Determining International Agricultural Research Priorities

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ISBN 1 86320 290 0

Canberra
June 2000

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EXECUTIVE SUMMARY

The Australian Centre for International Agricultural Research (ACIAR) was established in 1982 as a statutory authority within the Commonwealth Government's Ministry of Foreign Affairs and Trade. ACIAR's mission is to reduce poverty, improve food security and promote sustainable natural resource management through international agricultural research partnerships for the benefit of developing countries and Australia (ACIAR 1997).

From its inception, ACIAR was interested in setting priorities for international agricultural research. These priorities can be summarised in the form of a priority table for each country or region. For each country or region, the priority table is a listing of agricultural commodities grouped into six priority categories. This table is used to screen projects to ensure that funds are targeted first towards commodities in high-priority categories. The priority tables are not prescriptive. However, when funds are directed to the commodities in the high priority categories, this is likely to result in more research benefits than if funds are spent on lower priority commodities.

This form of 'big picture' or aggregate priority setting is necessary for an agency such as ACIAR which funds research covering a wide range of agricultural commodities in many countries throughout Asia, the South Pacific and Africa. ACIAR has an annual budget of about A$44 million.

This monograph contains results from recent analyses of research priorities for a range of countries and commodities of interest to National Agricultural Research Systems (NARS) in developing countries and to agencies involved in international agricultural research. The analyses are ex-ante, and are for planning the allocation of research resources. By definition, ex-ante analyses estimate future research benefits to be realised if, and only if, the research is undertaken and the target users adopt the research results. Ex-ante analyses establish the magnitude of benefits likely to accrue from research before the research is undertaken. This type of analysis takes into account technological, social and economic constraints pertaining to the problem addressed by research.

In previous analyses (e.g. Davis et al. 1987), the ex-ante benefits from research were routinely modified by subjective estimates (built into the model RE4[1]) of:

- the capacity to undertake strategic research;
- the capacity to undertake applied research; and
- the capacity to facilitate the adoption of research.

The capacity to undertake strategic and/or applied research provided an indication of the probability of success of a research project. The capacity to facilitate the adoption of research was based on a country-level qualitative, subjective assessment of the quality of the extension and support systems. For each country, these estimates were different for different commodities.

Experience has shown that the use of these in-built modifiers to scale down the estimated ex-ante benefits reduces the transparency of the estimation process and therefore its credibility.

1 RE4 is short for Research Evaluation model version 4. This is a model built by Dr Jeff Davis and used for ex-ante analyses at ACIAR in the mid 1980s. RE4 was based on an earlier version developed by the International Food Policy Research Institute, Washington.

Anderson (1991), for example, described the use of modifiers as 'a highly personal and judgemental exercise'. This has been confirmed by recent experience which has shown that estimates of these modifiers for a given country vary significantly between experts.

To increase the transparency of, and reduce the subjective element in the determination of priorities, the estimates provided in this monograph are not modified by the capacity to undertake strategic research or applied research, or to adopt research results. This represents a change from Davis et al. (1987). Under the current system, research managers must use their own knowledge of the target countries to scale down potential benefits to reflect the research capacities of the countries and their capacities to facilitate the adoption of results.

The following standard assumptions are made in all analyses:

- successful agricultural research leads to a 5% reduction in the cost of producing an agricultural commodity in the target country;
- research undertaken in a target zone has potential to lead to reductions, equal to or less than 5%, in the cost of producing the same agricultural commodity in non-target countries which are agro-climatically similar to the target zone;
- in the target country, it takes 8 years from the start of a research project to the beginning of adoption;
- in the non-target benefiting country, it takes 12 years from the start of a research project to the beginning of adoption; and
- in both the target and non-target countries, from the year adoption starts, it takes 3 years to reach the ceiling or maximum adoption.

Objectives of the study

The study was designed to address the following questions:

- For a given national agricultural research system, what are the ex-ante relative benefits (excluding spillovers) of investing research funds in different agricultural commodities?
- What are the total benefits (to the target country plus those to other non-target countries through regional research spillovers) likely to arise from research focused on the target country?
- How do the priorities change in taking these two different viewpoints?

In order to explore these questions, a new model, *Spillovers*, was constructed (Lubulwa 1998) which was consistent with the RE4 model (Davis et al. 1987), except for the departures described earlier with respect to the use of modifiers.

The analyses reported in the monograph are partial. They assume that technological change affecting one commodity does not affect other commodities. Other things are assumed to be equal in the rest of the agricultural sector. This is equivalent to the assumption of zero cross-elasticity between agricultural commodities in the presence of technological change. To relax that assumption would require the analysis to take into account the complex relationships between commodities in both consumption and production. To do this requires a detailed general equilibrium model for each of the countries included in the analysis. This is not feasible given the current state of the art in this area.

Commodities are divided into eight major groups (see Table 1, column 1). The eight groups of commodities are: Livestock, Fish, Industrial crops, Forestry, Grains, Fruit and vegetables, and Other crops. Some 108 analyses are undertaken, made up of:

- 57 commodity analyses involving preharvest technologies (see Table 1, column 2);
- 9 commodity analyses involving animal breeding, grazing and stocking rate-related technologies (see Table 1, column 3);
- 27 commodity analyses involving postharvest technology affecting fruit, vegetables and livestock commodities, (see Table 1, column 4);
- 6 livestock commodity analyses involving technologies agronomic and soil research to develop fodder and minimise land degradation (see Table 1, columns 5 and 6); and
- 9 livestock commodity analyses involving animal health research to develop vaccines, disease resistance in animals, and similar technologies (see Table 1, column 6).

The increase in the number of commodities overcomes one of the criticisms of limited commodity coverage levelled by Anderson (1988, 1991) against earlier analyses in this area.

Table 1. Number of commodities by commodity group and by research area covered in the monograph

Commodity group	Research area					Total commodities analysed
	Preharvest technology	Animal breeding, grazing, and stocking rate options	Postharvest	Agronomy	Animal health	
Livestock		9	9	6	9	33
Fish	12					12
Industrial crops	7					7
Forestry	7					7
Grain	5					5
Fruit	11		11			22
Vegetables	7		6			13
Other crops						
Nuts	2		1			3
Oilseed crops	1					1
Pulses	3					3
Root crops	2					2
Total	57	9	27	6	9	108

Economic benefits in this monograph are computed from the perspective of an individual country—the country where research is focused or targeted. With this perspective, there are two types of benefits. First, there are benefits accruing to the country where research is focused. These are the benefits accruing, *without* spillovers, to the target country alone. Second, for research undertaken in a target country, there are varying degrees to which that research is applicable to other countries in the region, depending on the commodity and the similarity of the production environments between the target country and the rest of the region. Thus, non-target countries in the same region as the target country can benefit from research undertaken in the target country.

The ranking of commodities in a region is based on the average potential benefits (to target and non-target countries in the region) of undertaking agricultural research. Appendix A gives the detailed estimates which Figures 1–8 summarise. Appendix B gives a list of countries in the different regions.

Figures 1–8 summarise the rank ordering of commodities (by the eight commodity groups listed in Table 1) on the basis of potential research benefits to target and non-target countries (in different regions).

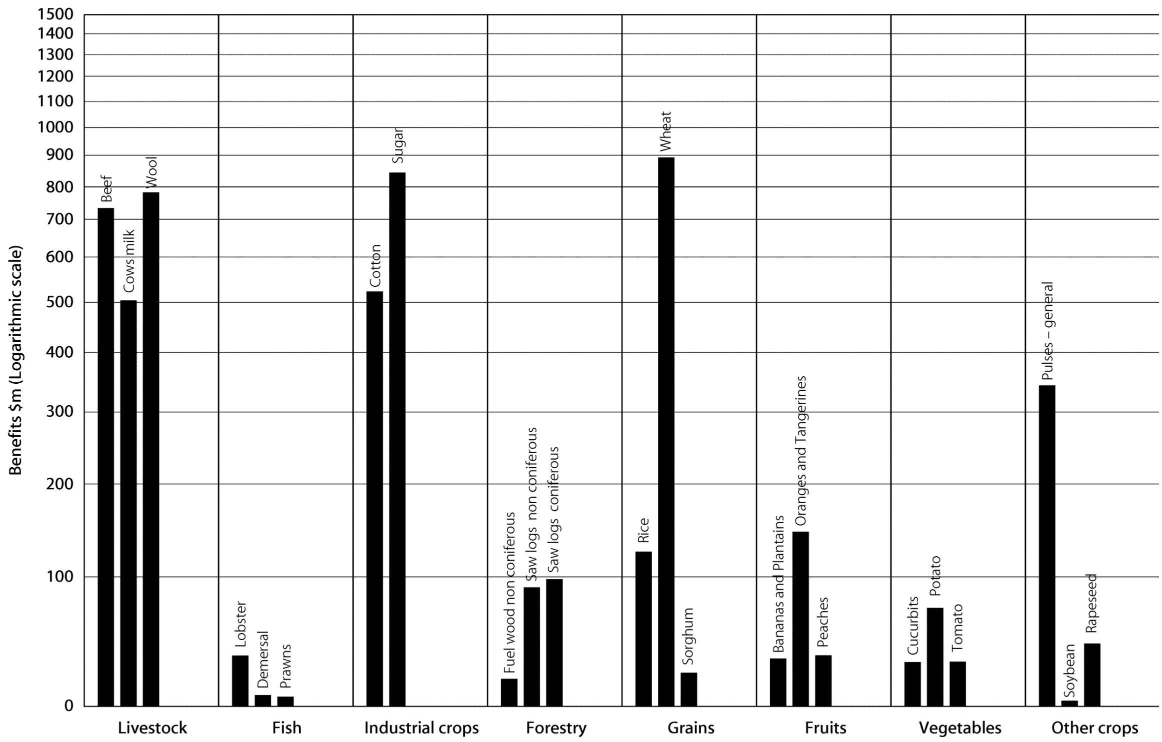


Figure 1. Australia – Priority ranking of selected commodities according to potential benefits resulting from agricultural research. These benefits are discounted at 8% per annum over a 30-year time horizon. The estimates are based on the assumption that research leads to a 5% cost reduction in the production of the commodity, has 100% probability of success, and that there is a 100% adoption of research results.

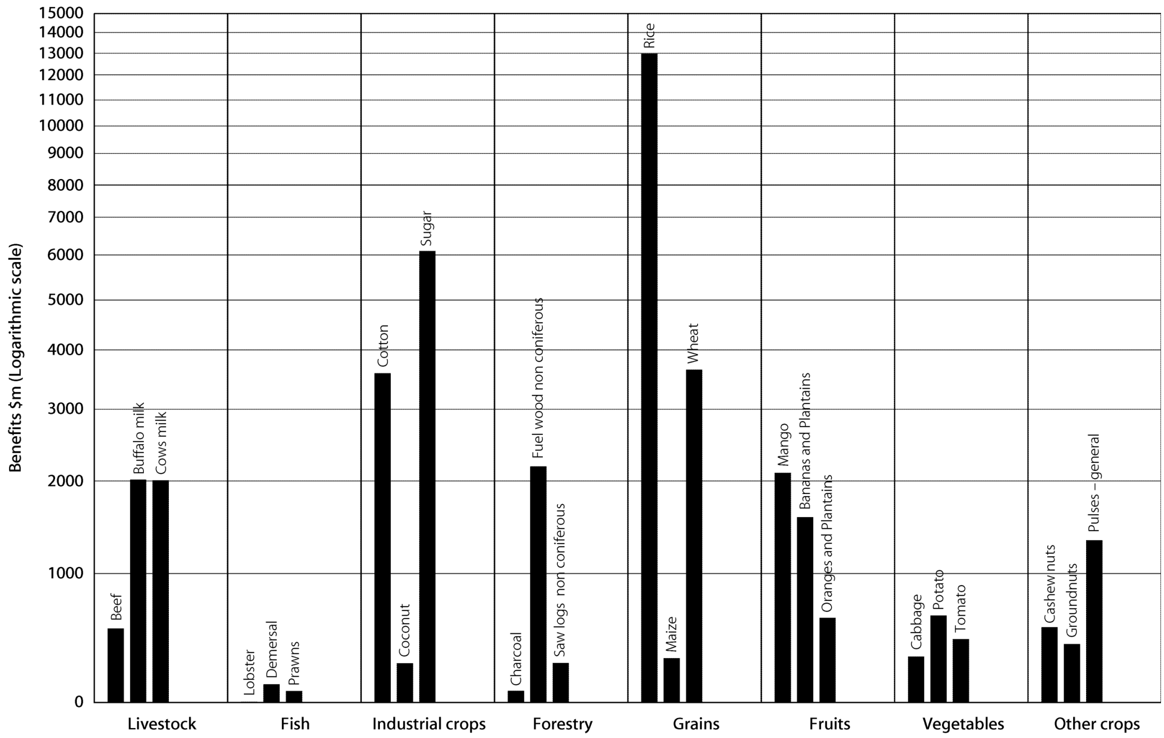


Figure 2. South Asia – Priority ranking of selected commodities according to potential benefits resulting from agricultural research. These benefits are discounted at 8% per annum over a 30-year time horizon. The estimates are based on the assumption that research leads to a 5% cost reduction in the production of the commodity, has 100% probability of success, and that there is a 100% adoption of research results.

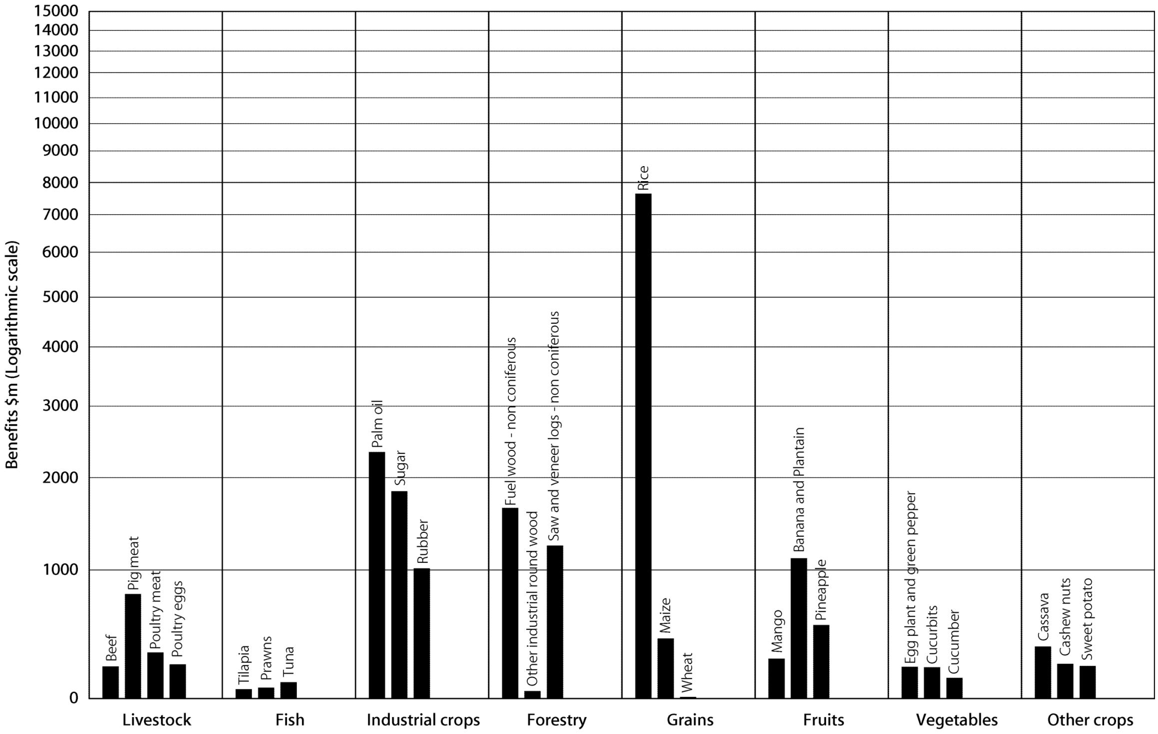


Figure 3. Southeast Asia – Priority ranking of selected commodities according to potential benefits resulting from agricultural research. These benefits are discounted at 8% per annum over a 30-year time horizon. The estimates are based on the assumption that research leads to a 5% cost reduction in the production of the commodity, has 100% probability of success, and that there is a 100% adoption of research results.

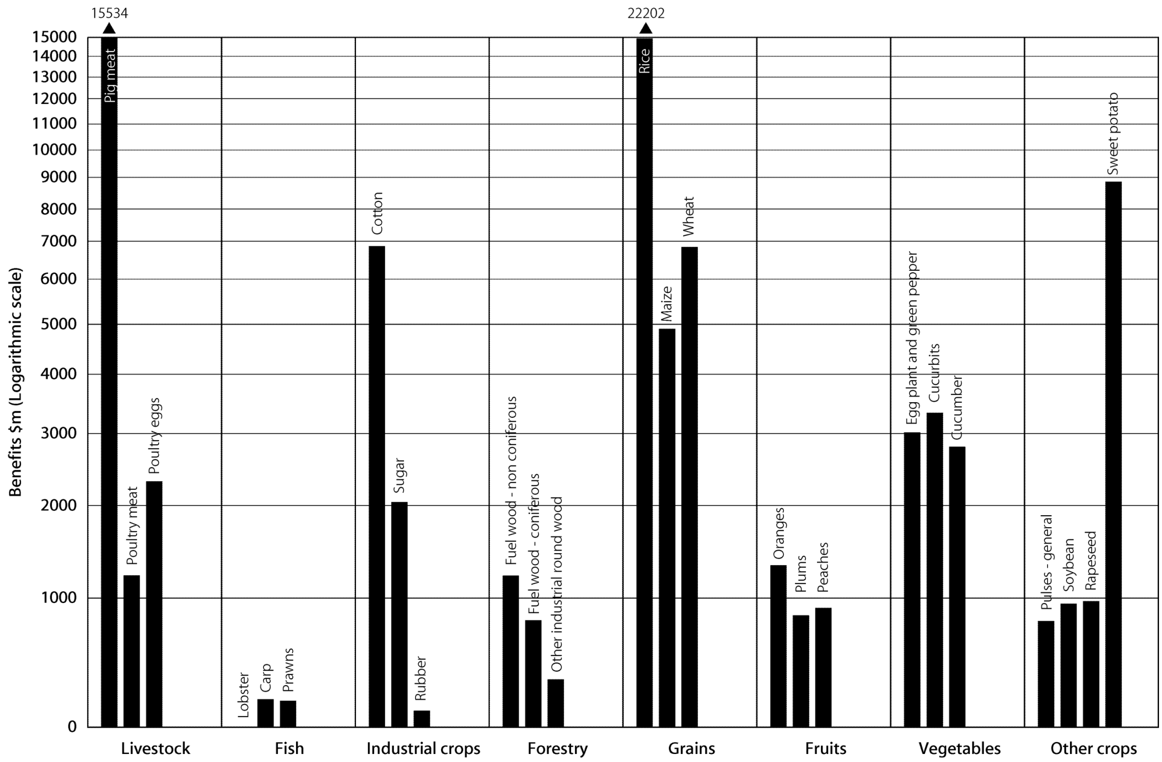


Figure 4. China – Priority ranking of selected commodities according to potential benefits resulting from agricultural research. These benefits are discounted at 8% per annum over a 30-year time horizon. The estimates are based on the assumption that research leads to a 5% cost reduction in the production of the commodity, has 100% probability of success, and that there is a 100% adoption of research results.

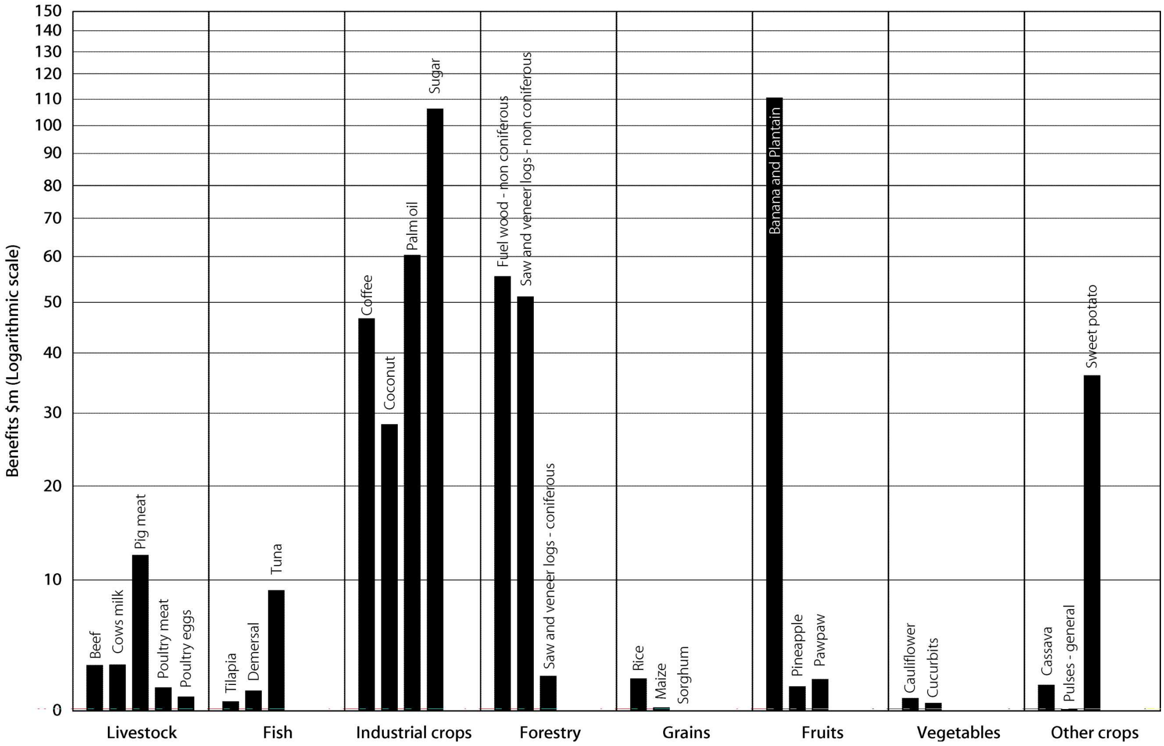


Figure 5. PNG and South Pacific – Priority ranking of selected commodities according to potential benefits resulting from agricultural research. These benefits are discounted at 8% per annum over a 30-year time horizon. The estimates are based on the assumption that research leads to a 5% cost reduction in the production of the commodity, has 100% probability of success, and that there is a 100% adoption of research results.

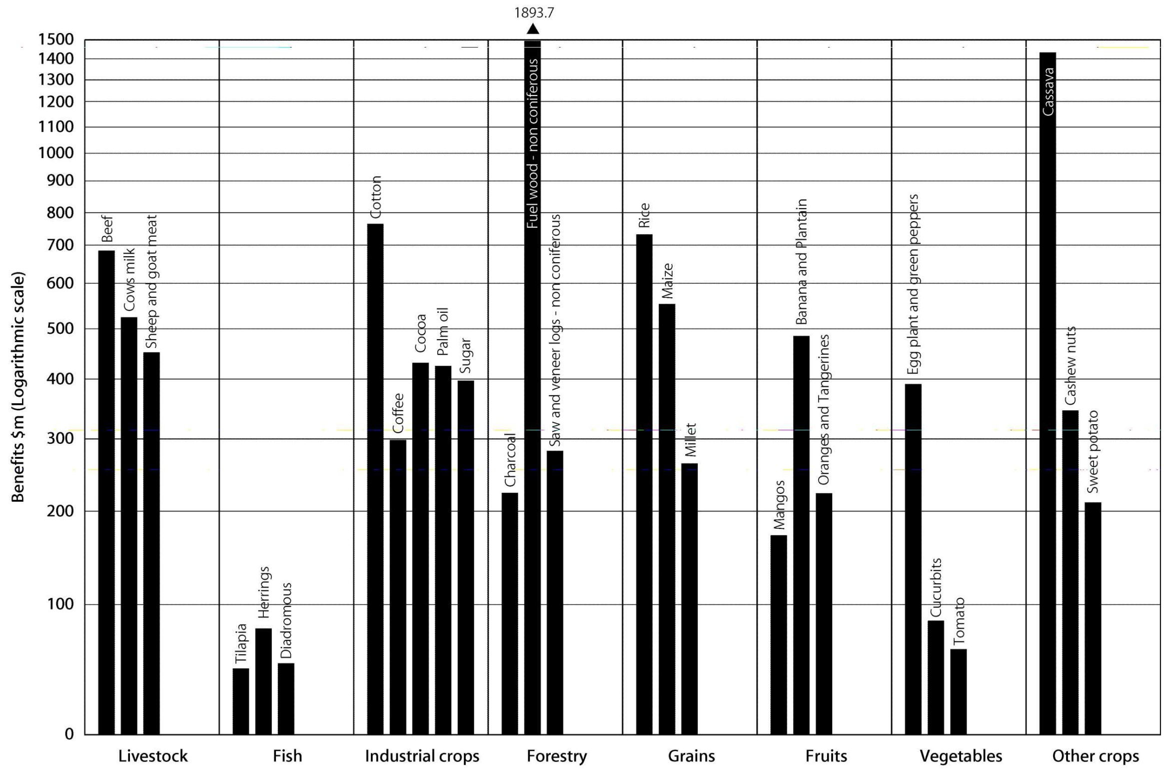


Figure 6. Sub-Saharan Africa – Priority ranking of selected commodities according to potential benefits resulting from agricultural research. These benefits are discounted at 8% per annum over a 30-year time horizon. The estimates are based on the assumption that research leads to a 5% cost reduction in the production of the commodity, has 100% probability of success, and that there is a 100% adoption of research results.

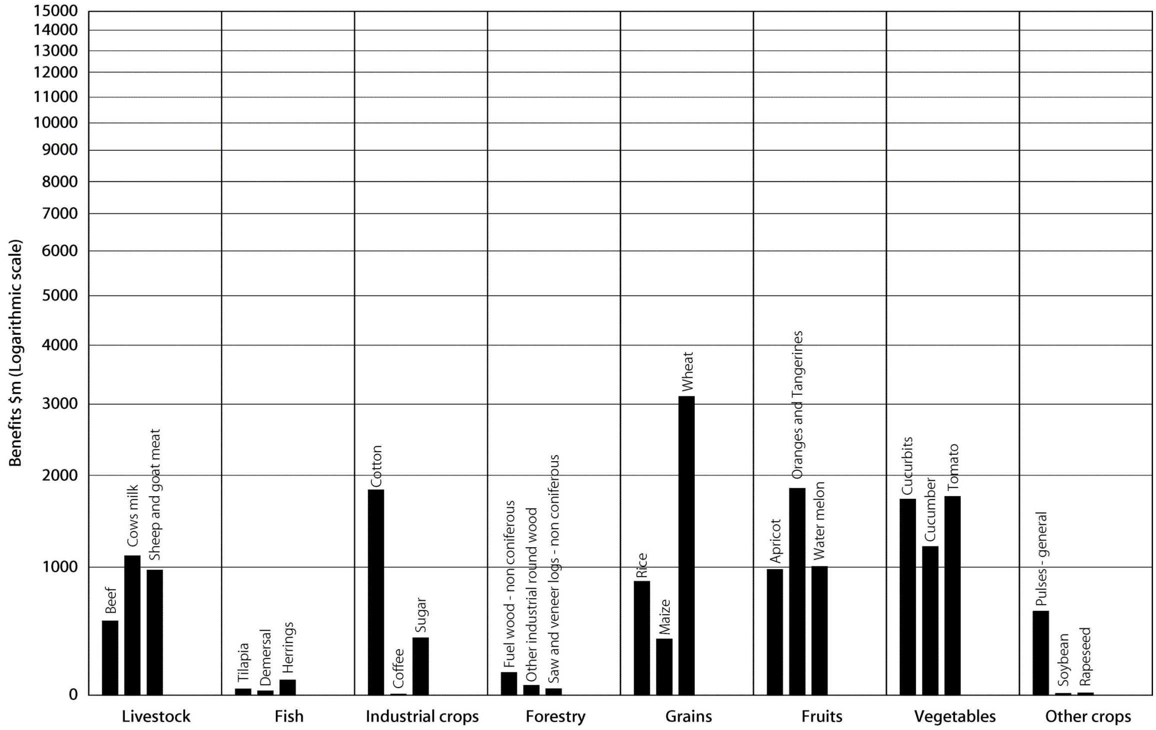


Figure 7. West Asia–North Africa – Priority ranking of selected commodities according to potential benefits resulting from agricultural research. These benefits are discounted at 8% per annum over a 30-year time horizon. The estimates are based on the assumption that research leads to a 5% cost reduction in the production of the commodity, has 100% probability of success, and that there is a 100% adoption of research results.

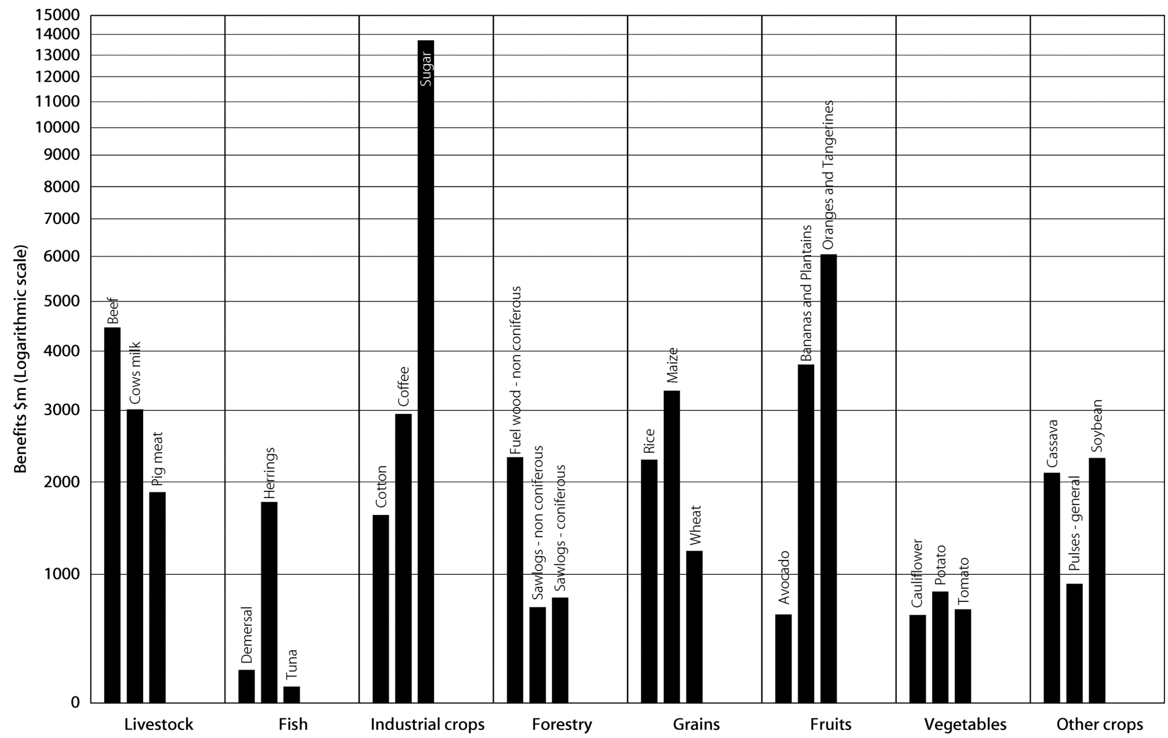


Figure 8. Latin America – Priority ranking of selected commodities according to potential benefits resulting from agricultural research. These benefits are discounted at 8% per annum over a 30-year time horizon. The estimates are based on the assumption that research leads to a 5% cost reduction in the production of the commodity, has 100% probability of success, and that there is a 100% adoption of research results.

1. INTRODUCTION

While the analyses reported in this monograph are broadly applicable, they were initially undertaken to assist with decision-making at ACIAR. This and the next section provide some historical context for the analyses.

1.1 Some history[2]

ACIAR funds projects in different parts of the world covering many commodities, ranging from livestock products, fisheries, forestry, fruit, vegetables and various other crops, as well as agricultural economic policy, postharvest technology, and land and water management. Table 2 shows the planned distribution of the ACIAR budget by region.

Table 2. Planned distribution of the ACIAR budget by region: 1997–2001

Region	Percentage of bilateral research budget
South Asia	10–20
Southeast Asia	50–60
China	10–20
Papua New Guinea and the South Pacific Island nations	10–20
Africa	5–10

Source: ACIAR (1997)

The percentage ranges in Table 2 are given as guidelines for ACIAR's day-to-day decision-making. With a wide range of countries, commodities and issues, ACIAR required procedures for setting priorities. One approach is to estimate which commodities are likely to generate the largest improvement in community welfare. Proponents of a project are asked to specify whether the proposed research is likely to affect an agricultural commodity. However, if the research proposed has no implications for any agricultural commodity, then that research cannot be brought within the sphere of influence of this analysis. While such projects may exist, experience has shown that they are not common. It is usually possible and desirable to identify an agricultural commodity likely to be affected by agricultural research.

The early 1980s

In the early 1980s, scoring methods were commonly used in setting ACIAR's research priorities. Senior managers visited developing countries to elicit their priorities and interest in collaborative agricultural research. In 1982–83 ACIAR polled its scientific staff to get their rankings and weightings of efficiency and equity criteria used in scoring models for priority assessment studies. Results from the poll highlighted the limitations of scoring approaches.

Mid-1980s

ACIAR's Policy Advisory Council established geographic regional funding guidelines similar to those in Table 2, and approved the initiation of a 'priorities project' to develop a methodology for setting international agricultural research priorities. The project on agricultural research priority assessment had the aim of providing a systematic and consistent framework for deriving

[2] This sub-section has benefited from comments and file notes kept by Dr Jeff Davis during the period when he was the manager of ACIAR's Economic Evaluation Unit (now called the Impact Assessment Program).

'big picture' priorities. The project developed a methodology for incorporating agricultural research spillovers in the evaluation of project ideas. The key elements in that framework were: (i) a focus on regional priorities, (ii) a recognition of agro-climatic research spillovers, (iii) inclusion of the capacity of national research systems, (iv) inclusion of Australian comparative advantage, and (v) a recognition that the framework should be a guide for program and project assessment rather than a panacea.

The effects included were:

- the world price effects that arise when, for example, a cost-reducing technology is introduced, which in turn leads to reductions in the world price of the target commodity; and
- technical spillovers that arise when strategic research generates an efficiency-improving technology that is broadly applicable beyond the agro-climatic production environment for which it was developed.

Late 1980s

Davis et al. (1987) developed an international priority assessment framework and methodology and applied it to 12 commodities. With the publication of Davis et al. (1987) this new, more rigorous framework replaced the scoring approach at ACIAR. Management agreed that the objective of agricultural research was to maximise total international benefits from funds invested in a region. The regional priorities were used on a routine basis to assess projects for funding by an in-house review committee of program managers.

The more rigorous approach was introduced (through a suite of concurrent agricultural research assessment studies) to the Philippines, Thailand, Papua New Guinea and Indonesia (in collaboration with the International Service for National Agricultural Research (ISNAR)).

Early 1990s

The procedure of ranking agricultural commodities based upon expected economic benefits from research led to what is now known as the 'commodities priorities table'. The salient attributes of the table were as follows.

- The results were aggregated, and (apart from China and Australia which were regarded as regions for this exercise) always reported at the regional level. This was advantageous in that, for example, one could summarise the priorities on one page, in a short space with a few numbers.
- The analysis recognised seven major regions, namely South Asia, Southeast Asia, China (including Mongolia), the South Pacific region, Sub-Saharan Africa, South and Central America, and Australia.
- By the early 1990s the priorities table had about 45 commodities. In 1992, the Economic Evaluation Unit (now the Impact Assessment Program) was formed. One of its functions was the development of 'big picture' priorities for international agricultural research.

Late 1990s

During this period, the inclusion of more commodities extended the priorities tables. At the same time, there was unease about the interpretation of regional priorities in a context where most projects were funded bilaterally with individual countries. The priorities for a region were influenced by the priorities of the largest or richest economy in the region. The regional priorities were less informative about poorer or smaller countries. Thus, for example, the priorities for the small island states in the South Pacific region were dominated by the priorities of Papua New Guinea in the specification of the regional priorities. To make it possible to move away from regional to national priorities a new model, *Spillovers*, (Lubulwa 1998) was developed.

1.2 Outline of the study

This monograph reports research priorities for different agricultural commodities in selected national agricultural systems. Recent developments in, and enhancements of, the aggregate level priority tables are discussed. The monograph is the product of (a) in-house modelling and analyses undertaken in ACIAR's Impact Assessment Program, and (b) input from external consultants. Chudleigh et al. (1998) compiled the databases for fruit and vegetables used in the priority tables. White et al. (1998) compiled the databases on livestock commodities and extended the analysis to distinguish between areas of livestock research. Four areas were considered: animal health research (vaccines etc.); research on breeding, grazing, and stocking rate options; agronomic and soil research to improve fodder supply and minimise land degradation; and postharvest research.

This monograph reports two distinct priority rankings. These are:

- a priority ranking based on national benefits that considers benefits to the target country (or countries) only, ignoring any possible regional spillovers; and
- a priority ranking based on benefits to the target country plus spillover benefits to other countries within the same region.

The priorities presented in this monograph focus on individual countries. One advantage of this is that it is possible, to a limited extent, to compare the priorities as computed from the *Spillovers* model with the priority ranking determined at high-level consultations with the managers of various national agricultural research systems.

Finally, the analysis deals with two other questions.

- Does it matter whether one spends more on postharvest as opposed to preharvest research?
- How different are the potential benefits from, and therefore the priority ranking of, different livestock research themes (say animal health research as opposed to research to improve the quality of feed for livestock)?

Answers to these questions enable incorporation in the priority tables of a capacity to discriminate (for some commodities) various types of research—e.g. preharvest versus postharvest for fruit and vegetables, and animal health versus breeding, say, for livestock commodities.

2. RESEARCH PRIORITIES AS PART OF AN INFORMATION SYSTEM

The research priorities system forms part of what is called the 'Project Information System of ACIAR' (*PISA*). *PISA* is a *Lotus Notes* database that provides a complete record of the information for each project funded. The information ranges from detailed budgets to publications and the country/commodity focus of the project, together with commodity priority information. The database produces a range of reports. Some of these are to assist day-to-day project management, while others provide summary information for all projects or various groups of projects.

The reasons for developing an institution-based research priorities system include:

- increased importance of public sector accountability;
- the diversity of research areas; and
- a need to be able to make comparisons of research benefits across this diversity.

The priorities presented in this monograph are part of this larger information system. This section briefly discusses seven steps that need to be followed when developing a priority-setting information system.

Step 1: Review existing and past decision-making systems.

Step 2: Identify the level of decision-making likely to use the results.

Step 3: Identify and clarify research objectives.
Comment: ACIAR's mission is 'to reduce poverty, improve food security and promote sustainable natural resource management through international agricultural research partnerships for the benefit of developing countries and Australia', while the objective used in the development of the priorities table is one of maximising economic welfare. The assumption is that research that increases the size of the national or regional 'cake' contributes to each of the components of the mission.

Step 4: Develop or choose quantitative measures that indicate achievement of objectives.
Comment: The *Spillovers* model uses monetary research benefits as a proxy measure of progress towards achieving the stated mission of an institution. Because the mission is so complex, one should use the priority tables with care. It is not possible to reduce to dollars terms all aspects of that mission. The economic and monetary component is nevertheless important.

Step 5: Develop a database to support information generation.
Comment: Having the database means that there is corporate memory of the basis for the priorities at a given time.

Step 6: Develop effective information-presentation procedures.
Comment: In the early stages of the priorities system, it is necessary to use a simple and easy to understand presentation system for the results on priorities. Until recently at ACIAR, the 1 to 6 category system at a regional level was considered adequate for decision-making at the beginning. However, as managers became more familiar with the priority system, and in response to individual countries, more country specific

information was desired. Currently, the priority information is presented at a national level in the form of 1 to 6 categories, with and without spillovers to non-target countries. In addition, the monetary values on which these categories are based are included in a standard statement on the priorities of a given commodity in a project proposal.

Step 7: Institutionalise the information system and support structure.
Comment: The institutionalisation of the information system entailed several steps. The first was the formation of the Economic Evaluation Unit (now called the Impact Assessment Program) with responsibility for monitoring and maintaining the information system. The second has been the incorporation of these priorities in project documents.

Rigid adherence to these steps is not essential, but unless most are at least considered, then the likelihood of adoption of the system by decision-makers could be significantly reduced because the information produced may not suit them or the environment they work in.

The rest of this section discusses the research evaluation sub-component of ACIAR's information system. This sub-component has three main parts:

- a priorities table;
- a project development evaluations (ex-ante) database; and
- a completed projects evaluations (ex-post) database.

The priorities tables

The priorities as reported are a convenient way of bunching commodities. They are used as a preliminary screening device: that is, research projects focusing on commodities in the ‘low’ and ‘very low’ priority groups are flagged as requiring closer scrutiny of the likely level of welfare gains which may result and, all things being equal, preference is given to the higher priority commodity. On the other hand, research projects addressing ‘very high’ to ‘medium’ priority commodities may need less scrutiny from the point of view of potential benefits.

Project development assessments

Project development (ex-ante) assessments were added to ACIAR’s information system around 1992 for several reasons:

- they present a means of comparing projects from the diverse program areas within an agency;
- they provide a mechanism for demonstrating the types of conditions under which technically attractive technologies applied to potentially ‘lower benefit’ commodities will generate high welfare gains; and
- the assessment activities provide a useful interdisciplinary interaction that often leads to clearer project specification and direction.

If a research proposal has the objective of undertaking research on commodities in the ‘low’ and ‘very low’ priority groups, this is a flag for a more detailed ex-ante economic assessment of the project. The ex-ante assessment gives a funding agency the opportunity to ascertain whether the project has other features that might redeem it—scientifically attractive attributes or human capacity enhancement benefits, for example, or other social or environmental benefits that supplement the low economic benefits. Inclusion of human health and ecological benefits in the priority table is close to impossible given the state of the art in this area. Thus, the decisions about a particular research activity need to rely on additional mechanisms to incorporate those other effects – for example, through the mechanism of ex-ante studies.

Completed project assessments

This component of the ACIAR system contains results from evaluations of completed projects. The current database includes estimates summarised in the following studies.

- Menz (1991) gives a summary of 12 assessments completed for the Parliamentary review undertaken at the end of the first period of ACIAR's statutory life. The primary basis for choosing the projects that were assessed was that the benefits from them had started to flow and that they were identifiable.
- Lubulwa and Davis (1993) estimated benefits from six projects on tropical fruits.
- Lubulwa (1995) reports estimates from research on cassava in Africa.
- Lubulwa and McMeniman (1998) report estimates of benefits from biological control in the South Pacific.
- Lubulwa et al. (1998) report estimates of the social benefits from forestry research in Africa.
- Menz and Lawrence (1999) summarise 12 recent evaluations of projects where the evaluations are by independent external consultants.

Evaluations of completed projects have typically assumed a time horizon of 30 years. Given that ACIAR was formed in 1982 and that projects generally run for 3–6 years from start to completion, benefits for the earliest projects are estimated from 1982 to about 2012. Thus, even for the very first project that ACIAR funded, completed project evaluations include an element of ex-ante assessment. Menz and Lawrence (1999) nevertheless report on evaluations that clearly identified and distinguished the benefits realised to date and those yet to be realised.

3. DETERMINING AGRICULTURAL RESEARCH PRIORITIES

3.1 The basis of the priorities

The basis of the priorities is the calculation of potential economic benefits from research. It is not simply the value of output—given by multiplying the appropriate price of the commodity with the quantity of the commodity produced at a given point in time. The estimation of potential benefits measured as changes in economic welfare also incorporates the following considerations:

- production and consumption levels;
- proportion of the commodity produced in specified environments;
- climatic zone to zone applicability of technology;
- geographical research focus;
- country to country spillovers matrices;
- prices;
- cost saving due to research; and
- a discount rate (necessary because the analysis estimates benefits over a 30-year time period).

Each of these factors is discussed briefly in section 3.2, along with more detail about the models and the data used in the analyses.

Alston et al. (1995) review methods used in agricultural research evaluation. The model used in this monograph has been fashioned to include most aspects of the research process.

The technical aspects of research evaluation, and therefore the model, focus on the potential for research spillovers to other countries. Research managers and technical experts assisted in the estimation of some of the parameters. Current estimates represent a comprehensive set of relevant data.

The research evaluation framework adopted in this monograph is based on an integrated technical (physical) and economic model of the research process, as shown in Figure 9. This model is used to determine the potential welfare impacts of research options. The economic components of Figure 9 have been modelled using a multi-region, traded-good model with the concept of producer and consumer surplus used to estimate the potential welfare effects of the research. To accommodate this part of the model, a range of data sets has been added to the database. These include production, consumption (both commercial and subsistence), prices and elasticities.

The approach assumes that agricultural research leads to a reduction in the cost of producing the agricultural commodity in question. This may involve either a farmer producing more with the same or less inputs, or producing the same with less inputs.

The important assumption used for the base-case set of welfare changes is that the research results in a 5% reduction in the cost of producing a unit (usually a tonne) of the commodity. The choice of 5% cost reduction is arbitrary. The actual percentage shift used in the analysis is not important, because the aim is to develop a ranking of commodities as opposed to the absolute values of potential benefits. The choice of the cost reduction, while it changes the absolute values of potential benefits from research, does not change the relativities between commodities.

Figure 9. A simplified schematic presentation of a research process model. Source: Lubulwa et al. (1996)

3.2 The models and data used

A diagrammatic representation of the model

Figure 10 shows in diagrammatic form a simple version of the model that is used in the analysis. Here a two-country model of an agricultural commodity is presented. The two countries are country A, a net exporter, and country B, a net importer of the commodity to be targeted by research. Figure 10 describes the situation before the changes associated with agricultural research.

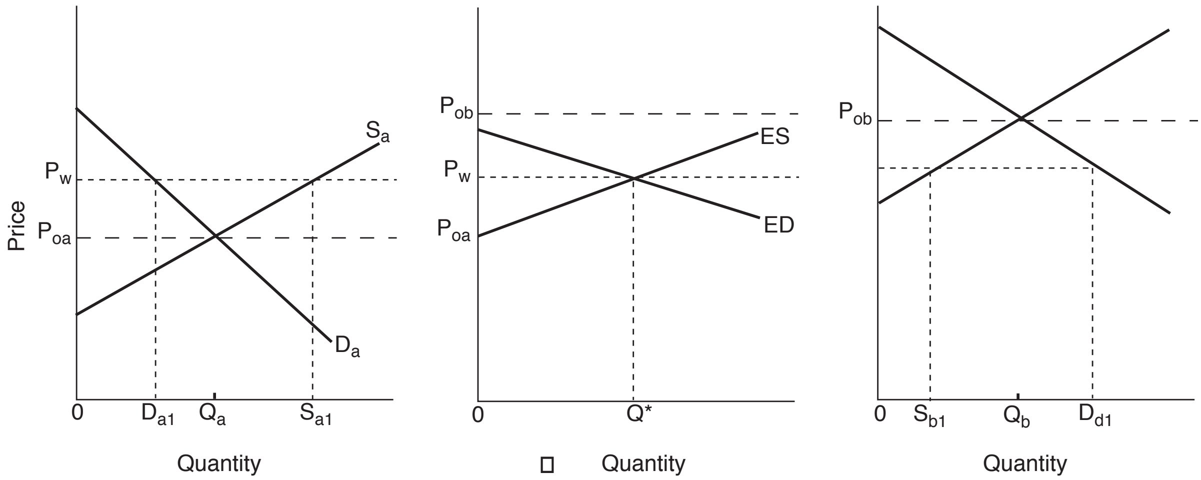


Figure 10. A two-country model of the market of an agricultural commodity

Before research—the net exporter

Country A is an exporter of the commodity in question. The diagram on the far left of Figure 10 shows the supply curve (S_a) and the demand curve (D_a) for the commodity in country A. In the simplified case in Figure 10, there are no transport costs and import and export taxes. Thus, the world price P_w determines the quantity demanded and produced in country A. At the price P_w, producers in country A produce S_{a1} of the commodity. On the other hand, consumers demand only D_{a1}. Since D_{a1} is less than S_{a1}, there is an excess of supply over demand in country A. That excess is sold off as exports on the world market.

In the diagram for country A, if the world price is too low, say at P_{oa}, country A would not have the incentive to produce for export. Country A would produce just enough to meet its domestic demand for the commodity.

Before research—the net importer

The diagram on the far right in Figure 10 shows the demand and supply situation for country B, which is a net importer of the commodity. At the world price P_w, country B produces S_{b1}, whereas the demand for the commodity in the country is D_{b1}. The country meets the excess demand for the commodity through international trade by importing $D_{b1} - S_{b1}$ of the commodity.

In the diagram for country B, the quantity demanded and supplied is determined by the world price P_w of the commodity. The higher the world-price, P_w, the more of the commodity is produced domestically and the less is imported. If the price rises to P_{ob} in Figure 10, country B would be better off producing domestically its total requirements of the commodity.

The world price is determined in the diagram in the centre of Figure 10. In that diagram, the world price is the price at which excess demand for the commodity (ED) is just equal to the excess supply. If, at a given price, both country A and B are self sufficient in the production of the commodity in question, then the two countries A and B would produce the commodity in a closed market situation. There would be no world market for the product. However, given that in Figure 10 country A is a much more efficient producer of this commodity than country B, there will always be opportunities to gain from trade for country A and B.

After research—the net exporter

Figure 11 shows the ‘after research’ situation in country A and B. The analysis in this monograph assumes that agricultural research reduces the cost of producing a given commodity. In Figure 11, country A is the country targeted by research. As a result of research, the cost of production in country A is reduced and this is reflected in a shift to the right in the supply curve from S_a to S_a'. The size of the cost reduction is given by the vertical distance between S_a and S_a' and is equal to k_{aa} as shown in Figure 11.

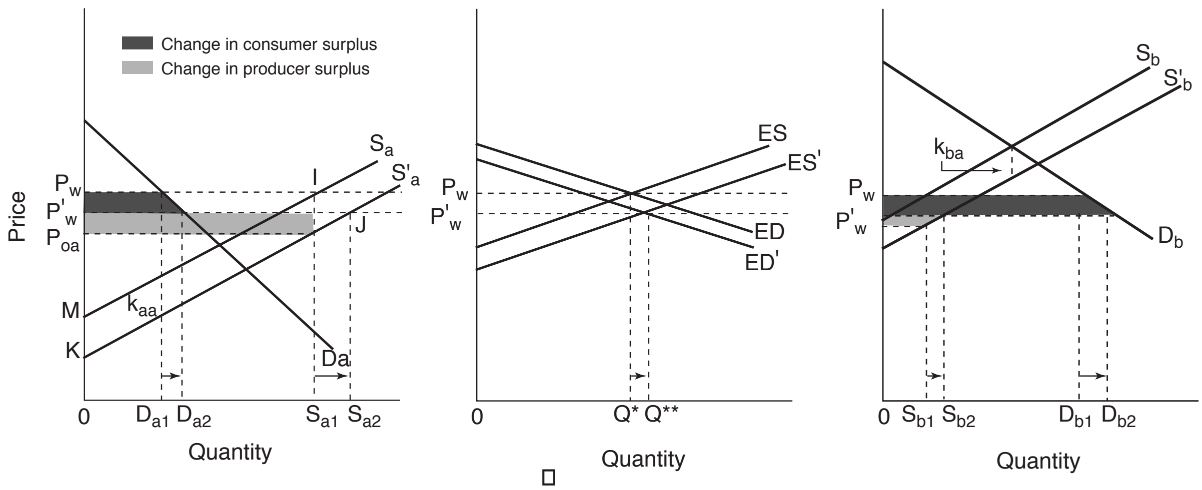


Figure 11. A two-country model of the market of an agricultural commodity — with spillover effects of research

As a result of this cost reduction, the situation of this commodity in the world market changes. Country A will produce relatively more of the commodity. More of the commodity will be consumed domestically in country A because the commodity is cheaper. In addition, if the costs of other producers in the rest of the world do not change, country A will be at an advantage since it would be more competitive relative to the rest of the world. Thus, country A exports will increase. The end result from this series of changes is shown in the centre diagram in Figure 11 where the world price drops from P_w to P_w'.

The impact of research in country A is shown in the left-most diagram in Figure 11. Both producers and consumers gain. The shaded areas show the gain to these two groups.

After research—the net importer

The diagram on the far right of Figure 11 shows the impact of research on a net-importer. Figure 11 allows for two main effects, namely:

- the world price effect of research; and
- the technical research spillovers effect.

The world price effect on a net importer arises from the fall in the world price, which is beneficial to consumers in country B.

The technical spillovers effect relates to the cost reduction k_{ba} to producers in country B (a non-target country) as a result of successful research in A —the target country. This cost reduction in the non-target country is shown as k_{ba} in Figure 11. However, this effect is not automatic. Its magnitude depends on the agro-climatic similarity between countries A and B. If the two countries are too dissimilar, then the spillovers of technology between them would be limited.

Figure 11 indicates that both producers and consumers in the non-target country B stand to gain from research undertaken in country A. However, this is not always the case.

A model for the computation of potential benefits

Figures 9–11 have shown the conceptual and theoretical aspects of the model applied in the analysis. The computational vehicle for the results discussed in this monograph is a new model called *Spillovers* (Lubulwa 1998). The *Spillovers* model is a multi-region, traded-good, research evaluation model. It estimates changes in consumer and producer surpluses as a result of agricultural research that reduces the cost of producing a commodity by a proportion of its price, in this case 5%. While the program allows spillovers between agro-climatic zones, and world price effects, it handles one commodity at a time.

The front screen of the *Spillovers* model (Figure 12) shows its various components. These are briefly discussed below.

3.2.1. More about the model

The model outline and details of its development are described in this introductory section of the program.

3.2.2. All countries considered

The analysis takes into account 211 countries of the world, but for simplicity most of the developed countries and other selected countries are aggregated into regions. [Appendix B of this monograph shows the regional aggregations of the countries.]

3.2.3 FAO production and consumption

United Nations Food and Agriculture Organization (FAO) data (a time series beginning in1961) on annual production and consumption for the 211 countries are used in the analysis. The averages of the most recent 3 years (1992, 1993, and 1994) are the basis for the estimates of potential benefits from research reported in the monograph.

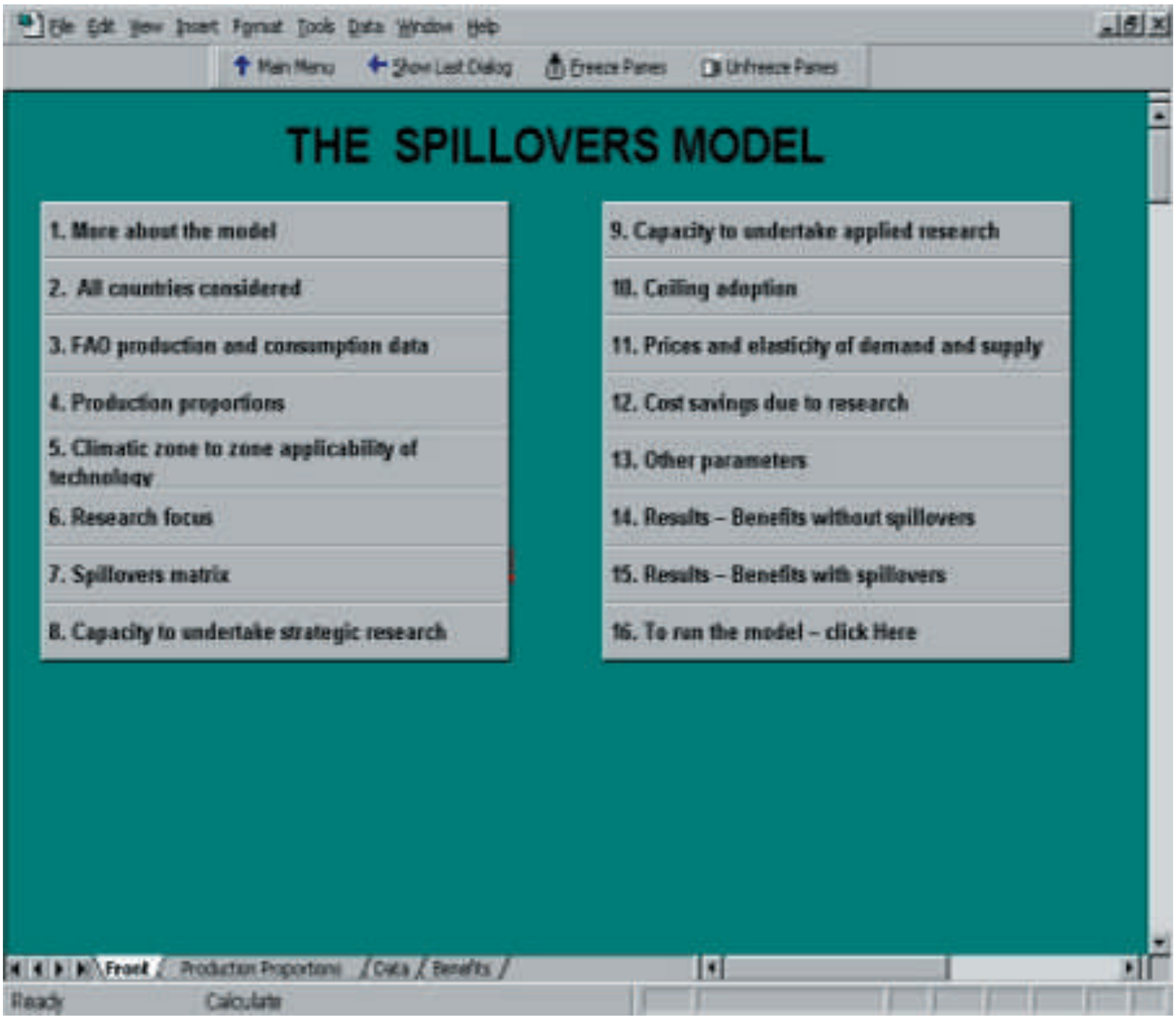


Figure 12. The opening screen of the *Spillovers* model

Production figures in the analysis relate to the total domestic production of a commodity (whether inside or outside the agricultural sector) as defined by FAO. Thus, production includes non-commercial and kitchen garden production.

Consumption was defined as the residual, that is:

Consumption = Production – Exports + Imports ± Changes in stocks.

Consumption levels are compared in *Spillovers* to the level of production in determining whether the estimation of benefits should use a closed or an open-economy model.

3.2.4 An appropriate set of agro-climatic zones

The first task in the analysis is to choose an appropriate set of agro-climatic zones for use in the analysis of the group of commodities. Too much detail (too many zones) is likely to be redundant; too little detail may result in aggregation error. This task requires a good understanding of the nature of the research, and of the production systems within which the commodities likely to be influenced by the research are produced.

For each of the groups of commodities listed in Table 1 a different set of production environments was defined. It is not possible to use one set of production environments for each and every commodity. Davis et al. (1987) describe the production environments that were subsequently used in the analysis of industrial crops, grains and other crops. The rest of this sub-section describes the production environments for the other commodities in Table 1.

Livestock

White et al. (1998) recommended that six agro-climatic zones be distinguished according to length of growing period (LGP). This classification is consistent with ongoing work by FAO and others on length of growing periods, and is complemented by satellite and other data, and estimates of total livestock biomass (Slingenbergh and Wint 1997). The six zones are listed in Table 3.

Table 3. Agro-climatic production environments for the production of livestock.

Zone	Length of growth period (days)
Desert	0
Arid	1 – 59
Semi-arid	60 – 119
Dry subhumid	120 – 179
Moist subhumid	180 – 269
Humid	>270

Source: White (1998)

FAO (1996a,b) strongly influenced the choice of agro-climatic zones for livestock used in this study. They provided livestock data that could be linked to the zones in Table 3. The use of human population density data was critical in providing initial estimates of livestock density distribution within countries, and for the most part these estimates appear to be sufficiently accurate in developing countries to provide information to aid in the targeting and prioritisation of agricultural research.

Fish

On fish production, Fearn and Davis (1991) concluded from the literature available at the time that:

- there was no uniformly accepted classification that defined ecologically homogenous aquatic environments for fisheries; and
- environmental characteristics such as salinity, water temperature, water depth, currents, winds, rainfall, dissolved oxygen levels and nutrients *do* combine to form distinct ecological areas.

Thus, in the case of fish, the biological differences between species within a given fish commodity provide the basis for determining the aqua-ecological zones. The individual species within a commodity are used as proxies for aqua-ecological zones. For example, ‘tunas’ is one of the fish commodities included in the analysis. However, ‘tunas’ is a combination of skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*), albacore (*Thunnus alalunga*), southern bluefin (*Thunnus maccoyii*), and other tuna and tuna-like fishes. A certain combination of environmental conditions needs to be present for each individual species to occur in a particular location. The location of each individual species determines the different homogenous aqua-ecological environments.

Forestry

Davis et al. (1989) concluded that the agro-climatic classification developed by Papadakis (1975) was an appropriate system for classifying forestry production environments. Papadakis's system separates agro-climatic conditions into 10 broad categories or zones—ranging from zone 1, which includes tropical environments, to zone 10 which includes polar categories. Within each of those zones there are up to nine, single-decimal sub-zones which include separations based on, for example, altitude and temperature.

Fruit and vegetables

Chudleigh et al. (1998) defined 14 climatic zones for the fruit and vegetable database. These are: (1) Warm tropics – irrigated; (2) Warm tropics – dry land; (3) Cool to cold tropics – irrigated; (4) Cool to cold tropics – dry land; (5) Warm sub-tropics summer rainfall – irrigated; (6) Warm sub-tropics summer rainfall – dry land; (7) Cool to cold tropics winter rainfall – irrigated; (8) Cool to cold tropics winter rainfall – dry land; (9) Sub tropics winter rainfall irrigated; (10) Sub tropics winter rainfall – dry land; (11) Cool to cold temperate – irrigated; (12) Cool to cold temperate – dry land; (13) Transitional irrigated; and (14) Transitional dry land. The technical definition of the different zones in terms of temperature and growing periods is given in Chudleigh et al. (1998).

The system of zones used was based upon an FAO agro-climatic classification. Apart from the agro-climatic zone, it was decided that whether production was based on irrigated or rain-fed systems was a second characteristic of production that would influence R&D spillovers.

Digitising an existing FAO map, Chudleigh et al. (1998) developed a set of 10 maps covering the whole world and illustrating the seven agro-climatic zones. Three of these maps are reproduced on the next three pages. Map 1 is an example showing the different zones for Australia, New Zealand and Papua New Guinea, Map 2 shows the regions for southern Africa, and Map 3 shows the regions for Central and Southern America.

3.2.5 Production proportions by agro-climatic environments ('F' in section 3.2.8)

Once the number and definitions of agro-climatic zones are agreed, the second key task is to estimate the production proportions (S_{ijc}) of output of a commodity produced in 211 countries (the countries that provide data to FAO) in the agreed agro-climatic zones[3]. These estimates can be derived using a variety of methods including: (i) knowledge of economic geography; (ii) geographical information systems; and (iii) model-based approaches and so on.

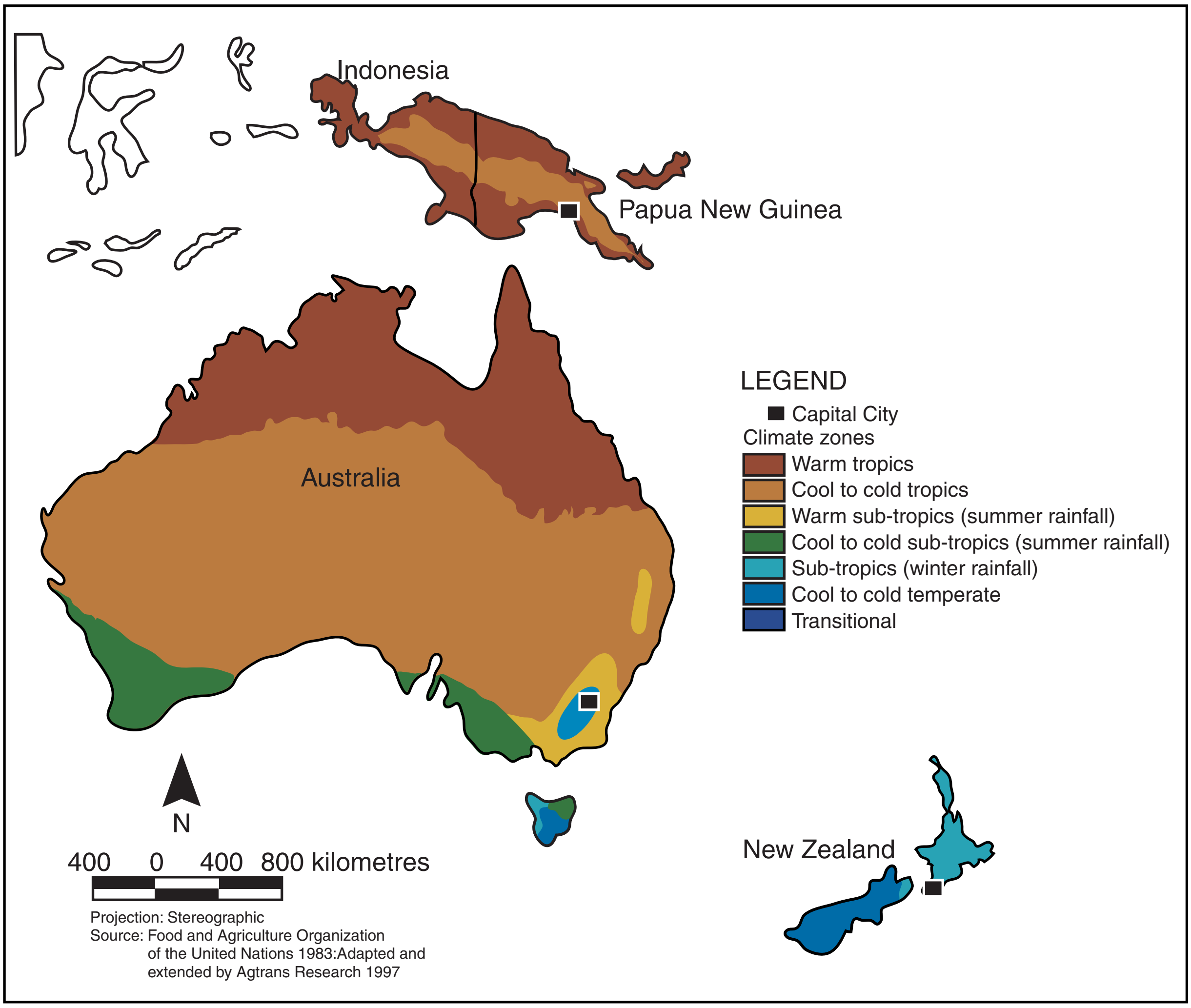
Let:

S_{ijc} = the proportion of commodity *i* produced in agro-climatic zone *j* in country *c*;
S_{ijc} = zero if commodity *i* is not produced in agro-climatic zone *j* in country *c*;
S_{ijc} = 1 if all the output of commodity *i* in country c is produced in agro-climatic zone *j*.

$0< S_{ijc} \leq 1$ i.e. the estimates are expected to be between 0 and 1;

$\sum S_{ijc}$ = 1, the estimates of S_{ijc} for a commodity in a given country must add to one.

3 Unfortunately, the number of countries providing data to FAO varies by commodity.



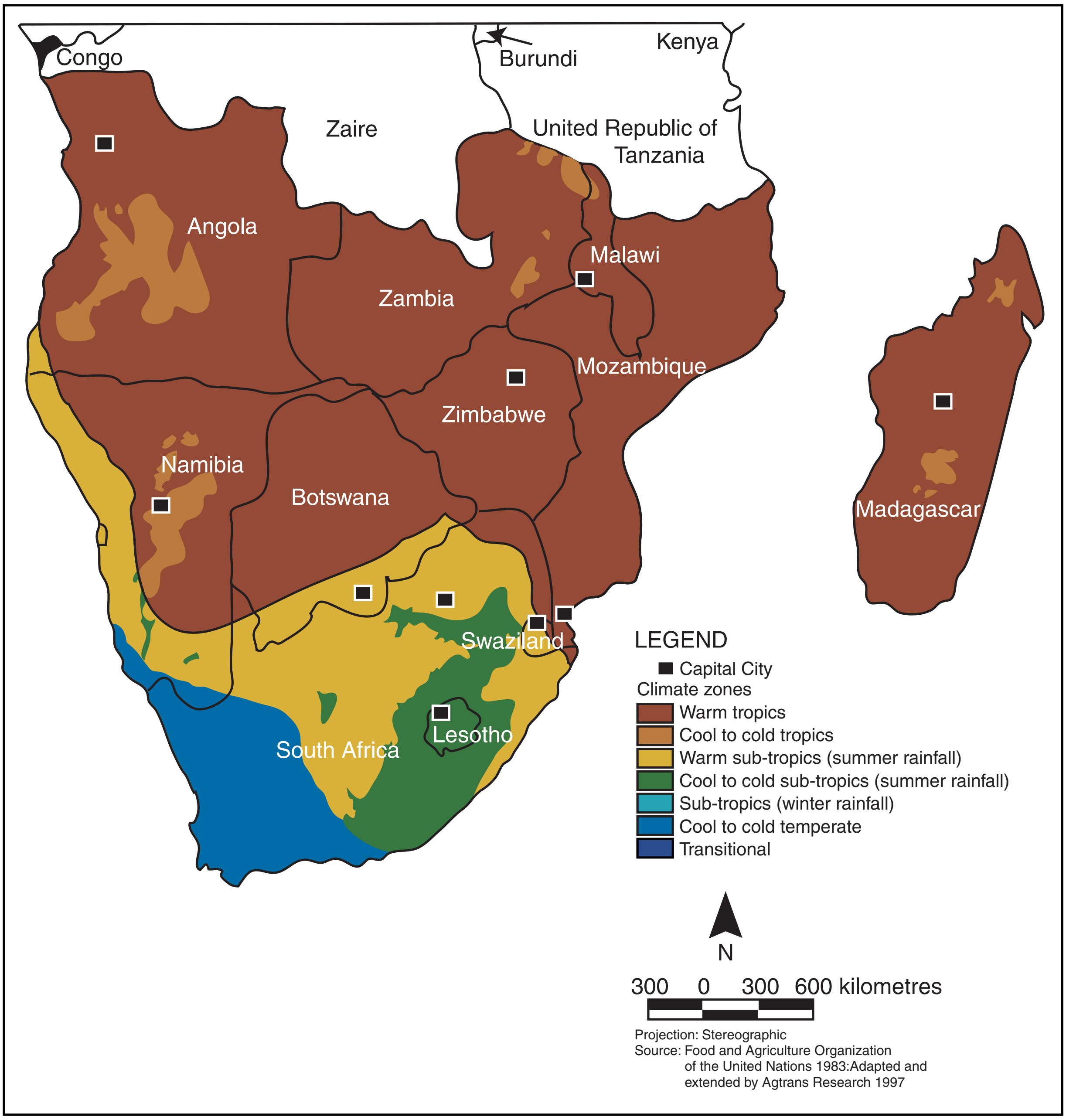
Map 1. Climatic zones of Australia and Papua New Guinea

While the table of production proportions for a given commodity is large, most of the cells need not be completed since in many countries a given crop has a few niche zones where most of it is grown.

For each of the agricultural commodities, the proportion of the crop grown in each of the agro-climatic zones within each country must be estimated.

If a particular country is situated in one zone, then it follows that all of the specific commodity in that country would be produced in that zone. If there are two or more agro-climatic zones within a particular country, the proportion of the commodity produced in each zone must be estimated. The units used to indicate the proportion of the commodity produced in each zone are between 0 and 1, with an accuracy to the nearest 0.05 if possible; i.e. if three quarters of the production of a commodity is in zone A, then this would be expressed as 0.75.

For each commodity, a table was drawn up showing, for each of 211 countries, how much of the commodity is produced, on average, in each of the agreed agro-climatic zones. The number and definition of zones varied by commodity group. For illustrative purposes, the next section discusses briefly what was done in the case of livestock commodities.



Map 2. Climatic zones of southern Africa

Livestock

FAO and Environmental Research Group Oxford (ERGO) Consulting, UK (W. Wint, pers. comm.) provided estimates of total livestock biomass for each domesticated livestock species within each agro-ecological zone within each country in an Excel work sheet. Using the mean weights assigned to livestock for each continent (see FAO 1996a), it is relatively easy to estimate the number of 'livestock units' in each agro-ecological zone within each country. These weights reflect both the genotypes and nutritional regimes that dominate each continent.

Map 3. Climatic zones of Central and South America

These estimates were compared with livestock numbers from the FAO World Agricultural Information Centre (Waicent) database for 1996. In most cases, particularly for developing countries, these more recent estimates by White (1998) corresponded very well with the raw data. In other countries, such as those in the former Soviet Union, there were appreciable differences between the estimates and the raw data. Some differences are to be expected, of course, given the variable quality of the national data, variability about the functions relating 1994 livestock levels to human populations within and between continents (see FAO 1996a), and other factors discussed by Slingenbergh and Wint (1997). In the case of the former Soviet States, the numbers of sheep and cattle were often significantly lower than one would have expected, this not being compensated for by counting goat numbers. This may largely reflect deficiencies in the quality of the data, or that ruminant production in these areas is well below expectation, possibly as a consequence of land degradation. It was decided that the most reliable approach was to use the FAO (1996a,b) analyses to determine, for each livestock species, the percentage of livestock biomass, livestock units or livestock commodity within each agro-ecological zone within each country. These percentages were then used by White (1998) to reallocate the most recent FAO data (1996) to the different zones.

Estimating the production proportions for livestock commodities involved the following steps:

- Estimates of total livestock biomass (within species, based on FAO 1994 data) were allocated to agro-climatic zones by FAO (1996b), i.e. Dr William Wint of ERGO Consulting, in collaboration with Dr Jan Slingenbergh of FAO.
- Data in Table 4 were used to convert the total livestock biomass to estimates of livestock units within agro-climatic zones within countries.
- For each livestock species, the proportion of livestock numbers within each agro-climatic zone within each country was then used to allocate the 1996 FAO data for national livestock numbers to the different agro-climatic zones. This gave a more up-to-date estimate and, more importantly, ensured that the total of all agro-climatic zones added up to the national total for 1996, according to the FAO database.
- This process was repeated for the major livestock commodities.

Table 4. Weights (kg) assigned to livestock for each continent (FAO 1996a)

Livestock species	Africa/Oceania	Asia	South America	North America/ Europe/Australia
Equines	125	125	125	125
Cattle	175	325	400	450
Sheep	25	30	50	50
Goats	25	25	40	45
Camels	250	250	250	250
Pigs	30	50	50	50
Buffalo	400	400	400	400
Other camelids	100	100	100	100
Chickens	2	2	2	2

Source:White (1998)

It is appreciated that ruminant animals are more strongly influenced by agro-ecological conditions than non-ruminants. For example, a report published by Winrock International (Anon. 1992) states that the arid and semi-arid zones, which together have 54% of the land area of sub-Saharan Africa, account for 57% of the ruminant livestock measured in tropical livestock units (TLU). The humid zone, making up 19% of the land mass, has 6% of ruminant TLUs. The largest share of goats (38%) and sheep (34%), and nearly all of the camels, are found in the arid zone. Most cattle are in the semi-arid (31%) and sub-humid zones (23%). Pigs are found mostly in the humid and sub-humid zones. Poultry are evenly distributed over all zones except the arid zone. Pigs and poultry are also produced in intensive commercial livestock systems that are influenced more by proximity to population centres and ports than by agro-ecological conditions.

The method of allocating livestock numbers to agro-climatic zones on the basis of human density distribution (FAO 1996a,b) does not directly discriminate between species. However, this is largely compensated for by entering the total number of each livestock species for each country. For example, if there are few large ruminants in a country then the area suitable for grazing ruminants will probably be dominated by sheep and goats.

Levels of livestock commodities may be estimated in different ways. For example, FAO provides data on slaughtering as well as indigenous production. Gross indigenous livestock production makes allowance for trade distortions, and is defined as:

> Meat production from slaughtered animals, plus the meat equivalent of all animals exported live, minus the meat equivalent of all animals imported during the reference period.

Emphasis has therefore been on using the indigenous livestock production, where these data are available.

The 'livestock commodity production index' is defined as the weight of product per kg of live animal (FAO 1996b). It is therefore an input/output ratio, being 'a very preliminary measure of *production efficiency*'. Livestock production commodity indices representing estimates of the amount of meat or other commodity produced per kg of livestock biomass were estimated for 1994 for each continent by FAO (1996b), as shown in Table 5.

Table 5. Calculated livestock production indices for 1994, by continent.

Continent	Red meat	Pig meat	Chicken meat	Hen eggs	White meat	All milk
Africa	0.12	1.17	1.05	0.92	1.06	0.44
Asia	0.09	2.12	1.11	1.85	1.66	0.50
Australia	0.36	2.51	3.73	1.37	3.07	1.42
Europe	0.18	2.36	2.44	2.57	2.33	2.27
N. America	0.19	2.22	3.17	1.50	2.67	1.17
Oceania	0.13	2.29	2.52	2.03	2.28	0.02
S. America	0.08	0.91	2.47	1.06	1.65	0.26

Source: FAO (1996b)

FAO's (1996b) approach provides estimates of livestock species biomass within the six agro-ecological zones in each country. These have been based on use of a direct ratio between animal numbers and people (animals per person) calculated from the FAO country numbers. It also means that the calculated national total should approximate the FAO national figures.

Manure dispersal (tonnes of dry matter (DM) per annum) was estimated using the assumption that intake approximates 2% of live-weight, and the digestibility of the herbage is 50%. It is therefore reasonable to assume that the weight of manure is 1% of live-weight. Given that estimates of the number of cattle, buffalo, sheep and goats had been estimated for the agro-ecological zones of each country, and that we had standard live-weights for each species within each continent, the calculation is straightforward. Totals produced for the different commodities in each of the agro-ecological zones are shown in Table 6.

Table 6. Commodity total for each of the agro-climatic zones

Commodity	Desert	Arid	Semi-arid	Dry sub-humid	Moist sub-humid	Humid
Ind. bovine meat (kt)	1,913	1,146	4,238	9,410	24,233	16,623
Fresh cattle hides (kt)	256	150	625	1,437	2,835	1,943
Cows milk (kt)	11,982	8,475	39,467	87,897	223,138	95,898
Cattle manure (kt DM)	47,445	29,849	141,040	326,490	648,590	499,534
Buffalo meat (kt)	437	104	348	796	665	354
Buffalo milk (kt)	9,407	2,837	9,072	18,660	9,856	2,042
Buffalo manure (kt DM)	20,573	6,321	28,229	72,846	62,608	31,535
Mutton and lamb (kt)	595	302	1,036	1,281	1,887	2,178
Indigenous sheep and goat meat (kt)	888	446	1,528	2,084	2,859	3,053
Scoured wool (kt)	60	56	159	228	390	717
Sheep skins (kt)	116	65	194	240	843	428
Sheep milk (kt)	761	357	1,441	1,734	2,714	700
Sheep manure (kt DM)	9,131	5,040	19,023	24,348	38,148	47,036
Goat skins (kt)	92	31	97	167	203	166
Goat milk (kt)	1,138	489	1,666	2,416	3,695	740
Goat meat (kt)	431	141	476	777	939	793
Goat manure (kt DM)	5,845	2,269	9,602	15,695	19,747	13,481
Indigenous pig meat (kt)	1,037	503	2,812	13,489	39,236	27,822
All poultry meat (kt)	2,329	758	3,099	8,085	24,974	19,098
All poultry eggs (kt)	1,335	480	2,683	8,523	18,760	15,390
Hen eggs (kt)	1,277	467	2,577	7,832	17,387	13,531
Land area (’000s km^2)	26,648	10,156	26,197	27,625	23,462	21,104

Source:White (1998)

3.2.6 Technical spillovers across agro-climatic environments (‘C’ in section 3.2.8)

Under this task it was necessary to estimate the likely spillovers to another zone of research conducted in a particular agro-climatic zone, for individual commodities listed in Table 1. The outputs from research into a particular agricultural commodity in a particular zone are likely to be of some relevance to the production of that same crop in other zones.

The units used to quantify the relevance to other zones of research conducted in a particular zone are between 0 and 1 (to the nearest 0.05 if possible, otherwise to the nearest 0.1). If the applicability of research results produced in one zone to another zone is high, the spillovers estimate is likely to be high (e.g. 0.9). If the applicability of research results to the second zone is low, the spillovers estimate is likely to be small (e.g. 0.1). However, for each commodity, there are likely to be several zones where the commodity is not produced, and thus there would be no technical spillovers both from and to these zones.

Livestock

Estimation of the feasibility for technical spillovers requires a focus on the effects of physical and biological differences between the agro-climatic or agro-ecological zones. The underlying question presupposes that one funds a research activity in an agro-climatic zone, and develops a technology that is most suited to that agro-climatic zone. What is sought is an appreciation of how that technology would perform against the best available technology in other agro-climatic zones.

The approach chosen involved first considering the constraints to technology spillovers between agro-climatic zones, from the aspect of the livestock commodity *and* the technology being evaluated. It was appreciated that there is also a host of social, cultural, educational, financial and even political factors (e.g. prohibition of the movement of livestock across national boundaries) that can limit technical spillovers. For example, political and administrative boundaries rarely coincide with broad ecological zones[4]. It was recognised that:

- the estimates are averages of spillovers of research impacts between zones;
- the estimates are to be [weighted] averages over all possible research projects; and
- the estimates are to be specific to a commodity.

There is a wide range of ruminant production systems. The simplest involve livestock grazing native grassland, either within a fixed property boundary or, at the other extreme, as part of a nomadic lifestyle. More intensive systems involve subdivided properties with the livestock grazing improved pastures and/or fodder crops, the most intensive systems being typified by the livestock being housed and fed ensiled pasture and crops and/or feed concentrates.

Consider first an animal health technology, such as a new vaccine. This could apply across the whole range of agro-ecosystems, so that the spillovers coefficients will be high. Physical constraints to its use might include:

- the range of the vector (e.g. bio-climatic limits of the tsetse fly, or the cattle tick);
- the density of livestock (disease spread is limited at very low stocking rates);
- the natural level of resistance to the vector or the disease (e.g. cattle tick);
- soil and pasture characteristics (e.g. persistent moisture for footrot in sheep);
- presence of, and access to, alternative hosts (e.g. tuberculosis in cattle);
- availability of fencing (e.g. to help control venereal diseases);
- the availability of veterinary services; and
- the level of nutrition and hence the vulnerability of the animals to disease.

It is also noted that large numbers of animals move around on transhumance in the arid, semi-arid and sub-humid areas of Africa. This presents problems to animal health control, and in ensuring that grazing pressure does not exceed both the short- and long-term carrying capacity of the land.

Rangeland maintenance requires an appreciation of the sensitivity of rangeland ecosystems, which are often being exposed to pressure from livestock species that are markedly different from those under which they evolved. Technologies developed in these areas may have limited applicability elsewhere. Likewise, technologies developed for improved pastures and intensive grazing systems will often have limited relevance to rangeland systems.

There also needs to be an appreciation of biophysical constraints that limit technological uptake within the zone in which it is developed. In more intensive grazing systems, improving the productivity on one part of a farm often limits the production on another part of the farm. Likewise, improving survival of, say, young stock during one part of the year may have

4 For fruit and vegetables, Chudleigh et al. (1998) estimated zone-to-zone spillovers on the basis of 'ignoring other constraints', but in a few cases social and cultural factors were taken into account.

deleterious effects on the breeding livestock, limiting their performance in the next season (Bowman et al. 1989). A major impact of an aggressive grass within a sward may be to smother a valuable legume. There are therefore many factors, including biological feedbacks, that can contribute to the failure to capture, in practice, the full value of a technology that appears considerable in the narrow confines of a field experiment. It should also be noted that many 'technical experts' have been trained in environments that are so dissimilar to those of their own countries that the technologies they, and 'visiting experts', attempt to introduce are at best inappropriate, and often counter-productive (Morley and White 1985; Scoones 1992).

For these various reasons, it was decided to apply the following dichotomies. Separate matrices of coefficients representing technical spillovers were developed for ruminants and non-ruminants. The coefficients were assumed to be relatively similar between livestock species within these groupings. However, different matrices were applied to differentiate between animal health, animal production and agronomic (including soil amelioration) technologies.

For non-ruminants, the agronomic technologies applied solely to the fodder on offer, and were considered part of non-ruminant production. Five matrices were therefore developed. The coefficients themselves are, in fact, best estimates made after systematically taking into account the major factors that would influence the pre- and postharvest transfer of different technologies in these areas, as indicated below, and discussing them with others.

Only the first matrix applicable to animal health services, that for ruminants, is reproduced here (Table 7). It was assumed that the effectiveness of most vaccines and medicines would be relatively independent of the agro-climatic zone in which they were applied, although the epidemiology of different diseases would certainly be affected by climate and other environmental factors. Herds and flocks in the more arid zones would be less exposed to disease, which would in part compensate for the reduced access to animal health services. As with other matrices, it is important to be conscious of the limits to vector and host ranges, which can have an overriding influence on the relevance and value of specific technologies.

Table 7. Technical preharvest spillovers: estimates for ruminant health

Zones	Desert	Arid	Semi-arid	Dry sub-humid	Moist sub-humid	Humid
Desert	1.00	0.90	0.80	0.70	0.60	0.50
Arid	0.90	1.00	0.90	0.80	0.70	0.60
Semi-arid	0.80	0.90	1.00	0.90	0.80	0.70
Dry humid	0.70	0.80	0.90	1.00	0.90	0.80
Moist humid	0.60	0.70	0.80	0.90	1.00	0.90
Humid	0.50	0.60	0.70	0.80	0.90	1.00

Source:White (1998)

Fruits and vegetables

Details of the commodities and countries with which each expert was familiar were assembled via a fax-transmitted questionnaire. Elicitation material was developed to facilitate collection of data from experts. A pilot test of the elicitation material using two consultants helped enhance the material. Relevant elicitation material was then mailed to each expert for completion and return. Reminder telephone calls were made to non-respondents to increase the number of responses received from experts. Remuneration was made to all experts providing useful information.

In the case of fruits and vegetables, estimates by experts showed inconsistencies and irregularity, and exhibited high standard errors. It was decided to use estimates made by Dr Keith Chapman, because their consistency and accuracy were considered to be better than average.

The results indicated that the spillovers of research for preharvest technology between zones are lower than that for postharvest technologies. This difference was apparent in estimates provided by individual experts, as well as in the final set of estimates used. Tables 8 and 9, for mangoes, are examples of the matrices produced for about 30 fruits and vegetables.

3.2.7 The research focus matrix

An important factor in estimating the potential benefits from agricultural research is the distribution of national research budgets across the different agro-climatic zones recognised in the model. However, this information is not generally available. Therefore, it is assumed that national governments fund agricultural research in each agro-climatic zone in direct proportion to the quantity of production in that zone.

3.2.8 Spillovers matrix

The spillovers matrix S is a product of three matrices. That is:

$$S = R^* C^* F$$

where:

S is an M by M matrix of the estimates of the potential research spillovers, weighted on a scale of 0 to 1, among countries/regions chosen for analysis. M is the number of countries or regions included in the analysis. M is equal to 44 in the analysis reported in this monograph;

R is a research focus matrix (section 3.2.7 above) which is the transpose of the production proportions matrix (F) and so is N (rows) by M (columns) in size;

C is a matrix showing the climatic zone to climatic zone applicability of technology (N by N); and

F is the production proportions matrix (M countries and N zones).

The matrix multiplication leads to a spillovers matrix (S) which is M by M. This matrix shows the potential for spillovers (as an index between 0 and 1) to other countries or regions from research done in a given country. Table 10 shows part of the spillovers matrix for preharvest technology for mangoes. The larger the share of the zone in total production and the closer the zone to the agro-climatic zone where the technology originates, the larger is the total spillovers effect to the zone.

For each of the commodities in the analysis, there is a spillovers matrix with 44 columns and 44 rows. Row 1 in Table 10, for Bangladesh, can be interpreted as follows. Suppose research is undertaken in Bangladesh which successfully introduces preharvest technology for mangoes in that country. Suppose that the research leads to a cost reduction of 5% on pre-research costs. Table 10 suggests that according to data on the agro-climatic production environments for mangoes the following are likely to be the spillover opportunities for that technology.

- None of that technology is likely to lead to cost reductions in Bhutan, Nepal and Myanmar. This may be because mangoes are not produced in those countries.

- If the technology is associated with a cost reduction of $9/t of mangoes in Bangladesh, it could lead to cost reductions of $8.60/t in India and Vietnam, $8.20/t in Pakistan, $9.00/t in Sri Lanka, $8.90/t in Indonesia, Laos and the Philippines, and $8.80/t in Cambodia.

Other rows in Table 10 can be interpreted in similar fashion. The entries in Table 10 are a result of the distribution of agro-climatic zones in those countries and the estimated production proportions of mangoes.

The *Spillovers* model estimates benefits first for the target country. In this case, the model would estimate the benefits accruing to Bangladesh as a result of introducing a certain cost reduction. The estimate for national benefits to Bangladesh *without* spillovers excludes both the technical spillovers to other countries referred to in Table 10 and the world price effects of agricultural research. However, the *Spillovers* model can allow for the introduction of these cost reductions in non-target countries and can estimate the benefits arising from both the price and technical spillovers.

3.2.9 Prices and elasticity of demand and supply

Prices are important in the analysis only in relation to the estimation of the cost saving due to research. Various sources were used for prices and price elasticities of demand and supply.

Elasticities are important when one is interested in measuring the distributive consequences of alternative commodity and regional research portfolios. Elasticities make it possible to determine what proportions of the total benefits accrue to producers and consumers. However, the analysis presented here is not sensitive to elasticity values, since it focuses on total benefits.

Fish

Price data and the information on price elasticities used in the fisheries commodities are discussed in Fearn and Davis (1991)

Forestry

Elasticities of demand and supply for forestry products are discussed in Davis et al. (1989). The estimates used in the study were based on the few available in the literature, modified to take account of the possibility for substitution between different products and private and public policy relating to the forestry sector in different countries.

Fruits, vegetables and other crops

The elasticities used for the fruits and vegetables are from Lubulwa and Davis (1993). For many of the fruits and vegetables it was not possible to get commodity-specific elasticities. For many of the fruits and vegetables price data were from Ausmarket Consultants (1998). Where available, prices from published sources of the World Bank (various dates) were used.

3.2.10 Cost savings due to research

The analysis involves the estimation of potential economic gains for producers and consumers in various countries under the assumption that agricultural research leads to increased efficiency in the production of a commodity. In the analysis, the cost reduction is estimated as follows.

Table 8. Applicability of pre-harvest research in one zone to other zones – mango (an example of the ‘C’ matrix discussed in section 3.2.8)

Agro-climatic zones			**R1-I**	**R1-D**	**R2-I**	**R2-D**	**R3-I**	**R3-D**	**R4-I**	**R4-D**	**R5-I**	**R5-D**	**R6-I**	**R6-D**	**R7-I**	**R7-D**
Warm tropics	Irrigated	R1-I	1.00	0.80	1.00	0.80	0.80	0.80	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
	Dry land	R1-D	0.80	1.00	0.80	1.00	0.80	0.80	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Cool to cold tropics	Irrigated	R2-I	1.00	0.80	1.00	0.80	1.00	0.80	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
..	Dry land	R2-D	0.80	1.00	0.80	1.00	0.80	1.00	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Warm sub-tropics [summer rainfall]	Irrigated	R3-I	0.80	0.80	1.00	0.80	1.00	0.80	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
..	Dry land	R3-D	0.80	0.80	0.80	1.00	0.80	1.00	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Cool to cold sub-tropics [summer rainfall]	Irrigated	R4-I	0.60	0.60	0.60	0.60	0.60	0.60	1.00	0.60	0.60	0.60	0.60	0.60	0.60	0.60
..	Dry land	R4-D	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.00	0.60	0.60	0.60	0.60	0.60	0.60
Sub-tropics [winter rainfall]	Irrigated	R5-I	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.00	0.60	0.60	0.60	0.60	0.60
..	Dry land	R5-D	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.00	0.60	0.60	0.60	0.60
Cool to cold temperate	Irrigated	R6-I	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.00	0.60	0.60	0.60
..	Dry land	R6-D	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.00	0.60	0.60
Transitional	Irrigated	R7-I	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.00	0.60
..	Dry land	R7-D	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.00

Source: Chudleigh et al. (1998)

Table 9. Applicability of postharvest research in one zone to other zones – mango (an example of the 'C' matrix discussed in section 3.2.8)

Agr o-climatic zones			**R1-I**	**R1-D**	**R2-I**	**R2-D**	**R3-I**	**R3-D**	**R4-I**	**R4-D**	**R5-I**	**R5-D**	**R6-I**	**R6-D**	**R7-I**	**R7-D**
Warm tropics	Irrigated	R1-I	1.00	0.95	1.00	0.95	0.95	0.95	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Dry land	R1-D	0.95	1.00	0.95	1.00	0.95	0.95	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Cool to cold tropics	Irrigated	R2-I	1.00	0.95	1.00	0.95	1.00	0.95	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Dry land	R2-D	0.95	1.00	0.95	1.00	0.95	1.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Warm sub-tropics [summer rainfall]	Irrigated	R3-I	0.95	0.95	1.00	0.95	1.00	0.95	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
..	Dry land	R3-D	0.95	0.95	0.95	1.00	0.95	1.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Cool to cold sub-tropics [summer rainfall]	Irrigated	R4-I	0.80	0.80	0.80	0.80	0.80	0.80	1.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80
..	Dry land	R4-D	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.00	0.80	0.80	0.80	0.80	0.80	0.80
Sub-tropics [winter rainfall]	Irrigated	R5-I	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.00	0.80	0.80	0.80	0.80	0.80
..	Dry land	R5-D	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.00	0.80	0.80	0.80	0.80
Cool to cold temperate	Irrigated	R6-I	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.00	0.80	0.80	0.80
..	Dry land	R6-D	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.00	0.80	0.80
Transitional	Irrigated	R7-I	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.00	0.80
..	Dry land	R7-D	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.00

Source:Chudleigh et al. (1998)

Table 10. An extract from a *Spillovers* matrix for mangoes – pre-harvest technology[a]

		Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka	Myanmar	Indonesia	Cambodia	Lao PDR	Philippines	Vietnam
1	Bangladesh	0.90	0.00	0.86	0.00	0.82	0.90	0.00	0.89	0.88	0.89	0.89	0.86
2	Bhutan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	India	0.86	0.00	0.86	0.00	0.86	0.86	0.00	0.85	0.84	0.85	0.85	0.85
4	Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Pakistan	0.82	0.00	0.86	0.00	0.93	0.82	0.00	0.80	0.80	0.80	0.80	0.83
6	Sri Lanka	0.90	0.00	0.86	0.00	0.82	0.90	0.00	0.91	0.91	0.91	0.91	0.87
7	Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Indonesia	0.89	0.00	0.85	0.00	0.80	0.91	0.00	0.94	0.97	0.95	0.94	0.87
9	Cambodia	0.88	0.00	0.84	0.00	0.80	0.91	0.00	0.97	1.00	0.97	0.97	0.87
10	Laos, PDR	0.89	0.00	0.85	0.00	0.80	0.91	0.00	0.95	0.97	0.95	0.95	0.87
11	Philippines	0.89	0.00	0.85	0.00	0.80	0.91	0.00	0.94	0.97	0.95	0.94	0.87
12	Vietnam	0.86	0.00	0.85	0.00	0.83	0.87	0.00	0.87	0.87	0.87	0.87	0.86
13	Malaysia	0.89	0.00	0.86	0.00	0.82	0.91	0.00	0.95	0.97	0.95	0.95	0.88
14	Thailand	0.89	0.00	0.86	0.00	0.81	0.90	0.00	0.92	0.93	0.92	0.92	0.87
15	China	0.84	0.00	0.86	0.00	0.86	0.86	0.00	0.88	0.89	0.88	0.88	0.87
16	Papua New Guinea	0.88	0.00	0.84	0.00	0.80	0.91	0.00	0.97	1.00	0.97	0.97	0.87

[a] Note that, in most cases, the spillover coefficient is less than 1. Even within a particular country, the spillover coefficient may be less than 1. This is because spillovers are determined on a *zonal* basis. Therefore, even within, say, Bangladesh, the spillover coefficient is 0.9. On the same logic, a spillover between countries can be higher than within a country (e.g. compare Lao spilovers to Cambodia with Lao spillovers within Lao).

In the target country, the cost reduction is equal to 5% of the initial equilibrium price, whereas in the non-target country it is equal to the spillovers coefficient times 5% of the initial equilibrium price. The maximum cost reduction in the non-target country is given by the cost reduction achievable in the target country. This would happen if the spillover coefficient is equal to 1, implying that the technology developed in the target country is perfectly transferable to the non-target country. The lowest cost-reduction for a non-target country is zero. This would be the case if the spillovers coefficient for the country is zero.

The choice of a 5% cost reduction is arbitrary. The actual percentage shift used in the analysis is not important, because the aim is to develop a ranking of commodities as opposed to absolute values of potential benefits. The choice of a particular percentage cost reduction, while it changes the absolute values of potential benefits from research, does not change the relativities between commodities.

3.2.11 Other parameters

The other significant parameters that have not yet been discussed are: the discount rate, the research lag, and the time to maximum or ceiling adoption. The analysis uses a discount rate of 8% as recommended by Department of Finance (1991) guidelines. It is assumed that, in the country where the research is undertaken, it takes about 8 years from the start of the project before there is any adoption. However, in countries where the benefit is through spillover effects, it is assumed that it takes about 12 years before any adoption takes place. To reach maximum adoption it is assumed that it takes 11 years from the start of the project in the research country and 15 years in the spillovers country[5]. These parameters are common to all the commodities.

3.2.12 Parameters for modifying estimated research benefits that can be activated in the model

Three parameters can be used to modify the estimated research benefits:

- the NARS's capacity to undertake strategic research;
- the NARS's capacity to undertake applied research; and
- the NARS's capacity to adopt research results.

Data on these modifiers were collected as part of this study, but for reasons given earlier the modifiers were not used in this analysis. They tended to introduce an unnecessary layer of subjectivity that reduced the transparency of the estimates. Nonetheless, the rest of the section describes briefly a process that was used in the compilation of the data.

Capacity to undertake strategic research

Strategic research is defined as research undertaken primarily to advance knowledge or to broaden the base of knowledge necessary for the solution of recognised practical problems. The capacity to undertake strategic research can depend on a range of factors, including, for example:

- the international level of knowledge, appropriate to the particular production environment, of the issue being researched;

5 The assumption of 3 years from the start of adoption to the ceiling adoption is based on Davis et al. (1987). This assumption may be optimistic; e.g. in Australia this may be the minimum adoption lag for most periods.

- the capacity of the research group to address the research issues;
- the facilities and resources available to the group;
- the potential research impact required or expected; and
- a country's resources available to undertake research on a particular agricultural commodity; e.g. the numbers and quality of research scientists and extension staff in each country, the level and quality of laboratory facilities etc.

Quantification of the capacity to undertake strategic research can be complex. It can be measured as a simple 0–1 index or as a probability distribution.

Capacity to undertake applied research

Applied research includes research that builds upon existing research results to develop appropriate technologies with a specific application. In past studies (e.g. Davis et al. 1987) each country was scored from 0 to 1, where 0 means the country has no capacity to undertake research, and 1 means that country has a very strong capacity to undertake research.

As there may not be significant differences in a country's ability to undertake research on closely related commodities, similar commodities were grouped together. For example, in the case of fruits and vegetables, a country's ability to undertake applied research on oranges and tangerines may be very similar.

Where possible, data on numbers and quality of scientists and laboratory facilities were used in the development of these qualitative indicators (e.g. White 1998). It is important to note that these indicators are used to rank the different countries and regions in terms of capacity for research.

In the case of fruits and vegetables, the estimates provided by experts about the strategic and the applied research capacity and capability of individual countries/regions for each commodity varied considerably. The variation may have been an outcome of the small number of estimates received from individuals for crop/country combination, or because individual experts used different scales to assess the research capability and capacity of an individual country.

Because of the high level of variation in estimates, the average value of individual estimates was seen to be an unreliable representation of the research capacity and capability of each country or region for the horticultural crops.

In the case of horticultural crops, an assessment over the whole system was made of the base research capacity and capability for each country across all commodities. Data from various organisations were used to create an index for each country/region. Data sources included:

- International Service for National Agricultural Research;
- CAB International;
- FAO; and
- World Health Organization.

This assessment was then used to produce estimates, for strategic and applied research, of research capacity and capability for each of the countries and regions.

In the case of horticultural crops, these indices, as well as the estimates by experts, were then taken into consideration by the consultancy team in forming a base estimate across all commodities for each country/region.

Adjustments were then made to indices for specific country/crop combinations based upon estimates provided by recognised experts for particular crops or countries. These adjustments were based on the relativities between countries for a series of specific crops, and relativities between crops for a series of specific countries, made by these recognised experts.

The estimates provided by experts and the final set of data on ability to conduct strategic and applied research, by country and commodity, indicated that the research capacity and capability for strategic research is lower than that for applied research, but this gap narrowed with higher levels of research capacities and capabilities.

Adoption patterns

The eventual level of welfare gains will depend on how long the research is likely to take. The length of the research lag becomes important. Once a technology is developed from the research knowledge, farmers must use it before it can begin to benefit community welfare. This adoption dimension can be quite complex. However, lack of adoption by farmers is often in fact an indication that the technology developed is not applicable or is irrelevant to many farmers. The technology may not be lower cost than existing technologies if the research was originally developed for a different production environment. Important aspects of adoption are:

- the length of the lag between the completion of the research or even development of the final technology and the commencement of adoption. It often takes some time for farmers to become aware of the technology, receive supplies of some aspects of it, or test it on a small scale to check for and site specific problems;
- the rate of adoption for a particular production environment; and
- the eventual ceiling level of adoption. Even if the technology is applicable there will usually be some farmers who never adopt it.

To estimate, for each commodity, the highest proportion of producers in a given country who are likely to adopt a technology, an ordinal ranking is made of countries on the basis of their ability to adopt research results. This ranking could be based on published results from technology adoption studies or on expert opinion. This information refers to the levels of maximum adoption of research outputs that are likely for each commodity in each country. This is equivalent to a 'ceiling adoption level'. Each country/commodity was scored from 0 to 1, where 1 is equivalent to 100% adoption of a new technology, and 0 is equivalent to no adoption of a new technology.

Fruits and vegetables

Factors influencing the maximum adoption level include the culture of producers (i.e. progressive or passive), the extent and efficacy of extension efforts, and the effectiveness of communication networks among producers. There was significant variation between estimates provided by individual horticultural experts about the maximum level of adoption of research outputs for each country/crop combination.

4. RESEARCH PRIORITIES — A SYNTHESIS BY COUNTRY

This section presents a summary of the results from an analysis of agricultural priorities in selected counties. The results are quantitative, though they are presented in tabular and graphic format to make them clearer. The section is divided into three sub-sections as follows:

- Section 4.1 discusses the detailed results for Uganda, one of the countries included in the analysis. The selection of the country to discuss in this sub-section is arbitrary. The aim of the sub-section is to give an indication of the nature of results summarised elsewhere in the monograph.
- Section 4.2 presents a summary of results on agricultural research priorities based on benefits *with* spillovers.
- Section 4.3 uses results for the South Pacific region to comment on how agricultural research priorities based on benefits *without* spillovers may differ from the priorities based on benefits *with* spillovers.

4.1 A detailed discussion of results for one country

Table 11 shows the detailed estimates for Uganda. Because of space constraints it is not possible to provide detailed results for all the countries included in the analysis[6]. Table 11 is an example of the results from the analysis using the *Spillovers* model. For each country, the results are given in two parts:

- One set of results, in columns C1–C5 in Table 11, refers to benefits estimated to accrue to Uganda, *without* spillovers to sub-Sahara Africa, from research targeted at Uganda.
- Another set of results, in columns C6–C10 in Table 11, refer to benefits estimated to accrue to Uganda, *plus spillovers* to sub-Saharan Africa, from research targeted at Uganda.

The rest of this sub-section describes the different columns in Table 11.

Column 1

Column 1 shows the ranking, in descending order, of the sizes of potential research benefits estimated to accrue to Uganda, *without* spillovers to sub-Saharan Africa, from research in Uganda targeting the different commodities. The last number in column 1 shows the total number of commodities included in the analysis for the selected country. For Uganda this is 48, which is the number of commodities for which FAO holds production and consumption data for Uganda. Appendix C shows the total number of commodities (145) in ACIAR's information system.

Usually, the smaller the country the smaller the number of commodities for which FAO holds full data sets. To overcome the problem of incompleteness in the FAO data sets, ACIAR has embarked on a joint project with the International Food Policy Research Institute (IFPRI). One of the objectives of this project is to develop new methods to enable the supplementation of FAO data sets with national data holdings of official and unofficial statistics on various commodities of interest.

Column 2

This column gives the names of the different commodities in order of the research benefits estimated to accrue to Uganda, *without* spillovers to sub-Saharan Africa, from research targeted at Uganda.

6 The detailed results are available in spreadsheet form on the disk attached to the back cover of this paper.

Column 3

This column gives the net present value of benefits estimated to accrue to Uganda, *without* spillovers to sub-Saharan Africa, from research targeted at Uganda. These estimates exclude both price spillovers and technical spillovers of research. The estimates are in Australian dollars (A$), over a 30-year period, discounted at 8%, and are arranged in descending order.

For each commodity, the estimates in column 3 cover only those benefits accruing to the country targeted by research, in this instance Uganda. The estimates in Column 3 exclude benefits accruing to countries other than the target country.

The motivation for the exclusion of these other benefits from estimates in column 3 was to arrive at an estimate which could be the basis for decision-making for a government or a national agricultural research system whose objective is to maximise *national* benefits from agricultural research. The ranking of commodities in column 3 answers the following question:

> What is the best commodity to invest in if a funding agency wants to maximise economic surplus (*without* spillovers) to a national agricultural research system from agricultural research?

In Table 11, cassava is the commodity at the top of the list with potential benefits estimated to accrue to Uganda, *without* spillovers to sub-Saharan Africa, from research targeted at Uganda. equal to about A$191m. Cassava is the yardstick or benchmark commodity for Uganda in the determination of agricultural research priorities. Different countries have different yardstick or benchmark commodities. In Asia, for example, rice is often the yardstick commodity.

Column 4

In column 4, the priority groupings of the different commodities are shown. In ACIAR, priorities are expressed using an index whose value is 1 for the commodities of the highest priority and 6 for the lowest priority. The six priority groups in Table 12 have proven useful in making 'big picture' allocations of research resources.

The cut-off points for the different priority groups are arbitrary. To counter this, it is now standard practice at ACIAR to report both the priority group and the estimates, in dollar terms, of potential benefits.

The description of the priority groups in this monograph is based on the parameters in the shaded column of Table 12. These descriptions of the priority groups are different from their historical definitions (see e.g. Lubulwa et al. 1996) also shown in Table 12. Thus care needs to be exercised in comparing the results in this monograph to earlier priority assessments.

The following six groups are used in the monograph:

Columns 5 to 8 relate to priorities based on benefits estimated to accrue to Uganda, *plus spillovers* to sub-Saharan Africa, from research targeted at Uganda[7]. The information in these columns is very similar to the information in columns 1 to 5.

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7 Benefits are estimated from the viewpoint of the target country. Changing the target country varies the benefits to the target country, the region with respect to which spillovers are computed, and the magnitude of the spillovers.

Column 5
Column 5 shows the ranking, in descending order of the magnitude, of potential research benefits estimated to accrue to Uganda, *plus spillovers* to sub-Saharan Africa, from research targeted at Uganda, of the different commodities. The difference between column 3 and Column 6 is that the ranking in Column 6 is based on benefits *with* spillovers.

Column 6
This column gives the names of the different commodities in order of the benefits estimated to accrue to Uganda, *plus spillovers* to sub-Saharan Africa, from research targeted at Uganda. In the case of Uganda, the yardstick commodity does not change whether one uses benefits with or without spillovers, but this is not always the case. In Table 11, while the yardstick commodity has not changed, the ordering of the other commodities has changed. Sweet potato that was number 2 in column 2, is number 26 when priorities are based on benefits estimated to accrue to Uganda, *plus spillovers* to sub-Saharan Africa, from research targeted at Uganda. Fuel wood – non-coniferous, which was number 3 in column 2, is number 2 in column 6. Coffee, which was number 4 in column 2, is number 22 in column 6. Beef moves up the priority list when spillovers are included, while bananas do not change from their number 5 position. Other changes can be observed in the ordering of commodities.

The general result is that the overall ranking of commodities based on benefits to the target country alone *without* spillovers, is different from the ordering of the same commodities based on benefits estimated to accrue to the target, *plus spillovers* to the relevant region, from research in the target country.

Column 7
This column gives the total of the benefits estimated to accrue to Uganda as shown in column 3, *plus spillovers* to sub-Saharan Africa, from research targeted at Uganda. The estimates in column 6 also include world price effects of research. In the *Spillovers* model, for a traded commodity (say rice), when research leads to a cost reduction for a large trading country in the production costs of the commodity, this in turn leads to lower prices in the rest of the world. This reduction in the world price normally benefits importers of the commodity, who can get it at a lower price.

Second, the estimates in Column 7 include spillovers that may accrue to countries that have similar agro-climatic conditions to Uganda. These countries are potential beneficiaries from research and technology that is developed in Uganda. Such technologies can be transferred to those countries through research spillovers. The spillovers are assumed to occur within well-defined regions. These regions are defined in Appendix B. In the case of Uganda, the spillovers accrue to sub-Saharan African countries. The *Spillovers* model routinely computes spillovers for a given commodity on the basis of agro-climatic similarity between the target country and the benefiting non-target countries. However, for purposes of determining priorities, only spillovers to non-target countries in the same region as the target country are included in the calculation of spillovers.

Generally, for a given commodity, benefits estimated to accrue to a target country, *plus spillovers* to the relevant region, from research targeted at the target country, are larger than benefits to the target country alone *without* spillovers.

Column 8

Column 8 shows the priority ranking of commodities based on the total benefits estimated to accrue to Uganda, *plus spillovers* to sub-Saharan Africa, from research targeted at Uganda. Though the benchmark commodity in Uganda is the same with and without spillovers, the ranking of many other commodities varies. This is because a number of changes occur when one includes spillovers associated with different commodities:

- the total benefit from the benchmark commodity changes;
- because the opportunities for agro-climatic spillovers of technology are different for different commodities, the total benefits *with* spillovers for the different commodities differ from the total benefits *without* spillovers;
- the changes in the total benefits lead to changes in the research opportunity costs for different commodities; and
- this, in turn, leads to changes in the ranking, and thus in the priority, of different commodities.

This section has focused on results for one country. It has used those results to discuss the features common to results for the 42 countries or regions included in the analysis. The details of the individual country results are available from ACIAR. In the next section, results on priorities based on benefits estimated to accrue to a target country, *plus spillovers* to the relevant region, from research in the target country, are considered in more detail.

4.2 Agricultural research priorities based on potential benefits *with* spillovers

Here we consider agricultural research priorities based on potential benefits to the target country *plus spillovers* to non-target countries in the region.

This section provides a summary of the ranking of the top 20 commodities for the countries included in the analysis. It is not possible to present results on the 108 commodity analyses undertaken for all of the countries or regions included in the sample. The summary uses Figures 13–17 to provide a listing of the top 20 commodities where:

- Figure 13 shows a listing of the top 20 commodities in South Asia based on benefits estimated to accrue to a target country, *plus spillovers* to the South Asian region, from research in the target country;
- Figure 14 shows a listing of the top 20 commodities in Southeast Asia based on benefits estimated to accrue to a target country, *plus spillovers* to the Southeast Asian region, from research in the target country;
- Figure 15 shows a listing of the top 20 commodities in Australia and China based on benefits estimated to accrue to Australia and China, respectively;
- Figure 16 shows a listing of the top 20 commodities in PNG and the South Pacific based on benefits estimated to accrue to a target country, *plus spillovers* to the PNG and the South Pacific region, from research in the target country; and
- Figure 17 shows a listing of the top 20 commodities in Africa based on benefits estimated to accrue to a target country, *plus spillovers* to the sub-Saharan region of Africa, from research in the target country.

The detailed numbers on which the different summary figures are based are available on disk at the end of this paper.

Table 11. Detailed results for Uganda

C1	C2	C3	C4	C5	C6	C7	C8
No		National benefits (net present value) to Uganda *without* spillovers to sub-Sahara Africa from research targeting Uganda A$m 1994	Priorities based on benefits to Uganda *without* spillovers to sub-Sahara Africa	No	Commodities	National benefits (net present value) to Uganda *with* spillovers to sub-Sahara Africa from research targeting Uganda A$m 1994	Priorities based on benefits to Uganda *with* spillovers to sub-Sahara Africa from research targeting Uganda
1	Root crops – Cassava	191.4	1	1	Root crops –Cassava	2450.5	1
2	Root crops –Sweet potato	156.3	1	2	Forestry – Fuel wood – non-coniferous	1439.6	1
3	Forestry – Fuel wood – non-coniferous	131.8	1	3	Animal –Beef –health	601.1	2
4	Industrial crops – Coffee	119.8	1	4	Animal –Beef – postharvest	601.1	2
5	Fruit –Bananas and plantains – postharvest	97.3	1	5	Fruit – Bananas and plantains – preharvest	515.4	2
6	Fruit – Bananas and plantains – pre-harvest	97.3	1	6	Fruit – Bananas and plantains – postharvest	512.5	2
7	Pulses – Pulses – General	41.6	2	7	Animal – Beef – breeding, grazing and stocking rate options	500.8	2
8	Grain – Maize	38.7	2	8	Industrial crops – Cotton	475.2	2
9	Animal – Beef – agronomy	35.0	2	9	Animal – Cows milk – health	454.3	2
10	Animal – Beef – breeding, grazing and stocking rate options	35.0	2	10	Grain – Rice – husked equivalent	443.4	2
11	Animal – Beef – health	35.0	2	11	Grain – Maize	441.2	2
12	Animal – Beef – postharvest	35.0	2	12	Animal – Cows milk – postharvest	438.1	2
13	Animal – Pig meat – breeding and stocking rate options	31.0	2	13	Animal – Beef – agronomy	432.4	2
14	Animal – Pig meat – health	31.0	2	14	Animal – Sheep and goat meat – breeding, stocking rate and grazing options	406.2	2

Table 11. (cont'd) Detailed results for Uganda

C1	C2	C3	C4	C5	C6	C7	C8
No		National benefits (net present value) to Uganda *without* spillovers to sub-Sahara Africa from research targeting Uganda A$m 1994	Priorities based on benefits to Uganda *without* spillovers to sub-Sahara Africa	No	Commodities	National benefits (net present value) to Uganda *with* spillovers to sub-Sahara Africa from research targeting Uganda A$m 1994	Priorities based on benefits to Uganda *with* spillovers to sub-Sahara Africa from research targeting Uganda
15	Animal – Pig meat – postharvest	31.0	2	15	Animal – Sheep and goat meat – postharvest	406.2	2
16	Fish – Tilapias and other cichlids	30.5	2	16	Animal – Sheep and goat meat – postharvest	406.2	2
17	Animal – Cows milk – agronomy	29.5	2	17	Animal – Cows milk – breeding, grazing and stocking rates	385.6	2
18	Animal – Cows milk – breeding, grazing and stocking rates	29.5	2	18	Industrial crops – Cocoa	357.9	2
19	Animal – Cows milk – health	29.5	2	19	Animal – Cows milk – agronomy	337.3	2
20	Animal – Cows milk – postharvest	29.5	2	20	Animal – Sheep and goat meat – agronomy	302.5	2
21	Industrial crops – Sugar	27.0	2	21	Animal – Pig meat – health	298.9	2
22	Fish – Miscellaneous diadromous	21.6	2	22	Industrial crops – Coffee	289.5	2
23	Grain – Millet	20.6	3	23	Animal – Pig meat – postharvest	281.5	2
24	Forestry – Other industrial round wood	20.2	3	24	Animal – Pig meat – breeding and stocking rate options	278.4	2
25	Vegetable – Potato	19.5	3	25	Industrial crops – Sugar	253.4	3
26	Industrial crops – Cotton	16.9	3	26	Root crops – Sweet potato	241.4	3
27	Animal – Sheep and goat meat – agronomy	14.3	3	27	Forestry – Charcoal	160.9	3
28	Animal – Sheep and goat meat – breeding, stocking rate and grazing options	14.3	3	28	Animal – Poultry meat – health	155.6	3
29	Animal – Sheep and goat meat – postharvest	14.3	3	29	Animal – Poultry meat – postharvest	144.0	3

Table 11. (cont'd) Detailed results for Uganda

C1	C2	C3	C4	C5	C6	C7	C8
No		National benefits (net present value) to Uganda *without* spillovers to sub-Sahara Africa from research targeting Uganda A$m 1994	Priorities based on benefits to Uganda *without* spillovers to sub-Sahara Africa	No	Commodities	National benefits (net present value) to Uganda *with* spillovers to sub-Sahara Africa from research targeting Uganda A$m 1994	Priorities based on benefits to Uganda *with* spillovers to sub-Sahara Africa from research targeting Uganda
30	Animal – Sheep and goat meat – postharvest	14.3	3	30	Animal – Poultry meat – breeding and stocking rate options	141.0	3
31	Grain – Sorghum	10.4	3	31	Pulses – Pulses – General	139.7	3
32	Grain – Rice – husked equivalent	8.9	3	32	Animal – Poultry eggs – health	137.2	3
33	Forestry – Charcoal	7.2	3	33	Animal – Poultry eggs – postharvest	134.7	3
34	Animal – Poultry meat – breeding and stocking rate options	6.5	4	34	Forestry – Saw logs and veneer logs – non-coniferous	125.2	3
35	Animal – Poultry meat – health	6.5	4	35	Animal – Poultry eggs – breeding and stocking rate options	121.5	3
36	Animal – Poultry meat – postharvest	6.5	4	36	Grain – Millet	100.6	3
37	Pulses – Soybeans	4.5	4	37	Forestry – Other industrial round wood	98.1	3
38	Animal – Poultry eggs – breeding and stocking rate options	3.2	4	38	Vegetable – Potato	61.3	4
39	Animal – Poultry eggs – health	3.2	4	39	Grain – Sorghum	60.9	4
40	Animal – Poultry eggs – postharvest	3.2	4	40	Fish – Tilapias and other cichlids	59.3	4
41	Forestry – Saw logs and veneer logs – non-coniferous	2.1	5	41	Fish – Miscellaneous diadromous	54.2	4
42	Nuts – Groundnuts	1.5	5	42	Forestry – Saw logs and veneer logs – coniferous	19.2	5
43	Vegetable – Tomatoes – postharvest	1.1	5	43	Grain – Wheat	19.2	5

Table 11. (cont'd) Detailed results for Uganda

C1	C2	C3	C4	C5	C6	C7	C8
No		National benefits (net present value) to Uganda *without* spillovers to sub-Sahara Africa from research targeting Uganda A$m 1994	Priorities based on benefits to Uganda *without* spillovers to sub-Sahara Africa	No	Commodities	National benefits (net present value) to Uganda *with* spillovers to sub-Sahara Africa from research targeting Uganda A$m 1994	Priorities based on benefits to Uganda *with* spillovers to sub-Sahara Africa from research targeting Uganda
44	Vegetable – Tomatoes – pre-harvest	1.1	5	44	Nuts – Groundnuts	17.3	5
45	Forestry – Saw logs and veneer logs – coniferous	1.1	5	45	Pulses – Soybeans	11.0	5
46	Grain – Wheat	0.6	6	46	Fish – Carps, barbels and other cyprinids	1.7	6
47	Industrial crops – Cocoa	0.3	6	47	Vegetable – Tomatoes – postharvest	1.1	6
48	Fish – Carps, barbels and other cyprinids	0.1	6	48	Vegetable – Tomatoes – pre-harvest	1.1	6

Table 12. Priority groupings and their cut-off points applied to all countries

Priority grouping	Economic benefit levels for classification into commodity groups in this monograph	Economic benefit levels for classification into priority groups in earlier ACIAR studies	Description of the priority grouping
1	1 ≥ break-even value ≥ 1/3	1 ≥ break-even value ≥ 1/10	Very high
2	1/3 ≥ break-even value ≥ 1/9	1/10 ≥ break-even value ≥ 1/20	High
3	1/9 ≥ break-even value ≥ 1/27	1/20 ≥ break-even value ≥ 1/40	Medium-1
4	1/27 ≥ break-even value ≥ 1/81	1/40 ≥ break-even value ≥ 1/80	Medium-2
5	1/81 ≥ break-even value ≥ 1/243	1/80 ≥ break-even value ≥ 1/160	Low
6	1/243< break-even value	1/160 ≥ break-even value	Very Low

Figure 13: South Asia
In Figure 13 for three of the South Asian countries—Bangladesh, India and Sri Lanka—rice is the benchmark commodity. In two of the countries where rice is not the benchmark commodity, it is a close number 2. Bhutan is an exception: there the yardstick commodity is buffalo milk. For all of the countries in Figure 13 an industrial crop appears in the top five commodities.

Figure 14: Southeast Asia
Figure 14 summarises the priority ranking of the top 20 commodities in the Southeast Asian region. The benchmark commodity in this region is rice. It is the commodity with the highest potential benefit for all the countries in Southeast Asia, except Malaysia, but even there it comes a very close second. In all the countries in the Southeast Asian region, forest products (particularly fuel wood) fall in the very high to high priority category.

Figure 15: Australia and China
For the purposes of this analysis, China and Australia are treated as regions. In Figure 15, wheat is the yardstick commodity for Australia when one considers benefits *with* spillovers. For China, rice is the benchmark commodity. In each of the countries in Figure 15, an industrial crop appears amongst the top five commodities.

Figure 16: Papua New Guinea and the South Pacific
Figure 16 summarises the commodity ranking of the top 20 commodities in each of the countries in the South Pacific region. The most common yardstick or benchmark commodity is bananas and plantains. Five of the countries in the region are estimated to have the highest benefits arising from research affecting bananas and plantains. Sugar is the most important crop in Fiji, while palm oil is estimated to yield the highest potential benefits from research in Solomon Islands.

Figure 17: Africa
Figure 17 summarises the ranking of commodities in the sub-Saharan region. The most common benchmark commodity in Africa is fuel wood non-coniferous. Of 17 regions/countries covered in Figure 17, 14 of them have fuel wood as the commodity which is likely to generate the highest potential benefits from agricultural research. In the case of Uganda, where cassava is the benchmark, fuel wood non-coniferous is a very close second.

Figure 13. A priority listing of 20 commodities based on the potential benefits to each target country[a] *plus spillovers*[b], to all non-target countries in the South Asian region[c], arising from research in the target country.

No	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
1	Rice	Buffalo milk	Rice	Sugar	Cotton	Rice
2	Buffalo milk	Cows milk	Sugar	Rice	Rice	Sugar
3	Sugar	Fuel wood – non coniferous	Wheat	Buffalo milk	Wheat	Mango
4	Mango	Oranges and tangerines	Cotton	Cows milk	Sugar	Buffalo milk
5	Cows milk	Wheat	Fuel wood	Wheat	Buffalo milk	Cows milk
6	Fuel wood	Beef	Buffalo milk	Fuel wood	Mango	Fuel wood
7	Cotton	Poultry eggs	Cows milk	Pulses – general	Cows milk	Oranges and tangerines
8	Bananas	Pig meat	Mango	Sheep and goats	Bananas	Pulses – general
9	Wheat	Saw and veneer logs – non coniferous	Banana	Beef	Pulses – general	Cashew nuts
10	Beef	Maize	Pulses – general	Buffalo meat	Oranges and tangerines	Beef
11	Oranges and tangerines	Other industrial round wood	Lobsters	Potato	Sheep/goat	Sheep/goat
12	Sheep and goats	Saw and veneer logs – coniferous	Potato	Rapeseed	Fuel wood – non coniferous	Tomato
13	Cashew nuts	Egg plant and green peppers	Oranges and tangerines	Poultry eggs	Beef	Potato
14	Tomato	Sugar	Beef	Maize	Tomato	Buffalo meat
15	Buffalo meat		Cashew nut	Pig meat	Rapeseed	Cabbages
16	Pulses – general		Sheep/goat	Poultry meat	Buffalo meat	Coconut
17	Cabbage		Rapeseed	Saw and veneer logs – non coniferous	Potato	Poultry eggs
18	Poultry eggs		Maize	Wool	Cabbage	Rapeseed
19	Coconut		Tomato	Millet	Poultry eggs	Cucurbits
20	Potato		Groundnuts	Fish – carp	Maize	Pig meat

a. In this figure each column shows the priority listing of commodities for the target country shown at the top of the column.

b. *Spillover* model estimates of benefits for a given target country on the assumption that research funds invested in the target country are enough to lead to a 5% cost reduction in the target country, in the first instance. In addition, in non-target countries in the region research leads to cost reductions equal to the initial 5% cost reduction times the corresponding spillover coefficient. The spillover coefficients differ by country. This footnote applies to Figures 13–17.

c. The South Asian region is defined to include Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka. This definition of South Asia is in line with Davis et al. (1987). Spillovers are constrained to occur within the South Asia region. While *Spillovers* computes global spillovers as well, the results reported here are based on within region spillovers which are more conservative than global spillovers and are based on less heroic assumptions. The 3rd sentence of this footnote applies to Figures 13–17.

Key

	Very high priority – Group 1
.	High priority – Group 2
	Medium priority – Groups 3 & 4
	Low priority – Groups 5 & 6

Figure 14. A priority listing of 20 commodities based on the potential benefits to each target country[a] *plus spillovers*, to all non-target countries in the Southeast Asian region[b], arising from research in the target country.

No	Cambodia	Lao PDR	Myanmar	Indonesia	Philippines	Vietnam	Malaysia	Thailand
1	Rice	Rice	Rice	Rice	Rice	Rice	Palm oil	Rice
2	Fuel wood – non coniferous	Fuel wood – non coniferous	Sugar	Palm oil	Sugar	Sugar	Rice	Sugar
3	Bananas	Bananas	Fuel wood – non coniferous	Fuel wood– non coniferous	Fuel wood – non coniferous	Fuel wood – non coniferous	Saw and veneer logs –non coniferous	Palm oil
4	Rubber	Pig meat	Pig meat	Sugar	Palm oil	Bananas	Fuel wood – non coniferous	Fuel wood – non coniferous
5	Saw and veneer logs –non coniferous	Saw and veneer logs	Saw and veneer logs	Saw and veneer logs	Bananas	Rubber	Sugar	Rubber
6	Pineapple	Pineapples	Rubber	Bananas	Saw and veneer logs – non coniferous	Saw and veneer logs	Rubber	Bananas and plantain
7	Maize	Maize	Cassava	Rubber	Pig meat	Pineapple	Bananas and plantain	Pig meat
8	Cassava	Poultry meat	Poultry meat	Pig meat	Rubber	Pig meat	Pig meat	Saw and veneer logs
9	Poultry meat	Cassava	Coconut	Coconut	Coconut	Coconut	Pineapples	Pineapples
10	Coconut	Mango	Maize	Maize	Pineapple	Maize	Coconut	Maize
11	Mango	Poultry eggs	Poultry eggs	Pineapple	Maize	Poultry meat	Poultry meat	Coconut
12	Poultry eggs	Beef	Beef	Cassava	Poultry meat	Cassava	Poultry eggs	Poultry meat
13	Beef	Oranges and tangerines	Pulses – general	Coffee	Cassava	Cashew nuts	Mango	Cassava
14	Oranges and tangerines	Sweet potato	Sweet potato	Poultry meat	Mango	Sweet potato	Cashew nuts	Mango
15	Sweet potato	Tilapia	Cotton	Mango	Poultry eggs	Mango	Cassava	Poultry eggs
16	Pulses – general	Other industrial round wood	Sheep and goats	Poultry eggs	Beef	Poultry eggs	Cucurbits	Cucurbits
17	Tilapia	Buffalo meat	Other industrial round wood	Beef	Coffee	Coffee	Beef	Oranges and tangerines
18	Other industrial round wood	Cotton	Buffalo meat	Egg plant and green pepper	Cashew nuts	Beef	Oranges and tangerines	Cashew nuts
19	Buffalo meat	Ground nuts	Cows milk	Cashew nuts	Cucurbits	Oranges and tangerines	Coffee	Beef
20	Ground nuts	Charcoal	Soybean	Sweet potato	Sweet potato	Pulses – general	Papaya	Coffee

a. In this figure each column shows the priority listing of commodities for the target country shown at the top of the column.
b. The Southeast Asian region is defined to included Cambodia, Lao People's Democratic Republic, Myanmar, Indonesia, Philippines, Vietnam, Malaysia and Thailand. Spillovers are constrained to occur within the Southeast Asian region.

Key

(green)	Very high priority – Group 1
(purple) .	High priority – Group 2
(peach)	Medium priority – Groups 3 & 4
(white)	Low priority – Groups 5 & 6

Figure 15. A priority listing of 20 commodities based on the potential benefits to Australia[a] and China[b].

No	Australia	China
1	Wheat	Rice
2	Sugar	Pig meat
3	Wool	Sweet potato
4	Beef	Cotton
5	Cotton	Wheat
6	Cows milk	Maize
7	Sheep and goats	Cucurbits
8	Pulses – general	Eggplant and peppers
9	Pig meat	Cucumber
10	Oranges and tangerines	Potato
11	Rice	Poultry eggs
12	Saw and veneer logs – coniferous	Sugar
13	Saw and veneer logs – non coniferous	Oranges and tangerines
14	Poultry meat	Fuel wood – non coniferous
15	Potato	Poultry meat
16	Rapeseed	Beef
17	Peaches	Rapeseed
18	Lobsters	Soybean
19	Bananas and plantains	Cabbage
20	Tomato	Peaches

a. In this figure each column shows the priority listing of commodities for the target country shown at the top of the column.
b. In the analysis, China (because of its size) is treated as a self-contained region. The benefits to China do not include spillovers to other countries. Similarly Australia is treated as one region.

Key

	Very high priority – Group 1
.	High priority – Group 2
	Medium priority – Groups 3 & 4
	Low priority – Groups 5 & 6

Figure 16. A priority listing of 20 commodities based on the potential benefits to the each target country[a] *plus spillovers*, to all non-target countries in Papua New Guinea and the South Pacific region[b], arising from research in the target country.

No	PNG	Fiji	Samoa	Solomon Is.	Tonga	Vanuatu	Rest of South Pacific
1	Bananas	Sugar	Bananas	Palm oil	Bananas	Bananas	Bananas
2	Palm oil	Bananas	Saw and veneer logs – non coniferous	Saw and veneer logs – non coniferous	Saw and veneer logs – non coniferous	Saw and veneer logs – non coniferous	Saw and veneer logs – non coniferous
3	Fuel wood – non coniferous	Saw and veneer logs – non coniferous	Coconuts	Coconuts	Coconuts	Fuel wood – non coniferous	Coconut
4	Saw and veneer logs – non coniferous	Coconuts	Fuel wood – non coniferous	Fuel wood non coniferous	Sweet potato	Coconut	Sweet potato
5	Sugar	Fuel wood – non coniferous	Pig meat	Sweet potato	Saw and veneer logs – coniferous	Cocoa	Pig meat
6	Coffee	Sweet potato	Papaya	Cocoa	Cassava	Fish – tuna	Fish – tuna
7	Sweet potato	Pig meat	Pineapple	Fish – tuna	Pig meat	Saw and veneer logs – coniferous	Saw and veneer logs – coniferous
8	Coconuts	Fish – tuna	Mango	Cassava	Oranges and tangerines	Beef	Cows milk
9	Pig meat	Beef	Avocado	Pig meat	Water melon	Pig meat	Papaya
10	Cocoa	Cows milk	Cauliflower	Poultry eggs	Tomato	Cows milk	Fish – demersal
11	Beef	Saw and veneer logs – non coniferous	Beef	Water melon	Poultry eggs	Maize	Pineapple
12	Cassava	Rice	Cows milk	Cows milk	Groundnuts	Poultry eggs	Cassava
13	Saw and veneer logs – coniferous	Poultry meat	Other industrial round wood			Fish – mackerels	Beef
14	Pineapple	Fish – demersal	Poultry eggs			Fish – prawns	Mango
15	Poultry meat	Cassava				Groundnuts	Poultry eggs
16	Rice	Pineapple					Water melon
17	Rubber	Poultry eggs					Oranges and tangerines
18	Poultry eggs	Mango					Cucurbits
19	Fish – tilapia	Sheep and goats					Lobster
20	Lobsters	Cucurbits					Herrings

a. In this figure each column shows the priority listing of commodities for the target country shown at the top of the column.
b. The Papua New Guinea and South Pacific region is defined to include Papua New Guinea, Fiji, Samoa, Solomon Is, Tonga, Vanuatu, and 'Rest of south Pacific'. The Rest of South Pacific includes Christmas Is, Cocos Is, Cook Is., Guam, Kiribati, Nauru, New Caledonia, Niue, French Polynesia, American Samoa, Tokelau, Trust Territory Pacific, Tuvalu, Wallis and Fut, French Southern Territory, Marshall Is., Micronesia Federated States, North Mariana Is., Palau, Pitcairn and Wake Is.

Key

(green)	Very high priority – Group 1
. (purple)	High priority – Group 2
(peach)	Medium priority – Groups 3 & 4
(white)	Low priority – Groups 5 & 6

Figure 17. A priority listing of 20 commodities based on the potential benefits to each target country[a] *plus spillovers*, to all non-target countries in the sub-Saharan Africa region[b] arising from research in the target country.

Rank	Angola	Botswana	Lesotho	Malawi	Namibia	Mozambique	South Africa	Swaziland	Tanzania
1	Fuel wood – non coniferous	Fuelwood	Fuel wood – non coniferous	Fuel wood – non coniferous	Beef	Fuel wood – non coniferous	Beef	Fuel wood – non coniferous	Fuel wood – non coniferous
2	Cassava	Beef	Beef	Beef	Cows milk	Beef	Maize	Beef	Beef
3	Beef	Cows milk	Cows milk	Maize	Sheep and goats	Cassava	Fuel wood – non coniferous	Cows milk	Cotton
4	Bananas	Sheep and goats	Sheep and goat milk	Cows milk	Pig meat	Cotton	Cows milk	Bananas	Bananas
5	Cotton	Pig meat	Pig meat	Bananas	Poultry meat	Bananas	Sugar	Sugar	Cows milk
6	Cows milk	Oranges and tangerines	Poultry meat	Sugar	Maize	Cows milk	Bananas	Sheep and goat meat	Rice
7	Rice	Poultry meat	Poultry eggs	Rice	Poultry eggs	Maize	Sheep and goats	Pig meat	Maize
8	Maize	Maize	Wool	Cassava	Millet	Sheep and goats	Pig meat	Maize	Sheep and goats
9	Sheep and goats	Poultry eggs	Maize	Sheep and goat milk	Sorghum	Sugar	Orange and tangerines	Oranges and tangerines	Sugar
10	Cashew nuts	Millet	Wheat	Pig meat	Wool	Cashew nuts	Pulses – general	Pulses – general	Sugar
11	Pig meat	Other industrial round wood	Sorghum	Coffee	Fish – herrings	Rice	Poultry meat	Pineapples	Cocoa
12	Coffee	Sorghum	Pulses – general	Mango	Fish – tilapia	Pig meat	Pineapple	Poultry meat	Cassava
13	Palm oil	Pulses – general		Poultry meat	Fish – demersal	Pineapple	Cotton	Cotton	Cashew nuts
14	Pineapples	Fish – tilapia		Charcoal	Fish – tuna	Oranges and tangerines	Mango	Other industrial round wood	Pig meat
15	Charcoal	Cotton		Pulses – general	Fish – lobster	Mango	Poultry eggs	Poultry eggs	Coffee
16	Pulses – general	Wheat		Poultry eggs	Fish – mackerels	Poultry meat	Wheat	Potato	Palm oil
17	Poultry meat			Saw and veneer logs	Pulses – general	Charcoal	Cucurbits	Saw and veneer logs – coniferous	Pineapple
18	Sweet potato			Other industrial round wood	Wheat	Sweet potato	Wool	Groundnuts	Mango
19	Poultry eggs			Sorghum		Oranges and tangerines	Peaches	Pulpwood	Sweet potato
20	Millet			Potato		Poultry eggs	Papaya	Tomato	Poultry meat

a. In this figure each column shows the priority listing of commodities for the target country shown at the top of the column.
b. Sub-Saharan Africa includes all the countries in Africa south of the Sahara Desert.

Figure 17. (cont'd) A priority listing of 20 commodities based on the potential benefits to each target country[a] *plus spillovers*, to all non-target countries in the sub-Saharan Africa region[b] arising from research in the target country.

Rank	Zambia	Zimbabwe	Mauritius	Kenya	Uganda	Rest of Eastern Africa	Central Africa	West Africa	West Asia–North Africa
1	Fuelwood – non coniferous	Fuelwood – non coniferous	Fuel wood – non coniferous	Fuel wood – non coniferous	Cassava	Fuel wood – non coniferous	Fuel wood – non coniferous	Fuel wood – non coniferous	Wheat
2	Beef	Beef	Beef	Beef	Fuel wood – non coniferous	Beef	Cassava	Cassava	Oranges & Tangerines
3	Cotton	Cows milk	Bananas	Cows milk	Beef	Cassava	Beef	Cotton	Cotton
4	Maize	Maize	Cows milk	Bananas	Bananas	Rice	Cotton	Rice	Tomato
5	Cows milk	Bananas	Pig meat	Cassava	Cotton	Cows milk	Bananas	Maize	Cucurbits
6	Bananas	Sheep and goats	Egg plant and green peppers	Sheep and goats	Cows milk	Sheep and goats	Cows milk	Bananas	Cucumber
7	Sheep and goats	Cassava	Pineapple	Cotton	Rice	Sugar	Rice	Beef	Egg plant and green peppers
8	Cassava	Pig meat	Sugar	Maize	Maize	Cotton	Sheep and goats	Cows milk	Cows milk
9	Rice	Cotton	Poultry meat	Sugar	Sheep and goats	Bananas	Sugar	Sheep and goats	Potato
10	Pig meat	Sugar	Poultry eggs	Cashew nuts	Cocoa	Cocoa	Maize	Palm oil	Water melon
11	Sugar	Pulses – general	Other industrial round wood	Pig meat	Pig meat	Maize	Cocoa	Cocoa	Apricots
12	Pulses – general	Coffee	Cucurbits	Coffee	Coffee	Coffee	Pig meat	Egg plant and green peppers	Sheep / goat
13	Oranges and tangerines	Oranges and tangerines	Fish – tilapia	Oranges and tangerines	Sugar	Cashew nuts	Coffee	Sugar	Rice
14	Sweet potato	Poultry meat	Potato	Pineapple	Sweet potato	Pig meat	Palm oil	Cashew nuts	Rock melon and other melon
15	Poultry meat	Millet	Cabbage	Rice	Charcoal	Charcoal	Saw and veneer logs	Coffee	Pulses General
16	Millet	Poultry eggs	Saw and veneer logs	Charcoal	Poultry meat	Sweet potato	Charcoal	Pig meat	Beef
17	Charcoal	Charcoal	Coconut	Sweet potato	Pulses – general	Oranges and tangerines	Oranges and tangerines	Saw and veneer logs – non coniferous	Sugar
18	Poultry eggs	Sorghum	Fish – tuna	Poultry meat	Poultry eggs	Pineapple	Poultry meat	Millet	Maize
19	Sorghum	Saw and veneer logs	Fish – demersal	Poultry eggs	Millet	Pulses – general	Sweet potato	Sorghum	Poultry meat
20	Saw and veneer logs	Cucurbits	Fuel wood – coniferous	Pulses - general	Other industrial round wood	Poultry meat	Millet	Charcoal	Peaches

a. In this figure each column shows the priority listing of commodities for the target country shown at the top of the column.
b. Sub-Saharan Africa includes all the countries in Africa south of the Sahara desert.

4.3 A comparison between priorities based on potential benefits *without* spillovers and those based on potential benefits *with* spillovers

This sub-section compares the priorities based on benefits *without* spillovers with priorities based on benefits *with* spillovers. This comparison relates to two countries in the South Pacific region with the aim of indicating the divergences that might occur between priorities when they are assessed in these two different ways. The comparisons are presented in Figures 18 and 19

Figure 18: Papua New Guinea

Figure 18 summarises the comparison between *without* and *with* priorities for Papua New Guinea. In the case of Papua New Guinea, the region for computing spillovers is the South Pacific. Figure 18 shows that for PNG:

- most of the commodities fall in the shaded boxes. Thus, there is no major difference between the two priorities; and
- the priorities based on benefits *with* spillovers increase the importance of sugar, beef and poultry meat for PNG.

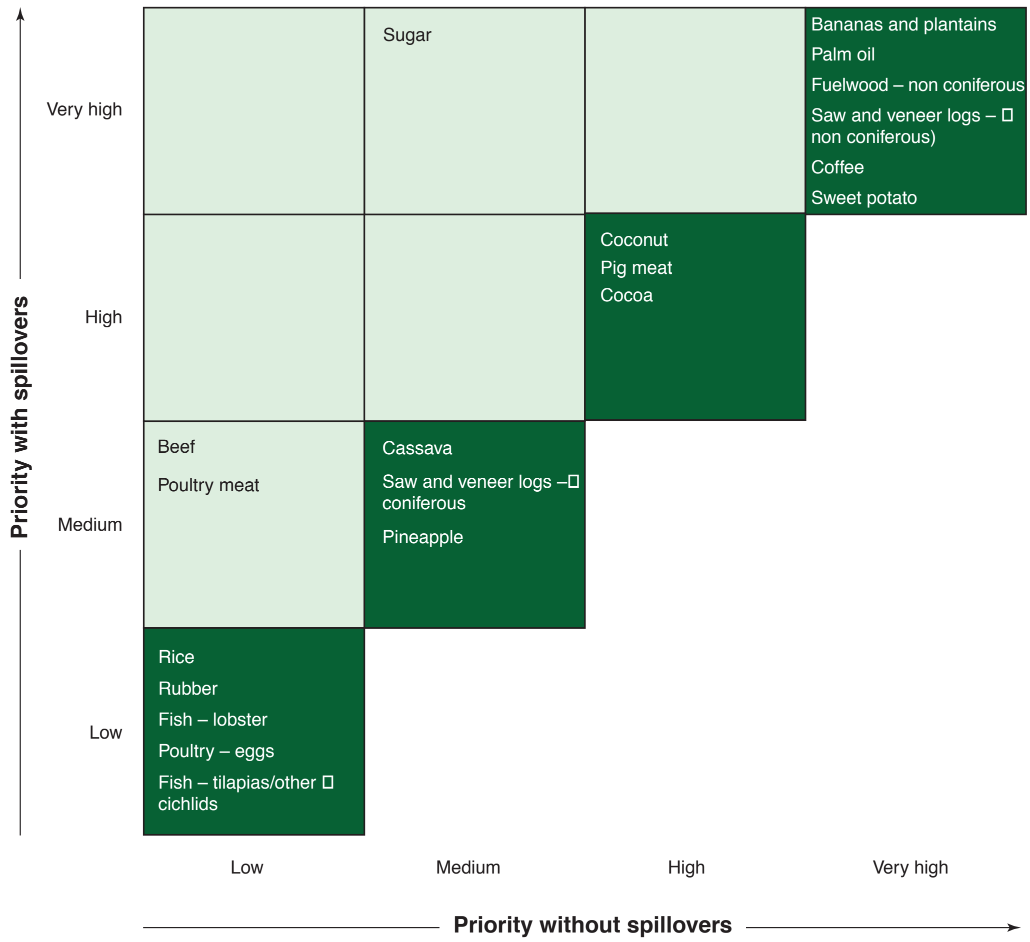


Figure 18. Papua New Guinea – Priorities of agricultural commodities based on benefits *with* spillovers compared to priorities based on benefits *without* spillovers. Commodities on the shaded diagonal have the same priority irrespective of whether or not one considers spillovers. Commodities that lie to the left of the shaded diagonal have higher priority when spillovers are considered. (Benefits *with* spillovers are higher than benefits *without* spillovers.)

Figure 19: Fiji

Figure 19 summarises the comparison between the two priorities for Fiji. The spillovers considered are spillovers to the South Pacific region. Figure 19 shows that for Fiji:

- the priorities for 10 commodities are the same whether one uses benefits with or without spillovers;
- the priorities based on benefits *with* spillovers increase the importance of nine commodities;
- the priorities based on benefits *with* spillovers do not understate the importance of any of the commodities. Thus, none of the commodities fall to the right of the shaded boxes in Figure 19.

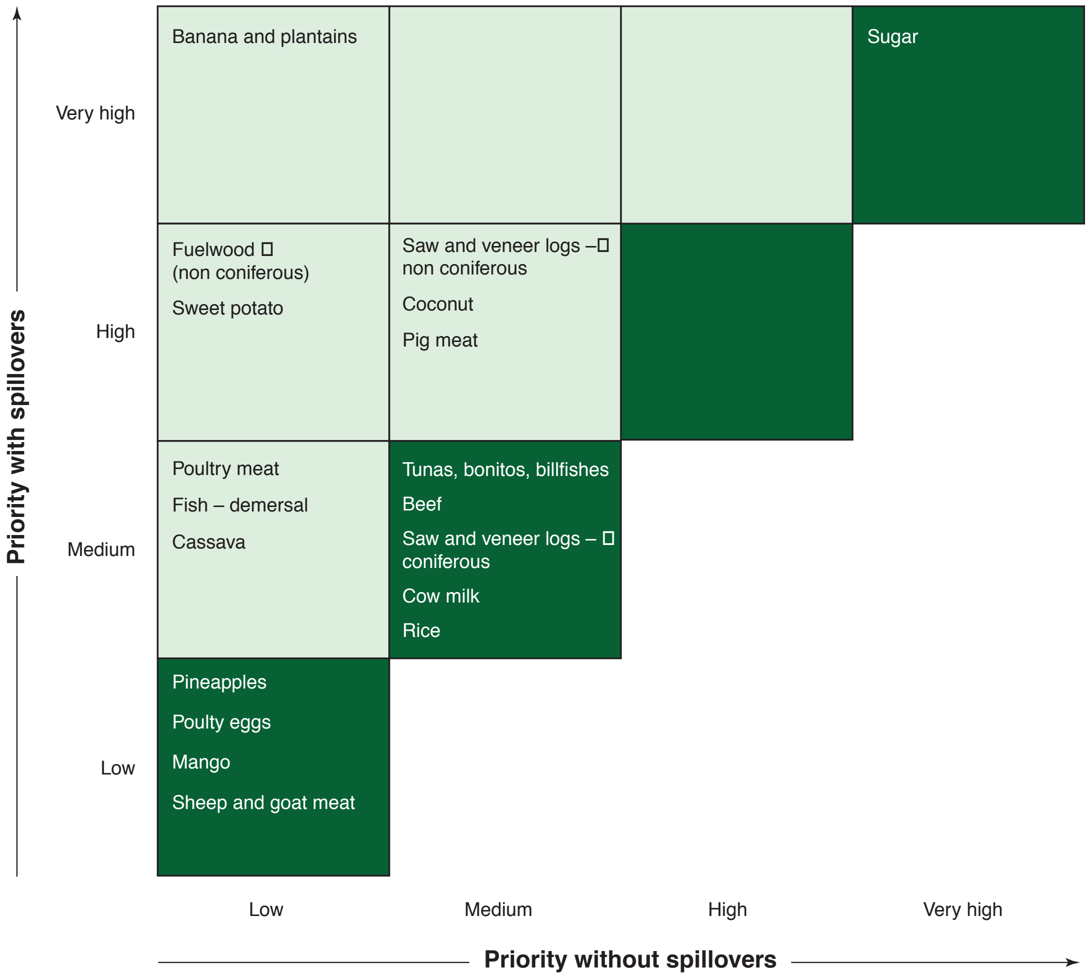


Figure 19. Fiji – Priorities of agricultural commodities based on benefits *with* spillovers compared to priorities based on benefits *without* spillovers. Commodities on the shaded diagonal have the same priority irrespective of whether or not one considers spillovers. Commodities that lie on the left of the shaded diagonal have higher priority when spillovers are considered. (Benefits *with* spillovers are higher than benefits *without* spillovers.)

The above figures show that priorities with and without spillovers differ considerably. The general result seems to be that for countries that are larger and therefore contribute a higher proportion to regional production of a commodity, the difference between priorities with and without spillovers is minimal.

4.4 Priority ranking of preharvest and postharvest research

How do the potential benefits from and preharvest and postharvest research compare? Are they similar in magnitude or do they differ?

To help resolve these questions, Chudleigh et al. (1998) developed two sets of matrices for the applicability of technology across the 14 agro-climatic zones defined for about 30 fruits and vegetables. For a number of commodities two analyses—one for postharvest and the other for preharvest research—were undertaken. In these pairs of analyses all the other parameters are the same except for the matrices for the applicability of technology. In each of these pairs of analyses the results *should not* be added to get a total of potential benefits. Rather, they are viewed as sensitivity analyses answering the question:

> What is the difference, if any, between the priority ranking of postharvest research and preharvest research?

Table 13 presents a summary of the results on the comparison between the priority rankings of postharvest versus preharvest research for different commodities. The results in Table 13 are based on the results from 16 countries:

- 6 in South Asia;
- 8 in Southeast Asia;
- China; and
- Australia.

These conclusions are conditional on the set of assumptions that underlie the analysis. The most important of these is that research invariably leads to a 5% reduction in the cost of production. It may be that the potential cost reduction differs between postharvest and preharvest research. However, these differences may also vary depending on the agricultural commodity and the country targeted by research. A comprehensive investigation of all these potential differences was beyond the resources available for this study. Furthermore, information on production costs for the commodities included in the study is not readily available. One way of estimating these costs would have been to ask experts for their opinions on the likely cost reductions by research theme. This path would have increased the value judgments and subjective inputs in the study, whereas an important objective of this study was to generate a set of priorities minimal subjective estimates.

4.5 Priority ranking of research themes in animal sciences

> Are there differences between potential benefits from research on different livestock research themes in the animal sciences program?

The context for this question was the following themes:

- research to extend breeding, grazing and stocking rate options;
- agronomic and soil research to develop new feed sources or to prevent land degradation;
- animal health related research, say, to develop a vaccine or to increase disease resistance using new techniques; and
- postharvest research to address quality and shelf life aspects of animal products.

Table 13. A comparison between the priority ranking of postharvest research versus preharvest research for selected commodities based on the potential benefits *with* spillovers for countries in South Asia, Southeast Asia and China

No	Commodity name	Number of countries (out of 16) where postharvest research has a different priority ranking from that of preharvest research[a]	Number of countries (out of 16) postharvest research has the same priority ranking from that of preharvest research	Number of countries (out of 16) it is not possible to compare the priority ranking of either postharvest preharvest research (NO DATA)
1	Apricot	0	4	12
2	Avocado	0	3	13
3	Bananas and plantains	0	12	4
4	Mango	0	13	3
5	Oranges and tangerines	2 (Bhutan, Bangladesh)	12	2
6	Papaya	0	9	7
7	Peaches	0	5	11
8	Pineapple	0	11	5
9	Plums	0	4	12
10	Rock melons	1 (Bangladesh)	6	9
11	Water melon	0	7	9
12	Cashew nuts	0	10	6
13	Cabbage	0	10	6
14	Cauliflower	0	3	13
15	Cucumber	1 (Philippines)	8	7
16	Cucurbits	0	9	7
17	Eggplant	0	9	8
18	Tomato	1 (Pakistan)	9	6

[a] The country in bracket refers to the country where *Spillovers* estimates different priorities for postharvest research from preharvest research

White (1998) constructed four different matrices describing the applicability (across different zones) of technology from each of these themes. External reviewers for these matrices indicated that the matrices provided reasonable estimates of the portability of technology across the different zones for these groups of research themes.

For each livestock commodity, simulations of the *Spillovers* model generated sensitivity analyses, with each simulation assuming all other parameters the same except for the matrix determining the applicability of technology. The results indicated that, for ruminants:

- The potential benefit from animal health research was the same as for postharvest research. This result is consistent with that of White (1998) who indicated that the opportunities for spillovers of technology are identical for both animal health and livestock postharvest research. Animal health and postharvest research are estimated to generate the highest potential benefits.
- Research on breeding, grazing and stocking rate options generates the next largest potential benefits in ruminant research.

- Agronomic and soil research to develop new feed sources or to prevent land degradation generated the smallest potential benefits in terms of spillovers between agro-climatic zones.

As indicated earlier when discussing preharvest versus postharvest research, these conclusions are conditional on the assumptions made in the analysis. One of the more crucial of these was the assumption that all research, irrespective of research theme, leads to a 5% cost reduction. The cost reduction likely to be associated with the different research themes is an empirical question. The research themes are likely to be ranked differently depending on the extent of land degradation and the state of the soils and vegetation.

For non-ruminants, there were only three technologies for analysis, and the results indicate that:

- the area of research with the highest potential benefits was livestock health;
- the second in order of magnitude of potential benefit was postharvest research; and
- breeding research had the smallest potential benefits.

The second question with respect to livestock research themes was:

> Does the priority of a livestock commodity change depending on the theme addressed by research?

To answer this question, a comparison was made between the priority of research to develop breeding, grazing and stocking rate options with the priority:

- of agronomic and soil research to develop new feed sources or to prevent land degradation (denoted by the letter *a*);
- of research to address issues of livestock health (e.g. vaccines) denoted by the letter *h*; and
- of research to develop postharvest technology denoted by the letter *p*.

The aim of this comparison was not to give the country level details, rather it was designed to reveal any patterns in the similarities or dissimilarities between the priorities of the different research themes.

The comparison was based on results from 2 × 42 simulations involving beef and buffalo meat —there are 42 countries/regions, and two livestock commodities. From a total of 84 simulations (each involving 4 research themes), only 11 (13%) resulted in a divergence between the priority estimated for breeding research and that assigned to the other research themes. This means that for every 100 instances in research projects on beef and buffalo when one assigns the same priority to beef and buffalo without distinguishing between research themes one is right in 87 of the 100 cases. In the majority of cases, research on beef and buffalo falls in the same priority group irrespective of the theme addressed by research. However, in 13 of 100 cases the assumption that beef and buffalo meat research has the same priority in a given country, irrespective of research theme, would be wrong. For example, in Bangladesh agronomic and soil (fodder) research that is of only medium priority could mistakenly be given a high priority. This result was replicated for the other ruminants.

For non-ruminant products, the priority of research to develop breeding, grazing and stocking rate options was compared with the priority of:

- research to address issues of livestock health (e.g. vaccines); and
- research to develop postharvest technology.

The results for non-ruminants are based on 3 × 42 simulations—there are 42 countries/ regions, and three livestock commodities. Of a total of 126 simulations (each involving three research themes) only five resulted in a divergence between the priorities accorded research themes. This means that of every 100 instances in research projects on sheep and goat meat and wool when one assigns the same priority to sheep and goat research without distinguishing between research themes one is correct in 99 of the cases.

The following conclusions can drawn.

- In the majority of cases the priority for a given commodity does not change with the research theme; where there are differences (in 13–15% of simulations) between the priorities of the different research themes, the differences are not major and are not likely to lead to significant errors in decision-making.
- In the case of sheep and goat meat, wool, pig meat, poultry meat and poultry eggs it seems that there are no gains to be made from differentiating between research themes. The introduction of research themes does not influence the ranking of these commodities in most countries.

5. CONCLUSIONS

This monograph has discussed an approach to the development of priorities in agricultural research. The approach involves an application of rigorous welfare economics on quantitative data to estimate potential benefits from research. These are in turn used to develop priorities for agricultural commodities included in the analysis. The approach is commodity based, but it can be used to implicitly develop priorities over research themes which have impacts on some commodity. Thus, research which, for example, is designed to conserve natural resources can be prioritised if it is known which commodities are to be affected. Indeed, it is a useful discipline to think about how the research results will translate into impact. Commodities provide one important impact pathway amenable to economic evaluation.

The approach assumes that the aim of agricultural research is to increase economic surplus in the target region or country. The approach does not address distributional issues, except to the extent that it is possible to split total benefits into those benefits accruing to consumers and those to producers. If the aim of agricultural research shifts to one of maximising benefits to the poor, the approach has to be modified to focus on the lowest-income consumers and producers. However, there are special cases where results at an aggregate level can provide information about the potential impact on the poor. These special cases include situations where:

- the poor are the major consumers of the commodity and the research leads to lower prices for the commodity, and there are no social–cultural barriers preventing the poor from benefiting from lower prices for the commodity;
- the technology is reducing costs of producing a commodity produced predominantly by the poor and there are no barriers (lack of capital, lack of knowledge about the technology, social cultural barriers to the technology) which prevent poor producers from accessing the new technology; and
- the research creates employment opportunities for the poor.

Section 4 of this paper has summarised the key results from this analysis showing that:

- it is possible to use this approach (it is currently used in ACIAR) from welfare economics to determine agricultural research priorities; and

- these priorities differ depending on whether they are computed using potential benefits *without* spillovers or using potential benefits *with* spillovers.

Nevertheless, the study leaves some questions which require further research and development. The rest of this section discusses the more important of these.

Refining the objective function

An important area of research is the development of practical techniques to introduce more specific or targeted objective functions in the analysis. Increasingly, there is a need to extend the approach used to derive results reported in this monograph so as to throw light on the potential for agricultural research to lead to poverty alleviation. This would require refining the objective function by, for example, introducing a distinction between producers and consumers by their socioeconomic or income groups.

Better use of GIS techniques

It is also possible to improve the analysis by integrating geographical information systems (GIS) with models like *Spillovers* for use in priority setting. User-friendly GIS products would make it easier to verify and validate the agro-climatic zone definitions and the estimated production proportions by country that are critical in the estimation of ago-climatic spillovers.

Trade-offs in the refinement of screening process

Finally, there is the question of how detailed the process of screening projects needs to be to give acceptably robust signals for decision-making. Figure 20 indicates some of the issues that have been explored in this monograph. The monograph resolves some of them but on several no decision can yet be made. The rest of this section discusses some of these issues.

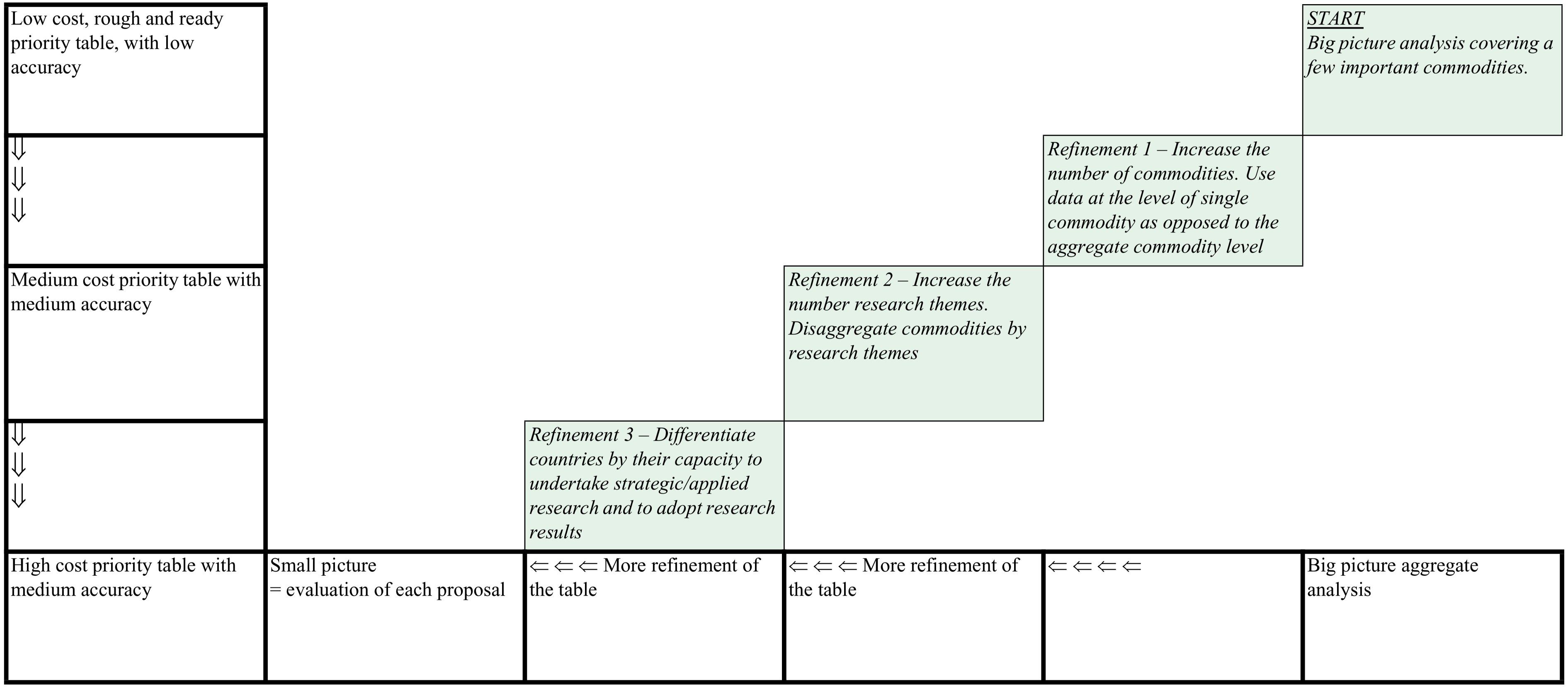
Refinement 1. The optimal commodity-coverage of the priority table

In Figure 20, the starting point is in the right-hand top corner of the figure. Before the analysis reported in this monograph ACIAR had a priorities table with 45 commodities. The issue at the time was that the limited coverage of the table reduced its value. By increasing the commodity coverage to 108, the value of the table has been increased. In increasing the number of commodities, the emphasis has been on use of individual commodity data as opposed to aggregate data. A few of the commodities (lentils, pulses, oranges and tangerines) have been aggregated because less disaggregated data are not available. The focus on individual commodity analysis was supported by the fact that most research tends to target individual commodities. It is very rare that a project addresses a group of commodities. In many cases, projects are addressing individual species or groups of species within a given commodity and thus it would be possible to argue that the single commodity is already too aggregated.

Refinement 2. Optimal level of disaggregation within a commodity

In this monograph an attempt was made at disaggregating commodities by research themes (preharvest versus postharvest for fruits and vegetables; breeding, versus agronomic and soil (fodder), versus livestock health versus postharvest for livestock commodities). In absence of data on differences in cost reductions by research theme, the conclusion seems to be that there

Figure 20. Trade-off between more refinement of 'big picture' screening process versus the evaluation of individual projects



is not much value in disaggregating along the path of research themes. This result is closely linked to the assumption that each research theme leads to the same 5% cost reduction.

However, there are other ways of taking into account the diversity of possible research impacts. One way partially tried in this monograph is the recognition of the agro-climatic distribution of commodities. This distribution of production is taken into account in estimating spillovers from research. However, the way the *Spillovers* and RE4 models take into account the agro-climatic distribution of production does not enable one to distinguish the research focus on the basis of the agro-climatic environment. If rice were disaggregated by agro-climatic environments, then the priority table would be able to give a project on, say, rice in the marginal environments a lower priority to a project on rice in the more fertile environments. This can be corrected as soon as GIS methods and research evaluation techniques are properly integrated.

Refinement 3. Capacity for strategic and applied research, and to adopt results

It is common to estimate the capacity for strategic and applied research for a given NARS, and the industry capacity to adopt research results. In this monograph, this practice has been changed in order to increase transparency and reduce subjectivity of the estimates. The estimates of potential benefits have to be scaled down by decision-makers to allow for variability in these capacities among the different NARS. This approach is deemed to be better than the approach where these modifiers are embedded in the estimation process. In the approach where the subjective modifiers are embedded in the model it was difficult to determine whether the priority level was the result of purely economic factors (production, prices, costs) or to the subjective modifiers. The new approach needs further testing before one can decide whether it is indisputably better than the old approach.

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APPENDIX A

THE TOTAL NET PRESENT VALUE OF POTENTIAL BENEFITS *WITH* SPILLOVERS (A$m)

	Australia	South Asia	Southeast Asia	China	PNG and South Pacific	Sub-Saharan Africa	West Asia–North Africa	Latin America
Livestock								
Beef	739.1	575.7	249.0	0.0	3.5	686.9	595.0	4492.0
Buffalo milk	0.0	2194.1	7.0	0.0	0.0	0.0	122.0	0.0
Buffalo meat	0.0	389.5	59.5	0.0	0.0	0.0	56.9	0.0
Cows milk	504.0	2077.7	51.0	0.0	3.9	524.8	1115.9	3025.6
Pig meat	217.4	231.2	804.5	15534.3	12.6	301.8	3.2	1898.0
Poultry meat	88.6	118.0	373.0	1241.6	1.9	176.0	436.3	1364.8
Poultry eggs	29.7	276.9	274.7	2339.2	1.1	158.5	340.1	751.0
Wool	781.1	65.8	0.4	0.0	0.0	73.7	199.1	166.0
Sheep and goat meat	428.4	554.9	76.5	0.0	0.7	452.1	974.2	251.5
Fish								
Lobster	39.6	1.3	6.9	0.3	0.6	3.3	1.1	81.8
Tilapia	0.0	6.0	83.7	87.3	0.8	50.9	41.4	50.7
Carp	0.0	46.7	10.1	211.6	0.0	2.1	3.4	1.2
Clam	0.0	0.0	22.6	124.0	0.1	0.0	0.0	0.0
Demersal	9.2	140.1	73.9	118.1	1.6	27.0	32.2	269.2
Herrings	1.7	37.6	64.5	67.9	0.5	81.9	119.6	1798.5
Mackerel	1.0	24.1	50.0	135.5	0.1	3.4	7.6	21.3
Diadromous	0.3	0.0	61.0	11.0	0.1	54.0	0.0	0.3
Mussels	0.4	0.0	7.8	62.3	0.0	0.3	0.9	3.6
Oyster	6.5	0.0	18.1	166.3	0.0	0.4	1.3	27.8
Prawns	8.3	96.7	93.1	202.9	0.4	6.0	10.5	122.8
Tuna	4.1	27.8	120.0	168.1	9.2	26.5	20.8	126.4
Industrial crops								
Cotton	523.8	3613.2	58.7	6881.8	0.0	767.6	1854.6	1648.0
Coffee	0.0	132.8	318.9	32.1	46.9	298.5	6.6	2949.8
Coconut	0.0	303.5	593.4	2.4	28.3	32.0	0.0	101.4
Cocoa	0.0	3.6	144.3	0.0	13.5	430.9	0.0	202.9
Palm oil	0.0	0.0	2355.8	39.4	60.4	426.5	0.0	240.2
Sugar	846.8	6119.7	1846.0	2067.6	106.3	399.5	452.3	13704.5
Rubber	0.0	149.3	1054.6	128.4	1.3	97.3	0.0	20.1
Forestry								
Charcoal	1.6	92.7	40.4	0.5	0.0	224.7	19.1	394.0
Fuel wood non coniferous	21.4	2203.6	1688.5	1243.0	55.5	1893.7	190.4	2348.6
Fuel wood coniferous	6.1	68.6	0.0	822.2	0.0	28.9	63.7	340.0

APPENDIX A (CONT'D)

THE TOTAL NET PRESENT VALUE OF POTENTIAL BENEFITS *WITH* SPILLOVERS (A$m)

	Australia	South Asia	Southeast Asia	China	PNG and South Pacific	Sub-Saharan Africa	West Asia–North Africa	Latin America
Forestry (cont'd)								
Other Industrial round wood	5.8	47.3	69.6	387.6	0.1	106.6	88.6	94.3
Pulpwood	8.6	0.3	10.7	21.1	0.0	13.4	4.6	73.3
Saw logs and veneer logs non coniferous	90.2	309.0	1249.5	396.4	51.3	281.2	56.6	733.9
Saw logs and veneer logs coniferous	99.4	49.2	11.0	684.8	2.7	67.7	79.2	812.5
Grain								
Rice	128.5	12980.6	7651.2	22202.2	2.5	730.2	898.4	2314.7
Maize	11.8	437.4	467.8	4904.2	0.2	556.3	444.7	3339.7
Millet	0.8	336.7	3.7	119.7	0.0	267.8	4.0	0.9
Wheat	892.9	3677.6	8.7	6858.9	0.0	95.4	3125.4	1255.8
Sorghum	26.7	302.9	6.2	180.2	0.0	217.2	36.8	261.7
Fruits and vegetables								
Mango	13.3	2108.4	302.2	226.6	1.3	174.8	41.6	523.8
Avocado	6.3	0.0	55.8	0.0	1.0	50.8	0.0	694.5
Apricot	29.2	139.7	0.0	71.4	0.0	48.6	994.4	51.1
Bananas and plantains	37.8	1603.9	1116.0	491.9	110.7	486.2	119.4	3770.6
Oranges and tangerines	149.7	666.3	235.5	1357.0	0.8	225.0	1864.8	6050.3
Water melon	7.9	44.4	67.4	785.1	0.6	13.5	1007.2	197.8
Plums	15.1	49.9	0.0	861.6	0.0	11.2	300.3	137.2
Pineapples	23.8	144.2	582.1	123.5	1.8	208.4	0.0	382.4
Peaches	39.7	49.3	0.0	918.8	0.0	82.0	433.7	427.7
Pawpaw	1.2	111.3	199.9	32.2	2.4	105.1	13.3	615.7
Rock melon	12.9	61.6	6.6	578.9	0.0	5.1	716.3	209.7
Cabbage	8.4	361.0	136.2	954.3	0.2	24.0	134.0	88.0
Cauliflower	6.3	0.0	43.6	0.0	1.0	29.1	0.0	694.5
Egg plant and green peppers	8.2	72.5	253.6	3008.7	0.4	390.4	1173.0	441.2
Cucurbits	33.2	147.0	252.8	3357.3	0.6	87.8	1744.7	566.0
Cucumber	5.3	13.0	158.3	2806.6	0.4	7.5	1222.6	151.9
Potato	75.9	675.3	51.7	2510.1	0.4	54.3	1017.2	875.9
Tomatoes	34.1	492.1	23.3	876.8	0.3	66.4	1782.7	713.8

APPENDIX A (CONT'D)

THE TOTAL NET PRESENT VALUE OF POTENTIAL BENEFITS *WITH* SPILLOVERS (A$m)

	Australia	South Asia	Southeast Asia	China	PNG and South Pacific	Sub-Saharan Africa	West Asia–North Africa	Latin America
Other crops								
Cassava	0.0	155.4	404.5	66.9	2.0	1431.9	0.0	2135.2
Cashew nuts	2.7	580.5	272.4	27.8	0.0	348.5	0.0	288.9
Lentils	0.0	56.4	0.1	1.1	0.0	0.4	9.5	0.6
Groundnuts	0.4	459.7	56.4	84.2	0.0	30.4	2.0	8.4
Pulses-general	343.9	1357.6	143.3	823.9	0.1	176.3	658.9	924.3
Soybean	4.0	234.3	106.1	955.6	0.0	9.8	17.8	2320.2
Rapeseed	48.2	541.7	0.9	986.3	0.0	2.5	18.4	16.2
Sweet potatoes	0.6	86.7	252.1	8867.6	36.2	211.7	10.8	143.8

APPENDIX B

REGIONAL GROUPINGS USED IN THE ANALYSIS

Region	Country(ies) in the region
SOUTH ASIA (Individual country level)	
1	Bangladesh
2	Bhutan
3	India
4	Nepal
5	Pakistan
5	Sri Lanka
SOUTHEAST ASIA (Individual country level)	
6	Myanmar
7	Indonesia (includes Timor /East Timor)
8	Cambodia
9	Laos, PDR
10	Philippines
11	Vietnam
12	Malaysia
13	Thailand
CHINA includes the following countries each of which has the same priority and benefits as CHINA	China
14	China PDR
15	Mongolia
16	Taiwan
PNG AND SOUTH PACIFIC (Individual country level)	
17	Papua New Guinea
18	Fiji
19	Samoa
20	Solomon Is.
21	Tonga
22	Vanuatu
SOUTH PACIFIC – OTHER (grouped) includes the following countries each of which has the same priority and benefits as SOUTH PACIFIC OTHER	
23	Christmas Is
24	Cocos Is
25	Cook Is
26	Guam
27	Kiribati
28	Nauru
29	New Caledonia
30	Niue

APPENDIX B (CONT'D)

REGIONAL GROUPINGS USED IN THE ANALYSIS

Region	Country(ies) in the region
SOUTH PACIFIC – OTHER (grouped) – (cont'd) includes the following countries each of which has the same priority and benefits as SOUTH PACIFIC OTHER	
31	Polynesia, French
32	Samoa, American
33	Tokelau
34	Trust Territory Pacific
35	Tuvalu
36	Wallis & Futuna Island
37	French Sthn Terr
38	Marshall Is
39	Micronesia Fed St
40	Nth Mariana Is
41	Palau
42	Pitcairn
43	Wake Is
AFRICA – SOUTHERN AFRICA DEVELOPMENT COMMUNITY (Individual country level)	
44	Angola
45	Botswana
46	Lesotho
47	Malawi
48	Namibia
49	Mozambique
50	Swaziland
51	South Africa
52	Tanzania
53	Zambia
54	Zimbabwe
55	Mauritius
EASTERN AFRICA (Individual country level)	
56	Kenya
57	Uganda
EASTERN AFRICA OTHER (Grouped) includes the following countries each of which has the same priority and benefits	
58	British Indian Ocean Territory
59	Burundi
60	Comoros
61	Djibouti
62	Ethiopia

APPENDIX B (CONT'D)

REGIONAL GROUPINGS USED IN THE ANALYSIS

Region	Country(ies) in the region
63	Madagascar
64	Maldives
65	Reunion
66	Rwanda
67	Seychelles
67	Somalia
69	Sudan
CENTRAL AFRICA includes the following countries each of which has the same priority and benefits	
69	Central African Republic
70	Chad
71	Congo
72	Equatorial Guinea
73	Gabon
74	Sao Tome & p
75	Zaire
WEST AFRICA includes the following countries each of which has the same priority and benefits	
76	Benin
77	Burkina Faso
78	Cameroon
79	Cape Verde
80	Gambia
81	Ghana
82	Guinea
83	Guinea-Bissau
84	Ivory Coast
85	Liberia
86	Mali
87	Mauritania
88	Niger
89	Nigeria
90	Senegal
91	Sierra Leone
92	St Helena
93	Togo
WEST ASIA–NORTH AFRICA includes the following countries each of which has the same priority and benefits	
94	Afghanistan
95	Algeria
96	Egypt

APPENDIX B (CONT'D)

REGIONAL GROUPINGS USED IN THE ANALYSIS

Region	Country(ies) in the region
97	Iran
98	Iraq
99	Jordan
100	Lebanon
101	Libya
102	Morocco
103	Syria
104	Tunisia
105	Turkey
106	Western Sahara
107	Yemen Arab Rep
108	Yemen PDR
109	West Bank
CENTRAL AND SOUTH AMERICA includes the following countries each of which has the same priority and benefits	
110	Brazil
111	Colombia
112	Peru
113	Venezuela
114	Bolivia
115	Ecuador
116	Mexico
117	Argentina
118	Chile
119	Paraguay
120	Uruguay
121	Costa Rica
122	Cuba
123	Dominican Rep
124	El Salvador
125	Guatemala
126	Haiti
127	Honduras
128	Nicaragua
129	Panama
130	Suriname
131	Antigua
132	Bahamas
133	Barbados
134	Belize

APPENDIX B (CONT'D)

REGIONAL GROUPINGS USED IN THE ANALYSIS

Region	Country(ies) in the region
135	Bermuda
136	Br. Virgin Is
137	Cayman Is
138	Dominica
139	Grenada
140	Guadeloupe
141	Guiana, French
142	Guyana
143	Jamaica
144	Martinique
145	Montserrat
146	Netherlands - Antilles
147	St Kitts-Nevis
148	St. Lucia
149	St. Pierre &
150	St. Vincent &
151	Trinidad & Tobago
152	Turks Caicos Is.
ASIA – DEVELOPED (Grouped)	
153	Bahrain
154	Brunei
155	Gaza Strip
156	Hong Kong
157	Israel
158	Korea, DPR
159	Korea, Rep.
160	Kuwait
161	Macao
162	Oman
163	Qatar
164	Saudi Arabia
165	Singapore
166	United Arab Emirates
167	Australia
OTHER DEVELOPED	
168	Andorra
169	Anguilla
170	Aruba
171	Gibraltar
172	Liechtenstein

APPENDIX B (CONT'D)

REGIONAL GROUPINGS USED IN THE ANALYSIS

Region	Country(ies) in the region
173	Canada
174	USA
175	USSR
176	Japan
177	Albania
178	Cyprus
179	Greece
180	Italy
181	Portugal
182	Spain
183	Yugoslavia
184	Austria
185	Bulgaria
186	Czechoslovakia
187	Hungary
188	Romania
189	Switzerland
190	Belgium-Luxembourg
191	Denmark
192	France
193	Germany
194	Netherlands
195	New Zealand
196	Poland
197	United Kingdom
198	Faeroe Is
199	Falkland Is
200	Finland
201	Greenland
202	Iceland
203	Ireland, Rep
204	Malta
205	Norfolk Is.
206	Norway
207	Puerto Rico
208	Sweden
209	Virgin Is

APPENDIX C

A COMPLETE LIST OF COMMODITIES WHICH HAVE BEEN TARGETED IN PAST ACIAR-FUNDED RESEARCH

1 Animal – Beef – agronomy
2 Animal – Beef – breeding, grazing and stocking rate options
3 Animal – Beef – health
4 Animal – Beef – postharvest
5 Animal – Buffalo meat – agronomy
6 Animal – Buffalo meat – breeding, grazing and stocking rate options
7 Animal – Buffalo meat – health
8 Animal – Buffalo milk – agronomy
9 Animal – Buffalo milk – breeding, grazing and stocking rate options
10 Animal – Buffalo milk – health
11 Animal – Buffalo milk – postharvest
12 Animal – Cows milk – agronomy
13 Animal – Cows milk – breeding, grazing and stocking rates
14 Animal – Cows milk – health
15 Animal – Cows milk – postharvest
16 Animal – Honey
17 Animal – Horse
18 Animal – Other
19 Animal – Pig meat – breeding and stocking rate options
20 Animal – Pig meat – health
21 Animal – Pig meat – postharvest
22 Animal – Poultry eggs – breeding and stocking rate option
23 Animal – Poultry eggs – health
24 Animal – Poultry eggs – postharvest
25 Animal – Poultry meat – health
26 Animal – Poultry meat – postharvest
27 Animal – Sheep and goat meat – agronomy
28 Animal – Sheep and goat meat – health
30 Animal – Sheep and goat meat – postharvest
31 Animal – Sheep meat – breeding, stocking rate and grazing
32 Animal – Turtles
32 Animal – Wool – agronomy
33 Animal – Wool – breeding, stocking rate and grazing options
34 Animal – Wool – health
35 Animal – Wool – postharvest
36 Fibre crops – Abaca
37 Fibre crops – Kenaf
38 Fibre crops – Other
39 Fish – Carps, barbels and other cyprinids
40 Fish – Clams, cockles and ark–shells
41 Fish – Crabs
42 Fish – Demersal
43 Fish – Herrings, sardines, anchovies
44 Fish – Lobsters
45 Fish – Mackerels, snoeks, cutlass fishes
46 Fish – Miscellaneous diadromous
47 Fish – Mussels
48 Fish – Other
49 Fish – Oysters
50 Fish – Prawns, shrimps
51 Fish – Sharks, rays
52 Fish – Shells, pearls
53 Fish – Tilapias and other cichlids
54 Fish – Tunas, bonitos, billfishes
55 Forestry – Charcoal
56 Forestry – Fuelwood – coniferous
57 Forestry – Fuelwood – non–coniferous
58 Forestry – Other
59 Forestry – Pit–props
60 Forestry – Wood – coniferous saw logs and veneer logs
61 Forestry – Wood – non–coniferous saw logs and veneer logs
62 Forestry – Wood – other industrial round wood

63 Forestry – Wood – processed wood
64 Forestry – Wood – pulpwood
65 Fruit – Apples
66 Fruit – Apricots – postharvest
67 Fruit – Apricots – preharvest
68 Fruit – Avocado – postharvest
69 Fruit – Avocado – preharvest
70 Fruit – Bananas and plantains – postharvest
71 Fruit – Bananas and plantains – preharvest
72 Fruit – Breadfruit
73 Fruit – Custard apple
74 Fruit – Durian
75 Fruit – Grapes
76 Fruit – Jackfruit
77 Fruit – Longan
78 Fruit – Lychee
79 Fruit – Mango – postharvest
80 Fruit – Mango – preharvest
81 Fruit – Mangosteen
82 Fruit – Oranges and tangerines – postharvest
83 Fruit – Oranges and tangerines – preharvest
84 Fruit – Other
85 Fruit – Passionfruit
86 Fruit – Pawpaw – postharvest
87 Fruit – Pawpaw – preharvest
88 Fruit – Peaches – postharvest
89 Fruit – Peaches – preharvest
90 Fruit – Pears
91 Fruit – Pineapples – postharvest
92 Fruit – Pineapples – preharvest
93 Fruit – Plums – postharvest
93 Fruit – Plums – preharvest
94 Fruit – Rambutan
95 Fruit – Rockmelons and other melons – postharvest
96 Fruit – Rockmelons and other melons – preharvest
97 Fruit – Watermelon – postharvest
98 Fruit – Watermelon – preharvest
99 Grain – Barley
100 Grain – Maize
101 Grain – Millet
102 Grain – Other
103 Grain – Rice – husked equivalent
104 Grain – Sorghum
105 Grain – Wheat
106 Industrial crops – Cocoa
107 Industrial crops – Coconut
108 Industrial crops – Coffee
109 Industrial crops – Cotton
109 Industrial crops – Other
110 Industrial crops – Palm oil
111 Industrial crops – Rubber – natural
112 Industrial crops – Sugar
113 Industrial crops – Tea
114 Industrial crops – Tobacco
115 Nuts – Cashew nuts – postharvest
116 Nuts – Cashew nuts – preharvest
117 Nuts – Macadamia
118 Nuts – Other
119 Oilseed – Groundnuts
120 Oilseed – Other
121 Oilseed – Rapeseed (canola)
122 Oilseed – Sunflower
123 Other – Hydro–electricity
124 Other – River transport
125 Other – Sericulture (silk worm production)
126 Other – Tourism
127 Other – Wildlife preservation

128 Pulses – Cowpeas
129 Pulses – General
130 Pulses – Lentils
131 Pulses – Mungbeans
132 Pulses – Other
133 Pulses – Soybeans
134 Root crops – Cassava
135 Root crops – Kava
136 Root crops – Other
137 Root crops – Sweet potato
138 Root crops – Taro
139 Root crops – Yam
140 Vegetable – Brassicas
141 Vegetable – Cabbages – postharvest
142 Vegetable – Cabbages – preharvest
143 Vegetable – Carrots
144 Vegetable – Cauliflower – postharvest
145 Vegetable – Cauliflower – preharvest
146 Vegetable – Cucumber – postharvest
147 Vegetable – Cucumber – preharvest
148 Vegetable – Cucurbits – postharvest
149 Vegetable – Cucurbits – preharvest
150 Vegetable – Eggplant and green peppers – postharvest
151 Vegetable – Eggplant and green peppers – preharvest
152 Vegetable – Lettuce
153 Vegetable – Other
154 Vegetable – Potato
155 Vegetable – Pumpkin
156 Vegetable – Tomatoes – postharvest
157 Vegetable – Tomatoes – preharvest