ILRI 1995:
Building a Global Research Institute

International Livestock Research Institute

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The importance of livestock

Livestock have an image problem in the developed world. They are blamed for everything from global warming to increasing heart disease. The recent emergence in Britain of 'mad cow disease'—or bovine spongiform encephalopathy—hasn't helped. Livestock are seen as wasteful, growing fat on grain that people could eat and polluting the environment with their faeces and urine and the gases they give off. But these charges are not true of livestock in the developing world.

True, ruminants produce methane gas, one of the 'greenhouse gases' but methane from ruminants accounts for only some 2.5% of the total greenhouse gases. Power stations and cars produce millions of tonnes of carbon dioxide each year, contributing to global warming to a much greater extent. Pastures grown to feed livestock actually take carbon dioxide out of the atmosphere, tying it up in plant material, just as forests do.

True, eating too much animal product may increase the risk of heart disease—but this is a problem of the developed world, not the developing world. People in the developing world generally eat less meat than those in the developed world, and the meat they eat is less fatty. Most people in the developing world cannot afford the range of foods and supplements that allow vegetarians in the developed world to create a balanced diet for themselves and their children. Indeed, recent studies from Kenya, Egypt and Mexico show that children who do not get enough meat and milk in their diets may end up physically and mentally compromised.

Livestock play a vital role in the agricultural and rural economies of the developing world. Not only do they produce food directly, they provide key inputs to crop agriculture. Most farms in the developing world are too small to justify owning or using a tractor, and the alternatives are animal power or human labour.

For many smallholder farmers, livestock are the only ready source of cash to buy the inputs they need to increase their crop production—seeds, fertilisers and pesticides. Livestock income also goes towards buying things the farmers cannot make for themselves. And that includes paying for school fees. Income from cropping is highly seasonal, almost all of it coming in just a few weeks after harvest. In contrast, small stock, with their high rates of reproduction and growth, can provide a regular source of income from sales. So can milk and milk products like butter and cheese. Larger animals such as cattle are a capital reserve, built up in good times to be used when crops are poor or when the family is facing large expenses such as the cost of a wedding or a hospital bill.

The animal manure and urine that people in the developed world see as pollutants are vital fertilisers to smallholder farmers in the developing world. Few smallholders can afford to buy enough inorganic fertilisers, and their cropping depends on cycling nutrients through plants and animals. In the past, farmers could restore the fertility of their land by letting it lie fallow for several years or longer. But as population pressure increases, fallow periods decline or even disappear and different ways of maintaining food production are needed: enter the animal.

Animals are a crucial link in nutrient cycles, returning nutrients to the soil in forms that plants can readily use. They can bring nutrients from pasture and range land and concentrate them on crop land through their manure and urine. And they can give farmers a reason to plant legumes as pastures and cover crops that protect the soil and restore its structure and fertility.

According to a Winrock report in 1992, 'The greatest threat to [the African rangelands] comes from human populations and expansion of cultivation. There is no solid evidence linking livestock to this process [desertificationl.' Increasing the productivity of livestock systems and mixed crop–livestock systems will give farmers more reason to protect the rangelands and use them sustainably for raising livestock rather than putting them to the plough.

This idea of adding value to 'idle' land could be crucial in the future to efforts to protect fragile land. As farmers come under increasing pressure physical, from the growing human population, and financial, as they are increasingly brought into monetarised economies—to get as much as possible out of their land, livestock will provide a reason to keep marginal land—range lands and hillsides, for example — under pasture rather than putting it to the plough. But to act as such a buffer against expanding cropping onto fragile land, the farmer's livestock must be an integral and valuable part of the farm enterprise.

Already, in many parts of the world mixed crop–livestock systems are the norm, but the livestock component has been ignored or its importance overlooked. Even the language we use tends to reinforce this. When we talk about the non-grain parts of cereal crops, we tend to use terms like 'crop residues' or 'crop by-products'. Yet in many farming systems, such as the barley-sheep system of the drier parts of the West Asia and North Africa and the teff-based system in the Ethiopian highlands, the farmers value these 'by-products' as much as, if not more than, the grain. Why? Because they are the principal feed for their livestock. 'Improved' varieties or production packages that overlook the feeding value of these 'residues' will find little favour with the majority of farmers.

Intensive animal production in the developed world often uses resources that could be directed to other uses—grain that could be eaten by people, land that could be used to produce food crops, electricity that could be used to light and heat people's homes. But in the developing world livestock add value to resources that would otherwise go to waste. Land that cannot, and indeed should not, be ploughed, straw, stovers, groundnut haulm, household wastes, all go to feeding livestock in smallholder systems. Cassava peel, for example, makes up a large part of the diet of goats in humid West Africa. In Syria farmers allow weeds to grow in their cereal fields and then 'rogue' them to feed to their sheep. The weeds slightly reduce cereal grain yields, but the productivity of the system as a whole is higher than if they sprayed weed killer to control the weeds. And the environment is protected.

The research task facing ILRI and its partners is to develop ways of managing livestock that maximise the benefits to smallholders while minimising any harm livestock can inflict on the environment when, for example, they are overstocked or are poorly managed in other ways. Wellmanaged, the benefits to smallholders of keeping livestock are overwhelming.

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A global livestock research institute

The early 1990s saw a flurry of interest in the role of livestock in developing world agriculture in general and in the research agenda of the Consultative Group on International Agricultural Research (CGIAR) in particular. This included a major review of the role of animal agriculture in sub-Saharan Africa, led by the Winrock International Institute for Agricultural Development on behalf of several development agencies. This was also a period when each of the international agricultural research centres supported by the CGIAR was called on to develop medium-term plans that would take them through nearly to the end of the century. Several referred for the first time to the importance of livestock in smallholder production systems in their mandate areas.

When the CCIAR established ILCA and ILRAD in the early 1970s it considered it likely that the two centres would eventually come together as a unified livestock research entity This possibility emerged again with the external reviews of the two centres in 1991/92, when the review teams were asked to consider whether the plan to amalgamate the two centres should be revived. In the event, both teams recommended increased co-operation between the centres, but were not in favour of a merger *per se*. Winrock's report, *Assessment of Animal Agriculture in Sub-Saharan Africa*, also recommended closer collaboration rather than merger.

At the same time that ILCA and ILRAD were developing their medium-term plans for 1994–98, the Technical Advisory Committee (TAC) of the CGIAR was developing and refining its proposals for priorities and strategies for research in the CGIAR.

TAC examined CGIAR priorities and strategies by comparing the value of production of various commodities with the CGIAR's investment in research on these commodities. The congruence analysis was modified by such factors as the number of poor people, total usable land area, efficiency, equity, sustainability, strength of national programmes and self-reliance. TAC then used the results to set priorities by region, agro-ecological zone, production sector and commodity.

The International Livestock Research Institute (ILRI) is building on the staff resources and facilities of the International Laboratory for Research on Animal Diseases (ILRAD) and the International Livestock Centre for Africa (ILCA).

TAC recommended a substantial increase in research on resource management, including germplasm conservation. Higher priority was also given to socioeconomic, public policy and public-management research. In comparison, institution building and activities aimed at developing and managing production systems were given lower priority outside sub-Saharan

Africa, while germplasm enhancement and breeding priorities were to be kept at their existing levels.

According to TAC, the subhumid tropics, the higher-rainfall areas of the semi-arid tropics and the cool tropics offer the greatest potential for increasing livestock production. TAC expected productivity and income gains in these zones to come from integrated crop–livestock systems that had dairying, animal traction, poultry and pig production components. To develop such systems, TAC asserted, research should focus on improving feed supplies, animal health, animal genotypes, natural resource management and the economics of livestock production. TAC believed that opportunities for technical interventions to increase the productivity of livestock in the drier semi-arid and arid tropics were too limited (despite the large number of ruminants supported by these areas) to warrant a major research effort.

Both ILCA's and ILRAD's research efforts focused on African livestock problems.

TAC affirmed the system's focus on the key ruminant livestock species, cattle, sheep and goats, and on meat, milk and traction. According to TAC, the centres should give priority to increasing livestock productivity in the subhumid and semi-arid tropics and in the highlands. TAC also identified a need for livestock research in other agro-ecological zones as a component of research on agricultural production systems. Their emphasis on mixed crop–livestock systems highlighted the opportunity for the plant-oriented international research centres to redirect some of their research to include livestock and feed resources.

A discussion draft of TAC's proposals was presented and discussed at International Centers Week in Washington, DC, in October 1992. ILCA's Board of Trustees questioned the basis and conclusions of this proposal. In particular, the Board challenged the figures used for CGIAR spending on livestock research and for the value of production from livestock. ILCA's figures suggested that the CCIAR was under-investing in livestock research, even in sub-Saharan Africa. ILRAD also pointed out the relevance and spill-over of strategic research on livestock to all developing country regions, irrespective of where the research was conducted.

TAC released a revised version of its priorities and strategies paper in April 1993, in time for the CGIAR's mid-term meeting in Puerto Rico in May 1993. But in the event, TAC's proposals were superseded by decisions taken by the donors at the mid-term meeting.

The key issue raised by TAC was how the CGIAR's livestock research could best address research needs outside sub-Saharan Africa. TAC's analyses had documented the important role of livestock in mixed crop–livestock systems in all the major regions of the developing world, and their considerable economic contribution in these regions. Further analyses indicated that the vast majority of the CGIAR's expenditure on livestock research was in sub-Saharan Africa, with lesser amounts in the Latin America and Caribbean (LAC) region — through CIAT — and the West Asia and North Africa region (WANA) — through ICARDA and virtually none in Asia, despite the importance of livestock in that region.

TAC proposed retaining ILCA and ILRAD as separate entities while increasing the use of ecoregional programmes to bring together crop and livestock research in 'systems research' programmes in different agro-ecological zones.

But the issues raised by TAC's studies began a process that led to the establishment in September 1994 of the International Livestock Research Institute (ILRI). The CCIAR mid-term meeting in May 1993 went beyond TAC's proposals with a decision to develop a unified strategy for livestock research in the CCIAR system. The meeting set up a committee 'to identify priority activities for international livestock research, which would be managed through a single institution and be constrained by the current proportion of CGIAR resources allocated to livestock.' This committee reported to the CGIAR at International Centers Week in October 1993. The central element of its proposal was the establishment of a single livestock research institute, which would bring together components of the programmes of ILCA and ILRAD. The CGIAR approved the committee's report, and steps were taken to put it into effect.

Moves towards a new institute

In December 1993, the CCIAR designated the Rockefeller Foundation as the 'Implementing Agency' to manage the establishment of the new institute.

One of the first tasks was to develop a global livestock research strategy for the CGIAR and an interim strategy and a medium-term plan for the new institute. A strategic planning 'task force' had the job of developing the strategic plans in only a few months. Their strategy built on three main reference points enunciated by TAC in its priorities and strategies paper:

1. The activities must be research or research-related. The first objective is the generation of new knowledge or products, while the second includes dissemination, training and collaborative programmes with NARS.
2. The activities must be international in character and target CGIAR priorities
3. The activities must be ones in which the CGIAR centres have a comparative advantage.

Other considerations outlined by the task force were:

- CGIAR centres should be leaders, not followers, in their particular fields of scientific expertise.
- For practical as well as philosophical reasons, the CCIAR centres must seek active partnerships with other institutions, particularly in the developing countries.
- The responsibility of CGIAR centres extends beyond the production of research information, and includes dissemination of the results to intermediate users or end-users, as appropriate. This process should be carried out interlinked with training and institution building activities.
- The livestock research programme must particularly acknowledge world concerns about the environment, sustainability, food security and poverty reduction.

Major trends

The task force called on experts from around the developing world to help determine the key issues facing livestock research and development in the developing world. They identified five important trends affecting the livestock sector world-wide:

- Most of the increase in production will come from intensification of livestock production in mixed farming systems.
- Urbanisation of consumers will tend to encourage specialisation of producers and, for some products (e.g. poultry and pigs), a shift to industrial-scale production.
- Almost all production of milk, beef and small ruminant meat, and most pig-meat production, will still come from smallholder systems.
- Pastoral areas will have limited scope for increasing production, but will present challenges in natural resource management.
- New scientific developments will provide significant opportunities for improving productivity, particularly through animal–health interventions.

Of the seven priority research areas identified by TAC, the task force saw three — animal health, animal genetics and nutrition — as being mainly of a strategic nature with global relevance, regarding the remaining four — feed resources, production systems, natural resource management and socioeconomic analysis — as being primarily of an ecoregional nature.

Animal health

Animal health is a major constraint to increasing livestock productivity in tropical countries. In sub-Saharan Africa, for example, losses due to disease may be equal in value to one quarter of the region's annual total animal production. Disease problems can be classified into three categories: epizootic infectious diseases (mainly virus diseases such as foot-and-mouth disease and rinderpest); parasitic diseases; and diseases of intensification and zoonoses.

Epizootic diseases have been important in the past in the developed world, and a great deal has been invested in developing technologies for their control. The challenge in developing countries is essentially one of transferring these technologies into effective programmes that can be carried out by national veterinary services, voluntary groups and other agencies.

Parasitic diseases are the most important causes of animal losses, and key among these are two diseases that were the focus of ILRAD's work for 20 years, trypanosomiasis and theileriosis, or East Coast fever. The technical challenges facing scientists studying these diseases are great, although advances in biochemistry, immunology and molecular genetics are improving the prospects for developing effective vaccines. These diseases are a continuing focus for ILRI because of their economic importance, because of ILRI's leading position in knowledge and expertise, because such diseases must be studied where they occur and because of the great potential spill-over of research results from these programmes into research on other important animal diseases globally. This animal health research also has potential benefits for human health, because the animal disease is useful in studying human immune responses. Diseases that can profit from ILRI's work include other tick-borne diseases, e.g. forms of theileriosis, babesiosis, anaplasmosis and cowdriosis and dermatophilosis (a bacterial skin infection), all of which are widespread in tropical developing countries.

The strategy document also identified diseases caused by internal parasites as a widespread and costly problem facing livestock producers.

Diseases that occur more frequently in intensive livestock production systems include mastitis and salmonellosis, while zoonoses — animal diseases that can be transferred to humans — include tuberculosis, brucellosis and rabies. As with the epizootic diseases, both these groups of diseases have been subject to extensive research in the developed world in the past and the challenge now is largely to transfer the technology effectively.

There is little commercial research aimed at solving animal health problems in the developing world. Part of the challenge facing ILRI is not only to develop better control methods but also to ensure that these are cheap enough to be adopted in developing countries and that they are appropriate to the skills and knowledge of the farmers and animal health workers there.

One of ILRI's advantages over ILRAD and ILCA is that it is able to combine skills in livestock husbandry, animal diseases, epidemiology, sociology and economics to extend biotechnological research on complex diseases into the determination of their effect on production systems. It also has available the range of skills and knowledge needed to explore and exploit natural resistance to tropical diseases which is now recognised as a highly valuable part of the genetic heritage of domestic livestock in developing countries.

Costly diseases

Animal diseases impose three kinds of costs: losses through deaths and reduced performance, costs of preventive and curative treatments, and the cost of lost opportunities where development is prevented. All three cost elements are very high in the case of diseases caused by blood parasites, which are prevalent in tropical countries. They particularly inhibit development of milk production, which is usually sought by upgrading local cows using genotypes that can produce more. However, exotic and up-graded cattle are also more susceptible to diseases and other stresses. Often dairying develops only at the price of an additional cost to the environment — the heavy use of insecticides and acaricides to control the pests that transmit the parasites.

Of the tick-borne diseases, anaplasmosis and babesiosis are the most widely distributed. They are found together or separately in most of the tropics and subtropics between 40ºN and 32ºS. They threaten over 700 million cattle world-wide, including two-thirds of those in South-East Asia. Livestock producers in Latin America may lose $1.5 billion a year to these diseases. East Coast fever, a form of theileriosis specific to Africa, has been estimated to cause direct losses of $170 million a year. In 1989 the disease killed over 11 million cattle in eastern, central and southern Africa.

Trypanosomiasis, transmitted by the tsetse fly, affects both livestock and people and is endemic across some 10 million square kilometres in 37 African countries. Its cost in cattle alone is estimated at more than $500 million each year. Other forms of trypanosomiasis are important diseases in Latin America and South-East Asia. In Indonesia, for example, trypanosomiasis is ranked as the third most important livestock disease, with losses in 1984 estimated to be in excess of $20 million.

Effective vaccines would be the ideal way to control these diseases, but, as with malaria, these have proved an elusive goal. ILRI and its partners are pursuing new approaches to producing a vaccine for East Coast fever, but for each of these diseases ILRI is broadening its programme to investigate all avenues of cost-effective control.

Genetics

Livestock in developing countries must perform under exceptional environmental challenges: disease, poor nutrition, climatic stress. Scientists can best study the genetic ability of indigenous animals to withstand these challenges in their natural environments, and ILRI has a clear role to play in this field. Using such naturally occurring climatic and disease adaptation mechanisms offers a potentially sustainable way of overcoming some of the major constraints to livestock production, and is an area in which ILRI already has a strong track record. Past and current work in this area focuses on exploiting breeds of cattle and sheep indigenous to Africa that resist the effects of trypanosomiasis and helminthiasis, but the results of this research benefit research on other diseases as well.

Advances in molecular biology are steadily opening up new possibilities for understanding and using genetic variability in animal—and indeed plant—populations. It is difficult to predict where the benefits will come, but in the context of livestock in tropical environments the most exciting possibilities lie in the area of naturally occurring genetic mechanisms that counter disease challenges. The map of the bovine genome is now almost complete at a usable level of resolution and will allow the mapping and identification of genes governing important traits — e.g. immune response, growth, disease resistance, milk yield etc — in cattle and related ruminants. Scientists at ILRAD played a leading role in this development, and the momentum of that work is being maintained in collaboration with advanced institutions in the developed world.

There is a growing awareness that the many different types, strains and breeds of domestic animals around the world that have evolved over the millennia are now, like much biodiversity, disappearing at an unprecedented rate. There is therefore an urgent need to evaluate, document and, in certain cases, conserve this genetic treasury. This is an activity that has both research and operational dimensions, and is therefore one which goes beyond the responsibilities of a research institute such as ILRI. ILRI is taking a major role in determining the numbers of different ruminant livestock 'breeds' in Africa and is collaborating closely with the Food and Agriculture Organization of the United Nations in characterising and documenting livestock breeds world-wide.

The promise of the new genetics

Early in 1994, scientists from several advanced research institutes provided the first comprehensive linkage maps of the bovine genome. Over 200 genetic markers, spaced throughout the genome, have been identified. The purpose is to create a reference set against which useful genes — for disease resistance or production traits — can be located.

ILRAD scientists were part of this co-operative activity, and the compilation of the maps is a milestone in marking, identifying and, potentially, using genes governing important characters to improve the performance of cattle world-wide, and particularly in developing countries. Similar work in sheep and pigs is advancing rapidly.

In countries where agriculture is highly organised, systematic selection has transformed the productivity of cattle populations. However, intensive selection has been possible only because of extensive and accurate production and lineage recording, often enhanced by selected artificial insemination, combined with high reproductive rates and lower mortality. In most developing countries, it will be many years before the infrastructure for this exists. The particular promise of the molecular genetics is that it offers the possibility of putting in place effective selection programmes using molecular markers (marker-assisted selection, or MAS) without the need to develop a large infrastructure.

The prospects of success with NIAS should become clear within the next five years. They depend heavily on the extent to which significant traits are controlled by relatively few genes. Exploring the potential of this area requires a combination of available knowledge and more research in animal diseases, breeding systems and production structures, as well as molecular and quantitative genetics. ILRI is therefore strongly placed to play a leading role in the application of new genetic approaches to animal improvement in developing countries.

Nutrition and feed resources

Feeding their animals adequately is the single most difficult problem facing farmers in the developing world, especially smallholders. In the developing world, nearly 9 out of every 10 ruminants and pigs are kept in farming systems where the feed supply is a varying and sometimes inadequate mixture of natural or specially grown forages, high energy feeds and crop residues. Half of developing country poultry are produced in landless systems with bought-in feed, while the remainder subsist mainly as scavengers.

Nutritional research on monogastrics and poultry is welldeveloped world-wide. Ruminant nutrition has also been extensively researched, but there are opportunities for developing new insights into the unique metabolism and rumen microbial populations of animals indigenous to tropical developing countries. These are areas on which ILRI is focusing its nutrition research.

Key areas that need to be addressed include sources of protein, supplementation strategies, technology for improving the digestibility of crop residues and techniques for storing residues and forage crops. Most of this research falls within the context of farming systems research, and therefore offers good opportunities for interaction with other CCIAR centres and with national institutions in developing countries.

As with animal genetic resources, ILRI has a major responsibility for documenting, conserving and testing forage-plant resources.

Feed utilisation research

Inadequate year-round nutrition for livestock is probably the main constraint on smallholder animal production in tropical countries. Most ruminants raised in the developing world will continue to subsist, for the foreseeable future, on unimproved native pastures and crop residues. These poor-quality feeds are bulky, high in fibre, poorly degraded in the animal's rumen and low in nitrogen and minerals — in short, not very nutritious. These deficiencies can be corrected by supplementing the animal's diet with herbaceous legumes and foliage from fodder and multi-purpose trees.

There is increasing interest from livestock producers in the use of multi-purpose trees as well as agro-industrial by-products as sustainable sources of essential nutrients to improve ruminant diets. ILRI is studying how various biochemical components of multi-purpose trees affect the microbial ecosystem in the rumen, particularly how secondary plant compounds such as tannins interact with the rumen microbes. This aims at increasing the supply of nutrients to animals by manipulating the rumen environment and microflora to detoxify harmful compounds and maximise the availability of protein and energy to the animal.

The nutritive value of fibrous feeds is traditionally described in terms of digestibility and chemical composition, but this gives little indication of how much of the feed an animal will eat. Without this information it is difficult for scientists or farmers to predict how well the animal will perform or how much feed they will need at what time of the year. A key area of ILRI's nutrition research is into the factors that influence how much of these feeds an animal will eat and how the rumen microbes deal with them, so that we can design diets that are more readily eaten and more efficiently used.

Livestock production systems

If the developing world is to meet the growing food demands of its population, scientists must develop strategies for increasing food production while conserving production resources — land, water, the environment. Research at ILRI and elsewhere has shown that mixed crop–livestock farming systems can achieve these dual goals. By combining crop and livestock production on their farms, smallholders receive the benefits of draft power, make use of crop by-products as feed for their livestock and cycle nutrients between the two systems. These benefits lead to increased productivity that can be sustained over the long term without harm to the environment.

Key elements of work in this area are understanding and enhancing the roles of livestock in complex mixed crop–livestock systems and assessing the impact — both potential and actual — of interventions on system productivity and sustainability.

Natural resources

Good farming practice should conserve natural resources — this truism applies as much to the developing world as to the developed world. Preserving the natural resource base on which their livelihood depends is in the farmers' long-term interest. But people can lose sight of their long-term interests when they are struggling to feed themselves today.

In the past, most traditional farming systems were in harmony with their environment, conserving natural resources. But as human populations increased the basis that these systems were built on has been undermined. Fallow periods have shortened or disappeared. Livestock herders are keeping more stock to support their growing families. Farmers strive to produce surpluses for sale to raise their standard of living and join the market economy. Managing natural resources is increasingly a focus of concern, and demands are growing for action to protect the environment.

This concern for husbanding natural resources lies at the centre of all of ILRI's research programmes. Every research protocol carries a statement of the likely environmental impact of that research. Livestock provide an entry point for many interventions that help increase the productivity of a farming system, as well as contributing directly to nutrient cycles that maintain the resource base. Forage legumes, for example, help restore the fertility of soil more rapidly than just letting the land lie fallow. Feeding forages to livestock increases the productivity of those animals, increasing the likelihood of farmers planting them. If farmers keep animals that are tolerant of diseases or pests they do not need to treat them so frequently with drugs and chemicals, saving the environment from extraneous toxins. Some people argue that this will allow farmers to keep animals in places where they could not before, and that this will harm the environment. But evidence refutes this argument. Farmers will keep livestock even in the face of disease risk, using chemicals to control the disease or to kill the vectors of the disease. Efforts to control trypanosomiasis, for example, have led to spraying large tracts of land with insecticides to kill the tsetse flies that carry the disease, or to clearing the bush that harbours the fly Farmers can keep trypanotolerant cattle without resorting to these extreme measures. Recent ecological research in Ethiopia shows that natural plant and animal biodiversity actually increases as agricultural activity increases, up to a point.

Research on proper management of natural resources is largely done in the context of farming systems typical of particular agro-ecological zones, and thus falls within the brief of ecoregional programmes. ILRI conducts much of its natural resources research in collaboration with national institutes. The work is by nature multidisciplinary, involving economic, social and technical analysis at the field level, together with the use of geographic information systems and system modelling.

Policy, economics and social sciences

Most people now recognise that the constraints on the adoption of technical innovations to enhance agricultural productivity often lie with economic policies and with social and economic factors. Research in these areas is essential if ILRI's technical interventions are to be appropriate to the needs, aspirations and political environments of the farmers it hopes to serve.

ILRI has a strategic advantage in studying the socioeconomic parameters affecting adoption of livestock technology because it can integrate its technical, social and economic information and expertise. ILRI and the International Food Policy Research Institute (IFPRI) are collaborating in developing and implementing research in four areas: policies and institutions for improving the sustainability of crop–livestock systems; competitiveness of smallholder dairy sectors; policy reforms and livestock and output markets; and property rights and the sustainable development of livestock production systems. The two institutes have also established a joint livestock policy research committee to oversee this work.

The Mombasa dairy project — an example of systems research

As elsewhere in the developing world, demographic changes have led to rapid increases in demand for milk in the coastal subhumid zone in Africa, especially from urban centres. Production in the zone has lagged because of technical constraints (feed shortages, disease and use of animals with low production potentials), policies that discourage producers and poor market links. ILCA addressed these problems through a collaborative project with the Kenya Agricultural Research Institute (KARI) in Kenya's coastal zone. This project has been recognised by donors and others as a model for ecoregionally relevant livestock systems research.

In 1988, ILCA established the KARI/ILCA research project to develop intensive smallholder dairying in the Coast Province. The KARI/ILCA team worked closely with the National Dairy Development Project, national and international research institutes (including ILRAD) and extension agencies. KARI scientists focused on locally relevant research while ILCA scientists addressed the broader issues relevant to market-oriented dairy production in East and West Africa.

The project made considerable progress in advancing local production as well as in developing and testing more general models of dairy systems. Improved feed production, based on grass/legume mixtures, has reduced farmers' reliance on bought-in feed. Cost-effective feeding practices increased milk yields by 25% and reduced dry-season live-weight losses by 75%. Milk sales increased household income by the equivalent of the salary of one casual wage earner per lactating cow.

In addition to its technical successes, the KARI/ILCA project developed and tested effective institutional mechanisms for strengthening the linkages between research, extension and farmers. This model of co-operation has been adopted by KARI and Kenya's Ministry of Agriculture, Livestock Development and Marketing for research and extension programmes throughout the country.

Developing a Medium-term plan

While the task force was developing the livestock research strategy for the CGIAR, the job of preparing an interim medium-term plan for the new institute fell to ILCA and ILRAD staff.

A first draft of the MTP was developed by bringing together key areas of research from the MTPs of the two institutes under the priority research areas identified by TAC, in particular those elements of the programme that were considered appropriate to a strategic agenda for addressing global livestock problems.

The indicative medium-term plan of August 1994 framed the programme of ILRI through four goals that arose from the strategic planning for the CGIARs approach to livestock:

- To improve animal performance by overcoming identified constraints to animal productivity, through technological research and the conservation of the existing genetic diversity amongst livestock in developing regions;
- To improve the productivity of the major livestock and crop–livestock production systems typical of developing regions and to maintain their long-term productivity;
- To improve the technical and economic performance of the livestock sector in these regions to ensure the appropriate translation of production-system improvements into increase food security and economic welfare; and
- To improve the development of technologies, their transfer to and use by national programmes and client farmers in the agricultural systems of these regions.

The interim medium-term plan (IMTP) for 1994–98 outlined a programme of research in the seven priority areas for research identified by TAC's analysis: animal health; animal nutrition and physiology; physiology of tropically adapted ruminants, animal genetics; feed resources; livestock production systems, natural resource management, and livestock and resource management policy. It also developed a programme for strengthening national research capacities. For each of these areas the IMTP identified what aspects ILRI should work on initially, based on ILRI's comparative advantage and building on the achievements of ILRAD and ILCA in the previous 20 years.

The medium-term plan for 1998–2000 is currently being developed by ILRI's staff and Board of Trustees in consultation with stakeholders around the world.

Broadening horizons

Probably the biggest single change brought about by the creation of ILRI is the new institute's global mandate. Both ILRAD and ILCA focused their efforts on problems facing farmers in sub-Saharan Africa, ILCA because of its mandate, ILRAD in its choice of diseases.

A consultation to begin mapping out priorities for the global agenda was held in Nairobi, Kenya, in mid-January 1995 with ILRI scientists and 28 other livestock specialists from 25 countries. Representing eight national and 11 international agricultural research institutions and several donor agencies, these experts concurred that animal production in developing regions is constrained primarily by inadequate feed resources. Other important research objectives identified by the consultants were reducing pressure on natural resources, conserving and enhancing indigenous animal and forage genetic resources, improving animal health, improving livestock policies and strengthening the capacity for livestock research of developing countries. The pre-eminence of the feed-related problems led to the development of a system-wide livestock initiative focusing on producing and using feed.

This meeting was followed by other consultations: in the Philippines in May to determine priorities for livestock research in South-East Asia. in India in June to set research priorities for South Asia; and in Costa Rica in October to set priorities for the Latin American and Caribbean region. A final meeting in the series will be held in early 1996 to set research priorities for the West Asia and North Africa region. Participants in these consultations identified the greatest need for livestock research to be concentrated in mixed crop–livestock systems of various types in the different regions. This is important because for the past several decades livestock have largely been ignored or overlooked in the drive for ever higher crop yields. The greater awareness of the involvement of livestock in almost all smallholder agricultural systems opens new vistas for collaboration, but also highlights problems that researchers will have to face. In particular, participants noted that researchers need better methods for analysing integrated farming systems. ILRI has been developing such methods over several years, a good example being the research framework developed for studying smallholder dairying. It will be important to take account of the different production system settings and crop–animal combinations as ILRI designs research applicable to different developing country regions.

As part of the process of formulating a vision of where livestock research and development should be headed, senior staff from ILRI and the Food and Agriculture Organization of the United Nations (FAO) held a round-table meeting in Addis Ababa, Ethiopia, at the end of February 1995. They reviewed the relative importance of constraints on tropical animal husbandry and set long-term development objectives. This and several other planning meetings initiated by ILRI and its partners in 1995/96 will help set the research agenda for the new institute over the next several years.

ILRI established September 1994

The International Livestock Research Institute (ILRI) officially came into being on 21 September 1994 at a ceremony in Berne, Switzerland.

Representatives of the governments of Switzerland, Sweden, Denmark, Kenya and Ethiopia, and of the United Nations Environment Programme (UNEP), gathered in Berne to sign the international agreement and constitution officially creating ILRI. The signing of the documents gave the new institute legal status under international law.

Signing the establishment agreement were H.E. Walter Fust, Director of Swiss Development Cooperation. H.E. Dr Teketel Forssido, Minister of Agriculture, Ethiopia; The Honourable Simeon Nyachae, Minister for Agriculture, Livestock Development and Marketing, Kenya; H.E. Mr Jan Per

Gosta Martenson, Ambassador of Sweden to Switzerland; Dr Ebbe Schioler, Head of Research Section, Danish International Development Agency; and Dr Hans Alders, Director, UNEP Regional Office for Europe.

System-wide Livestock Initiative

The CCIAR has given ILRI the task of spearheading its global research efforts to improve animal agriculture. During the formation phase of ILRI in 1994 the Strategic Planning Task Force developed a CCIAR strategy for research on animal agriculture which acknowledged the various comparative advantages of the centres along with the roles played by other livestock research and development institutes world-wide. Within this strategy, ILRI's role was defined in relation to other centres of the Group already conducting livestock or livestock-related research. The first element of this approach is for ILRI to develop its own global agenda for livestock research; it is doing this through a series of regional consultations and planning workshops. The second key element is the forging of a System-wide Livestock Initiative (SLI) amongst centres of the CGIAR and their national and international partners.

The initial aims of the SLI are to design and implement programmes of research to improve livestock feed production and utilisation in tropical regions through consortia of national and international research centres (from both the developing and developed world). Many of the international agricultural research centres supported by the CGIAR are repositories of expertise in tropical crops and cropping systems and possess plant genetic resources that can be brought to bear on improving feed production, for the benefit of livestock producers and their farming practices. As with other system-wide initiatives, the goal is to work with partners in consortia so as to be able to tackle research that individual centres would not have had the resources to handle alone.

In a new departure for the CCIAR system, the SLI uses a process of competitive selection of research proposals to award its funds. These funds are seen as 'seed money' to mobilise the initial research, with the aim of attracting further bilateral funds to support the research as it progresses. This process has so far been managed by an Inter-Centre Livestock Programme Group comprising, to date, representatives of eight CGIAR centres in addition to ILRI (CIAT, CIP, ICARDA, ICRAF, ICRISAT, IFPRI, IITA and IRRI) and chaired by ILRI's Director General. This group first met in May 1995, when it called for centre-led consortia to submit proposals for funding under the SLI. Eight proposals were received and sent out to a panel of international livestock experts for independent review.

Meeting again in October, the Livestock Programme Group recommended three proposals for funding in 1996. These are:

- Improved legume-based feeding systems for smallholder dual-purpose cattle production in tropical Latin America (CIAT-led consortium)
- Production and utilisation of multi-purpose fodder shrubs in West Asia and North Africa (ICARDA-led)
- Utilisation of forage legume biodiversity for dairy production and natural resource management in the East and central African highlands (ICRAF-led)

While these proposals each have a specific ecoregional focus, there will be common themes that will permit

cross-regional comparisons, broadening the relevance of the research conducted by each consortium.

Several consortia proposed research on producing and using forages, residues and by-products from food and cash cropping systems and related natural resource management research. While these proposals provided evidence that plant breeding programmes and other means might improve the digestibility and nutritive value of crop residues, the scientific reviewers were divided on whether it would be possible to improve both grain and residue qualities. Therefore, the Livestock Programme Group recommended holding a research planning workshop in 1996, using SLI funds, to address this crop–livestock interface, with particular emphasis on using feed resources from cropping systems and related natural resource management issues. This research area is relevant to all ecoregions and is expected to be a key element in the formulation of future proposals on the improvement of livestock feeds. The workshop will be convened by ICRISAT at its Asian Center, in Hyderabad, India, in April 1996.

Other CGIAR centres working in livestock research

While ILRI is the CGIAR's lead livestock research institute, it is not the only one working in the field. Two others have considerable livestock research components: the International Center for Agricultural Research in the Dry Areas (ICARDA), based in Aleppo, Syria, and the International Center for Tropical Agriculture (CIAT), in Cali, Colombia.

The countries of West Asia and North Africa (WANA) import huge amounts of feed grains and meat and milk products to meet the demands of their large and rapidly expanding human population. Some sources estimate that these countries will have to import more than 100 million tonnes of feed grains each year by the year 2020. All available arable land is already cultivated and the region is starting to face severe shortages of water. Increased domestic food production will thus have to come from crops and livestock that make more efficient use of existing water and land resources.

In addition to its responsibility for cereal and food legume improvement and farm resource management, ICARDA works closely with the NARS of WANA on improved systems of feed production and use and on sheep management and nutrition. Research on feed resources addresses three major topics: annually sown forage legumes such as vetch for grazing in spring and for conservation for use in winter. improvement of rangelands by reseeding with native species, by introducing fodder shrubs and by applying phosphate fertiliser; and studies on property rights and policies to enhance the uptake of better range-management practices.

The two animal scientists at ICARDA conduct research with the NARS on four main topics: (1) Identification and development of efficient small ruminant production systems adapted to the emerging farming systems of WANA; (2) On-farm testing of solutions to the constraints to efficient meat and milk production; (3) Optimising the use of local feed resources at critical stages in the breeding cycle of sheep. and (4) Identifying simple and fast procedures that allow cereal breeders to screen germplasm for straw quality early in the selection process.

CIAT has an extensive programme of research on tropical forages. The goal of CIAT's Tropical Forages Program is to acquire, identify and improve tropical forage germplasm that has a role in increasing the efficiency of livestock production and sustainable land use in production systems of the subhumid and humid tropics. Particular attention is focused on *Brachiaria*, *Arachis* and *Stylosanthes* species. Much of the forage work has focused on the humid tropical lowland savannahs of Latin America, with their acid, infertile soils and high incidence of disease and pests; the forest margins;

and mid-altitude hillsides throughout the humid and subhumid tropics. Recent research has shown the benefits of rice–pasture cropping systems for restoring soil structure and fertility. There has been a lot of media attention on the role of livestock in the destruction of the Amazon rain forest, but CIAT's work is demonstrating that livestock have a role to play in ameliorating the effects of agriculture on the rain forests. CIAT, together with other international and national research institutes, also developed a collaborative project that is part of the System-wide Livestock Initiative. This project, Tropileche, focuses on use of legume-based forages for dual-purpose cattle production in the Latin American region.

Collaboration and integration the names of the game

The CGIAR is progressing beyond centre-focused activities and towards multidisciplinary intercentre research programmes. These involve several centres and national partners in integrated efforts to address high-priority problems. This will help make best possible use of the CGIAR's resources by bringing to bear expertise from a range of sources and backgrounds on crucial issues. Individual centres will no longer need to have a full range of specialists to study and improve complex agricultural systems. Rather, they will call on each others' expertise in consortia of national, regional and international agencies.

ILRI is closely involved in several system-wide initiatives, including those on plant and animal genetic resources, soil and water management and property rights. There are also several ecoregional initiatives that ILRI is taking part in, in particular the East African Highlands initiative, convened by the International Centre for Research in Agroforestry (ICRAF), and the Desert Margins initiative, led by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger and the Moist Savanna Initiative led by IITA.

Thus ILRI, building on the achievements of ILRAD and ILCA, is poised to address its global mandate through collaboration with national and international partners around the world.

Live vaccine delivery systems for East Coast fever

Researchers at ILRI have developed a potential vaccine against East Coast fever, a deadly disease of cattle caused by a single-celled organism, *Theileria parva*. This parasite, transmitted from one animal to another by ticks, costs farmers in eastern, central and southern Africa some US$ 170 million every year in direct losses (animals killed and costs of treatment and control). In 1989 the disease killed over 11 million cattle in eastern, central and southern Africa. Heavy use of acaricides — tick-killing chemicals — to control the ticks harms the environment.

Since the 1960s, scientists have focused much attention on the 'infection-and-treatment' system for immunising cattle against East Coast fever. This system is based on inoculating cattle with a lethal dose of live parasites while simultaneously treating them with a long-acting antibiotic to reduce the severity of the resultant infection. In 1995, ILRI continued to work closely with the Kenya Agricultural Research Institute (KARI) on improving control of tick-borne diseases. ILRI transferred technologies and essential laboratory reagents, such as monoclonal antibodies and DNA probes, to KARI, as well as providing the so-called 'Marikebuni' stabilate. KARI has used this stabilate at the Kenya coast in infection-and-treatment immunisation against East Coast fever and is now using it in the country's Central Province. KARI, in turn, is helping ILRI to develop a panel of reagents for use in diagnosing tick-borne diseases. At the regional level, ILRI is supporting a Programme for Tick and Tick-borne Disease Control in eastern, central and southern Africa, co-ordinated by the Food and Agriculture Organization of the United Nations (FAO). This support includes providing stabilates for use in infection-and-treatment immunisation and assays for diagnosing infections with tick-borne-disease organisms.

While the system works well in many areas and production systems it has three serious drawbacks. First, the parasites to be injected must be kept frozen before use in liquid nitrogen to remain viable, and the facilities for this are rarely available in developing countries. Second, the immunised animal is protected against only the strain or strains it was infected with, not against other strains it might encounter in the field .

Millions of cattle in eastern, central and southern Africa are at risk from East Coast fever, a deadly disease caused by the single-celled organism Theileria parva. *ILRI is pursuing several approaches for controlling this disease.*

This article elaborates on the presentation on ILRIs upstream research given by ILRI's Director General, Hank Fitzhugh, at International Centers Week 1995.

And third, and in some ways the most serious drawback, once infected the animal carries a reservoir of the parasite with it for the rest of its life and can thus become a source of the disease. The system is also expensive: liquid nitrogen and tetracycline — the antibiotic used — are both costly in developing countries.

For these reasons, the infection-and-treatment method is not practical across much of Africa. ILRI's tick-borne diseases research programme has thus also worked to develop novel vaccination strategies against East Coast fever. ILRI molecular biologists have been experimenting with a protein found on the surface of the *T. parva* sporozoite — the form of the parasite that passes from the tick into cattle. This protein, known as p67, is found in all stocks of *T. parva* that have been tested. Early trials showed that injecting cattle with purified p67 causes them to produce antibodies against this protein that stop the sporozoites entering the white blood cells under laboratory conditions.

In 1989, ILRAD scientists cloned the gene that produces p67. By inserting the parasite gene into other organisms, such as *Escherichia coli,* they were able to produce large quantities of the protein. ILRI scientists have been inoculating cattle with p67 produced by *E. coli* for several years now and have found that, in certain formulations, it can generate strong immune responses that protect 60 to 100% of the animals inoculated.

A drawback of this experimental vaccine is the time and expense involved in producing both the p67 antigen and the adjuvant formulation that enhances immune responses to it. ILRI scientists are thus now working to develop ways to 'deliver' the p67 antigen to the cattle's immune system in a way that will provoke a similar immune response to that obtained by injecting them with the pure antigen. This is where the 'live delivery systems' come in.

Recombinant vaccinia viruses incorporating the Theileria parva *gene that codes for the p67 antigen. ILRI is testing a number of recombinant micro-organisms for their ability to protect cattle against East Coast fever.*

What is a live delivery system?

A live delivery system is one in which a recombinant microorganism—that is a bacterium or virus into which a parasite gene has been introduced by molecular engineering—that produces the desired antigen is injected into the animal. This organism then produces the antigen in the animal, the animal's immune system responds by producing antibodies, resulting in immunity Most of ILRI's work on live delivery systems has focused on recombinant viruses and bacteria.

Why live delivery systems?

Live delivery systems have a number of advantages over the purified antigen vaccination system under African conditions. They do not need sophisticated storage and handling. Vaccinia viruses or *Salmonella* bacteria can be lyophilised — freeze-dried like coffee — and kept indefinitely Add water and they come back to life. They are cheap to make. Another advantage is that you do not have to purify the antigen and there is no need for an adjuvant; the organisms themselves act as their own adjuvants.

Progress to date

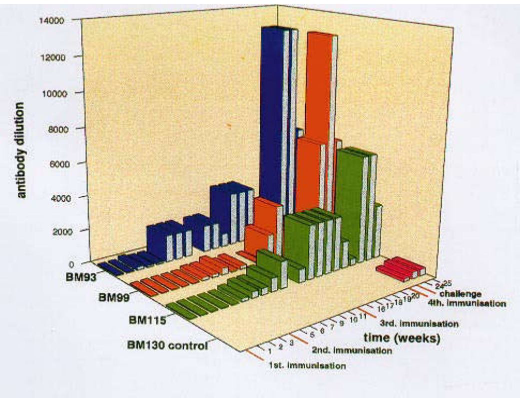
ILRI has produced recombinant *Salmonella* bacteria and vaccinia viruses that produce p67 in infected cells and these have been tested in laboratory animals and in cattle with some promising results.

Responses to inoculation with recombinant vaccinia virus have generally been quite poor, possibly because the virus does not produce enough p67 to provoke an immune response that is strong enough to eliminate a large proportion of *T. parva* sporozoites. One approach that is being explored to increase the efficacy of inoculating with vaccinia virus is to develop recombinant viruses that also produce cytokines—chemicals that modulate immune responses. In trials in 1995, inoculating cattle with a recombinant virus producing p67 and another producing a cytokine, IL4, resulted in dramatically enhanced antibody responses. Tests with several other cytokines failed to elicit greater immune responses. ILRI scientists have now created a strain of vaccinia virus that produces both p67 and IL4 and trials are under way to test its efficacy

Trials with *Salmonella* have been more promising. In the limited vaccination trials conducted so far with the recombinant *Salmonella*, vaccinated animals show a less intense reaction to the engineered parasite protein than they do to the protein plus adjuvant — antibody titres range from 1:6400 to 1:12,800 with *Salmonella* compared with 1:500,000 to 1:1,000,000 for the antigen plus adjuvant — but the levels of protection conferred seem to be the same. Of the three calves inoculated with recombinant *Salmonella*, one showed complete resistance to a subsequent *T. parva* infection, one developed a mild case of the disease, and one developed severe disease.

In working with recombinant organisms, ILRI is sensitive to public concerns about releasing genetically altered organisms. Some people have expressed concern about using altered vaccinia viruses, although these have been used to vaccinate animals against rabies for several years in Europe and North America without problems. However, ILRI is responding to these concerns by looking to other organisms that are already present in the environment. For example, in East Africa there is an indigenous disease known as Lumpy Skin Disease that is caused by a relative of the vaccinia virus called capripox virus. Farmers in the region already routinely vaccinate their animals against capripox virus. ILRI has already made a recombinant capripox virus that incorporates the p67 gene which may work as a dual vaccine against both Lumpy Skin Disease and East Coast fever. This should be readily accepted by farmers, since they are already vaccinating against capripox, and it should overcome environmental concerns, as the virus is already present in the environment.

Immunising calves with recombinant Salmonella *bacteria expressing the p67gene appears to confer levels of protection similar to those achieved by inoculating calves with the purified antigen plus an adjuvant. The graph shows specific antibody responses of calves immunised with recombinant* Salmonella *bacteria expressing the* Theileria parva *p67gene.*



Attacking the schizont form

Further work is under way to try to improve the efficacy of the p67-based inoculation system. One difficulty with this vaccination system is that the sporozoite form is present in the tissues for only a short time. Once the parasite enters the host?s lymphocytes it is no longer vulnerable to antibodies. And it is the later, schizont form which develops in the lymphocytes that kills the host, causing uncontrolled multiplication of the lymphocytes in a way that resembles leukaemia. If even a few sporozoites manage to evade the antibody response and enter lymphocytes the animal will develop the disease.

Lymphocytes infected with the *T. parva* schizonts are attacked by cytotoxic T cells (CTL). These cells destroy body cells that display ?foreign? proteins, including cancerous cells and cells infected with viruses and schizonts. But stimulating a CTL response is almost impossible using conventional vaccine formulations.

One way that it can be done is to use recombinant vaccinia virus, in much the same way that ILRI has done with p67. In this case a gene coding for a schizont protein is inserted into the vaccinia virus, and the virus is injected into cattle. On infecting the host cells the virus produces the *T. parva* schizont protein, provoking a CTL response. Preliminary tests with such a recombinant virus showed that cells infected with it are killed by *Theileria*-specific cytotoxic T cells *in vitro.* In 1995, trials with cattle showed that inoculation with the recombinant virus provoked a specific CTL response directed at the *T. parva* protein.

Trials are also under way testing the possibility of using *Salmonella, Listeria* and naked DNA as the carriers for the parasite gene, but these are still at an early stage.

Where to now?

So far ILRI?s programme has developed live recombinant vaccines, based on attenuated *Salmonella,* that give a reasonable antibody response and a good degree of protection against *T. parva* infections. This work is progressing, as is work on developing improved vaccinia viruses that produce both p67 and IL4, the cytokine that helps stimulate antibody production by the B cells.

The next stage is the development of a vaccine that will stimulate an effective cytotoxic T cell response that will fight the infection once the parasite has entered the host?s lymphocytes. ILRI scientists have identified a protein expressed by the schizont stage which stimulates a CTL response. The gene coding for this protein has been cloned, sequenced and inserted in vaccinia virus, and early trials to test its effectiveness as a vaccine are in progress. Further work is in progress to make recombinant viruses that produce IL7, another cytokine, but one that promotes the CTL response, rather than the antibody response.

Once the institute has completed it laboratory testing of the p67 antigen, it will seek close collaboration with national and regional project to help it validate the efficacy of the p67-based vaccine in protecting cattle against East Coast fever.

Similar work is also addressing another important cattle disease, heartwater, caused by the parasite *Cowdria ruminantium*.

While the major focus of this research is on East Coast fever, the results appear to be applicable to another *Theileria* parasite, *T. annulata*, which causes tropical theileriosis. This parasite affects a much larger area than *T. parva* does, being found all the way from the south of Spain, across North Africa, to China. It is of considerably more economic importance but because of its distribution — much of it within Europe and the former Soviet Union — it was not initially seen as a disease that the CGIAR should be working on. But ILRI's work with *T. parva* has relevance to *T. annulata*. There is an analogue of p67 in *T. annulata* and p67-specific antibodies cross-react with sporozoites of *T. annulata*. ILRI has not yet tested whether this would protect against *T. annulata*, although there is some indication that it would. It is also likely that the schizont antigen that ILRI is working on has an analogue in *T. annulata*.

As scientists gain a greater understanding of the bovine immune system, they are better able to engineer vaccine systems that produce the desired response—antibody response against free parasites in the blood, CTL responses against parasite-infected cells. As our knowledge grows, so does the prospect of effective, safe vaccines against a range of livestock diseases.

Mice and cattle immune systems like chalk and cheese

Recent research at ILRI shows that trypanosome parasites affect the immune systems of mice and cattle in radically different ways. Hardly surprising, some might say, but a crucial finding nonetheless since much of the research on trypanosomiasis is done in mice, not cattle. ILRI is, in fact, the only major research institute studying the immunology of trypanosomiasis in cattle.

Scientists usually divide the immune system in two main parts: the innate system (composed mainly of macrophages and their products) and the acquired system, which induces memory (and which is the part stimulated by vaccinations). The acquired system of all higher animals involves at least three key white cell types: B cells (important for the antibodies that they secrete), CD8-T cells (which include cytotoxic T cells) and CD4- or helper T cells, which include the regulatory cells that help the immune system to manage its affairs in a controlled manner. B cells produce antibodies that bind to foreign organisms circulating freely in the body fluids. Helper T cells, once activated, produce cytokines, chemical messengers that, among other things, help B cells to proliferate, differentiate and secrete antibodies. Cytotoxic CD8-T cells kill cells of the host that are infected with pathogens, such as the protozoan parasite *Theileria parva,* which causes East Coast fever in livestock, and the influenza virus which affects humans. Trypanosomes do not enter the cells of their hosts, and hence cytotoxic T cells do not have a direct role in destroying them. Other CD8 cells secrete cytokines that may impair harmful pathogens.

Helper T cells in mice and cattle

Research in mice has shown that helper T cells have no effect on the animal's response to a trypanosome infection, and that CD8-T cells increase the rate at which trypanosomes proliferate. ILRI's findings from cattle contradict these findings: helper T cells are vital to the immune response of cattle while cytotoxic T cells have no effect on a trypanosome multiplication.

Scientists have bred strains of mice that have no helper T cells, and they can thus readily compare the effects of a trypanosome infection in mice that either have or do not have these cells. And their finding is that there is no difference in the amount or type of antibodies the mice produce. Ergo, helper T cells are not involved in producing antibodies against trypanosomes. In mice.

No-one has bred cattle that do not have helper T cells, so such a comparison is much more difficult in cattle. What ILRI's scientists did was to make antibodies to bovine helper T cells and inject these into normal cattle. This knocked out at least 99% of the helper T cells for two weeks, allowing the scientists to assess their effects on a trypanosome infection.

And what they found was that the cattle produced almost no antibodies—not even the 'crude' IgM antibodies that are the initial response to infection. So clearly helper T cells play a strong role in the antibody response of cattle to trypanosomes, in contrast to the situation in mice.

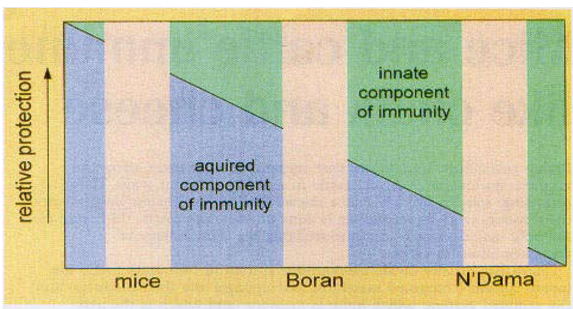
Interestingly, and again in contrast to what happens in mice, removing the antibodies did not completely destroy the cattle's ability to control the parasite, only lessened it. Mice with no B cells and hence no ability to produce antibodies — have no control over the parasites and die soon after infection. So, while mice are totally dependent on antibodies for their ability to control trypanosome infections, cattle have a second mechanism that is normally masked by the antibody response.

Acquired and innate immunity

Tests in susceptible Boran cattle and trypanotolerant N?Dama cattle using this T-cell-depletion system showed differences between the breeds in the proportion of their ability to control trypanosome infections that is provided by the ?acquired?antibody response and the ?innate?response. N?Dama cattle rely less on their antibodies and helper T cells to control parasitaemia, and probably have a more efficient innate control system than do Boran cattle.

This is the first time that scientists have been able to eliminate effectively the acquired immune system in cattle and actually observe the innate system at work. Scientists have speculated about the existence of the innate system and its role in trypanotolerance for a long time but have not been able to study it. ILRI scientists believe that this innate control system is based on macrophages, and already studies have identified mechanisms the parasite uses to avoid this system *(see 'Interpreting the language of parasites').*

Mice depend entirely on their antibodies for protection against trypanosomes. Cattle have a second, ?innate?, mechanism that helps protect them against trypanosomes. This innate system is particularly well developed in trypanotolerant cattle such as the N?Dama.



CD8-T cells—again a difference between cattle and mice

Recent research in mice has indicated that CD8-T cells actually increase the proliferation of trypanosomes by up to a thousandfold. Again, in mice. If this were true also in cattle, it would open up possibilities for developing novel control strategies.

Using antibodies to knock out the CD8-T cells in cattle, ILRI scientists have shown that these cells have little or no effect on trypanosome proliferation in cattle, in contrast with their effect in mice.

Vital reminders

These findings, highlighting crucial differences in the immune system between mice and cattle, provide a vital reminder of the need to study trypanosomes in their natural hosts, cattle, rather than relying too much on the mouse model. The mouse model has its uses but, as one ILRI scientist noted, if we blindly follow results from mice we may end up with a vaccine for mice but not for cattle.

Interpreting the language of parasites

ILRI's dozen or so bench scientists investigating trypanosomiasis are taking several approaches to finding new and better ways of controlling this widespread tropical disease. A group of immunologists, for example, has been dissecting the responses of the immune cells of cattle to trypanosome infections, while molecular geneticists have developed ways to isolate genes of the single-celled trypanosome parasite that are 'switched on' during part of the parasite's life cycle in its animal host.

Results obtained in the last year in these two very different research projects point to the same chemical compound — a protein molecule that has important functions within trypanosomes but that can also act as a biological messenger molecule in an infected animal causing perturbations of its immune system. Trypanosomes survive and multiply in the blood of an infected animal, a very hostile environment where the trypanosomes are under continuous attack by the host's immune system. However, they have developed ways to fool the immune system into reducing the intensity of its attack and directing it elsewhere.

Scientists undertaking very different kinds of research rarely arrive simultaneously at exactly the same point — in this case a single protein molecule. When they do, the results of each approach tend to validate those of the other. In this case, the evidence indicates that the protein identified by both groups is likely to be significant in the interactions between trypanosomes and cattle that are susceptible to their pathogenic effects.

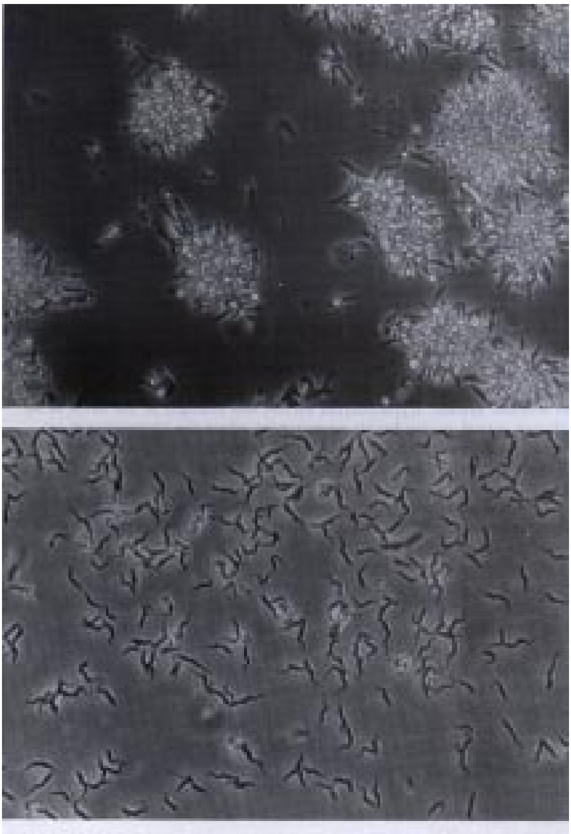
The knowledge that eukaryotic cells — which include nucleated cells ' of mammals as well as protozoa such as trypanosomes — communicate with each other is not new but is becoming a fashionable topic in parasitology. Recent articles in *New Scientist* and other popular science publications describe evidence that groups of single-celled organisms can behave like communities, behaviour that implies communication.

ILRI has invested considerable scientific effort in characterising different kinds of cells of the ruminant immune systems and discovering how protozoan parasites interact with the cells of the immune system and how the immune cells interact with and influence each other.

Starting from the parasite

Building on this expertise, a few years ago ILRI molecular parasitologists began to search directly for trypanosome genes and products that influence the rates at which the parasites proliferate and differentiate in their animal host into different life-cycle forms. Results of these studies confirm that trypanosomes communicate with each other using chemical messenger molecules and that they also send chemical messages to and receive them from cells of their hosts. By developing new analytical methodologies and by adapting the latest genetic tools to pick out signals of interest from the multitude of other signals sent by parasites and mammalian immune cells ILRI's scientists have intercepted and decoded several chemical signals of great potential use in controlling trypanosome infections and the disease they cause.

The trypanosome has a complex life cycle, switching rapidly from one form to another, particularly as the parasite passes from the tsetse-fly vector to the bovine host and from the host to the vector. As it goes through these changes the parasite has to switch on the genes needed to establish itself in its new environment, switching them off when they are no longer needed. When a gene is turned on the protein it codes for is produced; when the gene is turned off, production of that protein stops. ILRI research has shown that some of the genes turned on when the metacyclic form of the trypanosome first enters the animal host are ones that code for the protein molecules that depress some of the host's immune responses and enhance others that do not control the disease.



Two different life-cycle stages of trypanosomes grown in culture: one, which forms clusters of cells, is found in the mouthparts of tsetse flies and gives rise to forms that infect cattle; the other, which grows as individual cells, is found in infected animals. Different genes are expressed in these two forms. ILRI scientists are identifying and characterising these differentially expressed genes to understand how the parasites cause disease and to develop new ways to control them.

By finding out which genes are switched on at any given stage in the parasite's development, scientists can discover what proteins the genes code for and, ultimately, find and block signals that help the parasite establish itself.

Another promising area is the mechanism by which the parasite controls its rate of proliferation, switching from an actively dividing form to a non-dividing form. By switching to the non-dividing form the parasite avoids overwhelming and killing its host. Signals between the parasites and the host must trigger the change to non-dividing forms. If scientists can identify these signals, they may be able to mimic them, as well as other signals already identified that modulate the host's immune system, thus slowing the proliferation of the parasite and giving the animal's immune system a chance to clear the parasites from the blood.

Scientists at ILRI have developed a highly sensitive and powerful technique that allows them rapidly to identify genes that become active, or are expressed, in different stages of the parasite's life cycle or in response to different environments. This technique, known as RADES-PCR—short for randomly amplified developmentally expressed sequences by the polymerase chain reaction—identifies differences in gene expression by producing barcodelike 'fingerprints': where there is a bar of DNA, there is an active gene. By comparing fingerprints from trypanosomes in different developmental stages, scientists can see which genes are switched on in one stage but off in another. The ILRI technique is exceptionally quick: it has reduced the amount of time it takes to identify a gene to a thousandth, and reduced the amount of parasite material needed to one ten-millionth, of what was needed previously. And since all living things employ the same genetic code, this technique for deciphering the language used by trypanosomes can be applied to all living things.

Having found genes that are switched on, it is possible to clone them and derive their DNA sequence. This is then compared with DNA databases around the world through the Internet to find out if a similar type of gene has been described elsewhere, either in the same kind of organism or another organism, or whether the gene is as yet unknown. The DNA sequence also gives the scientist an indication of what kind of product the gene is producing, whether, for example, it is likely to be a surface molecule, a molecule that is excreted or one that will stay within the cell.

ILRI scientists are currently examining about 100 potential target molecules produced by genes that are switched on in the bloodstream-form trypanosomes but switched off in metacyclic trypanosomes (the form found in the tsetse fly). Among these molecules is cyclophilin, an enzyme that has also been identified as a potential target for therapeutic intervention by another research team that is investigating protein molecules from parasite extracts that influence the bovine immune system.

One of the effects of trypanosomiasis is to alter the function of macrophages, cells that dispose of diseased and damaged body cells and other debris by ingesting them. These changes can account for some of the pathology observed in trypanosome-infected animals. Cyclophdin has now been shown to influence macrophage function and trypanosome cyclophilin, in association with other parasite factors, may well have a role in the pathogenesis of the disease. An immunosuppressant drug called cyclosporin, which is used in tissue transplants to suppress the immune system of the recipient and prevent tissue rejection, acts by binding to cyclophilin. This effectively inhibits T-cell activation and so knocks out an arm of the immune system. It thus seems likely that cyclophilin is involved in altering this arm of the immune system - an arm that has little or no effect on the trypanosomes but, in effect, turns the immune system's efforts against itself

Cyclophdin from the three trypanosome species being studied by ILRI—*T. congolense, T. vivax* and *T. brucei*—shows some differences in amino acid sequences. What was surprising was that the bovine gene encoding this enzyme—which has been cloned and is now in the global databases differs in significant parts of its sequence to that encoding the same enzyme in the parasite. Two regions of the sequence are absolutely specific to the parasite. These two segments occur in all three parasite species but not in the bovine sequence, strongly suggesting that they are needed for the molecule to function properly in trypanosomes.

ILRI scientists are now trying to knock out these parasite-specific parts of the molecule, singly and together, and see whether this influences the molecule's effects on the immune system. That will tell them whether these are real targets or not, whether they are really important to the activity of the molecule. The next step will be to take the gene for cyclophilin, mutate it and put it back into the parasite. The parasite will thus have a defective gene for cyclophilin and will either produce dysfunctional cyclophflin or will not produce the molecule at all. The scientists will then see what effects this malfunction has on the virulence of the parasite *in vivo*. *If* the genetic alteration reduces the virulence of the parasite, the host's immune system should be able to overwhelm the parasite and clear the infection.

One potential problem is that if the 'new' gene produces cyclophilin that no longer works, the parasite may evolve mechanisms that make up for the malfunction. If the parasite is readily able to do this, ILRI scientists will include additional molecular targets, which they continue to identify, in their intervention strategies. Current experiences indicate that an attack on more than one part of an infecting organism significantly reduces its chances of overcoming the attack.

Starting with the host

The second project that identified cyclophilin as a possible cause of pathology in trypanosomiasis was a collaborative activity between ILRI immunologists and a research group at the Free University of Brussels. It started from the standpoint of the host's immune system, rather than the parasite's genes. Observing that immune dysfunction is a sign of trypanosomiasis, and that macrophage activity is altered, the immunologists hypothesised that the trypanosomes cause disease by altering the activity of macrophages. Macrophages produce cytokines, chemical messengers that regulate actions of the immune system. One of the cytokines that appears to be involved in trypanosomiasis is TNFα—tumour necrosis factor alpha—which appears to be produced in larger quantities in trypanosome-infected cattle than in uninfected cattle. The amount produced seems to be related to the severity of anaemia that develops during an infection. TNFα has also been implicated in the development of anaemia in malaria.

Having identified a possible cause of anaemia, the next step was to find out what trypanosome products induced the macrophages to produce TNFα. This involved breaking down trypanosomes into their component molecules and treating macrophages with the resultant fractions to see which, if any, had an effect on macrophage function. Using this approach, ILRI scientists identified a fraction, consisting of two major proteins, that activates macrophages *in vitro*. One of the two proteins is cyclophilin. Preliminary immunisation trials show that cattle inoculated with this fraction produce antibodies that can stop the fraction from having an effect on macrophages. Immunisation with this fraction delayed the fall in packed cell volume—a measure of anaemia—by five to six weeks when the animals were infected with an unrelated trypanosome strain. The antibodies also cross-reacted with the protein identified by the molecular genetic approach described at the beginning of this article.

Promise for the future

Two different approaches, the same molecule. These preliminary results suggest that the research is on the right track, that there is 'cross-talk' between the parasite and the host. Early results suggest that it may be possible to intervene and disrupt the trypanosome's messages to restore the host's normal immune response.

In the years between the major breakthroughs in molecular biology in the 1960s and 1970s and the discovery of the nature of the trypanosome's variable surface coats in the 1980s, researchers working on trypanosomiasis had great hope that they would isolate a dominant protein on the surface of the trypanosome that would elicit protective immune responses in cattle. In the 1980s, elucidation by ILRI and other research institutes of the extensive repertoire of genetic mechanisms employed by the parasite to change its surface coat reduced hopes for a conventional vaccine against trypanosome infections. In the last decade or so, this pessimism led many scientists in the area to turn to research aimed at stopping the development of the disease rather than stopping infection. Over the last few years, all has changed again, with prospects for developing several powerful interventions to control trypanosomiasis, including a conventional' vaccine, rising dramatically.

Such feast and famine cycles in opportunities are in the nature of research; scientists who cannot withstand the periods of famine, during which protocols have to be perfected or new techniques developed before they can move forward, will not remain at the lab bench for long. In ILRI's trypanosomiasis programme today, however, the famine is decidedly over.

GIS—a research tool and beyond

Geographical information systems (GIS) are helping ILRI scientists get more out of their data and understand complex environmentally influenced problems in ways that were not possible before the advent of these powerful computer tools. GIS are computer systems that synthesise, analyse and display many different types of geographic data in an understandable form. GIS allows us for the first time to test research and management questions rigorously at the scale of whole ecosystems, regions or even the globe. Current uses range from investigations of agricultural production systems at the village level through decision-support systems for disease control and management at a national level to continental-level assessments of the potential costs and benefits of disease control.

Controlling tick-borne diseases in Zimbabwe

Collaboration between ILRI and the Department of Veterinary Services in Zimbabwe is developing a computer-based decision-support system that will help make best use of veterinary resources in the country.

This decision-support system grew out of research in Zimbabwe on factors that affect national strategies to control tick-borne diseases. For many years the country operated a highly effective national tick-borne-disease control programme, based on intensive application of acaricides. In the 1970s, however, this system broke down during the pre-independence war and the Department of Veterinary Services (DVS) began considering alternative control options that were not so heavily dependent on the acaricides. ILRI started working with the DVS in 1988 to enhance studies already initiated by Zimbabwean scientists on the economics of different control strategies.

Economics of alternative control strategies

These initial studies considered three possible strategies:

- an intensive control programme, involving weekly dipping during the summer and fortnightly dipping for the rest of the year
- reduced dipping, involving fortnightly dipping in the summer and monthly dipping for the rest of the year
- a combination of weekly dipping during the summer supplemented by natural or artificially induced herd immunity to tick-borne diseases and minimal dipping.

Scientists identified target populations for each of these strategies and made projections of their likely effects on the distribution and occurrence of the tick-borne diseases. The analyses indicated that both the reduced dipping and the strategic minimal dipping strategies were more cost-effective than the intensive dipping system, potentially reducing the cost of control in the Communal Lands by up to 46%. Since this time, Zimbabwe has abandoned its intensive dipping programme and relaxed the reduced-dipping regimen. Now the country is following a strategic tick control policy that is flexible in its application and more responsive to different needs.

Testing assumptions

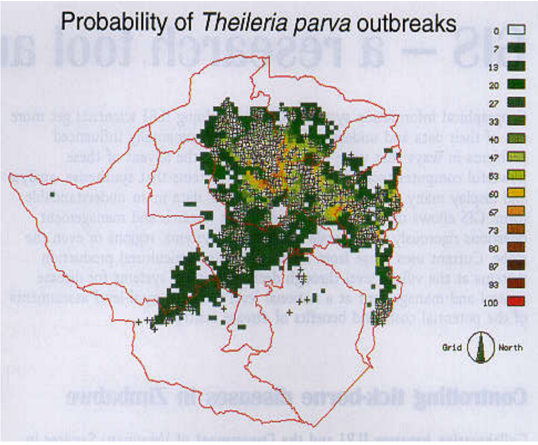
These analyses relied on a number of critical assumptions, which had to be tested. This was the origin of the use of GIS in the project, which ultimately led to the precursor of a decision-support system.

One of the most important assumptions was that reducing acaricide use would not affect the distribution and occurrence of tick-borne diseases. To test this, scientists developed a series of models within the GIS to examine the influence of climate, vegetation and land use on the distributions of the main tick species in Zimbabwe, *Rhipicephalus appendiculatus, Boophilus decotoratus, Amblyomma hebraeum* and *A. variegatum.*

Scientists first used a model that matches climatic variables with the requirements of particular organisms to determine the areas of Zimbabwe that are best suited to these four tick species. They then compared these areas of climatic suitability with those areas where the ticks are found and, in the case of *R. appendiculatus,* where theileriosis (East Coast fever) occurs.

The predicted distribution of *B. decoloratus* matched well with its actual distribution. It was thus concluded that reducing tick control would be unlikely to increase the incidence of the diseases carried by these ticks (babesiosis and anaplasmosis).

The match between predicted and actual distribution was good also for *R. appendiculatus,* and the accuracy of the predicted distribution was enhanced when land-use category (commercial or communal) was included in an improved model. While the highveld is climatically suitable for this tick, much of the communal lands there are overgrazed and the ticks do not have the vegetation cover they need to survive. Again, the model suggests that it is unlikely that there would be an increase in the occurrence of thelieriosis in these areas given the continuing high grazing pressure.



A GIS-generated map of zimbabwe showing locations of actual outbreaks of East Coast fever (crosses) and probabilities of outbreaks based on environmental factors.

The actual distributions of the two *Amblyomma* species were almost totally at odds with the predicted distribution based on climatic suitability. Climatically, the highveld is the best environment for these ticks, but they have been found almost exclusively in the northern (*A. variegatum)* and southern (*A. hebraeum)* lowvelds in the past. The analyses suggested that the main factor favouring the survival of these ticks in the lowveld is the presence of abundant wildlife, particularly large herbivores, that acts as alternative hosts for the adult ticks. Although the highveld is climatically more suitable for the ticks, farmers have long been intensively treating their cattle with acaricides and there have been relatively few wild alternative hosts for the ticks. The analyses thus suggest that reducing tick control will result in the spread of *Amblyomma* ticks, and cowdriosis, the heartwater disease they spread, to the highveld.

Multiple uses

Since 1989, the collaborative project has developed almost 100 georeferenced data sets covering a wide range of factors that can, or might, influence tick distribution or other determinants of disease outbreaks. ILRI's initial interest was in gaining a better understanding of the epidemiology of tick-borne diseases and the likely effects of implementing different control strategies in southern Africa, in collaboration with the Zimbabwe Department of Veterinary Sciences, but the DVS in Harare has taken the system and broadened its use to meet the Department's needs. These include information on other diseases that are not tick-borne, including rabies, tuberculosis, African swine fever and Newcastle disease, which affects poultry.

A key use of the GIS system is in disease reporting and management. The DVS now produces a weekly report on rabies distribution, together with monthly, quarterly and annual summaries. The system was used recently in managing a large outbreak of Newcastle disease in the country Using the system, the Department was able to monitor both the occurrence of the disease and the progress of their vaccination programme, matching one to the other faster than would have been possible using conventional means.

Going beyond this disease reporting function, once the full system is in place—microcomputers in all veterinary department offices around the country, together with modems so they can send their information to the central office quickly and easily—it will support disease control decisions by providing rapid access to information on which these decisions can be based. The systems have great potential in decision support. Take, for example, the case of a disease outbreak in a particular place. To prevent the disease from spreading, veterinarians might consider vaccinating all the animals within, say, a 10-km radius of the focus of the outbreak. What does this involve? How many animals? What age ranges? Where is the nearest veterinary centre holding vaccines and what does it have in stock? When and where are the markets where animals are traded? With this information, stored in geo-referenced data 'layers' in the GIS system, the people organising the response to the disease outbreak can rapidly determine the size of the problem they have to deal with and what. resources are available to them.

The degree of sophistication of such a system is limited only by the quality of the data that are put into it and the models that are programmed into it. Data quality is a crucial area, and knowledge of the behaviour of a disease and its vectors is central to the development of a decision-support function.

Maximising human benefits, minimising environmental costs

A key use of GIS techniques at ILRI is to help identify where resources can best be focused to increase food production through livestock while minimising harm to the environment.

The argument for controlling the tsetse fly that transmits trypanosomiasis in livestock is strong. The threat of trypanosomiasis restricts livestock production in over 10 million km^2 of Africa. Where the incidence of the disease is high, farmers can keep trypanosusceptible livestock only by treating them regularly with trypanocidal drugs, by reducing the fly population, or both. If farmers cannot keep livestock, they cannot plough their fields as effectively or plough as much land as they could if they had draft animals to help them. They have less access to livestock products such as meat and milk, which are so important in human nutrition.

The argument against controlling the tsetse fly is also strong. If the tsetse fly is eliminated or trypanosomiasis is controlled, it may unleash the expansion of cultivation and livestock populations throughout formerly tsetse-infested areas. Farmers will cut down trees, converting forest and savannah to crop land, with all the associated harm to the environment: loss of biodiversity, increased erosion *inter alia*.

Modelling the effects of trypanosomiasis control

As part of its efforts to ensure that animal health interventions will benefit as many people as possible while minimising harm to the environment, ILRI scientists have developed GIS-based models to identify regions where:

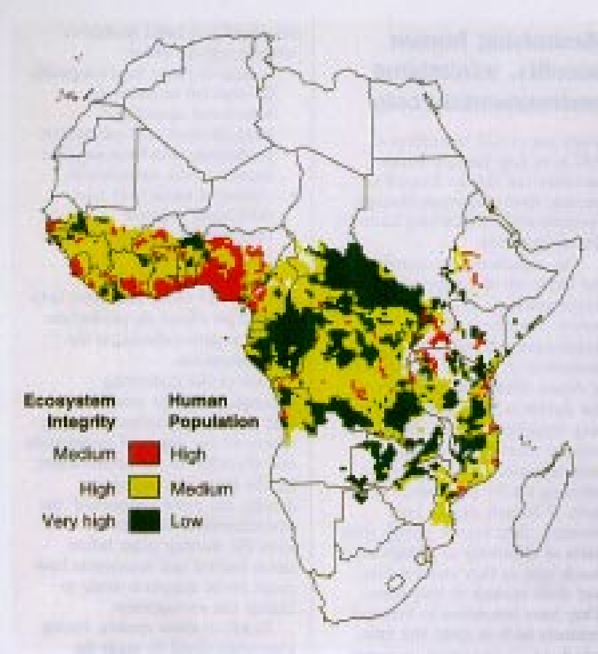
- control of tsetse may reasonably be expected to result in substantial agricultural intensification and increases in production with little negative impact on the environment
- control of tsetse may have substantial negative environmental impacts with little positive effect on agricultural production
- control of tsetse may have both positive effects on production and negative effects on the environment.

One of the underlying assumptions of the models was that human population density is related to the degree of exploitation and alteration of the environment, i.e. the lower the population density, the more 'untouched' the environment is likely to be. This gives the starting point before tsetse control and determines how much tsetse control is likely to change the environment.

Based on these models, strong arguments could be made for controlling trypanosomiasis where the human population density is already moderate to high since large numbers of people would benefit from having more, healthy livestock in their production systems. Most, if not all, land suitable for agriculture would already be cultivated in these areas, and increases in agricultural production would have to come from intensifying the production systems through adding a livestock component or further integrating crops and livestock. Since the human population density is high, it is likely that these environments have already been substantially altered by human activity, so increasing agricultural use is unlikely to cause further substantial losses of biodiversity or habitats.

At the other end of the scale there are areas where there are virtually no people. Based on the assumption that low human population density indicates relatively unchanged environments, these are the areas where any change that increases human exploitation may lead to large negative impacts on ecosystems. Most of these areas are a long way from places where there are high human population densities, so opening them up by controlling trypanosomiasis would benefit fewer people.

Then there are the intermediate areas. These are the areas where there is a moderate level of population. There is scope for increasing the amount of land that is cultivated in these areas. There are already large numbers of people in these areas and the areas are close to more-densely populated areas, hence large numbers of people would benefit from the increase in agricultural production The downside is that there is considerable risk of harm to the environment through opening up new land and fragmenting plant and wildlife habitats.



GIS-generated map indicating levels of ecosystem integrity in tsetse-infested areas of Africa. The model used to develop the map uses level of human population as an indicator of the degree of ecosystem exploitation. GIS-based models can help guide research and development efforts and targeting of resources.

Providing guidelines

This GIS approach is useful in helping guide development efforts and target the use of resources. It still needs refining, with an updated map of tsetse distribution and the addition of databases on soil fertility or land-use suitability, infrastructure (to help determine how easily populations and goods can move into and out of an area) and ecological 'hotspots' that need protecting. But this project is showing what can be done with GIS techniques to help policy makers and decision makers in their efforts to assign resources where they are most needed and can provide the most long-term benefit to the most people while minimising the cost to the environment.

GIS in production system research

Several ILRI projects are using GIS techniques to model local land use and its effect on productivity One of these is a project in Niger that is studying nutrient flows in farming systems in the southern Sahel.

Levels of nitrogen and phosphorus in Sahelian soils are major determinants of crop and rangeland production in this region. Livestock play a central role in cycling these nutrients from pastures to crop lands and from crop residues back to the soil. But many factors affect these nutrient flows, in terms of both amounts and their distribution in space and time. These include land and soil type, land use, feed production and herd size and management. Making sense of all these factors and how they affect each other and nutrient flows is highly complex. This is where GIS tools come in.

The study covers three villages and their associated lands. The three villages are close to one another in similar environments, 80 km east of Niamey, but differ markedly in human population density, the proportion of their lands that is cultivated and livestock stocking rates. Together, they cover roughly 500 km^2 of land.

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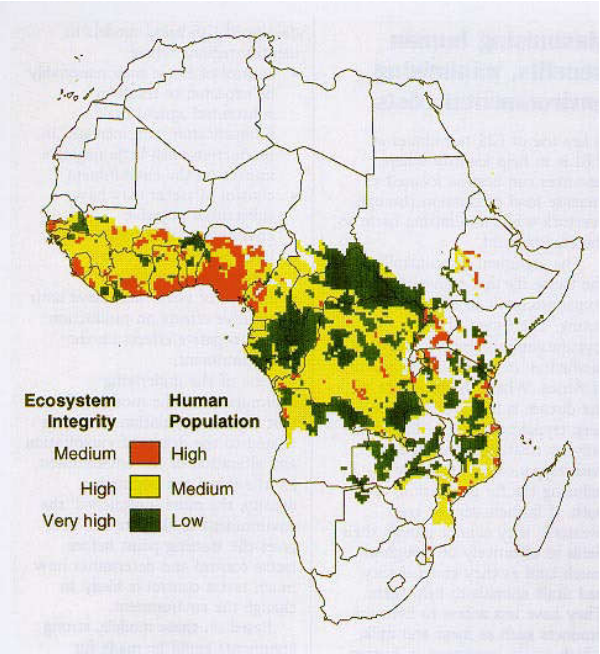

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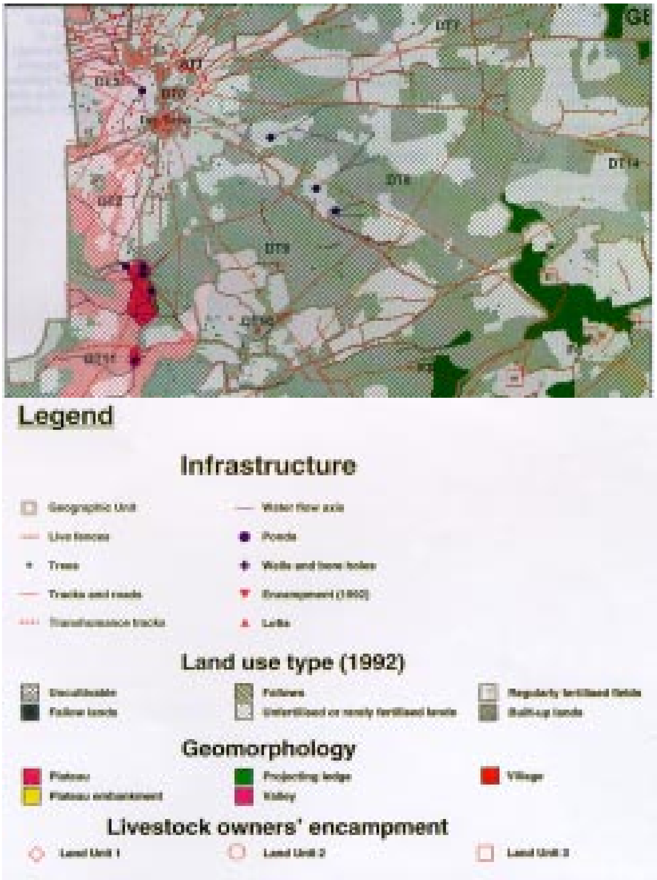
The first stage of the GIS work has seen the development of detailed maps of geomorphology and land use for each of the villages from aerial photographs. Land-use features mapped include the boundaries of fields (manured and not manured), fallows, rangelands, villages and encampments, roads and paths, cattle tracks, field hedges and isolated trees. Based on this information, the area mapped has been divided up into nearly 700 territorial units that will form the basis of the nutrient— and organic-matter budgeting exercise.



A GIS-based map of a village and its associated lands in Niger, focusing on geomorphology and land use.

The GIS system is also being used to generate the maps that are guiding the field surveys and year-round monitoring of feed resources, herds and herdmanagement practices. Data are being collected every three weeks on the numbers of animals in each herd, species, age categories, resting locations and management factors. These are being related to each of the territorial units identified on the maps. Scientists are studying standing biomass, nitrogen and phosphorus concentrations and digestibility of herbage, species composition on the rangelands and nutrient acquisition and excretion by livestock. Again, this information is being stored as GIS data layers.

Once the surveys and field data collection are complete, the GIS system will be used to calculate nutrient flows and test hypotheses to explain the role of herd management in natural resource and soil fertility maintenance. Ultimately, modelling will help extrapolate from the site where the studies were made to the broader geographical region of the West African semi-arid zone.

Tools for development and development

ILRI is making extensive use of GIS techniques for a range of purposes, from local-level analysis of livestock systems through continent-level models of the likely effects of disease control. As the technology, techniques and data sets improve, the information that these systems can provide increases in value, both to research scientists and to policy makers.

Women dairy farmers in Africa

Women provide 46% of Africa's agricultural labour, produce about 70% of its food, perform almost 60% of the marketing and do at least half of the tasks involved in storing food and raising animals. Alarmingly, however, only 20% of these women are the direct recipients of extension advice. Studies by ILRI and the Kenya Agricultural Research Institute (KARI) have investigated how this may have affected adoption of improved dairying practices.

Demand for milk is increasing in Africa and other parts of the developing world. In the past, much of this demand was met by cheap imports, especially from the European Union. But with recent falls in the 'milk lake' and consequent increases in world market prices, most developing-world governments can no longer afford this option. This has created opportunities to develop local production.

From 1988 to 1994, ILRI and KARI carried out research together at the Kenya coast to improve smallholder milk production and marketing systems for subhumid East Africa. Research focused on improving a package of practices recommended by the National Dairy Development Project (NDDP) of the Ministry of Agriculture, Livestock Development and Marketing. The package was based on introducing improved dairy cows, implementing disease control and improving feeding, in particular through growing forages such as Napier grass *(Pennisetum purpureum)*. The cows were managed in intensive zero-grazing units, farmers cutting feed and bringing it to them.

The KARI/ILRI team's improvements to the NDDP package has increased daily household income by the equivalent of one daily casual wage rate for each lactating cow in the unit. In addition, the dairy unit provides the farm family with an average of two litres of milk a day for its own consumption, improving family nutrition. But there were signs that women were shouldering a large part of the work involved in the intensive dairy units. The KARI/ILRI team and extension agents carried out a study to determine what effects the NDDP package had on women's workloads and what implications this would have for dairy development.

Milking time at the Kenya coast. But who really does all the dairy work? ILRI research shows that 84 % of dairy work is done by women on farms in the coastal subhumid zone.

The team interviewed women on 32 farms selected at random from among those that had adopted the NDDP package. Roughly half were on farms where extension workers delivered their technical advice to men; the other half were farms where the extensionists' contact was with women. By selecting the farms in this way, the study hoped to learn if technical advice was in fact reaching the person who actually used the technology and whether the choice of extension contact affected adoption and use of the NDDP dairy technology.

Who should extension workers be talking to?

The study showed that, while 84% of the farms included in the study were owned by men, 84% of the dairy operators were women. On the farms where extension messages were delivered to men, three-quarters of the dairy operators were women.

The problem with this is that technical information is not given directly to the person who will use it, but has to be passed on by the contact person to the dairy operator. This extra step in the line of communication hinders transfer of knowledge and reduces the efficiency of the extension agent's efforts. Furthermore, because the extension agent does not deal directly with the person using the information there is little opportunity for the dairy operator to ask questions if something is not clear to her or him. Similarly, the extension agent is less likely to get feedback on the new technology. Such feedback is critically important if researchers are to serve farmers effectively.

Who does the work?

Across all the farms, 48% of the people interviewed said that women did all or most of the dairy work, 25% said that hired labourers did most of the work and 22% indicated it was children who provided most of the labour. Only 5% said that husbands did most of the work in the dairy unit. But when they were asked who controls household dairy income, only 20% of the women on male contact farms stated that they did. Another 27% who reported receiving dairy income said that they shared its control with their husbands. Thus, on male contact farms, where three-quarters of the dairy operators were female, over half of the husbands had exclusive control over the income generated by the dairy enterprise and in another 27% of the cases they shared control.

Not surprisingly, this kind of inequity harms technology adoption and agricultural production in general. Indeed, NDDP extension officers reported that some female dairy operators said that their lack of enthusiasm and conscientiousness in following extension advice stemmed from the fact that, beyond meeting family milk consumption needs, they derived little reward from their input to the dairy enterprise. In response, they limit how much time and effort they put into the dairy unit.

What are the benefits of dairying?

Overall, three out of four women interviewed said that the package had added to their work load. Nonetheless, most were positive about the package. Almost all (97%) of the people interviewed said that their household income had increased since they adopted the NDDP package and nine out of ten said that they had more milk for home consumption.

The most common use of the additional dairy income was food for the household (72%), followed by school fees (34%), dairy inputs (34%), hired labour (22%), school books (16%) and clothing (9%).

Implications for dairy development

Any strategy for increasing dairy production in subhumid East Africa must take into account that many, if not most, smallholder units are managed by women. Dairying gives women a means of generating income and providing for the needs of the family. Women farmers will adopt new technologies, even if it means more work for them, if there are clear benefits to them and their families. But to operate their dairy units effectively, women must have access to and control over the resources they need. And women must be involved in defining the research agenda to make sure their needs are taken into account.

Ploughing with cows feasible in East African highlands

Research by ILRI and the Ethiopian Institute of Agricultural Research (IAR) has shown that crossbred cows can be successfully used for both traction and milk production in the East African highlands as long as they are adequately fed. Since 1993, scientists from ILRI and IAR and staff of the Ethiopian Ministry of Agriculture have been working with groups of farmers testing dairy–draft crossbred cows on farms in the Holetta area, about 60 km west of Addis Ababa. Surveys of the attitudes of these farmers in 1993 and 1995 are helping determine future courses of action.

The East African highlands are densely populated by people and support huge livestock populations. Pressure on land is intense. Many smallholder farmers use oxen for ploughing, but these animals work for only a few weeks each year. The rest of the year they consume valuable feed but produce little. One way to increase the productivity of these farms would be to replace the oxen with crossbred cows that can both work and produce milk and calves.

Ploughing with cows technically feasible

On-station trials over several years have shown that using crossbred cows—crosses between European dairy and dual-purpose (milk and meat) breeds and local zebus—as dairy–draft animals is feasible. The crossbred cows need more feed than local cows, in part because they are much bigger crossbred cows weigh about 350 kilograms compared with 250 kilograms for a local cow. But this weight advantage helps them work, because they are more powerful. Overall, if the crossbred cows were fed well enough, they were able to handle a full workload without substantially reducing the amount of milk they produced or reducing their reproductive performance. Economic analyses showed that using crossbred cows as dairy–draft animals could be profitable.

Extensive on-station trials by the Ethiopian Institute of agricultural Research and ILRI have demonstrated the technical feasibility of using crossbred cows as draft animals in the East African highlands.

Farmers test dairy–draft cows on farms

In 1993, the project started testing the crossbred cow package with 14 farmers near the Holetta station, where the on-station trials had been conducted. Each farmer bought two pregnant crossbred cows for 1200 birr (approximately US$ 200); the project provided credit for the purchase. Half of the farmers were asked to use their cows for milk production alone, while the other half were asked to use them for both milk production and traction. In 1994 and 1995 another 50 farmers were selected to take part in the study These farmers each bought two pregnant crossbred cows for 2400 birr (US$ 400) for the pair. Again, the project provided credit. Project staff visit each of the farmers weekly and collect production data on work, milk yields, feeding, body condition and health, and socioeconomic data on labour allocation, income generation, expenditures, consumption and anthropometric health measures. The on-farm trials were funded in part by a grant to IAR from the World Food Programme.

In 1995 the project carried out an anthropological survey to assess what project farmers and their neighbours thought of using crossbred cows as dairy–draft animals, what problems they were facing and who the project should focus its efforts on.

The survey showed an emerging group of younger farmers with more formal education who were more likely to adopt the use of crossbred cows as dairy–draft animals than older farmers with little formal education. Willingness to use cows as traction animals is also related to the amount of land the farmer has and how many cattle he or she owns: farmers with little crop and grazing land and with small livestock holdings were more willing to consider using cows as traction animals.

These findings present some difficulties for the development of cow traction in the area. 'Rich' farmers — those with plenty of land and large livestock holdings were keen to have crossbred cows, but only for milk production. They mostly saw no need to use cows as traction animals. 'Poor' farmers those with few livestock and little land — in contrast, were keen to use crossbred cows for traction but probably would not be able to afford to buy them and feed them. This group of farmers tends to follow a subsistence, risk-averse production strategy. The group most likely to be willing and able to use cows as traction animals were the young, educated, middleincome farmers. Although this is a small group, it offers the best prospects for sustainable adoption of dairy–draft crossbred cows.

Many farmers originally believed that using cows for traction would drastically reduce their milk yield, but experience has changed their attitude. Over the first two years of the project the average milk yield of working cows was only slightly less than that of nonworking cows (2620 vs 2980 kg).

Farmers emphasise milk yields

All the farmers were keen to have crossbred cows, but most were primarily interested because crossbred cows produce 8–10 litres of milk a day whereas local cows produce less than two litres a day Several farmers had obtained crossbred cows from sources other than the project for this reason.

Before the project brought crossbred cows to the Holetta area farmers sold only very small amounts of milk and dairy products. In large part this was because they did not produce much surplus milk. Farmers estimated that income from dairy-product sales averaged about 120 to 150 birr a year (US$ 20–25). Since the crossbred cows were brought in, however, project farmers are producing surpluses of milk and selling up to 14 litres a day to the Dairy Development Enterprise.

Farmers now estimate that they make 2000 to 2500 birr (US$ 320–400) net profit a year from their dairy enterprise.

The survey identified several concerns that farmers had. Foremost among these were the perceived susceptibility of the crossbred cows to diseases and the continuing availability of feed. In 1995 ILRI trained extension workers and project farmers to produce forage seed to ensure that farmers would be able to meet their seed demands once the project ends. Project staff are investigating how best to address the disease concern.

Moving into new areas with new partners

Moving beyond the project in Ethiopia, in September 1995 ILRI hosted an expert consultation on the transfer of technology for multi-purpose cows for milk, meat and traction in smallholder mixed farming systems. This meeting was organised in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the Australian Centre for International Agricultural Research (ACIAR). Participants from Ethiopia, Kenya, Malawi, Mozambique, Tanzania and Uganda brought proposals for adaptive trials in their countries. Scientists from Australia, Bangladesh, China, India, Indonesia, the Philippines and Thailand shared their experience with cow traction and discussed extending the project to Asia. The meeting developed a funding request to implement and study the transfer of the IAR/ILRI multi-purpose crossbred cow technologies to East African smallholders through a regional FAO/ILRI project. Activities in each country will be carried out with assistance from FAO experts, with ILRI scientists acting as resource persons.

Toxin-degrading microbes release multi-purpose tree feed potential

Most animals kept by smallholders in the tropics face periods when they have too little to eat or when the food they are offered is hardly worth eating. Much of what they have to cat consists of unimproved native pastures or crop residues. These poor-quality feeds are bulky, high in fibre, poorly degraded in the animal's rumen and low in nitrogen and minerals — basically, not very nutritious. Farmers can correct these deficiencies by supplementing the animal's diet with herbaceous legumes and foliage from fodder and multi-purpose trees.

However, many potential fodder trees contain antinutritive substances that limit their use as feed. ILRI is using two approaches to identify multi-purpose trees that farmers can use to feed their animals. The first is using palatability trials to determine which trees animals prefer to feed on. Animals usually avoid eating plants that contain antinutritional substances, at least when they have a choice of feed. Forty potential fodder tree species were screened in 1995 using this approach. The second approach is to investigate the possibility of overcoming toxicity in potential fodder trees that have outstanding agronomic performance and show good feed potential in laboratory tests.

Research on the fodder tree *Leucaena leucocephala* has shown that some microbes that live in the rumen — the 'fermenter' stomach that allows ruminants to digest fibrous, low-quality feeds — can break down antinutritional substances, in this case mimosine. Australian scientists working in Hawaii found bacteria in ruminants that were able to break down mimosine and successfully transferred them to ruminants in Australia, allowing farmers there to make fuller use of this useful leguminous tree. ILRI is studying how widely this is applicable to tropical multi-purpose trees and how to manipulate the rumen ecology to increase the supply of nutrients to animals. A series of trials in 1995 investigated the effects of *Acacia angustissima* fed as a supplement to Ethiopian highland sheep, both on the animals and on their rumen microbes. This tropical leguminous tree is well adapted to free-draining infertile acid soils, is drought-tolerant and remains leafy during long dry seasons. It seeds profusely and produces a lot of leaf — up to 5 tonnes per hectare yearly — and it withstands frequent cutting.

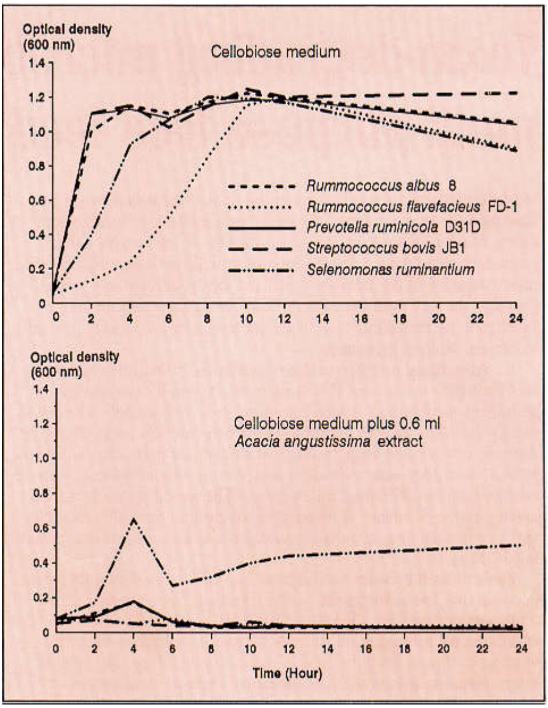
Livestock in the developing world are fed mostly low-quality roughages. Leaves from multi-purpose trees would be useful supplements to these diets, if problems with toxicity could be overcome. ILRI research indicates that this can be achieved by manipulating the rumen microflora.

Too much, too soon

Sheep fed a diet consisting of roughly one-third *Acacia angustissima* foliage (300 grams a day) and two-thirds maize stover (700 grams a day) sickened within three weeks of starting on the diet. In contrast, sheep that were gradually ?weaned? onto*Acacia angustissima,* starting with 50 grams a day and increasing to 200 grams a day over nine weeks, flourished and showed no signs of toxicity Once they had adapted to the new diet they were able to eat up to 300 grams of the tree leaf each day without coming to harm.

In vitro tests showed that *A. angustissima* foliage reduced growth of rumen bacteria. Extracts from the acacia leaves inhibited the growth of a variety of rumen bacteria tested in pure cultures.

Extracts from Acacia angustissima *dramatically reduced the growth of five rumen bacteria species* in vitro.



Gradual adaptation

Since sheep that were gradually weaned onto the acacia supplement showed no signs of harm even at high levels of supplementation, it seemed likely that the rumen microflora were adapting to the acacia toxins and rendering them harmless.

To test whether this adaptation was due to changes in the rumen microbial population, scientists took some of the rumen contents from adapted sheep and placed them in the rumens of sheep that had not been fed the acacia. These sheep were then fed a diet supplemented with 50 grams of acacia leaves for three days, after which the amount of acacia was increased to 200 grams a day None of the ?inoculated? sheep showed any signs of toxicity while the non-inoculated sheep became seriously ill, suggesting that the adaptation was at the microbial level and that the microbes that detoxify the acacia leaves can readily be transferred between animals.

Subsequent laboratory tests isolated 26 microbial colonies that are able to grow on the acacia leaves. These are currently being characterised further.

Another string to the farmers' how

These early results offer hope that scientists can isolate microbes from sheep adapted to eating *Acacia angustissima* and transfer them to other sheep to avoid the toxicity associated with feeding large amounts of the acacia leaves.

Too much reliance on only a few species is a recipe for disaster. *Leucaena leucocephala* provides an example of what can happen. This species is extensively used as a multi-purpose tree in the tropics but is attacked by a psyllid — a bug that strips the tree of its leaves. The psyllid, which originated in the Far East, has now spread as far as Africa, threatening the continued use of this tree by farmers. There is thus an urgent need to find alternatives to *Leucaena* and other multi-purpose trees currently being grown by farmers in the tropics. Research at ILRI is both identifying potential fodder species that are readily eaten by ruminants and finding ways to use species that, until now, were unavailable because of toxins.

Biodiversity—the future of world food production

For all the promise that biotechnology holds, the future of the world's food production lies primarily in the genes of domesticated plants and animals and of their much more numerous, but threatened, wild relatives. These genes provide resistance to pests and diseases and tolerance of harsh environments — physical attributes that help the plant or animal to grow in diverse conditions. Many of these characteristics are not yet known, and many that are known may not be useful now but may be in the future.

But many plants and animals that have been used by humans for thousands of years are today falling out of favour with farmers. Traditional breeds of cattle are being replaced by supposedly more productive breeds from elsewhere, or are being lost through crossbreeding. Local landraces of crops are being replaced by 'improved' cultivars. Forages and wild relatives of crop plants are being lost as farming and urban growth encroach on their natural habitats.

The world is waking up to the urgent need to conserve this vital genetic diversity before it is lost for ever. But how is it best conserved, and how do we know what to conserve? There are thousands of breeds of cattle, sheep and goats around the world and millions of different plants that might be useful to farmers at sometime in the future. The task of collecting and conserving all of them is beyond the world's will and resources.

Knowing what to conserve

One of the big problems facing genetic resources specialists, especially those working on livestock, is that of determining whether animals or populations belong to different breeds or whether they represent variations within a single breed.

In Africa, in particular, livestock breeds tend to occur across countries and even regions — the East African Zebu. the Boran cattle in Ethiopia, Kenya and Somalia. Nguni or Nkone cattle in Swaziland, Zimbabwe and Botswana. and Djallonké sheep in West Africa, to name but a few. These animals are known by the same name in different places, but often look quite different from one place to another. Conversely, there are breeds that look alike but have different names in different places. Before setting out to try to conserve, or even characterise, these breeds, scientists need to know if they really are different breeds.

Angoni cattle in Zambia, one of the breeds ILRI is genotyping using molecular-genetic techniques

In 1995 ILRI embarked on a project to determine which of Africa's cattle 'breeds' are most genetically distinct and to measure the 'genetic distance' between them — that is, how different they are from each other. This will give rise to a much more rational classification of breeds than is currently possible on the basis of available historical and anthropological evidence and phenotypic data.

The first step in the project is to identify a set of 20 to 25 genetic 'markers' in African cattle. This is being done in consultation with several laboratories around the world that are working to map the bovine genome. The ILRI project is also linked with a global project to determine genetic distances between domestic animal species that the Food and Agriculture Organization of the United Nations (FAO) is leading. These markers will then have to be set up in multiplex' systems to increase the efficiency of the genotyping and to minimise the costs involved. This work is almost complete.

During 1995 ILRI scientists and colleagues in African research institutes collected blood samples from 67 cattle populations in eight countries. Blood samples are taken from about 30 unrelated cattle that the scientists judge to be typical of each strain or population the project is covering. Project scientists have tentatively identified over 150 African cattle breeds that will be sampled during the life of the project. These cover the major breed types found in Africa, including zebu *(Bos indicus)*, taurine *(Bos taurus)*, sanga (zebu x taurine) and various combinations of these types.

Once the blood samples have been collected, scientists at ILRI's laboratories in Nairobi, Kenya, will extract the DNA. This DNA will then be 'amplified' — copied in the laboratory to make large quantities — and catalogued as a given type using the markers identified at the start of the project.

All the blood samples of the African cattle will be collected by the end of 1996. The information generated by the project will help animal geneticists and conservationists decide where to start in conserving the genes representing Africa's indigenous cattle populations. Then begins the task of putting the knowledge into effect to ensure that potentially important genetic diversity is conserved through the efforts of ILRI's national partners and FAO.

Knowing what has been collected

Molecular genetic techniques can, of course, also be applied to plant material, and ILRI is screening its forage germplasm holdings to determine whether it needs to keep all the accessions that it currently holds. This is especially important in vegetatively propagated species where clones have been spread over large areas.

At present, the forage gene bank holds 13,000 accessions of 1258 plant species. There are numerous accessions — examples collected from different places — of each species. But what is not known is how different these accessions are from each other, or even if some are actually duplicates of one accession obtained from different sources. It may be that the amount of material held could be markedly reduced — thereby saving money and effort — without reducing the genetic diversity represented in the collection.

This programme is at early stages, with discussions between forage germplasm specialists and ILRI's molecular geneticists in Nairobi to determine how to set about the task. Initial screening using gel electrophoresis of seed proteins in *Sesbania sesban* showed some variation in banding patterns between accessions.

Knowing what it can do

Genetic resources of plants and animals can be conserved in gene banks, but then these gene pools become 'frozen'. they no longer evolve to meet farmers' needs. Far better to keep genetic resources in the hands of the people who need them, so that the process of fitting them to changing circumstances can continue.

But if farmers and stockbreeders are going to use plants and animals, they must know what they are capable of, and what they are best suited to. That means characterising them and making the information on their characteristics widely known.

A key element of ILRI's forage germplasm work is characterising forages. Environment strongly influences some characters and ILRI scientists are evaluating material in a range of environments to identify accessions with high agronomic potential. Much of this work is done at ILRI's zonal sites and in collaborative research networks. In Nigeria a range of forages is being screened in the subhumid and derived savannah zones. In the past this work focused on forages suited to fodder banks — small, densely planted fields of legumes used to supplement the feed of cattle, especially during the dry season, Now screening is emphasising species that can be used to provide year-round feed, either alone or in combination with other plants, to support smallholder dairying.

As more intensive mixed crop–livestock farming systems develop—a trend that many expect to increase—legumes will play an increasing role both in providing feed for livestock and in maintaining soil fertility and structure. Alley farming—growing leguminous trees in hedgerows between small crop plots—has already shown considerable promise for being able to provide supplementary feed for livestock while maintaining or even increasing crop yields in subhumid conditions in Nigeria and Kenya. Crucial to many of these feed production systems is the ability of plants to grow in mixtures with others, and trials are investigating the agronomic performance, persistence and palatability of a range of species both in pure swards and in mixtures.

A millet field infested with striga (Striga hermontica). *Striga infestation reduces cereal yield by up to 85%; some forage legumes can help reduce striga infestation in farmers' fields while restoring soil fertility and structure and providing feed for livestock.*

Forages are being evaluated for environmental adaptation, suitability for the farming system and other uses, such as green manure and weed control. An example of a forage legume assisting in weed control is *Aeschynomene histrix,* which can act as a 'trap' crop for the parasitic weed *Striga hermontica.* The weed attaches itself to the roots of cereals and some leguminous crops, reducing yields by up to 85%. Striga seeds germinate in the presence of some forage legumes but the seedlings cannot attach to the legume's roots and hence die. During 1995 ILRI screened a collection of 65 accessions of *A. histrix* from CIAT (the International Center for Tropical Agriculture) for agronomic performance and ability to stimulate suicidal germination in striga. This work, in collaboration with the International Institute of

Tropical Agriculture (IITA), identified seven accessions that combined good agronomic performance with good striga germination.

Forage germplasm activities at ILRI involve many partners, including other CCIAR centres, advanced research laboratories and national forage research and development institutes. The institute has particularly strong links with CIAT's forage programme. ILRI and CIAT are currently rationalising their germplasm activities and exchanging germplasm to avoid duplicating their efforts in this field.

The collaborative research support networks that ILRI is involved in have tested over 600 accessions of 120 forage species belonging to 55 genera in 25 countries in sub-Saharan Africa. NARS scientists in the networks have identified useful accessions and species of forage legumes, grasses and fodder trees for the highland, semi-arid, subhumid and humid zones. On-farm research aimed at boosting the introduction and use of recommended forages is going on in Cameroon, Côte d'Ivoire, Kenya, Tanzania, Uganda and Zimbabwe. In 1995 the gene bank distributed almost 3000 samples of seeds of 400 species to scientists in 23 countries.

Keeping it clean

Distributing seed and planting materials is essential if the genetic resources held in the ILRI gene bank are to be of use to scientists and farmers. But equally important is making sure that no pests and diseases are sent out along with the germplasm.

During 1995 a virologist working with the gene bank assayed about 2000 samples from 114 legume seed lots at ILRI's Debre Zeit research station. The samples were tested for the presence of eight important seed-borne diseases, using enzyme-linked immunosorbent assay (ELISA) techniques. All eight viruses were found among the samples, with some samples harbouring several of the viruses. The most prevalent viruses were bean yellow mosaic, bean common mosaic, soybean mosaic and peanut mottle. Accessions that were heavily infected with viruses were removed from the field and destroyed. The bean yellow mosaic virus was also found in some *Sesbania sesban* trees at the station. These trees were removed and burned. Newly planted trees and accessions are being monitored and tested regularly to eradicate the diseases.

Napier grass *(Pennisetum purpureum)* poses particular plant health problems, in that it is propagated vegetatively There is thus a risk of spreading any pathogens that infect the 'parent' plant. During 1995 scientists continued experiments on using in vitro culture techniques to eliminate Elephant Grass Mosaic Virus in Napier grass. A few virus-free plants were recovered from cultures made from shoot apices of an infected clone, showing the potential of the technique for 'cleaning' infected clones. Other studies are examining possibilities of including antibiotics in culture media to cure bacterial infections.

The future of world food production

The value of biodiversity has received increasing recognition since the Earth Summit in 1992, when the need for sustainable development and use of natural resources was brought to the attention of the world. The Summit resulted in the establishment of the Convention on Biological Diversity, which came into force on 29 December 1994. ILRI is part of this global effort to conserve and use biodiversity. In 1995 the institute placed the germplasm collection held in trust at ILRI under the auspices of FAO to ensure continued free access to this valuable resource.

The future of world food production lies in the genes in domesticated crops and livestock and their close wild relatives. The world must act to preserve this heritage for future generations. ILRI is playing its part in this effort.

A library on a disc

1995 saw the first of a new generation of information products from ILRI—databases on CD-ROM (compact disc-read only memory). ILRI's first CD-ROM product contains statistical data on livestock production and trade, land use and human population covering 232 countries from 1961 to 1993. Its second venture into this field, still in prototype form, is a bibliographic database listing over 28,000 publications on livestock research in Africa.

A technology for today

Only a few years ago, CD-ROM drives were an expensive 'extra' on microcomputers, demanded only by specialist users. Despite their advantages, particularly their ability to store huge amounts of data, few people in the developing world would be able to use CD-ROMS. Now, new PCs are commonly fitted with CD-ROM drives as standard, and much software comes on CD-ROMS. We may not yet have reached Bill Gates' vision of a PC in every home, but PCs with CD-ROM drives are common enough to make CD-ROMs a viable way of storing and distributing large amounts of information in a readily accessible form.

CD-ROMs can store vast amounts of information. A normal 3.5' diskette used by most computers holds up to 1.44 megabytes (million 'bytes') of information. That is equivalent to over 700 pages of text. A single CD-ROM holds up to 660 megabytes, equal to over 450 diskettes or over 300,000 pages of text. According to one estimate, if the information stored on a CD-ROM were printed on paper, the paper needed would weigh about 400 kilograms. And just imagine having to search through 400 kilograms of paper to find a bit of information you want.

CD-ROMs have several other advantages over other ways of storing information. Users cannot erase or change data once they have been 'written' to a CD-ROM so the information is safe. They are small and light, so it is easy and cheap to send them by mail. And they do not appear to deteriorate in tropical environments, nor suffer from mould or mildew the way paper does.

The advent of affordable CD recording drives has brought CD-ROM publishing to the desktop. Over the past few years the cost of these drives has fallen from several thousands of dollars to only a few hundred. These drives can create CD-ROMs almost as quickly and easily as loading data to a diskette. They can be used economically to make prototype titles destined for conventional pressing, final production of limited numbers of discs and for archiving data.

ILRI's CD-ROMs

ILRI's first CD-ROM product grew out of the institute's database of statistics on livestock production and related data. The institute compiled this information from the Food and Agriculture Organization of the United Nations (FAO) sources. Until recently, the database was available only on ILRI's local area network at its Addis Ababa, Ethiopia, campus. ILRI's information scientists regularly conducted searches on this database for ILRI scientists and library users from national agricultural research systems, but access to the database was limited by where and how it was stored.

By putting the database on CD-ROM, ILRI has ensured that the valuable information stored on the database can be made widely available. The CD-

ROM uses FAO's retrieval software, which allows users to search the data by country, commodity and year. Users can 'download' data from their searches in ASCII or Lotus database formats, so they can use them in a variety of ways without having to re-enter the data. Copies of the disk have already been installed at all ILRI's research sites, making the information much more readily accessible.

ILRI's prototype bibliographic CD-ROM contains 28,000 bibliographic records covering all aspects of animal agriculture, including animal health and veterinary science, from ILRI's in-house database and FAO's ACRIS database. Among the publications listed are non-conventional documents collected by ILRI from sub-Saharan African countries. Users who were asked to test the CD-ROM found that searching was very slow and were not satisfied with the 'user-friendliness' of the search facility. ILRI's information scientists have now bought new software that should speed up searching and make the database easier to use. A new version of the CD-ROM will be produced soon using this new software and will be tested with a range of users before being released.

Early days

Information is a cornerstone of any development effort. If scientists have access to bibliographic databases such as ILRI's they can avoid duplicating what has been done before, saving time and limited resources. ILRI's Information Services provide a range of services that give scientists in the developing world access to information on animal agriculture. These include bibliographies, retrospective searches of the institute's in-house database and major international agricultural databases, and selective dissemination of information. Now, ILRI is producing a new generation of information products that ILRI will produce on CD-ROM.

With their ability to store vast amounts of information of a variety of forms — text, images and sound — CD-ROMs are ideal for a wide range of information and publications uses. They add another tool to ILRI's efforts to produce and disseminate information on livestock-related topics to researchers in the developing world. ILRI plans to produce a range of products on CD-ROM, including other statistical and bibliographic databases and 'electronic publications'.

ILRI programme and project activities in 1995

Biodiversity (Conservation. Characterisation)

Animal genetic resources

Characterisation and conservation of indigenous African animal genetic resources

Physiology of adaptive traits in small ruminants associated with feed utilisation

Forage genetic resources

Characterisation and conservation of forage germplasm

Production Systems Research

Production systems analysis and impact assessment

Socio-economic evaluation and environmental impact of alternative trypanosomiasis control measures

Assessing the economic and environmental impacts of livestock disease and its control

Heartwater epidemiology and economics

Economics of rinderpest

Environmental impact in Zimbabwe

Environmental impact of trypanosomiasis

Economics of trypanosomiasis

Ecoregional integrated systems

Highlands

Crop–forage integration and nutrient management in the cool tropics

Watershed management for improving and sustaining crop and livestock production on Vertisols in the Ethiopian highlands

Feed/fodder development and management practices in integrated crop–livestock systems: resource assessment for forage technology

Alternative sources of draft animals: use of crossbred dairy cows for traction

Subhumid

Impact of livestock on soil and vegetation dynamics in mixed crop–livestock systems on the West African moist savannahs

Epidemiology of trypanosomiasis in ruminants in sub-Saharan Africa

Trypanotolerance and trypanosomiasis control

Semi-arid

Socio-economic analysis of livestock production and natural resource management in semi-arid Africa

Dynamics of livestock-mediated nutrient transfers in semi-arid West African landscapes: Implications of natural resource management

Smallholder dairying

Development of a conceptual framework and methodologies for smallholder dairying research in sub-Saharan Africa

Identification of socioeconomic policy and technical constraints to the performance of dairy systems

Development of smallholder peri-urban dairy production systems involving indigenous and crossbred animals in the subhumid zones (Kaduna)

Development of dairy based peri-urban milk production in crop–livestock systems (Ibadan)

Peri-urban dairy production: on-farm milk production potential of crossbred cows in the African highlands

Development of feeding and management systems for different classes of dairy cattle in the African highlands

Development and testing of milk preservation and processing technologies

Impact of diseases of intensification and reproductive wastage on the efficiency of African peri-urban milk production systems

Feed Resources

Strategies to evaluate and match nutritional requirements of livestock exposed to fluctuating feed supply

Feed resources and feed strategies in subhumid West Africa

Nutrient partitioning for milk production, reproduction and body reserves in low and high producing cows in the tropics

Effects of work and associated heat stress on nutrient intake, digestion and body condition of draft oxen

Feed utilisation strategies for traction

Ruminal detoxification

Feed resource use and nutrition of ruminants in crop–livestock systems of semi-arid West Africa

Animal Health Improvement

Tick-borne diseases

Molecular parasitology of *Theileria parva*

Development of new and improved epidemiological tools for tick-borne diseases

Dynamics of transmission of *Theileria parva*

Application of new technologies for improved tick-borne disease control

Antigens of tick-derived stages of *Theileria* and other tick-borne pathogens

Identification and characterisation of *T. parva* schizont antigens which invoke cell-mediated responses

Antigens of crythrocytic stages of *T. parva* and other tick-borne pathogens

Immunisation with *Theileria* antigens

Evaluation of antigen delivery systems in cattle

Studies of cell-mediated immune responses of cattle

Trypanosomiasis

Epidemiology of animal trypanosomiasis

Diagnosis of trypanosomiasis

Trypanosomiasis chemotherapy and chemoprophylaxis

Parasite-host interaction

T-B cell function in resistance to bovine trypanosomiasis

Macrophage activation and function

Anaemia of trypanosomiasis

Genetics of disease resistance

Application of bovine genome analysis to the identification of markers and genes associated with trypanotolerance

Genetics of trypanotolerance and genetic improvement of trypanotolerant livestock

Heiminthiasis

Genetic resistance to gastro-intestinal parasitism in small ruminants

Epidemiology, control and impact of gastro-intestinal endoparasites in indigenous sheep breeds

Livestock Policy Analysis

Policies and institutions for improving the sustainability of crop–livestock systems

Competitiveness of smallholder dairy sector

Policy reforms and livestock input and output markets.

Property rights and sustainable improvement of livestock production systems

Strengthening NARS

Training

Information

Publishing

African Small Ruminant Research Network

Cattle Research Network

African Feed Resources Network

ILRI senior staff in 1995

Directorate General

Hank Fitzhugh, *Director General*

Akke van der Zijpp, *Deputy Director General*

Hugh Murphy, *Director of Administration*

Ralph von Kaufmann, *Director for External Relations and Public Awareness*

Gerard O'Donoghue, *Chief Financial Officer*

Peter Gardiner, *Institute Planning Officer*

Programme Leaders

Tom Dolan, *Co-ordinator, Animal Health Improvement*

Simeon Ehui, *Livestock Policy Analysis*

Hank Fitzhugh, *Acting Programme Leader, Production Systems*

Jean Hanson, *Biodiversity*

Paschal Osuji, *Acting Programme Leader, Feed Resources*

Michael Smalley, *Strengthening National Agricultural Research Systems*

Kenya

Animal Health Improvement Programme

Improvement and Application of Existing Disease Control Technologies

Alfred Adema, *research technologist*

Richard Bishop, *molecular parasitologist*

Mark Eisler[1], *visiting epidemiologist*

Newton Gitire, *research technologist*

John Kabata, *research technologist*

Albert Kafwa, *technical assistant*

Noah Karanja, *technical assistant*

Fredrick Karia, *research technologist*

Joseph Katende, *research associate*

Sammy Kemei, *research technologist*

James Kiarie[§], *research technologist*

Juma Kiundi, *research technologist*

Nelson Kuria, *research technologist*

Stephen Leak, *research associate*

Pierre Lessard, *epidemiologist*

Clement Lugonzo, *research technologist*

Humphrey Lwamba, *research technologist*

Mary Maina, *research technologist*

Phelix Majiwa, *molecular parasitologist*

Jackson Makau, *research technologist*

Rachel Masake, *immunoparasitologist*

Stephen Minja, *research associate*
Deen Moloo, *entomologist*
Subhash Morzaria, *molecular parasitologist*
Joseph Muia, *technical assistant*
Stephen Mwaura, *research* technologist
Reeves Njamunggeh, *research technologist*
George Njihia, *research technologist*
Thomas Njoroge, *research technologist*
Stephen Njuguna, *research technologist*
Joseph Odhiambo, *research technologist*
George Oduol, *research technologist*
Ignatius Okumu, *research technologist*
Julius Osaso, *research technologist*
Maurice Owino, *technical assistant*
David Parkin[§2], *visiting biochemist*
Andrew Peregrine, *parasitologist*
Rob Skilton, *research associate*
John Tangus, *technical assistant*
James Thuo, *research technologist*
Alfred Tonui, *research technologist*
Toyohiko Urakawa[§], *molecular biologist*
Mary Waithaka, *research technologist*
Stephen Wasike, *research technologist*
Jon Wilkes, *cell membrane physiologist*
Alan Young, *entomologist (died 15 March)*

Development of New Disease Control Technologies

Aurelic Andrianarivo, *post-doctoral scientist*
Edith Authié[3], *immunologist*
Keith Ballingall, *post-doctoral scientist*
Edward de Buysscher[4], *visiting immunologist*
Francis Chuma, *research technologist*
Claudia Daubenberger, *post-doctoral scientist*
Laima Gaidulis[§], *research associate*
Benson Gichuki, *research technologist*
Lucy Gichuru, *research technologist*
Elke Gobright, *research associate*
Volker Heussler, *post-doctoral scientist*
Yoshikazu Honda, *virologist*
Anita Khausal[§], *research technologist*
Linda Logan-Henfrey, *pathologist*
Dismus Lugo, *research technologist*
Vittoria Lutje, *post-doctoral scientist*
Anthony Luyai, *research technologist*

Niall MacHugh, *research associate*
Guy Mareels[5], *peptide biologist*
Yutaka Matsubara[6], *pathologist*
John Mburu, *research technologist*
Ferdinard Mbwika, *research technologist*
Declan McKeever, *immunologist*
Francis McOdimba, *research technologist*
Bea Mertens[7], *immunologist*
Paul Muiya, *research technologist*
Cecilia Muriuki, *research technologist*
Noel Murphy, *molecular geneticist*
Tony Musoke, *immunologist*
David Muteti, *research technologist*
Anthony Muthiani, *research technologist*
Duncan Mwangi[8], *post-doctoral scientist*
Waithaka Mwangi, *research technologist*
Jan Naessens[9], *immunologist*
David Ndegwa, *research technologist*
Vish Nene, *molecular biologist*
Daniel Ngugi, *research technologist*
James Ngugi, *research technologist*
Catherine Nkonge, *research associate*
Joseph Nthale, *research technologist*
John Nyanjui, *research technologist*
Elias Owino, *research technologist*
Pratibala Pandit, *research technologist*
Roger Pellé, *molecular parasitologist*
Rosemary Saya, *research technologist*
Maarten Sileghem, *immunologist*
Baljinder Sohanpal, *research technologist*
Paul Spooner, *research associate*
Evans Taracha, *post-doctoral scientist*
Kathy Taylor, *research associate*
Philip Totté[10], *immunologist*
John Wando, *research technologist*
Stephen Wanyonyi, *research technologist*

Genetics of Disease Resistance

Eric Aduda, *research assistant*
James Audho, *technical assistant*
Leyden Baker, *quantitative geneticist*
Henry Gathuo, *research technologist*
Annette Gelhaus[11], *immunogeneticist*
Olivier Hanotte, *post-doctoral scientist*
Fuad Iraqui, *post-doctoral scientist*

Steve Kemp[§], *molecular geneticist*

Alice Njeri Maina, *research technologist*

Joel Mwakaya, *research technologist*

John Ngatti, *research technologist*

Joel Ochieng, *research technologist*

Moses Ogugo, *research technologist*

Manassey Omenya, *research technologist*

Japheth Sore, *research technologist*

Alan Teale, *molecular geneticist*

Ravinder Thatthi[§], *research technologist*

Yasmin Verjec, *research technologist*

John Wambugu, *research technologist*

Programme Support

Chris Hinson, *laboratory manager*

David Kennedy, *veterinarian*

Bob King, *head, experimental animal units*

James Magondu, *head, fluorescence-activated cell sorter services*

Francis Mucheru, *research technologist, fluorescence-activated cell sorter services*

Christopher Ogomo, *research technologist, electron microscopy services*

Clive Wells, *head, electron microscopy services*

Biodiversity Programme

Animal Genetic Resources

Osamu Hishida[12], *molecular geneticist*

Production Systems Programme

Systems Analysis and Impact Assessment

Mohamed Baya, research technologist

Luc Duchateau[13], statistician and modeller

Protase Echessah, research technologist

Russ Kruska, geographic information systems specialist

Adrian Mukhebi, agricultural economist

Veronica Muthui, research technician

Brian Perry, veterinary epidemiologist/team leader

Robin Reid, ecologist

Livestock Production Under Trypanosomiasis Risk

Guy d'Ieteren, *animal scientist/team leader*

Sonal Nagda, *data analyst*

John Rowlands, *biometrician*

Brent Swallow, *agricultural economist*

Ecoregional Integrated Systems for sub-Saharan Africa: Market-oriented smallholder dairying

Matthew Kenyanjui, *research technologist*

Gary Mullins[§], *agricultural economist*

David Njubi, *senior computer programmer*

Emmanuel Rugema, *research technologist (died 5 April)*

William Thorpe, *animal scientist/team leader*

Strengthening NARS Programme

Training and Conferences

Rob Eley, *education officer*

Mody Touré[§], *co-operative programmes co-ordinator*

Information

Damaris Ng'ang'a, *librarian*

Publications

Dave Elsworth, *head, graphics unit*

Susan MacMillan, *science writer*

Peter Werehire, *publications assistant*

Networks

Sahr Lebbie, *co-ordinator, Small Ruminant Research Network*

Jean Ndikumana, *co-ordinator, African Feed Resources Research Network*

Institutional Support

Administrative

Mike Craig, *business manager*

Brian Lloyd, *financial controller*

Faith Matee, *purchasing officer*

Gacheru Migwi, *chief personnel officer*

George Mzera, *stores superintendent*

Kenneth Ndunda[§], *chief security officer*

Charles Ndungi, *transport manager*

Onesmus Nthiwa, *chief accountant*

Janepher Owino, *housing officer*

Technical

Sylvester Kisonzo, *computer software officer*

Alex Lobo, *engineering superintendent*

Paul Ng'eno, *manager, Kapiti Ranch*

Jim Scott, *head, computing services*

David Wanzala, *building and maintenance supervisor*

Ethiopia*

Production Systems Programme

Asfaw Yemegnuhal, *research technologist (Debre Zeit)*
Azage Tegegne, *research officer (Debre Zeit)*
Abdel-Latif Lahlou-Kassi[§], *animal scientist*
Karanfil Olga, *research technologist (Debre Zeit)*

Livestock Production Under Trypanosomiasis Risk

Negussie T/Michael, *research technologist (Ghibe)*
Tesfaye Legesse, *research technologist (Ghibe)*
Woudyalew Mulatu, *research technologist (Ghibe)*

Ecoregional Integrated Systems for sub-Saharan Africa: Highlands

Abate Tedla, *research officer*
Abiye Astatke, *research officer*
Kahsai Berhane, *research technologist*
Mohamed Mohamed-Saleem, *agronomist*
Mulugeta Mamo, *technical assistant*
Emmanuel Mwendera, *post-doctoral associate*
Nigist Wagaye, *research technologist*
Solomon Gebre Selassie, *research technologist*
Wagnew Ayalneh, *research technologist*
Ahmed El Wakeel[§], *research associate*
Ercole Zerbini, *animal scientist*

Ecoregional Integrated Systems for sub-Saharan Africa: Market-oriented smallholder dairying

Abebe Tessema, *research technologist (Debre Zeit)*
Aberra Adie, *technical assistant (Debre Zeit)*
Dawit Negassa, *technical assistant (Debre Zeit)*
Charles O'Connor[§], *dairy technologist (Debre Zeit)*
Solomon Kebede, *research technologist (Debre Zeit)*
Victor Umunna, *animal scientist/station manager (Debre Zeit)*

Biodiversity Programme

Forage Genetic Resources

Asebe Abdena, *research technologist (Debre Zeit)*
Girma Gebre Mariam, *research technologist*
Jemal Mohammed, *research technologist (Zwai)*
Afui Mathias Mih, *post-doctoral associate*
Natalia L. Moukhina[§], *research technologist*
Kaburu M'Ribu, *post-doctoral associate*
Zhi Biao Nan, *associate scientist*
Temeselew Mamo, *research technologist*
Mark van de Wouw, *associate scientist (Debre Zeit)*

Animal Genetic Resources

Azeb Haile, *research technologist*
Beyene Ambaye, *research technologist*
Dawit Gezahegn, *research technologist*
Girma Abebe, *research technologist*
Kahsay Berhe, *research technologist*
Lemma Mekonnen, *technical assistant*
Mesfin Shibre, *research technologist*
Eddie Mukasa-Mugerwa, *veterinarian*
Edward Rege, *animal breeder*
Chi Lawrence Tawah, *associate scientist*
Tesfaye Gebre Selassie[§], *research technician*
Rita Torto, *post-doctoral associate*
Valentine Yapi-Gnaore, *post-doctoral associate*

Feed Resources Programme

David Anindo, *associate scientist/station manager (Debre Birhan)*
Ignatius Nsahlai, *associate scientist (Debre Zeit)*
Agnes Odenyo, *post-doctoral associate (Debre Zeit)*

Animal Health Improvement Programme

Genetics of Disease Resistance

Saidou Tembely, *associate scientist*

Livestock Policy Analysis Programme

Abebe Misgina, *research technologist*
Guillaume Duteurtre[l4], *associate scientist*
Horatio A. Freeman, *associate scientist*
Sarah Gavian, *associate scientist*
Gemechu Degefa, *research technologist*
Mohammed Jabbar, *agricultural economist*
Mohammed Mussa, *research technologist*
Nega Gebre Selassie, *research technologist*
Charles E Nicholson, *social scientist (Rockefeller Foundation Social Sciences Fellow)*
Barry Shapiro, *agricultural economist*

Strengthening NARS Programme

Training and Conferences

Leticia Padolina, *assistant to the SNARS programme leader*

Information

Azeb Abraham, *librarian*
Marcos Sahlu, *documentation supervisor*
Pramod Sinha, *head, information services*

Publications

Sourou Adoutan, *French translator/editor*
Paul Neate, *head of publications*
Anne Nyamu, *science writer/editor*
Tekleab H/Michael, *head, pre-print operations*
Wondwossen Girma, *head, printshop*

Networks

Ebenezer Olaloku, *co-ordinator, Cattle Research Network*

Institutional Support

Administrative

Ahmed Osman, *assistant personnel officer*
Inca Alipui[§], *executive assistant, public awareness unit*
Antonio Silla, *internal auditor*
Belayhun Wondimu, *chief accountant*
Emmanuel T/Mariam, *budget officer*
Pernilla Fajersson, *special assistant to the Director General*
Ghebru BeicneS, *catering officer*
Michael Abebe, *medical officer*
Million Gebreab, *housing officer*
Negussie Abraham, *general accounts supervisor*
Revathi Rao, *manager, housing and catering*
Tadesse Minas, *assistant personnel officer*
Aguibou Tall, *head of administration (Ethiopia)*
Techalew Negash, *supervisor, disbursement and collection*

Technical

Abeba Goitom, *research technologist*
Abraham Bekele, *computer engineer*
Ali Mohammed, *research technologist*
Aynalem Tesfahun, *computer programmer*
Mamadou Diedhiou, *biometrician*
Genet Assefa, *research technologist*
Girmaye Tamiru, *research technologist*
Franco Leone, *physical plant manager*
Mebrahtu Ogbai, *research technologist*
James Ochang, *senior research assistant (Debre Zeit)*
Solomon Tessema, *computer engineer*
Solomon Zewdie[§], *senior computer programmer*
Tekeste Gebre Wold, *research technologist*
Tenaye Serekeberhan, *research technologist*
Yimer Ahmed, *research technologist*
Yohannes Yehualashet, *project supervisor*

Ibadan, Nigeria

Production Systems Programme

Ecoregional Integrated Systems for sub-Saharan Africa: Subhumid zone

Kwaku Agyemang, *animal production scientist*
Hailu Zegeye[§], *associate scientist*
Asmoah Larbi, *forage agronomist*
Augustine Naazie, *post-doctoral associate*
Michael Peters[15], *post-doctoral scientist*
Jimmy Smith, *animal scientist/team leader*

Niamey, Niger (ICRISAT Sahelian Center)

Production Systems Programme

Ecoregional Integrated Systems for sub-Saharan Africa: Semi-arid zone

Salvador Fernández-Rivera, *animal scientist/team leader*
Pierre Hiernaux, *range ecologist*
Eva Schlecht[16], *post-doctoral associate*
Matthew Turner[§]**,** *research associate*
Tim Williams, *agricultural economist*

Bobo-Diolasso, Burkina Faso

Production Systems Programme

Ecoregional Integrated Systems for sub-Saharan Africa: livestock production under trypanosomiasis risk

J.B. Mulumba Kamuanga, *agricultural economist*

Bamako, Mali

Administrative Support

Moustapha Sall[§], *regional representative, West and Central Africa*

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1. Salary provided by the UK *ODA (Overseas Development Administration) and the University Of Glasgow* and by the European Union

2. Salary provided by the USA *National Institutes of Health*

3. Salary provided by France *CIRAD-EMVT. Centre de Coopération Internationale en Recherche Agronomique pour le Développement–Elevage et Médecine Vétérinaire des Pays Tropicaux* (Centre for International Cooperation in Agronomic Research and Development–Animal Husbandry and Veterinary Medicine in Tropical Countries)

4. Salary provided by USA *North Carolina State University*

5. Salary provided by Belgium *VVOB: Vlaamse Vereniging Voor Ontwikkelingssamenwerking en Technische Bijstand*

6. Salary provided by Japan *JIRCAS: Japan International Research Center for Agricultural Sciences*

7. Salary provided by Belgium

8. Salary provided by the USA *USAID (United States Agency for International Development) and the University of Florida*

9. Salary provided by Belgium

10. Salary provided by France *CIRAD-EMVT*

11. Salary provided by Germany *BMZ: Bundesministerium für Wirtschaftliche Zusammenarbeit* (Federal Ministry for Economic Co-operation with Developing Countries) and the University of Hamburg

12. Salary provided by Japan *JICA: Japan International Cooperation Agency*

13. Salary provided by Belgium *VVOB*

14. Salary provided by France *CIRAD-EMVT*

15. Salary provided by Germany *GTZ: Deutsche Gesellschaft für Technische Zusammenarbeit* (German Agency for Technical Co-operation)

16. Salary provided by Germany BASF/German National Scholarship Foundation

* Ethiopian names traditionally comprise given names only rather than a combination of given and family names; the Ethiopian names in this list are therefore alphabetised according to the first rather than second name listed. Names of all other nationals are alphabetised by family (second) names.

§ Left ILRI in 1995.

Additional programmatic and administrative leadership appointments during the year:

Tom Dolan was Interim Deputy Director General until November and Head of the Tick-Borne Diseases Research Programme until August.

Koen Geerts was Interim Director for Administration until November.

Ed English was Director of Administration (Ethiopia) until November.

Michael Smalley was Acting Resident Director (Ethiopia) throughout the year.

Alan Teale was Head of the Trypanosomiasis Research Programme until August.

Brian Perry was Head of the Socio-economics and Environmental Impacts Programme until August.

Mody Touré was Head of Co-operative Programmes until August.

Post-doctoral Associates and Graduate Fellows at ILRI in 1995

Post-doctoral Associates

Start	End	Name/ Nationality	Project Title	Programme/ Country
1992	1995	Ahmed El Wakeel, Sudan	Formulation of growth rules and assessment of growth characteristics of forages for development of feed calendars and land conservation strategies	PSP/Ethiopia
1993	1995	J Enyaro, Ugandan	Development of quantitative PCR method for the rapid and accurate estimation of *Trypanosoma congolense* numbers in early infections	AHIP/Kenya
1993	1996	Michael Peters, German	Selecting and testing forage legumes for sustainable agriculture and livestock production in subhumid West Africa with special emphasis on legume-legume combination	BP/Nigeria
1994	1996	Afui Mathias Mih, Cameroonian	Characterisation and conservation of forage germplasm and evaluation for development of livestock feeds	BP/Ethiopia
1994	1996	Rita Torto, Ghanaian	Physiology of non-disease adaptive traits in small ruminants (Ethiopian highland sheep)	BP/Ethiopia
1994	1996	V Yapi Chia-Gnaoré, Ivoirien	Classification and characterisation of African small ruminants genetic resources	BP/Ethiopia
1994	1996	H Kaburu M'Ribu, Kenyan	*In-vitro* cultivation of Napier grass and the molecular characterisation of *Sesbania*, accessions and of Napier grass	BP/Ethiopia
1994	1996	Agnes Awino Odenyo, Kenyan	Rumen manipulation to enhance fibre utilisation	UTFRP/Ethiopia
1995	1997	Emmanuel Mwendera, Malawian	Livestock productivity and environmental interference modelling	PSP/Ethiopia
1995	1997	Eva Schlecht, German	Sustainable crop–livestock production and natural resource management in semi-arid West Africa	PSP/Niger
1995	1997	Augustine Naazie, Ghanaian	Model development on aspects of digestion kinetics	PSP/Nigeria

PSP = Production Systems Programme; AHIP = Animal Health Improvement Programme; BP = Biodiversity Programme; LPAIP = livestock Policy Analysis Programme; UTFRP = Utilisation of Tropical Feed Resources Programme.

Graduate Fellows

Start	End	Name/ Nationality	University/ Institute	Degree	Project Title	Programme/ Country
1988	1995	R Jamnadass, Kenyan	Brunei	PhD	Identification and characterisation of an extrachromosomal element from a multidrug-resistant strain of *Trypanosoma brucei brucei*	AHIP/Kenya
1991	1995	E. Kibe, Kenyan	Brunei	PhD	Identification and molecular characterisation of the gene encoding the P-glycoprotein analog of *T. parva*	AHIP/Kenya
1991	1995	A Boulange, French	Paris	PhD	Contribution to the study of two immunodominant invariant antigens of *Trypanosoma congolense*	AHIP/Kenya
1992	1995	A Amadou, Cameroonian	Reading	PhD	Economic and environmental impacts of tsetse and trypanosomiasis control in the Adamawa Province of Cameroon	PSP/Kenya
1992	1995	John Omiti, Kenyan	New England, Armidale	PhD	The potential contribution of the livestock sub-sector to farm income and environmental protection in sub-Saharan Africa: Implications for policy	LPAP/Ethiopia
1992	1995	Francois Toe, Burkinabe	Rabat Institute	PhD	Ram fertility and management in African traditional systems	PSP/Ethiopia
1993	1995	Ademola Raii, Nigerian	Ibadan	PhD	Forage production for smallholder production	PSP/Nigeria
1993	1995	A Kolawole, Nigerian	Ibadan	MSc	Management of feed resources for smallholders	PSP/Nigeria
1994	1995	Sisay Gezahegne,. Ethiopian	Alemaya	MSc	Breed characterisation	BP/Ethiopia
1994	1995	Solomon Mamo, Ethiopian	Alemaya	MSc	Peri-urban dairy production: On-farm feed production priorities, feeding regime and behaviour, work output of oxen and lactation performance of cows	PSP/Ethiopia
1994	1995	Hailemariam Teferra, Ethiopian	Alemava	MSc	Adoption of improved management and feeding strategies for crossbred dairy cows: A whole farm evaluation	PSP/Ethiopia
1994	1995	W Bulima, Kenyan	Nairobi	MSc	The role of cytokines in the control of *T. parva* infection in cattle	AHIP/Kenya
1995	1995	N Collins, South African	OVI	PhD	Characterisation of *Theileria* parasites causing East Coast fever and Corridor disease	AHIP/Kenya
1995	1995	A Diaite, Senegalese	Brunei	MPhil	Evaluation of novel non-recombinant antigen delivery systems in cattle	AHIP/Kenya
1995	1995	G Ndoutamia, Chadian	Brunei	PhD	Induction and characterisation of a quinapyramine resistant clone of *T. congolense*	AHIP/Kenya
1995	1995	O Tosomba, Zairean	Natal	PhD	Acid phosphatases of *Trypanosoma congolense*	AHIP/Kenya

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Graduate Fellows (cont'd)

Start	End	Name/ Nationality	University/ Institute	Degree	Project Title	Programme/ Country
1995	1995	Ulrike Merkel, German	Hohenheim	MSc	Evaluation of a collection of *Aeschynomene histrix* accessions	BP/Nigeria
1995	1995	Renate Schneider, German	Berlin	MSc	Epidemiology of helminthiasis in sheep in Ethiopia	AHIP/Ethiopia
1995	1995	Catherine Melard, Belgian	Notre Dame de la Paix	MSc	Labour management in Ginchi watershed: Impact on common good management	PSP/Ethiopia
1995	1995	Feza Mpungu, Zairean	Notre Dame de la Paix	MSc	Land tenure in Ginchi watershed: Impact on common good management	PSP/Ethiopia
1995	1995	Markus Weber, German	Humboldt	MSc	Cross-site whole-farm economic evaluation of the broad-bed maker	PSP/Ethiopia
1992	1996	N Tebele, Zimbabwean	Brunei	PhD	Identification and characterisation of the gene encoding the 200 Kda diagnostic antigen of *Babesia bigemina*	AHIP/Kenya
1992	1996	S Mwangi, Kenyan	Kenyatta	PhD	Molecular cloning of a CDNA encoding bovine IL-3 and characterisation of the activity of the recombinant protein	AHIP/Kenya
1992	1996	M Agaba, Ugandan	Brunei	PhD	Identification and linkage mapping of bovine expressed DNA sequence polymorphisms	AHIP/Kenya
1992	1996	M Suliman, Sudanese	Virginia	PhD	Molecular cloning of bovine erythropoictin (EPO) and investigation into its role in the pathophysiology of trypanosome infections associated with anaemia in cattle	AHIP/Kenya
1993	1996	C Shukla, Indian	Brunei	PhD	Role of the 7.1 kb extrachromosomal genetic element of *Theileria parva* in parasite biology	AHIP/Kenya
1993	1996	E Wekare, Zimbabwean	Nairobi	MSc	Trypanosomiasis epidemiology in Zimbabwe	PSP/Kenya
1993	1996	J Buza, Tanzanian	Sokoine	PhD	B-Iymphocyte responses in trypanosome-infected cattle	AHIP/Kenya
1993	1996	G Gitau, Kenyan	Nairobi	PhD	Quantitative assessment of the impacts of endemic stability and instability to tickborne diseases on dairy production in Murang'a District, Kenya	PSP/Kenya

PSP = Production Systems Programme; AHIP = Animal Health Improvement Programme; BP = Biodiversity Programme; LPAP = Livestock Policy Analysis Programme; UTFRP = Utilisation of Tropical Feed Resources Programme.

Graduate Fellows (cont'd)

Start	End	Name/ Nationality	University/ Institute	Degree	Project Title	Programme/ Country
1993	1996	Pokou Koffi, Ivoirien	CIPES	PhD	Economic analysis of livestock production with tsetse control, multiple species and multiple breeds	PSP/Côte d'Ivoire.
1993	1996	Kimberly Swallow, American	Wisconsin	PhD	Local socioeconomic institutions and their influence on smallholder farmers' enterprise and technical adoption decisions: The case of the adoption of dairy cattle enterprises and improved cattle feed production techniques in the coconut-cassava agro-ecologicai zone of coastal Kenya	PSP/Kenya
1994	1996	M Wubet, Ethiopian	Brunei	Mphil	Role of trypanosomal mitochondrial energetics in the accumulation and resistance to isometamidium by bloodstream forms of trypanosomes	AHIP/Kenya
1994	1996	M Nderi, Kenyan	Kenyatta	MSc	Role of tsetse flies in the transmission of trypanosome infections to cattle in Ziwani Field Farm in Taveta Division of Taita/Taveta District, Coast Province, Kenya	PSP/Kenya
1994	1996	Getachew Gebru, Ethiopian	Wisconsin	PhD	Assessment of feed resource base and the factors that affect access to feed resources in crop–livestock systems in the Ethiopian highlands	PSP/Ethiopia
1994	1996	Ika Darnhofer, Austrain	Vienna	PhD	Land tenure resource management systems	LPAP/Ethiopia
1994	1996	Lambert Muhr, German	Hohenheim	MSc	Potential of selected forage legumes planted on fallow land and fodder production and soil improvement in integrated crop–livestock systems	BP/Nigeria
1994	1996	Jimoh Olanite, Nigerian	Ilorin	MSc	Evaluation and promising grass-legume mixtures for feeding to early weaned calves, thereby allowing small-scale dairy farmers to collect and sell more of the milk from the dams of the calves	BP/Nigeria
1995	1996	Mengistu Alemayehu, Ethiopian	Alemaya	MSc	Draft performances of F_1 crossbred dairy cows and local oxen under smallholder farm management conditions	PSP/Ethiopia

PSP = Production Systems Programme; AHIP = Animal Health Improvement Programme; BP = Biodiversity Programme; LPAP = Livestock Policy Analysis Programme; UTFRP = Utilisation of Tropical Feed Resources Programme.

Graduate Fellows (cont'd)

Start	End	Name/ Nationality	University/ Institute	Degree	Project Title	Programme/ Country
1995	1996	Mengistu Buta, Ethiopian	Alemaya	MSc	Crossbred cows for milk and traction in the Ethiopian highlands: A whole-farm evaluation	PSP/Ethiopia
1995	1996	Carol Cabal, Filipino	Hawaii	PhD	Integrated crop–livestock agricultural system: Impacts on household food security in the central Ethiopian highlands	LPAP/Ethiopia
1995	1996	H Mwambi, Kenyan	Nairobi	PhD	A mathematical model for the life cycle of *R. appendiculatus* and its interaction with cattle hosts	AHIP/Kenya
1995	1996	M Durante, Italian	Bristol	PhD	The development of DBA markers to differentiate between two strains of trypanosome, one a *Trypanosoma brucei rhodesiense* and the other a *T. brucei brucei*	PSP/Kenya
1994	1997	Atse Atse Pascal, Ivoirien	Côte d'Ivoire National	PhD	Productivity of ruminant livestock exposed to trypanosomiasis risk in Côte d'Ivoire	PSP/Côte d'Ivoire
1994	1997	Robert Kaitho, Kenyan	Wageningen	PhD	Nutrient supply in forage legume-based supplementation in ruminants	PSP/Ethiopia
1994	1997	A Ayantunde, Nigerian	Wageningen	PhD	Livestock-mediated nutrient transfers in SAWA landscape	PSP/Niger
1994	1997	Denis Mpairwe, Ugandan	Makerere	PhD	Nutrient partitioning in lactating cows	PSP/Ethiopia
1994	1997	R Janoo, Kenyan	Brunel	PhD	Characterisation of GTPases regulating protein trafficking in *Theileria parva*	AHIP/Kenya
1994	1997	D Olila, Ugandan	Nairobi	PhD	Molecular epidemiology of trypanosomiasis with particular emphasis on drug-resistant phenotypes in Mukono District, Uganda	AHIP/Kenya
1994	1997	C Laker, Ugandan	Makerere	PhD	Assessment of the economic impact of the bovine trypanosomiasis and its control in Mukono Country, Uganda	PSP/Kenya
1995	1997	E Sebitosi, Kenyan	ABU/ICIPE	PhD	The physiology of the tick *Rhipicephalus appendiculatus* in relation to the transmission of *Theileria parva*	AHIP/Kenya

PSP = Production Systems Programme; AHIP = Animal Health Improvement Programme; BP = Biodiversity Programme; LPAP = Livestock Policy Analysis Programme; UTFRP = Utilisation of Tropical Feed Resources Programme.

Graduate Fellows (cont'd)

Start	End	Name/ Nationality	University/ Institute	Degree	Project Title	Programme/ Country
1995	1997	N Wachira, Kenyan	Nairobi	MSc	Risk and resource management strategies in smallholder dairy farms in central Kenya	PSP/Kenya
1995	1997	A Diack, Senegalese	Brunel	MPhil	The effect of multiple treatment of cattle that harbour drug-resistant *Trypanosoma congolense* on the effectiveness of the parasites for *Clossina mortisans cent*	AHIP/Kenya
1995	1997	J Coverch, Zimbabwean	Michigan	PhD	The effects of tsetse control on resource management institutions in the mid-Zambesi valley of Zimbabwe	PSP/Kenya
1995	1997	Workineh Abebe, Ethiopian	Alemaya	MSc	Processing/milk analysis	PSP/Ethiopia
1995	1998	A Djikeng, Cameroonian	Brunel	PhD	Expressed sequence tags of *Trypanosoma brucei rhodesiense:* reagents for the derivation of a transitional map of the causative agent of human sleeping sickness	AHIP/Kenya
1995	1998	A Osanya, Kenyan	Brunel	PhD	Contribution to the characterisation of the *Trypanosoma brucei* genome: Identification and characterisation of differentially expressed sequence tags	AHIP/Kenya
1995	1998	Constance Mugalla, Kenyan	Penn State	PhD	Livestock production in The Gambia and implications of trypanosomiasis control on the Gambian household	PSP/The Gambia
1995	1998	Kouadio Tano, Ivoirien	Manitoba	PhD	Collaborative research on trypanosomiasis and trypanotolerant livestock for West Africa	PSP/Burkina Faso
1995	1998	Eneyew Negussie, Ethiopian	Technische Munchen	PhD	Characterisation of the indigenous Ethiopian sheep breeds for feed intake and fat deposition as an adaptive characterisitcs	PSP/Ethiopia

PSP = Production Systems Programme; AHIP = Animal Health Improvement Programme; BP = Biodiversity Programme; LPAP = Livestock Policy Analysis Programme; UTFRP = Utilisation of Tropical Feed Resources Programme.

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Financial Summary

INTERNATIONAL LIVESTOCK RESEARCH NSTITUTE
STATEMENT OF ACTIVITY
for the year ended 31 December 1995
(US$ '000)

Revenue

Grant	23,846
Other income	1,198
Total revenue	25,044

Expenses

Research	15,713
Information services	1,290
Training and conferences	983
General administration and operations	4,379
Board and management	853
Depreciation	2,022
Total expenses	25,240
Surplus (deficit) for the year	(196)

INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA
STATEMENT OF FINANCIAL DIVISION
At 31 December 1995
(US$'000)

Current assets	**1995**	**1994**
Bank and cash balances	15,987	17,467
Accoutns receivable	1,228	1,207
Receivable from donors	2,826	936
Inventories	1,344	1,300
Deposits and prepayments	419	542
Total current assets	21,804	21,452
Fixed assets		
Property, plant and equipment	18,187	18,336
Construction work-in-progress	719	44
Investment in subsidiary	1,816	1,816
Total fixed assets	20,722	20,196
Total assets	42,526	41,648
Liabilities		
Accounts payable	3,829	2,505
Payments iin advance – donors	2,214	2,671
In-trust funds	264	326
Accruals and provisions	3,357	3,075
Total liabilities	9,664	8,577
Fund balances		
Captial invested in fixed assets	20,722	20,187
Operating fund	7,038	7,235
Capital fund	5,102	5,649
Total fund balances	32,862	33,071
Total liabilities and fund balances	42,526	41,648

INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA
STATEMENT OF GRANT REVENUE
for the year ended 31 December 1995
(US$'000)

	Funds received	Accounts receivable	Payments in advance	1995 grant
Unrestricted				
Australia	224	-	-	224
Austria	150	-	-	150
Belgium	-	433	-	433
Canada	966	-	-	966
Denmark	888	-	-	888
Finland	421	-	-	421
BMZ/GTZ	1,187	-	-	1,187
India	-	37	-	37
Japan	1,282	-	-	1,282
The Netherlands	316	-	-	316
Norway	772	-	-	772
Spain	50	-	-	50
Sweden	615	-	-	615
Switzerland	3,663	-	1,952	1,711
United Kingdom	961	-	-	961
United States of America	2,550	850	-	3,400
World Bank	6,230		-	6,230
Sub-total	20,275	1,320	1,952	19,643

Statement of Grant Revenue (continued)

Donor	Project	Funds received	Accounts receivable	Payments in advance	1995 grant
Restricted					
ACIAR	Small Ruminant	10	-	-	10
ACIAR	Regular consultation	26	-	-	26
ACIAR	Regular workshop	30	-	-	30
ACIAR	Genetics	28	-	15	13
Austria	Graduate student	25	-	-	25
Belgium	Diagnostics	-	167	-	167
Belgium	ECF	-	167	-	167
Belgium	Immunosuppression	-	133	-	133
Belgium	Genetics N'Dama	-	272	-	272
Belgium	Reproduction N'Dama	-	216	-	216
BMZ/GTZ	Forage Genetics	700	5	-	705
BMZ/GTZ	Forage Evaluation	127	-	15	112
EU	Research Co-ordination	-	396	-	396
EU	Trypanosomiasis WA	202	116	-	318
France		333	-	-	333
IFAD	Trypanosomiasis	196	-	94	102
Italy		300	-	-	300
Ireland		500	-	-	500
The Netherlands	Joint Vertisol Project	308	-	104	204
OPEC	Sahelian Research	15	16	-	31
Rockefeller		39	-	-	39
USAID		34	-	-	34
ODA		53	-	-	53
WFP		17	-	-	17
Sub-total		1,943	1,488	228	4,203
Total Grants		23,218	2,808	2,180	23,846

Credits

Text: Paul Neate

Principal Scientific Sources: D. McKeever *(Live vaccine delivery systems for East Coast fever);* J. Naessens and M. Sileghem *(Mice and cattle immune systems like chalk and cheese);* N. Murphy, J. Naessens and M. Sileghem *(Interpreting the language of parasites);* P. Hiernaux, R. Kruska, B. Perry and R. Reid *(GIS – a research tool and more);* G. Mullins *(Women dairy farmers in Africa)i* E. Zerbilni *(Ploughing with cows feasible in East African highlands);* A. Odenyo and P. Osuji *(Toxin–degrading microbes release multi–purpose tree feed potential);* J. Hanson and J.E.O. Rege *(Biodiversity – the future of world food production);* P. Sinha (A *library on a disc).*

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