop residue uses

The following technical, institutional and policy (TIP) options were identified to increase crop residue production, improve residue uses and deal with the trade-offs. They need to be further specified according to the area-specific demand for and supply of crop residues.

Opportunity costs for alternative uses of crop residues are much higher in areas with limited biomass (e.g. Nkayi, Changara) than in areas where crop residues are abundantly available but not appropriately utilized (e.g. Mzimba).

Technical options need to increase biomass production per unit land and enhance the efficiency in crop residue uses, thus produce higher quantities and better quality residues for livestock and sufficient mulch for croplands. Technical options can include:

- Awareness creation on more effective crop residue utilization for livestock feed and soil amendment. This applies especially to areas with feed shortages, but also sites like Mzimba where residues seem abundantly available but land and resources for feed production are limited.
- Strategic application of inorganic fertilizer (timely, soil specific, small quantities that are affordable for farmers) complemented with manure application to reduce nutrient deficiencies and increase the effects of mulching.
- Introduction of dual-purpose food-feed crops and post-harvesting technologies (improved residue collection, storage and processing) to increase the returns per unit land. There is substantial potential for exploiting the genetic variability of crops and raising fodder quality traits. This option is especially for established crops like maize, which can be disseminated through existing seed supply channels.
- Fodder production to supplement livestock nutritional feed requirements. Feed quality is a major bottleneck and providing higher protein feed biomass through legume forages can set low quality residues free for mulching.
- Sustainable rangeland management to prevent further degradation and provide high quality feed for livestock. It will reduce pressure from competitive uses for mulching.

Institutional options need to facilitate technologies and processes that support area-specific development pathways. They need to address the most critical challenges within the context of agro-ecological potential and market opportunities. They should strengthen effective use of crop-livestock interactions. Institutional options include:

- Support services (extension services, private providers) to engage in participatory technology development and adjustments. They need to explicitly address crop-livestock synergies, rather than sectoral approaches. Extension services, national research and development should work hand in hand on the development of support strategies.
- Market development for crop and livestock inputs and outputs to enhance overall systems productivity. Livestock sales can enable farmers' to access commercial farming inputs and reduce their reliance on government support. Livestock markets can also create niche markets for fodder crops, releasing pressure on crop residues. Improved legume markets can facilitate investments in soil fertility; lack of seed and output markets are major constraints for their adoption.
- Accessibility of farming inputs to address major systems bottlenecks. Lessons can be drawn from Malawi about input supply, financing schemes and dissemination channels; these can be transferred and adjusted to other contexts and products, including livestock. Developing institutional structures for supply of adequate inputs is critical for farming systems to evolve.
- Multi-stakeholder forums for effective stakeholder coordination: Collective action among farmers associations, extension services and NGOs as well as the private sector (producing industries, rural retailers, agro-dealers) are important for effectively linking farmers to markets and relevant support services. Positive feedback loops between

crops and livestock can evolve, e.g. more diverse input supply channels, and improved capacity to adjust to changing conditions, e.g. better preparedness to re-organize the activities in case of droughts or other shocks, or better ability to respond to new market opportunities.

- Property rights for controlled crop residues use: Property rights need to be developed within the local context and can change depending on the pressure on the crop residues. By-laws on access to crop residues in Nkayi give a good example of how common access to residues can be maintained, but time and area specific regulations restrict the access.

Policy options must enable sustainable use of crop residues, acknowledging that in mixed farming systems crop residues are becoming increasingly contested.

- Support services: Research, extension and development organizations should be capacitated to fulfil their mandates and facilitate better integration of crops and livestock with clear messages on appropriate crop residue utilization and alternative biomass enhancing technologies.
- Access to inputs and technologies: While subsidies can stimulate farmers' investments in soil fertility, crop diversification (cereals and legumes), food-feed crops and improved rangeland management, they should be phased out over time in favour of market-based solutions. Incentives should entice input and service providers to scale out to rural areas.
- Market development: Policies should provide opportunities for investments ina market infrastructure and organization; sensitize the private sector about market potential among smallholder farmers (fertilizer, animal feed and health, cereal and legume crops and livestock), promote business linkages among industry, rural outlets/agrodealers and support services.
- Local land use regulations: Local policy makers should be informed about the comparative advantages of crop and livestock activities; e.g. encourage more intensive use of croplands rather than cropland expansion; increase the off-take and quality production of livestock.

4.3 Options for livelihoods and sustainability

Different pathways were identified for the three research sites (Figure 1). Options for improving livelihoods and sustainable intensification need to be identified in the light of those pathways:

Mzimba – Enhance crop and livestock integration and special markets: Of all the three sites, biomass is the least limiting in Mzimba, allowing farmers to make different choices with regards to crop residue uses. Farmers can use crop residues to improve soil fertility in maize or tobacco fields. Alternatively, farmers interested in pursuing dairy production can adopt dual-purpose crops and feed the residues to livestock, given the limited availability of grazing land. We suggest greater investments in the livestock sub-sector and greater integration of crops and livestock, capitalizing on the demand for livestock products and making use of the scope for more efficient use of crop and livestock inputs. Improved markets for crops and livestock outputs are expected to enhance the returns on those investments.

Nkayi - Strengthen crop-livestock intensification: Given the constraints placed by limited availability of land and water, farmers in Nkayi need to intensify their crop and livestock production. Cost-effective availability of crop and livestock inputs is of high priority. Feed technologies, especially dual-purpose crops and forages of high protein and biomass content can fuel overall systems development. Existing market channels need to be strengthened and include stakeholders operating in the area. Better-managed herds and higher off-takes will allow farmers to reinvest in enhancing the profitability of the overall farming system. This is expected to attract private sector investment in rural areas. In the long term, improved market access can encourage investments in soil fertility and rangeland management.

Changara – More farmers would like to venture into livestock production to derive livelihood benefits. Considerable growth potential for livestock markets has been recognized, driven by strong demand for livestock products at national and regional markets. However, for farmers to engage successfully in livestock production, greater emphasis must be placed on improving livestock production, especially feed supply. National programs are challenged to support the development of the crop and livestock sector through infrastructure and service delivery. Investments in livestock production can pull investments into crop production, and enhance the adoption of improved crop technologies. There is large scope for improved crop management to increase crop yields, biomass and feed quality.

Development programmes should take cognizance of this diversity of mixed farming systems in the context of specific drivers and emerging opportunities, and align interventions with those factors as well as with farmers' aspirations and resource endowments.

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6 Appendix

Appendix A. Summary statistics on socio-economic household level variables used in the econometric analysis by site

Variables	Changara Mozambique		Nkayi Zimbabwe		Mzimba Malawi		Full sample		Test statistics		
	Mean	Stan. Dev.	Mean	Stan. Dev.	Mean	Stan. Dev.	Mean	Stan. Dev.	Moz/ Zim	Moz./ Malawi	Mal./ Zim
Total number of households	158		157		160		475				
Household head age (in years)	44.8	16	52	16	45.4	19	47	17	-49	-4	40
Household head education (in years)	3.1	3.0	6.4	3.2	6.8	3.1	5.5	3.5	-118	-136	-14
Female level involvement in decision making[a]	1.4	1.7	1.2	1.7	0.7	1.3	1.1	1.6	11	47	35
Off-farm income out of total income (%)	78	32	68	32	47	38	64	36	37	98	65
Dependency rate (members /work members)[b]	2.6	1.1	3.0	1.5	2.5	1.2	2.7	1.3	-33	2	34
Own mobile phone (1 if yes, 0 if no)	0.04	0.19	0.18	0.38	0.39	0.49	0.20	0.40	-51	-106	-53
Food self-sufficiency index[c]	87	19	79	24	90	12	85	20	39	-22	-64
Importance of legumes[d]	0.10	0.18	0.10	0.15	0.19	0.19	0.13	0.18	-3	-55	-57
Total cultivated area (ha)	1.4	1.1	1.8	1.2	1.3	0.9	1.5	1.1	-36	15	52
Labor availability (working members/area)	3.3	3.0	2.9	1.8	3.0	2.4	3.1	2.4	22	14	-8
Info. on crop production [e]	0.16	0.37	0.92	0.28	0.82	0.39	0.63	0.48	-260	-197	33
Distance to crop/livestock output market (km)[f]	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1	1	1
CR improves soil fertility (1 if yes 0 if no)	0.70	0.46	0.78	0.42	0.83	0.38	0.77	0.42	-19	-34	-15
CR is vital feed for livestock (1 if yes 0 if no)	0.53	0.50	0.77	0.42	0.45	0.50	0.58	0.49	-59	17	78
Tropical livestock units (TLU)[g]	4.7	8.4	5.0	7.7	1.97	3.7	3.9	7.0	-4	48	56
Importance of goats (n goats/herd size)	0.3	0.4	0.4	0.4	0.3	0.4	0.3	0.4	-7	17	25
Info. on livestock [h]	0.2	0.4	0.7	0.5	0.6	0.5	0.5	0.5	-137	-113	19
Proportion of TLU sold[i]	0.11	0.19	0.12	0.30	0.16	0.31	0.13	0.27	-5	-21	-14

Notes:
a) Female level of involvement in decision making is a variable that increases with the level of involvement of female spouse/head in the household. Accordingly, the variable takes a value of 0 if females do not make decision, 1 if head is female de facto, 2 if females decide on CR management, 3 if females decide on small ruminants, and 4 if the household de jure head is female.
b) Number of working members used in calculating dependency ration is: number of HH members between 16 and 60+0.7*(members

10 to 15 years old + members over 60).
c) Food self sufficiency index is the percent of months the household consumes self-produced staple food in average year.
d) Importance of legumes is measured by dividing legumes area to cereals area.
e) Information on crop production takes a value of 1 if household obtains information on crop production from government non-government organizations and 0 otherwise.
f) Distance to crop market assigns a value of 1 for households located relatively far away from the market and 0 otherwise.
g) TLU converts livestock into cattle units. Accordingly, it is calculated using the formula: TLU= total cattle+0.6 *total donkey+0.15* total sheep+0.15*total goats + 0.01* total poultry.
h) Information on livestock takes a value of 1 if household obtains information on livestock feed and market from government non-government organizations and 0 otherwise.
i) Proportion of TLU sold is the ration of the number of live animals sold relative to total live animals owned, both in TLU terms.

Appendix B. Summary statistics of crop specific variables by site and crop

Variables	Changara Mozambique		Nkayi Zimbabwe		Mzimba Malawi		Full sample		Test statistics of equality of district		
	Mean	Stan. Dev.	Mean	Stan. Dev.	Mean	Stan. Dev.	Mean	Stan. Dev.	Moz / Zim	Moz / Mal	Mal / Zim
Maize											
Total number of households	64		155		160		379				
Crop yield (Quintals/hectare)	10.1	13.6	11.3	16.4	28.8	27.9	18.5	23.3	-6	-61	-59
Did you plough land (1 yes, 0 no)	0.52	0.5	1.0	0.2	0.04	0.2	0.5	0.5	-84	89	392
Seed type used[a]	0.11	0.31	0.31	0.43	0.43	0.49	0.33	0.46	-37	-55	-20
Seed rate (kg/ha)	19.8	10.6	26.9	12.8	23.7	9.4	24.3	11.4	-42	-28	22
Manure application rate (kg/ha)	0.00	0.0	552	1403	60	152	251	935	-39	-40	38
Chemical fertilizer (kg)	0.00	0.0	11.8	31.7	59.5	34.7	30.0	39.7	-37	-173	-111
Proportion of crop sold (%)	0.02	0.08	0.07	0.14	0.10	0.14	0.07	0.14	-29	-50	-19
Proportion of CR use											
Soil (mulching)	17.6	34.1	6.6	16.5	19.2	27.9	13.8	25.9	29	-4	-43
Grazing	67.8	41.0	64.8	33.1	55.5	31.1	61.4	34.1	6	24	22
Kraal feeding	5.0	17.9	20.7	28.3	1.2	8.1	9.8	22.2	-46	19	73
Small grains											
Total number of households	147		44		3		194				
Crop yield (Quintals/hectare)	9.7	14.6	16.7	23.6	23.9	32.4	11.5	17.5	-25	-40	-20
Did you plough land (1 yes, 0 no)	0.48	0.50	1.00	0.00	0.00	0.00	0.6	0.5	-104	96	-
Seed type used[a]	0.01	0.12	0.05	0.21	0.00	0.00	0.02	0.14	-13	12	24
Seed rate (kg/ha)	17.2	12.8	12.7	8.5	11.6	12.4	16.1	12.1	29	32	8
Manure application rate (kg/ha)	2.4	19.8	100	466	0.0	0.0	24.4	224	-21	12	23
Chemical fertilizer (kg)	0.0	0.0	0.9	6.0	0.0	0.0	0.2	2.9	-	-	17
Proportion of crop sold (%)	0.01	0.05	0.08	0.21	0.39	0.42	0.03	0.1	-32	-91	-73
Proportion of CR use											
Soil (mulching)	21.9	35.9	3.4	16.7	0.0	0.0	17.4	33.2	46	61	23
Grazing	58.6	38.1	76.4	36.7	63.3	55.1	62.7	38.6	-33	-7	22
Kraal feeding	1.6	7.9	3.3	12.0	0.0	0.0	2.0	8.9	-12	21	31

	Legumes										
Total number of households	47		65		92		204				
Crop yield (Quintals/hectare)	3.8	6.1	27.8	31.9	29.2	29.8	23.0	29.0	-73	-84	-4
Did you plough land (1 yes, 0 no)	0.70	0.47	0.95	0.21	0.05	0.23	0.5	0.5	-50	125	318
Seed type used[a]	0.04	0.21	0.07	0.25	0.77	0.42	0.38	0.5	-8	-156	-158
Seed rate (kg/ha)	13.3	17.9	19.7	15.4	15.1	6.8	16.2	13.2	-27	-9	30
Manure application rate (kg/ha)	4.3	29.5	28.9	233	7.1	46.8	13.4	136	-10	-5	10
Chemical fertilizer (kg)	0.0	0.0	0.3	2.5	0.1	1.3	0.2	1.7	-12	-11	7
Proportion of crop sold (%)	0.01	0.05	0.08	0.20	0.22	0.26	0.13	0.23	-33	-83	-50
Proportion of CR use											
Soil (mulching)	20.1	38.3	8.0	23.0	18.9	30.4	15.7	30.6	27	2	-32
Grazing	53.1	36.5	39.0	42.7	65.3	35.1	54.1	39.5	25	-24	-52
Kraal feeding	3.4	15.8	33.1	42.3	1.7	10.8	12.1	29.7	-65	9	79

Note a) Seed type takes a value of 1 if hybrid seed is used and 0 otherwise.

Appendix C. Three stage least-squares estimates of factors affecting maize residue uses for the aggregate sample and by sites

Variables	Full sample			Changara Mozamb.	Nkayi Zimbabwe		Mzimba Malawi	
	Mulching	Grazing	Kraal feed	Grazing	Grazing[b]	Kraal feed[a]	Mulching	Grazing
Household head age (in years)	-0.021	-0.029	0.048	0.133	-0.325	0.053	-0.144	0.140
Household head education (in years)	0.079	-0.752	-0.011	-0.747	-0.725	0.195	-0.202	-0.702
Female level in decision making	0.713	0.472	-1.42**	-0.758	2.8*	-2.024	1.981	-4.9***
Off-farm income out total income (%)	-0.036	0.064	-0.015	-0.236	0.042	-0.090	-0.013	0.034
Dependency rate (HH size/work memb.)	0.644	-1.466	0.657	10.1**	0.245	0.466	2.229	-1.207
Own mobile phone (1 if yes, 0 if no)	-2.894	-1.396	0.988	3.575	-4.078	4.882	-4.381	-3.795
Food self-sufficiency index	7.448	-21.1**	12.3**	-65.7**	-8.259	7.140	21.8	-57.1***
Importance of legumes	10.331	-10.742	6.756	-27.6	-37.7*	30.5*	4.813	14.827
Total cultivated area	-0.971	0.778	-0.694	-15.12**	2.911	0.246	-0.886	-3.448
Labor availability (work memb./cult. area)	0.376	0.194	-0.541	-10.6***	1.408	-0.908	1.436	-4.1**
Info. on crop production: govern. and NGO	6.09**	-8.75*	0.457	-18.809	-1.742	2.223	9.147	-11.666*
Distance to crop market (1 far, 0 other)	-4.5**	3.992	2.595	11.336	9.157	4.728	-4.705	3.906
Incorporation of CR improves soil fertility	8.9***	-1.064	-1.314	-17.2*	-4.456	-0.730	21.4***	-14.0**
Crop yield (Quintals/hectare)	-0.073	0.039	-0.005	0.359	0.089	0.088	-0.062	0.078
Did you plough the crop (1 if yes 0 if no)	-11.5***	24***	-1.952	5.940	12.275	30.0**	23.8**	-11.838
Seed type used (1 if hybrid 0 if otherwise)	3.984	4.866	0.197	-5.854	1.836	-4.819	8.096*	-3.710
Seed rate (KG/ha)	0.026	0.296*	-0.083	0.029	0.204	-0.203	0.031	0.400
Manure application rate (KG/ha)	-0.001	0.001	0.001		0.000	-0.000	0.026	0.000
Chemical fertilizer (KG)	0.063	-0.14**	0.051		-0.122	0.107	-0.020	0.096
Proportion of crop sold (%)	-3.372	-0.688	9.270	16.923	-9.866	21.980	5.485	3.661
CR is vital source of feed for livestock	-3.070	-8.4**	4.664*	14.199	-10.66	15.3***	-6.391	-5.256
Tropical livestock units	-0.000	0.395	-0.001	-0.089	0.428	0.030	-0.589	1.138
Importance of goats (N goats/total livestock)	2.518	1.447	-0.210	27.368	-2.815	-0.406	6.890	-1.660
Info. on livestock: government and NGO	1.364	-1.833	0.400	-32.2**	1.698	3.927	2.452	-4.780
Proportion of TLU sold	-5.709	-7.223	-3.161	4.260	-9.013	1.607	-11.902*	-3.422
Zimbabwe dummy		-21***	21.4***					

Malawi dummy		2.47	-4.787					
Constant	-2.304	91***	-11.399	161***	71.8***	-27.896	-25.7	133***
R squared	0.26	0.16	0.32	0.47	0.14	0.21	0.24	0.25
Chi-squared statistics	109	84	145	57	24	41	52	54
Number of observations		379		64	155		160	

Note: Coefficients with superscripts ***, **, and * are significant at 1, 5, and 10 percent levels, respectively. The coefficients are jointly significant at 1 percent in all models except those with superscripts a and b, which are significant at 5 percent and not significant, respectively.

Appendix D. Three stage least-squares estimates of factors affecting small grain residue uses for the aggregate sample and by sites

Variables	Full sample		Changara Mozambique		Nkayi Zimbabwe
	Mulching	Grazing	Mulching	Grazing	Grazing
Household head age (in years)	-0.55***	0.4**	-0.34*	0.268	-0.479
Household head education (in years)	-2.4***	2.57**	-1.445	0.602	1.416
Female level of involved in decision making	0.473	2.156	0.928	-0.207	12***
Off-farm income out of total income (%)	-0.038	0.013	-0.094	0.084	-0.023
Dependency rate (HH size/working members)	-1.560	1.768	-2.207	2.082	-0.968
Own mobile phone (1 if yes, 0 if no)	10.872	-4.088	17.1	-2.054	-15.2
Food self-sufficiency index	18.2*	-7.431	15.65	7.665	-43.971
Importance of legumes	5.456	-21.945	-3.100	-17.042	-5.800
Total cultivated area	2.245	-6.4**	4.51	-6.907*	-3.661
Labor availability (working memb./cult. area)	1.177	-0.995	1.586	-1.412	0.603
Info. on crop production: govern. and NGO	13.4**	-6.761	26.5***	-22.5***	46.6
Distance to crop market (1 if far 0 otherwise)	-2.596	1.265	-4.888	7.361	-18.439
Incorporation of CR improves soil fertility	17.5***	-16.5***	13.7***	-10.7*	-0.753
Crop yield (Quintals/hectare)	0.139	-0.221	0.57***	-0.69***	-0.200
Did you plough the land (1 if yes 0 if no)	-0.264	-2.900	4.136	-9.554	62.1
Seed type used (1 if hybrid 0 if otherwise)	19.064	-5.541	19.24	-5.323	-83.2***
Seed rate (KG/ha)	0.96***	-0.66***	0.8***	-0.55**	-0.600
Manure application rate (KG/ha)	-0.020	-0.006	-0.020	-0.24*	0.040*
Chemical fertilizer (KG)	0.663	1.935			-2.067
Proportion of crop sold (%)	-27.8*	-2.988	-20.1	29.502	-18.2
CR is vital source of feed for livestock	-11.4**	8.104	-7.206	8.095	34.7
Tropical livestock units	-0.162	0.421	-0.475	0.714	0.371
Importance of goats (No. of goats/total livestock)	-3.276	15**	-9.345	14.115*	21.242
Info. on livestock: government and NGO	-3.604	4.053	4.459	-7.304	7.278
Proportion of TLU sold	-5.407	6.487	-3.952	1.350	20.2
Zimbabwe dummy		1.615			

Constant	12.3	62***	2.63	60.5**	
R squared	0.42	0.25	0.49	0.35	0.53
Chi-squared statistics	141	66	139	79	465
Number of observations	194		147		44

Note: Coefficients with superscripts ***, **, and * are significant at 1, 5, and 10 percent levels, respectively. The coefficients are jointly significant at 1 percent in all models except the equation for Zimbabwe in which they are significant at 5 percent.

Appendix E. Three stage least-squares estimates of factors affecting legume residue uses in the aggregate sample and Changara

Variables	Full sample			Changara Mozambique	
	Mulching	Grazing	Kraal feeding	Mulching	Grazing
Household head age (in years)	-0.30**	0.308	0.011	-0.600	0.471
Household head education (in years)	-2.8***	1.580	1.080	-1.722	2.432
Female level of involvement in decision making	-0.793	-0.169	0.721	1.837	1.599
Off-farm income out of total income (%)	-0.109*	0.23**	0.023	0.002	-0.35**
Dependency rate (HH size/working members)	-0.921	-0.464	-0.916	-8.78***	7.8***
Own mobile phone (1 if yes, 0 if no)	-1.310	-4.837	0.908	34.9	15.5
Food self-sufficiency index	37.2***	-35.2**	-2.623	6.646	4.212
Importance of legumes	27.4*	-20.6	-6.354	2.842	3.274
Total cultivated area	2.961	-1.575	-2.922	6.867	-14.4***
Labor availability (working members/cult. area)	2.2**	-2.137	1.014	9***	-9***
Info. on crop production: govern. and NGO	9.2*	-10.27	11.5**	70.8***	-62.1***
Distance to crop market (1 if far 0 otherwise)	-1.467	6.313	-1.458	-8.92	17.9**
Incorporation of CR improves soil fertility	10.6**	-0.010	-7.998*	5.466	0.344
Crop yield (Quintals/hectare)	0.021	-0.090	0.021	0.410	-0.777
Did you plough the land (1 if yes 0 if no)	-33.2***	16.244	21.6***	0.915	-0.827
Seed type used (1 if hybrid 0 if otherwise)	-1.914	-5.634	3.227	-85.3**	118.4***
Seed rate (KG/ha)	0.012	-0.004	0.311**	0.379	-0.237
Manure application rate (KG/ha)	-0.001	-0.022	0.031**	0.132	-0.96***
Chemical fertilizer (KG)	-0.728	1.986	-1.297		
Proportion of crop sold (%)	-14.1	28.9**	-10.9	-20.9	87.8
CR is vital source of feed for livestock	-11.1**	5.418	0.910	-19.63	-6.64
Tropical livestock units	-0.040	0.121	0.396*	0.022	0.400
Importance of goats (No. of goats/total livestock)	5.043	2.660	7.158	11.4	29.3**
Info. on livestock: government and NGO	7.542	-6.696	4.736	-11.9	-1.714
Proportion of TLU sold	-0.029	-7.860	9.460	44.9	-45.2*
Zimbabwe dummy		-11.24			

Malawi dummy	-21.1**	35.3***			
Constant	17.056	51.2**	-15.6	23.5	69.8*
R squared	0.33	0.24	0.38	0.66	0.71
Chi-squared statistics	91	53	114	91	114
Number of observations		203		46	

Note: Coefficients with superscripts ***, **, and * are significant at 1, 5, and 10 percent levels, respectively. The coefficients are jointly significant at 1 percent in all models.

Appendix F. Three stage least-squares estimates of factors affecting legume residue uses in Nkayi and Mzimba

Variables	Nkayi		Mzimba	
	Zimbabwe		Malawi	
	Grazing	Kraal feeding	Mulching	Grazing
Household head age (in years)	-0.405	-0.178	-0.085	0.34*
Household head education (in years)	-3.510	2.393	-2.1*	2.8**
Female level of involved in decision making	-3.426	-0.307	-1.472	4.9**
Off-farm income out of total income (%)	0.45**	-0.159	-0.123	0.37***
Dependency rate (HH size/working members)	-0.559	-1.780	0.866	-2.696
Own mobile phone (1 if yes, 0 if no)	-29.1**	0.781	-4.894	-0.400
Food self-sufficiency index	3.611	2.273	51.171*	-26.148
Importance of legumes	61.707	37.7	21.9	-79***
Total cultivated area	0.682	0.533	0.844	-0.945
Labor availability (working memb./cult. area)	1.469	0.067	0.433	-0.064
Info. on crop production: govern. and NGO	33.601	20.019	12.7*	-20.0**
Distance to crop market (1 if far 0 otherwise)	7.380	-7.324	-0.904	7.164
Incorporation of CR improves soil fertility	11.9	-16.7	13.7**	-10.5
Crop yield (Quintals/hectare)	0.020	0.243	0.153	-0.23**
Did you plough the land (1 if yes 0 if no)	13.867	50.492**	-13.39	16.38
Seed type used (1 if hybrid 0 if otherwise)	-13.108	33.290*	0.372	-10.156
Seed rate (KG/ha)	0.142	0.408	0.211	0.081
Manure application rate (KG/ha)	-0.005	0.024	0.18***	-0.15**
Chemical fertilizer (KG)	5***	-2.295	1.984	-1.260
Proportion of crop sold (%)	52.7**	-28.0	-16.3	17.8
CR is vital source of feed for livestock	3.85	7.452	-15.6***	12*
Tropical livestock units	0.021	0.994*	-0.745	1.043
Importance of goats (No. of goats/total livestock)	-10.888	20.904	2.651	-2.080
Info. on livestock: government and NGO	-22.689	5.512	21***	2.605
Proportion of TLU sold	-13.6	70***	-15.0	7.1
Constant	-5.717	-64.391	-40.788	87.4**

R squared	0.48	0.50	0.43	0.43
Chi-squared statistics	60	66	70	70
Number of observations	65		92	

Note: Coefficients with superscripts ***, **, and * are significant at 1, 5, and 10 percent levels, respectively. The coefficients are jointly significant at 1 percent in all models.