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Assessment of priorities to 2010 for the poor and the environment

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Without implicating them in any way, we are also very grateful to John Lynam, Guido Gryseels and Jan Peter Groenewold, who made comments on the technical content of the document. Errors and omissions remain our responsibility, however.

Priority Assessment Criteria Working Group
Nairobi, March 2000

Foreword

This report describes the development and application of a quantitative priority assessment framework to be used as a decision support tool for livestock research priority setting and resource allocation. The research described was undertaken in 1999 by the *Priority Assessment Criteria Working Group* at ILRI. The report forms a companion document to two others published in 2000: *ILRI Strategy to 2010: making the Livestock Revolution work for the poor*, and ILRI's *Medium-term plan 2001–2003*.

The priority assessment framework remains a 'work in progress' with improvements to be made from experience with its use and as better data become available on poverty and environmental factors. The outcomes and implications of the priority assessment will increasingly shape ILRI's research activities over the coming years as commitments are completed and new opportunities become available through new science and new investments. A principal value of the priority assessment framework will be to provide investors with quantitative projections on the probable impacts of the research they support.

A continuing task of the PAC Working Group is to assist ILRI management in monitoring resource allocation by research theme, so that ultimately the full benefits of the priority assessment exercise can be realised, through making ILRI's research activities more focused and better targeted to resource-poor livestock keepers in the tropics and subtropics. The framework will also be provided to partners to assist national programmes in setting their priorities and allocating their resources.

Hank Fitzhugh
Director General
International Livestock Research Institute
Nairobi, Kenya

Preface

In this report, we describe the development and application of a quantitative priority assessment framework that allows the linking of agreed research priorities and resultant resource allocations. The principal objective for writing this document was to have a record of the process that ILRI went through during 1999, although the roots of this exercise lie in preliminary work carried out from 1996 onwards. While this is a record of the process that ILRI went through, the document also has value from a methodological standpoint. Various alternative approaches to priority setting are documented, and we attempt to give the reasons why we approached certain problems in a particular way. The document is thus a hybrid of a description of a process and a scientific report, and so contains elements that may be of interest to research managers and scientists as well as to those in international agricultural research centres involved in impact assessment and priority setting.

The report is complete and self-contained so far as the process itself is concerned. In terms of the background to ILRI's priority assessment activity and the many elements that went into it, and the reasons behind the identification of the research themes that entered the priority assessment process, for example, the report is not self-contained. Rather, it forms a companion document to the strategic plan published in 2000, *ILRI strategy to 2010: making the Livestock Revolution work for the poor*. The strategic plan discusses in considerable detail many issues inherent in livestock research and technology development, and those discussions are not repeated here. Some cross-references to the strategic plan are located in the current document at a few key points. The results of the analyses reported here formed a key input to ILRI's medium-term plan 2001–2003, published in 2000.

As we note in the conclusions, the assembly and application of this priority assessment framework is not something that was to be done once and then forgotten about. We see the development and further application of the framework as important activities for ILRI in the coming years, particularly as the rate of change in the international agricultural research landscape shows no signs of slowing down. In addition, there is considerable scope for other organisations engaged in livestock research to make use of this framework in their own situations. Plans are already being drawn up to include the priority assessment framework in training materials based in information technology that ILRI will produce over the next two years or so. Development of the framework itself has already gone beyond what we describe in this document, and the work is currently being written up. The plan is to publish it as a peer-reviewed journal article.

Executive summary

This report describes the development and application of a quantitative priority assessment framework. The framework allows a link between agreed priorities and resultant resource allocations. There are five primary criteria by which priorities are assessed in the framework, reflecting the vision, mission and mandate of ILRI and the priorities and strategies of the CGIAR:

- contribution to poverty reduction
- expected economic impact using an economic surplus framework
- environmental impact
- internationality of the problem
- contribution to capacity building, development of new research tools, and improved research efficiency

A highly participatory process was undertaken throughout 1999. It involved a series of workshops in which ILRI and external scientists considered a set of questions in arriving at candidate research themes for priority assessment in developing ILRI's future strategy and plans towards 2010. These questions included consideration of the extent of the problem by using 11 livestock production systems (Seré and Steinfeld 1996) to specify recommendation domains (that is, the target areas for the uptake of the outputs of research), the goals and purposes of the proposed work, how the work would contribute to reducing poverty, improving food security and protecting the environment, the researchability of the work, the probability of research success, ILRI's complementary and comparative advantage, and notional resource requirements for each theme. Research briefs were prepared for each candidate theme so that themes could be compared. The research briefs were validated and harmonised in two workshops using a Delphi approach. A composite index was then derived for each theme from the five criteria, weighted according to the inputs of focus groups and others.

Results of the priority assessment are discussed in relation to seven broad research and related areas. There is some clustering of the candidate research themes in terms of their composite index, but the constituent impact criteria are quite distinct. Sensitivity analysis reveals that the composite index values are only moderately sensitive to the weights used. Results indicate that the broad research activities covered in the themes potentially will lead to a wide range in types of impact. No themes score highly in all criteria, indicating that a portfolio approach is necessary for assessing research activities, which will inevitably involve trade-offs between the various dimensions of impact considered. Despite limitations in applying the priority assessment framework, it can provide highly useful information to help determine priorities in ILRI's medium-term plan for 2001 to 2003 and beyond.

The framework itself has considerable value for priority setting by other organisations and institutions involved in

livestock research. A major benefit of the framework is that it requires researchers and managers to consider explicitly the determinants of successful research activities and the factors that can facilitate the delivery of research products so that they have measurable impact at the farm level.

There are some difficult issues still to be addressed, but over the next two years the framework will be developed and refined. At the same time, considerable attention will be paid to improving the definition of recommendation domains and to assembling economic, poverty and production data that can improve the priority assessment framework as ILRI and other collaborating organisations involved in livestock-related research use it in a resource-constrained environment.

1 Introduction: the institutional context

The International Livestock Research Institute (ILRI) was formed in 1995 as an amalgamation of the International Laboratory for Research on Animal Diseases (ILRAD) based in Nairobi, Kenya, and the International Livestock Centre for Africa (ILCA), based in Addis Ababa, Ethiopia. Even before ILRI was established, it became clear that a transparent, quantitative process for priority setting and resource allocation was necessary, when considering the enormous range of research and related activities that the new institute might undertake. Management decisions to lead to the development and application of such a process were initially taken in 1995. Since then, there has been increasing emphasis at ILRI on systems analysis and impact assessment for a variety of purposes, including priority setting and research resource allocation.

In March 1999, ILRI underwent its first external programme and management review (EPMR). The various recommendations it made included the following:

> Considering the need to orient livestock research more closely towards the requirements of rapidly changing animal agriculture in developing countries, and the need to define and operationalise ILRI's global mandate more precisely, the Panel recommends that ILRI revisit its vision, strategy, and priorities and redesign its planning processes to position the Institute compellingly at the core of the international animal agriculture research agenda (CGIAR 1999).

In a commentary on the EPMR report, the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) endorsed the development and use of a transparent, quantitative priority assessment framework that would allow ILRI to make a clear link between setting research priorities and allocating resources to research activities (TAC 1999).

ILRI's previous strategic plan, published in 1996 (ILRI 1996a), was originally commissioned by the Rockefeller Foundation, acting on behalf of the CGIAR. That strategic plan involved a long process between October 1992 and late 1994, with working groups, independent studies and extensive consultation. The plan served as the basis for a unified strategy for livestock research in the CGIAR and for developing various iterations of the three-year medium-term plans (MTPs) that guided ILRI programmes and activities.

The basis for that strategic plan was the recognition that the livestock industry was then expected to be the fastest growing major sector of agriculture in developing countries in the coming decades. Some of the major constraints facing the industry could be resolved only by research at the international level, particularly on feed resources, animal health, animal genetics, production systems, economic and social aspects of livestock development, and management of natural resources. Plans were also set out to undertake research activities in areas hitherto new to ILRI, in

Asia and Latin America. The importance of partnerships was stressed, with other international centres but particularly with national partners and networks already in place, in an effort to reap the benefits and synergies of research on an ecoregional basis.

The 1996 strategic plan set the context for developing and implementing ILRI's activities until the EPMR. Many of the recommendations made then are apropos today. On the other hand, three things have changed quite radically since then, and they underline the importance of a revised strategic plan.

First, the available evidence indicates that the growth in demand for livestock products will be greater than was anticipated in the early 1990s. Delgado and others (1999) speak of a 'revolution' in the demand for livestock products to the year 2020, and the implications for the international agricultural research centres (IARCs) of the CGIAR in general may be profound. There are, of course, productivity and policy constraints to overcome to meet the rising demand, and there are also likely to be substantial environmental issues that will come to the fore and require urgent attention.

Second, the nature of the CGIAR's funding has changed substantially, even since 1996. The share of ILRI's budget that was unrestricted in nature, that is, funds made available to the institute that could be expended in any way in pursuit of the institute's goals and mandate area, in 1996 was about 85%. By 1999, this had fallen to less than 45%, the balance being made up of project and programme funds that are restricted in the sense that they are directed towards very specific activities and outputs, for which research teams are held directly responsible. It is not known with any certainty what will happen to this decreasing percentage, but the general feeling is that it will continue to decline, in similar fashion to the decline (not to say disappearance) of 'no-strings-attached' funds to the universities of North America and western Europe, for example. If what is occurring in these universities is an accurate guide to what will happen in the CGIAR centres (and this generally seems to be the case), then the nature of CGIAR funding is going to continue to change rapidly and radically.

Third, there have been quite remarkable shifts in what donors expect of IARCs and agricultural research in general. Indeed, Schuh (1999) recently lambasted the 'faddishness that characterises the economic development community' and the fact that this faddishness victimises agricultural research institutes. Is ecoregional research currently firmly within the agenda of most donors, for instance? How can IARCs work strategically and yet produce on-the-ground impact on household poverty within the time frame of most donor-funded projects (two or three years)? The CGIAR started out with the goal of producing more food. Then IARCs were expected to reduce poverty. Now they are expected to make major contributions to natural resource management (NRM). Mellor (1998) makes much the same argument with respect to

Africa, lamenting the proliferation of special interests at the expense of a loss of focus on the basic processes of agricultural growth.

This adds up to a complicated picture for an IARC such as ILRI. The external environment suggests massive demand for livestock products over the next 20 years, but donors are increasingly making funds available for specific targets aimed at NRM, poverty reduction and so on, often in time that is unrealistically short for the impact on the farm that they seem to expect. How to balance these things, so that the institute is not donor driven, can have positive impact on the poor within a reasonable length of time, and increase production to meet rising demand?

These are very difficult questions, and ultimately they strike at the heart of what the CGIAR is and how it operates. The CGIAR in even five years may appear a very different entity; the constituent centres may be managed in new and innovative ways; and mechanisms for implementing high-quality strategic research work may likewise be very different. Despite such uncertainties, various factors are highly unlikely to change over the next 10 years, and these can be used to help guide an institute such as ILRI in times of rapid change.

First, ILRI will still have an international mandate. ILRI is different from a national agricultural research system (NARS) or an advanced research institute (ARI). Advantages are that this gives ILRI the opportunity to work on strategic issues that are of importance, possibly to systems in general but certainly to multiple locations. ILRI's work is thus also of wide applicability and not merely site specific, and ILRI is one of the few institutes to be working on international public goods.

On the other hand, this mandate means that ILRI cannot be really entrepreneurial in the same way that ARIs can in North America or western Europe, for example.

Second, ILRI will still be a member of the CGIAR, although as noted above, the CGIAR itself may look very different in 10 years. There are definite advantages to this. It means that ILRI is part of a group with common vision, common themes and common donors.

Third, ILRI will still have a focus on poor people in developing countries—probably both rural and urban. ILRI thus has a share in the moral high ground, through helping the economically disadvantaged and vulnerable. On the other hand, with this focus, impact may not be as large or as quickly achieved as if ILRI were working directly with more commercialised livestock producers.

Fourth, ILRI will still be working on livestock-related research. As noted above, the demand for livestock products will increase greatly in the coming years, and the constraints to be overcome if this demand is to be satisfied are many. However, ILRI's commodity, livestock, may still be perceived as a major cause of natural resource degradation.

In sum, important and very fast-acting drivers of change are affecting interna-

tional agricultural research. Despite this, the general nature of ILRI and its place in the world can be stated with a fair degree of certainty in these volatile times. It was against this background that ILRI embarked on a new strategic planning process in 1999. This document describes the framework that was constructed to carry out the priority assessment exercise (Section 2), and then in Section 3 summarises the highly participatory process that was undertaken to define possible research activities (referred to below as 'research and related themes') within the context of the priority assessment framework. Section 4 contains the results of the priority assessment, and in Section 5 conclusions are drawn, with discussion on how to improve the priority assessment framework for future planning.

2 A framework for assessing priorities

The requirement was for ILRI to develop and use a priority assessment framework that is transparent and quantitative, and that allows a clear link between agreed priorities and resultant resource allocations. There are additional reasons why such a framework is both timely and valuable for ILRI. First, it provides an opportunity to link in a systematic way the considerable amount of recent work at ILRI on impact assessment with future priority setting. This will enable a more informed decision-making environment. Second, it provides a mechanism to identify gaps in knowledge of global livestock constraints, and thus it allows ILRI to further enhance its reputation as a centre of excellence and knowledge of the challenges and opportunities for global livestock research and development. Third, such a framework can assist in ILRI's funding and marketing strategies, by allowing the agreed priority agenda to drive funding, rather than the reverse.

In recent years national governments and international research and development agencies have increased the attention that they pay to measuring and documenting the impact of publicly funded agricultural research. This attention has been primarily motivated by a growing need to justify future public investments in the sector and by the related issue of appropriate balance between public and private investment. Achieving the right balance has become especially important with the dynamics of intellectual property rights and both national and international concerns about those rights. In some cases this balance has tipped to turn what were public goods into private ones.

This concern for impact has translated into an imperative for research institutions to incorporate ways to measure the potential impact of alternative future research investments into a priority assessment framework, and from it derive a defensible and marketable portfolio. For example, ISNAR has devoted considerable attention to assisting NARS in this process (Mills 1998). A wide variety of approaches is available, some of which are discussed in this section, along with the particular one chosen for the ILRI exercise.

Alternative approaches

At least 10 identifiable approaches have been used to measure the contributions of research to agreed objectives and then to array competing programmes or projects into a set of priorities for resource allocations. The approaches are not necessarily mutually exclusive and a number are often used in combination. They are elaborated in Alston and others (1995). Each has its own advantages and disadvantages.

Informal or ad hoc. These approaches, the simplest, usually involve little assembly of data or analysis.

Precedence. The previous year's funding is used as the base for the

subsequent year, with incremental changes only. The advantage is that this is simple and quick, and it does not require extensive data or analysis. The disadvantages are that it is supply driven and that it contains an inherent inertia to entertain new priorities or to terminate unproductive ones.

Peer review. Individuals or groups are asked to subjectively assess alternative proposals and rank them according to their preferences. This technique may be most useful for decisions about individual operational projects rather than broad programmes. It also may be best for assessing the scientific merits of proposals rather than their economic worth.

Congruence. Research resources are allocated across research areas in proportion to the value of agricultural production. The technique is best suited to decisions about the relative intensity of research among alternative commodity programmes in various agroecological zones. It is reasonably simple to conduct and a useful starting point in assessing priorities. Comparing current research intensities (research spending as a proportion of the value of production) across commodities or regions or both with allocations that would equalise the proportions allows analysts to ask questions about the appropriateness of current intensities. Congruence ignores other factors that condition the return to research investments such as probability of success, likely adoption and differential productivity gains. It assumes that the payoff to each incremental dollar of investment is the same across alternatives of commodity and region.

Scoring methods. When there are multiple objectives specified for research, they are translated into a set of criteria, and measurable indicators are assigned or elicited to the alternatives to be assessed using Delphi techniques. Weights are also assigned to the criteria based upon the judgements of decision-makers, again using Delphi methods, and these are used to create a weighted composite index for each alternative. These indexes are used to rank alternatives for determining priorities. There are difficulties associated with the scaling of the indicators and assuring their relevance to the policy objectives. The more criteria that are used, the greater the chance that the indicators selected will be duplicates and arbitrarily create unintended weighting factors. The approach has the advantage of intuitive appeal to non-economists but can be demanding of data and analytical resources.

Economic surplus. This is the preferred approach from an economist's perspective. 'There is really no substitute for the economic surplus model' according to Alston and others (1995 p. 493). Indeed most of their book *Science under Scarcity* is devoted to the theory and practice involved in estimating the economic surplus from alternative research investments. The essence of this approach is to measure the extent to which research success and subsequent adoption improve on-farm productivity and hence reduce the unit costs of production. This

measured amount is then placed in a market framework to translate the cost reduction into supply responses operating on demand to generate price reductions. Except in extreme cases, these mechanisms generally lead to real income gains for both producers and consumers, which together represent the economic surplus or benefit from the research. The size of these gains depends on the extent of the productivity gains, the value of production, various market parameters, probabilities of research success, the ceiling levels of adoption achieved and the time it takes to reach them. This approach is demanding of data, economic skill, time required for scientists to elicit the key variables and analytical capacity. It is also most readily applied to alternative commodity research programmes, although it can be extended to evaluate alternative farming systems or natural resource management programmes as well (ICRISAT 1992, Kilambya and others 1998).

Index numbers. Changes in measured productivity indexes over time are related to past agricultural investments, to compare the two. Various index numbers can be used. As the approach requires extensive time series data, it is more relevant for *ex post* than for *ex ante* studies.

Benefit–cost analysis. Usually used in association with the economic surplus method described earlier, this approach estimates the discounted net present value of the stream of economic surpluses from the innovations arising from the research. To do this, it employs the costs of undertaking the research and the time required, the time to reach ceiling levels of adoption, and the social rate of time preference (the discount rate). Net benefit–cost ratios are then calculated. In addition to the demands of the economic surplus approach, this method requires further elicitation of variables from scientists and use of standard computer routines for the benefit–cost analysis. In place of using economic surplus estimations, simpler budgeting procedures can be used that are less demanding of data and market parameter estimates but that lack the precision of the former.

Econometric approaches. More appropriate for *ex post* analysis of the aggregate impact of past national research investments than for *ex ante* priority assessment at a lower level of aggregation, these approaches commonly use index number series on input and output growth. They include research, education and extension investments, measuring their contributions to economic growth. The methodology takes in growth accounting, cost or profit functions, supply functions and production functions. All are demanding in terms of time series data, analytical, econometric and economic skills, and time.

Mathematical programming. The approach of choice of Alston and others (1995), it has the advantage over its shortcut counterpart of scoring methods as it allows optimising the research portfolio subject to resource constraints. It contains the possibility of maximising the contribution of these constrained research re-

sources to economic growth or other objectives. Scoring methods only allow ordinal rankings of discrete research alternatives with no opportunity to allow more marginal adjustments among them. However, the programming approach requires information on the research production function underlying each research programme being assessed, which is extremely demanding on time, resources and heroism of those from which the information is being elicited. The methodology is sophisticated and involves many assumptions in order to become operational. As a result there are few examples of its successful application, especially at an aggregate level.

Experience with approaches

The Technical Advisory Committee of the CGIAR used a spreadsheet approach to the scoring method in assessing priorities for the CG system (TAC 1992). Using this method was criticised by Alston and others (1995) because of the possible dangers of duplication in the choice of indicators and the arbitrariness involved in scaling the measures used to reflect the chosen criteria. McCalla and Ryan (1992) pointed out that the TAC approach also reflected only demand-side considerations without reference to the supply side, which is critical in assessing potential impact such as adoption levels and rates, likely productivity gains, probabilities of success and alternative suppliers.

The Australian Centre for International Agricultural Research (ACIAR) used an economic surplus approach with a partial equilibrium international trade model to assess the prospective impact of alternative commodity research portfolios at an international level (Davis and others 1987). The model accommodated research and economic spillovers among countries, regions and agro-ecologies. It is appropriate for international agencies, but it is demanding of resources, data and economic skills.

The work of ISNAR and KARI (the Kenya Agricultural Research Institute) in Kenya is an example of use of a range of approaches in assessing priorities within various subsectors of agriculture (Mills 1998, Janssen and Waithaka 1999). It is noteworthy that the use of quadratic and utility-efficient risk programming described in Janssen and Waithaka (pp. 71–86) was confined to the dairy subsector and did not consider the whole agricultural sector. These two approaches suggested markedly different optimal dairy research portfolios, both of which were again different from the portfolio suggested by a baseline deterministic mathematical programming model with neutral attitudes to risk.

In 1996 ILRI conducted a priority assessment exercise that embraced a combination of scoring methods with peer review (ILRI 1996b). The 20 ILRI project descriptions that were then current were subjectively ranked at the annual programme planning meeting using four criteria: potential economic and environmental benefits; ability of target beneficiary countries to exploit the

research results; research potential in terms of probability of success and time frame; and ILRI's research capability and comparative advantage. This exercise and the results are discussed comparatively with the current priority assessment exercise in Appendix 7.

The results of the exercise were arrayed diagrammatically by two composite indexes—attractiveness and feasibility—to see to what extent the projects involved trade-offs between these two criteria. The former related to the potential benefits and ability to exploit those benefits and the latter to research potential and capability. Together they were regarded as measuring the returns to ILRI's research and an aid to priority setting.

The scoring exercise elicited several concerns from the participants. They felt that some research areas were overrepresented in the meeting, which led to a bias in the results (a moral hazard that is a feature of such approaches), that participants had different interpretations of the criteria, that it was difficult to rank research areas that had not yet begun, and that it was difficult to judge the potential payoffs for ongoing research in new geographic areas and systems about which the participants had little experience or knowledge. Despite these and other concerns, the exercise stimulated a great deal of discussion throughout the institute and reinforced for many scientists the fact that in the current funding climate, research planning and implementation must consider factors such as probability of success, likely target beneficiaries, and potential constraints to adoption. The exercise proved to be a highly useful start to a process that culminated in the assessment of 1999 described in this document.

Since the 1996 exercise ILRI has placed considerable emphasis on estimating the impact of ILRI's research, much of this using economic surplus and benefit–cost approaches (see Kristjanson 1997, Thornton and Odero 1998, Elbasha and others 1999, Kristjanson and others 1999, Nicholson and others 1999). These studies have tended to focus on a single research theme or product.

The chosen priority assessment framework

To update and improve upon the 1996 exercise, another centrewide priority assessment was undertaken as part of ILRI's current strategy review for 2000–2010. It was decided to use a framework that involved integrating scoring methods, economic surplus and benefit–cost approaches, similar to that used by ICRISAT (ICRISAT 1992, Kelley and others 1995). In the framework, priorities are assessed by five primary criteria, which reflect the vision, mission and mandate of ILRI and the goals of the CGIAR:

- expected economic impact
- contribution to poverty alleviation
- environmental impact
- internationality of the problem and the solution
- capacity building, research tools and research efficiency-related outputs

A key issue at the outset of the assessment was to decide on the appropriate unit of analysis to use in assessing priorities.

Unit of analysis: the research theme

In the present exercise, ILRI's future research agenda is represented by a set of research themes. The priority assessment consists of comparing and ranking these proposed themes, most of which concern research, but some are concerned with related activities such as capacity building. In the discussion that follows, 'research themes' should be taken to include research and these related activities. To permit such a comparison, themes are assumed to conform to a simple model of the process of research, as illustrated in Figure 1. As part of the priority assessment process, ILRI scientists were asked to describe the key parameters based on this simple model, as outlined below.

The ILRI research project. Each research theme is defined as a project covering a fixed number of years (X in

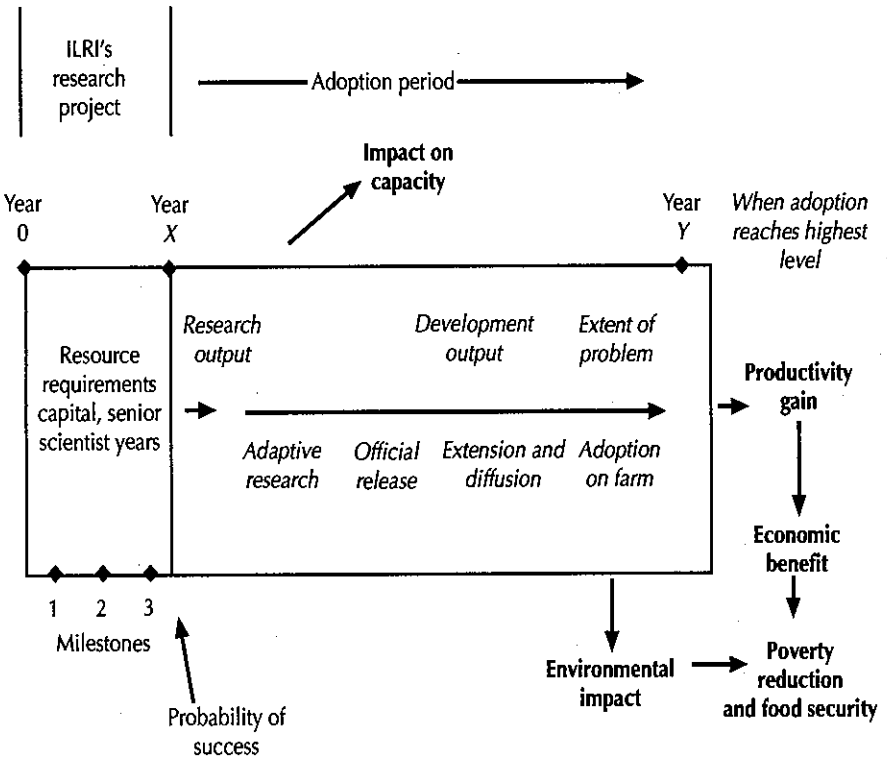


Figure 1 *A simplified model of the progression over time from research output (that is, a new technology) through to ultimate impact on institutional capacity, the economy, poverty and the environment.*

Figure 1) to achieve planned milestones and, in the end, generate the intended research output. In cases in which research is expected to continuously generate outputs over the life of the project, the research and other outputs are assumed to be generated midway through the life of the project. Resources required to achieve the objectives are measured in terms of 1) scientific human resources reflected as senior scientist years, costed to include all of their ancillary fixed and operating costs such as support staff and laboratory infrastructure; and 2) any large new capital investments. Since there is a degree of uncertainty inherent in science, we can consider the probability of achieving the planned outputs given the proposed level of resources within the defined time frame. This probability of success needs to be conditioned by the risks of non-ILRI scientific inputs not being available at the expected time or not being able to find appropriate scientific solutions to the research problem.

The adoption period. Once the intended research output has been generated, a process of further adaptive research follows, if needed, or development of products customised to specific geographical areas, production systems or sets of end users. This may entail a process in which NARS evaluate the product before it can be officially introduced in a given country. The product is then disseminated to the end users through either formal or informal extension channels. For our purposes, adoption of the end product is assumed to begin immediately at the end of the ILRI research project period, and then to follow the standard sigmoid curve by which adoption starts very slowly, accelerates gradually, then decelerates until the adoption ceiling is reached (Figure 2). The period between the end of the ILRI component (Year X in Figure 2) and when the adoption ceiling would be reached (Year Y) constitutes the adoption lag. The adoption lag and the adoption ceiling or maximum level of adoption are the two key parameters defining the adoption period.

The estimate of the adoption ceiling comprises two elements: the extent of the problem being addressed by the research—which we term the relevance domain—and the portion of producers within that domain likely to adopt the end product based on the research. The extent of the problem within each production system is evaluated as being widespread, moderately present, limited or not present at all. A similar ranking is used to describe the degree of adoption within the relevance domain and is associated with conservative numeric values: high (20–30%), medium (10–20%), or low (0–10%) level of adoption. Multiplying these adoption estimates by the degree of relevance yields the appropriate adoption ceiling by production system by region.

Although grossly oversimplifying the numerous variations in technology development and transfer that exist, and ignoring the fact that this process is clearly often not as linear over time as

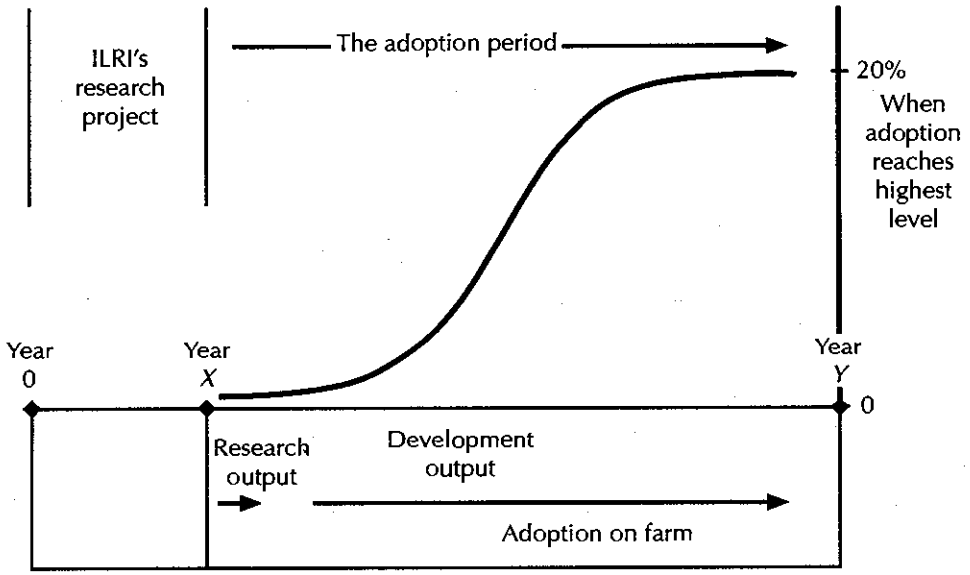


Figure 2 *The research output released in year X is assumed to go through further development and experimentation on farm before being steadily adopted by an increasing number of producers to reach a maximum (ceiling) adoption after Y years.*

suggested in the figures, the model provides a useful framework that scientists formulating the parameter estimates can easily understand and that adapts well to the needs of the priority assessment analysis.

Impact. ILRI endeavours to achieve its objectives mainly through improving productivity of smallholder livestock production systems. The principal (but by no means the only) pathway by which research is expected to have impact is via adoption of the anticipated research products leading to productivity gains on farm, typically measured as increased output per animal of meat, eggs and milk. These gains then translate into economic benefits in terms of improved incomes, possibly through improved profitability (lower production costs), improved revenues (expanded production), and lower produce prices (of benefit to consumers). A generic discovery-to-delivery chain for research products is shown in Figure 3, together with the mechanisms and partners for producing final impact on people.

When estimating productivity gains, it must be recognised that not all research themes affect on-farm productivity directly. Research themes focusing in particular on capacity building (information, training and networking), policy, systems analysis and impact assessment are viewed as enhancing research efficiency through improved capacity and

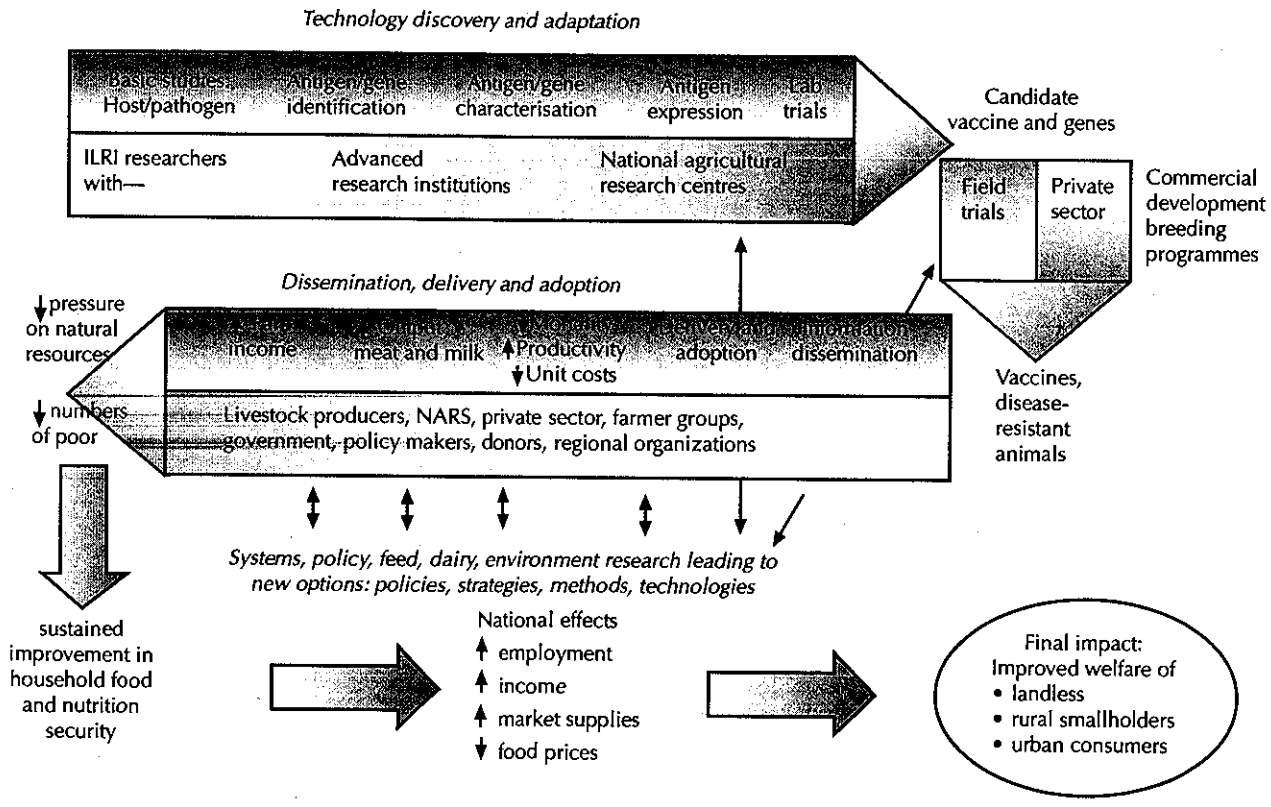


Figure 3 *A generic discovery-to-delivery chain for the outputs of research produced by ILRI and partners.*

management, and thereby accelerating the generation and transfer of research products more directly aimed at improving on-farm productivity. Unfortunately, no evidence is currently available as to the degree to which this acceleration factor generates incremental productivity gains on farm.

In addition to productivity gains leading to economic benefits, three other types of impact are associated with each theme (Figure 1). Contribution to capacity building is the first and may occur directly during the research project or be its primary output (for example, tools for improved research decision-making). Second, adoption of the end product based on the research may have positive or negative effects on the environment, due either to the nature of the end product (technologies involving toxic chemical use, for example) or to the implications that productivity gains and enhanced profitability may have for expanding livestock production. Lastly, depending on the proportion of poor among the beneficiaries of the research products, this environmental impact—because it affects the quality of the primary productive asset of many poor, namely land and water—when combined with the economic impact then determines the ultimate impact on reducing poverty and improving food security.

To obtain information that would allow quantification of these criteria, a number of focus groups were formed to review key areas of current or potential relevance to ILRI. These focus groups were asked to answer a number of questions in arriving at candidate research and related themes for priority assessment in developing ILRI's future strategy and plans towards 2010 (the process is outlined in Section 3).

These questions, outlined in Appendix 1, formed the basis of a detailed set of guidelines (also included in Appendix 1). Together with material discussing livestock research issues and the external environment (von Kaufmann 1999) that formed a key part of the strategic plan (ILRI 2000), focus groups used these guidelines in a series of workshops. Each focus group completed a research brief for its candidate theme so that the institute was positioned to compare themes both within and among focus groups. The guidelines enable measures of the contribution of the candidate themes to the achievement of ILRI's vision, mission and mandate as a CGIAR centre, using the five primary criteria noted above. Figures 4 and 5 describe how the priority assessment framework relates to the strategic planning process at ILRI. Each of the five criteria in the framework is elaborated below.

Expected economic impact

The first criterion for comparing the worthiness of different research themes is the economic impact the research is expected to generate. It is easy to understand why research managers often turn first to an economic evaluation of priorities: monetary value serves well as a

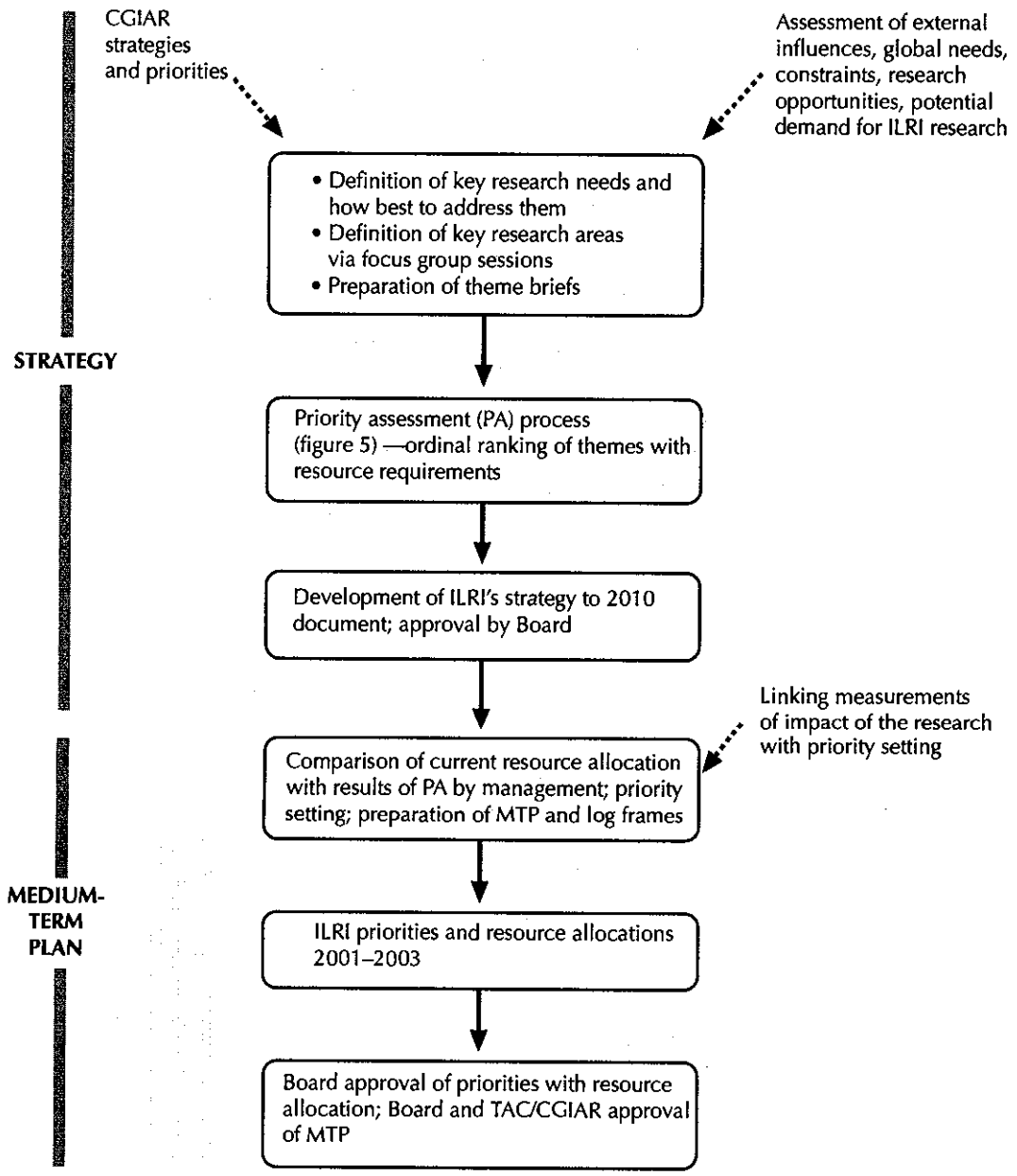


Figure 4 *The ILRI strategic planning process. See Figure 5 for details of the priority assessment process.*

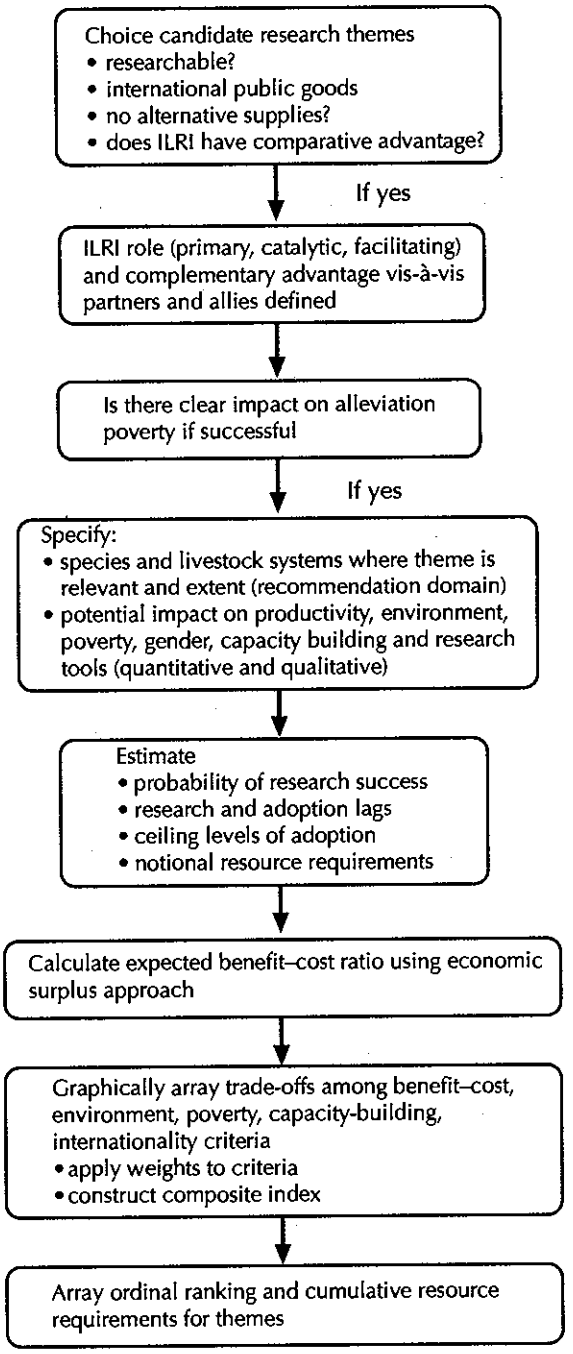


Figure 5 *Details of the ILRI priority assessment process.*

common unit of measurement when comparing benefits in the form of productivity gains for a variety of crops, livestock and their products. It permits comparing apples with oranges, literally, by translating productivity gains into increased value of production or income. Similarly, it permits comparing these benefits with the research funds invested in the project.

The general approach, then, for developing the economic impact indicator is to first identify and value the potential incremental productivity gains attributable to the research outcome. Second, productivity gains and changing production costs are likely to change the amount of the commodity or commodities supplied, and so will affect the market. In the standard graph of crossing supply and demand curves used by economists, the impact on the market can be represented as a series of shifts of the supply curve and consequent adjustments in the equilibrium market price and quantity traded. This means that the benefit generated by the research product is not simply a matter of multiplying the productivity gain by a fixed price; in fact, the net gain and price are likely to vary as supplies generated by the productivity gain are added to the market for that commodity. These adjustments are captured by using the economic surplus model described earlier. Lastly, the stream of estimated future benefits appropriately adjusted to account for the market effects and the time value of money are compared with the initial stream of research investments using a standard cost–benefit analysis. This analysis permits estimating the benefit–cost ratio (BCR) for the research theme, which essentially measures the value of the productivity gain generated per dollar invested in that research theme. It is the BCR that serves as the indicator for comparing the economic impact across research themes.[1]

Putting this approach into operation involves several cumulative steps:

- identifying research target zones and research themes
- compiling a detailed information base on each target zone, particularly on the distinguishing features of the major production systems and the commodities produced within these systems on which research was likely to have an impact, under each theme
- identifying commodity-specific potentials for technology generation and adoption under each theme and in each zone
- computing commodity-specific benefits accordingly

The required economic information base thus includes the following:

- spatially disaggregated agro-ecological data distinguishing research target zones and livestock production systems

[1] An alternative indicator used to compare the worthiness of investments is the internal rate of return (IRR). The IRR could not be estimated for certain research themes because of the structure of their cost and benefit streams, and so it was not used.

- zone- and system-specific output levels at the appropriate farm level for commodities on which research is likely to have an impact, and prices for those commodities
- where available, background information on farmer constraints, technology adoption, and socio-economic differentiation

These data were merged with information derived from the research briefs that ILRI and other scientists compiled within their relevant focus groups, which identified the research and related themes (see Section 3). Research target zones were taken to be those identified by the CGIAR—sub-Saharan Africa, West Asia and North Africa, Latin America and the Caribbean, South Asia, East Asia, and South-East Asia. Principal livestock production systems within these zones were taken from Seré and Steinfeld (1996). A brief description of these systems is included in Appendix 1. For each theme and zone, the focus groups estimated the degree to which the yield of each commodity in each affected production system would either increase due to research interventions or remain unchanged. These productivity gains in fact represent 'net' gains by implicitly first subtracting the additional costs incurred by farmers to realise the gross gains provided by the research product. These net yield gains were then applied to the current production levels for the affected commodities across the relevant livestock production systems and target zone that the research theme was specified as influencing.

Economic benefits under each theme and zone were then computed in a standard economic surplus framework (see Alston and others 1995, for example; notes on the computations and assumptions used can be found in Appendix 2). Estimates of economic surplus generated under each theme were then multiplied by the corresponding probabilities of research success to arrive at expected maximum economic benefits. These gains were adjusted to reflect likely ceiling levels of adoption and the time taken to reach these levels. These adjusted gains were combined with the notional resource requirements and the research lags specified in the briefs to calculate the discounted present value of the net benefit streams and the discounted costs. The expected BCR for each theme was thus derived as the ratio of the discounted value stream of net benefits (net of research costs) to the discounted value stream of costs associated with the theme over a 50-year time frame,

$$BCR = \frac{\sum b_{it}}{\sum c_t}$$

where b_{it} is the discounted net benefit in the ith region production system in year t, and c is the discounted cost. To be consistent in scale with the other priority assessment criteria, the BCRs for all themes were then internally normalised between 0 and 1.

Poverty

Given the importance that the CGIAR and many donors place on reducing, alleviat-

ing or eradicating poverty (the terminology varies), a key indicator relates to the broad impact that each research area at ILRI could have in affecting the depth and breadth of poverty in each region and each system. To do this, some data were needed that estimate the number of poor and that give an idea of the extent and severity of poverty in each system and could ultimately be assembled into an index for scoring each research theme.

Data for all countries were amalgamated into the six regions defined by Delgado and others (1999): sub-Saharan Africa (SSA), South Asia (SA), East Asia (EA), South-East Asia (SEA), Latin America and the Caribbean (LAC), and West Asia–North Africa (WANA). Human population figures were available by livestock production system by region from the spreadsheets of Seré and Steinfeld (1996), with manual divisions carried out for Brazil, China, Ethiopia, India, Mexico, Nigeria, Sudan and the USA. These figures are the average of the 1992–94 FAOSTAT data (FAO 1990–98). For the ILRI study, we concentrated on four numbers related to poverty: an income measure adjusted for societal inequity (as a proxy for a welfare indicator); a poverty indicator reflecting the severity of poverty in the country; the absolute number of poor people in the country; and the number of rural poor in the country.

To construct an income measure W, the data and methods of Gryseels and others (1997) were used. The purchasing power parity (PPP) incomes reported in the UNDP Human Development Report (1994), which are taken from World Bank data, were adjusted by a World Bank estimate of the Gini coefficient,

$$W = (1-G)y$$

where G is the Gini coefficient, a measure of the inequality of income distribution, and y is average income per capita at PPP. This adjustment is made to reduce the estimated income if the income distribution in a given country is highly skewed. Thus the higher is G, the lower W. If all income is distributed equally in a country, then G is 0, and W is the same as y. On the other hand, if all income is in the hands of one individual, then G is 1, and adjusted income per person is 0. In the data set, values of G range from 0.63 (Brazil) to 0.28 (Bangladesh). Gryseels and others (1997) found that Gini coefficients were available for 40 countries. For countries with no available value of G, average values for each of the six regions were estimated using the available figures weighted by individual country population. These six weighted values were then applied to those countries in each region with no available value of G. The weighted values of G were 0.40 for SSA, 0.35 for SA, SEA and EA, 0.36 for WANA, and 0.56 for LAC.

Values of PPP income for the year 2010 were estimated using growth rates in GDP per capita as reported in the data files of Gryseels and others (1997). Country figures for 1994 PPP income per capita were then inflated using these growth rates. The assumption here is that the relative values of PPP are constant

over time. Ethiopia is thus estimated to have a value for W of US$301 in 2010, and Zimbabwe US$1252, for example.

Gryseels and others (1997) then proceeded to construct a poverty indicator P as follows,

If $W < Z$, then $P = (1 - W/Z)^a$
If $W > Z$, then $P = 0$

where Z is a threshold income level per capita and a is an exponent that defines the severity of the poverty index.

The poverty index P is thus unitless: the greater the number, the greater the poverty index. Gryseels and others (1997) used threshold values of both US$6000 and US$9000 in the TAC study and set the exponent at both 2 and 3. An increase in the value of the exponent has the effect of raising the relative P for countries with lower W, so that the poverty indicator is increased for such countries.

In the ILRI analysis, we calculated P based on a threshold of US$6000 in 2010, using an exponent of 2. By using a lower threshold rather than a higher one, we are in effect giving more weight to poverty, which is in accord with CGIAR goals. As will be seen, in 2010, various countries, such as China and Mexico, are estimated to have a poverty indicator P of 0 (that is, a PPP income greater than the threshold of US$6000 per capita). Ethiopia, for instance, has a P value of 0.902 and Zimbabwe 0.626.

To estimate the absolute number of poor people per country, the spreadsheets of Gryseels and others (1997) were again used. They give country data for 63 countries of the number of people below the 'poverty line' as defined by FAO, which is less than US$1 per day. Again, for countries where such data are not available, a regional population weighted average was estimated for each of the six regions and then applied to the countries with no data. Thus complete country figures were derived for the total poor by country, and for the percentage breakdown into rural and urban poor. The percentage of rural poor was then also calculated for each country.

At this stage, we thus had values of W, P, total poor and rural poor by country by region. To break these figures down by production system to use with the research theme descriptions (termed 'briefs' below), we proceeded as follows. The study of Seré and Steinfeld (1996) has spreadsheets with breakdowns of human population by the nine land-based systems. The method used was essentially to assign population to the land-based systems on the basis of the proportion of arable land in each agro-ecological zone, or AEZ (for the landless systems, the prorating factor used was the population in each AEZ in proportional terms). For some of the larger countries, Seré and Steinfeld (1996) had by hand allocated population between AEZ and production system.

Thus for each country, total population figures were available broken down into production systems (Table 1). These were then summed (Table 2, Block 2.1) to provide estimates of total human population by region by production system.

Table 1 *Poverty-related data by country and system*

	Population (1000s)	Welfare indicat'r US$	Poverty indicat'r	Number of poor (1000s)	Human population by system (1000s)										Urban poor (%)
					LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other	
SUB-SAHARAN AFRICA															
Angola	10279	1723	0.508	5503	2853	5321	1722	0	0	0	0	0	0	383	0.11
Benin	5088	1192	0.642	2443	0	0	0	0	4360	560	0	0	0	168	0.19
Botswana	1401	3073	0.000	676	0	0	1313	0	0	0	0	0	0	88	0.17
Burkina Faso	9773	533	0.830	7675	0	0	0	0	2130	7386	0	0	0	257	0.05
Burundi	6027	462	0.852	5014	0	0	0	5824	0	0	0	0	0	203	0.04
Cameroon	12526	1188	0.643	3695	0	0	0	0	12201	0	0	0	0	325	0.21
Cape Verde	370	1259	0.624	129	0	0	0	0	0	384	0	0	0	0	0.19
Centr. Afr. Rep.	3156	632	0.800	1819	0	0	0	0	3174	0	0	0	0	0	0.19
Chad	6013	548	0.826	2836	0	0	5849	0	0	0	0	0	0	164	0.22
Congo	2443	1104	0.666	1365	0	2369	0	0	0	0	0	0	0	74	0.17
Comoros	607	769	0.760	255	0	0	0	0	585	0	0	0	0	22	0.16
Cote d'Ivoire	13319	769	0.760	6705	0	0	0	0	12914	0	0	0	0	405	0.25
Djibouti	556	926	0.715	162	0	0	0	0	0	0	0	0	0	556	0.66
Equat. Guinea	379	471	0.849	254	0	0	0	0	369	0	0	0	0	10	0.26
Ethiopia	52981	301	0.902	30592	0	0	0	33360	9001	9819	0	0	0	801	0.05
Gabon	1248	1925	0.461	403	0	1238	0	0	0	0	0	0	0	10	0.33
Gambia	1042	927	0.715	730	0	0	0	0	0	908	0	0	0	134	0.08
Ghana	16450	1858	0.477	6925	0	0	0	0	15963	0	0	0	0	487	0.17
Guinea	6308	368	0.881	3607	0	6118	0	0	0	0	0	0	0	190	0.11
Guinea Bissau	1028	448	0.856	663	0	0	0	0	1006	0	0	0	0	22	0.07
Kenya	26388	656	0.793	11545	15038	0	10200	0	0	0	0	0	0	1150	0.06
Lesotho	1943	1180	0.645	1048	1836	0	0	0	0	0	0	0	0	107	0.19
Liberia	2845	881	0.728	648	0	2752	0	0	0	0	0	0	0	93	0.47
Madagascar	13858	454	0.854	5924	6719	5156	957	0	0	0	0	0	0	1026	0.12
Malawi	10508	461	0.852	8638	0	0	0	0	8132	2213	0	0	0	163	0.04
Mali	10137	364	0.882	5246	0	0	9822	0	0	0	0	0	0	315	0.13
Mauritania	2162	899	0.723	1109	0	0	2144	0	0	0	0	0	0	18	0.22
Mauritius	1091	15123	0.000	178	0	0	0	0	1098	0	0	0	0	0	0.57
Mozambique	15121	477	0.847	8695	0	5308	9588	0	0	0	0	0	0	225	0.21
Namibia	1461	2584	0.324	771	0	0	1535	0	0	0	0	0	0	0	0.12
Niger	8553	492	0.843	2791	0	0	0	0	0	8256	0	0	0	297	0.13

	Population (1000s)	Welfare indicat'r (US$)	Poverty indicat'r	Number of poor (1000s)	Human population by system (1000s)										Urban poor (%)
					LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other	
Nigeria	105287	1031	0.686	42010	0	6892	5736	0	72537	30524	0	0	0	0	0.19
Reunion	634	2382	0.364	143	0	0	0	0	624	0	0	0	0	10	1.00
Rwanda	7555	494	0.842	6528	0	0	0	7529	0	0	0	0	0	26	0.02
Senegal	7904	874	0.730	3995	0	0	0	0	0	7738	0	0	0	166	0.18
Sierra Leone	4298	559	0.822	2228	0	0	0	0	4377	0	0	0	0	0	0.13
Somalia	8965	413	0.867	4787	0	0	9214	0	0	0	0	0	0	0	0.15
Sudan	26647	367	0.881	18823	0	4245	12094	0	1415	4289	0	0	4617	0	0.07
Swaziland	809	1920	0.462	393	0	0	792	0	0	0	0	0	0	17	0.26
Tanzania	28023	418	0.865	13731	6375	9718	11744	0	0	0	0	0	0	186	0.04
Togo	3886	761	0.762	1082	0	0	0	0	3764	0	0	0	0	122	0.23
Uganda	19941	728	0.772	14578	0	0	0	0	15102	3575	0	0	0	1264	0.04
Zaire	41241	276	0.910	29050	0	0	0	0	39891	0	0	0	0	1350	0.09
Zambia	8935	570	0.819	5910	0	4794	3844	0	0	0	0	0	0	297	0.30
Zimbabwe	10737	1252	0.626	5236	0	0	0	0	6832	3750	0	0	0	155	0.14
SUM	519923			276538	32821	53911	86554	46713	215475	79402	0	0	4617	11286	
LATIN AMERICA AND THE CARIBBEAN															
Argentina	33780	6377	0.000	5287	598	30551	1951	0	0	0	0	0	0	680	0.83
Barbados	260	7151	0.000	69	0	0	0	0	259	0	0	0	0	1	0.53
Belize	204	3251	0.000	97	0	0	0	0	198	0	0	0	0	6	0.33
Bolivia	7065	1776	0.496	4019	1580	4206	1737	0	0	0	0	0	0	0	0.27
Brazil	156483	2767	0.000	72060	0	9691	0	0	113984	30470	0	0	0	2338	0.64
Chile	13822	6691	0.000	4107	0	0	0	0	0	0	0	0	13599	223	0.87
Colombia	33985	5088	0.000	14087	24907	8517	0	0	0	0	0	0	0	561	0.69
Costa Rica	3270	4260	0.000	955	2615	577	0	0	0	0	0	0	0	78	0.39
Cuba	10874	2537	0.333	3443	0	0	0	0	0	7113	0	3696	0	65	0.72
Dominican Rep.	7542	2616	0.318	4110	0	0	0	0	7460	0	0	0	0	82	0.51
Ecuador	10981	3176	0.222	5545	0	0	0	6269	4123	0	0	163	500	0	0.46
El Salvador	5518	1543	0.552	2773	0	0	0	0	1282	0	4104	0	0	132	0.18
French Guyana	135	2042	0.435	41	0	0	0	0	104	0	0	0	0	31	1.00
Guadeloupe	413	2042	0.435	126	0	0	0	0	403	0	0	0	0	10	1.00
Guatemala	10032	1779	0.495	7103	0	0	0	9430	317	0	0	0	0	285	0.37
Guyana	816	1737	0.505	408	0	0	0	0	0	0	0	808	0	8	0.21
Haiti	6894	446	0.857	5205	0	0	0	0	0	6756	0	0	0	138	0.26

	Population (1000s)	Welfare indicat'r (US$)	Poverty indicat'r	Number of poor (1000s)	Human population by system (1000s)										Urban poor (%)
					LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other	
Honduras	5336	1200	0.640	1950	0	0	0	3860	1603	0	0	0	0	0	0.17
Jamaica	2411	3080	0.237	1285	0	0	0	0	2450	0	0	0	0	0	0.31
Martinique	371	2042	0.435	113	0	0	0	0	0	0	0	369	0	2	1.00
Mexico	90024	5704	0.000	27259	0	4093	11652	23897	10578	5969	20388	0	11577	1870	0.56
Nicaragua	4115	1183	0.644	832	0	0	0	0	3959	0	0	0	0	156	0.63
Panama	2538	4718	0.000	1074	0	0	0	0	2515	0	0	0	0	23	0.51
Paraguay	4701	2221	0.397	1636	0	4520	0	0	0	0	0	0	0	181	0.27
Peru	22888	2661	0.310	7091	13463	938	8039	0	0	0	0	0	0	448	0.3
Puerto Rico	3618	6758	0.000	1105	0	0	0	0	0	0	0	3594	0	24	1.00
St. Lucia	138	2297	0.381	42	0	0	0	0	137	0	0	0	0	1	1.00
Suriname	414	1923	0.462	189	0	0	0	0	0	0	0	438	0	0	0.29
Trinidad & Tobago	1278	5353	0.000	427	0	0	0	0	0	0	0	1265	0	13	0.6
Uruguay	3149	3812	0.000	381	0	3130	0	0	0	0	0	0	0	19	0.74
Venezuela	20912	6087	0.000	6420	0	0	0	0	11668	8503	0	0	0	741	0.83
SUM	463967				43163	66223	23379	43456	161040	58811	24492	10333	25676	8116	
WEST ASIA–NORTH AFRICA															
Afghanistan	17731	983	0.699	9224	0	0	0	0	0	0	0	0	19099	0	0.07
Algeria	26724	3925	0.000	5973	0	0	0	0	0	26342	0	0	0	382	0.47
Bahrain	535	10619	0.000	115	0	0	0	0	0	0	0	0	533	2	1.00
Cyprus	726	10083	0.000	115	0	0	0	0	0	0	0	0	716	10	0.74
Egypt	60314	3529	0.170	14017	0	0	0	0	0	0	0	0	54844	5470	0.40
Iran	64145	4156	0.000	16107	0	0	0	0	0	0	0	0	61564	2581	0.50
Iraq	19464	3153	0.225	4641	0	0	0	0	0	0	0	0	19295	169	0.66
Jordan	4079	2572	0.326	609	0	0	0	0	0	3538	0	0	0	541	0.65
Kuwait	1782	21554	0.000	391	0	0	1961	0	0	0	0	0	0	0	0.94
Lebanon	2807	4999	0.000	578	0	0	0	0	0	0	0	0	2841	0	0.89
Libya	5050	3119	0.231	1163	0	0	4877	0	0	0	0	0	0	173	0.79
Morocco	25945	3317	0.200	9602	0	0	0	0	0	26320	0	0	0	0	0.36
Oman	1993	8050	0.000	154	0	0	1638	0	0	0	0	0	0	355	0.31
Qatar	529	19676	0.000	124	0	0	453	0	0	0	0	0	0	76	0.73
Saudi Arabia	17131	6924	0.000	4099	0	0	15927	0	0	0	0	0	0	1204	0.67
Syria	13700	3332	0.198	5132	0	0	0	0	0	13282	0	0	0	418	0.29
Tunisia	8570	4902	0.000	1530	0	0	0	0	0	8402	0	0	0	168	0.64

	Population (1000s)	Welfare indicat'r (US$)	Poverty indicat'r	Number of poor (1000s)	Human population by system (1000s)										Urban poor (%)
					LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other	
Turkey	59598	5228	0.000	11231	0	0	0	0	0	S8368	0	0	0	1230	0.73
UAE	1815	15046	0.000	421	0	0	1670	0	0	0	0	0	0	145	0.76
Yemen	13193	829	0.743	3613	9566	0	2972	0	0	0	0	0	0	655	0.24
SUM	328100				9566	0	29498	0	0	136252	0	0	139793	13579	
SOUTH ASIA															
Afghanistan	17731	983	0.699	9224	0	0	0	0	0	0	0	0	19099	0	0.07
Bangladesh	115233	1406	0.586	84910	0	0	0	0	0	0	0	119314	0	0	0.04
Bhutan	1597	1006	0.693	1379	0	0	0	0	0	0	0	1612	0	0	0.01
India	901485	1390	0.590	357529	0	6842	0	0	131004	287450	0	56722	397602	21865	0.22
Nepal	20816	1046	0.682	12448	0	0	0	0	0	0	0	20578	0	238	0.10
Pakistan	132967	2761	0.291	37244	0	0	0	0	0	0	0	0	124772	8195	0.31
Sri Lanka	17898	4453	0.000	7012	0	0	0	0	0	0	0	17667	0	231	0.08
SUM	1207727				0	6842	0	0	131004	287450	0	215893	541473	30529	
SOUTH-EAST ASIA															
Brunei	274	12896	0.000	48	0	0	0	0	0	0	0	270	0	4	1.00
Indonesia	191675	4573	0.000	47727	0	0	0	0	0	0	0	191170	0	505	0.24
Kampuchea	9683	1102	0.667	2820	0	0	0	0	8775	0	0	0	0	908	0.07
Laos	4605	1943	0.457	3293	0	0	0	0	4470	0	0	0	0	135	0.05
Malaysia	19246	10725	0.000	3022	0	0	0	0	0	0	0	18791	0	455	0.23
Myanmar	44601	2468	0.347	15341	0	0	0	0	43673	0	0	0	0	928	0.13
Papua N. Guinea	4110	3941	0.000	2655	0	0	0	0	4056	0	0	0	0	54	0.02
Philippines	64805	2581	0.325	16153	0	0	0	0	0	0	0	65183	0	0	0.31
Singapore	2792	34757	0.000	419	0	0	0	0	2769	0	0	0	0	23	1.00
Thailand	57580	11175	0.000	17326	0	0	0	0	51638	0	0	0	4492	1450	0.13
Vietnam	71330	1400	0.588	36747	0	0	0	0	0	0	0	69490	0	1840	0.07
SUM	470701				0	0	0	0	115381	0	0	344904	4492	6302	
EAST ASIA															
China	1175449	4262	0.000	131415	86803	173437	3441	192872	120086	0	210579	380367	0	7864	0.16
Mongolia	2318	3276	0.206	563	2310	0	0	0	0	0	0	0	0	8	0.10
North Korea	23049	5981	0.000	4281	0	0	0	0	0	0	22620	0	0	429	0.31
South Korea	44132	18817	0.000	1880	0	0	0	0	0	0	44154	0	0	0	0.69

	Population (1000s)	Welfare indicat'r (US$)	Poverty indicat'r	Number of poor (1000s)	Human population by system (1000s)											Urban poor (%)
					LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other		
Taiwan	20823	23897	0.000	3662	0	0	0	0	0	0	0	20693	0	130		1.00
SUM	1265771				89113	173437	3441	192872	120086	0	277353	401060	0	8431		

SSA – sub-Saharan Africa; LAC – Latin America and the Caribbean; WANA – West Asia and North Africa; SA – South Asia; SEA – South-East Asia; EA – East Asia
L – livestock; M – mixed; G – grassland based; R – rainfed; I – irrigated; T – temperate and tropical highland; A – arid and semi-arid; H – humid and subhumid

It should be noted that the production system figures match the totals in Table 12 of Seré and Steinfeld (1996) almost exactly, except that we now put Afghanistan in South Asia (following Delgado and others 1999) and not in WANA as Seré and Steinfeld (1996) do.

The welfare indicator *W* was then broken down by system, to provide the weighted averages in Block 2.2 of Table 2. These values are weighted by population, and the column and row summaries are again the weighted averages for the columns and rows. As an illustration, consider SSA and the production system LGT (grassland-based livestock production system in the temperate and tropical highland zones). This production system occurs in SSA in Angola, Kenya, Lesotho, Madagascar and Tanzania, and a total of 32,821,000 people occupy these areas in these countries according to Seré and Steinfeld (1996). The weighted average value of *W* for the LGT system in SSA was thus calculated as

$$W_{SSA\ LGT} = \sum_{j=1}^{5} W_j * Pop_j \,/\, 32{,}821{,}000$$

where *Pop* is total population in the system LGT in country *j* and *W* is the welfare indicator for country *j*.

Similarly, Block 2.3 of Table 2 shows the poverty indicator by region by the Seré and Steinfeld system, again weighted by population. The column and row summaries are the weighted averages for the columns and rows. The absolute number of poor people by region and by

Table 2 *Poverty-related data as used in the analysis, by region and by livestock production system*

Block 2.1 Total human population (1000s)

	LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other	Sum
SSA	32821	53911	86554	46713	215475	79402	0	0	4617	11286	530779
LAC	43163	66223	23379	43456	161040	58811	24492	10333	25676	8116	464689
WANA	9566	0	29498	0	0	136252	0	0	139793	13579	328688
SA	0	6842	0	0	131004	287450	0	215893	541473	30529	1213191
SEA	0	0	0	0	115381	0	0	344904	4492	6302	471079
EA	89113	173437	3441	192872	120086	0	277353	401060	0	8431	1265793
Sum	174663	300413	142872	283041	742986	561915	301845	972190	716051	78243	4274219

Block 2.2 Welfare indicator (PPP income US$ per capita)

	LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other	Wtd av
SSA	690	727	626	352	925	769	0	0	367	715	758
LAC	4177	4873	4422	4088	3178	3251	5007	4254	6178	4206	3973
WANA	829	0	7372	0	0	4333	0	0	3844	4284	4294
SA	0	1390	0	0	1390	1390	0	1614	1692	1779	1574
SEA	0	0	0	0	7067	0	0	3899	11175	4853	4757
EA	4236	4262	4262	4262	4262	0	6719	5275	0	4651	5122
Wtd av	3369	3697	2727	3590	2988	2211	6580	3963	2324	2869	3344

Block 2.3 Poverty indicator (unitless)

	LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other	Wtd av
SSA	0.79	0.78	0.81	0.89	0.74	0.76	0.00	0.00	0.88	0.78	0.77
LAC	0.11	0.06	0.14	0.20	0.05	0.14	0.09	0.20	0.00	0.09	0.09
WANA	0.74	0.00	0.11	0.00	0.00	0.07	0.00	0.00	0.10	0.13	0.11
SA	0.00	0.59	0.00	0.00	0.59	0.59	0.00	0.55	0.52	0.51	0.55
SEA	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.18	0.00	0.33	0.19
EA	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wtd av	0.22	0.17	0.53	0.18	0.36	0.44	0.01	0.19	0.42	0.37	0.29

Block 2.4 Total number of poor (1000s)

	LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	Other	Sum
SSA	15093	27635	46125	30613	111490	40584	0	0	3261	6125	280927
LAC	16251	18817	7312	18489	70406	25802	8236	3489	7799	3013	179615
WANA	2620	0	6798	0	0	33631	0	0	33618	3132	79800
SA	0	2714	0	0	51956	114003	0	131032	202573	11200	513478
SEA	0	0	0	0	39348	0	0	102645	1352	2301	145645
EA	10266	19390	385	21563	13426	0	29625	46164	0	984	141802
Sum	44229	68556	60621	70665	286625	214021	37861	283331	248603	26755	1341267

Block 2.5 Number of poor (1000s)

	RURAL POOR									URBAN	TOTAL
	LGT	LGH	LGA	MRT	MRH	MRA	MIT	MIH	MIA	POOR	
SSA	13872	23505	39971	29326	96676	35870	0	0	3033	38673	280927
LAC	7258	7359	4069	10270	27001	10696	4407	1002	2204	105349	179615
WANA	1991	0	2347	0	0	16582	0	0	17035	41846	79800
SA	0	2117	0	0	40526	88922	0	120768	156352	104793	513478
SEA	0	0	0	0	34568	0	0	82953	1176	26949	145645
EA	8657	16288	323	18113	11277	0	23258	35721	0	28165	141802
Sum	31778	49269	46710	57710	210048	152069	27665	240444	179800	345774	1341267

SSA – sub-Saharan Africa; LAC – Latin America and the Caribbean; WANA – West Asia and North Africa; SA – South Asia; SEA – South-East Asia; EA – East Asia

L – livestock; M – mixed; G – grassland based; R – rainfed; I – irrigated; T – temperate and tropical highland; A – arid and semi-arid; H – humid and subhumid

livestock system was calculated (Block 2.4, Table 2) simply by taking the proportion of poor people in the country and applying this proportion to the system population totals. Column and row totals are thus absolute totals. For each country, we took the total number of people in the land-based systems and subtracted this from the FAO country totals of Gryseels and others (1997). If the number was positive, we termed it 'other' population, and it would presumably include some of the landless but other people also. This explains why some of the figures under 'other' in Table 1 are zero—in these cases, the sum of population by system equalled or exceeded the FAO country totals.

The figures in Block 2.4 of Table 2 assume, of course, that poor people are distributed throughout each country in proportion to the population in each system. While this may be a somewhat heroic assumption, in the absence of detailed country-level data as to the location of the poor, there is little else that can be done.

Finally, Block 2.5 of Table 2 shows the numbers of rural poor by region in the nine land-based systems. These were calculated by applying the country-level percentage of rural poor equally across all systems by country. Again, this is a rather broad assumption but, in the absence of more detailed data, not an unreasonable one. To derive the number of poor in the other two landless systems, we equated the difference between the total number of poor and the rural poor in the nine land-based systems of Seré and Steinfeld with the numbers of urban poor and assumed that these were the numbers appropriate to the two landless systems. Thus in the priority assessment exercise presented in Section 4, we used the number of rural poor in relation to land-based systems and the number of urban poor in relation to the landless systems.

Some comments may be made concerning the data in Table 2. Despite the limitations of the data and the breadth of the assumptions used, the results clearly show the overwhelming importance of sub-Saharan Africa and South Asia in terms of welfare and poverty indicators. They are much lower (adjusted income, *W*) and much higher (severity of poverty, *P*) in these two regions than anywhere else. More than half the people of SSA live below the poverty line, and this prompted the reviewers of the Third Systems Review of the CGIAR in 1998 to plead that special attention be given to this region.

Three-quarters of the poor in developing countries live in rural areas; in Asia and SSA, the proportions are higher than this, while in LAC and WANA, poverty is more an urban phenomenon.

Most of the total poor live in the humid and subhumid parts of the world (47%) and in the arid and semi-arid zones (39%), rather than in the temperate and tropical highland zones (11%). For sub-Saharan Africa, the pattern is similar: 50% for the humid and subhumid zones, 32% for the arid and semi-arid, and 16% for the temperate and tropical highland

zones. The patterns and percentages are very similar for the numbers of rural poor.

Other data complement those in Table 2. For example, nearly 680 million of the rural poor keep livestock in developing countries (Ashley and others 1999; Holden, personal communication), or about two-thirds of the rural poor, which clearly indicates the importance of animals to their livelihoods. In addition, in the strategic plan (ILRI 2000), the poverty data above were combined with data on the economic value of animal production, broken down again by system and by region. In essence, the correlation is high between the economic importance of animal products and the number of poor living in the same systems in the six regions combined. This has important implications for institutes such as ILRI as they formulate strategic priorities that seek to maximise benefits for the largest number of poor people. The prospects are good, therefore, that focusing livestock research and development on the systems where the economic impact is likely to be greatest will benefit the largest number of poor people.

The rainfed and irrigated mixed humid and subhumid tropical and subtropical systems (MRH and MIH, see Appendix 1) dominate in the number of rural poor and the economic value of animal production, in East Asia, South-East Asia and sub-Saharan Africa. In LAC, the industrial systems predominate; the large proportion of urban poor and the relatively high economic value of industrial animal production there may make the task of effectively targeting the poor in that region easier than in some other regions, depending on how significant the urban poor are as consumers of the products of industrial systems. In SSA, targeting the high-value arid and semi-arid grassland livestock production system in the tropics and subtropics potentially affects around 40 million rural poor. Almost 100 million poor depend on the mixed humid and subhumid livestock production system in the tropics and subtropics in this region, but the economic value of the livestock products in this system is 40% less than in the arid and semi-arid grassland system. Thus, for example, the potential for large economic impact in the latter may be limited (ILRI 2000).

Such considerations can clearly inform strategic decisions concerning resource allocation and priorities for a global institute. If the poverty alleviation goal is to be taken seriously, then questions can legitimately be raised as to the strategic value of a large proportion of ILRI's research activities in the highland regions, and anywhere outside South Asia and sub-Saharan Africa, for example. Many other considerations, of course, come into play in determining resource allocation, but despite their imperfections, these poverty data convey clear messages.

For the analysis in the priority assessment framework, various alternative indexes were considered, as described in Appendix 3. The index G used in the analysis is the value of P derived above weighted by the number of poor people. Thus for any research brief that is estimated to produce economic impact in various

systems and regions, the value of P is weighted by the numbers of poor people specific to region and production system,

$$PovertyG = \frac{\sum P_i x_i}{\sum x_i}$$

where for system i, P is as defined above and x is the number of poor people. This particular index rewards research themes that focus their impact on regions and production systems that have relatively more poverty.

One possible way to improve the poverty data and how they are treated in the analysis is to allocate poor people in a spatially explicit manner within the broad systems definitions of Seré and Steinfeld. A key step in doing this is to spatially locate the various agro-ecological definitions that are used in their classification: tropical highland–temperate zones, arid–semi-arid zones, and humid–subhumid zones. A second key step is spatially allocating land to livestock or mixed systems, and then to grassland, rainfed or irrigated systems. A highly preliminary step was taken towards this goal by carrying out analyses to compare the agro-ecological definition of the highlands used in the Seré and Steinfeld databases with various other recent definitions of the highlands. A brief description of this analysis appears as Appendix 4, but essentially the results show that the population data for the highlands of Kenya and Ethiopia, and the spatial extent of the highlands themselves, fall squarely in the middle of the range of other definitions of highland areas. The implications of being able to spatially locate total population and poor people using the Seré and Steinfeld classification are that considerable refinements would be possible in targeting technology and policy interventions at the continental level within the priority assessment framework.

Environment

Each of the proposed research briefs was assessed for potential environmental impact, public health impact (restricted to its effect on zoonotic diseases) and its effect on genetic diversity of domestic plant and animal resources.[2] Successful application[3] of the products and outputs proposed in each brief is assumed. Environmental impact was distinguished in three ways:

- by the environmental property affected under the headings of soil resources, water resources, greenhouse gas emissions, and non-domesticated biodiversity
- by the fragility of the ecosystem affected
- by the likelihood that the intervention would lead to extensification (as opposed to intensification) of agricultural systems

The analysis focused on the probable direct (immediate) impact of the interven-

[2] This analysis on the environment was planned, carried out and written up by Robin Reid and Tim Robinson.
[3] Successful application means successful development of a research product and successful delivery and adoption of that product.

tion on selected environmental properties. Indirect (longer-term) impact of the intervention was estimated through two parameters: the index for the likelihood of extensification and the fragility of the habitat (agro-ecological zone) towards which the research would be directed.

We placed the impact of the research briefs under three broad headings: direct and indirect environmental impact, public health impact, and impact on domesticated biodiversity. Immediate or direct impact was assessed on four environmental properties: soil resources, water resources, greenhouse gas emissions, and non-domesticated biodiversity.

Under each of these properties, two to three subgroups were scored for impact independently, and the average score was taken for each environmental property. Indirect impact was estimated through the likelihood of extensification and the fragility of the agro-ecological zone. Public health impact was restricted to the effect on zoonotic diseases affecting people. Domesticated biodiversity does not focus explicitly on environmental impact; rather, it focuses on genetic information for productivity impact.

Direct environmental impact

Under soil resources, we scored the impact of the interventions proposed for each research brief on erosion (soil loss on site) separately from the impact on soil fertility (organic matter and nutrients). For example, introduction of improved animal health technologies in highland areas can lead to increased grazing pressure, which can in turn increase erosion rates on slopes strongly. Introduction of a leguminous fodder or better manure management can improve both the organic matter content of the soil and the total nutrient levels.

Water resources were divided into quality of water (levels of organic and inorganic nutrients, sediments, toxins) and quantity of water (water availability on site). Strong intensification of livestock systems can lead to nutrient surpluses that pollute waterways and policies can be developed to mitigate this type of impact. Reduced use of insecticides and acaricides after vaccines are introduced can reduce the level of toxins in water resources.

Greenhouse gas emissions were separated into methane, carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions. These are the three greenhouse gases that we anticipate will be most directly affected by livestock interventions. Advances in rumen ecology and feed utilisation by improved livestock breeds may reduce methane emissions from ruminants directly. New fodder varieties may increase or decrease carbon sequestration. Substitution of legumes and manure for inorganic fertiliser may decrease emission of nitrous oxide from fertilisers.

Non-domesticated biodiversity concerns the impact of livestock interventions on the millions of known non-domesticated and the estimated several million undiscovered species on earth (Wilson 1992). These include all taxa of species from bacteria and viruses, through plants, to insects and

mammals. We chose to use two indexes of biodiversity: species number and species composition. Species biodiversity is a proxy for genetic biodiversity, while habitat or ecosystem biodiversity is estimated by species composition and is addressed further, though indirectly, through the index of the likelihood of extensification described below. A newly introduced fodder species may inadvertently outcompete native species, leading to local or global loss of the affected species. Increased grazing pressure, a likely outcome of many ILRI interventions,[4] may not affect the total number of plant species in a system, but it may shift the composition of species from potentially more valuable locally adapted species to more cosmopolitan weeds. Interventions focused on improving integrated livestock and wildlife systems may reduce the loss of wildlife species in the face of cropland encroachment on rangelands.

The scoring system for direct environmental impact included five levels: two positive, two negative and one neutral (that is, scores ranging from –2 to 2). Positive and negative impact was divided between strong and weak. The neutral score indicated that impact was non-existent or negligible. We assigned the global mean of the environmental impact score for all research areas for any research theme that relied on the outputs of institute-wide research (characterisation, capacity building, information).

For research briefs that were likely to lead to an increase in animal production and thus animal numbers, we applied a general detrimental impact score depending on the level of intensification of the system where the intervention would be applied. For intensive systems, we gave a score of –0.5 and for extensive systems, –1.0. These scores were applied only to the environmental properties that are potentially directly affected by increased herd size: soil erosion, water quantity, methane emission, species number and species composition.

Indirect environmental impact

The likelihood of extensification was used to give some indication of the more indirect impact of intervention in the medium to longer term. We expect interventions that encourage extensification to have greater environmental impact than those that encourage intensification of agricultural systems. These more indirect, system-level types of impact were included because we

[4] Most ILRI interventions are focused on increasing productivity (increased output per animal) and not on increasing the numbers of animals. However, we assume that farmers in most production systems, if they have access to more productive animals and lower production costs, will also have incentive to increase herd size to some degree, depending on the level of intensification of the system (small increases in herd size for intensive systems, larger increases for extensive systems). Increases in herd size can increase soil erosion, reduce moisture available in the soil (through loss of vegetative cover), increase methane emissions and reduce biodiversity.

anticipate, in many cases, that they will be greater and more important than the more immediate, local-level types of impact. For example, control of the livestock disease trypanosomosis may encourage the expansion of agriculture on the agricultural frontier (Jordan 1986). Clearing native forest and savanna has strong, and likely negative, consequences for biodiversity, greenhouse gas emission, soil resources, and water resources. This index was given a value of low (0.0), medium (–0.5) or high (–1.0).

Fragility of the ecological region was included as an indirect impact, although we are aware that the direct environmental impact will be compounded in fragile habitats. This gives a simple sense of the sensitivity of the recommendation domain to environmental impact for a particular intervention. Ecological regions imply climatic aspects (arid to humid), soil and topographic characteristics, and geographical location (Latin America vs. Asia). Rainforest systems, for example, are particularly sensitive to clearing for livestock grazing. Arid grazing systems in general can be quite resistant to the impact of livestock, unless the impact is high. Also, particular geographical locations are more sensitive to impact than others. South American grazing systems, with a short history of evolution with grazing ungulates, are more sensitive to grazing impact than African savannas, where ungulates and grasses have co-evolved over millennia. This index was given a value of low (0.0), medium (–0.5) or high (–1.0).

To produce the overall environmental impact score, direct and indirect impact were weighted equally, as shown in Table 3: x 0.50 for direct impact, x 0.25 for likelihood of extensification and x 0.25 for fragility of agro-ecological zones.

Public health impact

The single public health index focuses on the impact of livestock interventions on the prevalence of zoonotic diseases. Control of animal trypanosomosis in Uganda, for example, may lead to direct control of human sleeping sickness as well. Ways in which the public health impact of the research briefs might be addressed more fully in the future are discussed below. Only positive impact was considered and it was scored between 0 and 1.

Domesticated biodiversity impact

Domesticated biodiversity includes the impact of livestock interventions on the total store of domesticated breeds and species available for humankind to exploit. Improvements in domesticated biodiversity can increase the number of species and varieties on earth, but we think this is a minor environmental impact compared with the potential loss of native species that increased livestock use around the world will cause. As such, the impact of domesticated biodiversity should be considered a production benefit rather than an environmental impact.

This category was divided into species and breeds of animals and plants, specifi-

Table 3 *Summary of environmental properties used to assess impact*

Property	Weight	Type of impact
Direct impact		
Soil resources	0.125	soil erosion soil fertility
Water resources	0.125	water quality water quantity
Greenhouse gas emissions	0.125	methane carbon dioxide nitrous oxide
Biodiversity	0.125	species number species composition
Indirect impact		
Extensification	0.25	likelihood of extensificaton
Habitat fragility	0.25	fragility of agro-ecological zones

cally livestock and fodder. Several of the projects under genetics and feeds programmes will attempt to improve and conserve the biodiversity of species and breeds of livestock and fodder. Some work will focus on conserving these species *in situ* through conserving the native habitat, and these activities will also have a direct impact on non-domesticated biodiversity that is recorded separately. Only positive impact was considered and it was scored between 0 and 1.

Overall externality score

The overall 'externality' score was a weighted combination of the overall environmental score (x 0.90), the public health impact (x 0.05) and the domesticated biodiversity impact (x 0.05). Public health impact and domesticated biodiversity impact were weighted low as we considered these factors much less important in the overall score than the environmental factors considered.

Improvements to the methodology

This analysis of environmental impact had several weaknesses. First, the analysis was conducted by scientists within the institute, who may have their own bias in the outcome of the analysis. Future assessments should include an outside participant or possibly be conducted wholly outside the institute. This also applies to all the other impact analyses we have conducted.

Second, the analysis of environmental impact is often site specific, with the same

intervention having positive impact in one place and negative impact in another. For example, introduction of more productive fodder species on cattle farms in Costa Rica has resulted in reduced deforestation because farmers need less land for grazing (R. Reid, personal observation). On the other hand, if cattle become more profitable (through greater productive abilities), farmers may move strongly to produce more meat, increasing the deforestation as they create more pasture. Thus, the analysis needs to become more site specific.

Third, the list of possible types of impact is far from all-inclusive. For example, intensification of livestock systems may reduce the practice of savanna burning by replacing open savanna grazing areas with mixed crop–livestock systems. Decreasing biomass burning reduces the emission of CO_2, sulphur compounds and aerosols (Lobert and Warnatz 1993).

Fourth, we do not think that all types of impact should necessarily be weighted equally. Impact on water resources, for example, may be minor compared with impact on biodiversity from the point of view of irreversibility and system sustainability. Refining the weighting to accommodate these differences needs further thought and development.

The analysis could be made more rigorous by linking it to the estimated production impact of the research briefs. As explained above, we have applied a general index of detrimental environmental effects that result from increased livestock production. If this were weighted to reflect the expected increase in production it would provide a more realistic estimate of the environmental impact. On the other hand, this might also lead to a high correlation between economic impact and environmental impact for many of the research themes. This type of double counting is similar to the problem that was encountered with some of the candidate poverty indexes (see Appendix 3).

As mentioned above, the fragility of the agro-ecological zone needs to be site specific. Moreover, 'fragility' needs to be more clearly defined and should probably be incorporated as some kind of multiplier for a number of specific types of direct environmental impact (for example, soil erosion) to which its definition refers.

Finally, the public health impact of the research briefs needs to be considered in more detail. Zoonotic diseases (trypanosomosis, brucellosis, tuberculosis and Rift Valley fever, for example) are important to consider but, particularly in industrial systems, the effect of animal wastes also needs to be included in the analysis, as indeed must the effect of food toxins (such as salmonella, *E. coli*, botulism, staphylococcus) and growth hormones and antibiotics. This very important impact of livestock on public health deserves to be considered more carefully in ILRI's research programme.

Internationality

Agro-ecological environments straddle national boundaries, as do major constraints to livestock development. Consequently, so do opportunities to override

these constraints, including those that are research induced. Considerable scope therefore exists to capture geographical spillovers in research output. National research systems generally have little incentive to acknowledge or incorporate such spillovers into planning and implementation of their research programmes. Because ILRI has a global mandate for livestock research, these spillovers must be made explicit. Capturing them lies at the core of the institute's comparative advantage.

The cross-national character, or 'internationality', of a given research theme was therefore considered a prominent feature in determining its priority ranking. As a measure of internationality, the Simpson Index of Diversity, I_k, was used:

$$I_k = \Sigma_m (S_{km}/100)^2$$

where S_{km} is the share of economic returns to research theme k realized in country or region or livestock system m. A variable $(I - I_k)$ was defined such that a higher value indicated greater internationality. This variable thus gave greater priority to themes that raised producer and consumer welfare in several parts of the world. Specifically, a theme that generated economic gains that were relatively small but occurred in several regions had a higher internationality score than a theme that had a relatively large aggregate impact but was concentrated in one region.

Capacity building and research efficiency

ILRI is but one link in the discovery-to-delivery continuum for most of the technologies on which it is working. The institute thus has to work in partnership with several organisations to achieve impact on the farm. The most important of these are the national research organisations and systems charged with adapting and disseminating improved technologies to farmers. One of ILRI's current programmes is dedicated to strengthening the capacity of researchers in these systems to undertake high-quality research. But ideally, all research activities should have this aim in view. To this end, a research theme's contribution to capacity building and research efficiency in collaborating national agricultural research systems was identified as a key criterion in the priority assessment.

The focus groups were asked to take a disaggregated view by identifying if and how research briefs had an impact on capacity building and research efficiency according to five subcriteria:

- strengthened national human resources for research
- strengthened national institutions for research
- improved research tools adapted to national research needs
- improved national human resources for development
- improved national and local institutions for development

A scoring scheme was developed as follows. If activities and outputs under a theme had a direct focus on any of these five subcriteria, then its impact was considered to be 'important' and it was

given a value of 2. If activities and outputs under a theme had an indirect focus on any of these five subcriteria, then its impact was considered to be 'incidental' and it was given a value of 1. If activities and outputs under a theme did not focus on any of these five subcriteria, then its impact was considered to be 'not applicable' and it was given a value of 0. The maximum score that a theme could attain for its impact on capacity building and research efficiency was therefore 10.

Composite index

Given the information generated on the five criteria outlined above (economic impact, poverty, environment, internationality, capacity building–research efficiency–research tools), some method is needed that will facilitate priority assessment. One way to do this is by a series of two-dimensional graphs where the likely trade-offs between pairs of criteria can be arrayed. Another complementary way is to take each normalised index and weight them all to produce a single, integrated index for each theme.[5] With an appropriate set of weights E_i on each theme k and criterion i, we arrive at a weighted average composite index CI_k, which combines normalised measures of each of the five criteria C_{ki} as follows:

$$CI_k = \Sigma_i C_{ki} E_i$$

It is the case that the normalisation process and the weighting represent arbitrary scaling. However, if it is accepted that there are indeed multiple objectives to be achieved in the conduct of publicly funded international agricultural research, and that often there are trade-offs among alternative research themes in their achievement, it is inescapable that some form of weighting, either explicit or implicit, be used to assess thematic priorities. The composite index approach makes the process explicit.[6]

If the ultimate aim is to derive an ordinal ranking of candidate themes to assist in priority assessment, then perhaps

[5] Care has to be taken when the highest values of a criterion represent outliers on a highly skewed distribution, as this can mean many themes will cluster around low values and discriminatory power is lost. In such cases one chooses a lower base value as the normaliser. This process is described in Kelley and others (1995) and ICRISAT (1992) and provides a mechanism to avoid the problems of scoring analyses with many criteria as discussed by Alston and others (1995, pp. 376–377, 463–498).

[6] An additive rather than a multiplicative index is preferred, as the latter significantly penalizes themes that have very low values for one or more criteria. Multiplicative indexes are useful in situations where some minimum level of impact for each criterion must be achieved. As Kelley and others (1995) point out, use of weights to create an index in this manner is equivalent to eliciting the indifference curves of decision-makers among the chosen criteria. This is analogous to the 'utility' function of the research system or the revealed preferences of the clients of an analysis such as this, which Alston and others (1995, pp. 372–379) point out is needed to be able to choose an optimal research portfolio when faced with multiple objectives.

the legitimate concerns about the arbitrariness of scaling may be less of a problem.[7] In any case, we subject the resultant thematic rankings to sensitivity analyses, which alter the weightings to see how responsive they are to these changes, and hence how robust the priority assessment is. In addition, Monte Carlo techniques can be employed on the quantitative measures of the criteria in recognition of the fact that point estimates of variables such as the likely productivity gains from research are not appropriate. Instead, probability distributions are employed using ranges in the estimates. These will enable confidence bands to be associated with the measures of the five criteria, to avoid single-valued estimates that suggest a level of precision, which in practice is not attainable. The confidence bands will help in evaluating how robust the ranking of candidate themes is to the uncertainties involved in the quantitative assessments.

In the participatory spirit of the rest of the priority setting work, we elicited suggested weights on the five criteria from various groups: the Steering Committee, the focus groups, and ILRI's Board of Trustees all had input to this process. Results are shown in Table 4. After various iterations, the final baseline weights used in the analysis are 0.30 for the economic impact index, 0.25 for the poverty index, 0.20 for the environmental impact index, 0.15 for the capacity-building index, and 0.10 for the internationality index. Thus the composite index (*CI*) for each theme is a number ranging from 0 to 1 calculated thus:

$$\begin{aligned} CI = {} & 0.30\ (\text{economic impact index}) + \\ & 0.25\ (\text{poverty alleviation index}) + \\ & 0.20\ (\text{environmental impact index}) + \\ & 0.15\ (\text{capacity-building index}) + \\ & 0.10\ (\text{internationality index}) \end{aligned}$$

with each component index normalised to range from 0 to 1. We chose to elicit the weights before estimating and presenting the benefit–cost ratios for the themes. Alston and others (1995 pp. 474–475) suggest that the weights be elicited against the background of the benefit–cost ratios so that trade-offs between this efficiency objective and others are

[7] Alston and others (1995, pp. 369–372) indicate that ranking is a meaningful approach to priority assessment when constraints on research programmes mean that not all candidate themes with positive net present values (preferably using an economic surplus approach, as is done here) can be supported. They point out that moving down such a list until the budget constraint is binding and ruling out themes below the line is an optimum approach given the constrained choice between the alternatives. However, this will not necessarily maximise the overall net present value per dollar invested, as themes are presented as discrete alternatives without the possibility of reallocating resources among them, which could increase the overall net present value. As the ILRI planning exercise did not find it possible to derive for each candidate theme a relationship between varying levels of resources and outcomes, the themes all represent discrete options, amenable to a ranking approach. ICRISAT (1992) used a ranking approach along with variable resourcing on a small number of the candidate themes.

Table 4 *Weights on the five impact criteria elicited from the Steering Committee, the focus groups and ILRI's Board of Trustees*

Criteria	Number of responses	Mean weight	Minimum weight	Maximum weight
Expected economic impact	23	27	0	40
Poverty	23	24	10	50
Environmental impact	23	18	5	30
Internationality	23	12	0	30
Capacity building, research tools, research efficiency outputs	22	15	0	30
Other—comparative advantage	1	2	0	40
Other—equity	1	1	0	20
Other—likelihood of impact on poor	1	1	0	20

evident to decision-makers. We prefer to array the priorities implied by the benefit–cost analysis against those implied by the composite index and the other criteria individually so that ILRI's decisions are as fully informed as possible.

3 The process

Given the need for a new strategic plan, a transparent process and a framework for helping ILRI to allocate resources to many different research activities, a participatory strategic planning and priority assessment process was embarked upon, which started at the end of March 1999. The process was overseen by the Ad Hoc Committee on Strategic Principles consisting of members of the Board of Trustees and senior management. A Steering Committee made up of ILRI management and staff was formed to develop and implement the strategic planning process. The process took as a starting point the series of consultations with partners and stakeholders conducted between 1995 and 1998 in Asia, Latin America and West Asia–North Africa (Devendra and Gardiner 1995a, b; Gardiner and Devendra 1995; Devendra and others 1997, 1998, in press; Vercoe and others 1997).

The 1999 strategic planning process consisted of several distinct components. A comprehensive background paper (von Kaufmann 1999) was prepared that considered the external environment affecting ILRI and its future direction (and see the discussion in ILRI 2000). A working group, the Priority Assessment Criteria Working Group, was established to develop the priority assessment framework and a set of measurable criteria that could be used to inform decisions about priorities so as to reflect the goals of the CGIAR and the vision of ILRI. Six thematic focus groups were then established, covering the major research and related areas in which ILRI might work in the future:

- application of genomics and the conservation and use of genetic resources
- improvement of feed utilisation and animal nutrition
- improvement of animal health
- sustainable improvement of production systems; improved livestock productivity and natural resource management
- integrated systems analysis: livestock policy analysis, decision support systems, and economic and environmental impact assessment
- capacity building, strengthening partnerships and knowledge brokering to improve livestock productivity

A seventh focus group was concerned with management services. The focus groups had several tasks. First, they each prepared a background paper describing the external environment, identifying the needs, problems, opportunities and possible areas of future research. This formed the basis of discussions in the subsequent workshops that each focus group held. The focus groups consisted of ILRI scientists and managers and external participants. ILRI participants included both those primarily interested in the discipline or area of work being considered by the focus group and others from related disciplines to facilitate the emer-

gence of interdisciplinary solutions. The external participants represented a wide variety of interests: regional organisations, acknowledged experts in the relevant disciplines and research areas, and representatives of potential partners such as NARS, NGOs and the private sector. The composition of the focus groups and their task helped to ensure that their outputs incorporated both a demand-side as well as the expected supply-side perspective.

Participants in each of the seven focus group workshops were asked to assess the needs in livestock research to the year 2010, to identify potential opportunities, and to suggest research and associated activities that could contribute towards addressing the needs. This was done in the context of prospective impact on poverty, awareness of the alternative suppliers and ILRI's comparative and complementary advantage, the essential researchability of the topic, the feasibility of arriving at a solution, and whether the outputs were international public goods. The outputs of the workshops consisted of summary reports containing descriptions of the constraints and opportunities identified and 44 research and research-related theme briefs that described the activities proposed by the workshop participants.

After the planning workshops had taken place in May and June, and after the summary reports and theme briefs had been circulated, a facilitated Strategic Planning Workshop was held in Nairobi from 29 June to 1 July. This was attended by the chairpersons and rapporteurs of each focus group and members of the Steering Committee, the Institute Management Committee, and the Priority Assessment Criteria Working Group. The objective was to review the outputs of the planning workshops and synthesise these into an integrated whole. Among them, the focus groups had described 32 problems, which were subsequently clustered into eight major problem areas. From these eight problem areas, 12 strategic approaches were derived, which were the potential solutions to the problems. The 44 themes previously proposed by the focus groups were arrayed against the problems and strategic approaches to which they would make a major contribution.

In September 1999 at ILRI's annual programme meeting in Addis Ababa, the priority assessment framework was presented by the Priority Assessment Criteria Working Group, along with a set of illustrative results for the original 44 research briefs. Because of overlaps and synergies between the briefs, in October and November the 44 themes were condensed, through mergers, to 26 themes, for which comprehensive descriptive briefs were prepared and the data in them validated. At the same time, work had proceeded on drafting ILRI's strategic plan, in which seven key research and related areas (KRRAs) were identified, which were not perfectly congruent with the original seven focus groups. The 26 merged briefs were thus assigned to these new KRRAs as appropri-

ate (the process is summarised in Table 5). Much background information on the external environment and ILRI's response in identifying the KRRAs and possible livestock research activities may be found in the strategic plan (ILRI 2000).

Before analysing the potential returns to each research and related theme, an additional validation step was undertaken. A multidisciplinary group of researchers representing the various research areas at ILRI was asked to go through summary tables of all the theme briefs (44 for the first validation exercise, 26 for the second) and address the following issues:

- assess the 'reasonableness' of the estimates; for instance, were some groups being overly optimistic or pessimistic with regard to their estimates of time frames, productivity gains, and so on?
- arrive at some decision rules for adjusting those estimates judged not to be 'reasonable'
- rationalise the suggested theme mergers

The key parameters addressed in the validation sessions were

- research time frame
- probability of research success (within the defined time frame)
- adoption lag
- recommendation domain
- relevance within the recommendation domain

Table 5 *The original focus subject areas and their metamorphosis to key research and related areas in ILRI's strategic plan; numbers in parentheses indicate the number of research briefs associated with each area*

Focus groups (44 themes)	Key research and related areas (26 themes)
Genomics and genetic resources (10)	Livestock genetics and genomics (3)
Policy and systems analysis (9)	Livestock policy (4)
	Systems analysis and impact assessment (3)
Sustainable production systems (4)	Livestock and the environment (5)
Feed utilisation and animal nutrition (7)	Livestock feeds and nutrition (4)
Animal health (11)	Livestock health improvement (4)
Capacity building (3)	Capacity strengthening for livestock research (3)
Management services	

- adoption ceiling
- productivity gain
- notional resources
- non-ILRI research and delivery costs

The first step of the validation process was to examine the range of each of these parameters across themes.

Since the most difficult parameter for researchers to estimate was the expected productivity gain that would result if the final research output was fully adopted, some simple decision rules were adopted. Productivity gains were defined as follows:

- high, 5%, direct productivity gains, small recommendation domain
- medium, 3%, direct productivity gains, well-defined recommendation domain
- low, 1%, direct productivity gains, large recommendation domain
- low-low, 0.1%, indirect productivity gains, large recommendation domain
- low-low-low, 0.01%, very difficult to define impact in terms of productivity gain

Arguably the second most difficult set of parameters for each theme group to estimate was adoption lags and the expected ceiling level of adoption, that is, the percentage of producers within the relevant recommendation domain expected to have adopted a technology by the end of the defined adoption period. Recent work at ILRI has indicated that adoption rates, even of highly effective and perfectly feasible technology, may be very modest. While it is difficult to estimate adoption rates for these studies, currently within the relevant target domains they appear to be about 0.5% for both dairy technology in coastal Kenya (Nicholson and others 1999) and legume fodder banks in West Africa (Elbasha and others 1999). The following conservative decision rules were therefore chosen. Low, medium, or high adoption ceiling rates would be used, where

- high = 21 – 30%
- medium = 11 – 20%
- low = 0 – 10%

As adoption lags appeared to be still overly optimistic for some research themes, given recent experience within the CGIAR with technically sound technologies (see Sechrest and others 1999, for example), the second validation exercise reviewed this issue. The following decision rule was agreed upon:

- long 26–40 years
- medium 16–25 years
- short 10–15 years

In general, research outputs that required significant changes in behaviour, in input costs, or to the current system in place were deemed to have a long adoption lag. Conversely, outputs requiring relatively small changes in the current livestock system were assumed to have a relatively short adoption lag.

Another decision made during the validation sessions included an agreement to rationalise the recommendation domains for different research themes addressing the same diseases. In addition, an attempt was made in the final revisions

of the research theme briefs to include non-ILRI research costs, but during the second validation exercise it was agreed that it would not yet be feasible to include these costs in the analysis. Most felt that the estimates of other parameters such as productivity gains and research lags were already implicitly adjusted for differentials in these other costs. In addition, some of the focus groups felt that they were not able to adequately assess these non-ILRI costs in a very objective fashion (see the final section of Appendix 1 for details).

A summary of the final 26 research theme briefs is provided in Appendix 5; it contains details of the parameters used in the priority-setting analysis. The results of that analysis are presented in Section 4 following.

4 Results of the priority assessment

The results of the ranking exercise are presented in Table 6. The themes are ranked according to the composite index reported in the first column, beginning with the theme displaying the highest priority and listing the others in descending order. The columns to the right provide the normalised index and rank for the five components of the composite index. To give a sense of the resource implications, the last two columns of the table report the estimated average annual cost of each theme and the cumulative total cost. Below, we look at the conclusions for setting ILRI's research priorities that can be drawn from the results. We then review the performance of the indexes, before reporting results of some sensitivity analysis.

How the themes rank

To interpret the results, it is useful to compare the general performance of the themes by KRRA. Table 7 permits such a comparison by tabulating the number of themes in each KRRA ranked among the top 50% versus those in the bottom 50%. Research in the Livestock Policy and Capacity Strengthening KRRAs is ranked uniformly highly using the adopted criteria. This can be attributed to a large extent to their expected impact over a broad range of production systems, even assuming a very conservative impact on productivity (0.01% gain). Themes for the policy KRRA are rewarded in particular for targeting poverty and generating positive environmental impact.

Research with an environmental focus scores relatively highly, with one exception, LE1. Environmental themes benefit not only from their perceived positive environmental impact but also from their ability to generate economic benefits and target production systems with a high concentration of poor people.

Themes in the Livestock Feeds and Nutrition KRRA are found across the full range of rankings. Those feed and nutrition themes that fall in the lower half involve research that is longer term and higher risk.

Among the Systems Analysis and Impact Assessment themes, research on systems research ranks higher than impact assessment. The impact assessment themes, including the related theme in Livestock Health Improvement, all fall in the lower half of the rankings despite their potentially broad adoption domain. Their inability to generate significant direct economic benefits appears to be their principal drawback.

All of the Livestock Genetics and Genomics themes fall in the lower half of the rankings. The genetics research considered here tends to be very long term, since it is constrained by the long breeding cycles of ruminants and has fairly narrowly defined impact domains. The highest ranked among the genetics themes tends to be shorter term with more direct impact, generating consider-

Table 6 *Ranking of the 26 research themes in terms of the composite index made up of weighted benefit–cost ratio (BCR), environmental index (ENV), capacity-building index (CP), internationality index (INT) and the poverty index (POV); index values are normalised from 0 to 1 (Value) and their ranks given*

Composite index	THEME		BCR		ENV		CP		INT		POV		COST (US$ million)	
	No.	Title	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Annual	Cumulative
		Weights = >	*0.30*		*0.20*		*0.15*		*0.10*		*0.25*			
0.57	LFN2	Increasing livestock productivity through improved feed conservation	0.88	2	0.34	18	0.43	7	0.96	8	0.31	17	0.50	0.50
0.51	LE4	Improving rangeland systems	0.10	7	0.70	4	0.43	7	0.31	25	1.00	1	0.74	1.24
0.51	LE5	Reducing deforestation	0.09	8	1.00	1	0.29	13	0.39	24	0.80	4	0.88	2.12
0.50	LE2	Reducing environmental costs of intensive livestock systems	1.00	1	0.67	5	0.14	19	0.40	23	0.00	26	0.42	2.54
0.49	LP4	Using different species to reduce negative environmental impact	0.27	3	0.49	8	0.00	25	0.83	22	0.93	2	1.49	4.02
0.48	SAIA1	Ensuring future viability of smallholder systems	0.00	23	0.65	6	0.43	7	0.92	16	0.77	5	1.44	5.46
0.45	LP1	Participatory policy research to improve technology adoption	0.00	21	0.43	10	0.29	13	0.94	14	0.89	3	0.83	6.29
0.43	LP2	Policies for improving natural resource management	0.00	26	0.85	2	0.29	13	0.94	13	0.47	13	2.88	9.17
0.42	LFN1	Increasing feed quantity and quality through genetic enhancement	0.16	6	0.54	7	0.43	7	0.96	9	0.40	16	1.34	10.51
0.40	CSLR3	Strengthening capacity—networking	0.02	14	0.43	10	1.00	1	0.96	10	0.25	21	0.72	11.23
0.40	CSLR2	Strengthening capacity—information	0.00	22	0.43	10	1.00	1	1.00	1	0.25	21	1.95	13.18
0.40	CSLR1	Strengthening capacity—training	0.01	18	0.43	10	1.00	1	0.96	11	0.25	21	1.11	14.29
0.38	LP3	Reforming input and output markets	0.03	12	0.36	17	0.29	13	0.96	6	0.65	8	1.21	15.49
0.38	LHI3	Improved prevention and control of ticks and tickborne diseases	0.01	16	0.28	19	0.57	6	0.97	3	0.54	11	4.67	20.16

Composite index	THEME No.	THEME Title	BCR Value	BCR Rank	ENV Value	ENV Rank	CP Value	CP Rank	INT Value	INT Rank	POV Value	POV Rank	Cost (US$ million) Annual	Cost (US$ million) Cumulative
		Weights = >	*0.30*		*0.20*		*0.15*		*0.10*		*0.25*			
0.37	LE3	Land-use strategies to increase production and protect the environment	0.00	25	0.85	2	0.29	13	0.96	7	0.24	25	2.18	22.34
0.37	LHI4	Improved prevention and control of trypanosomosis	0.03	13	0.00	26	0.71	4	0.87	20	0.65	7	5.08	27.42
0.36	LFN4	Breeding for improved feed utilisation efficiency	0.07	10	0.23	22	0.43	7	0.90	18	0.56	10	1.13	28.55
0.36	LGG3	Genetic improvement and delivery strategies	0.26	4	0.22	23	0.14	19	0.99	2	0.46	15	0.79	29.34
0.35	5AIA3	Understanding systems evolution	0.00	24	0.43	10	0.43	7	0.85	21	0.47	14	1.16	30.50
0.35	5AIA2	Global prioritisation	0.01	19	0.43	10	0.71	4	0.93	15	0.24	24	0.98	31.49
0.33	LGG1	Assessment and valuation of animal genetic resources	0.01	17	0.40	16	0.14	19	0.97	4	0.51	12	1.12	32.61
0.33	LHI2	Improving delivery, adoption and impact of technologies	0.20	5	0.25	20	0.29	13	0.95	12	0.31	18	1.46	34.06
0.32	LFN3	Improving feed utilisation through enhanced rumen function	0.07	9	0.20	24	0.14	19	0.92	17	0.59	9	1.50	35.56
0.31	LGG2	Identification and characterisation of genetic resistance to disease	0.04	11	0.13	25	0.00	25	0.90	19	0.72	6	1.16	36.72
0.25	LHI1	Comparative global impact assessment of livestock diseases	0.01	15	0.25	20	0.14	19	0.96	5	0.31	18	0.37	37.08
0.18	LE1	Strategies to improve nutrient supply	0.00	20	0.45	9	0.14	19	0.00	26	0.29	20	1.30	38.38

CSLR – Capacity Strengthening for Livestock Research; LE – Livestock and the Environment; LFN – Livestock Feeds and Nutrition; LGG – Livestock Genetics and Genomics; LHI – Livestock Health Improvement; LP – Livestock Policy; SAIA – Systems Analysis and Impact Assessment

Table 7 *Ranking of research themes by key research and related areas*

Key research and related areas	Number of themes falling in	
	Top 50%	Bottom 50%
Livestock Policy	4	0
Capacity Strengthening for Livestock Research	3	0
Livestock and the Environment	3	2
Livestock Feeds and Nutrition	2	2
Systems Analysis and Impact Assessment	1	2
Livestock Genetics and Genomics	0	3
Livestock Health Improvement	0	4

able economic benefit, but it is penalised for mediocre to poor returns in targeting the poor and in making an impact on the environment.

The technology-generating themes in animal health research (LHI3 and 4) fall in the mid-range of rankings. This type of research exhibits reasonable economic returns despite the large investments required, the longer term nature of the research and relatively narrow impact domains, especially in trypanosomosis research. The anticipated economic benefits are mediocre, however, compared with other themes, and this, combined with generally low environmental impact, results in a relatively low ranking. Somewhat surprising is the much lower ranking of the shorter-term research to adapt and improve adoption of existing technologies (LHI2). Despite generating relatively high economic benefits, this theme scores poorly on all the other criteria.

Evaluating the indicators

Ideally, a quantitative assessment of research priorities provides information that permits decision-makers to distinguish clearly the relative worthiness of the proposed themes. As indicated in Table 6 and as shown in Figure 6 part 6.1, many themes (14 of the total 26) have approximately equivalent composite index scores, clustered in a narrow range between 0.35 and 0.45. On the basis of the composite index alone, therefore, it is not possible to conclude, for example, that the 17th ranked theme is clearly superior to the 18th.

The clustering of results for the composite index is due to the counterbalancing effects of the five component indexes. It is also due to the nature of distribution of the underlying component indexes. Their distributions are displayed in Figure 6 parts 6.2 to 6.6. The results of the economic benefit index are skewed heavily to the right, with substantial differentiation at the

higher range of the scale but with most of the lower values clustered under 0.05. This type of distribution permits identification of clear 'winners' but is less useful in distinguishing between the candidate themes at the lower end of the range, which is where resource constraints are most likely to require decisions as to whether or not to undertake the research activities within a theme.

Values for the poverty impact and environmental impact indexes (Figure 6 parts 6.3 and 6.4) are generally distributed smoothly across the full range. Some clustering appears in the poverty impact index in the critical area at the lower values of the index, but this is simply the result of having to apply the same sets of assumptions to particular sets of themes in the KRRAs of policy, systems analysis and impact assessment, and capacity building. Some clustering appears in the middle of the environmental impact index, but this is again largely due to the same assumptions being applied to the three capacity-building themes.

The distribution of the capacity-building index (Figure 6 part 6.5) is characterised by a step distribution, reflecting its rather simple structure of five component indicators, each with three levels. As a result, there is a cluster of two to six themes with equivalent index values at each step. Despite this, the distribution of steps is approximately smooth across the full range.

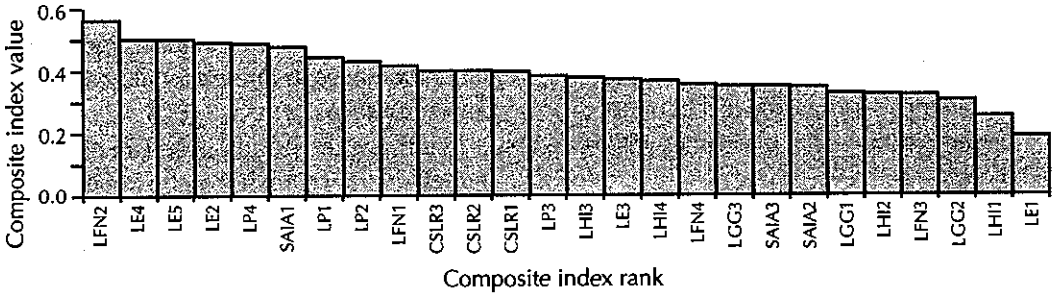
In the internationality index distribution (Figure 6 part 6.6), the majority of themes are clustered at the top end of the index range, falling between 1.0 and 0.9. Only four themes fall below this range. This is a reflection of the wide recommendation domains defined for many of the research themes, consequently making it difficult to distinguish significant differences in internationality impact between KRRAs.

In refining the priority assessment framework in future, it may be beneficial to further develop the economic benefit and internationality indexes, to improve their differentiating power. However, it is still quite possible that the counterbalancing values of the individual component indexes will lead to a composite index that continues to be clustered, as in the present situation. One measure of the likelihood of such clustering occurring is the strength of correlation between the individual composite indexes. Correlation coefficients for the five component indexes and the composite index are reported in Table 8. As would be expected, the correlation between the composite index and the component indexes is a function of the weight accorded each component index in the computation of the composite index. With a sample size much larger than the 26 used, we would not see the small-sample effect in Table 8, where the poverty index (25% of the composite index) has a smaller correlation coefficient than the environmental impact index (20%).

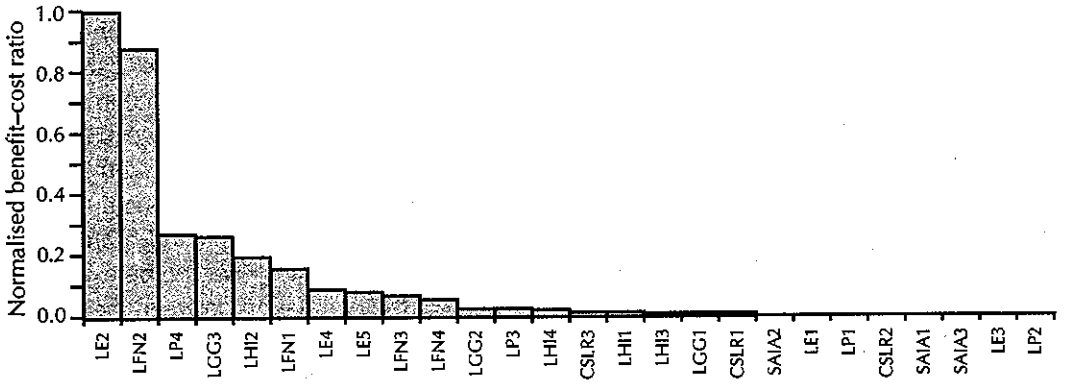
Among the component indexes, there are no statistically significant correlation coefficients that might contribute a

Figure 6 *Distribution of the composite index and the five constituent indexes for the final rankings of the 26 research themes.*

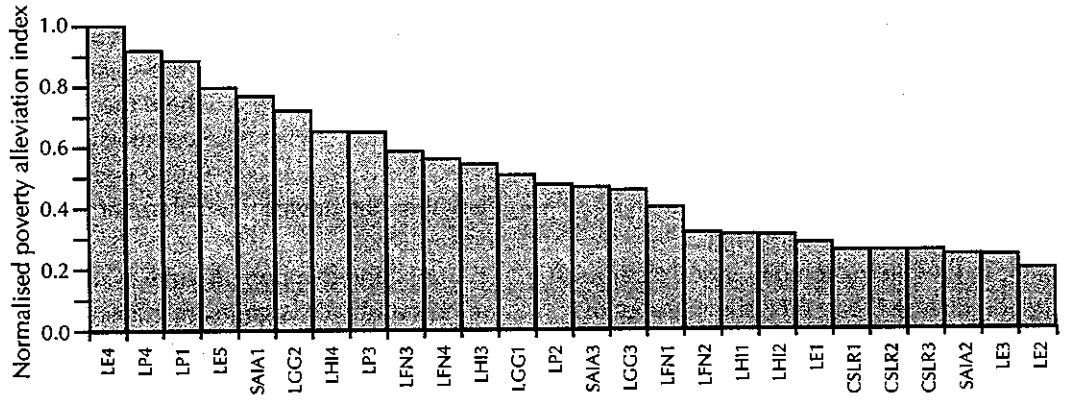
6.1 Composite index



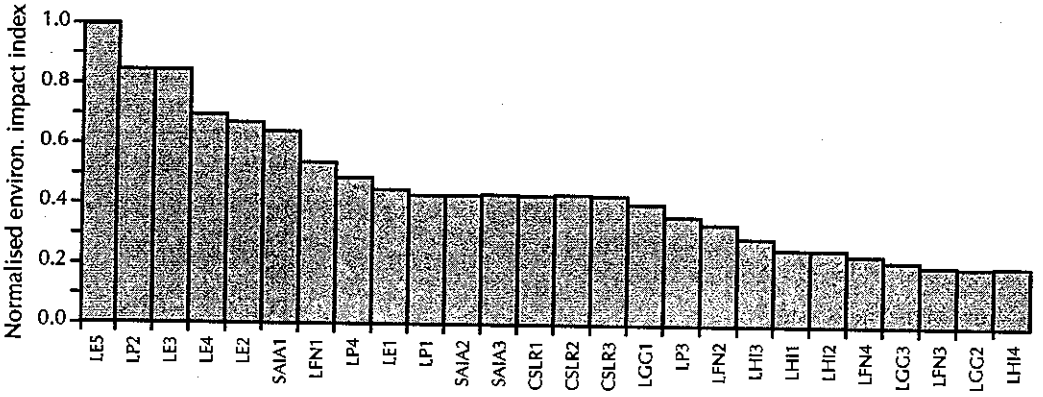
6.2 Normalised benefit–cost ratio



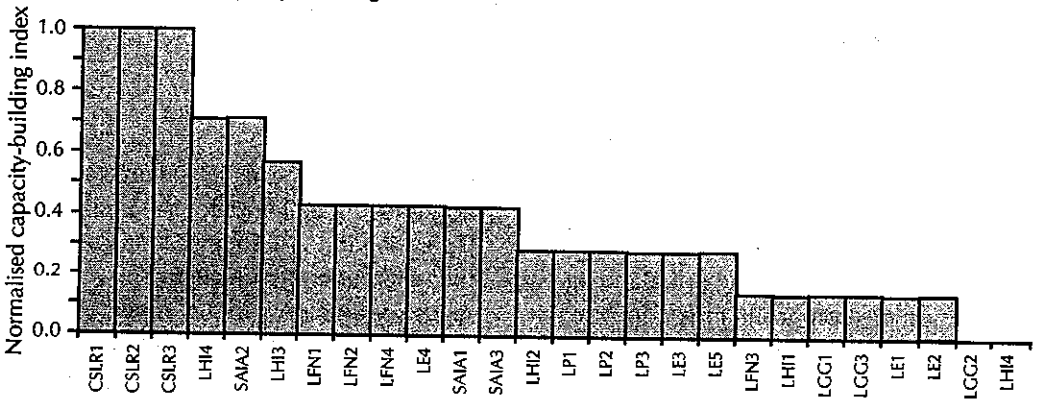
6.3 Normalised poverty index



6.4 Normalised environmental index



6.5 Normalised capacity-building index



6.6 Normalised internationality index

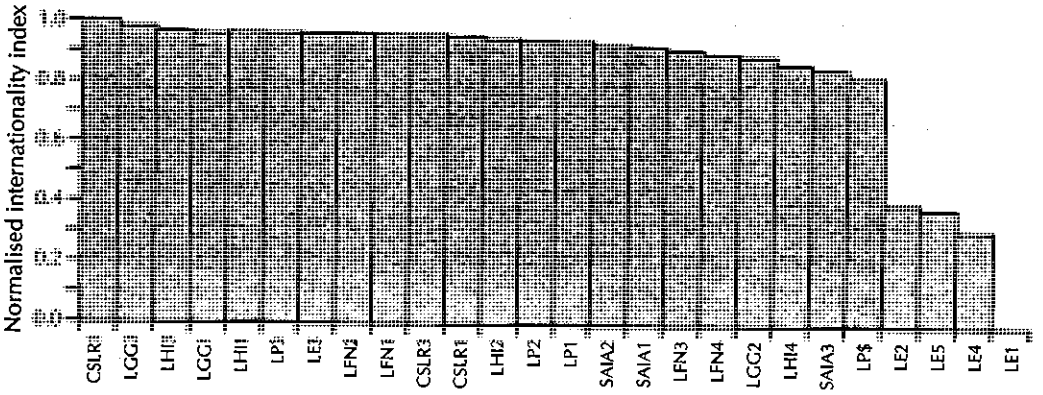


Table 8 *Pearson's correlation coefficients between the normalised scores of the five priority assessment criteria for the 26 research briefs*

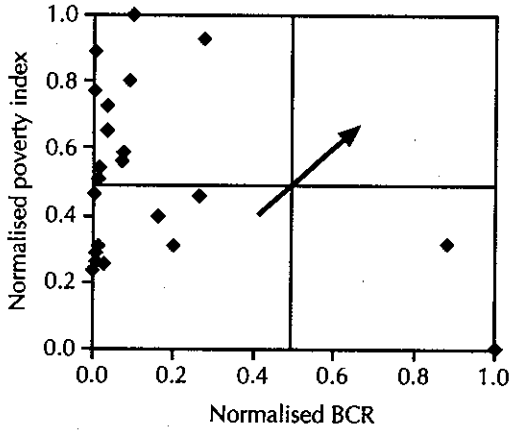
Index	Composite	Economic benefit	Poverty reduction	Environmental impact	Capacity building	Internationality
Composite	1.00	0.51*	0.30	0.49*	0.14	–0.01
Economic benefit		1.00	–0.32	0.06	–0.23	–0.19
Poverty reduction			1.00	0.03	–0.29	–0.08
Environmental impact				1.00	–0.05	–0.38
Capacity building					1.00	0.25
Internationality						1.00

*Values statistically significantly different from zero at the 5% level with 24 degrees of freedom are shown with an asterisk (Snedecor and Cochran 1980)

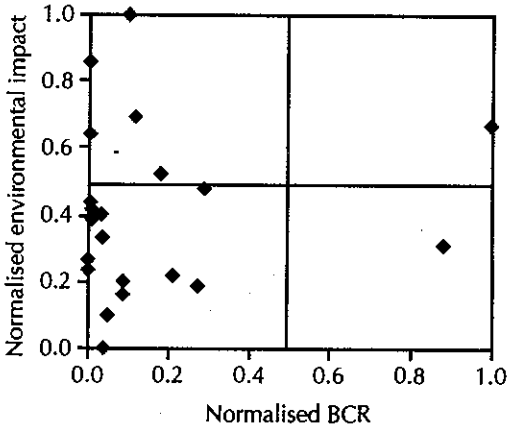
counterbalancing effect to the composite index. The lack of highly positive or negative correlation coefficients, which would have a reinforcing or balancing effect on the composite index, indicates that the current formulation of the indexes does not contribute to any significant 'double counting' across the component indexes. We can conclude that the indexes are indeed measuring different dimensions of impact, because statistically these indexes are independent.

One of the advantages of having component indexes representing the five criteria is that it permits evaluating the trade-offs in achieving the different objectives associated with each theme. For example, the ability of themes to address the two most important objectives—economic benefit and poverty reduction—can be visualised in a scatter plot of the index levels for the 26 themes (Figure 7 part 7.1). Themes that successfully address both objectives simultaneously will appear in the upper right-hand quadrant, following the direction of the arrow. In this example, the skewed nature of the distribution for the economic benefit index means that not one research theme falls in that quadrant. Figure 7 parts 7.2 to 7.4 show a series of other two-dimensional plots—of the benefit–cost ratio against the environmental and capacity-building indexes, and the poverty index against the environmental index. No research theme is consistently in the top right-hand quadrant. For informing research resource allocation decisions, there are trade-offs that clearly have to be made between the

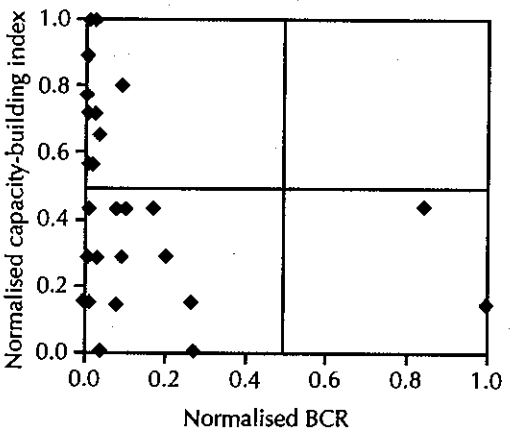
7.1 Normalised poverty index against the normalised BCR



7.2 Normalised environmental impact against the normalised BCR



7.3 Normalised capacity-building impact against the normalised BCR



7.4 Normalised environmental impact against the normalised poverty index

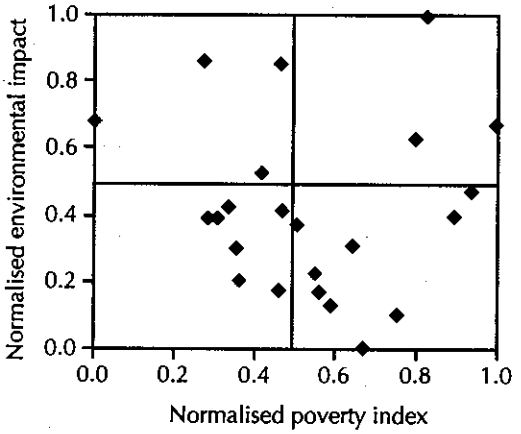


Figure 7 *Trade-off scatter plots for various indexes of the 26 research themes (BCR = benefit–cost ratio).*

various impact criteria. The composite index is useful, but the make-up of the impact of the individual research theme also has to be considered. We return to the implications of this.

Sensitivity analysis

We carried out sensitivity analysis on the weights associated with the five criteria that go to make up the composite index (Table 9). This was done as one method to assess the robustness of the rankings. Four sets of weights were applied to the criteria and the themes reranked. These sets were chosen as follows:

- a 'poverty imperative' set of weights, where the poverty weight was doubled from its standard value (p. 38), and the remaining four weights were adjusted pro rata; this represents the situation in which poverty is the overriding criterion for assessing research themes
- an 'economic imperative' set of weights, where the economic weight was doubled from its standard value (p. 38), and the remaining four weights were adjusted pro rata; this represents the situation in which the benefit–cost ratio is the overriding criterion for assessing research themes
- an 'environmental imperative' set of weights, where the environment weight was doubled from its standard value (p. 38), and the remaining four weights were adjusted pro rata; this represents the situation in which environmental issues are the overriding criterion for assessing research themes
- an 'equality' set of weights, where each was set to 0.2, representing a situation in which no criterion is overriding but each is equally important

Results are shown in Table 9 for the 26 research themes. Themes are listed in the table according to their rank using the standard set of weights (p. 38), as to whether they appear in the first (1), second (2), third (3) or fourth quarter (4) of the sorted list for each set of weights. Thus the first theme in the list, LFN2, always appeared in the top quarter of all ranked themes, regardless of which set of weights was used to derive the composite index. The second theme, LE4, was in the top quarter of all themes for all sets of weights except for the equality set, in which it appeared in the second quarter of the list.

In general, there is a strong relationship between themes and their quartile rankings, regardless of the set of weights used. There are a few notable exceptions to this. For example, theme LE2, the fourth entry in Table 9, ranked in the first quartile for the standard set of weights and the economic and environmental imperative sets but ranked in the third quartile for the equality set and in the fourth quartile for the poverty imperative set. This is not unreasonable, because the theme ranked last of the 26 in impact on poverty (see Table 6), with the result that any set of weights that gives more promi-

Table 9 Sensitivity analysis: results of ranking of 26 research and related themes by quartiles for five different sets of weights in the composite index

THEME		SENSITIVITY RUN				
No.	Title	STD	POV	ECO	ENV	EQU
LFN2	Increasing livestock productivity through improved feed conservation	1	1	1	1	1
LE4	Improving rangeland systems	1	1	1	1	2
LE5	Reducing deforestation	1	1	1	1	1
LE2	Reducing environmental costs of intensive livestock systems	1	4	1	1	3
LP4	Using different species to reduce negative environmental impact	1	1	1	2	2
SAIA1	Ensuring future viability of smallholder systems	1	1	2	1	1
LP1	Participatory policy research to improve technology adoption	2	1	2	2	2
LP2	Policies for improving natural resource management	2	2	2	1	2
LFN1	Increasing feed quantity and quality through genetic enhancement	2	2	2	2	2
CSLR3	Strengthening capacity—networking	2	3	2	2	1
CSLR2	Strengthening capacity—information	2	3	3	2	1
CSLR1	Strengthening capacity—training	2	4	3	2	1
LP3	Reforming input and output markets	2	2	3	3	3
LHI3	Improved prevention and control of ticks and tickborne diseases	3	2	3	3	2
LE3	Land-use strategies to increase production and protect the environment	3	4	4	2	2
LHI4	Improved prevention and control of trypanosomosis	3	2	3	4	3
LFN4	Breeding for improved feed utilisation efficiency	3	2	2	3	3
LGG3	Genetic improvement and delivery strategies	3	3	1	4	4
SAIA3	Understanding systems evolution	3	3	4	3	3
SAIA2	Global prioritisation	4	4	4	3	3
LGG1	Assessment and valuation of animal genetic resources	4	3	4	3	4

THEME No.	Title	SENSITIVITY RUN STD	POV	ECO	ENV	EQU
LHI2	Improving delivery, adoption and impact of technologies	4	4	2	4	4
LFN3	Improving feed utilisation through enhanced rumen function	4	3	3	4	4
LGG2	Identification and characterisation of genetic resistance to disease	4	2	4	4	4
LHI1	Comparative global impact assessment of livestock diseases	4	4	4	4	4
LE1	Strategies to improve nutrient supply	4	4	4	4	4

STD = standard set of weights	BCR 0.30, environment 0.20, capacity building 0.15, internationality 0.10, poverty 0.25
POV = poverty imperative	BCR 0.20, environment 0.13, capacity building 0.11, internationality 0.06, poverty 0.50
ECO = economic imperative	BCR 0.60, environment 0.11, capacity building 0.09, internationality 0.06, poverty 0.14
ENV = environmental imperative	BCR 0.23, environment 0.40, capacity building 0.11, internationality 0.07, poverty 0.19
EQU = equal weights	BCR 0.20, environment 0.20, capacity building 0.20, internationality 0.20, poverty 0.20

CSLR – Capacity Strengthening for Livestock Research; LE – Livestock and the Environment; LFN – Livestock Feeds and Nutrition; LGG – Livestock Genetics and Genomics; LHI – Livestock Health Improvement; LP – Livestock Policy; SAIA – Systems Analysis and Impact Assessment

nence to poverty will reduce the ranking of this theme markedly.

Another way of looking at these sets of weights is shown in Table 10. Here, instead of a simple list ranking by quartile as in Table 9, we show the appropriate quartile (1 is the highest 25%, 4 the lowest 25%) of the cumulative distribution of the composite index. Thus for the standard set of weights, 11 of the 26 themes fall in the third quartile of this distribution, and only two fall in the fourth quartile. This reinforces the observation made above that half of the themes have values of the composite index that are very similar. The other sets of weights lead to similarly non-uniform and skewed distributions. For example, using the economic imperative set of weights, only two themes fall in the first quartile and none in the second.

Taken together, these results show that the ranking of themes is only moderately sensitive to the choice of weights. Only five themes changed their rank quartile by more than one quartile either side of the standard set of weights (see Table 9: for instance, LE2 moved from quartile 1 to quartile 4 in one case). None of the set of weights analysed resulted in uniform distribution of the composite index; on the contrary, all sensitivity runs resulted in considerable bunching of themes. While the composite impact of many of the research themes appears quite similar, impact of the individual constituents may vary, sometimes quite markedly. This would suggest that, while the composite index gives a good picture of overall

impact to be expected, different research themes can lead to different types of impact, and any priority assessment would need to take the constituent impact types into account.

Summary of the results

Some summary points can be made concerning the results.

- Half of the themes have composite index values between 0.35 and 0.45. However, there is considerable variability in the make-up of the composite index, so that in general, research themes have different and distinct (usually by KRRA) impact profiles, with different strengths and weaknesses.
- This is borne out by the lack of correlation between the normalised index values for the five criteria. Plots in two-dimensional space highlight the fact that there are no research themes with an 'ideal' profile of high-potential impact in all five criteria. The 'best' theme in this regard, LE4, still scored only 8.8 in average rank per criterion, the highest average value for all 26 themes.
- The benefit–cost ratio is obviously an important component of the composite index, but the results of the sensitivity analysis indicate that it is not overwhelmingly so. Theme rankings are broadly interpretable in the methods that were used to estimate productivity impact related to recommendation domain size (described in Section 3). Themes with broad recommendation

Table 10 *Sensitivity analysis: 26 research and related themes ranked by quartiles of the cumulative distribution of the composite index for five different sets of weights*

THEME		SENSITIVITY RUN				
		STD	POV	ECO	ENV	EQU
LFN2	Increasing livestock productivity through improved feed conservation	1	2	1	2	1
LE4	Improving rangeland systems	1	1	3	1	1
LE5	Reducing deforestation	1	1	3	1	1
LE2	Reducing environmental costs of intensive livestock systems	1	4	1	1	2
LP4	Using different species to reduce negative environmental impact	1	1	3	2	1
SAIA1	Ensuring future viability of smallholder systems	1	1	3	2	1
LP1	Participatory policy research to improve technology adoption	2	1	3	2	1
LP2	Policies for improving natural resource management	2	3	4	2	1
LFN1	Increasing feed quantity and quality through genetic enhancement	2	3	3	2	1
CSLR3	Strengthening capacity—networking	2	3	4	3	1

THEME		SENSITIVITY RUN				
		STD	POV	ECO	ENV	EQU
CSLR2	Strengthening capacity—information	2	3	4	3	1
CSLR1	Strengthening capacity—training	2	3	4	3	1
LP3	Reforming input and output markets	2	2	4	3	2
LHI3	Improved prevention and control of ticks and tickborne diseases	3	3	4	3	2
LE3	Land-use strategies to increase production and protect the environment	3	4	4	2	2
LHI4	Improved prevention and control of trypanosomosis	3	2	4	4	2
LFN4	Breeding for improved feed utilisation efficiency	3	3	4	4	2
LGG3	Genetic improvement and delivery strategies	3	3	3	4	2
SAIA3	Understanding systems evolution	3	3	4	3	2
SAIA2	Global prioritisation	3	4	4	3	2
LGG1	Assessment and valuation of animal genetic resources	3	3	4	3	2
LHI2	Improving delivery, adoption and impact of technologies	3	4	3	4	2
LFN3	Improving feed utilisation through enhanced rumen function	3	3	4	4	2
LGG2	Identification and characterisation of genetic resistance to disease	3	3	4	4	3
LHI1	Comparative global impact assessment of livestock diseases	4	4	4	4	3
LE1	Strategies to improve nutrient supply	4	4	4	4	4

STD = standard set of weights	BCR 0.30, environment 0.20, capacity building 0.15, internationality 0.10, poverty 0.25
POV = poverty imperative	BCR 0.20, environment 0.13, capacity building 0.11, internationality 0.06, poverty 0.50
ECO = economic imperative	BCR 0.60, environment 0.11, capacity building 0.09, internationality 0.06, poverty 0.14
ENV = environmental imperative	BCR 0.23, environment 0.40, capacity building 0.11, internationality 0.07, poverty 0.19
EQU = equal weights	BCR 0.20, environment 0.20, capacity building 0.20, internationality 0.20, poverty 0.20

CSLR – Capacity Strengthening for Livestock Research; LE – Livestock and the Environment; LFN – Livestock Feeds and Nutrition; LGG – Livestock Genetics and Genomics; LHI – Livestock Health Improvement; LP – Livestock Policy; SAIA – Systems Analysis and Impact Assessment

domains have small productivity impact, which will decrease the BCR. Relatively cheap, short-term research activities with short adoption lags will tend to have high BCRs, while longer-term, more expensive research activities with long adoption lags may have relatively small BCRs, partially because of discounting, all other things being equal.

Points 1 and 2 above would seem to highlight the fact that ILRI currently has, and will have in the future, a particularly broad research portfolio, and these activities clearly have a broad range in types of impact. Important implications emerge.

First, the results indicate the importance of taking an explicit portfolio approach to assessing research activities. The strategic planning and priority assessment process has not identified any 'wonder' research themes that score highly in all aspects of the chosen criteria. Much more realistically, in our view, the assessment has highlighted the fact that research managers have to trade off research benefits and impact, and they can do this only with a portfolio approach. Only by considering the totality of research activities and the likely impact of each can the portfolio adequately address the goals of the institute and of the CGIAR.

Second, this analysis points very clearly to the need for a broad-based approach to donors and to funding. In the absence of a 'super vaccine' or 'super cow' or 'super fodder', a portfolio of research activities with types of impact that are broad but that differ opens the way to approaching non-traditional agricultural donors, on the basis that some will be more interested in environmental aspects, others in poverty reduction, and yet others in capacity building. When this is added to the fact that the secondary and tertiary impact of some of the scientific research activities at ILRI is not taken into account and also spills over into other non-traditional (non-agricultural) arenas—such as the impact on human health of some of ILRI's research—it is clear that credible priority assessment can play a key role in helping to target new donors in new areas through using new justification for impact.

Third, the importance of the differential impact that the analysis has highlighted among research themes points to the need to appreciate the broad base of end users of the products of ILRI's research activities. The current priority-setting framework copes reasonably well with what are usually seen as the traditional end users of technology and information—from smallholders through to policy-makers, for example—but it omits explicit consideration of end users other than these, both within and outside ILRI (such as scientists working in the area of human health). For the former, a number of the research themes concerned with impact assessment score poorly, for obvious reasons; their recommendation domain may be large, but their resultant productivity impact may be small indeed,

and the ultimate pathway to impact may be exceedingly long and convoluted. The primary target audience for such research activity is ILRI itself, however. These are examples of spillovers that are not taken into account in the framework. Making ILRI's research better defined and better targeted through priority setting and impact assessment studies may well have no discernible primary impact, but the secondary or even tertiary impact may be substantial (and in the case of impact assessment, its justification is entirely due to these secondary and tertiary types of impact). For end users outside ILRI, the framework takes no explicit account of the spinoffs to other scientific areas of endeavour that arise from laboratory tools and techniques that are developed at ILRI but applied in very different arenas. If the current framework could be developed to incorporate some of these secondary and tertiary effects, this could have substantial impact on the results. Scientists from outside ILRI could very usefully be involved in such development. In addition, they could help define more realistic recommendation domains in an effort to increase the differentiating power of the internationality index.

5 Conclusions

The process of developing a priority assessment framework and applying it to current and potential research areas at ILRI took some nine months. Comparative results of earlier assessments are presented in Appendix 7. The process of development and application has highlighted a number of lessons.

First, one of the major values of all this activity has been the process itself. Within ILRI, it has raised the profile of impact assessment, but more importantly, it has highlighted the need to think about very difficult questions related to the probability of success of scientific endeavour, the potential impact of research, and the real nature of the constraints that afflict smallholder production and consumption systems in the tropics and subtropics. The donor community has changed rapidly over the last few years, in donors demanding accountability for their funds and impact in the household. The priority-setting process ILRI has undertaken has helped to put these demands in a new light for many at the institute. Fund raising is never likely to be the same again, and while the difficulties involved in thinking about impact are profound, the framework developed has real potential as a marketing tool for donors, which should be used by scientists in developing proposals.

Second, the priority assessment process has underlined the difficulties involved in assessing the impact of livestock-based research. There is no doubt that all ex *ante* research assessment is difficult, but it seems that the assessment of livestock-related research for an institute such as ILRI is even more difficult. Livestock are, in many ways, a 'difficult' commodity: large ruminants have a long generation interval; livestock are mobile, and in some parts of the world can make nonsense of the concept of a static livestock distribution map; livestock have an inherent capital value (and insurance or 'bank account' value) in many systems, and such values are not well captured in estimates of productivity gain; and the contribution of smaller livestock to smallholder welfare in much of the tropics and subtropics is far from well understood (the figures that are available for the distribution and density of, say, chickens in smallholder systems sum this up neatly—there are almost none).

In addition to the nature of livestock compared with crops, for example, ILRI has a particularly broad mandate—not only geographically, in terms of livestock systems in general around the world, but also in terms of the nature of the research activities undertaken, from immunology research to feeds research, on-farm testing of technologies with NARS partners to policy work, and database development. The overall scope of ILRI's work is thus very broad. All these factors make ex *ante* research assessment even more difficult than it may be for crop commodities with a relatively limited agro-ecological suitability.

Third, the process has highlighted the fact that even with a basic priority assessment framework in place, a major constraint to its effective use is the availability and quality of data. Again, for reasons of general applicability, but also because of the nature of livestock, much of what might be considered the basic systems data for livestock-based production activities is highly aggregated or of dubious quality.

Two major limitations—weaknesses in the framework itself and weaknesses in the data—are discussed below in relation to future work and future challenges.

Improving the priority assessment process

As noted above, the major impetus for developing and applying a priority assessment framework for ILRI's current and potential research activities came in the wake of an external programme and management review, although priority assessment activities in some form or other have been in progress since the mid-1980s at ILRI, ILCA and ILRAD (Thornton and Odero 1998). Given the level of input and effort involved to date, ILRI as an institution is committed to adopting the framework for future priority assessments and to refining the methodology and improving the quality of the data used. As has been noted throughout the text, there are currently serious limitations in the approach and in the data availability that need to be addressed. These are highlighted below.

First, there is the difficulty in defining research themes or activities at a consistent level of detail. It is apparent that some of the research themes in the priority assessment are small and very well defined, in terms of resource inputs and expected outputs and milestones. Others are much more generic and specify almost a blanket approach to producing relatively unspecific outputs in response to relatively large amounts of research resources. This relates largely to the nature of the research activities being contemplated. To take two examples from the Livestock Health Improvement KRRA, global impact assessments of current and future livestock disease problems can be relatively well defined in terms of what is required to do the work and the likely outputs. Improved prevention and control of ticks and tickborne diseases, on the other hand, is a research theme with many facets and with multiple approaches to the same basic problem, and by its nature, its specific activities and outputs can be specified much less well.

This inconsistency between research themes in level of detail became a problem at various stages in assessing priorities, notably when attempting to specify inputs and outputs and to quantify likely productivity and other types of impact. Since each research theme needs to correspond to a single set of impact types, some sort of implicit averaging has to be undertaken if very different types of output emanate from a given research activity. Similarly, it may be that only part of a large research theme can actually be

countenanced, given resource constraints, in which case a large research theme is not the most appropriate unit of analysis. This has to be balanced by the fact that the operation of the focus groups, and the subsequent analysis, would have become essentially impossible if the themes had been broken down into small pieces, oriented towards a single output. As usual, a trade-off is involved between excessive detail and too many research activities and outputs. For future analysis, more thought needs to be given to what is the most appropriate level of detail of the research theme for institute-wide priority assessment.

Second, it is difficult to estimate key parameters that are consistent across very different research themes. This problem really has two parts: estimating parameters at all for some research themes is difficult, but these parameters then need to be taken together to attempt to ensure consistency among them. The first part of this problem relates particularly to data availability and quality: what are the appropriate recommendation domains for particular interventions, what is the likely productivity impact that may result, how many of the target smallholders are really likely to adopt the intervention, and how many poor people really will be affected? Given the time constraints for the priority assessment process, only so much could be attempted. The databases of Seré and Steinfeld (1996) and TAC were extremely useful and added a great deal to the analysis. Yet much of the 'hard' data that went into assessing priorities was severely limited in quality or level of detail, and this deficiency must be resolved if the framework is to be improved. This relates as much to some of the economic data (elasticities of supply and demand for livestock commodities by region, for example) as to other types of data (livestock distribution, numbers of poor, and so on).

Considerable progress has been made in the last three to four years on defining the unit of analysis (the research theme). Much less progress has been made on defining the recommendation domain. For many of the research areas, the recommendation domain is defined so broadly that it does not provide much useful information. For those KRRAs that are not directly targeted at productivity increases within specific systems, such as livestock policy, capacity strengthening for livestock research, and systems analysis and impact assessment, a reasonable compromise was reached on the trade-off between productivity gains and span of the recommendation domain.

In research areas that should be more targeted, more work is needed to rigorously define a primary recommendation domain, where the research outputs are expected to have direct impact, and a secondary recommendation domain, where research outputs could conceivably lead to indirect or spillover impact. Examples would be a vaccine against *T. parva* having some influence on, or leading towards, the development of a vaccine against *T. evansi;* or livestock feed or management research aimed at

cattle or small ruminants that may lead to impact in pig systems.

The second part of this problem is the issue of consistency between themes. Again, the broad scope of ILRI's research activities makes this difficult to achieve. It is an important step, however; otherwise one runs the risk of comparing apples with oranges. This is why the focus groups were asked to concentrate on the final productivity impact of research activities, be they technological interventions, with an adoption pathway that is relatively easy to envisage, or impact assessments themselves, where the adoption pathway may be long and tortuous before any impact on the smallholder can even be conceived. This is also why two validation and harmonisation workshops were undertaken. Ultimate impact is a product of various factors, but particularly the extent of the recommendation domain and the productivity impact expected per unit (such as hectare, animal). The adoption rates of many agricultural technologies in the tropics and subtropics vary enormously, but many have been very modest (for example, the nine case studies discussed in Sechrest and others 1999). There are many reasons for this, but it highlights the need for caution in imputing potential adoption percentages. For credibility, conservatism is undoubtedly the best policy, even at the risk of somewhat underselling the potential benefits of technological or policy-related change. Validation and harmonisation can undoubtedly be improved, but the basis for improvement would still be better quality data.

Third, and this is very much related to the consistency issue above, there is the difficulty of evaluating and comparing knowledge-based with technology-based research themes. The difficulty of specifying plausible delivery pathways for, say, building the capacity of the smallholder household and improving the ultimate impact on it have already been alluded to. Many parts of that pathway, convoluted as it likely is, are firmly outside ILRI's control, so that such things have to be factored into the eventual ceiling adoption rate (which may be extremely small). But it is not difficult to list a number of cases over the last few years where policy reforms, carried out largely on the basis of sound policy work in the countries concerned, have had large, rapid, widespread and direct impact on smallholders, who are often extremely quick to exploit favourable changes in market conditions.

Yet because so many factors enter the policy-making decision process, one may have to conclude that ceiling adoption levels of policy-related information are generally rather low. And what can one realistically say about the likely farm-level impact of impact assessment itself? The focus groups delineated plausible adoption pathways for even these research results, and undoubtedly impact assessment can reorient, and indeed has reoriented in certain cases, research programmes in NARS in the tropics and subtropics. But putting a figure on the resultant increase in efficiency and

improvement in targeting technology as a direct result of this reorientation is difficult and contentious, to say the least.

Fourth, it is difficult to evaluate research themes that have important but difficult-to-quantify secondary (or even tertiary) forms of impact, compared with relatively straightforward estimates of productivity gains—such as arising from a new feeding strategy. This issue was noted in Section 4 above in relation to research themes in a number of the KRRAs such as that on livestock health improvement or on systems analysis and impact assessment. These are not so much spillover effects as spinoff effects. Spillover impact can be plausibly postulated on the basis of agro-ecological similarities or equivalent socio-economic conditions, for example.

But spinoff effects go straight to the heart of what constitutes science and the scientific method—formulation of hypotheses, partially on the basis of what has gone before; trial-and-error testing of these hypotheses to try to falsify them; and the planned and (especially) the serendipitous advances that are bound to arise as a direct consequence of this (historically) phenomenally successful method of going about the study of the real world. In many cases, how are these advances to be assessed within a priority assessment framework? It may not be possible at all. Indeed, it is hard not to conclude that there are philosophical as well as practical limits to what can be achieved with a quantitative priority assessment framework.

A few summary points can be made about the criteria used in the framework. The notion of economic surplus presents few problems as a concept; the assumptions used are documented in Appendix 2, and many of these could be relaxed or at least re-examined for appropriateness. The poverty data are reasonable at the continental level, but some effort could usefully be expended on spatial databases of poverty by production system and agro-ecological zone for better targeting of technologies and policies that can really benefit the poor. The environmental index that was developed is innovative and fairly comprehensive for a priority assessment exercise of this nature. It has some weaknesses, which were listed in Section 2, and certainly some of these should be examined as the framework is refined and developed over time. Considerable work is currently being done on the economic valuation of environmental services and natural capital; a more economic evaluation of such benefits in a future version of the priority assessment framework could then allow trade-offs and complementarities to be assessed between environmental costs and benefits, and gains in economic efficiency. The indicator for internationality seems reasonable, although with refined data on recommendation domains, a more accurate and site-specific index could probably be generated. The indicator for capacity building is likely to remain a stumbling block; this is very difficult to elucidate, but again better data on recommendation domains for particular

research briefs would probably make this easier to deal with.

Next steps

In the final analysis, a reasonably robust quantitative priority assessment framework is extremely useful. As noted above, more work is needed to refine the framework and to improve the quality of the data that feed it. Over the next medium-term planning period, some of this work will be carried out, to improve the utility of the tool both within ILRI, for scientists to use in writing grant proposals and to inform management, and outside ILRI, to NARS and other organisations involved in livestock-related research in a resource-constrained environment. While data quality is quite rightly a major issue, it is the very nature of any priority assessment framework that there will always be large uncertainties surrounding many of the key parameters. Our ability to predict the future is generally poor, and it is difficult to see how it can be improved much with respect to the probabilities of success of research activities with given resources and within defined time frames, as well as the expected impact of research products.

The work carried out so far has provided signposts or indications that can help to inform resource allocation decisions. The process has been reasonably inclusive and complete, but of course there are other criteria that research managers will consider that have not been taken into account. Most organisations will want a portfolio of research activities that combine long-term horizons with short-term horizons; it is important to produce outputs next year, as well as in 10 years' time. The research portfolio is bound to be based on managers' appreciation of current staff capabilities; of course, this can be changed, but it takes time. The portfolio will also be concerned about the elusive secondary and even tertiary impact of what is being done. For various KRRAs, it may point the way to using donors who have not traditionally been involved in funding agricultural research. Donor priorities can change rapidly in response to donors' own constituents, and the research portfolio is bound to be partially influenced by what scientists and research managers believe can get funded next year. Given the volatility of the funding situation, there may well be a case in future revisions of the framework for explicitly including a 'fundability' criterion as the sixth index, rather than including fundability as an initial screening criterion as was done in this exercise.

Work on the ILRI priority assessment framework is continuing, particularly with regard to carrying out strategic impact assessment research itself (how can the framework be made better and more inclusive) and with regard also to assembling better databases with which to flesh out the framework. Priority setting is of importance to all the CGIAR centres, and the type of data that are required is common to many. This is one opportunity for centrewide initiatives, such as the Consortium for Spatial Information, of

which ILRI is a core member, to make a large and lasting contribution to impact assessment and priority setting throughout the CGIAR. One area in which the framework is being improved is through the explicit inclusion of risk. Instead of using fixed values for key parameters in the framework, such as the probability of success of a particular research theme, a probability distribution can be ascribed to the parameter, in recognition of the fact that its value is uncertain. Monte Carlo sampling of these (input) probability distributions then leads to output probability distributions (rather than single values) for the individual indexes and the composite index for each research theme. The risk and variability associated with particular research themes can then be contrasted and compared. Such analyses can provide additional information concerning the relative riskiness and uncertainty of research themes.

It is envisaged that the priority assessment framework will be used in future to provide input to ILRI's medium-term plans. As noted above, in the short and medium term, actual resource allocation may reflect only imperfectly the results of priority setting for many reasons, not least because of current commitments to donors. Over the longer term, as existing operational projects come to an end and scope exists for new activities to be taken on, it may be expected that several of the new, more highly ranked research themes will enter ILRI's portfolio of activities.

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Appendix 1

Guidelines for focus groups: assembly of data for priority assessment

Priority setting is necessarily a key feature of ILRI's current strategy planning exercise. Priorities need to be set by the focus groups within each of their research areas, and then again at the centre level, across all of the research areas. To make this process as structured, logical and transparent as possible, the Strategy Planning Steering Committee has set the following questions to be considered when evaluating each candidate research theme:

- What is the extent of the problem globally?
- What are the goals and purposes of the themes?
- How is the proposed work addressing the needs of poor people dependent on livestock?
- What is ILRI's complementary (or comparative) advantage vis-à-vis alternative suppliers (using the discovery-to-delivery framework as a guide)?
- What is the prospective payoff and in what terms (for example, livestock productivity, income generation, environmental effects, capacity building)?
- What is the researchability or the feasibility of the themes?
- What is the probability of success in the proposed time frame and the milestones and indicators of success of achievement and impact?
- What are the synergies, complementarities and links among themes in ILRI?
- What are the notional resource requirements for each theme?

To try to make the answers as comparable as possible, both within and across focus groups, this note proposes guidelines for the focus groups to follow when addressing the questions set out by the Steering Committee. The guidelines are framed in the form of a theme brief that summarises the key characteristics of the proposed research focus, including information needed to evaluate its potential impact.

We would like to stress a number of assumptions underlying the use of these guidelines:

- The purpose of filling out the brief is to provide input into a quantitative, economic assessment of the potential returns to the research—but it is not just to generate data for the economists. It is also intended to facilitate discussion within the focus groups by ensuring that a series of key issues are asked in a similar fashion about each potential research theme. First, this makes sure that those questions are asked and thought about. Recall that the EPMR and TAC have requested this. Second, this should help avoid interminable debates, in which one side is talking apples and the other, oranges.
- The focus group participants are well qualified (and often the best qualified

persons) to make estimates concerning how the research would be conducted, its chances of success and its potential impact. Even if you do not feel confident about making predictions or feel that, for example, you are not sufficiently familiar with the geographical distribution of livestock systems to answer questions about the adoption domain of a given research product, remember that your estimates are certainly better than research managers making decisions with no information at all. Indeed, it could be argued that if we have difficulty justifying the priority to be given to a theme, maybe it should be discounted on these grounds in the focus groups. Perhaps the appropriate response in such cases is to define a new strategic research theme aimed at generating the needed information.

- The priority setting indicators included in the brief, especially quantitative ones concerning impact, are just one set of criteria that will need to be considered when making decisions about which research themes to pursue. We do not expect decisions to be made solely on the basis of the quantitative, economic impact measures that will be derived from the information that you will provide in the briefs. We do feel, though, that these quantitative indicators are useful and important to consider during the process.
- TAC will eventually require the same information. The information that you are providing in the brief will serve as the first step in developing a more detailed, and likely more rigorous, justification of our research priorities. This is to say that this exercise is unavoidable and that the results will later be refined, so that you do not have to feel that your answers are necessarily going to stand without some type of verification to ensure their credibility.

The brief is presented below with guidelines for how we would like each question approached. We are striving to make the guidelines clear and straightforward, anticipating the broad range of situations to which it will be applied. Please do not be discouraged by some of the complicated-looking tables; we expect that only a small portion of those tables will apply to any given research theme, and so will not be too difficult to fill out. We apologise up front for the production system classification used; it is the only one that has livestock numbers and production data broken down by production systems on a worldwide scale. We have tried to ease the pain of trying to understand and use it by giving examples of where in this classification system would lie production systems that we are more familiar with.

We envision a brief being developed for each of the candidate research themes considered by the focus groups. When exactly the brief is discussed and filled out will be up to each individual focus group. The briefs should then be included as part of the focus group report. Focus groups may find it useful to use a crude version of the brief during the initial discussion and identification of candidate research themes at the focus group workshop.

Focus group research theme brief

1 Research area	Focus group name
2 Research problem	Title of the research theme. What are the goals and purposes of the theme? As much as possible, the title should be framed as a problem to solve, with an indication of the general approach being applied to solve it. Example: timely treatment of ECF through the development of practical, affordable penside tests.
3 Research recommendation domain	This research will be relevant to which production systems around the world? The purpose of this question is to begin describing the 'extent of the problem' by identifying the production systems where the issue being addressed by the research is thought to be a problem and would likely benefit from the research outputs. This should help the focus group to establish consensus among the participants on what may be varying perceptions of what exactly the problem is and its scope. We propose using the classification system developed by Seré and Steinfeld (1996) for FAO that covers the full range of species, production systems and locations. The classification system is described more fully below in the section following the brief. Possible categories are organised in a table based on livestock production system and species and broken down by commercial (larger-scale industrial) versus smallholder. A table will be filled out for each relevant region in the developing world, which includes sub-Saharan Africa (SSA), West Asia and North Africa (WANA), South Asia (SA), South-East Asia (SEA), East Asia (EA) and Latin America and the Caribbean (LAC). At this point, the focus group is simply asked to check off the relevant cells in the table. In Part 2, you will come back to it to estimate the extent of adoption in each system.
4 Research impact	*A. Intermediate products.* What is the prospective payoff and in what terms? We would like to address the Steering Committee's question by reformulating it as: What is the anticipated impact of the primary output of the research? This is to be answered in two ways: 1) What is the nature of the anticipated impact? Examples would include • improved productivity (yield for input), such as reduced livestock mortality • environmental: – on-site (on the farm), such as improved soil fertility – off-site, such as reduced loss of biodiversity

Longer term impact may have a sustainability dimension:

- research or applied tools, especially diagnostics
- capacity building (human resources, institutional)
- improved efficiency, which can relate to
  - research efficiency
  - efficiency in achieving impact of research

This might relate, for example, to improving policies that enhance effective delivery of research products.

2) How large is the magnitude of this anticipated impact?

Here, we are asking for an estimate of the per unit (if applicable) impact if the problem is successfully solved by the research. For example, by how much would crop yields increase if a nutrient cycling technology is successfully designed and applied?

B. Impact in terms of the CGIAR mandate

How will the research address the needs of poor people dependent on livestock? We would like to address this question in two ways:

1) How will the intermediate impact described in Part A affect poor people? This can be answered by describing the 'chain' of impact: for example, improved nutrient cycling → improved crop productivity → higher net income for smallholder farmers, including many of the rural poor ...

2) Which production systems identified in Section 3 above are likely to contain a significant portion of poor people? This should be relatively easy to determine by reviewing the smallholder systems that have been identified.

5 Outputs and time frame

Major milestones and outputs identified as typically done for the medium-term plans, although on a much cruder scale, with the expected year of completion (assuming activity begun in Year 0) given:

- the most reasonable resource scenario (as you define it in Section 8)
- expected interactions and delays due to external collaboration or prerequisite scientific advances (for example, development of diagnostic tools)

6 Research ability

Evaluation on a scale of low/medium/high of

- current state of knowledge
- research momentum in the needed disciplines
- availability of the required research tools to support the research

7 Probability of success	Likelihood of achieving expected output within defined time frame, given in a percentage, a range of percentages (narrower than 0 to 100, though), or on a scale of low/medium/high. If appropriate, the likelihood for achieving the expected output in longer time frame can also be given (to be specified: number of years)
8 Notional resource requirements	1) Senior scientists by discipline x number of years 2) Additional capital requirements • < US$50,000 • US$50–100,000 • US$100,00–500,000 • > US$500,000
9 Delivery and adoption	What is the anticipated pathway for technology transfer? (for example, extension; commercial production and marketing) What time lag might be expected between development of the research output and availability for adoption, and to ceiling adoption level? In particular, will the ILRI research product require more adaptive research to tailor it for specific client groups? If so, what might be the expected additional time required?
10 Expected adoption	For each of the relevant production systems x regions x species identified in Section 3 above, estimate • the share (percentage or low/medium/high score) of system for which the technology will apply • the percentage or scoring of the above point that would be likely to actually adopt the technology The procedure for this is explained more fully in the section following this brief.
11 ILRI's comparative advantage	Evaluation of ILRI's comparative advantage vis-à-vis alternative suppliers; scored as low, medium or high. To address this issue, first answer the following questions: • Why shouldn't NARS do this work? • Why not the private sector? • Why not ARIs? Note any other relevant reasons.

Determining the recommendation domain

Given that the only data we have broken down by livestock system of some kind is the Seré and Steinfeld study (1996), we are using it to get at a crude estimate of quantities of animals and products potentially influenced by ILRI's research. Seré and Steinfeld define 11 systems, which we need to understand before attempting to answer

the question 'in which of these systems can we expect to have impact for different research products?' The definition of each system is given below, with examples of each. The 11 systems are based on the following 5 broad system types:

Grassland-based systems (LG): livestock systems in which > 90% of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds *and* < 10% of total value of production comes from crops. Also, annual average stocking rates are < 10 TLU (1 tropical livestock unit = 250 kg liveweight) per hectare agricultural land (that is, a high degree of importance of livestock in the farm household economy, a relatively large amount of land per head).

Mixed farming systems (M): livestock systems in which > 10% of the dry matter fed to animals comes from crop by-products and stubble *or* > 10% of the total value of production comes from non-livestock farming activities (that is, another source of income besides livestock, relatively small amount of land per head of cattle).

Mixed rainfed systems (MR): > 90% of the value of crops comes from rainfed land use.

Mixed irrigated (MI): > 10% of the value of crops comes from irrigated land.

Landless (LL): < 10% of the dry matter fed to animals is produced on the farm where the livestock are located, and where annual average stocking rates are > 10 TLU/ha agricultural land

The 11 systems themselves are as follows:

Temperate and tropical highlands (LGT). Examples: Mongolia's steppe system; dairy systems near Bogota, Colombia; Peru and Bolivia altiplano camelid and sheep grazing systems; Chinese merino wool sheep on communal grazing.

Humid and subhumid tropics and subtropics (LGH). Examples: extensive meat and milk ranching in the lowlands of South America; ranching systems in West and Central Africa; Amazonian ranching.

Arid and semi-arid tropics and subtropics (LGA). Examples: pastoralists in the Sahel; Bedouins in Syria; Near East and North Africa pastoralists; beef–milk systems on pastures in Mexico, Venezuela; southern Africa ranches.

Temperate and tropical highlands (MRT). Examples: smallholder peasant farmers in northern China; smallholders in the Ethiopian highlands where oxen for traction is important, mixed crop–livestock smallholders in the highlands of Central and South America; small-scale peri-urban dairy in the highlands of East Africa.

Humid and subhumid tropics and subtropics (MRH). Examples: areas of South America where rainforests are being cleared; large areas of sub-Saharan Africa (tsetse belt).

Arid and semi-arid tropics and subtropics (MRA). Examples: dryland farming-sheep systems in West Asia, North Africa and India, small ruminant–cassava systems in north-eastern Brazil, mixed crop–livestock farms in parts of the Sahel (for example, Burkina Faso, Nigeria); dairy in Senegal and Mali.

Temperate and tropical highlands (MIT). Examples: Mediterranean region, Far East Asian irrigated rice and dairy farms.

Humid and subhumid tropics and subtropics (MIH). Examples: particularly important in Asia, for example, irrigated rice–buffalo systems of the Philippines, Vietnam and India; irrigated rice, pig and poultry enterprises.

Arid and semi-arid tropics and subtropics (MIA). Examples: small-scale buffalo milk production in Pakistan and India; animal-traction-based cash crop production in Egypt and Afghanistan; intensive dairy systems in California, Israel and Mexico.

Landless monogastric systems (LLM). Where value of production of the pig and poultry enterprise is higher than that of the ruminant enterprises. Examples: pig production in Asia; poultry production in Central and South America.

Landless ruminant systems (LLR). Where value of production of the ruminant enterprises is higher than that of the pig and poultry enterprises. Examples: landless sheep production systems in West Asia and North Africa; sheep-fattening operations in Syria or Nigeria. Peri-urban dairy systems are not included here because the manure is typically used on home gardens or as fuel.

Focus group exercise

Table A1.1 is a comprehensive pro forma, which is needed to maintain consistency across focus groups. It includes all 11 systems and possible species. As not all will be relevant for any given research theme, much of each sheet will be left blank. Please fill out one table for each research theme your focus group comes up with and relevant regions for research outputs from that theme.

Relevance

For each system, by species and by region (SSA, SE Asia, S Asia, E Asia, WANA, LAC), would you expect the research output or outputs that reach the ultimate beneficiary, from each research theme identified, to have a limited (LT), moderate (MOD), or widespread (WI) applicability (that is, potential for impact) within that system? (Where LT = 0–33% share of the system; MOD = 34–66%; WI > 67%.)

Note: research outputs such as diagnostic tools and policy recommendations are usually aimed at our clients (for example, NARS) but will only achieve impact through being used or transferred by those clients to the ultimate users (such as livestock producers or consumers). In defining the recommendation domain, we need to think about where the ultimate beneficiaries of the technologies, strategies, policies, and so on are found.

Adoption

Within that coverage, do you expect final adoption of the research theme outputs by the ultimate beneficiaries to be low (L = 0–10% ceiling adoption), medium (10–20%), or high (20–30%)?

Table A1.2 shows the example of a trypanosomosis vaccine research theme. We may expect half of the grassland-based arid pastoral systems (LGA) to be relevant—therefore mark MOD for relevance

—but not to be adopted widely—therefore mark L for adoption, because of poor infrastructure for delivery.

Table A1.3 contains a capsule summary of the typology of the 11 systems to guide the focus groups as they discuss the potential research themes in terms of recommendation domains.

Final revisions

In the final revision of the research briefs done in November 1999, KRRA chairs are asked to add another item to the research brief: the non-ILRI costs associated with the research. This has arisen in response to comments from various quarters that we need to better capture differences between research themes in terms of the other costs associated with conducting a given theme and delivering it. KRRA chairs are asked to define three categories:

Non-ILRI research costs

Costs that need to be incurred by ILRI's partners (ARIs, other CGIAR centres, NARS) during the research time frame for the research outputs to be achieved in the prescribed time period come under non-ILRI research costs. Please estimate the costs to be

- lower than ILRI's investment, meaning that you expect total costs of associated research by our partners to be lower than ILRI's investment
- roughly equal to ILRI's investment
- greater than ILRI's investment, say up to two to three times greater than ILRI's investment
- much greater than ILRI's investment

Non-ILRI adaptive research costs

The adaptive research costs that do not fall on ILRI include any additional research costs that you anticipate ILRI's partners will incur to transform ILRI's research output into a development product ready for delivery to livestock keepers. Use the four categories listed under the subheading immediately previous to characterise the relative magnitude of the costs needed.

Non-ILRI delivery costs

Delivery costs for which ILRI is not responsible include the costs required to deliver the development product to livestock keepers. It is not realistic to try to compare this with ILRI's investment, so instead we try to characterise the delivery as:

- low cost, for example, a vaccine technology that requires no special infrastructure and can be procured directly by the livestock keeper on demand
- medium cost
- high cost for example, a feed management technology that may require substantial extension and demonstration efforts or pilot projects to deliver the technology as an extension message.

One more item, entitled ***spillover benefits,*** is to be added to the research brief. In this section, please briefly describe any expected benefits of the research that may not be captured in the primary output and its impact on livestock keepers. This information is needed so that we can evaluate whether there is a need to make such spillovers explicit in the priority assessment exercise.

Table A1.1 *Pro forma for research brief recommendation domain*

Region: **(will be either SSA, S Asia, SE Asia, E Asia, LAC or WANA)**

Research theme and output (describe)	Species	Relevant domain	Grassland temperate LGH	Grassland humid LGH	Grassland arid LGA	Mixed rainfed temperate MRT	Mixed rainfed humid MRH	Mixed rainfed arid MRA	Mixed irrigated temperate MIT	Mixed irrigated humid MIH	Mixed irrigated arid MIA	Landless mono-gastric LLM	Landless ruminant LLR
	Dairy–SS	relevance											
		adoption											
	Dairy–LS	relevance											
		adoption											
	Other cattle–SS	relevance											
		adoption											
	Other cattle–LS	relevance											
		adoption											
	Sheep and goats	relevance											
		adoption											
	Pigs	relevance											
		adoption											
	Poultry	relevance											
		adoption											
	Buffalo	relevance											
		adoption											

Dairy – primary use: milk
SS – smallholder
LS – large-scale, capital-intensive

Table A1.2 *The example of trypanosomosis research*

Region: SSA

Research theme and output (describe)	Species	Relevant domain	Grassland temperate LGH	Grassland humid LGH	Grassland arid LGA	Mixed rainfed temperate MRT	Mixed rainfed humid MRH	Mixed rainfed arid MRA	Mixed irrigated temperate MIT	Mixed irrigated humid MIH	Mixed irrigated arid MIA	Landless mono-gastric LLM	Landless ruminant LLR
improve productivity and use of livestock in trypanosomosis-endemic production systems through better use of trypanocides, improved immunity, improved diagnostics and epidemiology; integrated management of trypanosomosis	Dairy[a]–SS[b]	relevance		WI			WI	LT					
		adoption		M			M	M					
	Dairy–LS[c]	relevance		WI			WI						
		adoption		H			H						
	Other cattle –SS	relevance		WI	MOD	LT	WI	MOD			LT		
		adoption		M	M	L	M	M			M		
	Other cattle –LS	relevance		WI	LT		WI						
		adoption		H	H		H						
	Sheep and goats	relevance		WI	MOD	LT	WI	MOD					LT
		adoption		L	L	L	L	M					M
	Pigs	relevance											
		adoption											
	Poultry, ostrich	relevance											
		adoption											
	Camels	relevance			WI			MOD					
		adoption			M			M					

a Primary use: milk
b Smallholder
c Large-scale, capital-intensive

Table A1.3 *Summary of livestock systems and some examples to guide focus groups*

Region	Grassland temperate LGH	Grassland humid LGH	Grassland arid LGA	Mixed rainfed temperate MRT	Mixed rainfed humid MRH	Mixed rainfed arid MRA	Mixed irrigated temperate MIT	Mixed irrigated humid MIH	Mixed irrigated arid MIA	Landless mono-gastric LLM	Landless ruminant LLR
Sub-Saharan Africa		ranching systems in west and central Africa	Sahel pastoralists; southern Africa ranches	Ethiopian and E. Africa highlands mixed animal traction smallholders and peri-urban dairy	tsetse belt of west and central Africa	smallholders with traction or small ruminants in the Sahel					sheep fattening in Nigeria
SE Asia—Indonesia Indochina Malaysia Philippines Thailand South China Vietnam	Mongolia's steppe system; Chinese merino wool sheep			smallholder peasant farmers in northern China			Far East Asian irrigated rice–dairy	irrigated rice–buffalo systems in Philippines, Vietnam; irrigated rice–pig, poultry		pig production	
South Asia—India Pakistan Bangladesh Myanmar						dryland crop–LS systems in India		irrigated rice–buffalo systems in India	irrigated crop–LS systems in N. India; SS buffalo milk in Pakistan, India	pig production	
West Asia and North Africa			Bedouins in Syria; pastoralists in Northeast and N. Africa			dryland farming–sheep systems			AT-based cash crop production in Egypt, Afghanistan	poultry production	landless sheep
Latin America and the Caribbean	Peru and Bolivia altiplano camelid and sheep grazing	extensive ranching in lowlands of South America		mixed smallholders highlands of Central and South America	areas of S. America where rainforests are being cleared	SR–cassava systems in NE Brazil					

SS – smallholder, LS – large-scale, AT – animal traction, SR – small ruminant

Appendix 2

Notes on the calculations for the economic surplus model and the assumptions used

Following Alston and others (1995 p. 384), the formula for the change in total economic surplus, ΔTS, in an ex-*ante* closed economy situation is

$$\Delta TS = K_t P_0 Q_0 (1 + 0.5 Z_t \eta) \tag{A2.1}$$

where

$$K_t = \left[\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1 + E(Y)} \right] p A_t (1 - \delta_t) \tag{A2.2}$$

$$Z_t = \frac{K_t \varepsilon}{\varepsilon + \eta} \tag{A2.3}$$

and P_0 and Q_0 are current price and production levels, *E(Y)* is the expected proportionate yield change (what we refer to as the 'productivity gain' in percentage terms), *E(C)* is the proportionate change in input cost per unit of production, ε is the supply elasticity, η is the demand elasticity, *p* is the probability of success of the research, A_t is the degree of adoption, and δ_t is the annual depreciation rate.

In this analysis, we are assuming that *E(C)* is zero. Then, substituting (A2.2) and (A2.3) into (A2.1), the complete expression for our purposes is:

$$\Delta TS = \left(\frac{E(Y)}{\varepsilon} \right) p A_t (1 - \delta_t) P_0 Q_0 \left[1 + 0.5 \left(\frac{\frac{E(Y)}{\varepsilon} p A_t (1 - \delta_t) \varepsilon \cdot \eta}{\varepsilon + \eta} \right) \right] \tag{A2.4}$$

We use the following approach for both the aggregate (that is, by product) and disaggregated (that is, by individual region by production system by product cell) calculation of the total present value of economic benefits.

First, the total present value of economic benefits is calculated as

$$PVBenefits = \sum_T \frac{\Delta TS_t}{(1+r)^t} \tag{A2.5}$$

where r is the discount rate. Substituting A2.4 into A2.5, we want to estimate the full expression

$$PVBenefits = \sum_T \frac{\left(\frac{E(Y)}{\varepsilon}\right) pA_t(1-\delta_t)P_0Q_0\left[1+0.5\left(\frac{\frac{E(Y)}{\varepsilon}pA_t(1-\delta_t)\varepsilon\eta}{\varepsilon+\eta}\right)\right]}{(1+r)^t} \tag{A2.6}$$

Multiplying out the numerator gives

$$PVBenefits = \sum_T \frac{\left(\frac{E(Y)}{\varepsilon}\right) pA_t(1-\delta_t)P_0Q_0 + \left(\frac{0.5P_0Q_0\varepsilon\eta\left(\frac{E(Y)}{\varepsilon}pA_t(1-\delta_t)\right)^2}{\varepsilon+\eta}\right)}{(1+r)^t} \tag{A2.7}$$

or, equivalently,

$$PVBenefits = \sum_T \frac{\left(\frac{E(Y)}{\varepsilon}\right) pA_t(1-\delta_t)P_0Q_0}{(1+r)^t} + \sum_T \frac{0.5P_0Q_0\varepsilon\eta\left(\frac{E(Y)}{\varepsilon}pA_t(1-\delta_t)\right)^2}{(\varepsilon+\eta)(1+r)^t} \tag{A2.8}$$

Assume now that the adoption rate A_t is separated into two components: $\bar{A}$, the adoption ceiling value, which is constant; and $\tilde{A}_t$, the percentage of the adoption ceiling achieved, which varies from 0 to 100% over time, where $A_t = \bar{A} \cdot \tilde{A}_t$. Then, bringing all constants through the summation signs, we have

$$PVBenefits = \left(\frac{E(Y)}{\varepsilon}\right) p\bar{A}P_0Q_0 \sum_T \frac{\tilde{A}_t(1-\delta_t)}{(1+r)^t} + \frac{0.5P_0Q_0\varepsilon\eta\left(\frac{E(Y)}{\varepsilon}p\bar{A}\right)^2}{(\varepsilon+\eta)} \sum_T \frac{(\tilde{A}_t(1-\delta_t))^2}{(1+r)^t} \tag{A2.9}$$

Equation A2.9 is easily implemented in the spreadsheet since it is now seen to be composed of four terms that are readily computed and do not require computations for each year (that is, do not require doing individual calculations for each year in the benefit stream).

$$PVBenefits = \underbrace{\left(\frac{E(Y)}{\varepsilon}\right) pAP_0Q_0}_{\#1} \underbrace{\sum_T \frac{\tilde{A}_t(1-\delta_t)}{(1+r)^t}}_{\#2} \underbrace{\frac{0.5P_0Q_0\varepsilon\eta\left(\frac{E(Y)}{\varepsilon}p\bar{A}\right)^2}{\varepsilon+\eta}}_{\#3} \underbrace{\sum_T \frac{(\tilde{A}_t(1-\delta_t))^2}{(1+r)^t}}_{\#4} \quad \text{(A2.10)}$$

Terms no. 1 and no. 3 in A2.10 are constant values over the full 50-year period for a given region or production system or product, and so can be computed once for each region or production system or product combination. Terms no. 2 and no. 4 are based on the research and adoption-lag parameters, the depreciation rate and timing, and the discount rate, which are constant over all regions, production systems, products in a given research brief, and so can be estimated once for the whole theme and then used as multipliers for terms no. 1 and no. 3.

Assumptions used in the economic surplus modelling

In the economic surplus analysis that was carried out, a variety of assumptions was made that merit discussion:

- A closed economy was assumed (the basic model of Alston and others 1995), in which research benefits accrue to both consumers and producers, and trade in livestock commodities across regions and production systems is ignored. Such an assumption implies that improved productivity in the arid grasslands system, for example, will affect market supply and prices—and consequently, demand— only in that production system and not in neighbouring humid or temperate zones. This is in distinction to the open economy model, which assumes commodities are traded internationally. An implication of the open economy model, for small countries at least, is that their impact on world price is negligible, so the resultant change in economic surplus accrues solely to producers. The closed economy assumption would not hold in some areas of the developing world—for example, livestock trade between the

underpopulated Sahel zone of West Africa and the high population areas along the humid coast. On the other hand, the overall percentage of livestock products being traded internationally or across livestock production systems is relatively small, and these numbers tend to be overwhelmed by major livestock-producing countries where such trade is relatively limited, such as Ethiopia, Nigeria and India.

- No market distortions were assumed, including such policy instruments as price supports, price ceilings, subsidies on inputs or outputs, or output controls.
- There were assumed to be no technological or research spillovers arising from implementation of the research briefs.
- Changes in production and consumption of each commodity arising from research were assumed to be independent, that is, the cross-elasticities of supply and demand were set to zero.
- A non-zero real discount rate of 5% was assumed, as suggested by Alston and others (1995). They argue that it is not appropriate to deal with uncertainty by adjusting the rate at which future cost and benefit streams are discounted. While some have argued that low (or even zero) discount rates should be used so as to encourage research that leads to the conservation of natural resources, Alston and others (1995) conclude that this is unlikely to be a good way of accounting for intergenerational transfers of natural resources.
- No future trends were factored into demand and supply, largely because of lack of system-specific time series data. This, along with predictions of human and livestock population growth rates using GIS, are factors that should be included in future analyses.
- Any added costs of production to achieve the net productivity gains posited were assumed to be taken into account implicitly in the process.
- Price elasticities from various sources for the products of different species of livestock were used, including Delgado and others (1999). The literature reveals quite a bit of work estimating supply elasticities for crops in the developing world (see Tsakok 1990 for a review). However, there is limited information from secondary data sources estimating elasiticities for livestock products, and even less indicating how these price elasticities vary across the six regions. Demand elasticities are relatively unimportant in determining economic surplus, but choice of supply elasticities can affect substantially the estimate of *K* (equation A2.2) and hence the size of the economic surpluses. Again, how these vary among livestock species and between regions is far from clear. It was felt that an a priori case could be established for assuming lower supply elasticities for large ruminant animal products, on the grounds of the long generation intervals and their relatively large demands on fixed and variable resources compared with small rumi-

nants. In addition, ruminant supply elasticities were assumed to be generally lower than those for monogastrics because of both the shorter generation intervals of the latter and their ability to use substitutable inputs, especially in the industrial monogastric systems.

Derivation of system-specific and livestock-product-specific elasticities is clearly an area that needs attention before we will be able to incorporate sound, empirically based estimates into the analysis.

Appendix 3
Notes on the poverty criteria

Given that we had a number of different kinds of data relating to poverty (for example, number of rural and urban poor by system by region, and poverty and welfare indicators broken down similarly), one issue was to decide how to array them for consideration in one simple yet comprehensive criterion that could contribute to the composite index for each research theme. Various separate indexes were considered in terms of their representing the impact of the proposed research on reducing poverty. Each has its advantages and disadvantages. Seven indexes are discussed below, some with simple examples to illustrate their strengths and weaknesses.

Index A: The *P* index weighted by economic benefit

Index A captures the relative poverty in a region and production system by estimating the degree to which projected 2010 average incomes fall below the poverty line. Since the simple average income figure will be biased by unequal distribution of income within the region-production system (that is, a small number of the rich capture a relatively large portion of income), the projected 2010 average income figure is first adjusted by a Gini coefficient of income distribution; the more inequitable the distribution of income in the region-production system, the more the average income figure is adjusted downward. The adjusted average income (*W*) is then used to calculate the *P* index, which has values ranging from 0 to 1; a *P* value of 0 signifies that the adjusted average projected 2010 income for the region-production system is above the threshold of US$6000; higher values of *P* mean lower project average income, and relatively more poverty (see Section 2).

For this first index, a *P* value is calculated for each research theme by averaging the *P* values across the region and production systems in the theme's impact domain, with each individual *P* value weighted by the share of total economic benefit, *b*, from the theme contributed by the region-production system:

$$PovertyA = \frac{\sum P_i b_i}{\sum b_i}$$

Advantages:
- This measure rewards themes that focus their impact on those regions and production systems with relatively more poverty.
- It is a unitless measure, advantageous for making relative comparisons.

Disadvantages:
- It ignores the magnitude of the impact.
- As might be expected, it is negatively correlated with the economic benefit index ($r = -0.32$).
- It penalises themes that have impact or spillover in areas of both relatively high and relatively low poverty. To illustrate this, consider four scenarios:

Research theme	Projected economic benefits (US$)		Average weighted *P*
	Sub-Saharan Africa	East Asia	
Regional P value	*0.77*	*0.00*	
1	1	0	0.77
2	1	1	0.34
3	10	20	0.23
4	0	20	0.00

Themes 1 and 2 both generate the same benefits for high-poverty sub-Saharan Africa, but the average *P* value for Theme 2 is half that of Theme 1 because it generates additional benefits for no-poverty East Asia. Theme 3 generates much higher benefits for high-poverty sub-Saharan Africa but has an even lower average *P* value because it generates even higher benefits in East Asia.

Index B: Economic benefit per poor person

Index B is calculated as the total expected economic benefit (in US dollars) from a research theme divided by the total number of poor present in the regions and production systems targeted by the theme. It is then normalised to range from zero to one:

$$PovertyB = \frac{\sum b_i}{\sum x_i}$$

Advantage:

- An intuitive and absolute measure of the magnitude of the impact on the poor.

Disadvantages:

- As might be expected, it is strongly correlated with the economic benefit index ($r = 0.58$).
- It implies that economic benefits are indeed captured by the poor, and equally among them.
- It rewards themes that target regions and production systems with relatively few poor.
- It double counts to some degree the magnitude of the economic benefit captured in the index based on the benefit–cost ratio.

To illustrate, consider the following two themes:

Research theme	Projected economic benefits (US$)		Benefits per poor person (US$)
	South Asia	WANA	
Number of poor	*513 million*	*80 million*	
1	1 billion	0	2
2	0	1 billion	13

Themes 1 and 2 generate the same value of economic benefit, but because there are fewer poor in West Asia and North Africa, Theme 2 achieves higher impact per poor person.

Index C: The *P* index weighted by economic benefit per poor person

This index uses the same *P* value as described in the first poverty index A, but this time *P* is weighted by the region- and production system-specific economic benefit per poor person:

$$PovertyC = \frac{\sum P_i \frac{b_i}{x_i}}{\frac{\sum b_i}{\sum X_i}}$$

Advantages:

- This index rewards themes that focus their impact on the regions and production systems with relatively more poverty and where the magnitude of the impact is high, so it captures both dimensions of the relative intensity of poverty and of the absolute magnitude of the impact on those poor.
- The index is a unitless measure for relative comparisons.
- It appears to be independent of the economic benefit index ($r = -0.13$).

Disadvantages:

- This is not an easy index to interpret intuitively.
- It penalises research themes that have impact or spillover in areas of both relatively high and relatively low poverty. To illustrate this, consider the four scenarios tabulated below. Research themes 1 and 2 both generate the same benefits for high-poverty sub-Saharan Africa, but the average *P* value for Theme 2 is lower than that of Theme 1 because it generates additional benefits for no-poverty East Asia. Theme 3 generates much higher benefits for high-poverty sub-Saharan Africa but has an even lower average *P* value because it generates even higher benefits in East Asia. The distortions appear less than with Poverty Index A, however.

Research theme	Projected economic benefits (US$)		Average weighted *P*
	Sub-Saharan Africa	East Asia	
Regional P value	*0.77*	*0.00*	
Number of poor	*281 million*	*144 million*	
1	1	0	0.77
2	1	1	0.58
3	10	20	0.39
4	0	20	0.00

Index D: Numbers of poor

Index D is simply the sum of numbers of poor people located in the regions and production systems targeted by the theme.

$$PovertyD = \sum x_i$$

Advantages:

- This index is intuitively appealing.
- It is not correlated with the economic benefit index ($r = 0.03$).

Disadvantages:

- It contains the implicit assumption that the poor within the targeted regions and production systems capture the research benefits (although this disadvantage is not unique to this index).
- It ignores the distribution of income captured by *P*.

Index E: The *P* index weighted by number of poor people potentially benefiting per dollar of economic benefit

Index E uses the same *P* value as described in poverty index A, but this time *P* is weighted by the region- and production system-specific numbers of poor people per dollar of economic benefit:

$$PovertyE = \frac{\sum P_i \frac{x_i}{b_i}}{\frac{\sum x_i}{\sum b_i}}$$

Advantages:

- This index rewards themes that focus their impact on the regions and production systems with relatively more poverty and relatively larger numbers of poor people, so it captures both dimensions of the relative intensity of poverty and of the absolute magnitude of numbers of poor potentially benefiting, conditioned by the size of the benefit.
- It does not appear to be correlated with the economic benefit index ($r = -0.04$).
- It is a unitless measure, advantageous for making relative comparisons.

Disadvantages:

- This index is not particularly easy to interpret intuitively.
- By having the economic benefit in the denominator, the index penalises themes that generate relatively higher economic benefit in a given region and production system. Consider the following:

Research theme	Projected economic benefits (US$)		Average weighted *P*
	Sub-Saharan Africa	South Asia	
Regional P value	*0.77*	*0.55*	
Number of poor	*281 million*	*531 million*	
1	1	1	0.63
2	2	1	0.60
3	1	2	0.67
4	10	10	0.63

Research theme 2 generates higher economic benefits for high-poverty SSA than Theme 1, but it results in a lower index value (a drop from 0.63 to 0.60). Themes 1 and 4 have the same index values, although Theme 4 generates 10 times as much economic benefit.

Index F: The *P* index weighted by number of poor people dollars of economic benefit

Index F uses the same *P* value as in index A, but here *P* is weighted by the region- and production system-specific numbers of

poor people multiplied by the economic benefit ('poor people dollars'):

$$PovertyF = \frac{\sum P_i x_i b_i}{\sum x_i b_i}$$

Advantages:

- This index rewards research themes that focus their impact on regions and production systems with relative-ly more poverty and where there are both relatively high impact (economic benefit) and relatively large numbers of poor people, so it captures dimensions of both relative intensity of poverty and absolute magnitude, in both numbers of poor potentially benefiting and size of the benefit.
- It is likely to be correlated with the economic benefit index, although this has not been measured yet.

Disadvantages:

- It is not particularly easy to interpret this index intuitively.
- It will generally reward themes that have more impact in relatively more impoverished areas, but not always, as illustrated here.

Research theme 3 generates higher economic benefits for high-poverty South Asia, but because South Asia has a lower *P* value than sub-Saharan Africa, it results in a lower average weighted *P* value compared with Theme 1. Themes 1 and 4 have the same index values, although Theme 4 generates 10 times as much economic benefit.

Research theme	Projected economic benefits (US$)		Average weighted *P*
	Sub-Saharan Africa	South Asia	
Regional P value	*0.77*	*0.55*	
Number of poor	*281 million*	*531 million*	
1	1	1	0.63
2	2	1	0.67
3	1	2	0.60
4	10	10	0.63

Index G: The *P* index weighted by number of poor people

Index G uses the same *P* value as in index A, but here *P* is weighted by the region- and production system-specific numbers of poor people:

$$PovertyG = \frac{\sum P_i x_i}{\sum x_i}$$

Advantages:

- This index rewards research themes that focus their impact on regions and production systems with relatively more poverty.
- It is not correlated with the economic benefit index.

Disadvantage:

- It is not a particularly easy index to interpret intuitively.

Given the relative strengths and weaknesses of these seven indicators and the need for an index that behaves in an intuitively reasonable fashion, index G is the one that was used in the analyses described in Section 4.

Appendix 4
Notes on the 'highlands' poverty data

Discussion at ILRI concerning the poverty data in the highlands in Table 2 revolved around the question of the precise definition of 'highlands' that was used in the analysis. A broader and more important issue is whether human and livestock populations (and crop distribution) can be spatially allocated by agro-ecological zone and production system in a meaningful attempt to improve the production and poverty data that are used in the priority assessment framework. As a first step in addressing this issue, we undertook some GIS-based analyses, to estimate land area and total human population numbers in 2000 and 2010 for the highland areas of Kenya and Ethiopia—two countries for which we have substantial databases and that between them account for a substantial proportion of the highland areas (however defined) of sub-Saharan Africa.

Braun and others (1997) list three definitions of the highlands for eastern and central Africa:

- annual rainfall above 1000 mm and an altitude range of 1000–2500 m, used at ICRAF in the late 1980s
- a CGIAR/NARS taskforce definition of highlands as land above an altitude of 1500 m with an average rainfall of at least 1000 mm
- the definition currently used by the African Highlands Initiative, which is land above an altitude of 1200 m and below 3300 m, with rainfall that exceeds 400 mm in five or more consecutive months

To these three, we added the definition of Seré and Steinfeld (1996), which brings together temperate and tropical areas (see the *T* indicator for the 11 systems in Appendix 1). The temperate areas they define as areas where there is one month or more with a mean monthly temperature, corrected to sea level, of less than 5 °C. The tropical highlands they define as areas with a daily mean temperature during the growing period of 5 to 20 °C. Taken together, these define the *T* systems in their classification.

For each of these four definitions of highlands, we ran analyses outlining the appropriate areas using the spatial databases available at ILRI for Kenya and Ethiopia. The areas so delineated as highlands are shown in Figure A4.1. These areas were then overlaid with the coverage for human population density for sub-Saharan Africa based on Deichmann (1996) and extended by Reid and others (2000) to the years 2000 and 2040. From this overlay, the total area of the highlands and the human population projection for 2000 and 2010 for the highland areas were calculated. (The population figures for 2010 were obtained using linear interpolation; while this is bound to be inaccurate, the important thing here is the relative size of the numbers produced.) Results are shown in Table A4.1.

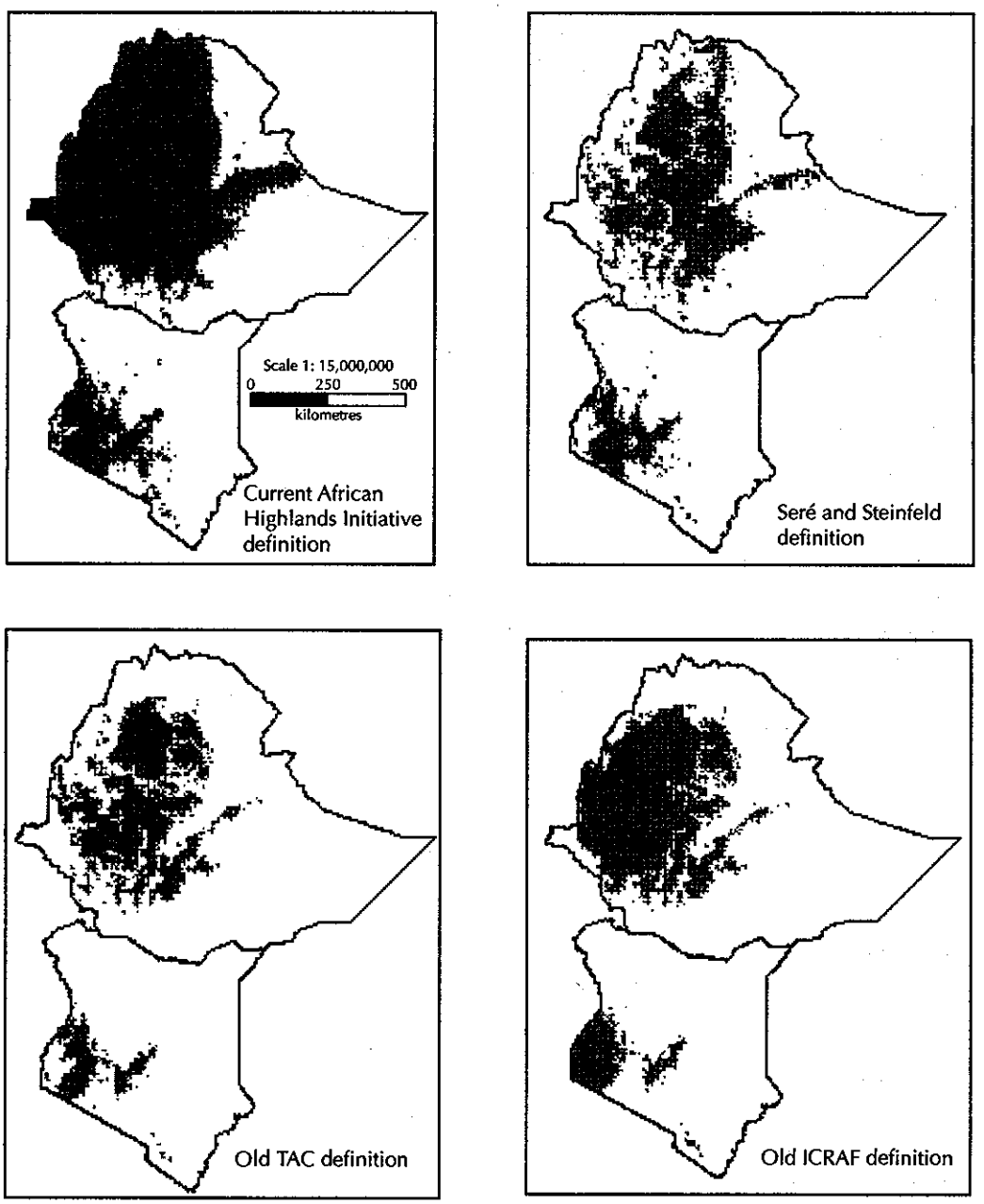

Figure A4.1 *Spatial extent of the highlands in Kenya and Ethiopia, using four different definitions of 'highlands' (see text for definitions and references). Analysis: L MacOpiyo, ILRI, December 1999.*

Table A4.1 *Estimated land area and human population for four different definitions of the highlands in Kenya and Ethiopia (see text for definitions and references)*

	Area (km^2)	Population in 2000 ('000)	Population in 2010 ('000)
Kenya			
Old ICRAF definition	59,344	16,635	20,784
Old CGIAR/NARS definition	44,094	10,374	12,960
Current AHI definition	104,856	21,541	26,908
Seré and Steinfeld definition	67,762	13,636	17,387
Ethiopia			
Old ICRAF definition	321,625	38,106	55,345
Old CGIAR/NARS definition	223,550	34,455	50,044
Current AHI definition	610,612	61,114	73,400
Seré and Steinfeld definition	291,285	42,129	56,065

Analysis: L MacOpiyo, ILRI, December 1999

The results clearly show two things in particular. First, the area and population of the highlands in these two countries depends a great deal on how the highlands are defined. While this is not surprising, it is remarkable that the AHI highlands are more than twice as extensive as the old CGIAR/NARS highlands. Second, the numbers for the Seré and Steinfeld definition, in both spatial extent and human population, fall squarely in the middle of the range of these various definitions. That being the case, while it is true that there are highland areas (defined in some way) in other parts of sub-Saharan Africa and elsewhere on the planet, the data for Kenya and Ethiopia support the notion that the population data for the highlands in Table A4.1 are reasonable, in the actual definition of the highland areas that was used by Seré and Steinfeld. Similar analyses for all of Africa, Latin America and Asia are currently under way, and ultimately we hope to produce spatially explicit poverty and production databases at the global scale that can greatly enhance impact assessments for priority setting and other purposes.

Appendix 5
Summaries of the research theme briefs

Livestock feeds and nutrition
Livestock health improvement
Livestock genetics and genomics
Livestock policy
Livestock and the environment
Systems analysis and impact assessment
Capacity strengthening for livestock research

Notes to the tables

Research brief: code and title

Outputs: major outputs of the research

Time frame
- research time frame in years
- adoption time frame to ceiling time frame (sh = 10–15 years; med = 16–25 years; long = 26–40 years)

Resource requirements
ILRI: Number of senior scientist years (SSY), either per year or total over the research time frame; capital requirements (Cap); operational requirements may be given (Ops); amounts in US dollars, K = thousands, M = millions

Non-ILRI: Estimate of equivalent non-ILRI effort needed for research (Res), adaptive research (Adapt), and delivery (Deliv), expressed in terms of less, equal to or more than the equivalent ILRI resource expenditure. Note that these were not actually taken into account in the analysis.

Researchability: high, medium or low

Probability of success: high (0.83), medium-high (0.67), medium (0.50), low-medium (0.34), or low (0.17)

Productivity impact
- high, 5%, direct productivity gains, small recommendation domain
- medium, 3%, direct productivity gains, well-defined recommendation domain
- low, 1%, direct productivity gains, large recommendation domain
- low-low, 0.1%, indirect productivity gains, large recommendation domain
- triple low, 0.01%, very difficult to define impact in terms of productivity gain

Environmental index: raw impact as calculated according to the text. For the 26 themes, values range from –0.42 to +0.30

Capacity-building index: raw impact as calculated according to the text. For the 26 themes, values range from 3.0 to 10.0

Adoption in target production systems by region, impact by species: low, 5%; low-medium, 10%; medium, 15%; medium-high, 20%; high, 25%

Note that if a range of adoption is given, it means that there is differential adoption depending on species and system; for full details, consult the spreadsheets.

Other species are sometimes noted in the tables (camelids, yaks, ostriches) but owing to lack of appropriate data, the productivity impact of these species is not taken into account in the analysis.

Livestock feeds and nutrition

Research brief	Outputs	Time frame		Resource requirements		Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	ILRI	Non-ILRI						SSA	WANA	SA	SEA	EA	LAC
LFN-1: Increasing quantity and quality of feed by genetic enhancement of crop residues and improved forage germplasm	•Strategies for biodiversity •Screening methods •Genetic markers for digestibility •Crop cultivars for stover •Forage germ-plasm	10 years	med	36 SSY Cap: $425K Ops: $8M *Yrs 1–8:* 4 SSY/yr *Yrs 9–10:* 2 SSY/yr Cap: Yr 1: $200K Yr 2: $50K Yrs 3–8: $25K	not given	hi	hi	low (1%)	–0.03	6	DCS ostrich L	DCS L	DCBS L	DCBP L	DCBPS L	DC camel-ids L
LFN-2: Increasing livestock productivity through improved feed conservation	•Feed conservation techniques •Feed budgeting and allocation tools	6 years	sh	11 SSY Cap: $100K Ops: $1.2M	hi	med-hi	hi	low (1%)	–0.18	6	DCS L	DCS L	DCBS L	DCBPS L	DCBPS L	DC camel-ids L
LFN-3: Improving feed utilisation efficiency through enhanced rumen function	•Novel rumen microbes •Methods to characterise rumen microbes	10 years	SR sh LR med	40 SSY Cap: $550K Ops: $6M	not given	hi	med	low (1%)	–0.28	4	DCS camel-ids L	DCS camel-ids L	DCBS L	DCBS L	DCS L	DCS L
LFN-4: Improving feed utilisation efficiency by selecting animals for maximal nutrient use	•Selection methods •Genetic markers •Breeding plans	10 years	SR med LR long	30 SSY Cap: $500K Ops: $4M	not given	hi	med-hi	low (1%)	–0.26	6	DCS L	S L	DCBS L	DCBS L	DCS L	DCS camel-ids L

Impact by species: D = dairy; C = other cattle; S = sheep and goats; P = pigs; F = poultry; B = buffalo; LR = large ruminants; SR = small ruminants

Livestock health improvement

Research brief	Outputs	Time frame		Resource requirements		Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	ILRI	Non-ILRI						SSA	WANA	SA	SEA	EA	LAC
LHI-1: Determining comparative impact of livestock diseases on global poverty and food security to improve research priority assessment	• Assessments of major diseases, research activities • Methods for animal health information systems	7 years	med	2 SSY/yr Cap: $50K	not given (7/14 are post-doc)	hi	hi	triple-low (0.01%)	–0.24	4	DCPF L-H	DCBSF L	DCBPF L	DCBPF L	DCBPF L	DCPF L
LHI-2: Improving delivery, adoption and impact of available technologies for control and prevention of animal diseases	• Decision-aid tools for production system specific and national/community-level animal health management systems and integrated disease control strategies	8 years	sh	4 SSY/yr x 16 yr + 1 post-doc x 6 yrs Cap: $250K	not given	hi	hi	low (1%)	–0.24	5	DCSPF L	DCBSF L	DCBSPF L	DCBPF L	DCBPF L	DCSPF L
LHI-3: Enhancing health, productivity and use of livestock through improved prevention and control of ticks and tick-borne diseases	• Improved diagnostic tools (bab, hw) and their improved delivery • Epidemiology, impact of ECF, anaplas, babesiosis, for decision-making • Vaccines • Methods for biophysical, economic evaluation of integrated TTBD control strategies	12 years	med	Yrs 1–5 14 SSY/yr Yrs 6-12 12 SSY/yr Total: 154 SSY Cap: $200K x 3	Res: > ILRI Adapt: < ILRI Deliv: low cost	med-hi	med-hi	low (1%)	–0.22	7	DCSP L	DCBS L	DCB L	DCB L	DCB L	DC L
LHI-4: Enhancing health, productivity and use of livestock through improved prevention and control of trypanosomosis	• Improved use of trypanocides • Vaccines • Improved diagnostics • Decision-support systems for managing tryps • NARS capacity building	15 years	med	14 SSY/yr Total: 210 SSY Cap: $200K every 5 yrs	Res: = ILRI Adapt: < ILRI Deliv: low cost	med-hi	med-hi	low-med (2%)	–0.42	8	DC5 camel-ids L-H	—	DCB L	DCB L	DCB L	DC L

Impact by species: D =dairy; C =other cattle; S =sheep and goats; P =pigs; F =poultry; B =buffalo

Livestock genetics and genomics

Research brief	Outputs	Time frame		Resource requirements		Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	ILRI	Non-ILRI						SSA	WANA	SA	SEA	EA	LAC
LGG-1: Assessment and valuation of animal genetic resources	• Quantitative data on extent of diversity • Genetic relationships among breeds • Database on breed characteristics • Spatial data on species and breeds • Economic values of species, breeds, traits • Methodologies for phenotypic and genetic characterisation and for economic valuation • Conservation strategies • Policy guidelines for conservation and use of indigenous AnGR	10 years	LR = med SR = sh	30 SSY Cap: $400K	Res: = ILRI Adapt: < ILRI Deliv: low cost	hi	hi	low-low (0.1%) triple-low (0.01%) for low priority regions	–0.13	4	DCSFP camel-ids L	S FB L	DCPS PSF cam-elids, L	BDC yaks L	yaks L	PCDSF camel-ids L
LGG-2: Identification and characterisation of genetic resistance to disease	• QTLs controlling trypanotolerance and helminthosis resistance identified and characterised • Candidate genes for trypanotolerance identified in cattle and mice • Tolerant or resistant breeds identified • Genetic parameters for various diseases estimated	10 years	LR = long SR = med	30 SSY Cap: $800K	Res: < ILRI Adapt: < ILRI Deliv: medium cost	hi	med	low–med (2%)	–0.33	3	DC L	—	DCBS L	DCBS L	—	DCS L

Livestock genetics and genomics (continued)

Research brief	Outputs	Time frame		Resource requirements		Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	ILRI	Non-ILRI						SSA	WANA	SA	SEA	EA	LAC
LGG-3: Genetic improvement and delivery strategies	• Contribution of host resistance in integrated disease control strategies assessed • Strategies for marker-assisted introgression of disease resistance or tolerance developed • Breeding objectives and strategies for smallholder systems developed • Factors determining success or failure of existing genetic improvement technologies determined	7 years	LR = med SR = sh	14 SSY Cap: $500K	Res: < ILRI Adapt: < ILRI Deliv: med. cost	hi	med-hi	low (1%)	–0.27	4	DCSPF L	S L	BDC PFS yaks L	BDC PFS L	DCPFS yaks L	DCS L

AnGR = animal genetic resources; QTL = quantitative trait locus

Impact by species: D = dairy; C = other cattle; S = sheep and goats; P = pigs; F = poultry; B = buffalo; LR and SR = large and small ruminants

Livestock policy

Research brief	Outputs	Time frame		Resource requirements		Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	ILRI	Non-ILRI						SSA	WANA	SA	SEA	EA	LAC
LP-1: Participatory, institution and policy research to improve livestock technology adoption	• Inventories of available technologies, constraints to adoption • Capacity building • Adapted technologies • Strategy and policy options	5 years	med	10 SSY 2 SSY/yr 3 post-docs/yr Cap: $0K Ops: $500K	Res: < ILRI Adapt: > ILRI Deliv: low cost	hi	med-hi	triple-low (0.01%)	–0.11	5	DCS L-M	—	BDCS L	DCPF L	—	—
LP-2: Policies for improving natural resource management	• Effects of policy on land expansion • Policy options to reduce resource degradation • Methods for farmer participatory research, institutional innovation	8 years	med	4 SSY/yr Cap: $0K	Res: = ILRI Adapt: > ILRI Deliv: low cost	hi	med-hi	triple-low (0.01%)	+0.20	5	DCFS L	DFS L	BDCFS L	DCFBPS L	—	BDCPFS L
LP-3: Reform of input and output markets serving smallholder livestock producers	• Methods for market analysis • Capacity building • Policy options to improve access to markets	4 years	sh	8 SSY 2 SSY/yr 3 post-docs/yr Cap: $0K Ops: $500K cost	Res: = ILRI Adapt: > ILRI Deliv: med.	hi	hi	low-low (0.1%) triple-low (0.01%) for low priority regions	–0.16	5	DCS L	BDCS L	BDCPS L	BDCPF L	CS L	DCFS L
LP-4: Use of different species to reduce negative environmental impact	• Qualitative and quantitative information for two case study sites • Dynamic stochastic model developed for case study sites • Policy options to mitigate impact of environmental variability	3 years	med	2 SSY /yr Cap: $100K	not given	med-hi	med-hi	med (3%)	–0.07	3	CS L	S L	C L	—	S L	DCS L

Impact by species: D = dairy; C = other cattle; S = sheep and goats; P = pigs; F = poultry; B = buffalo

Livestock and the environment

Research brief	Outputs	Time frame		Resource requirements		Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	ILRI	Non-ILRI						SSA	WANA	SA	SEA	EA	LAC
LE-1: Nutrient deficit: integrated crop–livestock management strategies to improve nutrient supply and use to sustainably increase farm and systems productivity	• Integrated nutrient management (INM) strategies • INM methods and models on farm and in watershed adapted and validated • Policy recommendations • Technologies disseminated • Impact of interventions assessed	10 years	med	15 SSY Cap: $500K	Res: L Adapt: L Delv: L	hi	med-hi	low-low (0.1%)	–0.10	4	DCS L	—	—	—	—	DCS L
LE-2: Nutrient surplus: reducing the environmental costs of intensive livestock systems for the urban and rural poor	• Review of existing technologies, management strategies, policies and regulations for treatment, utilisation of animal wastes • Evalution of costs, benefits of industrial livestock systems • Technical, management and policy options • Environmental impact assessment of options	10 years	sh	11 SSY Cap: $100K	Res: L Adapt: L Deliv: L	hi	hi	low (1%)	+0.07	4	—	—	DCP M	P M	—	DCPF M
LE-3: Land use: land-use strategies to increase livestock production and protect the environment	• Land-use options identified for different systems at different levels • Valuation of various land-use options in social, economic and environmental terms • Policy, management strategies • Impact assessments	6 years	long	36 SSY Cap: $500K	Res: L Adapt: L Deliv: L	hi	med-hi	triple low (0.01%)	+0.20	5	DCS L	DCS L	BDCFS L	BDCFS L	BDSPFS L	DCPFS L

Research brief	Outputs	Time frame		Resource requirements		Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	ILRI	Non-ILRI						SSA	WANA	SA	SEA	EA	LAC
LE-4: Grazing systems: improving productivity and long-term integrity of rangeland ecosystems	• Evaluation of ecological and social impact of various interventions on ecosystem integrity, food security and poverty • Ecosystem-level models of rangelands • Institutional and policy strategies • Strategic feeding systems and technologies identified and evaluated with stakeholders	10 years	long	20 SSY Cap: $250K	Res: L Adapt: L Deliv: L	med-hi	med	low (1%)	+0.08	6	CS M	S M	CS L	— 	— 	DCS L-M
LE-5: Humid systems: reducing deforestation through intensification of livestock systems adjacent to forests	• Improved pasture species, land-use practices and strategies at the landscape level identified, modelled, and evaluated with stakeholders • Decision support system disseminated • Seed produced and disseminated to farmers • Policy options to reduce deforestation identified and promoted	10 years	sh	20 SSY Cap: $150K	Res: L Adapt: L Deliv: L	med-hi	med-hi	low (1%)	+0.30	5	DCS L-M	— 	— 	DCS L-M	— 	DCS L-M

Impact by species: D = dairy; C = other cattle; S = sheep and goats; P = pigs; F = poultry; B = buffalo

Systems analysis and impact assessment

Research brief	Outputs	Time frame		Resource requirements		Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	ILRI	Non-ILRI						SSA	WANA	SA	SEA	EA	LAC
SAIA-1: Ensuring future viability, sustainability, and equity in smallholder livestock production	• Characterisation of production systems • Methodologies • Strategies • Policy recommendations • Capacity building	5 years	med	20 SSY Cap: $500K	Res: L Adapt: L Deliv: L	hi	hi	triple-low (0.01%)	+0.05	6	DCSPF L	—	DCSPFB L	DCPFB L	—	DCSPF L
SAIA-2: Global characterisation and prioritisation of livestock research and development for improved targeting of livestock interventions	• Decision support system • Databases • Refined methodologies	6 years	med	15 SSY Cap: $500K	Res: L Adapt: L Deliv: L	med	hi	triple-low (0.01%)	–0.11	8	DCS L	CSF L	DCSFB L	DCSPFB L	DCSPFB L	DCSPFB L
SAIA-3: Understanding systems evolution for better targeting of technology and policy options	• Validated models • Dynamic research domains defined for technology and policy options • Impact assessments	6 years	med	18 SSY Cap: $500K	Res: L Adapt: L Deliv: L	med	med	triple-low (0.01%)	–0.11	6	DS L	S L	BDCS L	BDCFP L	DCPFS L	DCS L

Impact by species: D = dairy; C = other cattle; S = sheep and goats; P = pigs; F = poultry; B = buffalo

Capacity strengthening for livestock research

Research brief	Outputs	Time frame		Resource requirements	Re-search-ability	Prob. of success	Prod-uctivity impact	Environ-ment	Capacity building	Adoption in target production systems					
		Re-search	Adoption	for ILRI						SSA	WANA	SA	SEA	EA	LAC
CSLR-1: Strengthening capacity for livestock research through improvement of skills and expertise of NARS faculty	• Needs assessment • Impact assessment • Training of personnel and production of materials • Theses and journal articles	5 years	med	28 SSY Cap: $600K to 1.4M	hi	hi	low-low (0.1%) triple low (0.01%) in low priority regions	–0.11	10	All L	All L	All L	All L	All L	All L
CSLR-2: Strengthening livestock R&D by providing access to accurate and timely information	• Improved document mgmt system • Web site and conventional information products • Global virtual information and knowledge system • Needs and impact assessments	5 years	med	50 SSY Cap: $650K to 1.8SM	hi	hi	triple low (0.01%)	–0.11	10	All L	All L	All L	All L	All L	All L
CSLR-3: Strengthening regional livestock research and development through collaborative research promotion in the NARS	• Regional research strategies and projects • Impact assessments • Database of ILRI's partnership arrangements	5 years	sh	20 SSY Cap: zero	hi	hi	low-low (0.1%) in SSA triple low (0.01%) elsewhere	–0.11	10	All L	All L	All L	All L	All L	All L

Impact by species: D = dairy; C = other cattle; S = sheep and goats; P = pigs

Appendix 6

Description of the spreadsheets

A total of 26 research briefs (designated P1 to P26) were included in this priority-setting exercise. These themes were derived from the initial 46 themes agreed at the annual programme meeting in September 1999. The evolution of the current themes is shown in Table A6.1. Each of the briefs is described in an Excel spreadsheet file that is linked to a master file, which integrates all the computations and indexes for final ranking. 'RPVersion3' is the name of the Access database that provides data on livestock production values from Seré and Steinfield (1996) by region, product and agro-ecological system, and the recommendation domains for each brief.

Each theme brief is an Excel workbook containing the 21 worksheets described below:

Brief worksheet		Description
1	Composite index	Integrates economic benefit, environmental impact, capacity building, internationality, poverty impact
2	Assumptions	Specifies the probability distribution of adoption, relevance parameters, productivity gain and probability of success. Product prices, supply and demand elasticities, and NPV factors arrayed over 50-year horizon are also shown
3	Relevance	Contains elicitations of relevance from the Access database
4	Relevance formula	Converts the relevance indexes to actual weights based on the probability distributions in 'Assumptions'
5	Production domain	Displays the livestock production values by region species and agro-ecology from the Access database
6	Relevant production	Shows the proportion of livestock production affected by specific theme (production x extent of relevance of problem)
7	Adoption	Contains elicitations of adoption by region species and agroecology from Access database
8	Adoption formula	Converts the adoption elicitations to actual weights based on the probability distributions in 'Assumptions'
9	First version of relevant production	Shows the proportion of livestock production affected by specific theme for the first model (production x extent of relevance of problem)
10	Product totals	Contains subtotal for each product in target production systems for the first model

11	Local benefit 1	Calculates the $\left(\frac{E(Y)}{\varepsilon}\right)p\bar{A}P_0Q_0$ term of the economic surplus model
12	Local benefit 2	Calculates the $\frac{0.5P_0Q_0\varepsilon\eta\left(\frac{E(Y)}{\varepsilon}p\bar{A}\right)^2}{\varepsilon+\eta}$ term of the economic surplus model
13	Local benefit present value	Computes the sum of 'Local benefit 1' and 'Local benefit 2', each multiplied by its corresponding NPV factor in 'Assumption', that is, $\left(\frac{E(Y)}{\varepsilon}\right)p\bar{A}P_0Q_0\sum_T\frac{(\tilde{A}_t(1-\delta_t))}{(1+r)^t}+\frac{0.5P_0Q_0\varepsilon\eta\left(\frac{E(Y)}{\varepsilon}p\bar{A}\right)^2}{\varepsilon+\eta}\sum_T\frac{(\tilde{A}_t(1-\delta_t))^2}{(1+r)^t}$
14	Aggregate benefit	Aggregates the benefit by region for each agro-ecology and by-product
15	Product benefit	Not used in these computations
16	Benefit stream	Calculates the present value (discounted) of net economic benefit over a 50-year horizon
17	Internationality index	Computes the Simpson Index for impact across the six regions and for all the 66 production systems
18	Environmental impact index	Computes the composite environmental index
19	Capacity-building index	Computes the composite capacity-building index
20	Poverty index	Contains the various indicators of poverty impact
21	Poverty data	Contains data on numbers of poor

The master file integrates all the computations and indexes from each of the briefs and calculates normalised values used for the final ranking of themes. The macro 'Eureka' is run to refresh the master file each time changes are made on the briefs.

Access database RPVersion3 is the database containing the latest recommendation domain tables for each of the briefs. Relevance, adoption and production values are extracted using theme-specific queries designated by theme abbreviations and suffixes: REL, AD, PROD, respectively.

Relevant production affected by specific theme. There was no information that allowed us to split the production values between small-scale and large-scale systems. To avoid the problem of double counting, where a theme is of relevance in the same agro-ecology in both small-scale (SS) and large-scale (LS) systems, the relevance values for large-scale systems were set to zero.

Table A6.1 *Evolution of the 26 research themes*

Key research area	Themes agreed at APM	Previous themes included	Current themes
Livestock feeds and nutrition	1 Increasing feed quantity and quality	FUAN3 Genetic enhancement of crop residues and improved forage	LFN1 (P1) Increased feed quantity and quality through genetic enhancement
	2 Improved feed conservation	FUAN5 Feed conservation	LFN2 (P2) Increased livestock productivity through improved feed conservation
	3 Rumen function	FUAN6 Rumen function	LFN3 (P3) Improved feed utilisation through enhanced rumen function
	4 Selection of animal for feed efficiency	FUAN7 Selection of animal for feed efficiency	LFN4 (P4) Breeding for improved feed utilisation efficiency
Livestock health improvement	1 Impact of diseases	AH1 Impact of diseases	LHI (P5) Comparative global impact assessment of livestock diseases
	2 Technology delivery and adoption	AH2 Technology and delivery of available technologies	LHI2 (P6) Improved delivery, adoption and impact of technologies
	3 Integrated TBD control	AH3 Improved population immunity to TTBDs AH4 Improved specificity of diagnostics for TTBDs AH5 Integrated TTBD control AH6 Decision-support systems for managing TTBDs	LHI3 (P7) Improved prevention and control of ticks and tickborne diseases
	4 Integrated trypanosomosis control	AH7 Improved trypanosomosis chemotherapy AH8 Improved population immunity to trypanosomosis AH9 Improved species-specific diagnostics for trypanosomosis AH10 Trypanosomosis impact assessment and technology evaluation AH11 Integrated trypanosomosis control	LHI4 (P8) Improved prevention and control of trypanosomosis
	5 Population immunity for other epidemic diseases	New	Removed

Key research area	Themes agreed at APM	Previous themes included	Current themes
Livestock genetics and genomics	1 Assessment and valuation of animal genetic resources	AnGR1 Assessment of diversity in indigenous animal genetic resources	LGG1 (P9) Assessment and valuation of animal genetic resources
		AnGR2 Economic valuation	LGG2 (P10) Identification and characterisation of genetic resistance to diseases
	2 Identification and characterisation of genetic resistance to disease	AnGR3 Identification and use of trypanotolerance QTLs AnGR4 Identification and use of genetic resistance to helminthosis AnGR5 Identification of QTLs, genes and gene products in mice models	
	3 Genetic improvement and delivery strategies	AnGR6 Developing breeding strategies AnGR7 Identification and use of indigenous African breeds for adaptation and milk production AnGR8 Breeding for trypano-tolerance in pilot schemes AnGR9 Incorporating genetic components into integrated disease control strategies	LGG3 (P11) Genetic improvement and delivery strategies
Livestock and the environment	1 Integrated crop–livestock management strategies to improve farm-level nutrient supply	PS1 Integrated crop–livestock management strategies to improve farm-level nutrient supply	LE1 (P16) Strategies to improve nutrient supply
	2 Reduced the environmental costs of intensive livestock systems for urban and rural poor	PS4 Promotion of area-wide integration PSA3 Environmental costs and benefits of industrial livestock systems	LE2 (P17) Reduced environmental costs of intensive livestock systems
	3 Land-use strategies to in-crease livestock production and protect the environment	FUAN4 Land-use strategies to increase crop-livestock produc-tion and protect the environment PSA5 Livestock/feed production relative to other land uses	LE3 (P18) Land-use strategies to increase production and protect the environment
	4 Improving productivity and long-term integrity of rangeland ecosystems	PS2 Improved productivity and sustainability of grazing-based production systems	LE4 (P19) Improved rangeland systems
	5 Reduced deforestation through intensification of livestock systems adjacent to forests	PS3 Reduced deforestation through intensification of livestock systems adjacent to forests	LE5(P20) Reduced deforestation

Key research area	Themes agreed at APM	Previous themes included	Current themes
Livestock policy	1 Participatory, institutional and policy research to improve technology adoption	PSA1 Improved R&D partnerships	LP1 (P12) Participatory policy research to improve technology adoption
		PSA2 Participatory and policy research to improve adoption	LP2 (P13) Policies for improving natural resource management
	2 Integrated NRM at landscape level	PSA3 Environmental costs and benefits of industrial livestock systems FUAN1 Promotion of collective action to improve feed and water resource management FUAN2 Policies to prevent negative effects of livestock production on human and environmental health	
	3 Reform of input and output markets	PSA4 Reform of input and output markets	LP3 (P14) Reforming of input and output markets
	4 Use of different livestock species to reduce negative impact of environmental variability	PSA7 Use of different livestock species to reduce negative impact of environmental variability	LP4 (P15) Use of different species to reduce negative environmental impact
Systems analysis and impact assessment	1 Ensuring future viability, sustainability and equity in smallholder livestock production	PSA6 Ensuring future viability, sustainability and equity in smallholder livestock production	SAIA1 (P20) Ensuring future viability of smallholder systems
	2 Global prioritisation, systems evolution and smallholder competitiveness	PSA8 Global prioritisation	SAIA2 (P21) Global prioritisation
	3 Understanding systems evolution for better targeting of technology and policy options	PSA9 Understanding systems evolution	SAIA3 (P22) Understanding systems evolution
Capacity strengthening for livestock research	1 Training	SPAN1 Training AnGR10 Genetics training	CSLR1 (P24) Training
	2 Information	SPAN2 Information	CSLR1 (P25) Information
	3 Technology exchange/ networks	SPAN3 Networks	CSLR1(P26) Networking

Appendix 7
Comparison with previous priority-setting exercises at ILRI

Two previous attempts were made at ILRI to do centrewide priority assessment. The first, at the 1996 annual programme meeting, involved an informal participatory ranking method. The second was an earlier version of the priority assessment framework described in this document, with various differences. This appendix compares the results coming out of these two earlier efforts with the results discussed in Section 4. While there were substantial differences in the number and scope of research themes considered in each, interesting lessons can be learned from a comparison of the results, which are worthy of note.

The informal 1996 approach

The approach taken at the 1996 annual meeting was a priority-ranking exercise involving 96 researchers, mostly from ILRI but including some non-ILRI participants. Each participant was asked to analyse 20 existing research projects (known in the institute as the 20 CG projects, with 10 in the Biosciences Programme and 10 in the Sustainable Production Systems Programme) on four criteria:

1 Potential benefits
- the nature and timing of the expected productivity increase
- main beneficiaries and how they will benefit
- economic benefits
- environmental benefits
- social benefits, including relevance to poverty and poor women

2 Ability to exploit results
- ability of target beneficiary countries to convert technical progress into commercial or other returns
- anticipated adoption rate
- ability to exploit results in other regions

3 Research potential
- likelihood of research success
- probability that scientific and technical objectives will be met
- availability of skills
- how far along in the process the research is and how close it is to reaching its output or outputs
- scientific merit, track record, strategic contribution to science

4 Research capability
- special advantage of ILRI and partners
- comparative advantage, and would it get done if ILRI did not do the work?
- cost of project and how it should be financed
- justification for public investment in this research
- contributions to collaborations with and strengthening of NARS
- extent of contribution to and influence on outcomes of other projects

Participants ranked each of the four criteria as low, medium or high. The importance of this being a relative ranking across all the research projects was emphasised. Each of the rankings was assigned a value (L = 1, M = 5, H = 10) and the values were averaged for each research theme to rank the themes according to each criterion. A project assessment matrix was also developed that summarised where the 20 research projects fell in relation to two composite indexes, called 'attractiveness' and 'feasibility'. Attractiveness related to the potential benefits and the ability to exploit those benefits. Feasibility related to research potential and capability. It was envisaged that the results could be used to examine possible imbalances in resource allocation across research areas. Research areas falling in the 'high attractiveness, low feasibility' category, for example, might then merit a higher allocation of resources to boost the feasibility dimension of the research theme.

The first version of the formal priority assessment framework

A preliminary version of the formal priority assessment framework outlined in Section 3 was used at the ILRI annual programme meeting in September 1999. The criteria differed in several ways from the current version. In particular, a different poverty index was used (poverty index E, Appendix 3), the capacity-building index was formulated differently, and the environmental index was much less developed. In addition, no merging of the original 46 research themes had taken place.

Changes in ranking from three priority-setting exercises

Table A7.1 shows the research themes that fell within the upper half of the rankings for each of the three ranking exercises undertaken. There is some difficulty in comparing the different set of research themes that was evaluated in each ranking exercise. However, major changes are discussed by research programme area.

Systems analysis and impact assessment. Themes in this KRRA were ranked highly on all four criteria in the first round. In the second round, when merged with policy themes, they also ranked highly in all respects. In the final round, however, only one of the three themes fell in the top half for the composite index; none had a high benefit–cost ratio; all ranked highly for the environmental index; and only one fell in the top half for the poverty measure.

Livestock feeds and nutrition. Themes in this KRRA ranked highly for research potential, potential benefits and ability to exploit in the first round, whereas rumen microbiology research was ranked in the bottom half for all the criteria. No significant changes occurred from the second to the third round, except with respect to the environmental ranking. In the second round five of the seven themes ranked highly for the composite index, six for the benefit–cost ratio, all for the environmen-

Table A7.1 *Research themes falling within the first half of the ranking for three priority assessment exercises*

Research theme	Quantitative framework				Qualitative framework			
	CI	BCR	ENV	POV	RP	PB	AE	RC
LIVESTOCK HEALTH IMPROVEMENT								
Final, 12/99								
LHI 1 Impact assessment of livestock diseases								
LHI 2 Delivery and adoption		✔						
LHI 3 Ticks and tickborne diseases (TBDs)				✔				
LHI 4 Trypanosomosis		✔		✔				
APM, 9/99								
AH1 Impact assessment of livestock diseases		✔		✔				
AH2 Delivery and adoption	✔	✔		✔				
AH3 Population immunity to TBDs				✔				
AH4 Diagnostics for TBDs		✔	✔	✔				
AH5 Integrated control of TBDs		✔		✔				
AH6 Decision support systems for ticks and TBDs								
AH7 Chemotherapy for trypanosomosis control			✔	✔				
AH8 Population immunity for trypanosomosis control								
AH9 Diagnostics for trypanosomosis control								
AH10 Impact assessment and technology evaluation (tryps)								
AH11 Integrated control of trypanosomosis								
APM, 1996								
Molecular biology and immunology					✔	✔	✔	✔
Epidemiology and control strategies					✔	✔	✔	✔
LIVESTOCK AND THE ENVIRONMENT								
Final, 12/99								
LE1 Improving nutrient supply			✔					
LE2 Intensive systems: reducing environmental costs		✔	✔					
LE3 Land-use strategies			✔					
LE4 Rangelands	✔	✔	✔	✔				
LE5 Deforestation	✔	✔	✔	✔				
PRODUCTION SYSTEMS								
APM, 9/99								
PS1 Crop–livestock management strategies		✔	✔	✔				
PS2 Institutions and policies—productivity			✔					
PS3 Technology and policies—deforestation			✔					
PS4 Technology and policies—crop–livestock interactions		✔	✔					
ECOREGIONAL PRODUCTION SYSTEMS								
APM, 1996								
Highlands sub-Saharan Africa					✔	✔		✔
Subhumid sub-Saharan Africa					✔			✔
Semi-arid sub-Saharan Africa							✔	
Semi-arid Asia								
Subhumid Asia								
Latin America, West Asia/North Africa								
Market-oriented smallholder dairy					✔	✔	✔	✔

Research theme	Quantitative framework				Qualitative framework			
	CI	BCR	ENV	POV	RP	PB	AE	RC
LIVESTOCK POLICY ANALYSIS								
Final, 12/99								
LP1 Participatory technology adoption	✔		✔	✔				
LP2 NRM policies	✔	✔		✔				
LP3 Input–output markets	✔	✔	✔	✔				
LP4 Reduced environment impact								
POLICY AND SYSTEMS ANALYSIS								
APM, 9/99								
PSA1 Research and development partnerships	✔	✔	✔					
PSA2 Industrial livestock systems	✔	✔						
PSA3 Participatory technology adoption	✔	✔	✔					
PSA4 Input–output markets	✔	✔		✔				
PSA5 Integrated livestock and feeds	✔	✔	✔					
PSA6 Future viability of smallholder livestock systems				✔				
PSA7 Reduced environmental impact	✔	✔	✔	✔				
PSA8 Global prioritisation	✔	✔	✔	✔				
APM, 1996								
LS Policy analysis					✔	✔	✓	✓
Systems analysis and impact assessment								
CAPACITY STRENGTHENING FOR LIVESTOCK RESEARCH								
Final, 12/99								
CSLR1 Training	✔		✔					
CSLR2 Information	✔		✔					
CSLR3 Networking	✔		✔					
APM, 9/99								
SPAN 1 Training	✔							
SPAN 2 Information	✔							
SPAN 3 Networking	✔							
APM, 1996	✔	✔						
Training						✔	✓	✓
Information and publications						✔	✓	
Networks							✓	
SYSTEMS ANALYSIS AND IMPACT ASSESSMENT								
Final, 12/99								
SAIA 1 Future viability of smallholder livestock systems	✔		✔	✔				
SAIA 2 Global prioritisation			✔					
SAIA 3 Systems evolution			✔					
LIVESTOCK FEEDS AND NUTRITION								
Final, 12/99								
LFN 1 Genetic enhancement	✔	✔	✔					
LFN 2 Feed conservation	✔	✔						
LFN 3 Enhanced rumen function		✔		✔				
LFN 4 Breeding and feed efficiency		✔		✔				
APM, 9/99								
FUAN 1 Collective action and feed management	✔	✔	✔					
FUAN 2 Environmental policies	✔		✔	✔				
FUAN 3 Genetic enhancement	✔	✔	✔	✔				

Research theme	Quantitative framework				Qualitative framework			
	CI	BCR	ENV	POV	RP	PB	AE	RC
FUAN 4 Land-use strategies	✔	✔	✔	✔				
FUAN 5 Feed conservation	✔	✔	✔					
FUAN 6 Enhanced rumen function		✔	✔					
FUAN 7 Breeding and feed efficiency		✔	✔					
APM, 1996								
Feeds for LS nutrition					✔	✔	✔	
Rumen microbiology								
LIVESTOCK GENETICS AND GENOMICS								
Final, 12/99								
LGG1 Assess and value animal genetic resources				✔				
LGG2 Characterise genetic resistance to disease		✔		✔				
LGG3 Genetic improvement and delivery of strategies		✔						
APM, 9/99								
AnGR1 Assessing diversity	✔		✔	✔				
AnGR2 Valuing animal genetic resources				✔				
AnGR3 Trypanosomosis QTLs				✔				
AnGR4 Genetic resistance to helminths								
AnGR5 QTLs and gene products								
AnGR6 Breeding strategies	✔	✔	✔					
AnGR7 ID and use of indigenous SSA cattle	✔		✔	✔				
AnGR8 Breeding for trypanosomosis				✔				
AnGR9 Host resistance and integrated control				✔				
ANGR10 Training, genetic resource management	✔			✔				
APM, 1996								
Animal genetic resources					✔	✔		
Forage genetic resources					✔		✔	✔
Genetics of disease resistance					✔	✔		✔

Column headings are as follows:
CI – composite index; BCR – benefit–cost ratio; ENV – environmental index; POV – poverty index; RP – research potential; PB – potential benefits; AE – ability to exploit; RC – research capability

tal indicator, and three for the poverty measure. In the final round, two (now of four) ranked in the top half for the composite index, all for the benefit–cost ratio, only one for the environmental index, and two for the poverty index.

Livestock health improvement themes. Themes in this KRRA fared better in the first informal exercise. All of these themes (only two were used in the first round) were ranked within the top 50% for all four criteria (research potential, potential benefits, ability to exploit the benefits, research capability). In contrast, in the final exercise, none of the four themes fell in the top half for the composite index and only two of the themes had benefit–cost ratios falling within the top half of the ranking. None of these research themes fell in the top half of the ranking for the environmental index in the final assessment (2 of the 11 did in the second exercise). Half of these themes had high poverty indexes in the second and final rankings.

Livestock genetics and genomics. In similar fashion to the livestock health improvement research themes, these

themes fared better in the first, less quantitative priority-setting exercise. All three genetics projects ranked highly, particularly with respect to research potential and capability; participants were not so sure about the ability to exploit the results (which implicitly accounted for the discount factor explicitly used in the quantitative approach). In the second exercise, 4 of the 10 genetics themes ranked in the top half with respect to the composite index; in the final exercise, none of them did. Two of the research themes did have high benefit–cost ratios in the final ranking. At least half of these themes fell in the top half for the environmental index and two-thirds for the poverty index in both the second and the final rankings.

Livestock policy analysis. The policy research themes were ranked highly in the final exercise, with all themes ranking in the top half for the composite index, half of them for the benefit–cost ratio, all for the poverty index, and three-quarters for the environmental index. These research areas showed up almost as well in the rankings for the second round (policy and systems analysis themes were merged for the second priority exercise), although they were not ranked as highly with respect to poverty (50% of the themes fell in the top half of the ranking). Conversely, in the first exercise, the livestock policy theme was not ranked in the top 50% for any of the four criteria, signalling the participants' misgivings about both the attractiveness and the feasibility of this broad research area.

Livestock and the environment themes. In the first exercise, only ecoregional production systems research in semi-arid and subhumid Africa and smallholder dairy research ranked in the top half. In the second exercise, none of the production systems research areas ranked in the top 50% for the composite index, although two themes had benefit–cost ratios falling within the top-ranked group and all four themes ranked highly on the environmental index. After final revision of the research areas into five environmental themes, two of the five themes fell in the top half of the ranking for the composite index and three and for the benefit–cost ratio.

Capacity strengthening for livestock research. The results for the training, information and networking areas did not change greatly, with all composite indexes falling in the top half of the rankings for both the second and the final exercises. During the first exercise, however, research potential and research capability were not ranked in the top 50% for any of these themes (with the exception of training for research capability). For the final exercise, the environmental indexes for all three fell in the top half of the ranking, whereas in the second exercise, none did.

Summary

Clearly, much progress has been made since 1996. The results of the rapid participatory approach taken then raised many concerns and issues. Perhaps the most important issue was that ILRI

researchers did not feel that they had sufficient information to rank many of the research themes identified for that exercise. It is difficult to say how the results of another similar participatory workshop approach would have worked three years later if it had been possible to provide such information to participants in the meantime. One of the lessons of going through the more formal and rigorous quantitative approach, however, was that a lot of resources, particularly time and human resources, were required to pull all the information together.

It is interesting to compare the results of the first round of results in September 1999 with the final results, but it is difficult to know exactly what to conclude from such a comparison (normalised rankings for both are shown in Figure A7.1; note that the correlation coefficient between the September rankings and the December rankings is 0.48). There were significant changes in the results after the rationalisation and merging of research themes as well as refinements to the capacity building, environmental and poverty indexes. On the one hand, it may suggest that after the preliminary round results were presented and discussed, the researchers got 'smarter' about describing the outputs, potential benefits and extent of impact of their research. On the other hand, it may indicate that with the refinements to the various indexes, we have now captured much better the full range of the direct impact of ILRI's research and the variability across research themes with respect to types of impact.

It is evident, however, that it is extremely difficult to describe the potential returns to ILRI's research and the impact of it using one descriptor (for example, potential benefits, following the 1996 rapid participatory approach) or with a single composite index, as was done in the final analysis using weights for each of five criteria. The information captured in the benefit–cost ratio, poverty, internationality, environment and capacity-building indexes has turned out to be both highly uncorrelated and variable across research themes (and within KRRAs). Critical information can thus be lost in a single composite index.

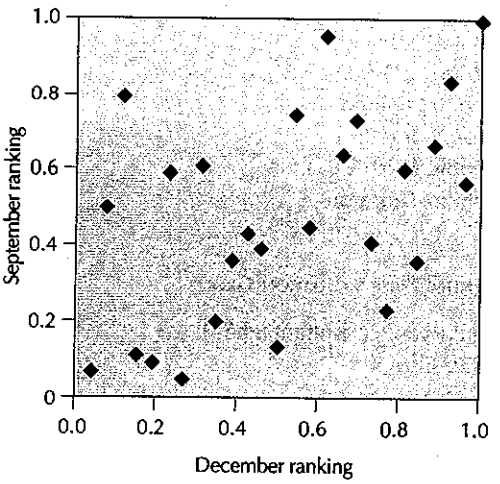

Figure A7.1. *Relationship between the September 1999 rankings and the December 1999 rankings for the same 26 themes*

Appendix 8
Participants in the priority assessment process

Participants are from ILRI, unless otherwise stated.

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Appendix 9
Abbreviations and acronyms

ACIAR	Australian Centre for International Agricultural Research
AEZ	agro-ecological zone
AHI	African Highlands Initiative
APM	annual programme meeting
ARI	advanced research institute
BCR	benefit–cost ratio
CABI	Center for Agriculture and Bio-sciences International
CGIAR	Consultative Group on International Agricultural Research
CSI	Consortium for Spatial Information
EA	East Asia
EARO	Ethiopian Agricultural Research Organization
ECF	East Coast fever
EMBRAPA	Empresa Brasileira de Pequisa Agropecuaria
EPMR	external programme management review
FAO	Food and Agriculture Organization of the United Nations
GIS	geographic information system
IAEG	Impact Assessment and Evaluation Group of the CGIAR
IARC	international agricultural research centre
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IFPRI	International Food Policy Research Institute
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
ILRI	International Livestock Research Institute
IRR	internal rate of return
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
KARI	Kenya Agricultural Research Institute
KRRA	key research and related area
LAC	Latin America and the Caribbean
MTP	medium-term plan
NARS	national agricultural research system
NGO	non-governmental organisation
NRM	natural resource management
PACWG	Priority Assessment Criteria Working Group
PPP	purchasing power parity
QTL	quantitative trait locus
SA	South Asia
SEA	South-East Asia
SSA	sub-Saharan Africa
SSY	senior scientist year
TAC	Technical Advisory Committee of the CGIAR
TBD	tickborne disease
TTBD	ticks and tickborne disease
UNDP	United Nations Development Programme
US$, $	US dollars
USDA-ARS	United States Department of Agriculture—Agricultural Research Service
WANA	West Asia and North Africa
WWF	World Wildlife Fund