Integrating crop–livestock research and development in Sub-Saharan Africa

Option, imperative or impossible?

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Abstract: *An analysis was made of the contributions to increasing the productivity of crop–livestock systems by over 100 DFID-RNRRS research projects and relevant work carried out by ILRI and its partners in Sub-Saharan Africa. Important lessons and critical challenges were highlighted to inform future donor investment. It was concluded that integrating crop–livestock R&D in Sub-Saharan Africa remained an imperative if crop and livestock research were to have a lasting impact on reducing poverty, improving the livelihoods of small-scale crop–livestock farmers and encouraging national economic growth.*

Keywords: *crop–livestock research; dual-purpose crop; multidisciplinary; poverty reduction; Sub-Saharan Africa*

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In a strongly argued paper ‘Integrated crop–livestock systems in sub-Saharan Africa: an option or an imperative?’ published several years ago (1997) in *Outlook on Agriculture*, Smith *et al* concluded that, to be sustainable, future increases in agricultural productivity in Sub-Saharan Africa (SSA) would have to be based on exploiting the synergies from integrating crops and livestock. They noted that although the challenges were considerable, the benefits were potentially enormous. Hence, research to develop technologies for effective crop–livestock integration was considered *imperative.* What has been the response to this call during the past nine years?

The main aim of this paper is to assess how knowledge and technologies generated since this call was made are relevant to improving livestock productivity in crop–livestock systems in SSA. Two main sources of information were used. First, an analysis was made of the contributions to increasing the productivity of crop–livestock systems by over 100 projects implemented by the Department for International Development’s Renewable Natural Resources Research Strategy (DFID-RNRRS) programmes, including the Crop Protection (CPP), Livestock Production (LPP), Plant Sciences (PSP), Natural Resources Systems (NRSP), Crop Post Harvest (CPHP) and Forestry Research (FRP) programmes, representing an investment of approximately £20 million. Most emphasis was on CPP and LPP projects implemented in East and southern Africa. Potential for outputs generated from projects implemented in South Asia to spill over to SSA was also considered. Second, the analysis was complemented by an assessment of research conducted by the

Consultative Group for International Agricultural Research (CGIAR) centres, especially the International Livestock Research Institute (ILRI), the System-wide Livestock Programme (SLP) and their partners in SSA, with an emphasis on maize, cowpea and fodder and tree legumes during the past nine years. The overall context was contributions to reducing poverty for small-scale farmers and national economic growth, as well as opportunities to *rework* the stock of generated knowledge to the wider benefit of small-scale farmers in SSA. Livestock diseases and environmental issues were considered beyond the scope of this analysis. Key lessons learnt and further critical challenges to integrating crop–livestock research and development (R&D) are highlighted to inform future donor investment to enhance the livelihoods of the poor in crop–livestock systems in SSA.

Integrating crop–livestock R&D: why?

Importance of crop–livestock systems

Mixed farming systems, in which crops and livestock are integrated on the same farm, are widespread in rain-fed agriculture in SSA (Thomas, 2006; Lenné and Thomas, 2005a). They are more important than any other system in terms of their contribution to the total output of animal products. Globally, crop–livestock systems produce 92% of world milk supply, all of the buffalo meat and 70% of small ruminant meat. Livestock account for 53% of the agricultural capital stock in SSA and contribute significantly (30%) to agricultural gross domestic product (GDP) (NEPAD, 2005). These systems provide food, income, draught power and employment to millions of poor people. It is estimated that meat, milk and eggs provide about one-fifth of the protein in African diets, and around 70% of the human population of SSA are primarily or partly dependent on livestock.

Need for increased livestock production

The population of SSA has grown at an average rate of 2.7% over the past 20 years (NEPAD, 2005). The urban population has grown even faster, at 4.2% over the same period. It is estimated that by 2015 approximately 45% of the total population of 1.1 billion will be living in cities and large towns. This growing urbanization will further amplify the growth in demand for livestock products, because urban populations generally have higher incomes than rural residents.

In SSA, the annual growth rate in total livestock production during 1993–2003 was 2.9% (NEPAD, 2005). Livestock production and productivity growth has, therefore, not been sufficient to satisfy the demands of expanding populations. This has led to increasing importation of livestock products into SSA, currently valued at approximately US$700 million per year. Based on recent projections (Delgado *et al*, 1999; FAO, 2002), total livestock production in SSA will have to grow at an average rate of 4.2% per year by 2015 to meet the needs of this growing population. If this demand is not met by increased production, more subsidized products will be imported, to the detriment of national economic growth and small-scale producers. The challenges are daunting but can be met if concerted efforts are made to address the major constraints facing livestock production in SSA (NEPAD, 2005).

Table 1. Key challenges facing small-scale crop–livestock farmers and plausible contributions to key MDGs.

Key challenges	Plausible contributions to MDGs
• Maintaining and/or increasing the involvement of small-scale farmers in the livestock sector	• Increasing income generation for poor small-scale female and male farmers from sale of livestock and crop products (MDGs 1,3)
• Producing quality livestock products that are affordable to local consumers	• Improving nutrition for the poor, especially children and mothers, through increased availability of milk and other livestock products (MDGs 1, 3, 4, 5)
• Increasing the productivity and production efficiency of food–feed crops per unit land area using the same inputs	• Sound intensification strategies for crop and livestock production, allowing the land to be more productive while sustaining natural resources (MDG 7)

Potential to reduce poverty and enhance livelihoods

Most key donors supporting agricultural R&D in SSA have strongly oriented their international development policy towards achieving the Millennium Development Goals (MDGs) by 2015. Research that sustainably increases the productivity of crop–livestock systems can contribute to the following MDGs:

- eradicate extreme poverty and hunger (MDG 1);
- promote gender equality (MDG 3);
- reduce child mortality (MDG 4);
- improve maternal health (MDG 5); and
- ensure environmental sustainability (MDG 7).

It can do this in several plausible ways through addressing key challenges facing small-scale crop–livestock farmers (Lenné and Thomas, 2005c; Table 1).

Pro-poor priorities in crop and livestock research

Maximizing the relevance of agricultural research to poverty reduction means focusing on improving the productivity of systems that will have greatest impact on overall poverty (DFID, 2005). Crop and livestock research implemented in SSA through the DFID-RNRRS programmes and the CGIAR and partners has focused strongly on farming systems where the majority of poor livestock keepers live and work: mixed rain-fed systems in the subhumid, semi-arid and tropical highland zones. These zones are home to more than 200 million poor people (Thornton *et al*, 2002). In addition, not only does 80% of African food production derive from just six farming systems, but, more importantly, three annual *mixed crop–livestock systems* – maize-mixed, cereal-legume-mixed and root-crop-legume-mixed farming systems, common in these zones – are considered to have the most potential for increasing future African food security (IAC, 2005).

The knowledge and technologies generated by this substantial research effort during the past nine years have achieved much (see Lenné and Thomas, 2005a for more detail). They urgently need to be comprehensively integrated to improve crop and livestock productivity further in these systems. Moreover, long-term productive local and regional partnerships have been developed through the participation of the National Agricultural Research and Extension System (NARES), universities, NGOs, CBOs, subregional organizations such as the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the private sector in East and southern Africa in this effort. *There is, therefore, a great opportunity to re-work the stock of knowledge generated by the DFID-RNRRS and integrate it with that generated by the CGIAR and partners to the further benefit of small-scale crop–livestock producers and national economic growth in SSA.*

Integrating crop–livestock R&D: what?

Systems-level development and promotion of *all* *livestock feed resources*

One of the major advantages in mixed farming systems in SSA is the large range of potential feed options (Lenné and Wood, 2004; Thomas, 2006). Throughout the year, farmers use a variety of local feed resources for their animals, eg crop residues, weeds, improved grasses, native pastures, shrubs and trees, selected herbaceous legumes, surplus grain, root and oilseed crops, as well as their by-products. The value of this wealth of feed resources has been understated. Individual animal nutrition research projects have generally concentrated on one or a limited number of available feeds in mixed systems, rather than looking at the resources available at systems level. In addition, there is substantial potential to apply and promote lessons learnt from projects successfully implemented in one region to other regions through spill-overs (CGIAR Science Council, 2005).

First, multipurpose legume trees can provide high-quality feed and improve soil fertility. Many niches are available on small farms where trees do not interfere with crop production. In the Kenyan highlands, several DFID projects (R5732, R6549)[1] with the International Centre for Research in Agroforestry (ICRAF) and African partners have contributed to the successful promotion of *Calliandra calothyrsus* on small-scale mixed dairy farms (Paterson *et al*, 1999). Trees were planted on underutilized fence lines and on terrace risers, without any adverse effects on crop yields. The value of *Calliandra* leaves as a cheap source of protein to replace commercial concentrate feeds and contribute to both liveweight gains and milk production was clearly demonstrated (Box 1; Paterson *et al*, 1999; Franzel *et al*, 2003).

Second, multipurpose herbaceous legumes such as *Stylosanthes* and *Mucuna* have been widely tested in West Africa by ILRI and partners over the past 30 years for feed, weed reduction and soil fertility improvement (Lenné and Wood, 2004). The fodder bank technology, which involved fencing and planting farmland to *Stylosanthes* or other legumes, has been a great success as a strategic feed resource (Elbasha *et al*, 1999; Box 1). Furthermore, recent ILRI partnership projects have been implemented in evolving crop–livestock systems in subhumid and semi-arid West Africa to develop a 'basket or tool kit' of herbaceous fodder legume options. These are being successfully applied to improve short-term fallows, especially to suppress weeds, and crop understorey planting in crop–livestock systems (Tarawali *et al*, 1999; Box 1).

Box 1. Promotion of multipurpose tree and herbaceous legumes.

Multipurpose tree legume: *Calliandra calothyrsus* in East Africa

- 3 kg *Calliandra* produced on-farm replaces 1 kg purchased concentrate for dairy cows.
- By 2002, >18,000 farmers cultivating *Calliandra* with increased farm income of 10%.
- If 50% of 600,000 highland dairy farmers adopt *Calliandra* technology, net benefits of US$81 million will be generated.

Herbaceous legumes: *Stylosanthes* and *Mucuna* in West Africa

- By 1999, 27,000 farmers cultivating *Stylosanthes* fodder banks on 19,000 ha in 15 countries of subhumid West Africa.
- To 1997, net benefits were US$16.5 million with IRR of 38%.
- In Benin, 10,000 farmers adopted *Mucuna* in fallow plantings.

Third, crop residues from dual-purpose crops such as cereals, legumes, vegetables, root and other crops are highly desirable quality livestock feeds, but are currently greatly underutilized and often poorly managed (Lenné and Thomas, 2005a, b, c). There is no doubt that increased future food and feed production will have to be met through increased productivity per unit area. Already, multiple cropping is a well established practice in many farming systems where climatic conditions are not a constraint. Concurrently, small-scale crop–livestock farmers are finding difficulties in providing enough high-quality forage for their animals. This scenario provides an exciting opportunity for greater emphasis on dual-purpose crops to meet the future challenge of increasing productivity, as well as spill-overs throughout SSA.

Dual-purpose crops can provide grain for human consumption and residues for livestock nutrition from the same land area with similar amounts of inputs, including water. Whilst a wide range of cereals and legumes, in particular, have traditionally provided both grain and fodder, only recently has the research focus begun to shift towards improving the productivity, quality and feeding systems of crop residues (Blummel *et al*, 2003; Lenné and Thomas, 2005a). There are now active programmes to breed dual-purpose sorghum, pearl millet, cowpea, groundnut and, recently, maize with high grain yields, high yields of good quality residues, and resistance to the major biotic and abiotic stresses (pests, diseases, parasitic weeds, drought and low soil fertility). Several South-east Asian countries have developed foliage hay from cassava (Wanapat and Rowlinson, 2005). It is likely that crop-based feeds will become the dominant feed resource in much of SSA in the future (Renard, 1997; Smith *et al*, 1997; Lenné *et al*, 2003; Zerbini and Thomas, 2003). There is great potential for spill-overs from Asia to SSA. In addition, the increasing value of stover (vis-à-vis grain) as a marketable commodity is providing opportunities for poor cereal and legume farmers to benefit from additional income generation from crop residues, and this is likely to increase in future in many regions.

Box 2. Development and promotion of disease-resistant, dual-purpose crops.

Groundnut and sorghum in India:

- Reduced residue losses due to diseases by >50% in groundnut and >60% in sorghum.
- Improved dry matter digestibility by 10–15% and increased dry matter intake by 10–32%.
- Improved milk yields by 0.44 kg/day and increased net returns to farmers of 25–29%.
- By 2005, 8,000 ha of improved dual-purpose groundnut cultivated in southern India.
- At current adoption rates, 80,000 ha will be cultivated by 2010.

Significant advances have already been made in the development and promotion of dual-purpose, disease-resistant cowpea in West Africa through ILRI-IITA research (Singh *et al*, 2003). In West Africa, by 2001, more than 8,000 farmers had cultivated improved varieties of dual-purpose cowpea. There is potential for this technology to reach millions of small-scale farmers in the dry savannas of West Africa with internal rates of return on research investment of 50–103% (Kristjanson *et al*, 2002). Similarly, in southern India, dual-purpose sorghum, millet and groundnut have been developed through ILRI-ICRISAT-DFID research (Blummel *et al*, 2003; Lenné and Thomas, 2005c; projects R7346, R7375, R7379, R8183, R8339, R8450 – see Box 2).

Maize is often grown in crop–livestock systems in East and southern Africa where 50% of the poor are livestock keepers (Thornton *et al*, 2002). Due to population growth and land scarcity, in small-scale dairy systems in the Kenyan highlands, up to 34% of total offered feed is sourced on-farm (Romney *et al*, 2003). Improving the yield, nutritive quality and utilization systems for maize fodder offers great potential for reducing the feed constraints for crop–livestock farmers in these systems (Thorne *et al*, 2002; Romney *et al*, 2003; Murdoch *et al*, 2003, 2005; projects R6775 and R7955; see below). Furthermore, the genetic potential of maize as a more productive, dual-purpose crop is beginning to be exploited.

In parallel with the development of dual-purpose crops, there is a need to increase farmer awareness of the value of residues as fodder. Paradoxically, cowpea and groundnut residues are valued as fodder in West Africa and South Asia, but not in East and southern Africa; sorghum residues are valued in South Asia, but not widely in SSA; while maize residues are valued in highland East Africa, but less so elsewhere. In addition, development of seed multiplication systems, especially at village and community levels, and where appropriate, facilitated links with private seed companies, should be an integral part of any food–feed crop improvement initiative in SSA (see LPP and CPP projects R7346, R7429, R7566, R8219, R8220, R8339, R8406, R8415, R8450, R8455). Improved, dual-purpose crops can be promoted through existing promotional pathways for seed of food crops. High priority should be given to the development and promotion of productive dual-purpose varieties of the most important food–feed crops throughout SSA and, concurrently, to increase farmer awareness of their value as feed resources.

Fourth, although the use of cereals, roots and tubers as animal feed is sometimes perceived as a threat to food security, globally, some 660 million Mt of cereals (over 30% of global cereal use) are used annually as livestock feed (FAO, 2002). However, it is important to realize that if these cereals were not used as animal feed, they would probably not be produced at all, so would not be available as food in any case (Lenné and Thomas, 2005a). The commercial livestock sector is responsive to the price of cereals: whenever shortages raise prices, livestock producers tend to switch to other feeds, releasing more cereals for human food. Over the next three decades, growth in the use of cereals as animal feed is projected to account for half of the additional use of cereals (FAO, 2002).

A number of DFID-RNRRS projects have indicated that both cereal and root/tuber crops can be used for poultry and pig feed without prejudicing human food security (Lenné and Thomas, 2005a). In fact, the replacement of maize as an energy source in diets by surplus coarse cereals and root/tuber crops would increase the availability of this important food staple for humans, whilst producing extra protein in the form of poultry/pig meat and eggs. In Uganda, the market size for dried chips from sweet potato as animal feed is estimated by Wanda (2003) at more than 100 Mt. The crop is produced by small-scale farmers, and the animal feed market, unlike the fresh/export market, does not exhibit high quality requirements and enjoys price stability. Therefore, the chances for small-scale farmers to succeed with this growing market are relatively higher than for the fresh/export market.

In Zimbabwe, the LPP R7524 has demonstrated the potential of sunflower seed cake (from small-scale processing operations) for inclusion in rations for poultry and small ruminants, particularly where small-scale farmers cannot afford to purchase commercial feeds. The project developed a low-cost fibre reduction methodology. This increased protein levels by 20–25%, improving markedly the nutritive value for poultry. Where the by-product replaced commercial feed concentrates by up to 50%, hybrid broilers realized their growth potential without adverse effects. Replacement with sunflower seed cake reduced the cost of rations and increased the economic viability of small-scale poultry production. A similar approach could be used for groundnut and soyabean where, after the extraction of oil, the residues are often made into oilseed cakes. Such cakes are used for animal feed in parts of India and West Africa and have the potential to be more widely used in SSA.

In developing countries, limited work has been conducted on scientific feeding strategies that match varying animal nutrient demands at different times in the production cycle, based on availability and strategic use of *all feed resources* in crop–livestock systems. Failure to do this, particularly in smallholder milk production systems, can lead to wastage of feed resources over the year (see LPP projects R6282, R6609, R7431, R7855). Systems-based approaches to more efficient and effective use of *all available feed resources* in crop–livestock systems are beginning to evolve based on the needs of farmers

(Thornton *et al,* 2003). Not only does this evolutionary process need to be aligned with existing feeding strategies of farmers and emerging crop–livestock systems, but also with the institutional arrangements necessary to ensure that end-users will benefit from the research outputs (see below). Development and promotion of improved and enlightened livestock feeding strategies that reflect the availability of a wide range of on- and off-farm local feed resources (crop residues, pastures, forage crops, multipurpose trees, agricultural by-products) should be an integral part of future initiatives to improve the productivity and efficiency of crop–livestock systems in SSA.

Recent approaches have shown that successful promotion of fodder technologies involves building partnerships with a range of stakeholders, especially farmer groups, understanding smallholder systems and targeting appropriately, and assisting local communities to mobilize resources (Franzel *et al,* 2003; Peters and Lascano, 2003). Furthermore, the advantages of linking farmers with industry (feed manufacturers and livestock producers) through a coalition approach for promotion of technologies has been demonstrated in the poultry sector in India by DFID project R8267 (Hall *et al*, 2004). Being generic in nature, this coalition approach could be readily applied to other situations in which there is increasing demand for feed and food, but the market is constrained by lack of linkages between the suppliers (farmers) and users (animal producers and consumers). Increased availability of spatial data sets and improved modelling approaches is also facilitating more efficient scaling-up of technologies (Thornton *et al,* 2003).

Improvement in the yield and quality of on-farm feed resources through managing crop diseases, pests and weeds

Successful control of any major pest, disease or weed that is significantly reducing crop yield and/or quality will contribute to improving the availability not only of food, but also of feed resources in small-scale crop–livestock systems in SSA (Lenné and Thomas, 2005a). Many CPP research projects have successfully developed technologies to reduce crop losses due to pests, diseases and weeds in mixed crop–livestock farming systems (see Table 2 for examples and www.cpp.uk.com for more information). The development and promotion of successful control strategies has been demonstrated by *significant and sustained increases in grain yield and quality* but rarely by *improved availability of feed resources, increased productivity of ruminants, pigs and poultry, and increased incomes from sale of livestock products.* It is likely that these projects (see Table 2) have *unknowingly* provided opportunities to increase crop residue/animal feed production and quality. These potential contributions have *rarely* been captured in project outputs, as crop protection and livestock scientists rarely work together.

Two joint CPP / LPP project series in India and Kenya, however, have clearly demonstrated the significant value of controlling diseases, pests and weeds on *both* grain and residue productivity and quality and, therefore, on the availability of animal feed resources in mixed crop–livestock systems. In India, foliar diseases of sorghum and groundnut not only reduce yields of grain and fodder, but also reduce the nutritive value (dry matter intake and digestibility) of the residues for large ruminants (Blummel *et al,* 2003; Pande *et al,* 2003; see projects R7346, R8339, R8450 and Box 2). In fodder markets, plant diseases constitute one of the most important determinants of the sale price of cereal crop residues. Successful strategies to control these diseases through resistant/tolerant dual-purpose varieties with higher grain and stover yields are already increasing both food and feed production from sorghum and groundnut in India. Consistent evidence showed that feeding of stover of improved varieties resulted in higher milk yields and better animal health, with consequent improved income generation (Box 3).

In highland maize–dairy systems in Kenya, maize (as thinned plants and stover) is an important fodder, especially in the dry season. Maize streak virus disease (MStV), stem-borer and weeds such as *Striga* are the main production constraints in this region, where over 30% of the fodder is from maize (Murdoch *et al*, 2003, 2005; see R6775, R7955 and Box 3). A multiple maize management strategy was used based on resistant or tolerant maize varieties, increased planting density, and the ‘push–pull’ strategy for stem-borer and weed management. Extra soil nutrients were required, but economic analysis indicated that positive returns could still be achieved. Use of MStV-resistant varieties increased fodder and grain production in the long rains, especially under conditions of early infection. Weeding reduced competition with maize and contributed to farm-sourced fodder.

In East African maize systems, farmers are increasingly adopting the push–pull habitat management system for maize stem-borer control, principally motivated by the prospect of additional fodder and secondarily by pest control (Khan *et al*, 1997; Lenné and Thomas, 2005c; see projects R8212, R8515 and Box 4). The push–pull system uses trap and repellent plants for management of stem-borers in maize-based farming systems in SSA. Stem-borers are repelled from the main crop (maize) and are simultaneously attracted to a trap plant, Napier grass. The legume *Desmodium uncinatum* has additional repellent properties and adds nitrogen to the soil, which contributes to the control of *Striga.* As well as controlling pests and weeds, feed output and quality are greatly increased. In Suba district, western Kenya, there was a strong positive correlation between farmer adoption of the push–pull system and the number of grade milking cows. Between 1997 and 2002, the numbers of farmers adopting the push–pull strategy increased from <10 to 200, whilst the numbers of grade milking cows owned by the same farmers increased from <10 to 380. Farmers

Box 3. Improving productivity, quality and management of food–feed maize in Kenya.

- 100% MStV infection reduced dry-matter production of thinned maize from 5.4 Mt/ha to 3.5 Mt/ha, while weeds reduced maize yields by 15–90%.
- Improved management increased yields of thinnings and stover by 40–166% and 118–409 kg/season respectively.
- Increased fodder met the maintenance requirements of a 350 kg cow for 19–66 days.

Table 2. Crop protection technologies developed through CPP-funded projects and implications for livestock and small-scale farmers in crop–livestock systems.

Crops	Biotic constraints	Management methods	Implications for livestock and farmers
Maize	Maize streak virus (R6642, 7429, 7955, 8219, 8220, 8406) Grey leaf spot (R7566, 8220, 8406) *Striga*; other weeds (R7564, 7405, 7404, 7955, 8212, 8215, 8219, 8452, 8455) Stem-borer (R6400, 7955, 8212, 8215) Termites (R6653, 7026, 7951)	Host-plant resistance and/or tolerance Planting & harvesting dates Selection of clean seed Intercropping, eg push–pull Crop rotation & green manures Biological control Pesticides and herbicides	Increased quantity and quality of crop-based feeds as thinnings and stover produced on-farm Increased productivity and performance of ruminants and poultry (milk, meat, eggs) Increased incomes and improved nutritional status of farm families
Sorghum	Smut (R6581, 7518) Foliar diseases (R7346, 8339, 8450) Grain mould (R7506) Stem-borers, shoot-fly, midge (R7572) *Striga* (R6654, 6921, 7564, 6655) IPM (R7401)	Selection of clean seed & seed treatment Host-plant resistance and/or tolerance Planting date Dry season field sanitation Intercropping & green manure Conservation tillage	Increased quantity and quality of crop-based feeds as thinnings, stover and grain Increased productivity and performance of ruminants and poultry (milk, meat, eggs) Increased incomes and improved nutritional status of farm families
Millets	Finger millet blast (R6733, 8030, 8445) Stem-borer & head miner of pearl millet (R6693)	Host-plant resistance and/or tolerance Removing infected material, especially weeds Clean seed selection Pheromones	Increased quantity and quality of crop-based feeds as thinnings and stover Increased productivity of ruminants and poultry (milk, meat, eggs) Increased incomes and improved nutritional status of farm families
Groundnut	Rosette virus (R6811, 7445, 8105, 8442) Late & early leaf spot and rust (R7346, 8339, 8450) Aflatoxin (R7809, 8298, 8483)	Host-plant resistance and/or tolerance Strategic application of fungicides Removing infected material, especially pods Compost & gypsum Biological control Post-harvest management	Increased quantity and quality of crop-based feeds as stover and seed cake Increased productivity and performance of ruminants (milk, meat) Increased incomes and improved nutritional status of farm families
Root crops (cassava, sweet potato, yam)	African cassava mosaic virus (ACMVD): R6614, 7565, 7705, 8041, 8222) Brown streak virus (R6765, 7563, 7796, 8227) Viruses (R6617, 7492, 8040, 8041, 8167, 8253) Weevils (R6769, 8167) Nematodes (R6694) Diseases (R5983, 6691, 7504, 8278)	Host-plant resistance and/or tolerance Vector management Phyto-sanitation (including selection of clean planting materials) IPM	Increased quantity and quality of crop-based feeds as peelings, chips and excess roots Increased productivity of ruminants, pigs and poultry (milk, meat, eggs) Increased incomes and improved nutritional status of farm families

benefited substantially from the increased on-farm fodder output due to the adoption of crop protection technologies. The push–pull strategy has great potential to be more widely promoted in East and southern African maize systems.

These projects clearly demonstrate the substantial potential of *multidisciplinary approaches* to multiple problem solving in crop–livestock systems where crop protection, livestock and social scientists work together in integrated teams. Each series of projects developed and promoted successful strategies for (a) reducing grain losses from damaging crop diseases and, as a result, (b) increasing the quantity and quality of fodder produced on-farm. Such approaches should be *mainstreamed* in future research initiatives to increase the productivity and efficiency of crop–livestock systems.

Development and promotion of fodder conservation strategies

The major roughage source in the dry season in small-scale farming systems in SSA is crop residues that are stored opportunistically or grazed *in situ* (Manyong *et al*, 1997). Farmers adopt different storage strategies according to the value of the residue. Storage conditions of harvested residues can impact on quality, especially for cowpea, which deteriorates quickly in contrast to groundnut. This can be exacerbated by spoilage due to unseasonable weather conditions. Due to the importance of crop residues for animal feed, especially in mixed, rain-fed systems in SSA and the importance of maintaining quality (1% reduction in digestibility can significantly reduce milk and meat outputs; Kristjanson and Zerbini, 1998), research on improving residue conservation merits further support.

Box 4. 'Push–pull strategy' for maize stem-borer control and increased fodder in Kenya.

- Increased yields of maize grain, thinnings and stover.
- Increased fodder from high-quality Napier grass and *Desmodium*.
- Increased income from sale of milk and *Desmodium* seed.
- Substantial increased purchase of grade milking cows in western Kenya.

Efforts to date on developing simple, practical, low-cost methods of fodder conservation, supported by DFID, such as box-baling and bag silage of maize stover, fodder legumes, bean residues and Napier grass, show considerable potential for wider application across feed resources throughout SSA (eg LPP and CPP projects: R6610, R6619, R7010, R7955, R8414). Development and wider promotion of these fodder conservation methods should be supported in small-scale crop–livestock systems to alleviate seasonal fodder shortages.

Improved marketing systems for livestock products and fodder

In SSA, marketing chains for livestock products are either nonexistent or weak due to their complexity, inefficiency and unreliability (NEPAD, 2005). Poor marketing systems linked with poor transport systems and storage facilities hinder the successful marketing of quality products by small-scale farmers. Such inefficient systems are a significant constraint to development of the livestock sector in SSA. These must be addressed if the full potential of technical innovations is to be realized to the benefit of the poor, as shown by several LPP projects (eg R7321, R7542, R7631). Furthermore, it is unlikely that small-scale farmers will adopt productivity-enhancing technologies if genuine and secure markets are not available. There is an urgent need for more comprehensive studies of the marketing systems for livestock products in SSA to identify the most practical and feasible improvements.

Small-scale farmers in India have realized the advantages of collective marketing and innovative coalitions. First, the impact of Operation Flood, based on both technical improvements and improved marketing systems through dairy cooperatives, on rural incomes, milk prices and gender equality (6,000 village level Women's Dairy Cooperative Societies formed) in India has been substantial (FAO, 2002). Second, the development of an innovative coalition between small-scale sorghum producers, traders, feed manufacturers and poultry producers in India enabled farmers to exploit market opportunities in the sorghum–poultry feed chain (joint LPP × CPHP project R8267; Hall *et al*, 2004). There is potential for spill-overs from these successful initiatives to link small-scale farmers with markets in India to the livestock sector in SSA.

In SSA regions, where crop–livestock systems predominate, there is active formal and informal fodder trading. In semi-arid West Africa, sophisticated legume fodder markets thrive, while in East Africa, fodder is traded informally at village level. Moreover, trade in fodder has developed rapidly in India, driven by the growth of peri-urban dairy enterprises. Due to land scarcity and the increased demand for livestock products in SSA in future, it is likely that small-scale farmers will increasingly market fodder and crop residues produced on-farm for income generation. There is potential for the livestock sector in East and southern Africa to learn from the successful development of fodder trading and markets in West Africa and India, to address increased demands for livestock feed.

Greater attention to policy issues

Although the livestock sector in many SSA countries makes a significant contribution to agricultural GDP, in general, it has been subjected to unfavourable government policies with bias towards urban consumers, excessive regulation and unfair public sector competition (NEPAD, 2005). National policies are often designed to promote crop production. A wide variety of inappropriate policies has seriously hampered rather than stimulated development of animal industries. Modernizing the livestock sector in SSA and providing the flexibility for it to respond adequately to the increased global demand for animal products requires a change of attitude and appropriate development policies. This should be reflected in the appropriate allocation of funds and the improvement of institutional facilities. Government agencies must expand public investments that facilitate the development of sustainable, small-scale systems of market-orientated animal production. Future international donor investment needs to increase and involve appropriate CGIAR centres, eg IFPRI and ILRI, on researchable policy issues in the SSA livestock sector to ensure the viability and economic growth of the African livestock sector based on small-scale producers.

Integrating crop–livestock R&D: how?

Key challenges

The DFID-RNRRS programmes and ILRI, the SLP and their African partners have made important contributions to increasing crop productivity and improving livestock nutrition and productivity in priority production systems in some locations in SSA to the benefit of the poor. However, the full realization of the benefits from this substantial research effort has been hampered by the historical and ongoing lack of cross-disciplinary linkages and cross-sectoral approaches. *Research on crops and livestock has been removed from its integrated systems context.*

The DFID-RNRRS has largely been discipline-based (eg plant sciences, livestock production, crop protection, crop post-harvest, forestry, etc), with the exception of the above-mentioned crop–livestock projects (Lenné and Thomas, 2005a). Even in the CGIAR system, ILRI has no crop-specific scientists. It relies on partnerships with crop institutes to implement research in crop–livestock systems. Without in-house expertise, long-term strategic planning at systems level is difficult. NARES institutions in SSA are also organized on disciplines and there are barriers between the soil, plant and animal sciences. This situation precludes a holistic approach to complex system-based problems. Within animal sciences, pasture science and animal nutrition have often been separated from animal production (ie management). Such an organizational structure ignores the real problems faced by farmers and interactions in farming practice between

the disciplines. This situation is happening despite awareness amongst scientists of the increasing importance of crop–livestock integration in small-scale farming systems.

Most unfortunately, there is currently no comprehensive, well supported, international partnership initiative on crop–animal interactions to improve the productivity of rain-fed crop–livestock systems, even though this is where investment is most likely to reduce poverty and enhance the livelihoods of the poor in SSA. Research effort is spread amongst a plethora of institutes and unlinked projects, funded by many different donors. There is great diversity in the extent to which different end-users and delivery agents are integrated to ensure that research is both relevant and deliverable to farmers. If the full impact of DFID and other donor investment in crop and livestock research is to be realized, it must be better integrated and linked more directly to contributions in poverty alleviation and livelihood enhancement opportunities *at systems level.*

Potential solutions

Systems-based research approaches to crop–livestock research in SSA are slowly evolving based on the needs of farmers (Thornton *et al,* 2003). Highlighted projects supported by the CPP, LPP and PSRP (eg R6755, R7346, R7375, R7379, R7955, R8183, R8339, R8450) as well as those implemented by ILRI, the SLP and African partners, have aligned knowledge generation and technology development to the needs of farmers in existing and evolving crop–livestock systems. *Critically, these projects have significantly improved the institutional arrangements necessary to ensure that end-users will benefit from the research outputs.*

Key characteristics of successful and productive crop–livestock projects were that they:

- fostered multidisciplinary research teams of crop, livestock and social scientists;
- worked with *crop* and *livestock* R&D institutes;
- built on existing knowledge bases and integrated multiple knowledge bases;
- 're-worked' the stock of knowledge according to farmer and system needs;
- developed productive and sustainable partnerships; and
- sought opportunities for spill-overs to other locations and regions.

There is, therefore, great potential to build these model projects and partnerships into *a crop–livestock systems research initiative* in SSA. Through such an initiative, poor small-scale farmers, poor livestock keepers and poor consumers will benefit even more from existing and emerging technologies that increase the productivity of mixed farming systems. At the least, this should be given high priority in the new DFID Strategy for Research on Sustainable Agriculture (SRSA), the CGIAR strategy for 2006–2016, and by other major agricultural R&D donors in SSA.

For example, integrating crop–livestock research in the new DFID-SRSA will provide an indispensable platform for wider economic growth that reduces poverty far beyond the rural and agricultural sector. By embedding *a crop–livestock research theme in the SRSA*, it can uniquely link and integrate strategy across the CGIAR, the planned eco-regional research programmes for increasing agricultural productivity in Africa and Asia, as well as the planned facility to promote outputs of the RNRRS. Furthermore, there are probably similar opportunities for other major donors.

Technology spill-overs have been a pervasive feature of the history of agricultural R&D. In fact, up to half of the local productivity increases in agriculture in the past few decades can be attributed to spill-over of technologies developed elsewhere (Alston, 2002). Multidisciplinary research activities under a crop–livestock theme would not only be conducted across each region, but would also spill over all relevant regions. This would improve efficiency by avoiding duplication of effort, ensure critical mass, actively promote synergies from stronger to weaker NARES, and have potential for more rapid and greater impact (CGIAR Science Council, 2005).

Conclusion

Integrating crop–livestock R&D is no longer just an *option* in SSA if crop and livestock research is to have a lasting impact on improving the livelihoods of small-scale crop–livestock farmers and national economic growth; and it is more of an *imperative* now than nine years ago when an earlier call was made (Smith *et al,* 1997). If donors do not respond to the reality of the rapid evolution and integration of crops and livestock in farming systems throughout SSA by linking and integrating research strategy and resources *at all levels,* wide-scale impact on the poor in crop–livestock systems in SSA will remain *elusive* – perhaps even *impossible.*

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Note

[1] R numbers refer to DFID-RNRRS projects; further information about these projects is available from Lenné and Thomas (2005a); the DFID NARSIS database; and specific DFID-RNRRS programmes.

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