Integrating crop-livestock R & D in sub-Saharan Africa: option, imperative or impossible?

"An opportunity to *rework* the stock of RNRRS knowledge to the benefit of small-scale crop-livestock farmers"

Introduction

An analysis[1] was made of the contributions to increasing the productivity of crop-livestock systems by over 100 DFID-RNRRS research projects (from the CPP, LPP, PSRP, NRSP, CPHP and FRP). Most emphasis was on CPP and LPP projects in East and southern Africa. The context was contributions to reducing poverty for small-scale farmers and national economic growth. Potential for outputs generated in South Asia to spill-over to sub-Saharan Africa (SSA) was also considered. Important lessons and critical challenges to integrating crop-livestock R & D were highlighted to inform future DFID investment.

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 SSA. They are more important than any other system in terms of their contribution to the total output of animal products and contribute to enhancing the livelihoods of the poor through provision of food, income generation, draught power and employment (Lenné and Thomas, 2005a). Livestock account for 53 percent of the agricultural capital stock in SSA and contribute significantly (30%) to agricultural GDP (NEPAD, 2005). Around 70 percent of the human population of SSA are primarily or partly dependent on livestock. It is predicted that the demand for livestock products in SSA will increase substantially over the next 25 years (Delgado *et al.*, 1999). If this demand is not met by increased production, subsidized products will be imported, to the detriment of national economic growth and small-scale producers.

- *Potential to reduce poverty and enhance livelihoods*

The DFID has strongly oriented its international development policy towards achieving the Millennium Development Goals (MDGs) by 2015, with particular emphasis in SSA. 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)

in the following plausible ways:

- by increasing income generation for poor small-scale female and male farmers from sale of livestock and crop products (MDGs 1, 3) and by providing insurance against uncertainties e.g. drought;

[1] The detailed analysis R8444 "Identifying options to reduce poverty and enhance the livelihoods of small-scale crop-livestock producers in sub-Saharan Africa" – Lenné, J. and Thomas, D. is available from the DFID Crop Protection Programme.

- by improving nutrition for the poor, especially children and mothers, through increased availability of milk and other livestock products (MDGs 1, 3, 4, 5); and
- through sound intensification strategies for crop and livestock production allowing the land to be more productive while sustaining the environment (MDG 7)

through addressing the key challenges:

- increasing the productivity and production efficiency of food and feed crops per unit land area using the same inputs;
- maintaining and/or increasing the involvement of small-scale farmers in the livestock sector; and
- producing quality livestock products that are affordable to local consumers (Lenné and Thomas, 2005b).

- *Pro-poor priorities in crop and livestock RNRRS 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. Although world research has paid inadequate attention to crop and livestock research in SSA (DFID, 2005), research implemented through the RNRRS programmes has focused strongly on farming systems where the majority of poor livestock keepers live and work: mixed rain-fed systems in the humid/sub-humid, semi-arid and tropical highland zones in SSA. 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* cropping 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 the CPP, LPP and other DFID research programmes during the past 10 years has achieved much. It can now be integrated to further improve crop and livestock productivity in these systems (see Annex 4). At the same time, the RNRRS programmes have fostered long-term productive partnerships through participation with NARES, universities, IARCS, NGOs, CBOs and the private sector in East and southern Africa. *There is therefore a great opportunity to re-work the stock of knowledge generated by the RNRRS and integrate it with that generated by the CGIAR and other partners to the further benefit of small-scale crop-livestock producers and national economic growth in SSA.*

Integrating crop-livestock R & D: what?

- *Development and promotion of dual-purpose/food-feed crops*

The arable land per inhabitant in SSA is continuing to decline. Future food needs will have to be met *sustainably* through increased productivity per unit area. Dual-purpose crops enable farmers to increase unit area productivity with the same resources. Significant advances have already been made in the development and promotion of dual-purpose cowpea in West Africa (Singh *et al*., 2003) and dual-purpose sorghum, millet and groundnut in India (Blummel *et al*., 2003) by the CGIAR and its partners, partly funded by the DFID. This has included the CPP, LPP and PSRP projects: R7346, R7375, R7379, R8183, R8339, and R8450 (Box 1). In addition, the increasing value of sorghum, groundnut and cowpea residues as marketable commodities in India and West Africa, respectively, is generating income for poor farmers (Lenné and Thomas, 2005b; R8339). Although maize is already managed by Kenyan highland dairy farmers as a food-feed crop (Romney *et al*., 2003; R6775, R7955; Box 2), its genetic potential as a stover crop is only beginning to be exploited. Several South-East Asian countries have developed chipped roots and foliage hay from cassava (Wanapat and Rowlinson, 2005). There is great potential for spill-overs from Asia to SSA.

Box 1. Development and promotion of dual-purpose crops

Cowpea in West Africa:

- By 2001, >8,000 farmers cultivating improved dual-purpose cowpea in semi-arid West Africa
- At current adoption rates, the technology has potential to reach several million cowpea farmers with IRR of 50-103%

See: Kristjanson et al., (2002); Singh et al., (2003)

Groundnut and sorghum in India:

- Reduced disease losses by >50%; improved dry matter digestibility by 10-15%; increased dry matter intake by 10-32%
- Improved milk yields by 0.44 kg/day and improved 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

See: R7346, R8339, and R8450; Blummel et al., (2003); Lenné and Thomas (2005b)

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 in SSA; while maize residues are valued in highland East Africa but less so elsewhere. Most importantly, improved, dual-purpose crops can be promoted through existing promotional pathways for seed of food crops (see below). 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.

Box 2. Improving productivity, quality and management of maize as a food-feed crop

- Management of Maize Streak Virus reduced losses by 20-25%
- Increased yields of thinnings and stover by 40-166% and 118-409 kg/season, resp.
- Increased fodder met the maintenance requirements of a 350 kg cow for 19-66 days

See: R6775, 7955; Romney et al. (2003)

- *Enhanced potential for improving soil-fertility*

Mixed farming systems in rain-fed SSA are nutrient deficient. Projects supported by the LPP, NRSP, CPP and FRP (e.g. R5732, R5999, R6001, R6282,R6283, R6339, R6549, R6603, R6610, R6731, R6757, R7855, R8219, R8445) have identified innovations to enhance soil fertility in the nutrient-deficient crop-livestock systems through more enlightened integration of organic and inorganic fertilizer sources and improved crop management. These include: increased use of fodder trees, shrubs, and herbaceous legumes and crops in appropriate niches, mini-packs of inorganic fertilizer and seed of dual-purpose crops, improved feed quality, strategic supplementation and improved management and composting of manure. Farming system productivity has improved as well as system health. Future attention should be given to promoting such integrated natural resources management options in crop-livestock systems for increased livestock and crop productivity.

- *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,b). Several CPP x LPP projects (R7346, R7955, R8339 and R8450) and many CPP projects (Annex 5) have focused on the development and promotion of technologies to reduce losses due to pests, diseases and weeds in mixed crop-livestock farming systems. These have mostly *unknowingly* provided opportunities to increase crop residue/animal feed production and quality. Excitingly, crop-livestock farmers in East Africa are rapidly adopting the 'push-pull strategy' for controlling maize stemborers primarily due to the additional high quality feed produced by maize, Napier grass and *Desmodium* (Box 3; R8212, R8215; Lenné and Thomas, 2005b). With the exception of the joint and push-pull projects, the potential contributions of crop protection technologies to increased quantity and quality of animal feed resources *have not been captured* by these projects. Development of knowledge and technologies to manage biotic constraints with potential to reduce crop production (both food and feed products) should therefore be *main-streamed* in future research crop-livestock initiatives.

Box 3. 'Push-pull strategy' for maize stemborer control and increased fodder

- Increased yields of maize grain, thinnings and stover
- Increased fodder from Napier grass and *Desmodium*
- Increased income from sale of milk and *Desmodium* seed
- Increased purchase of grade milking cows

See: R8212, R8215; Lenné and Thomas (2005b)

- *Improved and enlightened use of available systems-based feed resources for ruminants and non-ruminants*

There are potentially many feeds available in mixed systems in SSA as RNRRS projects have shown (Annex 4). Throughout the year, farmers use a variety of local feed resources for their animals e.g. crop residues, weeds, grass, pasture, shrubs, trees and herbaceous legumes (Box 4), surplus grain, root crops and oilseed crops, and their residues and by-products etc. (Lenné and Wood, 2004). This is often not taken into account in individual animal nutrition projects. Furthermore, in developing countries, limited work has been done 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 available feed resources*. Failure to do this, particularly in small-holder milk production systems, can lead to wastage of feed resources over the year. Development and promotion of animal feeding strategies that reflect the availability of a wide range of on- and off- farm local feed resources and target variation in animal demand during the production cycle should be strongly supported in future (R6282, R6609, R7431, R7855).

Box 4. Promotion of multi-purpose shrub and herbaceous legumes

Multi-purpose shrub 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 legume: *Stylosanthes* in West Africa

- By 1999, 27,000 farmers cultivating Stylo fodder banks on 19,000 ha in 15 countries of sub-humid West Africa

- To 1997, net benefits were US$ 16.5 million with IRR of 38%

See: Elabasha et al. (1999); Tarawali et al. (1999); R5732, R6549; Franzel et al. (2003)

- *Development and promotion of fodder conservation strategies*

Increased production of fodder on-farm will enable farmers to store fodder for the dry season. The conservation of fodder as hay or silage, however, has not been common practice in small-scale farming systems in SSA due to lack of information on conserving fodder under tropical conditions. Crop residues are sometimes stored but most are left in the field after harvest, opportunistically grazed, and often spoiled and under-utilized. Some practical and low cost conservation methods such as box-baling and bag silage of maize stover, fodder legumes, bean residues, and Napier grass (e.g. LPP and CPP projects: R6610, R6619, R7010, R7955, R8414) show considerable potential for spill-overs across feed resources and throughout SSA. Development and wider promotion of these fodder conservation methods should be supported in small-scale crop-livestock systems to alleviate seasonal fodder shortages.

- *Development of sustainable seed systems for food-feed crops*

Access to affordable, high quality seed of food-feed crops is one of the most important constraints facing small-scale crop-livestock farmers in SSA. Due to the inadequacies of the public sector and lack of private seed sector interest (with some exceptions), farmer-led seed multiplication systems have been effectively developed to rapidly multiply and disseminate quality seed of groundnut, beans, pigeon pea and maize (e.g. CPP and LPP projects: R7346, R7429, R7445, R7566, R7569, R7947, R8105, R8205, R8219, R8220, R8339, R8406, R8415, R8445, R8450, R8453, R8455, R8481). 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.

- *Improved marketing systems for livestock products and fodder*

In SSA, marketing chains for livestock products are either non-existent or weak due to complexities, inefficiencies, and unreliability. 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 (e.g. R7321, R7542, R7631). 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 solutions improvements.

Small-scale farmers in India have realized the advantages of collective marketing and innovative coalitions. Firstly, 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 (six-thousand village level Women's Dairy Cooperative Societies formed) in India has been substantial (Lenné and Thomas, 2005a,b). Secondly, 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 x CPHP project R8267). 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 fodder trading. In semi-arid West Africa, sophisticated legume fodder markets thrive while in East Africa, fodder is traded informally at village level. Furthermore, trade in animal fodder has developed rapidly in India driven by the growth of peri-urban dairy enterprises. Crop residues are becoming increasingly appreciated by small-scale farmers for income generation. Due to land scarcity, 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. There is potential for the livestock sector in SSA to learn from the successful development of fodder trading and markets in West Africa and India, (including from the CPP x LPP R8339), as it addresses increased demands for livestock feed.

- *Innovative promotional strategies for crop and livestock research knowledge and technologies*

There is a large unmet demand for information and technology in SSA, especially by women, due to the inadequacies of traditional promotional pathways. A number of successful promotional strategies for crop and livestock knowledge and technologies have been developed by the RNRRS programmes (Annex 4). Such strategies have often relied on group learning through farmer, women's and church groups, schools, coalitions with the private sector, and village information centers. Much sought-after training and promotional tools (leaflets, posters, comic books, videos, computer programmes, radio and TV programmes, drama, national newspapers etc.) have been developed. Successful promotional strategies – whether developed through crop or livestock projects – should be used to promote knowledge and technologies in crop-livestock systems in SSA in future.

- *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. The livestock sector has largely been ignored by policy makers and policy research, including, to date, by the RNRRS programmes. Without more favourable policies, the growing urban demand for livestock products will be met by subsidized imports to the detriment of further growth of domestic sectors based on small-scale producers. There is an urgent need to address this opportunity for national economic growth. The new DFID strategy will greatly benefit from partnerships with appropriate CGIAR centres e.g. IFPRI and ILRI on researchable policy issues in the SSA livestock sector to ensure the future viability of the African livestock sector.

Integrating crop-livestock R & D: how?

- *Key challenges*

Clearly, the DFID RNRRS programmes have made major investments during the past ten years in increasing crop and livestock productivity in priority production systems in SSA to the benefit of the poor. Similarly, ILRI, the CGIAR System-wide Livestock Programme (SLP) and their African partners have made a major contribution to improving ruminant livestock nutrition. However, the full realization of the benefits from this substantial research effort has been hampered by the historical lack of cross-disciplinary linkages and cross-sectoral approaches. *Research on crops and livestock has been removed from its integrated systems context.*

Most unfortunately, there is currently no comprehensive UK or international partnership initiative on crop-animal interactions to improve the productivity of rain-fed crop-livestock

systems even though this is the major production system in SSA where investment is most likely to reduce poverty and enhance the livelihoods of the poor. 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 the 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 crop-livestock 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). Model projects supported by the CPP, LPP and PSRP (e.g. R6755, R7346, R7375, R7379, R7955, R8183, R8339, R8450) as well as those implemented by ILRI, the SLP and African partners (in many cases, funded by DFID) have aligned knowledge generation and technology development to farmers' needs 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:

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

There is, therefore, great potential to use these model projects and partnerships as the basis of *a crop-livestock systems research initiative* in SSA. This will ensure that poor small-scale farmers, poor livestock keepers and poor consumers benefit even more from existing and emerging technologies that increase the productivity of mixed farming systems. This should be given high priority in the new DFID Strategy for Research on Sustainable Agriculture (SRSA).

Integrating crop-livestock R & D: when?

Integrating crop-livestock research in the new DFID SRSA provides 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 integrate the strategy across its four elements: i) the eco-regional research programmes for increasing agricultural productivity in Africa and Asia; ii) the programme to facilitate uptake of past and current outputs of the RNRRS; iii) the new responsive programme for linking Advanced Research Institutes with regional research initiatives; and iv) on-going support to International Agricultural Research Institutes (especially the CGIAR). Multi-disciplinary research activities under a crop-livestock theme would not only be conducted across each eco-region but would also spill-over all eco-regions. This would improve efficiency by avoiding duplication of effort, ensuring critical mass and actively promoting synergies from stronger to weaker NARES (CGIAR Science Council, 2005).

Conclusion

Integrating crop-livestock R & D in SSA is no longer just an *option* if DFID crop and livestock research is to have lasting impact on improving the livelihoods of poor livestock keepers 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 such as the DFID do not respond to the reality of the rapid evolution and integration of crops and livestock in farming systems throughout SSA by integrating the new research strategy *at all levels*, wide-scale impact on the poor in crop-livestock systems in SSA will remain *elusive* – perhaps, even *impossible!*

List of Annexes

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Annex 4a. Analysis of the CPP maize projects cluster

During 1995-2003, the CPP funded 2-3 cycles of three year projects (18 projects in all) to develop technologies and management strategies for the most important fungal, insect pest, virus and weed constraints affecting maize in small-holder systems in Eastern and Southern Africa. The progress and outcomes of these projects are well-documented in the CPP Annual Reports of the same period. Relevant aspects of these projects are summarized below.

PS	No. & Title	Country	Date	Comments
HP	R5341/3 6582 Epidemiology and management of maize ear rot complex	Kenya, Malawi	<1995-2000	The project assessed ear rot incidence, crop loss, potential risks from mycotoxins, the results of which were used to develop management strategies. Ear rot incidence ranged from 22-68% and was closely associated with stalk borer damage. Tolerant H614 was less affected. An ICM strategy including use of H614, early planting, recommended fertilizer application, use of insecticide against stalk borer, early harvest and storage hygiene. Management of disease and pest will result in more productive plants and potentially more stover for animal fodder.
	R7566 Management of maize grey leaf spot (GLS)	Kenya, Zimbabwe	2000-2004	Maize Grey Leaf Spot (GLS) caused by the pathogen, *Cercospora zeae-maydis,* and to a lesser extent, *Cercospora sorghi* var. *maydis*, occurs on <75% small-holder maize farms in East Africa and is considered to pose a serious threat to food security. Effective management practices for maize GLS were developed through the project based on sound epidemiological principles. These included cultural practices including removal of crop debris to reduce disease incidence and severity as well as host resistance based on an understanding of pathogen variability. Seed of GLS resistant varieties is available to small-holders. Management of disease and pest will result in more productive plants and potentially more stover for animal fodder. Removing the stover from the field will also contribute to reducing disease levels. Another way is to feed it to cattle. Animals are very important in Zimbabwe (82% farmers used only draught animals for land preparations) but less important in Kenya (39% farmers). 61% of farmers in Kenya and 46% in Zimbabwe fed maize stover/debris to cattle but no significant effect of reducing inoculum could be found on GLS.
	R5238/5785/6653 Integrated management strategies for insect soil pests of maize	Malawi, Uganda	<1995-2000	Promising potential management strategies for termites in maize were developed involving biocontrol, intercropping, resistant varieties and a mycopesticide formulation. Management of pest will result in more productive plants and potentially more stover for animal fodder.

	R7951 Testing biocontrol of pest termites in maize-based systems in Uganda (linked with R7026(C) Microbial control of termites)	Uganda	2000-2001	Management of pest termites was investigated using a crude formulation of Metarhizium anisopliae and several application methods (broadcast vs apllied in planting holes). Seasonal effects were observed with broadcasting being feasible in the long rains. Management of pest will result in more productive plants and potentially more stover for animal fodder.
	R5246/7/6642/7429 Development of management strategies for MSV	East Africa	<1995-2000	The project selected MSV resistant maize varieties and developed on-farm seed selection techniques with farmers to enhance the sustainability of MSV-resistant maize varieties. Management of disease will result in more productive plants and potentially more stover for animal fodder.
	Links with R6400(H) Management of stemborers (ICIPE/IACR Rothamsted)			Developed further through projects R8212 and R8449 (see below)
	R5883/6003/6047/6690 Management/biocontrol /modelling Rottboellia	Costa Rica, Bolivia, Mexico	<1995-1999	Several projects developed an integrated management strategy for Rottboellia cochinensis (itch grass) in maize-based cropping systems including the use of a smut as a biocontrol agent. Management of weed will result in more productive plants and potentially more stover for animal fodder.
	R5343 Weed management in Malawi (with links to R7564 Management of Striga in Tanzania in SA2)	Malawi	<1995-1996	Management of weed will result in more productive plants and potentially more stover for animal fodder.
	R7405 Development of weed management in maize-based farming systems	Kenya, Uganda	1999-2002	The use of herbicides increased yields by 21% compared to standard hand-weeding and reduced labour by 42%. Use of herbicides gave a 20% increase in gross benefits. Herbicides improve yields, reduce weed populations, and are cost-effective. Management of weed will result in more productive plants and potentially more stover for animal fodder.
	R7404 Uptake of herbicide technology	Kenya, Uganda	1999-2000	Analysis of trends in herbicide use indicated that the small number of farmers using herbicides are generally better off, better educated, and cultivate more land. The potential net benefits associated with herbicide use include yield benefits and reduced labour requirements for weeding; net benefits from cultivating maize could increase by 80%. The main constraints faced by farmers regarding adoption of herbicides are lack of funds/credit to purchase herbicides and sprayers. Thus prospects for widespread uptake in the current economic situation are low despite the potentially high benefits.
	R7489 Uptake of maize research outputs	East Africa	1999-2000	Constraints to the uptake of research outputs from maize projects were identified to inform programme management of the most effective promotional strategies to follow.

These projects generated a basket of crop protection technologies which together with technologies generated by breeding, soil fertility management, agronomy and marketing activities in the region were appropriately combined in 2002/2003 to address integrated pest management and integrated crop management problems affecting maize in Eastern and Southern Africa. One project R7955 IPM of maize in highland dairy systems in Kenya specifically focused on crop-livestock systems. These projects are summarized below.

PS	No. & Title	Country	Date	Comments
HP	R7955 Strategies for feeding small-holder dairy cattle in intensive maize forage production systems and implications for IPM **(joint LPP x CPP)**	Kenya	2002-2005	The joint CPP-LPP project addressed two main outputs: to develop and promote strategies to improve the seasonal availability of livestock feed (LPP) and to develop and promote strategies to reduce the impact of pests on poor peoples' crops and to improve quality and yield from maize-based systems (CPP). In highland maize-dairy systems in Kenya, maize as thinnings and stover is an important fodder esp. in the dry season (Jan-Mar). Much of the fodder used is sourced on-farm. During the short rains, more off-farm feed is purchased. MSV, stemborer and weeds reduce maize production. Early MSVD infection can substantially reduce forage off-take but does not appear to reduce quality significantly at farm level. Use of MSV-resistant maize varieties will increase forage and grain production in the long rains especially under early infection conditions. This will result in more fodder and enable fodder conservation for alleviating feed shortages in the dry season. Green maize stover is worth KSh 50 per human load (approx. 40 kg) and 1 ha will yield approx. KSh 6900. MSV affected thinnings did not achieve a lower price than healthy thinnings. Limited indication that MSVD affected stover reduced milk yields. Weeding reduced competition with maize, contributed to farm-sourced fodder (but not significantly) but weed seeds passed through cattle unharmed. Passaging of maize head smut through the animal and composting dung for 3 months killed smut spores and most weed seed but issues related to animal health re smut were not considered (potential for link to R7436). The value of MSV resistant cvs on fodder yield was demonstrated. Farmers showed great interest in trying out the push-pull habitat management system for maize stemborer control on their farms motivated by the dual prospect of additional forage and pest control. Forage demand is an incentive for farmers to adopt push-pull. Forage output and quality (the combination of Napier/maize and the legume, *Desmodium*) increases considerably and indeed some farmers already grow mixtures of Napier and Desmodium. Validation of the push-pull system (Napier grass was part of the strategy) is needed.

				Other feed sources used in these systems included: banana pseudo-stems, bean residues and sweet potato vines. The main beneficiaries of the outputs – higher forage production to alleviate feed shortages in the dry season to sustain/enhance milk production - from this project are resource-poor crop-livestock small-holders and non-livestock keepers who sell fodder to crop-livestock farmers in intensive peri-urban crop-livestock systems in central Kenya.
	R7955 Completion of exit strategy for and implications of R7955 for maize-forage dairying systems **(joint LPP x CPP)**	Kenya	2005-2006	The high quality forage produced as a result of IPM methods is mostly produced in November-December and May-July when no forage shortages are expected. Hence, in conjunction with the NGO, Land O'Lakes, project R7955 has also shown farmers and extension small-scale (polythene bag) conservation methods. This silage produced as a result of improved crop protection may then be stored to alleviate seasonal forage shortages. The potential impact on livelihoods is considerable and the system was well-received by farmers Alleviation of forage shortages by controlling biotic constraints to maize followed by conservation is the most important impact of this project on livelihoods. The dissemination message is essentially: Better IPM (weeds, pests, diseases) → more maize → more forage (and grain) → less seasonal forage shortages → more milk → more money → improved livelihoods of Resource Poor Livestock Keepers (RPLK) and non-livestock keepers producing forage With the opportunity of limited additional funding through to December 2005 we believe it will be possible to achieve two main aims: to consolidate and complete this exit strategy for R7955 during the long and short rains seasons in 2005 when promotion partners are actively disseminating outputs to farmer groups in a wider geographical area than that of the original PMF. This proposal therefore seeks to maximise the value of the investment by LPP and CPP in project R7955 by continuing to support promotion partners through the 2005 long and short rains crops, when promotion partners and the farmer groups, with which they are working, would be trying the technologies for the first time; and to write an additional report in which the implications of this project for maize-dairy cropping systems, for plant breeding, policy makers and planners can be made clear. Lessons learned and their general application to other areas will also be described.

	R8453 Promotion of an IPM Strategy for Maize Grey Leaf Spot (GLS) in East Africa	Kenya, Tanzania, Uganda	2005-2006	Based on the findings of R7566, the project will develop an IPM strategy for managing maize GLS based on enhancing the awareness of the disease amongst small-scale maize farmers and extensionists in East Africa and the availability of maize varieties with resistance to GLS and complementary cultural control strategies for GLS. **In addition, through linkages with R7955, the importance of forage maize in the spread of GLS is now recognised and will be addressed through follow-up activities.** IPM strategy is based on a 'basket of options' including resistant maize varieties in association with seed companies in Kenya, Uganda and Tanzania and cultural control strategies aimed at reducing carry-over inoculum in crop residues and stover. **The importance of forage maize in the spread and over-wintering of maize GLS will be highlighted.** The IPM Strategy for managing maize GLS will be promoted to large numbers of target beneficiaries' i.e. small-scale maize farmers, throughout East Africa (Kenya, Tanzania and Uganda). Pathways for the uptake and promotion of the outputs are: Farmer Field Schools, Training-of-Trainers, Farmer Participatory Field Days, Posters and leaflets, Radio, National newspapers and video. Direct interaction with small-holder farmers **(>25,000**) through the IFAD-funded farmer field schools in East Africa, especially those in GLS hot-spots has shown a clear demand for knowledge on maize GLS and in particular. strategies for managing the disease. The recent extension of this project will provide continuity to the promotional strategy and allow more farmers to be reached.
	R8212 Integrated pest and soil management to combat Striga, stemborers and declining soil fertility in the Lake Victoria basin	Kenya, Uganda, Tanzania	2002-2005	The project is developing and disseminating and integrated pest and soil fertility management strategy (IPSFM) against Striga, stemborers and declining soil fertility in maize-based systems. Technologies include: push-pull for stemborer and Striga control, herbicide-resistant maize cvs (IR maize), and crop rotation for soil fertility improvement and Striga control. Farmer preferences for different technologies varied in different sites. Over 2000 farmers have adopted the push-pull strategy. Push-pull treatments have high gross margins due to low input costs. Napier grass and Desmodium push-pull technologies increase fodder production in the system which can result in better fed and increased numbers of cattle. A study in Suba District showed a strong positive correlation between increased adoption of push-pull and increased numbers of grade dairy cows. Some farmers also sell Napier grass and Desmodium for cash income at KSh 50 (per wheelbarrow load) and KSh 75 (per gunny sack) respectively.

	R8449 Promotion and dissemination of Integrated Pest and Soil Fertility Management Strategies to combat striga, stemborers and declining soil fertility in the Lake Victoria basin	Kenya, Uganda, Tanzania	2005-2006	The short project will rigorously evaluate striga, stemborer and soil fertility management techniques (IPSFM), with emphasis on socio-economic data, using both scientists' and farmers' evaluation criteria; train farmers in striga and stemborer control and soil fertility enhancement and NGO and extension staff, and researchers in providing useful and relevant information to farmers, thus strengthening the capacity of stakeholders; facilitate the availability of seeds and fertilizer through public-private partnerships and the implementation of a local credit scheme; scale up and out project products through the development of linkages with other CBOs, NGOs, and extension services; and assess the initial and potential impact of the IPSFM options in the target areas and beyond. The outputs of the project will contribute to food security, human health (improved quality diet), gender empowerment, soil conservation and fertility through Desmodium and dual purpose grain legumes, and **enhanced dairy and livestock production through increased fodder production from maize, Napier grass, Desmodium and dual-purpose legumes.**
	R8215 Increasing food security and improving livelihoods through the promotion of integrated pest and soil management in lowland maize in Tanzania	Tanzania	2002-2005	The project is developing participatory pest, weed and soil fertility management strategies against Striga, stemborers and declining soil fertility in maize-based systems using green manure crops, Striga-resistant maize, neem and Napier grass (pull part of push-pull). Green manure-maize outperformed maize-maize (higher yields, reduced labour costs). A key problem is the lack of a system to ensure greater access by farmers to seed of improved varieties. Napier grass as well as green manures e.g. Canavalia, Mucuna and Crotalaria increases fodder production in the system which can result in better fed and increased numbers of cattle. **Green manures can also be fed to animals.**
	R8452 Increasing food security and improving livelihoods through the promotion of integrated pest and soil management in lowland maize systems, Phase II	Tanzania	2005-2006	Initial conclusions from the use of the legume/maize rotation indicate that green manures are attractive and likely to be adopted, when, i) sustained increases in maize yield are achieved, ii) additional benefits over and above improving soil fertility and reducing *Striga* infestation, such as food or **fodder for household use or sale** are obtained and, iii) land is not limiting and green manures can be used to improve fallows. The new project will build on F8215 through: Participatory technology development and promotion of pest management, and soil fertility management techniques, building on 15 established farmer groups in Muheza as well as others in surrounding Districts and providing the opportunity for using a farmer field school approach for scaling-up. This will involve training in integrated natural resources management (*Striga* control,

				stemborer control, soil fertility management and rain water harvesting/soil conservation) using extension materials developed by the project and Market for crop seed in small packs promoted. This will involve improving farmer access to input supplies through establishment of village level supplies linked to local stockists. The private seed company Mbegu Technologies Inc., Limited will be an important source of improved seed. Project activities will assist in creating demand for *Striga* tolerant maize varieties and green manure seed for distribution in small packs, affordable by farmers.
	R8219 Improved access to farm inputs for ICM	Kenya	2003-2005	The main aim of the project is to improve the food security of small-scale farmers through improving their access to, and rapid dissemination of technology to improve crop production (appropriate fertilizers, lime) and crop protection (MSV-tolerant maize varieties, herbicides). This is achieved through developing and marketing 1 kg bags of Mavuno multi-nutrient fertilizer from ARM together with 150g samples of MSV-tolerant maize seed for KSh 30 from Western Seed Company. Pannar (PAN 67), Freshco (KH 500-21A), Monsanto (DK 8071, DK 8051, DK 8031), and Seedco have also donated MSV-tolerant varieties to FIPS Africa free-of-charge for demonstrations. To date, FIPS Africa has catalysed the supply of over 100 tonnes of *Mavuno* fertilizer and 6.5T of WSC's MSV-tolerant maize varieties. The partnerships with the private sector have been instrumental to the achievements. Approximately 100,000 farmers have received packets and demand far outstrips supply. Mini-packs of glyphosate are also being marketed. The demand for fertilizer mini-packs is increasing throughout Kenya. Through the use of improved maize varieties (herbicide-tolerant) and improved access to cheaper inputs (fertilizer, seed), maize production is increased. In crop-livestock systems this will be translated in additional fodder.
	R8455 Improved access to appropriate farm inputs for integrated maize crop management by small-scale farmers in Kenya and Tanzania	Kenya, Tanzania	2005-2006	This project will further refine FIPS promotion methodology through the development of a food security input package, and a strategy for the dissemination of glyphosate (Roundup) herbicide in small sachets. It is also proposed to extend promotions of MSV-tolerant varieties and improved fertilizers into neighbouring districts (Meru and Nyeri) which has already started in a pilot phase with funding from ARM. In addition, due to requests from other CPP projects and seed and fertilizer companies in Tanzania, FIPS Africa proposes to extend its promotion methodology to assist the dissemination of

				disease-tolerant maize varieties in projects (R 8220) and pest-tolerant bean varieties (R7965) in project target areas in N. and S. Highlands of Tanzania. Co-operation with R7965 project will also enable FIPS Africa to assist farmers to experiment with mini-packs of beans varieties in Kenya. Finally, despite the large numbers of small packets distributed, and uptake of technologies by farmers as indicated by sales of inputs in Embu/Kirinyaga districts, there is need for an impact assessment to determine the impact of different promotion methods on adoption, and the effect of the project on farmers' yields and livelihoods. This will help to fine tune their dissemination strategies for future programme activities.
	R8220 Improving access to and management of disease resistant maize cultivars in the Southern Highlands	Tanzania	2003-2005	Improved performance of the GLS-resistant variety UH615 has been validated on-farm but the level of tolerance in MSV-tolerant varieties is not sufficient under the high disease pressure in the SH. Developing strategies to improve access to and management of MSV resistant cultivars is likely to be successful in small-holder systems through improving the selection of MSV resistance under disease-conducive conditions, targeting the best opportunities for MSV resistant cvs, and developing a more complete resistance in OPVs. Cost-effective strategies are being developed to improve seed systems including recognition of quality declared seed and farmer-saved seed to improve access by farmers to quality seed. Through the use of improved disease resistant maize varieties, maize production is increased. In crop-livestock systems this will be translated in additional fodder.
	R8406 Improving farmers access to and management of maize seed in the Southern Highlands of Tanzania – Phase 2	Tanzania	2005-2006	Disease resistant maize varieties appropriate to farmers' needs and adapted to local conditions will be validated by and promoted to farmers and other stakeholders including a new MSV/GLS resistant maize hybrid, UH6303, MSV resistant top crosses involving adapted OPVs e.g. Staha and Kilima. In partnership with FIPS Africa, it is envisaged that soil fertility learning plots will be established with each farmer group e.g. comparing Mavuno fertilizer and/ or a minjingo rock phosphate blend with existing fertilizer recommendations. District level promotional strategy approaches will be developed for improving access to and management of quality seed by farmers and more widely promoted. A zonal maize promotion strategy will be developed in partnership with the private sector and monitoring and evaluation of activities will be carried out in order to learn lessons about improving access to and management of seed to meet farmers' needs.

				This project builds on R8220 as well as R7429 on farmers seed management of maize in Uganda using a village-based system. A range of GLS-resistant and more recently, MSV-resistant maize varieties have been developed in Tanzania. A GLS resistant[1] version of TMV-2 (open-pollinated variety-OPV).

Annex 4b. Analysis of CPP semi-arid production system purpose 2 projects

During 1995-2002/3, the CPP funded 2-3 cycles of three year projects (over 20 projects) to develop management strategies and technologies for the most important fungal, insect pest, virus and weed constraints affecting cereals and legumes in small-holder systems in Eastern and Southern Africa, West Africa and India. The progress and outcomes of these projects are well-documented in the CPP Annual Reports of the same period. The projects carried out from 1996-2004 are summarized below.

a) Cereals (sorghum, finger millet, pearl millet)

PS	No. & Title	Country	Date	Comments
SA	R6581 Epidemiology of sorghum diseases	Kenya, Uganda, Tanzania	1996-1999	The demand for reduction of sorghum losses caused by covered kernel smut (*Sphacelotheca sorghi*) in Tanzania and Kenya was identified through use of CKS free sorghum heads for seed of subsequent crops and removal of this material from the field prior to the main harvesting operation - as potential low-cost sustainable control measures. Management of disease will result in more productive plants and potentially more stover for animal fodder.
	R7518 An investigation into the epidemiology and control of fungal pathogens of sorghum in semi-arid production systems in East Africa (with emphasis on smut)	Kenya, Uganda, Tanzania	1999-2002	Project activities focussed on evaluation of strategies to ensure availability of disease-free seed by reduction of seed-borne inoculum on farmers' seed stocks**.** In Kenya, the economics of seed treatment was improved through ratooning of crops. In Tanzania, broadening the cropping base to include cassava should improve household food security, which will enable the farmers to save clean seed from one cropping season to the next. Promotion was achieved through farmer groups and school events. Such control interventions may also contribute to increasing sorghum crop residue production which may be fed to animals in such systems.
	R7506 Review of the technical and institutional options for sorghum grain mould management and the potential impact on the poor	India	1999-2000	The short project produced a Pictorial Guide for the Identification of Grain Mould Fungi. In consultation with key stakeholders including grain traders and the private sector, the project also developed a grain mould research strategy addressing the most important operational, institutional and technical elements likely to best help resource-poor farmers. The important role that the private sector can play in developing markets was recognised.
	R8030 Management of finger millet blast	Uganda, Kenya	2001-2004	In the semi-arid tropics of East Africa, finger millet is not only important in the diets and economy of subsistence farmers but is also increasingly demanded as processed flour and porridge by urban consumers. Stover may be used to feed

				animals. The project aims to characterize blast populations, investigate the potential of seed and weeds as inoculum sources, understand the relationships between different types of blast and identify resistance sources for improved disease management. DNA fingerprinting revealed limited diversity among blast pathogen populations and that leaf, neck and panicle blast were caused by the same strains. Molecular and biological tests showed the potential of blast populations for sexual reproduction and thus 'rapid host adaptation'. Blast isolates on weeds, particularly wild millet, were genetically similar to those on finger millet, with some being highly aggressive. Field work carried out has shown that seedborne inoculum can contribute to initial blast development. This knowledge provides a framework for sustainable utilisation of host resistance and disease intervention. Various germplasm lines and farmer variety accessions with low blast levels and good agronomic performance have been identified. Promotion of these improved varieties has potential to reduce farm level grain losses considerably. The government of Uganda has identified millet as one of the priority crops to improve the livelihoods of internally displaced people. The increased demand for finger millet in East Africa is stimulating the growth of a processing industry, as well as regional trade, especially from Uganda to Kenya. Management of disease will result in more productive plants and potentially more stover for animal fodder. Draught animals are important in these systems which include Teso. The project has established a strong working partnership among national, regional and international scientists and close linkages with the East and Central African Sorghum and Millet Network (ECARSAM, supported by EU), industry representatives and a number of farmer groups. These and other international activities provide excellent opportunities for wider linkages and uptake pathways for the development and promotion of improved finger millet production technologies that can make a real difference to the rural poor and subsistence farmers.
	R6693 The chemical ecology and mating behaviour of the millet pests, *Coniesta ignefusalis* and *Heliocheilus albipunctella* (taken forward under an ICRISAT-IFAD project)	West Africa	1996-1999	The project aimed to develop and promote improved methods for management of the two most important insect pests of millet in West Africa, the millet stemborer, *Coniesta ignefusalis*, and the millet head miner, *Heliocheilus albipunctella*, in order to determine the potential of pheromones and plant chemicals in management of these pests. Pearl millet stover is an important source of animal feed in the Sahelian region. Extensive field and laboratory studies on mating behaviour of *H. albipunctella* demonstrated conclusively that

				female moths are attracted to the male moths, mainly by sound. There is no evidence for any chemical attraction. Significant progress has been made in investigating the mechanisms of resistance in millet to *H. albipunctella* in terms of host selection for oviposition and success of larval development in different varieties. This data is still being analysed and the results will contribute to improved management of this pest which is recognised as a major constraint on growing of millet in the Region. Management of pest will result in more productive plants and potentially more stover for animal fodder.
	R7572 IPM of major sorghum pests	Kenya, Uganda	2000-2003	The project identified and tested on-farm appropriate technologies for control of stemborers, shootfly and sorghum midge in Western and Eastern Kenya. Shootfly and stem borers cause damage seedlings and plants while midge damages panicles. Control strategies tested included sowing dates, dry-season plot sanitation, intercropping and varietal resistance. Successful management of shootfly and stemborers will contribute to increased stover yields for livestock.
	R6654 Integrated control of Striga	Tanzania, Kenya, Uganda	1996-2000	The project developed and evaluated the control of *Striga* species in cereal based cropping systems in Tanzania through the integration of techniques appropriate to smallholder farmers through on-farm trials. The main approach was the selection of Striga tolerant varieties which was integrated with inter-cropping with cowpea and under-sowing with the green manure Crotalaria. Farmers were interested in the Striga-tolerant varieties and use of Crotalaria. Increased yields of sorghum grain will also mean increased yields of sorghum stover which is available for animal feed. Cowpea residues and Crotalaria can also be used as high quality animal feed.
	R6921 Improved methods for the management of *Striga*: nitrogen, tolerance, screening and cultural practice	Tanzania, Kenya	1997-2000	The project identified improved methods for the management of *Striga*: nitrogen, tolerance, screening and cultural practice; cultivars of maize and sorghum that perform well in the presence of *Striga* and the most appropriate time for nitrogen application. The project also identified useful traits and characteristics in cereals that will allow breeders to develop potentially useful cultivars and novel sources of resistance that can be used in the medium term to alleviate the impacts of *Striga*. Increased yields of sorghum and maize will also mean increased yields of stover for animal feed.
	R7564 Integrated management of Striga in sorghum-based systems East Africa	Tanzania, Kenya, Uganda	2000-2003	Striga and other major weeds can reduce sorghum yields by 80% increasing the vulnerability of the poor who have to cope with an environment characterized by frequent drought and declining soil fertility. In farmer-participatory trials, the project identified two Striga-tolerant varieties of sorghum. Both Hakika and

				Wahi mature early and have good drought tolerance, grain quality and taste and support lower numbers of Striga. They can produce 10-150% higher yields in Striga-infested soil. By selecting the most appropriate variety for their particular fields, small-holders can manage Striga. Striga tolerant maize varieties were also identified and rotation of upland rice with Crotalaria was the best strategy for managing Striga in the rice-based system. Increased yields of sorghum and maize grain will also mean increased yields of stover which is available for animal feed. The upland rice system could provide Crotalaria as animal feed,
	R7401 Improving production in the Teso farming systems through the development of sustainable draught animal technologies This project was extended especially for promotion of technologies in the cotton system	Uganda	1999-2002	The project identified technologies that make an impact on the incomes of poor households in Ugandan semi-arid farming systems by reducing the labour requirements and drudgery by women for weeding through more effective use of draught animals. This allowed expansion of the area cultivated, higher crop yields and gross returns and reduced drudgery for women. The cropping systems are based on sorghum, groundnuts and cotton. Successful weed management will result in more productive plants and potentially more stover for animal fodder. However, animals graze crop residues left in the field in the dry season. There is no control and hence no strategies for organized feeding of residues. This is probably leading to considerable wastage and possibly shortages in the dry season.
	R8281 Linking demand for and supply of agricultural information in Uganda	Uganda	2003-2005	The project aimed to improve access to and relevance of agricultural information, especially that generated from CPP and LPP projects, for small-holder farmers in Uganda which in turn would contribute to reduced pest damage, improved quality and yield of crops, and improved survival and productivity of livestock. However the potential contribution of increased quantities and quality of crop residues was not included.
	R6655 Moisture conservation through improved weed management in savannah cropping systems	Zimbabwe	1996-1999	The project was designed to undertake participatory on-farm evaluation of weed-management components of conservation tillage systems previously developed in on-station trials in Zimbabwe for maize-based cropping systems. Data were collected on inputs, crop performance, weed control, weed seed production and soil moisture availability as influenced by tillage/weed control. These trials were also used establish a set of criteria which farmers use to evaluate tillage, crop establishment and weed control. In terms of crop water use efficiency weeding at 2 weeks and then 6 weeks after crop emergence performed better than a single weeding at 4 weeks. The extent to which farmers are likely to adopt a particular method depends largely upon the farmer's perception of its' efficiency

				and on household resources. A fully costed analysis of the performance of combinations of three crop establishment and three weeding practices under farmer management based on data for the whole of 1998/99 season, was done using participatory partial budgeting. The outputs can be used by extension to better target promotion of improved weed control within the "tillage/crop establishment/weed control" package to farmers with differing access to resources. Management of disease and pest will result in more productive plants and potentially more stover for animal fodder.

b) Legumes (groundnut, pigeon pea, cowpea)

PS	No. & Title	Country	Date	Comments
SA	R6811 Groundnut rosette epidemiology	E & S Africa	1996-1999	This project assisted in the development of a range of improved resistant (vector and virus) cultivars which have agronomically acceptable characteristics (i.e. early maturing, high yield, acceptable seed size etc) for E & S African semi-arid systems. Resistant Serenut 2 was released in Uganda in 1999.
	R7445 Groundnut rosette management in the Teso system	Uganda	1999-2002	Early-maturing, agronomically and culturally acceptable groundnut varieties resistant to rosette developed through R6811 were evaluated on-farm in the Teso system. This was complemented by strategic work on vector resistance in ICG 12991 so that segregating lines with both virus and vector resistance can be readily detected. Efforts were made to develop a self-sustaining seed system. Two early-maturing, rosette resistant groundnut varieties: Serenut 4T and 3R were selected as the best varieties by farmers. Adoption will allow a considerable number of Teso farmers to increase their incomes through sale of excess seed. This has enabled farmers to purchase assets such as cows and bulls. The additional groundnut production could potentially provide high quality residues for livestock feed.
	R7452 Sterility mosaic virus biodiversity	India	1999-2002	Infection with sterility mosaic virus disease (SMVD) is a serious threat to pigeon pea production in India. Not only is pigeon pea a major source of protein for many millions of Indians but the leaves are an important source of animal feed. Early infection can cause 100% sterility and even late infection can cause 20-60% yield loss. The project generated knowledge that resulted in identifying the vector and the novel virus, the mode of transmission, and the biology of the virus in the field. In addition, it enabled selection and production of broad-based PSMD-resistant genotypes in breeding programs which will provide the basis

				for sustaining and stabilizing pigeonpea production (both grain and residue) and increasing the income to poor farmers, in the Indian subcontinent. Management of disease will result in more productive plants and potentially more stover for animal fodder.
	R7809 Aflatoxin management in groundnut	India	2000-2002	The project aimed to improve food security and health of poor people and livestock through improved availability of aflatoxin-free groundnut-based foods and feeds (groundnut cake). There is lack of awareness of the problem and health risks associated with aflatoxin contamination and thus no incentives to produce and market aflatoxin-free groundnut. Extensive sampling showed that a) >30% of pod samples from farmers fields and stores and from traders and millers stores has greater than permissible levels of aflatoxin with insect damaged pods having the highest levels; b) groundnut fodder samples were also contaminated and 35-55% of milk samples had greater than permissible aflatoxin levels; c) 100% of groundnut cake samples were contaminated as were cotton and soyabean cake. Improved management practices for Aspergillus reduced aflatoxin contamination but were not robust enough under severe drought. High moisture content in storage will increase contamination. Informed judgements were made of the most feasible and practical potential contamination reducing practices which were validated on farm. The project clearly showed the need to promote awareness of the problem among stakeholders. Enhanced management of disease will lead to reduced aflatoxin levels and safer stover and other product for animal fodder.
	R6659 Development of pheromone traps for cowpea pod borer	Benin	1996-1999	Components of the female sex pheromone of *M. vitrata* were identified and a three-component blend shown to attract male moths to traps in the field
	R7441 Development of pheromone trapping for monitoring and control of the legume podborer, *Maruca vitrata* by small-holder farmers in West Africa	Benin, Ghana	1999-2002	The legume podborer, *M. vitrata* is a pan-tropical pest of legumes, but lack of knowledge of its ecology has hindered development of IPM strategies appropriate for developing countries. Building on previous work, this project developed cheap and effective pheromone traps to optimise management of the legume podborer as part of IPM strategies and technologies in small-holder cowpea systems in Ghana and Benin. Significant progress was made with pheromone control integrated with botanical pesticides such as neem and reduced use of pesticides. Increased grain yields of cowpea should be associated with increased residue production, commonly used as animal feed in West Africa.

	R7247 Entomopathogenic viruses for control of the legume pod borer in W. Africa	Benin	1998-2000	A pathogenic cytoplasmic polyhedrosis virus (CPV) for *M. vitrata* was characterised. Production of a CPV is more costly than an NPV, primarily because yields are lower. In the laboratory, high mortality was induced at high doses. The use of CPV under natural conditions is normally chronic and this has important consequences for the eventual field use of the agent, requiring prior innovative approaches to understanding the virus/plant/insect system ecology. Commercial production of this virus is highly unlikely. Farmer/local community level production may be possible.
	R7267 Principal pod-boring pests of tropical legume crops: economic importance, taxonomy, natural enemies and control.	Pan tropical	1998-2002	Data on exact distribution, host-range and natural enemies of a guild of twelve lepidopterous pod-boring pests of a broad range of leguminous crops are required to develop their effective and sustainable control. Field surveys of legume pod borers were undertaken in the four main collaborating countries: Malawi, Niger, Brazil and India on cowpea, pigeonpea and field beans. A large complex of borers has been discovered, many of which constitute production constraints. Many natural enemies have been reared from known hosts, identified and photographed.

These projects generated a basket of crop protection technologies which together with technologies generated by breeding, soil fertility management, agronomy and marketing activities in the region were appropriately integrated from 2003 onwards to promote the best technologies to manage pests, diseases and weeds affecting cereals and legumes in Sub-Saharan Africa and India. These projects are summarized below.

PS	**No. & Title**	**Country**	**Date**	**Comments**
SA	R8349 Developing crop protection research promotional strategies for semi-arid East Africa	Kenya, Tanzania	2003-2005	The project aimed to improve user access to crop protection knowledge and products; develop cost-effective approaches for delivery of crop protection information to farmers; establish feedback mechanisms on demand for crop protection information to farmers; and develop effective M&E for deriving lessons to inform related policy implementation (see review report). In Eastern Kenya, the project is working in mixed crop-livestock systems which offers the opportunity for promoting the benefits from crop protection technologies (such as increased quantity and quality of crop residues) to livestock production in such mixed systems.
	R8428 Communication and research promotion strategies in East Africa	Kenya, Tanzania	2005-2006	Further work on developing appropriate methods of delivering CP outputs to farmers is needed followed by the analysis and documentation of lessons and

				policy implications learnt from processes developed by project partners. Monitoring and evaluation mechanisms at village, extension provider and project levels, need to be modified and lessons identified by stakeholders are being consolidated. The main outputs of the project are: 1. Agricultural communication and research promotional strategies to meet farmers crop protection needs for semi-arid parts of Tanzania and Kenya further developed, evaluated and validated. 2. Policy lessons and implications identified and availed to influence the formulation and implementation of national agricultural research and extension policies and strategies for Kenya (KAPP) and Tanzania (ASDP). Links will be made to the KAPP and ASDP projects, optimising opportunities to influence policy and ensure sustainability beyond the end of the project. Added value can be summarised as follows:- Development of M&E methods and capacity, Policy influencing opportunities enhanced, Deepen lesson learning in relation to communication strategies, access to knowledge and products, dissemination methods/pathway cost-effectiveness, feedback mechanisms, "reach" and targeting (in relation to wealth and gender), sustainability of dissemination mechanisms, farmer preferences for receiving CP information, Expand opportunities to bring in other agricultural research outputs, exposing the selected uptake pathways to a wider range of technologies and responding to farmer demands made during the first season, Repeat dissemination pathway pilots for a second season, to firm up the results and lessons from the first seasons and enable M&E further down the impact chain for both seasons, and Enable sharing of approaches and lessons between sites, building up enthusiasm for further lesson learning and enabling testing of a wider range of novel methods and strategies for communication and also for monitoring and evaluation.
	R8194 on-farm verification and promotion of green manure for enhancing upland rice productivity on Striga infested fields in Tanzania	Tanzania	2002-2005	The project is building on previous work using the green manure Crotalaria in R7564 to improve soil fertility and rice vigour while suppressing Striga. Enhanced rice vigour could result in greater yields of stover which could be fed to animals while Crotalaria could also be used as an animal feed.
	R8445 Facilitating the promotion of improved and blast resistant finger millet varieties to enhance production	Kenya Uganda	2005-2006	The short project will concentrate on demonstrating the potential of improved and blast resistant finger millet varieties and promoting the best; enhancing farmer community awareness about blast problems and management issues enhanced through direct interaction and wider dissemination through

				leaflet/pamphlet distribution; and fostering connectivity between finger millet production - supply chain and R & D/E workers – farmers – industry continuum through a regional workshop and distribution of workshop proceedings to R & D/ E organisations, policy makers and donors. The possible development of coalitions of researchers, farmers and industry will potentially facilitate increased production of higher quality finger millet and products and will also make a positive contribution to the animals in these systems that rely on finger millet stover as fodder.
	R8105 Farmer-led seed multiplication and promotion of rosette resistant groundnut varieties for eastern Uganda	Uganda	2002-2005	The project aims to train farmer groups in groundnut seed production; multiply foundation seed of new early-maturing, rosette-resistant varieties (Serenut 2, 3 and 4) for 200 acres of production; generate sufficient seed to plant 2500 ha – 17,000 farmers growing improved varieties; and hand over the system to local leadership and management. The widespread promotion of disease and vector resistant, early-maturing and farmer-preferred groundnut varieties and the establishment of a sustainable seed system will increase production of both quality grain and haulms, the latter could be of great use as livestock feed.
	R8442 Commercial incentives for sustainable groundnut production	Uganda	2005-2006	Foundation seed of new rosette resistant groundnut varieties Serenut 3 and 4 will be procured and multiplied by farmer groups. The new groups benefiting from the seed need will be trained. To reinforce the training printed reading material will be required for reference by community trainers and also the beneficiaries. New training manuals for post harvest handling/quality control and marketing will be prepared in collaboration with SACRED and ILO and distributed. Management of multiplication and redistribution will be handed over to the local community leadership in 16 new sub-counties. The necessary structures i.e. Parish development committees and group production committees will build capacity to function. These local leaders will be responsible for overseeing repayment of seed, redistribution to the right beneficiaries according to the agreed distribution plans (considering the “poor but able” and female headed households as a priority) and record keeping. Training forms the foundation for effective and proper multiplication and distribution management. The community leaders will be trained in seed production and record keeping and will then be required to train other beneficiaries under the supervision of the extension staff. Market linkages will be established: groups will also be trained in collective

				marketing and negotiation skills to enable them to sell off the excess produce more profitably. Groups will be linked to regular sources of market information. Discussion is already underway on the need to assist the farmer groups to form themselves into a larger umbrella marketing organization. Groups will thus be assisted to initiate linkages to potential national and regional markets and to establish marketing centers where the production can be bulked and graded.
	R8205 Pigeon pea IPM promotion	India	2002-2004	The knowledge generate by FCR 7452 on the virus and vector allowed the development of refined screening methods to select for broad-based resistance. Two resistant varieties ICP7035 and ICP96058 performed well and have potential to mitigate losses due to SMD at no extra cost to the farmer. Village seed programmes have been established. The varieties are being promoted in collaboration with DFID KAWAD project and the commercial company Mahyco. The residues could be of great use as livestock feed.
	R8481 Building on strengths towards sustainable management of sterility mosaic disease for enhanced pigeonpea production in the Indian Subcontinent	India,	2005-2006	Development of short to medium duration (100-150 days) SMD resistant varieties to mitigate losses against the disease and terminal moisture stress, evaluation of pigeonpea core collection: the promising genotypes will be further promoted for farmer cultivation by on-farm testing and through state and national varietal programmes, and up-scaling on-farm SMD-mitigating technologies*:* seed-village programmes will be increased from 2 to 5, for sustainability of seed production of improved disease resistant varieties. These efforts would enhance farmers' capacity in sustainable management of diseases and pests and provide increased remuneration at no additional costs as the end products are seed-based they are simple to disseminate and sustainable and easily adoptable by farmers. Farmers with livestock will benefit from increased fodder.
	R8298 Aflatoxin management in groundnut in Southern India: raising awareness and transferring and disseminating technologies to reduce afaltoxin	India	2003-2005	Participatory varietal selection with high yielding, early maturing and aflatoxin resistant cultivars was scaled up. Several varieties substantially out-yielded TMV2 and were preferred by farmers. Low-cost technologies such as use of compost, gypsum and biocontrol agents were evaluated and post-harvest practices that reduce contamination of residues such as nut stripping were tested. Awareness of aflatoxin and aflatoxin reducing strategies was promoted among farmers, traders, millers and NGOs. The successful promotion of these varieties, technologies and awareness is likely to substantially reduce afaltoxin contamination of nuts and residues to the benefit of safer food and feed and the health of consumers and animals.

	R8483 Safer and better groundnut production for southern India	India	2005-2006	The new project will: Increase access to new aflatoxin resistant/improved cvs via PVS process. Access to improved cvs will be beneficial to long-term health, particularly among poor who are most likely to consume contaminated groundnut. Livelihoods will also be improved by access to higher yielding cvs and/or better quality cvs that command a higher price from oil millers or the market. Beneficiaries: farmers, millers/processors, consumers, and livestock. Increase awareness aflatoxin reducing technologies and improved production practices, and greater access to information about subsidies and markets via PVS process & Panel initiated dissemination. Any technology that raises yield is likely to beneficially reduce contamination, as well as improving the livelihood of farmers. For example, through the Panel NGOs, farmers and processors can be made aware of the various subsidies available to improve production and processing, of technologies to measure aflatoxin etc. In addition, through the wide representation on the Panel, integrated solutions and packages can be devised by all stakeholders in production, processing and marketing, and government Departments and Directorates made aware of the need for these. Beneficiaries: SHGs, farmers and millers/processors in AP Increase awareness of aflatoxin as health issue in all sectors via Panel activities. Building and supporting Panel activities will help reach a much larger group of stakeholders outside those involved in primary production and processing. This will contribute to the creation of a demand for aflatoxin-free produce. Radio programmes in Telegu will also build awareness of the dangers of aflatoxing by reaching many people. Beneficiaries include medical, nutritional and veterinary staff and institutions, groundnut exporters, poultry and dairy industries, rural and urban consumers. A process is being developed to establish an aflatoxin screening lab in the main groundnut growing area in AP.
	R8300 Promotion of pheromone traps and other technologies to control cowpea podborer in West Africa	Benin, Ghana	2003-2005	The project worked with farmers, NGOs and the private sector to commercialise pheromone traps and promoted a package combining traps with botanical pesticides through farmer field schools. Successful promotion of these technologies to cereal-cowpea mixed rainfed systems in West Africa should contribute to increased production of quality cowpea residues to the benefit of cattle and small ruminants in these systems.

Annex 4c Analysis of LPP, CPHP and FRP projects

Crop-livestock farmers

PS	No. & Title	Country	Dates	Comments
SA1	R6609. Matching feed energy resources to animal power requirements in SA crop-livestock systems to develop feeding strategies for work animals	South Africa	1996-1999	Recommended feeding strategies for smallholder work oxen to improve their effectiveness have been published and validated. A greater understanding of farming practices and constraints in relation to draught animal husbandry and farm power in the eastern Cape Province has been obtained.
FA1	R6283. Implications of livestock feeding management for long term soil fertility in smallholder mixed farming systems	Nepal	1995-1998	Development of simulation model (ANORAC-allocation of nitrogen in organic resources to animals and crops). The model allows the effects of different feeding strategies on manure quality and N release from incorporated manure to be evaluated. Trials showed a high degree of variation in manure quality through dietary manipulation of the level and form of protein supplements. The dynamics of N mineralization is affected by the provenance of manure. Faster mineralization occurs of manure from animals fed legumes than from poultry manure. The implications for manure application strategies are reported.
SA1	R6299. Intake of poor quality roughages and the effect of feeding forage mixtures	Global	1995-1998	Development of a new technique involving the measurement of short term intake rate (STIR) which shows potential to predict *in vivo* parameters and rank feeds in terms of intake, digestibility and rate of passage. Trials showed that intake responses to supplementation depend on the cell-wall content of the supplement and the quality of the basal forage. Interactions observed between length of chopped forage and supplementation.
FA1	R6319. Strategies for allocation of seasonally varying feed resources to optimise livestock productivity	Nepal	1995-1996	Seasonal patterns in feed supply and nutrient demands from mixed species herds, and the approaches of farmers to prioritising feed allocations in smallholder systems in eastern Nepal were identified. Biological relationships that link feed supply with animal performance in mixed farming systems were quantified. Data used for modelling in R5183.
HP1	R6339. Production of legume fodders by mixed cropping with rice and their supplementation with straw-based rations for cattle in rural areas	Bangladesh	1995-1999	Dairy production is the main option for poor, small-scale farmers, but milk production is low and the main problem is a shortage of feed. *Lathyrus sativus* and *Sesbania rostrata* were identified as low-cost green fodders to supplement poor quality rice straw. Legumes planted as intercrops/relay crops with T aman rice and boro rice. No disturbance to rice production system.
	R6610. Introduction of fodder legumes into rice-	Bangladesh	1999-2004	1-1.5kg/day of green fodder supplement increased milk yields by >20% ; rice

	based cropping systems and their use as supplements in straw-based rations for dairy cattle in Bangladesh			yields increased by 8-14% due to the legumes; economic analysis showed that farm gross margins significantly increased as a result of growing/feeding the legumes. *Lathyrus* hay produced manually by box-baling, and urea-molasses blocks were fed at low cost. Field demonstrations were the most effective method of extension and created great farmer interest.
HP1	R6775. Evaluation and improvement of feeding strategies for optimising feed intake in crop-livestock systems	Kenya	1996-2000	Farmers have options to grow maize at higher plant densities for feeding the thinnings, as well as using leaf strippings, green stover, dry stover and the whole crop in the event of grain failure. Farm trials showed that increasing seed density to allow for fodder production increased the quantity of thinnings by 48-166%. Even at the lowest thinning rate of 1.45t/ha, a farm with 0.17ha maize (average for the project area) could produce enough thinnings to keep a typical cow of 350kg for 19-66 days. Economic analysis based on extra fertiliser use showed a positive return. Inclusion of green maize or maize stover with other forages in a planned diet for ruminant livestock enabled farmers to maintain their stock through difficult times on small land areas and spread the feed resources over a longer period of time. Reduced need to purchase off-farm fodder, especially in the dry season.
SA1	R6781. Crop-livestock interaction: the dynamics of intensification in contrasting agro-ecologies	Zimbabwe Ethiopia Malawi	1997-2000	The project identified the range of crop-livestock intensification patterns and how they have evolved over the past 50-100 years, and generated a set of criteria for the identification of appropriate development pathways; the project provided a framework for use in future crop-livestock development projects with reference to fertility transfers through manure and the use of crop residues. Research suggested that **a technology-focused approach may be insufficient and greater attention needs to be paid to institutional contexts.**
SA2	R7401. Improving production in the Teso Farming System through the development of sustainable draught animal technologies	Uganda	1999-2004	The project concentrated on sorghum and groundnut. Draught animals graze crop residues. Crop losses due to weeds can range from 40-80%. Confirmed the positive impact of weeding using draught animals on income generation and reduced drudgery for women/children, who do most of the hand weeding. The project extended the technology further to other households and developed links between farmers and manufacturers of weeding equipment.
FA1	R7637. Integrating indigenous and biological knowledge to implement improved dry season feeding strategies on farms in the hills of Nepal	Nepal	2000-2004	Crop production dependent on livestock for manure and draught power. Cereals (rice, maize, millets, wheat), pulses and vegetables grown in mixed farming systems. Wide range of grasses, tree fodder, broad-leaved herbs, green/dry crop residues (including vegetables) fed. Dry season feed shortages a problem and access to tree fodder in forests and communal areas increasingly limited. The

				project aimed to improve year-round stability of fodder supplies and, therefore, food security. Biological basis of indigenous knowledge of farmers on tree fodder confirmed; farmer knowledge incorporated into a decision-support tool produced for extension personnel, NGOs and farmers that was developed for improved utilisation of fodder trees by ruminants, and the prediction of impact of feeding diets of different composition.

Smallholder milk producers

PS	No. & Title	Country	Dates	Comments
HP1	R6282. Development of practical dairy feed rationing system appropriate for use in developing countries	Bolivia Kenya Nepal Brazil	1995-1999	A key constraint to further development of small-scale dairy production is a lack of access to reliable information on appropriate feeding strategies. The capacity of the extension services to support the planning of effective feeding and management is limited. Existing extension literature is not readily accessible to extension staff. The project produced a user-friendly computer software package for dairy cattle feed rationing (DRASTIC). The programme was developed based on composition/efficient use of local feeds, nutrient requirements of local dairy animals and expected/predicted milk yields. Used by technical-support staff in the extension service, dairy co-operatives and dairy development projects. It allows staff to provide effective decision-making support (i.e. correct feeding advice) to smallholders based on the actual quality of feeds available to farmers. Testing in Bolivia/Tanzania has shown a high accuracy level. This project progressed into projects R7431 & R7855 (Talking Pictures).
HP1	R5732. Resource and on-farm evaluation of agroforestry livestock feeding systems **(joint FRP x LPP x NRSP)** Subsequent projects funded by the FRP including R6176, R6535 and R6549	Kenya Kenya, Uganda, Rwanda, Ethiopia, Tanzania	1993-1996 1996-2005	Abundant niches on small dairy farms for the establishment of fodder trees. Scattered trees in croplands (densities <625 trees/ha) cause only slight reductions in maize yields and is offset by the value of the fodder. Using Calliandra as a protein supplement for dairy cows fed a basal ration of Napier grass or maize stover, trials showed that 3kg fresh leaf had the same effect on milk yields as 1kg of additional dairy concentrate and, at normal production levels, the effects of the two supplements were additive. Calliandra increased butterfat content by about 10%. The average small farm can produce enough Calliandra fodder from under-utilised niches, such as fence lines and conservation bunds, to supplement two dairy cows and some small stock without affecting crop production.

HP1	R7431 Talking pictures	Tanzania	1999-2000	A new, generic, dynamic pictorial guide for evaluating the impact of feed management decisions in smallholder dairy systems developed. Use of scientific information on dairy nutrition packaged by the dairy rationing software package (DRASTIC-R6282).The guide is applicable for different production systems and locations, and easily applied by farmers themselves to the analysis and solutions of their own problems.
HP1	R7855. Analysis, management and decision support for farmers feeding strategies: Talking pictures II	Tanzania India	2000-2004	In Tanzania, farmers using the approach increased milk off-take compared to controls, augmenting milk-derived income by as much as 25%. The tool is widely accepted by farmers. More than 90% of the original "tester" farmers are still using the methodology, and its application is spreading amongst target farmers. Scaling-up activities in four Indian states. Acceptability high. Used to provide indications of pre-clinical mastitis. Also used to increase the efficiency of supplement use in late lactation, improving profit margins.
HP1	R6619. Husbandry strategies for improving the sustainable utilization of forages to increase profitable milk production from cows and goats on small-holder farms	Tanzania	1996-1999	Farmer to farmer learning/evaluation permitted the transfer of potentially-beneficial technology from one group to others. Simple, applied technologies such as manual box-baling of maize stover showed real economic benefits. This was allied with striping the most digestible portions of maize stover prior to baling. The same technology was applied to roadside harvested grass fodder (links to R6776). The cost of transported forage was reduced by >50%.
HP1	R7955. Strategies for feeding smallholder dairy cattle in intensive forage production systems and implications for integrated pest management **(joint LPP x CPP)**	Kenya	2001-2004	Project considered integrated pest management of maize and Napier grass to improve forage availability and quality. New varieties of maize were identified by farmers as resistant to Maize Streak Virus, a major constraint. Adoption of these varieties will increase milk production. Management of Napier grass smut by passage through the animal and composting for >3 months. Researcher-managed on-farm trials showed that forage yields from maize thinnings increased by about 100% if weeds controlled.
SA1	R7010. Production of high quality silage from adapted forage and legume crops for the maintenance of diary cow productivity on smallholder farms through the dry season in SA Zimbabwe	Zimbabwe	1997-2002	Bag silage technology, based on hand-cut drought-adapted forage (sorghum, Pennisetum hybrids and legume intercrops), developed with improved silage yields. Provided sufficient nutrition to maintain milk yields through the dry season. Income over feed costs doubled and reduced female labour requirements in the dry season. Technology being actively promoted by government dairy development programme and extension service. NGOs interested. Milk processing plant built to receive milk from local farmer cooperatives.

HP1	R7859. Improvement of the quality and availability of crop residues to better rural livelihoods in Bangladesh	Bangladesh	2001	Identification of constraints to the production and storage of safe and nutritious feed together with a variety of options for overcoming those constraints.
SA1	R6993. Effects of harvest and post-harvest practices on the production and nutritive value of maize and sorghum residues in Zimbabwe	Zimbabwe	1997-2002	Use of thatched-roof stores for improving the nutritive value and reducing aflatoxin contamination of crop residues. Results inconclusive and failed to establish any consistent pattern of degradation over time in stored stover, or any consistent differences between traditional and improved stores.
PU1	R7346. Evaluation of the effects of plant diseases on yield and nutritive value of crop residues used in peri-urban dairy production on the Deccan Plateau, India **(joint CPP x LPP)**	India	1999-2002	The project confirmed the effects of a range of foliage diseases of sorghum and groundnut in significantly reducing yield and quality of crop residues. Crop residue sales account for 50% of the income generated from cropping, but diseased crop residues demand lower prices in fodder markets. Implications for milk production as voluntary intake in buffalo and cattle appreciably reduced when animals fed diseased fodder.
	R8339. Plant diseases and crop resdues on the Deccan Plateau **(joint CPP x LPP)**	India	2003-2005	New disease-resistant cultivars of sorghum/groundnut and pest management technology being disseminated widely. Village-based seed multiplication emphasised for groundnut.
PU1	R7321. Improving the market mechanisms, processing and market efficiency and reducing public health risks in developing peri-urban smallholder dairy systems	Ghana Tanzania	1999-2001	Project investigated three major areas. Marketing, profits, economic efficiency; threats to public health from milk products; and processing of indigenous products. Problems identified and quantified, and training materials and policy options developed to help deal with them. Welfare of farmers and consumers improved. Technology developed and promoted for improving dairy product quality for consumers and increasing opportunities for improving the livelihoods of small-scale market agents.
HP1	R7459. Development of seasonal nutrition and resource management strategies for smallholder dairy systems	Kenya Bolivia	2000-2004	Identification of best-bet feeding and resource management interventions. Used to develop a general crop-livestock system model to enable *ex-ante* impact assessment of potential interventions. The project also aimed to examine strategies for optimal use of on-farm feed resources, to assess on-farm trade offs in their use and **to develop methodologies that could be used trans-regionally for analysis of tropical small-holder dairy systems.** In Kenya, model developed based on existing data-sets for smallholder dairy systems. In Bolivia, poverty maps developed which allowed precise identification of target groups and an understanding of the main constraints. Novel participatory methods used in community workshops, and farmer groups themselves selected case-study farms for monitoring. Farmer visits organised, as an information-exchange

				mechanism, on interventions such as feeding and manuring. Marketing studies indicated that options exist for poor smallholder dairy farmers to integrate into current markets and improve livelihoods.
FA1	R7820 Analysis and implementation of pro-poor uptake pathways: concerted action on livestock and livelihoods	Bolivia, Mexico Peru	2000-2004	The project mainly focuses on finding solutions to organizational and institutional constraints that limit the development of functional pro-poor uptake pathways for technologies that will help small farmers. Actions suggested to strengthen the knowledge systems and local organisations included regular attendance of project field staff at community meetings; creation of formal community organisations where absent; representation of community leaders in municipality meetings and contact with local/regional development projects; provision of training materials to local schools; training of animal health workers; establishment of community credit/savings systems; and scientific support in identifying problems and analyses of data/samples from pasture/animal health trials.

Smallstock keepers

PS	No. & Title	Country	Date	Comments
HP1	R5179. Use of sweet potato tuber and cassava root meals for poultry production: Adaptive research on cereal-free ration development and transfer to small-scale farmers in the Western Highlands of Cameroon	Cameroon	1992-1997	Results applicable to intensive production on mixed farms and commercial operations in peri-urban areas where poultry kept in confinement. Commercial rations use up to 70% imported maize. Opportunities to replace maize with root crops. Under-utilisation of sweet potato in the highlands and spare capacity to expand production further. Root crops processed into grits. On-station feeding trials with broilers showed that rations, in which maize was replaced by root crops, compared favourably with the maize-based control rations. Promising results obtained with egg production. On-farm trials with broilers showed significant savings in feed costs by replacing maize with root crops.
PU1	R7524. The use of oilseed cake from small-scale processing operations for inclusion in rations for peri-urban poultry and small ruminant production	Zimbabwe	1999-2003	Sunflower widely grown as cash crop. Government-supplied small-scale oilseed processing equipment has resulted in the availability of a by-product, sunflower seed cake, with potential for use in poultry feeds. On-station trials showed that sunflower seed cake can be used to replace commercial feed concentrates by up to 50% without significantly affecting broiler growth/feed intake. Replacement with sunflower seed cake reduced feed costs and increased profitability. Results replicated in on-farm trials. The high fibre fraction was used for feeding goats and draught animals; the process has stimulated increased planting of sunflower.

PU1	R7631. Strategies to strengthen bird productivity and business decision making in peri-urban smallholder poultry flocks	Ghana	2000-2003	Systems characterised by high production costs (mostly commercial feed), high chick mortality from Newcastle Disease, and the inability of farmers to target lucrative marketing channels (caterers/supermarkets). Need for smallholders to improve technical knowledge and business/marketing skills. Strategies giving greater flexibility in use of local feed resources and simple, but appropriate, business management techniques were developed and disseminated. Feed formulation handbook produced; least-cost maize diets for layers/broilers developed that produced similar outputs to commercial formulations, but with 10% lower costs.
PU1	R8267. Exploring marketing opportunities through a research, industry and users coalition: sorghum poultry feed **(joint LPP x CPHP)**	India	2003-2004	Poor, small-scale sorghum producers need improved technical knowledge and innovative institutional arrangements linking them to industry in order to increase productivity and incomes. Marketing opportunities were created for small-scale sorghum producers by developing sustainable economic linkages in the sorghum-poultry feed chain through innovative coalitions of researchers, farmers, poultry producers and the feed industry. Improved sorghum cultivars replaced maize in rations by 100% with no effect on poultry productivity, but with significant benefits to the costs of feed manufacturers. Farmers realised the importance of negotiating as a group and the benefits of collective marketing. **Lessons learnt are applicable to smallstock keepers in sub-Saharan Africa.**

Global public goods

PS	No. & Title	Country	Date	Comments
SA1	R8108. Strengthening the contribution of women to household livelihood through improved livestock production interventions and strategies in the Teso farming system	Uganda	2001-2004	50-70% of female labour into livestock activities. System is agro-pastoralism, with livestock contributing significantly through provision of draught power. Existing livestock production policies unfavourable to women. Government re-stocking scheme which could be an entry-point for women into livestock production, but only 42% of women aware of scheme. Project aims to create awareness amongst women participating in livestock production on policies affecting them and on new technology availability. Participatory involvement in policy analysis through group discussions and seminars using collated information. Stakeholder workshops held to discuss policy issues between policy makers and women.
SA1	R6781. Crop-livestock interaction: the dynamics of intensification in contrasting agro-ecologies	Zimbabwe Ethiopia	1997-2000	The project identified the range of crop-livestock intensification patterns and how they have evolved in the past 50-100 years, and generated a set of criteria

		Malawi		for the identification of appropriate development pathways. The project provided a framework for use in future crop-livestock development projects, with reference to fertility transfers through manure and the use of crop residues.
HP1	R6776. Evaluation of farmer participatory approaches to livestock production research	Kenya Tanzania	1996-2000	Documented experiences of participatory livestock research in case studies and an issues paper; emphasized the need for effective linkages and networking; addressed problems of meeting institutionally-enforced scientific objectives while addressing real world problems.

General relevance

PS	No. & Title	Country	Date	Comments
Global	R7425. Development, validation and promotion of appropriate extension messages and dissemination pathways	Kenya	1999-2001	Development of more sustainable long-term approaches to information provision to meet the requirements of appropriate communities, including primary schools, church groups and female groups. The Wambui comic books were one output of the project. Children act as effective extension agents and as a bridge between printed material and illiterate parents. Churches are especially effective for technical knowledge transfer as they are trusted in the community. Female groups had poor reach, were very small and were difficult to use as dissemination points.
HP1	ZC0205. Improving information and communication for small-holder farmers	Kenya	2003-2004	The project developed and tested pro-poor mechanisms of communication to improve information flows between farmers and between farmers, researchers and extension personnel.
Global	ZC0243. Development of a toolbox on small stock	Global	2003-2004	Development of a searchable toolbox for use by messenger groups to give advice to smallstock keepers.
Global	ZC0249. Development and production of radio soap and magazine programmes in Tanzania to communicate livestock health and production information	Tanzania	2002-2004	Promotion of sustainable messages aimed at resource poor farmers to raise awareness on new approaches that will impact positively on livelihoods.

Analysis of CPHP projects

PS	No. & Title	Country	Date	Comments
HP1	R8273. Marketing survey of the sweet potato sub-sector in Central Uganda	Uganda	2003	Important smallholder crop for human/animal nutrition. Market size for animal feed estimated at >100t dried chips/month. Market for animal feed does not demand high quality of tubers and enjoys price stability. Likely to expand in future. Chances for small-scale producers to succeed in this market higher than in fresh/export market. Main constraint is lack of planting material as market is variety specific. Market preference for orange-fleshed roots. Insufficient production currently to meet market demands in animal sub-sector. Other constraints include pests/diseases.
HP1	R6506. Development and orientation of cassava chip production in relation to national and international markets for food consumption and animal feed in Ghana	Ghana	1996-1999	Potential demand for cassava in poultry feed sector is 58,000t, assuming 50% maize replacement. Cassava chipped into spaghetti-like pieces. Low international prices for cassava led to focus on domestic market. Work with farmer groups involved in broiler production showed that replacement of maize with cassava resulted in very competitive growth rates when a 10% advantage in overall ration cost was taken into account. Addition of cassava to the ration of layers gave a 5% saving in feed costs compared to conventional rations. Trials with pigs showed that cassava-based rations gave 30% better growth rates than conventional rations.

Annex 4d. Analysis of CPP x LPP peri-urban projects

Only two project series specifically studied the effect of plant diseases on the stover or feed component of a crop and assessed the potential impact on animal production. R7955 Strategies for feeding small-holder dairy cattle in intensive maize forage production systems and implications for IPM is reviewed under Appendices 1 & 3. The other project series was carried out by joint CPP x LPP funding in the PU production system in India: R7346 Evaluation of the effects of plant diseases on the yield and nutritive value of crop residues used for peri-urban dairy production on the Deccan Plateau in India (1999-2002) followed by R8339 Evaluation of the effects of plant diseases on the yield and nutritive value of crop residues used for peri-urban dairy production on the Deccan Plateau in India (2003-2005) and a short promotional phase R8450. The progress and outcomes of these projects are well-documented in the CPP Annual Reports of the same period.

PS	No. & Title	Country	Date	Comments
PU	R7346 Evaluation of the effects of plant diseases on the yield and nutritive value of crop residues used for peri-urban dairy production on the Deccan Plateau in India	India	1999-2002	Sorghum/groundnut crop residues are used widely in India for feeding dairy buffalo/cattle. During the growing season, these crops are attacked by plant diseases that substantially reduce grain yields but no previous studies have assessed their effects on the quantity and nutritive value of the residues. This joint CPP and LPP project showed that foliar diseases substantially reduced yields and nutritive value of sorghum/groundnut residues, potentially resulting in reductions in milk production. PRAs indicated that diseased residues can cause health problems in animals (e.g. diarrhea). Fodder market surveys showed that plant diseases were one of the most important determinants of the sale price for sorghum residues, with diseased residues commanding a much lower price. Groundnut haulm is not traded in fodder markets but is traded among farmers. Sales of crop residues by farmers to peri-urban milk producers account for 50% of the income from cropping in rural areas. For example, groundnut accounts for >50% of dry fodder used and >25% of that produced may be traded within the village. About 80% of paddy straw and 50% of sorghum straw fed to animals are purchased from distant places. In sorghum, genotype (rather than agronomic factors) has the greatest effect on the management of foliar diseases to increase grain/residue yields. In groundnut, improved genotype (disease resistance) and strategic spraying of non-resistant local cultivars are the most appropriate management approaches. In buffalo, dry matter intake (DMI) of diseased sorghum residues was 8% lower than that of healthy sorghum residues. However, in groundnut, DMI of diseased haulms was 32% lower than that of healthy residues. In cattle, losses in DMI were 10% and 31% for sorghum and groundnut,

				respectively. In buffalo, losses in dry matter digestibility (DMD) for diseased sorghum and groundnut residues were 9% and 14%, respectively. In cattle, comparable values were 9% and 13% for sorghum and groundnut, respectively. Haulms obtained from disease-resistant groundnut cultivars, grown under high disease pressure, showed a very high *in vitro* digestibility of 11%. There was a positive correlation between digestibility and pod/haulm yield. There are implications for milk production/quality and income generation. PRA studies indicated that foliar diseases of groundnuts were perceived by farmers to affect animal health/milk yields when diseased residues were fed to ruminants. As a consequence of this and complementary work, new sorghum/groundnut varieties have been developed combining disease resistance and higher nutritive value. These varieties are being distributed to farmers. As seed cost is the single most expensive input accounting for 35% of total input cost, farmers will need to be convinced that the new varieties are better.
PU	R8339 Evaluation of the effects of plant diseases on the yield and nutritive value of crop residues used for peri-urban dairy production on the Deccan Plateau in India	India	2003-2005	Dual-purpose sorghum/groundnut varieties combining disease resistance and higher nutritive value have been developed. Improved groundnut varieties have higher grain and haulm yields. This joint CPP-LPP project is facilitating the distribution of improved varieties to farmers. Village level seed multiplication systems are being strengthened. Area under new cultivars is 3000 ha. Farmers rated the palatability of improved groundnut varieties as superior to local varieties. Consistent anecdotal evidence shows that feeding of haulms of improved varieties results in better milk yield and animal health. Feeding trials on farm showed that milk yields per animal were higher by about 0.44 kg/day for animals fed on the improved groundnut varieties. Net returns to farmers as a result of using improved groundnut varieties were 25-29% higher under both irrigated and rainfed conditions. Sales of crop residues to peri-urban and urban dairy produces account for up to 50% of the income from cropping. Farmers on an average sell 78% of the milk produced through formal and informal sources. Household income from milk is about 15-25% of the total income. Fodder market analysis indicated that sorghum stover quality and price are positively correlated in fodder trading. The interventions developed through R7346 and R8339 will contribute to increased milk production and income generation based on increased quantity and quality (higher nutritive value) of crop residues fed to livestock. In addition, promotion of improved varieties of groundnut resistant to foliar diseases could contribute to reduced mycotoxin contamination.

	R8450 Promotion of farmers participatory management of groundnut diseases for higher yield and nutritive value of crop residues (haulm) used for peri-urban dairy production on the Deccan Plateau in India	India	2005-2006	Village level seed systems for multiplication of improved groundnut cultivars will be established and up-scaled through farmers self help groups and NGOs . Partners from the above organisations will be trained both in seed production and disease management. Concurrently, community–based seed delivery systems will be further developed and put into place in the targeted villages. Farmers and their associations will be trained in quality seed multiplication (including integrated crop, disease and pest management practices) and proper storage practices. The optimised seed and management technologies will be validated, demonstrated, and popularised amongst farming communities through a variety of diffusion methods. 18,570 ha will have seeds of dual purpose improved management responsive varieties of groundnut for the 2006 rainy season. At this level of adoption, more than 10% of the 800,000 ha groundnut area in the district of Anantapur in Andhra Pradesh, India will be under improved cultivars of groundnut by 2010. It is also expected that this component of seed based technology will have spill over effects in the neighbouring states of Karnataka and Tamil Nadu. Improved crop and foliar disease management practices will be up-scaled, and new practises of growing groundnut in combination with sorghum will be demonstrated and implemented. Fodder resources will be further enhanced not only through through higher yields of better quality groundnut haulms but also with intercropped and/or borderline cropped dual-purpose sorghum (ICSV 700). Samples of groundnut pods attached to the haulms after harvest and threshing will be collected and estimated for aflatoxin contamination. Finally opportunities and constraints for introducing new approaches of disease management and improving fodder resources will be evaluated. Presently, dairy farmers are purchasing cereal fodder from long distances. The emphasis of this activity will be to identify technological, socio-economic and institutional constraints that prevent farmers from growing alternative cereal crops in the groundnut plots that would provide additional fodder versus buying fodder from long distances. Loss in income due to non-adoption of improved cultivars and gains in per unit production costs due to adoption of improved cultivars will be estimated. Impact assessment indicators (besides income) will be developed to assess the over all impact due to adoption of improved groundnut cultivars, and village seed multiplication system.

APPENDIX 4e. Analysis of PSRP projects

PS	No. & Title	Country	Dates	Comments
SA	R7069 Increasing pearl millet production through improved use of grain legumes and animal manures	Namibia	1997-2001	A range of approaches were used to address the potential for improving soil fertility management and productivity of pearl millet systems in northern Namibia. Improved cowpea germplasm showed potential for contributing to soil fertility however modelling showed that adoption of single management interventions is not enough. Legume residue management and nitrogen fixation need to be monitored.
SA	R7375 Use of molecular markers to improve terminal drought tolerance in pearl millet	India	1999-2002	QTLs were identified in pearl millet for terminal drought tolerance as well as plant height, panicle characteristics and yield. Top cross pollinator populations showed superior performance in terminal drought stress environments. Other QTLs for terminal drought resistance were also identified in other crosses and transferred to other backgrounds. The progress made will feed into subsequent projects to develop elite pearl millet cultivars with wider adaptability, high yields and resistance to diseases. This will contribute to the production of greater quantities of high quality stover for animal feed.
SA	R7379 Marker-assisted improvement of pearl millet downy mildew resistance in elite hybrid parental lines for Africa and Asia	South Asia W&S Africa	1999-2005	The project broadened the range of host plant resistance genes for pearl millet downy mildew for producing improved, productive millet hybrids. It also developed strategies for more efficient transfer of desired genes. The new sources of resistance will increase diversity for resistance to this damaging disease and result in higher yields of grain for humans and stover for animals.
SA	R8183 Making more miracles: exploiting marker assisted methods for pearl millet improvement	South Asia W&S Africa	2002-2005	This project extends the findings of previous projects e.g. R7375 to develop and apply marker-assisted selection techniques for pearl millet breeding programmes to more effectively address the needs of pearl millet producers and consumers in semi-arid production systems in South Asia and SS Africa. Characters involved include DM resistance, yield potential, terminal drought tolerance, acquisition of P from infertile soils and product quality traits. Successful deployment of these traits will result in higher yields of grain for humans and improved stover for animals.

Annex 4f. Analysis of NRSP projects

PS	No. & Title	Country	Date	Comments
SA	R6603 Nutrient cycling or soil mining? Agropastoralism in semi-arid West Africa	Nigeria	1996-1999	A model of nutrient dynamics was developed which considered nutrient flows between rangeland, fallowland and crop land managed by farmers, and the role of livestock in converting crop residues (pearl millet, sorghum, cowpea), pastures grasses and shrubs into manure. Manure is an important input to the nutrient balance of farmers' land holdings. Farmers with better nutrient balances are those with enhanced abilities to access nutrients from common sources e.g. grazing land and refuse heaps. The project recommended that increased nitrogen inputs by growing more legumes would provide more nutritious fodder for ruminants, a higher protein content in the farm family diet, higher value crop for sale and higher quality manure for subsequent crops.
HP	R6731 Manure management in the Kenya highlands: collection strategies to enhance fertilizer quality and quantity	Kenya	1996-1999	The project focused on improving the management of cattle, their feed and their excreta so that losses of nutrients during the transfer to the soil are minimized. The main source of nutrients is from manure (livestock-motivated nutrient transfers) hence the quality of fodder and the treatment of the excreta is very important. The project showed that improvements could be made in animal and excreta management that raised manure-compost quality and produced significant and lasting impact on the productivity of the crops grown in the system e.g. maize.
Hill	R6757 Soil fertility management for sustainable hillside farming systems in Nepal	Nepal	1997-1999	The project produced a series of systems nutrient balances for the major farming systems in the mid- and high-hills of Nepal; quantitative exposition of the effects of manure and fertilizer on long-term fertility of soils of the mid-hills with common crop sequences through analysis of past experiments and field experiments; and a synthesis of local knowledge. Recommendations on the sound use of fertilizers and manures for integrated nutrient management were communicated to farmers. Crop residues (rice and wheat straw, maize stover) and tree fodder were the main feeds in the dry winter season. Animals mainly grazed grass in the wet season.

Annex 5. 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 (R5246, 6642, 7429, 7955, 8219, 8220, 8406) Grey leaf spot (R7566, 8220, 8406) Striga; other weeds (R5343, 7564, 7405, 7404, 7955, 8212, 8215, 8219, 8452, R8455) Stem borer (R6400, 7955, 8212, 8215) Termites (R5238,5785,6653, 7026, 7951)	Host-plant resistance and/or tolerance Planting & harvesting dates Removing infected material & passage through the animal Selection of clean seed Intercropping & multiple cropping e.g. push-pull Crop rotation & green manures Recommended fertilizer application Biological control Pesticides and herbicides	Increased quantity and quality of crop-based feeds as thinnings and stover produced on-farm Increased productivity of ruminants and poultry (milk, meat, eggs) Improved performance of draught animals Increased incomes and improved nutritional status of farm families
Sorghum	Smut (R6581, R7518) Foliar diseases (R7346, R8339, R8450) Grain mould (R7506) Stem borers, shoot-fly, midge (R7572) Striga (R6654, 6921, 7564, 6655) IPM (R7401) Promotional strategies (R8349, 8428)	Selection of clean seed & seed treatment Host-plant resistance and/or tolerance Planting date Dry season field sanitation Intercropping & green manure Recommended fertilizer application Conservation tillage	Increased quantity and quality of crop-based feeds as thinnings, stover and grain Increased productivity of ruminants and poultry (milk, meat, eggs) Improved performance of draught animals Increased incomes and improved nutritional status of farm families
Millets	Finger millet blast (R6733, R8030, R8445) Stem borer & head miner of pearl millet (R6693)	Host-plant resistance and/or tolerance Removing infected material esp. 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) Improved performance of draught animals Increased incomes and improved nutritional status of farm families
Groundnut	Rosette virus (R6811, R7445, R8105, R8442) Late & early leaf spot and rust (R7346, R8339, R8450) Aflatoxin (R7809, R8298, R8483)	Host-plant resistance and/or tolerance Strategic application of fungicides Removing infected material esp. pods Compost & gypsum Biological control Post-harvest management	Increased quantity and quality of crop-based feeds as stover and seed cake Increased productivity of ruminants (milk, meat) Improved performance of draught animals Increased incomes and improved nutritional status of farm families
Pigeon pea	Sterility mosaic virus (R7452, R8205, R8481)	Host-plant resistance and/or tolerance	Increased quantity and quality of crop-based feeds as thinnings and

			stover Increased productivity of ruminants (milk, meat) Improved performance of draught animals Increased incomes and improved nutritional status of farm families
Cowpea	Pod borer (R6659, R7441, R7247, R7267)	Pheromones Botanical pesticides	Increased quantity and quality of crop-based feeds as stover Increased productivity of ruminants (milk, meat) Improved performance of draught animals Increased incomes and improved nutritional status of farm families
Beans	Insect pests (R7568, R7569, R7954, R8219, R8316, R8414) Diseases (R6651, R6807, R6847, R7947, R8415) Root rots (R7568, R8316, R8477)	Host-plant resistance and/or tolerance Green manures, animal manure, composting, fertilizers, soil amendments Insecticides IPM	Increased quantity and quality of crop-based feeds as stover Increased productivity of ruminants (milk, meat) Improved performance of draught animals Increased incomes and improved nutritional status of farm families
Root crops	Cassava: African Cassava Mosaic Virus (ACMVD): R5740, R6614, R7565, R7705, R8041, R8222) Brown Streak Virus (R5880, R6765, R7563, R7796, R8227) Sweet potato: Viruses (R5259, R6617, R7492, R8040, R8041, R8167, R8253) Weevils (R6769, R8167) Yams: Nematodes (R5259, R6694) Diseases (R5735, R5983, R6691, R7504, R8278)	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
Bananas	Nematodes (R6580, R6583) Fungal diseases (R6007, R6692, R6794) Insect pests (R7972) Viruses (R7478, R7529) IPM (R7476, R7567)	Host-plant resistance and/or tolerance Vector management Phyto-sanitation (including selection of clean planting materials) IPM Agronomic practices	Increased quantity and quality of crop-based feeds as leaves, pseudostems, and other residues Increased productivity of ruminants and poultry (milk, meat, eggs) Increased incomes and improved nutritional status of farm families