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TO: TAC Members

FROM: Executive Secretary, ~~TAC~~

SUBJECT: Documentation for the 32nd TAC meeting

Please find herewith attached "Quantitative Indicators for Priorities in International Agricultural Research" which FAO commissioned to GFA (Gesellschaft für Agrarprojekte in Übersee M.B.H.) for presentation to the Technical Advisory Committee at its 32nd meeting.

This document will be considered under Agenda Item 7 "Strategic Considerations".

cc: TAC Chairman
Co-sponsors
CGIAR Secretariat
TAC Secretariat

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

QUANTITATIVE INDICATORS FOR PRIORITIES IN INTERNATIONAL AGRICULTURAL RESEARCH

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Background working paper commissioned from GFA (Gesellschaft für Agrarprojekte in Übersee M.B.H.) by the Food and Agriculture Organization of the United Nations for the Technical Advisory Committee of the Consultative Group on International Agricultural Research.

September 1983

FOREWORD

This paper has arisen from a request by TAC to FAO to update and broaden from its sources the quantitative indicators which may guide the setting of priorities in international agricultural research. In 1978 IFPRI supplied such a paper on which TAC was able to base its priority report in 1979. Besides the periodic need for revision of such background data it was also felt that there existed new rich data sources within FAO that could now be exploited.

FAO commissioned the paper to GFA, a German consulting firm, in early July 1983. A first draft of the final report was discussed in Rome in the beginning of September. The final draft was supplied in mid-September.

While it was agreed that personal authorship in this particular effort should be recognized the paper really is the result of many man-years of work on different research projects within FAO and of the joint efforts of FAO subject-matter specialists, as well as data handling experts during our work on this paper. We thank Dr. D. F. R. Bommer, Assistant Director General, Agriculture Department, for providing access to the wealth of material accumulated in FAO. Dr. Bommer also provided the necessary guidance in the early conceptual stages of the report.

Dr. J. W. Monyo, Chief of the Research Development Centre within FAO, and Mr. A. von der Osten, Executive Sectretary of TAC, provided valuable background material, were important partners in conceptual discussions and gave moral support and encouragement.

Dr. J. Bruinsma of the Economic and Social Development Department provided access to the AT 2000 material which accounts for the greatest part of the data base in this report. The special structuring and formatting of the tables and the statistical analyses took an inordinate proportion of his time, including over-time. His econometric capabilities were essential for the processing of much of the data.

Mr. G. M. Higgins provided access to all the material developed in the context of the agro-ecological zones (AEZ) project. He took the trouble of explaining basic concepts, helping in the interpretation of the data for the present purposes, and commenting on first drafts.

Messrs. K. Becker, J. Krane, T. Kerr and S. Nelson were instrumental in obtaining and utilizing data from FAO's interlinked computer system (ICS).

Ms. M.-G. Ottaviani-Carra, I. Reyes-Ugarte, E. Lugli-Trinci and Mr. G. Maione helped with special analyses and the computation of derived tables. Mrs. S. Roe-Biggiero typed some of the earlier tables and provided general secretarial assistance.

Ms. H. Jenner, U. Siegmund and U. Paul of GFA undertook the tedious typing and editing work.

We are grateful to all the persons mentioned and many more for their contributions to the study. We also thank Prof. U. Koester, Institute of Agricultural Economics, Kiel University, for seconding Dr. Kirschke to GFA for this assignment.

Last, but by no means least, we must mention the person who played the central role during all phases from conception to data collection, preliminary interpretation and finalization: Dr. J.P. Hrabovszky. As the Senior Policy and Planning Coordinator at FAO's Agriculture Department he occupied a key position for the study from the start. Without his personal interest, his readiness to make available the whole wealth of his accumulated experience, and his capacity to draw on all sources within FAO this study would hardly have been possible. Our sincere thanks, therefore, go to Janos Hrabovszky.

All data sets have been checked for internal coherence and for consistency with source data. In some cases it did seem advisable to initiate cross-checking exercises. Not all of these have been completed. At this stage, therefore, it cannot be excluded that some data will still undergo revision although we do not expect this to lead to major changes.

Hans E. Jahnke / Dieter Kirschke
Hamburg
September 1983

ABBREVIATIONS AND ACRONYMS

AEZ	Agro-ecological Zones (FAO research project)
AT 2000	Agriculture: Toward 2000 (FAO study)
CGIAR	Consultative Group on International Agricultural Research
FAO	Food and Agriculture Organization
GFA	Gesellschaft für Agrarprojekte in Übersee (German Company for Agricultural Pojects Overseas)
IARC	International Agricultural Research Centre
ICS	Interlinked Computer Systems (FAO data retrieval system)
IDS	International Development Strategy (UN)
IFPRI	International Food Policy Research Institute
TAC	Technical Advisory Committee (of the CGIAR)
UNFPA	United Nations Fund for Population Activities
WHO	World Health Organization

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1. Introductory Considerations

1.1 Background

Since its inception, the CGIAR and its scientific support unit, TAC, have been faced with the problem of choice. While increased food production in developing countries is the overall objective, decisions have been called for on the relative importance of financial support to the different IARC's, on the nature and relative size of new research centres to be created, and on the appropriate size and structure of the overall effort of the group as well as of each individual centre. It has also been realized that the objective of increasing food production can be reached in many different ways in different regions and may or may not be overlain by distributional and other objectives. In the light of complex objectives and of great variation in the possible ways of reaching those objectives, efforts have been undertaken to put decision-making and priority setting on a rational basis. These efforts relate to the methodology of research planning (e.g. Schuh and Tollini 1979), to the compilation of quantitative indicators in support of setting research priorities (e.g. TAC 1973, 1976 and 1979) and to numerous reviews, both of the network of international agricultural research as a whole as well as of individual centres.

The need to think about appropriate priorities in international agricultural research is a never-ending one. Data used at one point in time have to be up-dated. Additional information becomes available. The actual situation in developing countries, including national research efforts and, thus, the potentials and constraints of international research change. Objective structures of both developing countries and donors to the CG undergo variation, new insights are gained into promising research paths and, last but not least, the budgetary situation of the group changes and, thus, the degree of rigidity with which priority decisions have to be made. The last point becomes particularly obvious when decisions no longer relate to the direction of expansion but may involve cuts within the existing system (CGIAR, 1983).

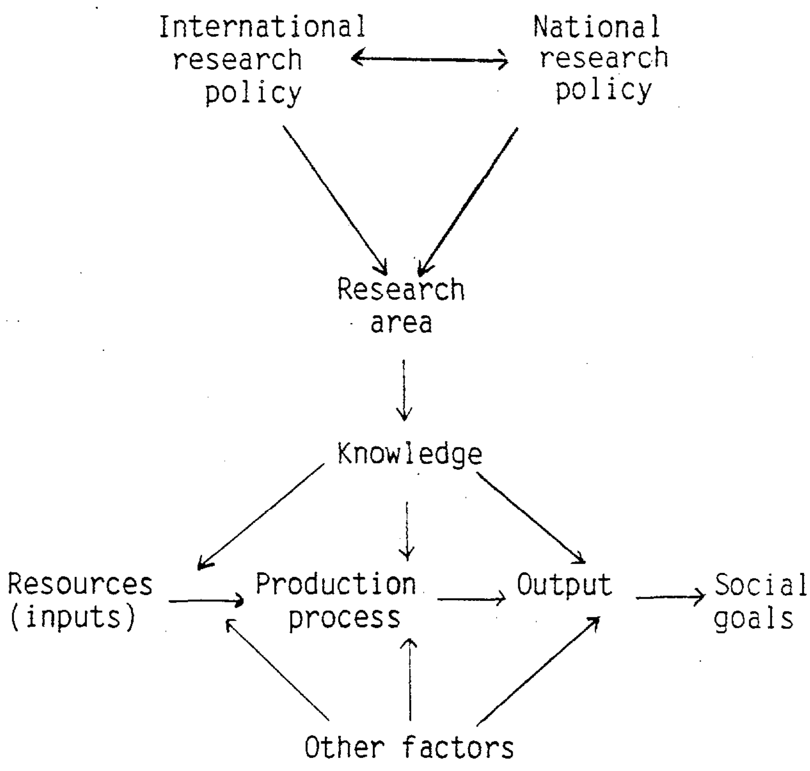
In this light TAC is taking a new look at its recommended priorities for support to international agricultural research. This present paper is to provide a background. Emphasis is on quantitative empirical information that may be of importance for the identification of research priorities. A starting point is the 1979 TAC report, itself based on the 1978 IFPRI report that contains a great deal of quantitative indicators. Such indicators have now been brought up to date. At the same time the data base has been broadened by the inclusion of FAO data sources that in the meantime have become available. This not only refers to FAO's general data files, but also to the data that resulted from the agro-ecological zones project and, in particular, to the rich material accumulated in the context of the AT 2000 study.

This present paper is to provide a possible basis for deciding about research priorities. It limits itself to the presentation of the data and to the discussion of possible implications. It does not itself draw conclusions for research priorities. That task has to remain with TAC and will have to take into account additional considerations.

1.2 Problems of Research Policy Evaluation

Identifying priorities in international agricultural research is a typical policy evaluation problem. A policy can be characterized as a set of actions through which a given societal situation is to be changed to one that corresponds better with a society's goals. In the case of research policy the transformation process can conceptually be expanded to take into account the influence on research areas and the generation of knowledge before social goals are influenced in a directly effective way. In addition it has to be realized that international research interacts with national research in a complex way. The knowledge generated will not only affect the agricultural production process directly but may also lead to changes in the quality of the resources used (e.g. through drainage or irrigation of the land, through genetic improvement of the seed) or in the quality and availability of the output (post-harvest technology on or off the farm, market research). Finally it must be realized that new knowledge is not the only factor to influence agricultural production in the socially desirable directions. Political will, financial resources, physical infrastructure can be mentioned as examples of other factors. Figure 1.2 represents a simplified model along the considerations made.

Figure 1.2 Research policy transformation process



One of the simplifications contained in the model in Figure 1.2 is that society's goals are exclusively related to output. Considerations relating to distribution, resource conservation or the reduction of the drudgery of agricultural work cannot be readily accommodated by the presentation. However the preoccupation with output, more particularly food, may be acceptable as a first approximation given the importance of production and food in most goal structures in developing countries.

The ultimate purpose of research policy is to enhance the attainment of socially desirable goals. Neither research by itself nor food production by itself are of value unless they relate to a society's goals. This is the view taken in this paper. There are immediate consequences for the identification of priorities in supporting international agricultural research: (1) such support has to be goal-oriented, (2) a causal relationship has to exist between the research areas supported and the social goals to be attained and (3) resource use in research has to be efficient.

(1) The call for goal-orientation is complicated by the fact that - even within one country - the existing goal structures tend to be multifacetted, conflicting and changing over time. Furthermore the group of developing countries is heterogeneous. A large, export-oriented country on the threshold to industrialization is likely to have different goals from a small, subsistence-oriented one concerned about maintaining food consumption above starvation levels. Finally goals postulated as important for developing countries by the donors to international research may differ from one another, and from those of the different developing countries.

The growing importance of special project funding within the IARC's may be taken as an indicator of such deviations in goal structures.

However, goals have to be identified and defined, unless one wishes to leave the direction of things to such factors as tradition, intuition or chance.

(2) A causal relationship between agricultural research and specified societal goals has to exist, otherwise there is little sense in orienting research priorities towards societal goals. A change in research priorities or the generation of knowlege in a particular field must be related to the attainment of a particular goal in a plausible way.

The vast body of literature demonstrating high payoffs of agricultural research might seem to be an adequate confirmation of such causal relationships (e.g. Arndt et al 1977, Evenson and Kislev 1975, Kaiser 1977). But there is reason for caution. Firstly, the extent to which these surveys relate to successful research only is not clear. Secondly, achievements in output may be offset by ill-effects in terms of distributional objectives although this is by no means an inherent characteristic of new technology. Thirdly, knowledge usually is the joint product of different lines of research; this makes attribution to one particular research effort problematic. Fourthly, for knowledge to be translated into practical effects, complementary inputs like seed multiplication, physical infrastructure, extension services and the like are necessary; again attribution of benefits may not be without ambiguities. Finally it is difficult to extrapolate from past experience to planned efforts; research is always a venture into the unknown. The past can only be used to guide expectations of such causal relationships in the future.

(3) The relationship between emphasis in a research area as measured by the financial input and the outcome of relevant knowledge is all but simple. A unit of effort can be expected to have vastly different returns in knowledge and - ceteris paribus - in goal achievement in the different research areas. This may be a result of differences in "researchability" as is sometimes indicated in crop research by

differences in natural genetic variation. It may also be a result of differences in efficiency of resource use for research. While efficiency of research is a difficult concept, certain indicators exist like the reputation of staff one is able to attract and the turn-over of staff.

The problems of (1) goal orientation, (2) causality and (3) efficiency of research cannot be resolved in a pure and generalizeable way in this study. A pragmatic approach is taken. The production of food, which at the same time implies the generation of income for farmers, is assumed to be a goal of eminent importance for all developing countries. In several places that are thought to be appropriate the relationship to distributional objectives is discussed. Issues like volume versus value, supply from home production versus imports, importance now versus importance in the future are taken up where they appear of particular relevance. A similar pragmatic approach is taken towards the problems of causality and efficiency: They are addressed in certain appropriate instances. However, this should not detract from the fact that they pervade the whole study.

These are not all the complications. Even if there was only one well-defined goal to be observed, if causality was established in an unambiguous way and if efficiency of research was guaranteed, there still remains the relationship to national research as an issue. Should support to international research, ceteris paribus, concentrate on the areas not covered by national research? Or should it be active in the same fields to exploit complementary relationships? Furthermore the discussion so far has been limited to publicly supported research, be it national or international. The relationship to research within the private sector would add another dimension (Ruttan 1982 b). Some justification in neglecting that dimension here is that it was the very absence or near-absence of private initiative in food crop research in developing countries that has led to the establishment of an international system.

In summary one remains with a great deal of conceptual inadequacies before one has even begun to define the indicators, by which one wishes to measure the relevant relationships. Conceptually the underlying assumption in this paper is that research should be guided by payoffs to society. The payoffs are determined by ultimate contributions of research to society's goals net of the costs (including uncertainty) that one has to incur in research.

1.3 Problems of Selecting Priority Indicators

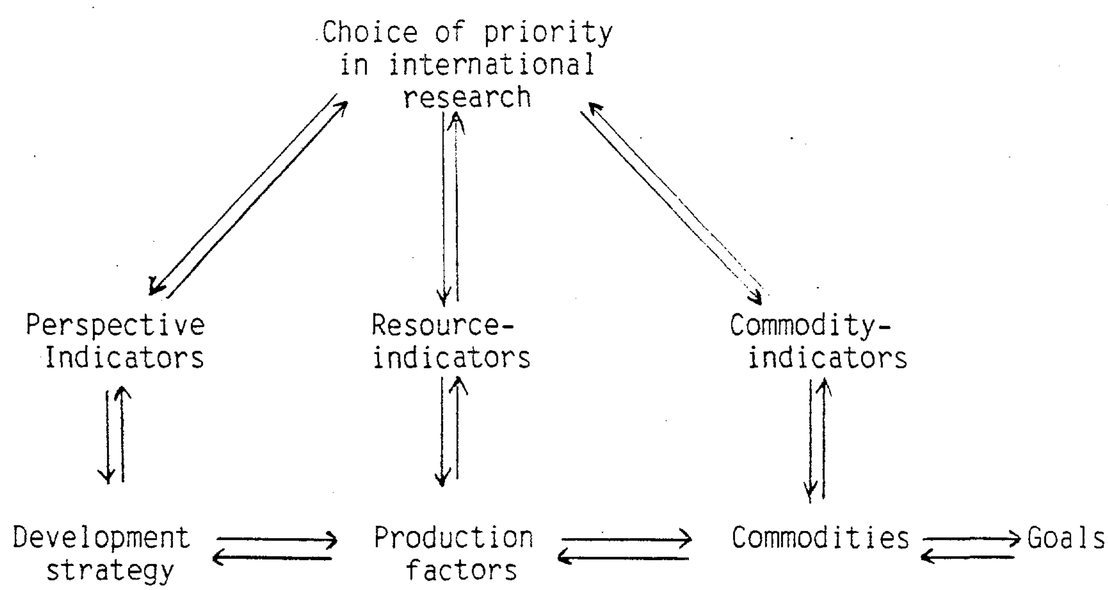
Setting priorities in agricultural research means that research areas deserving particular support are identified. According to Arnon (1975) a research area is characterized by
(1) its purpose,
(2) the commodity or resource involved, and
(3) its field of science (biological, mechanical/technical, economic and social science).

An example would be genetic improvement work (field of science) on wheat (commodity) in order to raise yields and production of food crops (purpose). Another would be productivity measurements of rangelands in order to examine land degradation under traditional management.

The definition of research areas can be carried much further, but this is not warranted for the present purpose. The research area will essentially be characterized by the commodity involved on one side (rice, wheat, beef etc) and by the resources affected on the other. The latter may refer to land, labour and capital as production factors in economic terminology but also to ecological zones or classes of material inputs like fertilizers, pesticides. This does not solve the detailed questions in establishing a research programme (e.g. how much of which type of genetics as compared to the agronomic trials), but in a broader sense it may allow to identify priority areas. It also ascertains that the selection of priorities is in line with the widely recognized concept that demand on one side and the relative scarcity of resources on the other are important factors in research orientation and technology development (Herlemann and Stamer 1954, Hayami and Ruttan 1969, Binswanger and Ruttan 1978). Thus, the importance of wheat as a research area is not only determined by the existence of a demand for wheat but also by the availablity of land suitable for wheat production and the scarcity of land relative to labour.

Assuming that there are no problems of causality and of efficiency interfering, the task is to select indicators that link research areas to inputs and outputs of production and to goals and development strategies. Figure 1.3 serves as an illustration for different classes of indicators.

Figure 1.3. Relationship between quantitative indicators, societal goals and research priorities



None of the indicator classes in Figure 1.3 can be represented by one variable alone. Perspective indicators characterize development strategies which in turn reflect policy decisions about the most appropriate development path as well as potentials and constraints of the natural and socio-economic environment. Resource-oriented indicators refer to production factors, land and others, their productivity and availability. Commodity-oriented indicators deal with the different crops, with groups of crops, with classes like "all crops" and "all livestock products" etc. and they use quantities in some instances, values in others. Considerations of availablility and plausibility of possible implications have had to take precedence over scientific rigour in the selection of appropriate indicators.

1.4 Aim, Scope and Approach

The aim of this paper is to provide quantitative indicators that may be useful in determining priorities in international agricultural research. The problems of identifying priorities and the problems of making inferences from such indicators have been outlined. They will be reiterated in the context of specific indicators. Thus the paper hopefully provides a background and basis for decisions. The actual decision will have to be taken by the CG, by TAC and by the individual centres, and will also be based on considerations other than the quantitative indicators and the possible interpretations presented in this paper. The indicators presented here are therefore not sufficient for priority setting, but they may be useful providing necessary information for rational decision-making.

The scope of the paper is determined by the more theoretical considerations contained in the previous two sections and by data availability. As usual a compromise has to be found between the ideal and the feasible. The term data availability requires further elaboration. All data stem from FAO sources. In fact it has been a particular concern to base this paper on the wealth of material that has in recent years become available within FAO and that goes well beyond the standard data files. At the same time this material is not completely uniform because of different sources (ICS, AT 2000, AEZ). While each set of data is adequate for self-contained interpretation across countries and over time, comparisons "across the board" have to be made with caution. Different data sets tend to show differences in time spans, in beginning years and end years, and in country groupings. To the extent practicable this is made explicit in the headings and legends of the tables. For details of the country groupings Annex II should be consulted. That will also make apparent that the aggregate "Asia" and the aggregate "low income countries" are largely synonymous, similarly "Africa" and "least developed countries". Separate interpretation is therefore often not warranted.

The quantitative indicators are organized and presented in six chapters. Chapters 2 and 3 deal with commodity-oriented indicators. Chapters 4 to 7 with resource-oriented ones and development perspective indicators.

Commodity-oriented indicators are concerned with the production of and demand for the different crop and livestock products. The importance of production as an essential component of a society's welfare is obvious. In this sense the relative importance of the different crops in overall production value is an important theme. Commodity-oriented indicators are examined from different angles in two chapters. The discussion includes considerations of income elasticities of demand that cause changes in relative importance of commodities over time, issues of production versus trade, risk and yield variations but also aspects related to distributional goals. Chapter 2 takes an aggregate view of all developing countries as a group while Chapter 3 deals with country groups based on regions and stages of economic development.

Resource-oriented and development perspective indicators, presented in Chapters 4-7, deal with the basic theme of resource endowment and resource productivity in developing countries. Chapter 4 provides an assessment of climates and soils as they determine agricultural suitability and productivity. Chapter 5 focusses on the production factor land and its productivity as measured by crop yield. Chapter 6 characterizes the structure of inputs other than land and their productivity. Included is an analysis of livestock populations and productivity. Chapter 7 analyses resource use and production as depicted in a normative scenario by FAO's study AT:2000. Both, Chapters 4 and 7, contain normative elements. Development perspectives are outlined in the former case based on the physical possibilities for food production, in the latter on a development path that is deemed realistic and desirable. Initially indicators of national research allocation were to be included as an additional main facet. Because of the difference in type, source and quality of the data and the consequent difference in the weight of possible conclusions that topic is dealt with in an annex.

The concluding remarks summarize for the three groups of chapters the highlights of the data presented and of the issues involved in their interpretation. Potential use and limitations of the quantitative indicators are also outlined.

2. Commodity-oriented Global Indicators

2.1 General

Agricultural commodities play an important role in the satisfaction of various societal goals: Food production, farm income, export-earning or import-substituting capacity, but also distribution, or at least the capacity to distribute enough food to all. The relative importance of a crop in overall food production is of interest for setting research priorities: A ten per-cent yield increase - as a result of research - in crop A with a large share in the present production value has, ceteris paribus, a greater impact on the welfare of developing countries than if that increase is achieved for an unimportant crop B. In reality, however, the conclusions one can draw for research are not so clear-cut. Thus crop B may promise much higher returns to a unit of research efforts or the probability of successful research may be judged much greater. Furthermore, the valuation of production may not correspond with national preferences. Finally, the values and production shares are those of the present. Research should, however, be geared to the relative importance of products in future. Despite of these and other caveats it is generally deemed useful to establish in various ways the relative importance of the commodities. That relative importance can be established with respect to production, demand, trade, food consumption and nutrition. In addition, the relationships between the importance of a crop and other indicators like per-caput income and production variability are also established.

The data contained in this chapter are taken from the AT 2000 data files and therefore refer to 90 developing countries representing 98% of the total population in developing countries excluding China. The term "global indicators" means that all these developing countries are in this Chapter looked at as a group.

2.2 Production, Demand, and Trade

Production values show the importance of commodities for the gross domestic product and, thus, for national income and welfare. Demand values show people's revealed preferences as given by utility and purchasing power. Values for export and import, finally, demonstrate comparative advantages in the production of different commodities.

The relevant information is given in table 2.2.a, which shows the value of production, demand, and trade in developing countries by commodity in percent of the total value. The data refer to the average of 1978/80. As far as production is concerned the dominance of rice is obvious (18.2%). Of the other cereals only wheat has a share of more than 5 percent, a value that is surpassed by several non-cereal crops like roots, sugar, vegetables, fruit and vegetable oils. This also demonstrates the importance of food crops other than cereals in developing countries. Overall, cereals account for 31%, other food crops for slightly over 40%. Non-food crops (8.4%) and livestock products (20.3%) are of lesser importance. Of the latter, however, beef (5.6%) and milk (7.1%) stand out with significant shares in the production value.

By and large the demand figures show a similar pattern and therefore do not require separate detailed comment. Overall cereals (particularly

Table 2.2.a: Value of production, demand and trade in developing countries by commodity [a], 1978/80, in percent of total value

	Production	Demand	Export	Import	Degree of self-sufficiency [b] percent
Wheat	5.5	7.6	2.7	23.9	73.7
Rice	18.2	19.0	5.4	10.0	98.5
Maize	3.8	4.1	3.0	5.8	95.4
Barley	0.9	1.1	0.1	1.8	85.1
Millets	2.6	2.6	1.5	1.4	101.9
Roots	6.7	6.4	4.6	0.3	108.7
Sugar	5.2	4.7	9.7	6.1	115.7
Pulses	3.4	3.5	1.2	1.0	101.3
Vegetables	8.1	8.3	1.4	1.1	100.8
Bananas	2.4	2.2	2.3	0.3	111.7
Citrus fruit	1.9	1.6	4.0	0.6	128.8
Fruit	5.5	5.4	3.1	1.7	104.3
Vegetable oils	6.5	6.0	13.8	16.8	110.9
Cocoa	0.8	0.1	5.4	0.3	568.5
Coffee	2.7	0.8	16.5	1.3	344.4
Tea	0.7	0.5	2.6	1.6	132.5
Tobacco	1.3	1.1	3.1	1.6	120.8
Cotton	2.2	1.9	6.1	3.7	122.5
Jute and hard fibres	0.6	0.5	1.0	0.4	116.2
Rubber	0.9	0.2	6.4	1.1	440.3
Fodder crops	-	-	-	-	-
Beef	5.6	5.5	5.1	4.1	104.4
Mutton	1.3	1.4	0.3	1.4	93.3
Pigmeat	2.5	2.6	0.1	0.3	99.2
Poultry	2.2	2.4	0.5	2.0	94.2
Milk	7.1	8.3	0.2	11.1	87.3
Eggs	1.6	1.7	0.0	0.4	98.1
Cereals [c]	31.0	34.3	12.6	42.9	92.0
Other food crops [d]	40.5	38.8	45.4	28.2	108.0
Non-food crops [e]	8.4	5.1	35.7	9.6	171.0
Livestock [f]	20.3	21.8	6.3	19.3	95.0
Total food [g]	91.6	94.9	64.3	90.4	99.0
Total	100.0	100.0	100.0	100.0	103.0

a) According to FAO's AT 2000 project data

b) Production/demand, based on volume for commodities, on value for aggregates

c) Wheat to millets

d) Roots to cocoa

e) Coffee to fodder crops

f) Beef to eggs

g) Cereals, other food crops and livestock

Source: FAO, AT 2000 data files

wheat) and livestock products have a higher share in demand than in production indicating that indigenous production has fallen behind.

Export and import figures reveal some comparative advantages of developing countries. Most of the export earnings come from food crops other than cereals and from non-food crops. Coffee accounts for 16.5% of the total export value. Other important export products are sugar (9.7%), vegetable oils (13.8%), cocoa (5.4%), cotton (6.1%), and rubber (6.4%). On the import side, the high share of cereals - almost 43% of the total import bill - is obvious. Among cereals wheat (23.9%) is by far the most important followed by rice (10.0%) and maize (5.8%).

The importance of other food crops like sugar (6.1%) and vegetable oils (16.8%) in exports as well as in imports points to the heterogeneity of the country group. Finally livestock products figure prominently accounting for almost 20% of the total import value. Milk in all its different forms is by far the most important single commodity (11.1%).

The degree of self-sufficiency is the result of the figures on production and demand in that total production is divided by the total demand for a particular commodity. In food crops other than cereals and particularly in non-food crops the developing countries as a group are more than self-sufficient. Within these groups there are the typical tropical commodities for which they have a comparative production advantage. For cereals (92%) and for livestock products (95%) the degree of self-sufficiency is well below 100%. Among cereals it is particularly low for wheat (73,7%). Among livestock products the lowest value is for milk (87.3%).

In Table 2.2.b trends for production, demand, and trade by commodity have been calculated for the past. The future trends are those estimated by FAO and represent the most likely evolution without there being any particular increases in the level of overall and sectoral development efforts. Though production has increased for all commodity groups considered, there are important differences. Overall, past and future trends accentuate the picture of Table 2.2.a. Cereal production has increased below average and would continue to do so. Non-food crops production shows even lower rates of increase. For "other food crops" beside cereals and livestock, there has been and would continue to be a production increase at or above average. Hence, the importance of cereals and non-food crops within the production bundle has gone down and would continue to do so whereas "other food crops" beside cereals and livestock products have gained and would continue to gain up to the year 2000. It should be stressed that for all categories the rates of change are positive signifying real production increases. The differential growth rates, however, lead to a change in the composition of the (growing) total food production.

Considering demand, trends for all commodity groups have always been higher than those of production. This is also the case in future trends for cereals and non-food crops. The rates of production increase in food crops other than cereals and in livestock match the rates of demand increases.

Such a development is also reflected by export and import trends. Generally, the figures are higher than production and demand trends. This clearly reflects the increasing importance of international trade

Table 2.2.b: Trends for production, demand, and trade in developing countries by commodity [a], annual rates of change, in percent

	Production			Demand			Export			Import		
	1966 - 80	1970 - 80	1978/80 - 2000	1966 - 80	1970 - 80	1978/80 - 2000	1966 - 81	1971 - 81	1978/80 - 2000	1966 - 81	1971 - 81	1978/80 - 2000
Wheat	4.7	3.9	2.3	4.7	4.3	2.2	4.1	12.2	5.4	4.9	6.1	2.3
Rice	2.9	2.7	2.2	2.9	2.6	2.2	3.7	8.7	5.3	3.2	4.1	5.1
Maize	1.9	1.6	2.5	3.2	3.3	3.5	0.8	1.2	3.8	19.5	22.0	7.2
Barley	0.8	1.0	1.8	1.9	2.1	3.7	2.7	10.0	2.2	13.1	11.7	8.1
Millets	2.2	2.1	2.0	2.0	2.2	3.1	8.7	8.2	4.6	7.6	12.0	11.1
Roots	2.4	2.5	2.6	1.9	1.8	2.9	12.7	14.9	1.5	4.4	4.8	12.1
Sugar	3.4	3.3	3.3	3.6	4.0	3.1	3.0	2.0	3.6	6.1	9.1	2.1
Pulses	0.9	0.4	1.4	0.9	0.5	2.7	2.8	3.8	1.3	6.5	11.1	12.5
Vegetables	3.4	3.6	3.5	3.4	3.6	2.9	6.2	6.2	13.0	6.9	12.2	5.2
Bananas	2.8	2.8	2.6	2.8	2.9	2.7	2.8	1.2	2.9	5.1	7.1	8.9
Citrus fruit	5.3	5.7	3.3	4.1	4.6	3.4	12.9	12.9	2.9	15.3	14.9	4.3
Fruit	2.7	2.8	3.6	2.8	3.0	3.3	1.9	2.3	6.8	3.6	5.5	4.0
Vegetable oils	4.2	4.3	2.9	4.9	5.1	2.6	5.9	7.2	4.1	12.6	16.2	3.4
Cocoa	1.2	0.1	2.1	0.8	1.4	2.0	2.0	1.2	1.6	3.9	6.8	- 2.4
Coffee	0.8	0.8	1.5	- 0.3	1.8	3.8	0.9	0.4	0.5	3.2	2.8	3.6
Tea	2.9	3.2	2.6	4.2	5.2	3.7	1.7	1.8	0.9	4.1	6.3	3.6
Tobacco	2.5	3.2	2.4	2.3	4.0	2.2	4.6	3.0	2.5	6.2	8.2	1.4
Cotton	0.7	0.1	1.4	3.3	3.2	2.3	- 2.2	- 2.9	0.2	4.5	4.4	4.0
Jute and hard fibres	- 0.4	- 0.2	0.0	1.9	2.4	0.2	- 6.0	- 6.2	0.0	- 1.1	- 1.1	3.3
Rubber	3.2	2.4	3.8	7.9	7.6	2.3	2.2	1.2	3.9	5.9	5.8	1.8
Fodder crops	-	-	-	-	-	-	-	-	-	-	-	-
Beef	2.2	2.5	2.6	2.7	3.3	3.1	0.2	0.3	3.1	6.5	9.9	8.1
Mutton	1.4	1.7	1.6	2.0	2.5	3.7	0.8	5.2	- 2.9	11.0	14.7	11.0
Pigmeat	3.3	3.4	3.8	3.3	3.4	3.4	- 1.8	- 10.8	25.6	3.1	7.2	11.6
Poultry	8.0	8.3	4.7	8.4	8.8	4.0	61.2	99.7	16.3	33.7	39.1	6.9
Milk	2.5	2.6	3.0	3.0	3.2	2.9	11.7	4.5	16.1	8.0	10.1	3.7
Eggs	5.7	5.8	4.6	5.8	6.0	4.2	- 2.3	- 5.2	24.7	14.1	15.6	9.9
Cereals [b]	2.9	2.7	2.2	3.2	3.0	2.5	3.4	6.6	4.9	5.8	7.4	4.9
Other food crops [c]	3.0	3.0	3.1	3.1	3.2	3.0	5.0	5.4	4.4	9.0	12.2	4.3
Non-food crops [d]	1.3	1.2	1.9	2.8	3.5	2.5	0.5	-	1.5	4.3	5.0	3.2
Livestock [e]	3.1	3.3	3.3	3.5	3.9	3.3	1.3	2.1	8.4	8.7	11.8	6.4
Total food [f]	3.0	3.0	2.9	3.2	3.3	2.9	4.2	5.2	5.1	7.3	9.7	5.0
Total	2.8	2.8	2.8	3.2	3.3	2.9	2.8	3.2	4.1	7.0	9.2	4.9

a) According to FAO's AT 2000 project data. Based on volume for commodities, on value for aggregates

b) Wheat to millet

c) Roots to cocoa

d) Coffee to fodder crops

e) Beef to eggs

f) Cereals, other food crops and livestock

Source: FAO, AT 2000 data files

for developing countries.

A very important aspect is that in the past the growth rate of demand for livestock products has consistently been above the average and higher than for any other commodity group. This trend is also supposed to hold for the future. This is only another way of saying that income elasticities of demand for livestock products are significantly higher than for crop products.

Summarizing Tables 2.2.a and 2.2.b, the relative importance of individual commodities for different societal goals becomes evident. Taking production and demand as proxies for national welfare and revealed preferences, the outstanding importance of rice is obvious. The relative importance of cereals as a group, however, tends to go down. The importance of some other food crops beside cereals has been mentioned. Trends for this commodity group are positive and above average, anyway. Also, the increasing importance of livestock has to be seen. People in developing countries mainly live on rice and other staples but they increasingly prefer to have more livestock products in their diet as clearly shown by all demand data. In that respect their behaviour is in no way different from that of people in today's industrialized countries. For the setting of research priorities a classical issue arises: Does one concentrate on staples because of their basic importance in the diet or does one concentrate on livestock products of which more and more is wanted?

Basic issues also arise with respect to demand and trade figures. For advocates of an inward strategy (import substitution, autarchy) the gap between production and demand, presently filled by imports, points to a relevant area of research and development. They might then emphasize research on wheat and milk production in developing countries. Others will interpret trade as primarily a reflection of comparative advantages and reach quite a different conclusion that would favour the more typical tropical commodities. The proceeds from these exports would continue to be used to finance imports of certain commodities. Both views have their limitations. On one hand it is difficult to promote a crop like wheat on the basis of demand figures only. The production conditions habe to be examined as well. On the other hand the growth potential of export crops may be restricted. The markets of the industrialized countries have very low rates of growth due to their stagnant populations and the low income elasticities of demand for most agricultural commodities. A real growth potential, however, lies in trade within the South. The most important determinant here is the rate of overall economic growth.

2.3 Food Consumption and Nutrition

Malnutrition and famine are among the most severe problems in developing countries. As a consequence, feeding people is an important goal. Commodities contribute to differing degrees to this goal. Food consumption data show how people actually behave in feeding themselves. This gives an idea about their preferences for commodities. In addition, the nutritional value of different commodities has to be taken into account, i.e. the actual contribution of the different commodities to the consumption of calories, protein, and fat.

Table 2.3.a shows the share of commodities in the total value of food

Table 2.3.a: Food consumption in developing countries by commodity [a], 1978/80, and annual rates of change 1966 - 80, 1970 - 80 and 1980 - 2000

	Value 1978/80	Trends [b]			Trends [b] in consumption per caput		
		1966 - 80	1970 - 80	1980 - 2000	1966 - 80	1970 - 80	1980 - 2000
	percent of total value	percent	percent	percent	percent	percent	percent
Wheat	7.9	4.6	4.4	2.4	1.9	1.8	- 0.0
Rice	21.2	8.1	2.6	2.3	0.5	0.1	- 0.1
Maize	2.6	2.5	2.6	2.8	- 0.1	- 0.0	0.4
Barley	0.5	0.8	- 0.1	3.7	- 1.8	- 2.6	1.2
Millets	2.2	1.2	1.2	2.8	- 1.3	- 1.3	0.4
Roots	5.7	2.3	2.2	2.7	- 0.3	- 0.3	0.2
Sugar	4.9	3.9	3.8	2.7	1.3	1.2	0.3
Pulses	3.4	1.0	0.5	2.9	- 1.6	- 2.0	0.5
Vegetables	9.2	3.4	3.6	2.8	0.8	1.0	0.4
Bananas	2.0	3.1	3.2	2.8	0.5	0.6	0.4
Citrus fruit	1.7	3.9	4.3	3.5	1.2	1.7	1.0
Fruit	5.8	2.8	2.8	3.2	0.2	0.3	0.8
Vegetable oils	5.6	4.4	4.7	2.8	1.8	2.0	0.4
Cocoa	0.1	1.9	2.6	3.5	- 0.7	0.0	1.1
Coffee	1.1	0.7	1.2	3.5	- 1.8	- 1.4	1.0
Tea	0.7	4.3	5.2	3.7	1.7	2.6	1.2
Beef	6.8	2.7	3.3	3.1	0.1	0.7	0.7
Mutton	1.7	2.0	2.5	3.7	- 0.5	- 0.0	1.2
Pigmeat	3.2	3.3	3.4	3.4	0.7	0.9	1.0
Poultry	2.9	8.4	8.8	4.0	5.7	6.1	1.5
Milk	8.8	3.1	3.5	2.9	0.5	0.9	0.4
Eggs	1.8	5.9	6.0	4.1	3.2	3.3	1.6
Cereals [c]	34.4	3.2	2.9	2.4	0.6	0.3	- 0.0
Other food crops [d]	39.4	3.1	3.2	2.9	0.5	0.6	0.5
Non-food crops [e]	0.8	1.9	2.6	3.6	- 0.6	0.0	1.1
Livestock [f]	25.4	3.6	4.0	3.3	1.0	1.4	0.9
Total food [g]	99.2	3.2	3.3	2.8	0.6	0.7	0.4
Total	100.0	3.2	3.3	2.9	0.6	0.7	0.4

a) According to FAO's AT 2000 project data

b) Based on volume for commodities, on value for aggregates

c) Wheat to millets

d) Roots to cocoa

e) Coffee and tea

f) Beef to eggs

g) Cereals, other food crops, and livestock

Source: FAO, AT 2000 data files

consumption in developing countries. The figures refer to 1978/80.

Not cereals (34.4%) but "other food crops" (39.4%) are the most important commodity group in the value of consumption. Livestock products also hold a substantial share, slightly over one fourth. The most important single commodity is rice at 21.2%. Other important commodities - all, however, below the ten-percent-mark - are in order of decreasing shares vegetables, milk, wheat, beef, fruit, roots and vegetable oils. The overall picture corresponds fairly closely with that drawn for production and demand.

A similar analogy emerges for trends. Cereal consumption is increasing, but below average and slowing down. The importance of "other food crops" and, especially, of livestock commodities is increasing. This pattern also holds for the trends of food consumption per caput.

Table 2.3.b shows per caput daily food supply in developing countries by commoditiy in percent of the total. The figures refer to calories, protein, and fat and cover the average of 1978/80.

Cereals contribute over 60% to total calorie supply and over 56% to total protein supply. Other important calorie contributions come from roots and tubers (7%) and sugars and honey (7%). Important sources of protein other than cereals are meat and offals (10.1%), pulses (9.8%), and milk (5,1%). Fat originates from vegetable oils and fats (32.0%), meat and offals (22.2%), cereals (15.1%), nuts and oil seeds (8.8%), animal oils and fats (8.1%) and milk (6.3%). If one compares the totals for crop and livestock products the former contribute 91% of all calories, 79.2% of all protein and 60.4% of all fat.

The trends again show a decrease in the share of crops and an increasing importance of livestock as a source of nutrients.

In summary an apparent inconsistency emerges. In the light of a world food problem one would like to stress cereals (and tubers) and see their importance grow as relatively cheap sources of all major nutrients. On the other hand people move away from crop products and show increasing preference for animal foods. One might argue that this picture is derived from aggregate data concealing important differences among and within countries. However, experience shows that on all income levels the desire to increase the share of animal products in the diet prevails. This does not negate the need to make special efforts to supply the poor with sufficient staples at low cost. This may be achieved through institutional measures (price policy, rationing and the like). Research, however, also has an important role. One of the major impacts of cereal research in the past has been to increase the overall supply of staples thus containing price increases. The major beneficiaries are the poorest of the poor among the consumers. Indirectly this also increases their capacity to add more animal products to their diet. An estimate of the social payoff of alternative research lines would have to take all these considerations into account.

Table 2.3.b: Per caput daily food supply in developing countries by commodity, 1978/80, in percent of total and annual rate of change in share 1969/71 - 78/80, in percent

	1978/80			1969/71 - 78/80		
	Calories	Protein	Fat	Calories	Protein	Fat
Cereals	61.0	56.1	15.1	0.0	0.2	- 1.1
Roots and tubers	7.0	3.1	1.0	- 1.7	- 1.3	- 2.0
Sugars and honey	7.0	0.2	-	0.7	0.0	0.0
Pulses	3.9	9.8	1.4	- 1.8	- 1.6	- 3.3
Nuts and oilseeds	2.3	4.9	8.8	- 0.9	- 0.7	- 1.4
Vegetables	1.5	3.4	0.8	0.0	0.3	- 1.3
Fruit	2.1	1.0	0.8	0.0	0.0	- 1.3
Meat and offals	4.5	10.1	22.2	1.0	0.9	0.5
Eggs	0.4	1.4	1.8	0.0	0.8	0.6
Fish and seafood	0.6	4.1	1.3	0.0	0.8	0.9
Milk	2.1	5.1	6.3	0.0	0.4	- 0.7
Vegetable oils and fats	4.8	0.0	32.0	1.8	0.0	1.1
Animal oils and fats	1.2	0.0	8.1	0.0	0.0	- 0.4
Spices	0.2	0.3	0.5	0.0	- 3.1	- 2.0
Stimulants	0.1	0.3	0.0	-	- 3.1	-
Alcoholic beverages	1.0	0.2	0.0	1.2	0.0	-
Crop products [a)]	91.0	79.2	60.4	- 0.1	- 0.2	- 0.1
Animal products [b)]	9.0	20.7	39.6	0.8	0.8	0.1
Total	100.0	100.0	100.0	-	-	-

a) Cereals, roots and tubers, sugars and honey, pulses, nuts and oilseeds, vegetables, fruit, vegetable oils and fats, spices, stimulants, alcoholic beverages

b) Meat and offals, eggs, fish and seafood, milk, animal oils and fats

Source: FAO, ICS data files

2.4 Production and Socio-economic Variables

The relative importance of commodities should not only be judged by their share in total production, trade, and other aggregates. It may be hypothesized that different commodities play different roles in the course of agricultural and overall development. They also relate in different ways to a whole range of socio-economic variables. Some typical questions may serve as illustrations: Are roots and tubers the more important as a commodity group the lower the stage of economic development? Does the promotion of cereals, in particular wheat, primarily benefit those countries that are already better off? Is agricultural growth correlated with the expansion of non-food crops? Are differences in commodity shares related with differences in demographic growth rates? Such relationships can, to an extent, be detected by simple correlation analyses. Table 2.4. shows correlation coefficients between commodity shares in the agricultural production value on one side and a number of socio-economic variables on the other.

A considerable number of the correlation coefficients are close to zero indicating the absence of a statistical connection (which of course is also an important result). This applies to the shares of non-food crops like coffee, tea, tobacco, rubber and indicators like per caput GDP, per caput value of agricultural production, agricultural sector shares, population growth rates or per caput calorie consumption. Cotton and jute do show some significant correlations but interpretation is rather difficult.

Other commodity groups do indicate significant relationships. Fruit, poultry, and eggs are relatively more important in countries with relatively high development levels. This is shown by highly significant positive correlation coefficients with per caput GDP, with per caput calorie intake and in significant negative coefficients with agricultural sector shares in GDP and population. To a lesser extent, this also applies to wheat, barley, sugar, vegetables, and citrus fruit.

On the other hand, some products are relatively more important in countries with a low development level. Pulses are an example. Production share is relatively high in countries with low per caput GDP, low per caput calorie supply, high agricultural sector shares in GDP and population. To a lesser extent, this also holds for rice, maize, millets and roots. All these products would appear to be more particularly associated with poverty than others. A similar association is shown for mutton but holds only because the category includes goat meat, which is of importance in African countries.

Significant relationships also exist between commodity shares and population growth rates. The higher the growth rate, the more important are maize and pulses and the less important are rice, sugar, citrus fruit, pigmeat and poultry. The underlying causal relationships, however, are not self-evident.

In summary a word of caution appears appropriate. The coefficients do not show the importance of different commodities for the process of agricultural development or for any particular goals of a society. They merely point to the possible existence of links between the development process and the different relative importance of commodities. Cultural and ecological differences between world regions and other factors make it impossible to draw rigid conclusions. But tentatively one could

Table 2.4.: Simple correlation coefficients for commodity shares in the agricultural production value and socio-economic variables [a)]

	Socio - economic variables						
		Per caput GDP		Agricultural sector shares		Population growth rate [b)]	Per caput calories
	Total	Agriculture	Non-agriculture agriculture	GDP	Population		
Wheat	.12	.08	.03	-.15	-.14	.13	.29 **
Rice	-.18	-.11	-.12	.29 **	.09	-.18	-.12
Maize	-.16	-.14	-.03	.03	.16	.29 **	-.07
Barley	.17	.04	-.02	-.24 *	-.17	.12	.34 **
Millets	-.17	-.22 *	.08	.27 *	.39 ***	.05	-.30 **
Roots	-.08	-.17	.01	.14	.25 *	.01	-.16
Sugar	.06	.29 **	-.10	-.17	-.38 ***	-.26 *	.13
Pulses	-.28 **	-.34 **	-.04	.42 ***	.43 ***	.18	-.27 *
Vegetables	.20	-.05	.15	-.21 *	-.17	.10	.09
Bananas	-.01	.01	-.03	.11	.11	.09	-.12
Citrus fruit	.16	.27 *	-.07	-.38 ***	-.43 ***	-.16	.34 **
Fruit	.43 ***	.07	.38 ***	-.44 ***	-.30 **	.03	.24 *
Vegetable oils	-.06	-.04	-.06	.15	.16	.05	.02
Cocoa	.06	.03	.02	-.01	.08	.08	-.04
Coffee	-.10	-.04	-.08	.03	.06	.18	-.18
Tea	-.10	-.02	-.05	.15	.04	-.03	-.02
Tobacco	-.08	-.07	-.05	-.02	.04	.14	.09
Cotton	-.16	-.12	-.07	.07	.11	.21 *	-.07
Jute and hard fibres	-.16	-.16	-.07	.33 **	.19	.01	-.23 *
Rubber	-.03	.02	-.04	.02	.02	.04	.07
Fodder crops	-	-	-	-	-	-	-
Beef	-.03	.34 **	-.06	-.09	-.09	-.12	.14
Mutton	-.06	-.17	.02	.05	.23 *	.03	-.15
Pigmeat	-.06	.07	-.15	-.07	-.19	-.25 *	.14
Poultry	.51 ***	.35 ***	.10	-.56 ***	-.57 ***	-.23 *	.25 *
Milk	.11	.01	.21 *	-.14	-.01	.03	-.02
Eggs	.42 ***	.28 **	.12	-.52 ***	-.57 ***	-.07	.25 *

a) According to FAO's AT 2000 project data. Production value shares refer to 1978/80 and socio-economic variables, with the exception of the population growth rate, to 1974/76.
Significance levels : 95 percent (*), 99 percent (**), 99.9 percent (***).

b) During the period 1975-80

Source: FAO, AT 2000 data files

state for example that research on pulses has its major potential benefit for the poorer countries and that countries experiencing high population growth rates would benefit most from further advances in maize research.

2.5 Production and Risk

Food security and the reduction of risk in food production are important goals for developing countries. Production risks are essential innovation problems. The choice of production structure and the choice of varieties by farmers is not only determined by potential yields and returns. Probabilities of production outcome and yield variation may be as important. This holds for the adoption of new high-yielding varieties whose adoption may be prevented by risk considerations. It also applies to agricultural production at large: To reduce production risks thereby increasing food security and income stability would constitute an important improvement of agriculture in developing countries.

Production risks have different causes and may differ significantly among commodities. This chapter is to give a starting point for the analysis of fluctuation and risk in agricultural production.

In Table 2.5. the fluctuation of different crops during the period 1966-80 is analysed. The fluctuations are trend-corrected which means that only fluctuations around exponential trends are considered. Such trends reflect long-term developments which should not be confounded with fluctuations. The analysis treats the developing countries as a group so that fluctuations may balance out among countries. The figures can therefore be considered as indicating minimum fluctuations of different crops for developing countries on a world-wide scale. They cannot demonstrate the fluctuation problem for individual countries, nor - for that matter - for regions within a country.

The degree of fluctuation is indicated by the coefficients of variation in the left-hand column of Table 2.5. These coefficients show that production fluctuation in developing countries is relatively high for barley, sugar beets (little grown), coffee, and jute. Production fluctuation is rather small, on the other hand, for maize, roots, and tea. Fluctuations for rice are lower than those for millets and wheat.

Production fluctuations may be caused by area or yield fluctuations. Area fluctuations reflect mainly farmers' decisions related to weather but certainly also to market prospects, whereas yield fluctuations are largely the result of environmental variations (weather, but also disease, pests etc.). These two kinds of fluctuations may have different impacts on production fluctuation. Furthermore, the additional impact of possible covariance has to be considered.

The different contributions of area and yield fluctuations and covariances are also shown in Table 2.5. For cereals yield fluctuations appear to be more important than area fluctuations particularly in the case of barley and millets. For roots and sugar area fluctuations dominate. For pulses, on the other hand, it is yield fluctuations again that stand in the foreground. For non-food crops, the impact of yield and area fluctuations tends to be more balanced. High yield fluctuations, however, exist for cotton.

Table 2.5.: Trend-corrected fluctuation of crop production in developing countries, 1966 - 80

	Coefficient of variation a) percent	Decomposition of variance b)		
		Variance in area percent	Variance in yield percent	Covariance for area and yield percent
Wheat	6.1	17.2	34.9	47.9
Rice	4.3	13.1	42.6	44.3
Maize	2.8	17.3	36.2	46.5
Barley	10.3	15.5	75.7	8.8
Millets & other cereals	5.3	4.5	73.7	21.8
Roots	1.8	70.1	4.3	25.6
Raw sugar (beet)	13.6	67.8	6.6	25.5
Raw sugar (cane)	4.8	57.7	7.0	35.3
Pulses	4.2	37.3	63.9	- 1.3
Cocoa	6.6	18.0	43.9	38.0
Coffee	7.7	29.1	52.2	18.7
Tea	2.4	22.5	30.2	47.3
Tobacco	4.2	25.8	34.2	39.9
Cotton	6.2	29.3	84.1	-13.4
Jute & hard fibres	7.7	59.2	14.7	26.1

a) Standard deviation/mean. The standard deviation reflects fluctuations around a fitted exponential trend whereas the mean considers the original production data

b) A trend-corrected decomposition of the production variance is possible by taking logarithms of the production formula. We get Variance (Production) = Variance (Area) + Variance (Yield) + 2 Covariance (Area,Yield). In the table each component is expressed as percentage of the production variance.

Source: FAO, AT 2000 data files

Most of the covariances have positive signs which means that area and yield fluctuations are positively correlated in most cases. Supposedly that is mainly due to a parallel effect of weather. Yield and area fluctuations do not balance each other out, rather they reinforce each other in their impact on production. This is especially true for wheat, rice, maize, and tea.

Theoretically the results could point to some research priorities. There may be biological, chemical and mechanical ways to reduce yield fluctuations. Socio-economic research may help to understand area fluctuations and to point to areas of biological research leading to counter-measures. Together such efforts would also reduce covariances and the impact on food security and stability could be substantial.

Although one hesitates to draw firm conclusions from the very aggregate analyses above it would appear that for millets, barley and pulses in particular risk and fluctuation may be as important as issues as yield levels.

3. Commodity-oriented Indicators for Country Groups

3.1 General

The general remarks made in the previous chapters about the relationship of commodity indicators with goals of a society on one side and with research priorities on the other apply to this chapter as well. But before the developing countries were viewed as an aggregate, and that aggregate is by no means homogeneous. Countries differ with respect to size, resource endowment, cultural background, stage of development, political systems and the like. Accordingly goals and thus also the relative importance of commodities may differ among countries. Therefore the developing countries are now viewed as different groups, the groupings being based on regions, income levels and levels of agricultural productivity. Figures for industrialized countries are sometimes included to allow comparisons.

3.2 Production

Importance of agricultural commodities as shown by their production volume differs considerably among geographical regions. In its 1979 report TAC presented production figures for major food crops by specified region. The material has been updated to demonstrate the present importance of major crops. Table 3.2. shows the figures for 1982.

World-wide, cereals play a dominant role as staple foods. In developing countries, too, their importance is obvious. Rice is the dominant crop in China, South and Southeast Asia, and India. Wheat is most important for the Middle East and North Africa, whereas maize is dominant in America and Central and South Africa. For the latter region the specific importance of sorghum and millets has to be mentioned.

On a world scale pulses only play a much lesser role. They do have particular importance in developing countries, however. India grows the largest part of pulses. World-wide, the most important species are dry beans, followed by chickpeas, and broad beans.

Legume oilseeds and, especially, soybeans are most important in China. This is also the case for sweet potatoes. Cassava is mostly grown in South and Southeast Asia, Central and South Africa, and South America. For Central/South Africa the importance of yams has to be mentioned.

In summary, the importance of commodities as measured by the production volume differs considerably between world regions. However, since the figures do not relate to the human population, interpretation cannot be carried very far.

3.3 Self-sufficiency

Self-sufficiency is defined as the ratio of production over demand. This indicator compares the production possibilities with revealed preferences. By implication, it can be interpreted as a measure of the comparative advantage a country has in producing a given commodity. Table 3.3.a shows self-sufficiency degrees in developing country groups by commodity for 1978/80.

Table 3.2.: Production of major food crops in world regions, 1982, in million metric tons

	World	USA, Canada	Western Europe	Japan, Australia, Oceania	USSR, Eastern Europe	China	South South-east Asia (except Japan, China, India)	India	Middle East North Africa	Central South Africa	Central America	South America
Cereals												
Rice	422.5	7.0	1.6	13.7	2.7	161.2	131.4	68.0	10.0	6.4	2.1	15.2
Wheat	483.2	104.1	73.4	9.9	117.1	68.4	2.0	37.8	44.2	1.1	4.5	18.3
Maize	451.5	219.7	34.8	0.4	36.8	60.0	13.5	6.5	7.1	13.9	15.1	35.2
Sorghum	68.1	21.4	0.5	1.3	0.2	7.0	0.5	10.8	3.0	8.3	5.5	9.2
Millets	28.4	-	0.02	0.04	2.0	6.0	0.7	9.0	1.3	9.2	-	0.2
Barley	160.6	25.4	53.2	2.5	57.8	3.2	1.2	2.0	12.7	1.2	0.5	0.7
Total, cereals above	1 614.3	377.6	163.5	27.9	216.6	305.9	149.2	134.1	78.3	40.3	27.8	78.7
Total, all cereals	1 701.6	393.3	179.6	28.8	261.5	311.4	149.5	134.1	79.5	41.7	27.8	79.9
Pulses												
Cowpeas	1.5	-	0.01	-	-	-	0.04	-	0.01	1.4	0.03	-
Pigeonpeas	2.5	-	-	-	-	-	0.04	2.2	-	0.1	0.03	-
Chickpeas	6.1	-	0.08	-	-	-	0.2	4.6	0.8	0.2	0.3	0.02
Dry beans	14.1	1.2	0.4	0.2	0.3	1.7	0.7	2.7	0.4	1.4	1.5	3.6
Lentils	1.3	0.2	0.06	-	0.02	-	0.05	0.5	0.4	0.06	0.01	0.04
Broad beans	4.0	-	0.4	0.01	0.06	2.4	-	-	0.5	0.5	0.08	0.1
Total, pulses above	29.5	1.4	1.0	0.2	0.4	4.1	1.0	10.0	2.1	3.6	1.9	3.8
Legume oilseeds												
Soybeans	94.4	62.8	0.2	0.3	1.1	9.0	1.4	0.7	0.3	0.2	0.7	17.7
Groundnuts	11.0	1.1	0.05	0.06	0.01	1.4	0.9	4.4	0.6	1.9	0.08	0.4
Roots and tubers												
Cassava	126.9	-	-	-	-	3.2	39.9	5.6	0.1	49.6	0.9	27.1
Irish potatoes	254.8	18.6	47.9	4.8	131.3	15.0	4.6	9.9	8.0	1.9	1.3	10.2
Sweet potatoes	138.7	0.7	0.1	1.4	-	118.4	7.2	1.5	0.3	5.1	0.7	1.5
Yams	22.9	-	-	0.1	-	-	0.03	-	0.1	21.8	0.2	0.4

Source: FAO, ICS data files

The developing countries as a whole are not self-sufficient in cereals. The degree of self-sufficiency is especially low for Africa and the Near East. Income level and agricultural growth do not seem to have any significant influence on self-sufficiency. Among the cereals wheat is the one with the lowest self-sufficiency levels (except Near East).

In the production of "other food crops" the developing countries have some comparative advantages that shows in substantially higher self-sufficiency levels, particularly in Latin America. Such comparative advantages include the virtual monopoly of tropical/subtropical countries in the production of certain vegetables, of bananas, certain fruits and vegetables oils and cocoa. Nevertheless, the Near East countries and the group of low income countries are not self-sufficient in these crops either.

The comparative advantages are even more pronounced for the production of non-food crops that are almost all the classical tropical crops. Self-sufficiency levels are particularly high in Africa and Latin America, in the group of least developed countries and in the group with high agricultural growth rates. A tentative interpretation might be that a suitable ecology is the first and overriding determinant for the production of these crops; where they can be grown they contribute substantially to agricultural growth.

Finally there is the group of livestock products for which, overall, the self-sufficiency rates are below 100%. This applies to all individual commodities except beef where Latin America's surplus outweighs the deficits of other regions. Throughout the groups milk tends to be the commodity with the largest deficits. Latin America stands out as the only region or country grouping with an overall self-sufficiency level for livestock products of above 100%. For milk, however, it is still below 90%.

Trends for self-sufficiency from 1970 to 1980 are presented in Table 3.3.b. As discussed in Chapter 2, production increases were lower than demand increases in developing countries as a whole. The gap has been especially large in Africa and the Near East. Only the Far East has been able to match demand increases with production increases. This is due to increases in self-sufficiency for cereals and "other food crops" outweighing a small decline in non-food crops and livestock products. Self-sufficiency in low income and least developed countries has deteriorated, but to no larger extent than in all developing countries together. The same is true for countries with low and high agricultural growth respectively.

Again, interpretation of these figures depends upon one's view of development strategies. From the point of view of an outward-oriented strategy different levels of self-sufficiency primarily point to differences in the comparative advantage of producing a particular commodity. In regions and country groups with a high level of self-sufficiency for a given commodity research would concentrate on further exploiting the existing comparative advantage.

An inward-oriented (import substitution) strategy draws different conclusions. For a country group research would concentrate on those commodities showing the largest deficits. The focus would be on the

Table 3.3.a: Self-sufficiency [a] in developing country groups by commodity [b], 1978/80, in percent

	Africa	Latin America	Near East	Far East	Low income [c]	Least developed [d]	Agricultural growth [e] under 3 percent	Agricultural growth [e] 3 percent or over	All developing countries
Wheat	38.7	67.5	75.8	82.8	79.0	60.3	74.8	72.4	73.7
Rice	66.4	98.6	71.0	100.9	98.4	95.4	97.5	100.0	98.5
Maize	92.6	100.6	71.1	96.1	94.3	97.2	106.7	89.6	95.4
Barley	82.4	67.7	87.1	92.6	93.5	93.2	89.0	82.4	85.1
Millets	99.0	112.7	97.2	100.1	99.8	100.4	107.7	86.2	101.9
Roots	100.1	99.7	101.3	131.6	102.3	101.3	100.2	118.1	108.7
Sugar	76.8	149.5	52.3	104.3	95.8	76.9	123.1	109.4	115.7
Pulses	101.9	102.2	103.8	100.6	99.6	102.3	99.9	104.5	101.3
Vegetables	99.6	106.5	99.6	100.3	100.3	99.8	100.5	101.3	100.8
Bananas	101.8	126.6	55.4	106.5	100.9	100.5	109.8	113.2	111.7
Citrus fruit	147.3	142.2	101.2	101.2	103.9	100.4	121.5	133.3	128.8
Fruit	109.9	104.6	103.8	103.1	100.4	104.7	104.7	103.9	104.3
Vegetable oils	92.9	127.7	62.1	122.4	89.0	100.1	91.4	130.8	110.9
Cocoa	876.3	430.1	-	181.0	567.3	1 517.1	1 315.3	419.3	568.5
Coffee	454.6	367.1	10.5	216.4	432.1	334.0	244.6	390.4	344.4
Tea	253.6	111.6	44.2	178.0	175.8	143.0	145.4	112.0	132.5
Tobacco	132.6	148.9	94.4	112.7	106.3	126.8	107.8	131.3	120.8
Cotton	225.7	162.4	196.5	78.1	117.5	347.8	115.9	128.5	122.5
Jute and hard fibres	131.6	119.4	23.8	116.5	116.5	154.3	118.2	110.5	116.2
Rubber	243.7	15.2	-	690.4	427.7	8.3	133.6	642.5	440.3
Fodder crops	-	-	-	-	-	-	-	-	-
Beef	94.0	112.7	82.6	96.4	100.4	105.9	109.3	98.9	104.4
Mutton	101.5	106.0	82.5	98.0	102.0	103.6	100.4	86.0	93.3
Pigmeat	97.8	99.3	87.4	99.5	99.6	99.1	99.3	99.2	99.2
Poultry	89.6	100.5	74.3	100.1	91.8	88.1	90.1	96.6	94.2
Milk	70.0	89.6	84.0	91.1	93.9	89.2	88.9	85.6	87.3
Eggs	92.5	99.5	94.5	100.0	99.2	98.7	96.6	98.8	98.1
Cereals [f]	75	92	77	98	95	92	94	90	92
Other food crops [g]	103	124	92	105	98	100	103	113	108
Non-food crops [h]	278	217	122	139	154	217	132	206	171
Livestock [i]	87	101	83	95	96	97	97	94	95
Total food [k]	93	109	85	100	96	96	98	100	99
Total	99	115	87	102	99	101	100	106	103

a) Production/demand. No decimal points are calculated for aggregates. Based on volume for commodities, on value for aggregates

b) According to FAO's AT 2000 project data

c) Per caput GDP of US $ 300 or lower in 1975

d) Official UN classification

e) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

f) Wheat to millets

g) Roots to cocoa

h) Coffee to fodder crops

i) Beef to eggs

k) Cereals, other food crops, and livestock

Source: FAO, AT 2000 data files

Table 3.3.b: Trends for self-sufficiency [a] in developing country groups by commodity [b], annual rate of change 1970 - 80, in percent

	Africa	Latin America	Near East	Far East	Low income [c]	Least developed [d]	Agricultural growth [e] under 3 percent	Agricultural growth [e] 3 percent or over	All developing countries
Wheat	- 6.6	- 0.6	- 0.8	0.7	- 0.1	- 0.1	- 0.7	- 0.1	- 0.4
Rice	- 2.8	- 0.2	- 4.8	0.4	0.1	- 0.2	0.0	0.3	0.1
Maize	- 1.2	- 1.9	- 3.6	- 1.4	- 0.8	- 0.2	- 1.3	- 2.0	- 1.8
Barley	- 2.0	- 2.8	- 1.1	0.0	0.0	- 0.4	- 1.2	- 1.1	- 1.3
Millets	-	- 1.2	0.1	- 0.1	0.2	0.2	0.4	- 1.6	- 0.1
Roots	- 0.1	0.0	- 0.3	1.9	0.0	0.0	0.0	1.3	0.6
Sugar	- 2.5	- 1.6	- 4.5	0.4	- 0.2	0.0	- 0.7	- 1.0	- 0.9
Pulses	- 0.8	0.0	0.2	0.1	- 0.5	- 0.1	- 0.2	0.1	- 0.1
Vegetables	- 0.2	0.2	- 0.2	0.0	0.0	0.0	0.0	0.0	- 0.1
Bananas	- 0.2	- 0.2	- 5.3	0.4	- 0.1	- 0.2	- 0.5	0.0	- 0.1
Citrus fruit	- 0.6	3.5	- 2.4	-	- 0.2	- 0.6	- 0.3	2.7	1.4
Fruit	- 1.9	0.4	- 0.4	0.1	0.2	0.4	- 0.2	- 0.2	- 0.2
Vegetable oils	- 3.4	1.9	- 2.7	- 0.2	- 2.7	- 2.3	- 2.2	- 0.3	- 0.9
Cocoa	- 24.3	10.7	- 16.9	- 17.3	80.7	- 31.2	- 21.0	4.2	18.5
Coffee	- 1.6	14.3	- 0.6	4.8	1.5	- 3.5	- 3.4	17.5	- 1.3
Tea	- 0.7	- 0.2	1.6	- 2.8	- 2.1	2.4	- 2.1	- 0.6	- 1.7
Tobacco	- 1.5	0.7	- 6.1	0.0	- 0.2	0.6	- 0.8	- 0.8	- 0.7
Cotton	- 5.4	- 2.0	- 6.0	- 1.3	- 2.1	- 0.8	- 1.0	- 4.9	- 2.9
Jute and hard fibres	- 9.9	- 2.7	- 5.2	- 1.7	- 1.7	- 3.8	- 1.5	- 4.7	- 2.3
Rubber	- 10.5	- 3.7	0.9	- 9.2	- 1.9	- 14.2	- 3.7	- 8.3	- 6.1
Fodder crops	-	-	-	-	-	-	-	-	-
Beef	- 0.7	- 0.7	- 2.3	- 0.3	- 0.5	- 0.5	- 0.3	- 1.1	- 0.7
Mutton	- 0.1	0.2	- 1.5	0.0	0.0	- 0.1	- 0.1	- 1.3	- 0.6
Pigmeat	- 0.1	- 0.1	- 1.1	- 0.1	- 0.1	0.1	0.0	0.0	0.0
Poultry	- 0.2	0.3	- 4.1	0.2	- 1.0	- 1.6	- 1.2	- 0.2	- 0.5
Milk	- 2.3	- 0.3	- 1.6	- 0.1	- 0.3	- 0.9	- 0.4	- 0.9	- 0.6
Eggs	- 0.9	0.0	- 0.5	0.0	- 0.1	- 0.3	- 0.4	- 0.1	- 0.2
Cereals [f]	- 2.3	- 1.1	- 1.6	0.2	0.0	- 0.2	- 2.3	- 0.4	- 0.4
Other food crops [g]	- 1.4	0.7	- 1.1	0.1	- 0.5	- 0.4	- 0.6	0.2	- 0.1
Non-food crops [h]	- 3.8	- 2.0	- 6.0	- 0.7	- 1.3	- 2.8	- 1.7	- 2.9	- 2.1
Livestock [i]	- 1.0	- 0.4	- 1.9	- 0.1	- 0.3	- 0.6	- 0.5	- 0.7	- 0.6
Total food [k]	- 1.5	- 0.1	- 1.5	0.2	- 0.3	- 0.3	- 0.5	- 0.2	- 0.3
Total	- 1.8	- 0.3	- 1.8	0.1	- 0.4	- 0.6	- 0.6	- 0.5	- 0.5

a) Production/demand
b) According to FAO's AT 2000 project data. Based on volume for commodities, on value for aggregates
c) Per caput GDP of US $ 300 or lower in 1975
d) Official UN classification
e) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered
f) Wheat to millets
g) Roots to cocoa
h) Coffee to fodder crops
i) Beef to eggs
k) Cereals, other food crops, and livestock

Source: FAO, AT 2000 data files

conditions that render the region, prima facie, less suitable for a particular crop.

Neither view can claim any ex-ante knowledge about the returns to research efforts. Therefore, conclusions about research priorities cannot be directly drawn. A more important caveat possibly is that self-sufficiency is expressed in ratios and not in absolute values. A move forward by two percentage points for commodity A may be more important for a country's welfare than a move forward by three points for commodity B simply because volume and value of production of commodity A may be a multiple of that of commodity B.

3.4 Trade

Self-sufficiency figures are ratios only and do not show the magnitudes involved. This section is to deal with deficits, surpluses and trade in absolute figures. Table 3.4.a gives figures for net trade by commodity for the different country groups. The figures again refer to 1978/80.

As a whole the developing countries are net importers of food. Latin America is the only region with a substantial net export. Cereals are the largest component in the net import bill. (Wheat is in the first place by a long way, followed by livestock products, particularly milk. For other food crops developing countries are net exporters with the exception of the Near East region and the group of low income countries. For non-food crops all regions and groupings have a net export position. The overall trade balance for agricultural commodities is positive for Latin America, the Far East, countries with high agricultural growth, and least developed countries. For the latter the trade volume is only small.

Considering individual commodities the high wheat deficit of "all developing countries" and of each country group is striking. Compared to wheat the trade volume in other cereals is rather modest and reflects regional differences. Africa, e.g., imports a large amount of rice, whereas the Far East is a net exporter of rice. A fair amount of rice, also, is imported by low income countries. Trade in food crops other than cereals is significant. Countries with high agricultural growth stand out as net exporters, especially, of roots. Latin America is the dominant sugar exporter.

Tables 3.4.b and 3.4.c provide information about 1970-80 trends of exports and imports respectively.

Trade has increased in importance in all developing countries and country groups. Imports have increased in virtually all country groups and for all commodities. The development of exports gives a more differentiated picture. They have been increasing in Latin America and the Far East. They have been decreasing in Africa and the Near East and, equally, in low income and least developed countries.

Summarizing this information, the increasing importance of trade for developing country groups is evident. Developing countries are increasingly integrated into the international division of labour. This process is not without problems for developing countries (dual structures of economy, trade infrastructure, dependence), but promises essential gains in national welfare. If the conclusion is that all

Table 3.4.a: Net trade [a] in developing country groups by commodity [b], 1978/80, in 1 000 metric tons for commodities, in million US $ for aggregates

	Africa	Latin America	Near East	Far East	Low income [c]	Least developed [d]	Agricultural growth [e] under 3 percent	3 percent or over	All developing countries
Wheat	- 7 531	- 7 192	- 9 798	- 9 149	- 13 121	- 3 109	- 17 832	- 15 839	- 33 671
Rice	- 2 873	- 216	- 1 927	1 628	- 2 688	- 1 164	- 3 408	20	- 3 388
Maize	- 1 068	247	- 2 231	- 830	- 1 486	- 190	1 915	- 5 798	- 3 882
Barley	- 770	- 712	- 1 251	- 303	- 244	- 83	- 900	- 2 136	- 3 036
Millets	- 187	1 481	- 161	14	- 67	49	3 315	- 2 169	1 147
Roots	79	- 155	78	15 613	1 951	250	161	15 454	15 615
Sugar	- 972	11 467	- 2 586	1 052	- 1 043	- 512	6 052	2 908	8 960
Pulses	83	101	63	77	- 67	66	- 16	341	325
Vegetables	- 48	859	- 95	170	171	- 14	312	574	886
Bananas	303	4 872	- 229	890	197	49	2 141	3 694	5 835
Citrus fruit	827	11 576	41	36	180	2	1 578	3 903	5 481
Fruit	602	783	846	733	97	190	1 564	1 401	2 965
Vegetable oils	- 276	1 244	- 874	2 076	- 1 149	1	- 865	3 036	2 170
Cocoa	831	403	- 13	18	137	12	535	704	1 239
Coffee	856	2 220	- 40	278	977	331	619	2 695	3 314
Tea	119	33	- 172	404	477	31	329	55	384
Tobacco	62	253	- 20	119	51	33	60	355	415
Cotton	268	668	677	- 576	450	306	353	683	1 036
Jute and hard fibres	55	90	- 43	529	486	451	523	108	631
Rubber	120	- 183	- 40	2 966	1 011	- 6	112	2 750	2 862
Fodder crops	-	-	-	-	-	-	-	-	-
Beef	- 117	939	- 219	- 59	11	71	552	- 8	554
Mutton	12	21	- 244	- 17	32	28	7	- 235	- 228
Pigmeat	- 5	- 16	- 3	- 8	- 3	- 1	- 9	- 24	- 33
Poultry	- 79	14	- 254	1	- 83	- 43	- 201	- 116	- 318
Milk	- 3 239	- 3 860	- 2 739	- 3 662	- 3 075	- 1 025	- 6 050	- 7 450	- 13 500
Eggs	- 46	- 11	- 39	-	- 9	- 5	- 57	- 39	- 96
Cereals [f]	- 2 124	- 1 086	- 2 480	- 1 228	- 2 937	- 792	- 3 108	- 3 810	- 6 918
Other food crops [g]	557	6 402	- 1 215	2 259	- 832	9	1 683	6 319	8 003
Non-food crops [h]	1 981	4 575	384	2 633	3 525	1 104	2 114	7 459	9 573
Livestock [i]	- 944	323	- 1 438	- 866	- 702	- 152	- 891	- 2 034	- 2 925
Total food [k]	- 2 512	5 639	- 5 134	165	- 4 472	- 936	- 2 316	476	- 1 840
Total	- 530	10 215	- 4 750	2 798	- 947	168	- 202	7 935	7 733

a) Export minus import

b) According to FAO's AT 2000 project data

c) Per caput GDP of US $ 300 or lower in 1975

d) Official UN classification

e) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

f) Wheat to millets

g) Roots to cocoa

h) Coffee to fodder crops

i) Beef to eggs

k) Cereals, other food crops, and livestock

Source: FAO, AT 2000 data files

Table 3.4.b: Trends for export in developing country groups by commodity [a], annual rate of change 1970 - 80, in percent

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	3 percent or over	All developing countries
Wheat	-12.0	9.8	33.0	10.3	1.9	-14.7	10.6	13.8	11.8
Rice	-13.5	9.1	-16.2	8.2	2.5	-14.6	0.0	10.3	6.4
Maize	-10.1	-1.9	55.6	1.9	-21.2	-22.9	-0.6	-2.6	-1.2
Barley	-7.7	5.8	9.5	31.0	23.0	-64.3	2.0	5.5	4.3
Millets	-4.1	6.5	25.1	4.4	7.1	11.7	6.4	7.7	6.6
Roots	-5.4	-2.5	3.8	15.9	2.0	-2.6	1.6	15.2	14.2
Sugar	-0.4	1.3	-10.7	7.0	-0.8	8.0	1.3	3.3	2.0
Pulses	-9.4	17.8	10.2	2.3	-6.0	-2.4	1.4	10.0	3.6
Vegetables	-3.6	6.1	8.2	10.2	2.5	-4.1	2.9	8.2	6.1
Bananas	-5.2	1.0	-12.2	16.6	-5.9	-13.8	-1.3	4.3	1.8
Citrus fruit	-0.7	21.2	3.0	13.1	1.4	12.2	1.6	20.9	12.4
Fruit	-7.4	8.6	1.4	7.5	9.3	7.0	-1.1	4.6	1.6
Vegetable oils	-7.4	16.3	-2.5	9.0	-3.0	-7.6	3.4	9.2	7.4
Cocoa	-1.7	6.5	18.9	4.4	-0.4	-4.2	-3.8	5.8	1.0
Coffee	-1.4	0.3	-5.1	11.2	0.0	-2.7	-2.0	1.2	0.5
Tea	4.9	3.4	-11.0	0.8	1.7	3.3	0.4	4.8	1.6
Tobacco	4.9	5.9	-2.6	2.3	2.7	8.3	2.8	3.5	3.3
Cotton	-3.3	-1.7	-5.5	-5.7	-5.4	-3.8	-3.4	-3.5	-3.5
Jute and hard fibres	-11.2	-7.6	-29.7	-5.5	-5.3	-5.2	-5.2	-10.0	-6.9
Rubber	-4.4	0.0	-83.1	2.1	1.2	-11.7	-2.0	2.1	1.8
Fodder crops	-	-	-	-	-	-	-	-	-
Beef	-2.9	0.2	-19.9	-1.1	-3.9	-3.2	1.0	-2.5	-0.3
Mutton	-1.0	-1.1	2.0	62.0	2.2	0.7	0.7	5.7	2.2
Pigmeat	-11.1	-1.3	16.6	-6.6	-15.6	-17.5	-9.4	-1.3	-4.5
Poultry	6.4	121.2	12.5	90.2	-0.9	-40.5	43.4	112.9	95.3
Milk	-15.2	11.9	2.9	21.8	-18.8	0.6	12.1	5.4	9.4
Eggs	-8.0	6.2	-15.7	-8.9	-6.0	-24.1	-13.1	0.5	-7.6
Cereals [e]	-9.5	4.0	1.3	7.1	1.8	-5.9	3.1	7.2	4.8
Other food crops [f]	-3.7	7.6	2.5	10.2	-1.0	-3.8	1.1	8.4	5.2
Non-food crops [g]	-1.3	0.3	-5.2	1.8	-0.9	-2.5	-1.7	0.6	-0.1
Livestock [h]	-3.1	1.4	-5.4	9.6	-3.3	-2.5	1.2	0.6	0.9
Total food [i]	-3.8	5.8	1.9	9.1	-0.4	-3.7	1.6	7.6	4.6
Total	-2.7	3.9	-1.5	5.9	-0.7	-2.9	0.7	4.2	2.8

a) According to FAO's AT 2000 project data. Based on volume for commodities, on value for aggregates
b) Per caput GDP of US $ 300 or lower in 1975
c) Official UN classification
d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered
e) Wheat to millets
f) Roots to cocoa
g) Coffee to fodder crops
h) Beef to eggs
i) Cereals, other food crops, and livestock

Source: FAO, AT 2000 data files

Table 3.4.c: Trends for import in developing country groups by commodity [a], annual rate of change 1970 - 80, in percent

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	3 percent or over	All developing countries
Wheat	12.0	6.9	9.0	1.6	5.5	3.6	7.4	5.4	6.4
Rice	13.2	9.1	16.5	- 3.4	0.2	1.8	0.2	5.6	2.8
Maize	15.5	22.5	28.7	18.9	16.9	3.9	16.3	24.2	21.2
Barley	14.3	10.4	14.5	2.5	1.7	7.5	10.8	11.6	11.4
Millets	0.8	18.5	9.7	9.6	- 7.4	5.2	3.2	17.2	13.1
Roots	6.7	1.5	11.6	0.8	0.3	- 9.9	3.1	9.4	5.2
Sugar	6.0	17.6	11.4	2.7	3.3	3.3	5.8	9.6	7.6
Pulses	8.4	9.0	10.4	0.6	4.7	- 9.3	6.2	9.6	8.1
Vegetables	8.0	7.0	15.5	6.6	4.6	2.2	7.7	12.7	10.8
Bananas	- 8.8	3.3	17.8	17.2	31.1	35.1	2.6	13.4	6.6
Citrus fruit	- 0.9	18.8	18.0	10.6	26.3	29.6	15.9	17.7	17.2
Fruit	- 3.1	5.7	13.9	2.0	- 1.8	4.2	- 0.7	9.6	5.7
Vegetable oils	13.5	13.9	11.4	21.2	17.8	2.8	14.4	16.7	15.4
Cocoa	0.9	- 0.1	17.6	6.4	- 0.5	- 3.4	3.7	7.2	5.6
Coffee	10.6	- 0.2	- 0.8	1.0	- 10.4	- 11.5	4.3	1.8	3.6
Tea	4.7	5.0	4.7	8.1	4.7	- 0.4	4.7	6.3	5.4
Tobacco	8.4	5.3	14.2	5.2	5.9	9.6	9.4	8.5	8.9
Cotton	4.6	- 0.3	20.0	5.4	- 0.2	- 0.2	- 3.4	10.7	5.0
Jute and hard fibres	0.8	0.4	4.2	- 2.3	- 1.6	0.6	- 5.1	5.8	- 0.3
Rubber	4.1	5.5	- 0.9	10.2	5.4	11.9	2.6	7.4	6.3
Fodder crops	-	-	-	-	-	-	-	-	-
Beef	3.2	6.8	20.5	9.1	4.9	- 2.5	4.3	13.0	8.7
Mutton	0.8	- 12.2	15.5	21.7	0.1	- 0.1	3.0	17.3	12.9
Pigmeat	1.6	5.3	11.1	13.6	6.9	- 5.7	0.4	11.6	6.5
Poultry	30.3	25.5	47.6	19.2	38.0	82.6	38.4	38.7	38.6
Milk	11.4	7.1	18.0	5.3	9.1	15.9	7.4	10.6	9.1
Eggs	57.7	12.2	8.0	- 0.5	44.6	54.0	15.7	12.2	14.2
Cereals [e]	12.5	10.5	11.8	0.4	3.5	2.9	5.8	8.3	7.0
Other food crops [f]	8.2	10.8	12.3	13.8	12.1	2.4	9.9	13.2	11.3
Non-food crops [g]	7.1	2.6	6.1	5.6	1.7	0.8	2.1	8.3	5.4
Livestock [h]	9.0	7.5	20.2	6.2	9.3	13.1	7.8	12.8	10.4
Total food [i]	10.0	9.8	13.5	4.7	6.6	4.2	7.6	10.6	9.0
Total	9.8	9.2	12.8	4.8	6.1	3.9	7.1	10.3	8.6

a) According to FAO's AT 2000 project data. Based on volume for commodities, on value for aggregates

b) Per caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Wheat to millets

f) Roots to cocoa

g) Coffee to fodder crops

h) Beef to eggs

i) Cereals, other food crops, and livestock

Source: FAO, AT 2000 data files

efforts, including research, should be made to increase export potential, this does not necessarily call for increased publicly supported international research. Research has been and continues to be done on the classical tropical export crops, but largely within the private sector. Publicly supported research is more geared to the deficit commodities in whose production developing countries appear to have a comparative disadvantage. Again it is not trade indicators but the social payoff of alternative research strategies that has to be compared.

3.5 Food Consumption

Food consumption patterns vary considerably among developing countries. In other words, the relative importance of different agricultural commodities in the food budget of people greatly depends upon the country or country group considered. Table 3.5.a shows the share of food consumption in developing country groups by commodity in percent. The figures refer to 1978/80.

For all commodities considered consumption budgets differ between regions. The share of cereals is rather low in Africa (23%), Latin America (16%), and the Near East (26%). It is of major importance for the Far East (49%), and for the groups of low income (45%) and least developed countries (42%). Predominant cereals are wheat in the Near East and rice in the Far East and in the low income countries. In Africa, the consumption value of cereals is made up of wheat, rice, maize, and millets in almost equal parts (between 4.9 and 5.8%). In Latin America rice and wheat dominate with maize in a considerably lower third position (3.7%) Food crops other than cereals play an important role in food consumption, especially in Africa, particularly root crops (19%). They are also important for low income and least developed countries in general. Vegetables represent an important share in the food budget in the Near (13%) and Far East (11%) and in low income countries (10%). The importance of fruit for the Near East also deserves mention (14%).

Livestock products stand out for their high share in Latin America (46%), their low share in the Far East (14%). An apparent anomaly is their relative high importance in least developed countries (24%) as opposed to low income countries (16%). The explanation is that within the former group the Sahel countries as typical livestock countries have a considerable weight while the latter group is dominated by the Asian countries.

A more or less definitional feature of Table 3.5.a is that cereals, "other food crops" and livestock products account for virtually all food consumption. Of the non food crops coffee and tea are the only ones included in food consumption budgets. They account for between 1 and 3% of the food budget in the different groups.

Trends for food consumption are given in Table 3.5.b. The figures refer to the period 1970-80.

Looking at food crops in total consumption increases in low income countries and in the Far East have been below the developing country average. The same is true for least developed countries and countries with low agricultural growth.

Table 3.5.a: Value of food consumption in developing country groups by commodity [a], 1978/80, in percent of total value

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	3 percent or over	All developing countries
Wheat	5.8	5.7	16.6	7.3	8.0	5.5	8.3	7.3	7.9
Rice	5.6	5.6	5.2	37.6	30.6	26.2	23.8	17.8	21.1
Maize	4.9	3.7	1.8	1.6	2.5	3.7	1.9	3.5	2.6
Barley	1.3	0.5	0.5	0.4	0.4	0.7	0.6	0.5	0.5
Millets	5.7	0.1	1.7	2.3	3.3	5.9	3.4	0.7	2.2
Roots	19.0	4.2	1.7	3.6	5.9	7.5	5.8	5.5	5.6
Sugar	3.4	6.9	5.2	4.6	4.5	2.3	4.6	5.6	5.1
Pulses	4.3	2.8	1.8	4.0	4.6	4.4	4.3	2.4	3.5
Vegetables	7.1	4.4	13.1	11.1	10.2	5.7	10.4	7.5	9.1
Bananas	4.4	2.9	0.2	1.3	1.6	3.1	1.6	2.6	2.0
Citrus fruit	1.1	3.6	2.5	0.6	0.8	0.5	1.2	2.2	1.7
Fruit	3.7	5.8	13.5	4.4	4.4	3.8	5.3	6.3	5.8
Vegetable oils	8.6	4.3	6.8	5.9	6.5	5.1	6.4	5.6	6.0
Cocoa	0.1	0.4	0.1	-	-	-	0.1	0.2	0.1
Coffee	1.4	2.4	0.3	0.3	0.4	1.1	0.6	1.5	1.0
Tea	0.3	0.6	1.4	0.5	0.7	0.4	0.7	0.6	0.7
Tobacco	-	-	-	-	-	-	-	-	-
Cotton	-	-	-	-	-	-	-	-	-
Jute and hard fibres	-	-	-	-	-	-	-	-	-
Rubber	-	-	-	-	-	-	-	-	-
Fodder crops	-	-	-	-	-	-	-	-	-
Beef	7.8	16.4	5.6	1.9	3.2	7.3	6.0	7.7	6.8
Mutton	3.1	0.7	5.7	0.9	1.7	4.2	1.7	1.9	1.8
Pigmeat	1.4	6.9	0.2	2.7	1.3	0.9	1.9	4.9	3.2
Poultry	2.9	5.8	4.2	1.1	1.1	2.0	2.0	4.0	2.9
Milk	6.9	13.0	10.3	6.7	7.7	8.6	8.4	9.1	8.7
Eggs	1.4	3.3	1.9	1.1	0.7	1.2	1.1	2.7	1.8
Cereals [e]	23.2	15.6	25.7	49.2	44.7	42.0	38.0	29.7	36.1
Other food crops [f]	51.7	35.2	44.9	35.5	38.5	32.4	39.7	37.9	38.9
Non-food crops [g]	1.7	3.0	1.6	1.0	1.1	1.5	1.3	2.1	1.7
Livestock [h]	23.4	46.1	27.8	14.4	15.7	24.2	21.0	30.1	25.2
Total food [i]	98.3	97.0	98.4	99.1	98.9	98.5	98.7	97.9	98.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

a) According to FAO's AT 2000 project data

b) Per caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Wheat to millets

f) Roots to cocoa

g) Coffee to fodder crops

h) Beef to eggs

i) Cereals, other food crops, and livestock

Source: FAO, AT 2000 data files

Table 3.5.b: Trends for food consumption in developing country groups by commodity [a], annual rate of change 1970 - 80, in percent

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	Agricultural growth [d] 3 percent or over	All developing countries
Wheat	5.2	4.2	4.5	4.2	4.5	3.8	4.2	4.7	4.4
Rice	5.6	3.8	5.5	2.4	2.2	2.3	2.0	3.8	2.6
Maize	2.4	2.6	3.4	2.5	1.9	1.6	1.7	3.2	2.6
Barley	2.3	5.5	- 0.3	- 4.1	- 1.8	- 0.4	- 0.3	0.4	- 0.1
Millets	0.9	1.1	1.0	1.5	1.3	1.3	1.1	1.5	1.2
Roots	2.1	- 0.5	6.5	4.1	3.2	2.8	2.7	1.7	2.2
Sugar	5.3	4.1	6.0	2.9	2.6	1.5	2.7	5.0	3.8
Pulses	2.5	- 0.8	2.0	0.2	0.4	1.2	0.5	0.5	0.5
Vegetables	3.8	3.1	5.0	3.3	2.7	2.3	3.5	3.9	3.6
Bananas	3.0	2.2	7.4	4.3	2.4	2.8	3.2	3.1	3.2
Citrus fruit	2.2	3.9	7.3	3.8	3.1	0.7	2.0	6.0	4.3
Fruit	2.0	2.7	3.1	2.9	1.4	1.3	1.8	4.0	2.8
Vegetable oils	4.9	3.5	6.2	4.6	4.3	3.7	3.6	6.1	4.7
Cocoa	2.7	1.7	8.9	5.0	3.3	- 1.5	- 1.3	3.9	2.6
Coffee	7.3	- 1.0	- 0.4	4.7	2.6	2.9	4.0	0.1	1.2
Tea	5.8	1.4	9.3	5.6	5.7	3.4	4.3	6.9	5.2
Beef	2.5	3.4	5.0	2.4	2.0	2.0	2.7	3.8	3.3
Mutton	1.6	- 2.2	4.1	3.6	3.1	2.9	0.7	4.8	2.5
Pigmeat	3.3	3.4	4.1	3.5	2.9	3.7	2.2	4.0	3.4
Poultry	7.8	9.2	12.9	5.5	4.7	5.0	6.4	10.5	8.8
Milk	4.2	3.9	5.1	2.3	2.2	3.1	2.4	4.7	3.5
Eggs	5.9	5.4	9.0	5.7	4.9	3.3	3.5	7.4	6.0
Cereals [e]	2.8	3.6	4.0	2.6	2.5	2.1	2.3	3.8	2.9
Other food crops [f]	3.1	2.4	4.7	3.1	2.5	2.3	2.7	3.8	3.2
Non-food crops [g]	7.0	- 0.5	7.1	5.2	4.4	3.0	4.2	1.5	2.6
Livestock [h]	3.6	4.2	6.0	3.1	2.5	2.9	2.7	5.2	4.0
Total food [i]	3.3	3.4	4.9	2.8	2.5	2.4	2.5	4.2	3.3
Total	3.3	3.3	5.0	2.8	2.5	2.4	2.6	4.2	3.3

a) According to FAO's AT 2000 project data. Based on volume for commodities, on value for aggregates

b) Estimated by OLS regression

c) Per caput GDP of US $ 300 or lower in 1975

d) Official UN classification

e) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

f) Wheat to millets

g) Roots to cocoa

h) Coffee and tea

i) Beef to eggs

k) Cereals, other food crops, and livestock

Source: FAO, AT 2000 data files

Cereal consumption has increased at a rate above the average for "all developing countries" in Africa, Latin America and the Near East. This refers to wheat and rice mainly. In the Far East, on the other hand, cereal consumption has increased at a rate below average. In the consumption of livestock products the Far East has also had a development below average. The Near East, on the other hand, stands out for significant increases. With respect to single commodities, finally the increase in poultry consumption deserves to be mentioned, particularly in Latin America and the Near East.

A shortcoming of the trend figures is that they have not been calculated on a per caput basis. Thus the lower than average growth of the Far East - 2.8% p.a. as compared to 3.3% for all countries - has to be seen in connection with the lower than average growth of the human population in that area. Similarly the growth rates of food consumption of over 3% in Africa and Latin America lose some of their glamour when compared to the demographic growth rates of the same magnitude.

In summary, it is not possible to draw, in an unambiguous way, conclusions for research priorities. However, the need to take into account essential differences among regions and country groups has become obvious.

3.6 Nutrition

The previous section dealt with food consumption patterns by commodities, i.e., with consumption behaviour of people as indicated by relative expenditures. This chapter relates to the nutritional value of commodities and compares their relative contribution to total calorie supply in different developing country groups.

Table 3.6.a shows per caput daily calorie supply in country groups by commodity group. The table refers to 1981. It is an update of a table used in the 1979 TAC report. In addition to the figures the dominant commodities in consumption are listed. The USA is included for reasons of comparison.

Again, the large regional differences stand out. Cereals , mainly rice, provide more than two thirds of calories in Asia. They are less important in South America (37%) and Equatorial (27%) and Humid West Africa (39%). In the African regions roots and tubers (cassava, sweet potatoes, yams) fill in for the cereals as well as pulses and, especially, oilcrops. In the other world regions potatoes tend to be dominant within the groups of roots and tubers. Central and South America stand out for the high share of sugar (15 and 18% respectively) and of livestock products (14 and 17%) in the diet.

Table 3.6.b gives trends for the period 1975-81. They demonstrate the evolution of the relative importance of commodities for calorie supply since 1975, the year of TAC's data. Cereals have undergone slight changes only. Changes are more pronounced for livestock products, especially in humid and semi-arid West Africa, where the share has gone up significantly. In other regions of Africa, however, the share has decreased. For almost all regions the share of roots and tubers and of pulses in calorie supply has gone down, while sugar crops and oilcrops have gained importance.

Table 3.6.a: Per caput daily calorie supply in country groups by commodity group, 1981, in percent of total

	USA	South Asia	Southeast Asia	Middle East, North Africa	Central America	South America	Equatorial Africa	Humid West Africa	East Africa	Semi-arid West Africa
Cereals	18.8	68.7	67.5	59.8	47.8	37.1	26.7	38.9	48.5	49.0
- dominant cereals	wheat, maize	rice, wheat, sorghum, millets	rice	wheat, rice, barley	maize	rice, wheat; maize	maize, rice	maize	maize, wheat, millets	sorghum, millets
Roots and tubers	2.9	2.0	9.8	1.5	1.9	7.4	41.4	29.6	18.6	19.1
- dominant roots and tubers	potatoes	potatoes, cassava	cassava, potatoes	potatoes	potatoes, cassava	cassava, potatoes	cassava	cassava	cassava, sweet potatoes	yams, cassava
Sugar crops	15.5	8.1	3.0	9.4	15.2	17.9	2.4	2.9	7.2	5.0
Pulses	0.9	5.3	1.7	2.4	6.1	3.9	4.9	1.5	3.8	3.5
- dominant pulses		chickpea, pigeonpea		lentils, broadbeans, chickpeas	beans	beans	cowpeas, beans	cowpeas, beans		cowpeas
Oilcrops	16.0	7.4	5.5	9.1	8.1	7.2	10.4	12.7	9.1	13.3
Fruit and vegetables	3.8	3.0	2.5	3.9	4.9	5.5	6.2	7.7	4.0	2.9
Livestock products	36.3	4.7	8.1	9.4	13.5	17.3	3.2	3.7	6.4	4.5
Other products	5.8	0.8	1.9	4.5	2.5	3.7	4.8	3.0	2.4	2.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: FAO, ICS data files and TAC, TAC review of priorities for international support to agricultural research, Rome 1979

Table 3.6.b: Trends for per caput daily calorie supply in country groups by commodity group, annual rate of change in share 1975 - 1981, in percent

	USA	South Asia	Southeast Asia	Middle East, North Africa	Central America	South America	Equatorial Africa	Humid West Africa	East Africa	Semi-arid West Africa
Cereals	0.1	0.1	-	- 0.7	- 0.6	0.6	0.4	1.5	- 0.5	0.4
Roots and tubers	- 1.1	- 2.3	- 2.3	-	- 1.7	- 2.3	1.6	- 0.6	- 0.3	- 3.7
Sugar crops	- 0.8	- 0.8	1.8	0.4	- 1.3	0.6	4.0	2.5	2.0	17.5
Pulses	2.0	- 2.8	- 1.8	- 4.2	3.0	- 0.8	- 1.6	- 1.1	- 2.8	- 1.8
Oilcrops	1.3	2.4	3.8	1.5	3.2	0.5	0.3	- 1.4	3.7	1.7
Fruit and vegetables	-	-	-	- 3.1	-	- 1.2	- 7.5	- 4.1	1.3	- 0.6
Livestock products	- 0.1	0.4	0.6	- 0.5	1.0	- 0.6	- 2.8	4.8	- 0.5	2.9
Other products	- 0.3	-	-	28.5	0.7	0.5	- 0.7	- 1.6	- 1.9	- 4.7

Source: FAO, ICS data files

Again, these tables have to be interpreted with caution. The figures merely indicate actual and possible future importance of agricultural commodities from a nutritional point of view. They may be a guide for research priority identification in relation to nutritional goals in developing countries. But interpretation cannot be carried too far: First, the importance of the nutritional goal in a social goal structure of developing countries has to be identified. Second, there is the general problem of causality and efficiency. And, third, the pursuit of a strict nutritional goal may, to an extent, contradict people's behaviour. This will by necessity require additional socio-economic research to avoid implementation problems.

All the data presented in Chapter 3 give insight into actual and potential importance of agricultural commodities for developing country groups. Different goals and different indicators have been discussed. The information, generally, points to essential regional differences which have to be taken into account as a first step in the identification of research priorities. This is not new and has always been taken into account by TAC. The indicators presented only provide further quantitative support in this task.

4. Agro-ecological Indicators

4.1 General

Environmental conditions severely affect developing countries' opportunities to meet their needs. They set the framework for agricultural production possibilities and, thus, for the attainment of important development goals. Research efforts have to explicitly acknowledge environmental constraints in the selection of the most promising areas.

Essentially, environmental conditions are determined by climate and soil. Temperature and moisture determine climatic conditions for agricultural production and are used to inventorize different agro-climates. Additional consideration of soil qualities provides quantification of the land environment. Areas with similar soils and climates imply similar environmental conditions for agricultural production and are grouped in so-called agro-ecological zones. For the purpose of this paper an agro-ecological zone is defined as an area of land whose soil and climatic conditions are sufficiently quantified to be able to predict crop yield potentials. Such zones implicitly delimit production potentials, both for individual commodities and for agricultural production as a whole, and are therefore also of relevance for agricultural research.

As a result of FAO's AEZ project, and the work on which it is based, it has become possible to make quantitative estimates of the food production potential of the different zones under different levels of inputs. From this population supporting capacities can be calculated. When compared to actual and projected human populations the potentials and limitations of the natural resources for increased food production become apparent.

4.2 Agro-climatic Zones

The map in Annex III depicts the main agro-climatic zones of the developing countries are depicted. Temperature regimes and lengths of growing period - which actually reflect moisture availability - are the delimitation criteria. Table 4.2. shows the extent of the agro-climatic zones, their temperature regimes, and their human population.

Almost two thirds of the total land area belong to the warm tropics. The subtropics - warm, moderately cool, cool and cold - account for about 30%. So-called cool and cold areas in the tropics - basically highland areas - cover relatively small areas. The extent of temperate climates is in the order of one percentage point only, limited to small areas in South America and the Near East.

For the major tropical and subtropical zones human population densities vary from 18 to 47 persons per square kilometre. Interpretation is rather difficult on this aggregate level.

The length of the growing period varies greatly. It is defined by the number of days for which precipitation exceeds half potential evapotranspiration, provided that total evapotranspiration is exceeded on at least some days and that temperatures are not too low for crop growth. Almost one fourth of the total area is desert-like (no growing days); another fourth is humid to very humid with a growing period of

Table 4.2.: Extent of and human population in major climates and growing period zones of developing countries a)

	Major climates								
	Tropics			Sub-tropics			Temperate		All developing countries
	warm	moderately cool and cool	cold	warm	moderately cool and cool	cold	cool	cold	
Extent									
million ha	4 064.2	277.4	37.7	728.8	1 125.8	173.7	66.9	21.0	6 494.9
percent	62.6	4.3	0.6	11.2	17.3	2.7	1.0	0.3	100.0
Population									
million persons	1 269.0	106.0	11.3	342.4	199.7	48.3	2.6	4.0	1 983.3
percent	64.0	5.3	0.6	17.3	10.1	2.4	0.1	0.2	100.0
Population density									
persons/sqkm	.31	.38	.30	.47	.18	.28	.04	.20	.31

	Growing period zones b)						
	Dry (0)	Arid (1 - 74)	Semi-arid (75 - 179)	Sub-humid (180 - 269)	Humid (270 - 365)	All year humid (365+)	All developing countries
Extent							
million ha	1 604.5	792.2	1 139.5	1 191.1	1 541.9	225.8	6 494.9
percent	24.8	12.2	17.5	18.3	23.7	3.5	100.0
Population							
million persons	170.8	110.9	602.0	607.2	470.0	22.1	1 983.3
percent	8.6	5.6	30.4	30.6	23.7	1.1	100.0
Population density							
persons/sqkm	.11	.14	.45	.51	.30	.10	.31

a) This table is based on FAO's agro-ecological zones project
b) The figures mark growing period days

Source: FAO, AEZ data files

over 270 days per year. The highest population densities are found in the intermediate zones. Again the level is too aggregate for further interpretation.

The agro-climatic zones characterize the natural environment of developing countries for agricultural production. Among other things and together with other factors they determine the crops that can be grown and the yield potentials.

4.3 Yield Potentials

Yield potentials are defined as maximum yields of a crop in a given environment and under a given set of input and management conditions. They depend upon biological potentials and various constraints like

a) temperature constraints
b) moisture constraints as reflected by length of growing period
c) agronomic constraints
d) soil constraints, and
e) input and management constraints.

Constraints a) and b) enter into the definition of agro-climatic zones dealt with above. They mark the major agro-climatic divisions of the world. Obviously, they are essential determinants of crop yield potentials. Agronomic constraints are mainly the result of climatic (rainfall) variability, moisture stress, excess moisture and losses due to pests, diseases, and weeds as they are known to prevail to varying extents in the different agro-climatic zones. The constraints of a) temperature, b) moisture, and c) agronomic problems determine the agro-climatically attainable yields in different climates and lengths of growing period zones. These are the potential yields dealt with in this section. Actual yields may be considerably lower due to the additional constraints of soil, inputs and management.

Yield potentials defined in the described way are remarkably similar across world regions. For all practical extents and purposes it is therefore sufficient to consider yield potential for one geographical region. Tables 4.3.a and b are based on the African region only. For the purposes here the differences among continents are small enough to be neglected. The unconstrained yield level (U) is that determined by temperature and moisture alone. The yield levels (H) and (L) take into account the mentioned agronomic constraints. They are dependent on inputs and management where (H) signifies a high, (L) a low level. A high input level is characterized by mechanical cultivation, extensive use of purchased inputs and, overall, capital intensive management practices. A low input level implies land cultivation and generally simple management practices.

Table 4.3.a reveals that for different crops unconstrained yield levels relate to the length of the growing period in different ways. For pearl millet, the length of growing period is of minor importance, while for cassava it is crucial. Thus the unconstrained yield level for millet is around three tons per hectare throughout. For cassava it goes from less than one ton (dry weight) in the dry areas to well over ten in more suitable humid areas and it is well known that yields even much higher can be achieved.

Table 4.3.a: Yield potentials under agro-climatic constraints in warm tropics and subtropics of Africa [a] by crop, in metric tons/ha

	Classification [b]	Growing period in days										
		75 - 89	90 - 119	120 - 149	150 - 179	180 - 209	210 - 239	240 - 269	270 - 299	300 - 329	330 - 364	365
Maize	U	1.9 -4.9	5.1 -7.3	5.0 -7.2	4.9 -7.1	4.8 -7.0	4.6 - 6.8	4.7 - 6.8	4.6 - 6.6	4.4 - 6.5	4.4 - 6.5	4.4 - 6.5
	H	0.5 -1.2	1.9 -2.7	3.7 -5.4	4.9 -7.1	4.8 -7.0	3.4 - 5.1	2.3 - 3.4	1.7 - 2.5	1.6 - 2.4	1.2 - 1.8	0.5 - 0.8
	L	0.1 -0.2	0.4 -0.5	0.7 -1.0	1.2 -1.8	1.2 -1.7	0.9 - 1.3	0.7 - 1.0	0.7 - 0.9	0.6 - 0.9	0.5 - 0.7	0.2 - 0.3
Pearl millet	U	3.0 -4.2	2.9 -4.1	2.9 -4.0	2.8 -3.9	2.7 -3.8	2.7 - 3.8	2.7 - 3.8	2.6 - 3.7	2.6 - 3.6	2.6 - 3.6	2.6 - 3.6
	H	1.1 -1.6	2.2 -3.1	2.2 -3.0	2.8 -3.9	2.0 -2.8	1.1 - 1.6	0.3 - 0.5	0.3 - 0.5	0.3 - 0.4	0.3 - 0.4	0.3 - 0.4
	L	0.3 -0.4	0.5 -0.8	0.5 -0.8	0.7 -1.0	0.5 -0.7	0.4 - 0.5	0.2 - 0.2	0.1 - 0.2	0.1 - 0.2	0.1 - 0.2	0.1 - 0.2
Sorghum	U	1.3 -3.4	3.7 -5.2	3.6 -5.1	3.5 -5.1	3.4 -5.0	3.3 - 4.9	3.3 - 4.9	3.3 - 4.7	3.2 - 4.7	3.2 - 4.7	3.1 - 4.6
	H	0.5 -1.3	1.8 -2.6	2.7 -3.8	3.5 -5.1	3.4 -5.0	1.8 - 2.7	0.8 - 1.2	0.6 - 0.9	0.4 - 0.6	0.4 - 0.6	0.4 - 0.6
	L	0.1 -0.2	0.3 -0.5	0.5 -0.7	0.9 -1.3	0.9 -1.3	0.5 - 0.7	0.2 - 0.3	0.1 - 0.2	0.1 - 0.2	0.1 - 0.2	0.1 - 0.2
Sweet potato	U	1.7 -3.2	3.3 -7.8	7.9 -10.2	7.7 -10.1	7.6 -9.9	7.4 - 9.7	7.4 - 9.7	7.3 - 9.5	7.2 - 9.4	7.1 - 9.2	7.1 - 9.3
	H	0.6 -1.2	1.2 -2.9	3.9 -5.1	7.7 -10.1	7.6 -9.9	7.4 - 9.7	7.4 - 9.7	5.5 - 7.1	2.7 - 3.5	2.7 - 3.4	1.8 - 2.3
	L	0.2 -0.3	0.3 -0.7	1.0 -1.3	1.9 -2.5	1.9 -2.5	1.8 - 2.4	1.4 - 1.8	1.4 - 1.8	1.4 - 1.8	0.9 - 1.2	0.7 - 0.9
Cassava	U	0.5 -0.8	0.9 -2.4	2.4 -4.7	4.7 -7.9	7.8 -9.7	10.3 -11.4	11.4 -12.4	11.9 -12.9	12.7 -13.6	13.3	13.4
	H	0.2 -0.3	0.3 -0.9	1.0 -2.0	2.6 -4.4	7.8 -9.7	10.3 -11.4	11.4 -12.4	11.9 -12.9	12.7 -13.6	7.4	5.0
	L	0.1 -0.1	0.1 -0.2	0.2 -0.5	0.7 -1.1	1.5 -1.8	1.9 - 2.1	2.1 - 2.3	2.2 - 2.4	2.4 - 2.6	1.9	1.4
Phaseolus bean	U	1.3 -2.3	2.5 -3.4	2.6 -3.4	2.4 -3.4	2.4 -3.3	2.3 - 3.3	2.3 - 3.3	2.3 - 3.2	2.2 - 3.1	2.2 - 3.1	2.2 - 3.1
	H	0.3 -0.6	0.9 -1.3	1.9 -2.5	2.4 -3.4	2.4 -3.3	1.7 - 2.5	1.1 - 1.6	0.9 - 1.2	0.6 - 0.9	0.4 - 0.6	0.3 - 0.4
	L	0.1 -0.1	0.2 -0.3	0.5 -0.6	0.6 -0.8	0.4 -0.6	0.3 - 0.5	0.2 - 0.3	0.2 - 0.2	0.1 - 0.2	0.1 - 0.1	0.1 - 0.1
Soybean	U	1.3 -2.3	2.5 -3.4	2.6 -3.4	2.4 -3.4	2.4 -3.3	2.3 - 3.3	2.3 - 3.3	2.3 - 3.2	2.2 - 3.1	2.2 - 3.1	2.2 - 3.1
	H	0.3 -0.6	0.9 -1.3	1.9 -2.5	2.4 -3.4	2.4 -3.3	1.7 - 2.5	1.1 - 1.6	0.9 - 1.2	0.6 - 0.9	0.4 - 0.6	0.3 - 0.4
	L	0.1 -0.1	0.2 -0.3	0.5 -0.6	0.6 -0.8	0.4 -0.6	0.3 - 0.5	0.3 - 0.5	0.2 - 0.3	0.1 - 0.2	0.1 - 0.1	0.1 - 0.1
Cotton	U	0.0 -0.07	0.07-0.44	0.44-1.08	1.07-1.11	1.05-1.11	1.02- 1.08	1.02- 1.08	1.0 - 1.05	0.99- 1.04	0.97- 1.02	0.99- 1.04
	H	-	0.0 -0.2	0.3 -0.8	1.1 -1.1	1.0 -1.1	0.6 - 0.6	0.5 - 0.5	0.3 - 0.3	0.2 - 0.2	0.1 - 0.1	0.1 - 0.1
	L	0.0 -0.01	0.01-0.03	0.05-0.11	0.15-0.16	0.15-0.16	0.14- 0.15	0.14- 0.15	0.07- 0.07	0.05- 0.05	0.03- 0.03	0.03- 0.03

a) This table is based on FAO's agro-ecological zones project

b) The following classifications are used:
- U - unconstrained yield level
- H - yield level under agro-ecological constraints, high input level characterized by mechanical cultivation under capital intensive management practices
- L - yield level under agro-ecological constraints, low input level characterized by low technological level and hand cultivation

The agro-ecological constraints comprise
- water stress constraints on crop growth;
- effects of pests, diseases and weeds constraints on crop growth;
- water stress, pests and diseases, and climatic constraints on crop yield, potential components, yield formation and quality of produce;
- workability constraints (all cultural operations including produce handling)

Source: FAO, Report on the Agro-ecological Zones Project, Vol. 1: Methodology and Results for Africa, World Soil Resources Report, No. 48, Rome 1978

Table 4.3.b: Yield potentials under agro-climatic constraints in cool tropics and subtropics of Africa [a)] by crop, in metric tons/ha

	Classification [b)]	Growing period in days										
		75 - 89	90 - 119	120 - 149	150 - 179	180 - 209	210 - 239	240 - 269	270 - 299	300 - 329	330 - 364	365
Spring wheat	U	0.2 - 0.8	0.8 - 2.7	2.5 - 4.7	4.2 - 5.5	4.4 - 5.6	4.4 - 5.6	4.3 - 5.5	4.3 - 5.5	4.3 - 5.5	4.3 - 5.5	4.3 - 5.5
	H	0.1 - 0.3	0.4 - 1.4	1.9 - 3.1	3.9 - 5.0	4.4 - 5.6	3.1 - 4.0	1.8 - 2.3	0.5 - 0.8	0.5 - 0.7	0.5 - 0.7	0.5 - 0.7
	L	0.0 - 0.1	0.1 - 0.3	0.5 - 0.8	1.0 - 1.3	1.1 - 1.4	0.9 - 1.1	0.6 - 0.7	0.2 - 0.3	0.2 - 0.3	0.1 - 0.2	0.1 - 0.2
Winter wheat	U	0.0 - 0.5	0.7 - 3.6	3.8 - 5.1	3.8 - 5.1	3.6 - 4.9	3.6 - 4.9	3.6 - 4.8	-	-	-	-
	H	0.0 - 0.2	0.3 - 1.4	1.9 - 2.6	2.9 - 3.8	3.6 - 4.9	2.7 - 3.7	2.7 - 3.6	-	-	-	-
	L	0.0 - 0.6	0.1 - 0.3	0.5 - 0.6	0.7 - 1.0	0.9 - 1.2	0.7 - 0.9	0.7 - 0.9	-	-	-	-
Maize	U	0.1 - 0.7	0.8 - 2.8	2.8 - 4.4	4.4 - 6.4	5.8 - 7.5	7.2 - 8.5	8.0 - 9.5	9.0 - 10.5	10.0 - 10.7	10.0 - 10.7	10.0 - 10.7
	H	0.0 - 0.2	0.3 - 1.0	1.9 - 2.5	3.4 - 4.6	4.5 - 5.6	5.7 - 6.5	5.4 - 6.2	5.3 - 6.1	4.5 - 4.8	2.8 - 3.0	1.3 - 1.3
	L	0.0 - 0.0	0.1 - 0.2	0.4 - 0.5	0.8 - 1.2	1.1 - 1.4	1.4 - 1.6	1.4 - 1.6	1.4 - 1.7	1.4 - 1.5	0.7 - 0.8	0.3 - 0.3
Sorghum	U	0.1 - 0.5	0.5 - 2.0	2.0 - 3.1	2.9 - 4.6	4.1 - 5.4	5.2 - 6.1	5.6 - 6.8	6.4 - 7.5	7.1 - 7.6	7.1 - 7.6	7.1 - 7.6
	H	0.0 - 0.1	0.2 - 0.1	1.3 - 1.7	2.3 - 2.3	3.2 - 4.1	3.6 - 4.1	2.8 - 3.3	2.2 - 2.3	1.5 - 1.6	0.9 - 1.0	0.9 - 1.0
	L	0.0 - 0.0	0.0 - 0.1	0.3 - 0.3	0.6 - 0.8	0.8 - 1.0	0.9 - 1.0	0.7 - 0.8	0.7 - 0.8	0.5 - 0.5	0.2 - 0.2	0.2 - 0.2
Potato	U	2.7 - 4.5	4.6 - 7.6	4.9 - 9.7	4.9 - 9.7	4.7 - 9.4	4.7 - 9.4	4.7 - 9.4	4.7 - 9.4	4.6 - 9.2	4.6 - 9.2	4.6 - 9.2
	H	1.0 - 1.7	1.7 - 2.8	2.8 - 5.5	4.9 - 9.7	4.7 - 9.4	2.6 - 5.3	2.6 - 5.3	0.9 - 1.8	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2
	L	0.3 - 0.4	0.4 - 0.7	0.7 - 1.4	1.2 - 2.4	1.2 - 2.4	0.9 - 1.8	0.7 - 1.3	0.3 - 0.7	0.1 - 0.3	0.1 - 0.3	0.1 - 0.3
Phaseolus bean	U	0.5 - 1.1	1.1 - 2.0	1.9 - 2.8	2.2 - 3.1	2.1 - 3.0	2.1 - 3.0	2.1 - 3.0	2.1 - 3.0	2.1 - 3.0	2.1 - 3.0	2.1 - 3.0
	H	0.1 - 0.3	0.4 - 0.6	0.9 - 1.3	1.9 - 2.7	2.1 - 3.0	1.8 - 2.5	1.6 - 2.3	0.8 - 1.1	0.6 - 0.8	0.4 - 0.6	0.3 - 0.4
	L	0.0 - 0.1	0.1 - 0.2	0.2 - 0.3	0.5 - 0.7	0.4 - 0.6	0.3 - 0.4	0.2 - 0.3	0.2 - 0.2	0.2 - 0.2	0.1 - 0.1	0.1 - 0.1

a) This table is based on FAO's agro-ecological zones project. Yields refer to the entire altitude range

b) The following classifications are used:

U - unconstrained yield level

H - yield level under agro-ecological constraints, high input level characterized by mechanical cultivation under capital intensive management practices

L - yield level under agro-ecological constraints, low input level characterized by low technological level and hand cultivation

The agro-ecological constraints comprise

- water stress constraints on crop growth;
- effects of pests, diseases and weeds constraints on crop growth;
- water stress, pests and diseases,and climatic constraints on crop yield, potential components, yield formation and quality of produce;
- workability constraints (all cultural operations including produce handling)

Source: FAO, Report on the Agro-ecological Zones Project, Vol. 1: Methodology and Results for Africa, World Soil Resources Report, No. 48, Rome 1978

For more realistic interpretations the input levels have to be taken into account. This shows to what extent existing yield potentials can actually be exploited under different agroclimatic conditions. Thus the relatively highest yields of pearl millet can be achieved in those tropical zones with a growing period of between 150 and 220 days. For cassava the most suitable zone is that with 220 to 330 growing days.

Table 4.3.b is to be interpreted in an analogous manner. The only difference is that here yield potentials are shown for major crops in cooler climates which include wheat and potatoes.

These are no new insights. The point to make is that yield potentials of different crops can be related to agro-climatic zones in a systematic way. It also becomes apparent that for every agro-climatic zone and for every crop one is able to define - at the present state of knowledge - a maximum attainable yield. To attain that level in practical agriculture may still require locality-specific efforts in research and crop trials. It would be unrealistic, on the other hand, to assume that much higher yields could be achieved in the near future.

The determination of research priorities cannot be a simple inference from these data. The specialized agronomist may have a great deal of evidence that for a given locality it is easier to achieve yield increases for rainfed maize than for cassava. However, if such general data have any utility at all one can draw the following conclusion: By tendency the potential to increase yields in the humid zones of the tropics and sub-tropics is many times greater than in the drier zones.

4.4 Land Suitability

This section adds considerations of soil quality to the previous ones of climate (temperature and moisture regimes) and agronomic constraints. Taking all these considerations together one arrives at a land suitability assessment for different crops. Table 4.4.a gives a first overview for the region of Africa by crop.

A first conclusion that can be drawn refers to the importance of the input level. Generally speaking, a higher input level leads to an increase of the area suitable for a particular crop. This might seem to be self-evident, but this relationship differs considerably among crops. Thus higher input levels lead to a manifold increase of suitable land in the case of cassava (six-fold) and cotton (four-fold) but to a mere 13 per cent increase in the case of wheat. The impact on applied research appears obvious.

If one concentrates on locally adapted innovation packages yields and the suitable area for cassava growing could increase manifold. For most cereals and for potatoes, on the other hand, the potential impacts are comparatively modest.

Table 4.4.b provides aggregate data for the world regions. Again a higher input level results in a higher proportion of suitable land for a particular crop, but again the results differ significantly for the different crops. Land suitability could be increased most substantially for cotton, rice and sorghum to mention the first ranking only.

Table 4.4.a: Land suitability a) in major African climates b), c) by crop, in 1 000 ha

	Tropics		Sub-tropics			Africa	Input level index d)
	warm	cool	warm, summer rainfall	cool, summer rainfall	cool, winter rainfall		percent
	Low input level b), e)						
Total f)	414 989.0	15 186.0	4 619.0	-	-	434 794.0 g)	100.0 g)
Wheat	-	10 480.0	-	3 965.0	9 472.0	23 917.0	100.0
Rice	61 018.0	-	402.0	-	-	61 420.0	100.0
Maize	177 333.0	10 960.0	3 528.0	1 257.0	-	193 078.0	100.0
Pearl millet	134 520.0	-	2 741.0	-	-	137 261.0	100.0
Sorghum	172 274.0	9 385.0	3 461.0	1 234.0	-	186 354.0	100.0
White potato	-	8 511.0	-	3 857.0	-	12 368.0	100.0
Sweet potato	199 934.0	-	3 431	-	-	203 365.0	100.0
Cassava	36 289.0	-	1 136.0	-	-	37 425.0	100.0
Phaseolus bean	140 923.0	8 478.0	2 899.0	3 359.0	-	155 659.0	100.0
Soybean	142 112.0	-	2 925.0	-	-	145 037.0	100.0
Cotton	53 883.0	-	1 406.0	-	-	55289.0	100.0
	High input level b), h)						
Total f)	546 708.0	16 219.0	5 879.0	-	-	568 806.0 g)	130.8 g)
Wheat	-	11 303.0	-	6 058.0	9 752.0	27 113.0	113.4
Rice	132 208.0	-	1 239.0	-	-	133 447.0	217.3
Maize	271 968.0	13 454.0	3 861.0	1 342.0	-	290 625.0	150.5
Pearl millet	239 498.0	-	4 227.0	-	-	243 725.0	177.6
Sorghum	257 098.0	13 250.0	3 927.0	1 402.0	-	275 677.0	147.9
White potato	-	10 143.0	-	3 664.0	-	13 807.0	111.6
Sweet potato	299 532.0	-	3 365.0	-	-	302 897.0	148 9
Cassava	236 619.0	-	1 705.0	-	-	238 324.0	636.8
Phaseolus bean	264 575.0	12 805.0	3 445.0	3 435.0	-	284 206.0	182.6
Soybean	265 415.0	-	3 564.0	-	-	268 979.0	185.5
Cotton	214 135.0	-	3 772.0	-	-	217 907.0	394.1

a) This table is based on the agro-climatic suitability assessment of FAO's agro-ecological zones project. Suitability comprises very suitable and suitable land as opposed to marginally suitable and not suitable land

b) According to the FAO agro-ecological zones project classification

c) Only those climates are listed which are suitable for at least one of the crops considered

d) Area in percent of low input level area for Africa

e) Low technological level and hand cultivation

f) As climates may be suitable for several crops aggregation over crops is not possible. The figures show the aggregated area of the most suitable crop in each growing period.

g) Without cool sub-tropics

h) Mechanical cultivation under capital intensive management practices

Source: FAO, Report on the Agro-ecological Zones Project, Vol. 1: Methodology and Results for Africa, World Soil Resources Report, No. 48, Rome 1978

Table 4.4.b: Land suitablity [a)] in developing country groups by crop, in million ha

	Africa	Central America	South America	Southwest Asia [b)]	Southeast Asia	All developing countries	Input level index percent [c)]
Low input level [d), e)]							
Total [f)]	438.8 [g)]	55.0	487.0	-	184.0	1160.8 [h)]	100.0 [h)]
Wheat	23.9	11.4	41.7	10.7	1.0	88.7	100.0
Rice	61.4	13.4	98.0	-	-	172.8	100.0
Maize	193.1	31.2	148.5	-	92.9	465.7	100.0
Pearl millet	137.3	15.2	33.5	-	71.3	257.3	100.0
Sorghum	186.4	25.9	54.8	-	79.0	346.1	100.0
White potato	12.4	9.7	42.5	-	1.0	65.6	100.0
Sweet potato	203.4	24.1	146.1	-	87.4	461.0	100.0
Cassava	37.4	18.0	311.7	-	66.4	433.5	100.0
Phaseolus bean	155.7	24.6	84.0	-	74.1	338.4	100.0
Soybean	145.0	18.0	65.8	-	73.6	302.4	100.0
Cotton	55.3	12.6	25.4	-	39.6	132.9	100.0
High input level [d), i)]							
Total [f)]	568.8 [g)]	57.8	562.7	-	226.3	1415.3 [h)]	121.8 [h)]
Wheat	27.1	10.6	65.2	13.0	1.1	117.0	131.9
Rice	133.4	26.8	202.8	-	-	363.0	210.1
Maize	290.6	33.5	184.3	-	124.9	633.3	136.0
Pearl millet	243.7	14.9	41.6	-	81.1	387.3	150.5
Sorghum	275.7	29.7	86.4	-	121.3	513.1	198.3
White potato	13.8	9.2	54.0	-	2.1	79.1	120.6
Sweet potato	302.9	29.2	229.2	-	109.9	571.2	145.6
Cassava	238.3	19.6	322.8	-	63.9	644.6	148.7
Phaseolus bean	284.3	33.2	153.8	-	116.0	587.8	173.6
Soybean	269.0	27.1	155.4	-	115.7	567.2	187.6
Cotton	217.9	26.6	140.5	-	100.5	485.5	365.3

a) This table is based on the agro-climatic suitability assessment of FAO's agro-ecological zones project. It summarizes the results for Africa, Central and South America, Southwest and Southeast Asia. Suitability comprises very suitable and suitable land as opposed to marginally suitable and not suitable land

b) Far Southwest Asia only wheat has been considered in FAO's land suitability assessment. Though wheat is the only crop of significance in Southwest Asia this procedure may somewhat overstate its importance

c) Area in percent of low input level area for all developing countries

d) According to the FAO agro-ecological zones project classification

e) Low technological level and hand cultivation

f) As climates may be suitable for several crops aggregation over crops is not possible. The figures show the aggregated area of the most suitable crop in each growing period over countries and climates.

g) Without cool sub-tropics

h) Without Southwest Asia and cool sub-tropics in Africa

i) Mechanical cultivation under capital intensive management practices

Source: FAO, Reports on the Agro-ecological Zones Projects, Vol. 1 - 4, World Soil Resources Reports, Nos. 48 - 48/4, Rome 1978, 1980 and 1981

A remark on wheat appears appropriate. At low levels of input only some 90 million hectares or 7.8% of the total land area are suitable for wheat growing. With high input levels the proportion only marginally increases to 8.4%. As important as wheat may be for the world population, as much as it may be demanded by the developing countries, the potential to grow wheat in developing countries is strictly limited. Again, of course, this is a well known fact. Also a qualification has to be added. All the considerations in this chapter refer to rainfed crop production. The potential for expansion of wheat, but also of the other cereals, has to be seen in connection with irrigation, an aspect dealt with in a later chapter.

In summary one is lead to suspect that the type of land suitablity assessment as provided by FAO's agro-ecological zones project has much greater research implications than one can elaborate in this paper. One example is the derivation, from the project's soil and climate data base, of the extent and location of land subject to specific soil and climatic constrains which might be the subject of research priorities such as toxicity, poor drainage, low ph, moisture stress. The differences among regions and among crops regarding their yield potential - unconstrained, under low input and under high input conditions - provide much food for thought.

4.5 Population Supporting Capacities

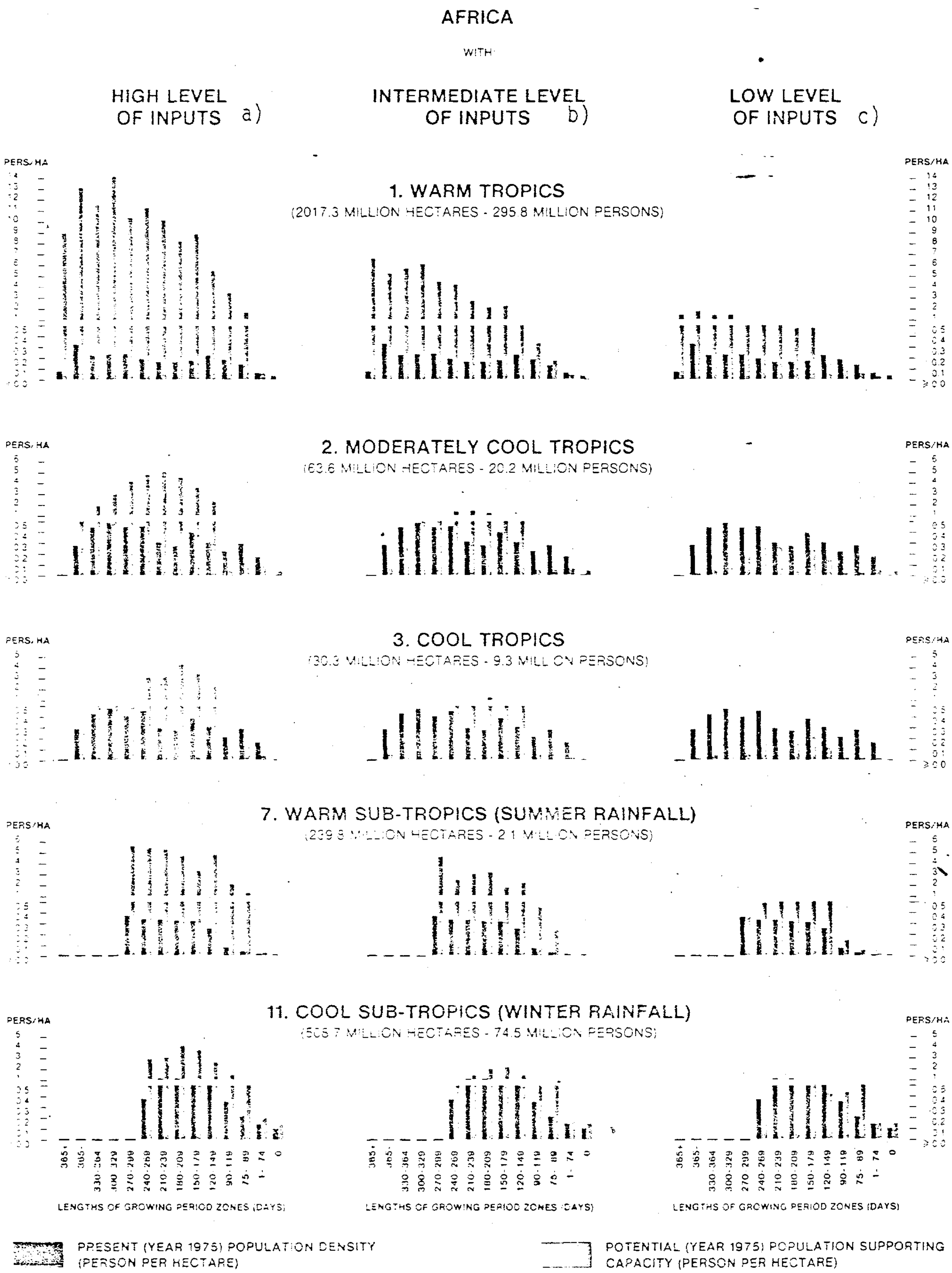
Environmental conditions play an important role in determining the production possibilities of developing countries. Different regions are differently affected as shown by crop suitability, yield potentials and proportion of land that can be used for the production of certain crops. These aspects in themselves indicate that research conclusions would have to be differentiated according to regions.

The analysis of the agro-ecological conditions (climate and soil) can be taken a step further. The assessment of of land potentials allows the estimation of the capacity of the land to produce food and thus to support people at different levels of input and management.

The estimation of the population supporting capacity of a region is based on the suitability of land resources for different crops and the yield levels under different input levels. A choice is made among different crops according to their calorie content to arrive at maximum supply while maintaining a reasonable calorie-protein ratio. The application of FAO/WHO country specific per capita/calorie protein requirements allows the computation of regional potential population supporting capacities. Comparison with the actual population size and/or with the projected one for the year 2000 allows the identification of critical zones where populations exceed the supporting capacity of the land.

Figure 4.5.a shows populations and potential population supporting capacities of the major climates and lengths of growing period zones in Africa. A distinction is made between high, intermediate, and low input levels. A huge potential population supporting capacity exists in the warm tropics. This is especially true for high input levels, but also

Figure 4.5.a: Populations and potential population supporting capacities in major African climates by length of growing period zone , 1975, in persons/ha



For footnotes see end of Chapter

Source: FAO/UNFPA/IIASA (1982)

for low input levels in most agro-climatic zones if all potentially cultivable land were cultivated to food crops. Considerable surplus capacities also exist in the warm sub-tropics.

Critical areas, on the other hand, can be found in the moderately cool and the cool tropics with high population densities, the highlands. At a low input level, actual population cannot be fed by domestic land resources. The situation is even more critical in arid and semi-arid areas, and in some highly populated humid zones. Only at intermediate to high input levels can the population there be fed by their own land resources. In the cool sub-tropics with winter rainfall, finally, actual population about reaches the capacity line and surpasses it in regions with more than 180 growing days.

Figure 4.5.b draws a picture of the developing world as a whole. Potential populations supporting capacities are compared to actual population and to projected populations in 2000. The figure suggests that the 1975 population could be fed on a low input level from aggregated land resources. On this level, however, limits are reached in 2000. Actual and future critical areas are widespread in Southwest Asia. Southeast Asia and Central America also are close to a critical population density. Problems are eased, of course, with increasing input levels. South America and Africa, on the other hand, show large areas of surplus capacity.

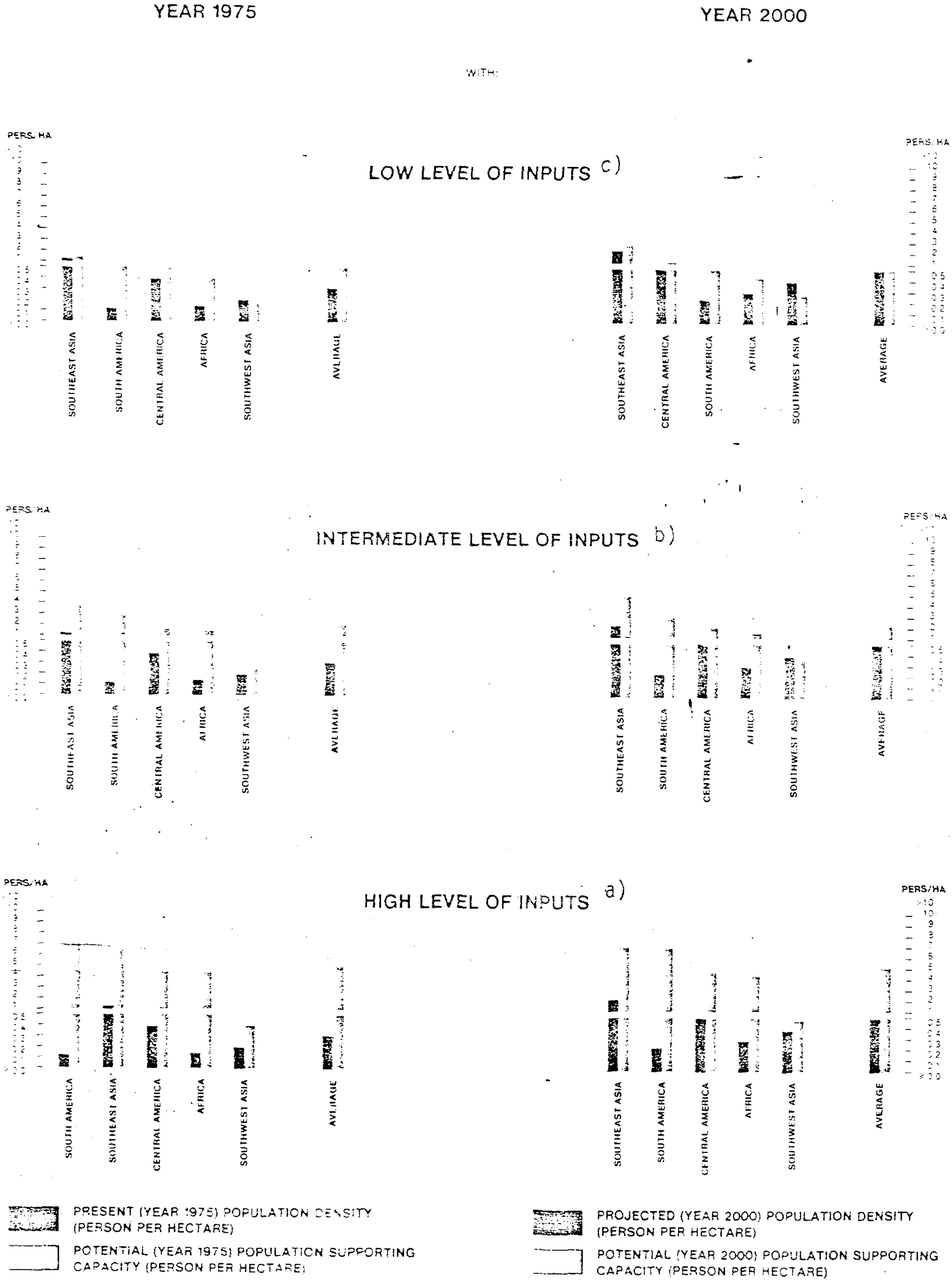
Finally, a map contained in Annex III shows the geographical location of critical areas. The presentation corresponds to the previous figures and needs no further interpretation.

The concept of population supporting capacities may bear on research priorities because there are several alternatives to meet this challenge:
a) input levels are increased,
b) food is imported,
c) productivity of land resources is increased, or
d) people migrate out of the area.

Already "critical areas" are under pressure to move towards the highest practically attainable input level. Research may be directed to help make the best use of land resources and to fully exploit production resources. While the need for improvement is particularly pressing in the so-called critical areas this does not necessarily mean that all research should be concentrated here. Returns may be particularly low. To concentrate on the areas with a high unexploited potential may well be the better research strategy that would eventually lead to expanded trade in food crops and for migration of people.

The differentiation by input levels and the previous considerations of potential yield show that the different zones have a vastly different capacity to increase production. In the semi-arid zones yields of a crop like pearl millet can be doubled or trebled through adapted production techniques and increased use of modern inputs. In the sub-humid zone cassava yields can, through similar techniques, be increased ten-fold. It is well known that the latter zone has its problems under permanent cultivation and requires a great deal of

Figure 4.5.b: Populations and potential population supporting capacities in developing coutry groups, 1975 and 2000, in persons/ha



For footnotes see end of Chapter

Source: FAO/UNFPA/IIASA (1982)

further research. However, research appears to have much greater scope and potential impact on production in that zone than in the drier zones. There is also a difference between the semi-arid and the highland areas in that respect. While both areas tend to be overpopulated the latter has great potential to increase the production of crops like wheat, maize, and potato while it is limited in the former.

One may, of course, still choose to concentrate on research in the semi-arid areas. One may value a unit impact in this area more highly than in other areas. Such social shadow pricing may have a very real justification in the social cost of moving food and moving people.

Footnotes/Figures 4.5.a and 4.5.b

a) Complete mechanization, full use of optimum genetic material, necessary farm chemicals and soil conservation measures, and cultivation of only the most calorie-protein productive crops on potentially cultivable rain-fed lands.

b) Use of improved hand tools and/or draught implements, some fertilizer and pesticide application, some simple soil conservation measures lessening productivity losses from land degradation, and cultivation of a combination of the presently grown mixture of crops and the most calorie-protein productive crops, on potentially cultivable rainfed lands.

c) Hand labour only, no fertilizer and pesticide applications, no soil conservation measures and hence full productivity losses arising from land degradation, and cultivation of the presently grown mixture of crops on potentially cultivable rainfed lands.

Area and 1975/2000 populations of the regions are as follows:

	Extent mio ha	Population mio	
		1975	2000
South America	1 770.2	215.8	392.6
Southeast Asia	897.6	1 117.7	1 937.1
Central America	271.6	106.5	215.2
Africa	2 878.1	406.9	828.5
Southwest Asia	677.4	136.3	264.7
Total	6 494.9	1 983.2	3 638.1

5. Indicators of Land Use and Productivity

5.1 General

The considerations by agro-ecological zones in the previous chapter have been much concerned with upper limits and ultimate constraints and potentials as set by the natural resources at our present state of knowledge. This is the first of two chapters dealing more specifically with availability and productivity of factors actually used in agricultural production.

Production can simply be defined as the output from a combination of factors reflecting a certain technology. The contribution of different production factors to the ouput varies and so do factor income shares. This clearly, reflects the different importance of production factors in the production process. More important, however, are the possible restrictions which some factors will impose for production increases. In some cases additional factors are easily available and could be used in an adequate production process. In other cases, however, supply of factors may be rather inelastic. These factors represent bottlenecks for increasing production. The only way to meet this goal, then, is to increase productivity of these factors.

Availability and productivity of production factors have important implications for research priorities. Productive research will reflect the relative scarcity of production factors. It will help to make more use of abundantly available factors and save scarce factors. New technologies will change factor intensities and combinations in ways to adequately reflect relative scarcities (see e.g. Binswanger and Ruttan, 1978). The scarcity of capital and material input in developing countries is well-known and in many parts land is becoming critically scarce, too. Labour is often abundant. This would suggest that research should concentrate on labour-intensive technologies which would also be in line with employment goals in developing countries. On the other hand, there are considerable land reserves in Africa and Latin America. Here labour often is in short supply.

The question is whether the conceptual framework can be translated into concrete research priorities. Which research areas should be supported once a factor has been identified to be particularly scarce? Again, an answer to this problem can only be based on the general principle of comparing social payoffs of alternative research strategies. Indicators of factor availability and productivity only provide some first guidelines.

This first chapter deals with the production factor land. Characteristics, distribution, reserves, cropping patterns, and crop yields are to provide a picture of availability and productivity that may guide the setting of research priorities.

5.2 Land Classes

For meaningful considerations of the production factor land a classification by characteristics important for crop production is necessary.

In Table 5.2.a the distribution of land classes by developing country

Table 5.2.a: Distribution of cultivated land in land classes by developing country group[a)], 1974/76, in percent of total cultivated land in developing countries

	Good rainfall[b)]	Low rainfall[c)]	Naturally flooded[d)]	Fully irrigated[e)]	Partially irrigated[f)]	Problem areas[g)]	Total
Africa	10.3	2.3	0.4	0.3	0.3	5.8	19.4
Latin America	11.3	0.7	0.5	1.6	0.4	4.9	19.5
Near East	4.6	1.7	0.4	1.8	1.2	0.3	10.0
Far East	12.3	9.3	8.5	6.9	6.1	8.0	51.1
Total	38.5	14.0	9.8	10.6	8.0	19.1	100.0[h)]
Low income[i)]	17.8	10.9	7.9	6.9	6.4	8.3	58.3
Least developed[k)]	6.1	1.4	2.0	0.5	0.5	1.3	11.7
Agricultural growth[l)]							
- under 3 percent	24.6	11.5	7.4	5.8	5.0	8.5	62.8
- 3 percent or over	13.9	2.5	2.5	4.7	3.0	10.7	37.2

a) According to FAO's AT 2000 project data

b) Rainfall providing 120 - 270 growing days, soil quality very suitable or suitable according to FAO's agro-ecological zones project classification

c) Rainfall providing 75 - 120 growing days, soil quality very suitable, suitable or marginally suitable according to FAO's agro-ecological project classification

d) Land under water for part of the year and lowland non-irrigated paddy-fields

e) Equipped for irrigation and suitable drainage and not suffering from water shortages

f) Equipped for irrigation, but lacking drainage or reliable water supplies or with low quality and reliability of distribution

g) Rainfall providing more than 270 growing days, soils of all qualities in this zone, plus that part of the 120 - 270 growing days zone where soil rating is only marginally suitable

h) Total cultivated area in all developing countries comprises 544.7 million ha

i) Per caput GDP of US $ 300 or lower in 1975

k) Official UN classification

l) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

Source: FAO, AT 2000 data files

group is shown. The figures refer to 1974/76 and are calculated as a percentage of the total cultivated land area in all developing countries. They show that more than half of the cultivated area is situated in the Far East. The Far East also has most of the land in each of the land classes considered. The high percentage of irrigated land in this region should be noted. Further interpretation without recourse to population figures is difficult.

The figures also show that the developing countries do possess good quality land resources for agricultural production. Still, however, some 20% of the cultivated land area is classified as problem areas and 14% as low rainfall areas. This means that over about one third of the cultivated area improvements in yield and production would be difficult to achieve.

Table 5.2.b shows the contribution of the different land classes to the total value of agricultural production by country group. The totals by country group are again difficult to interpret without population figures. The view by land classes shows the importance of partially and fully irrigated land in the Far East. Overall, fully irrigated land accounts for only 10% of the cultivated land area, but for well over 20% of the total production value. The reverse relationship holds for low rainfall areas: 14% of the land area generate only 3.5% of the production value. These are extreme differences with a considerable potential for interpretation in direction of research priorities.

The figures by country groups present a very differentiated picture and would need to be combined with additional information for meaningful interpretation.

5.3 Irrigation and Land Reserves

Agricultural production is heavily dependent on the available area of arable land. Production increases will require different technologies according to the supply of land. Improved land productivity is widely recognized as an important development path, but there may be crucial differences among developing countries in the relative scarcity of land. An important approach to intensification is irrigation as a means to enhance and stabilize production. Hence, both arable land reserves and irrigation draw a picture of the scarcity of the land base in developing countries.

Table 5.3.a shows arable land and irrigation in different developing country groups. The figures are expressed as percentages of the total land use in all developing countries and refer to 1974/76. They show that developing countries as a whole still have large reserves of arable land. They amount to more than 50% of the area presently used. Distribution is uneven. While Africa and Latin America are well endowed, reserves are below 10% of the presently used area in the Near East and the Far East. The latter region dominates the group of low income countries so that here reserves are low, too. The countries that have experienced high agricultural growth rates are also those with more abundant land reserves. There is an obvious interdependence between land reserves and irrigated land use. Wherever land is scarce, irrigated land use is relatively important as in the regions of the Near East and the Far East. In country groups with considerable land reserves, on the other hand, irrigation is not widespread.

Table 5.2.b: Distribution of agricultural gross value of production in land classes by developing country group [a], 1974/76, in percent of total in all developing countries

	Good rainfall [a]	Low rainfall [c]	Naturally flooded [d]	Fully irrigated [e]	Partially irrigated [f]	Problem areas [g]	Total
Africa	6.7	0.5	0.4	0.7	0.4	5.6	14.3
Latin America	10.6	0.3	0.4	4.8	0.9	8.0	25.1
Near East	3.7	0.5	0.2	5.1	1.6	0.2	11.3
Far East	10.9	2.2	8.7	12.0	7.0	8.5	49.2
Total	31.9	3.5	9.7	22.6	9.9	22.3	100.0 [h]
Low income [i]	13.5	2.5	7.8	11.9	7.3	8.6	51.6
Least developed [k]	4.2	0.2	1.7	0.8	0.5	1.2	8.8
Agricultural growth [l]							
- under 3 percent	18.9	2.7	7.2	11.4	6.0	8.0	54.2
- 3 percent or over	13.0	0.8	2.5	11.3	3.9	14.3	45.8

a) According to FAO's AT 2000 project data

b) Rainfall providing 120-270 growing days, soil quality very suitable or suitable according to FAO's agro-ecological zones project classification

c) Rainfall providing 75-120 growing days, soil quality very suitable, suitable or marginally suitable according to FAO's agro-ecological zones project classification

d) Land under water for part of the year and lowland non-irrigated paddy-fields

e) Equipped for irrigation and suitable drainage and not suffering from water shortages

f) Equipped for irrigation, but lacking drainage or reliable water supplies or with low quality and reliability of distribution

g) Rainfall providing more than 270 growing days, soils of all qualities in this zone; plus that part of the 120-270 growing days zone where soil rating is only marginally suitable

h) Total agricultural gross value of production in all developing countries comprises 202.9 billion US $

i) Per caput GDP of US $ 300or lower in 1975

k) Official UN classification

l) Annual rate of change of gross agricultural production 1961-80. All the commodities covered in FAO's AT 2000 project are considered

Source: FAO, AT 2000 data files

Table 5.3.a: Arable land and irrigation in developing country groups [a)], 1974/76, in percent of total arable land use in all developing countries

	Africa	Latin America	Near East	Far East	Low income [b)]	Least developed [c)]	Agricultural growth [d)] under 3 percent	3 percent or over	All developing countries
Rainfed use	27.5	22.1	9.3	28.1	44.3	15.5	52.8	34.2	87.0
Fully irrigated use [e)]	0.2	1.2	1.3	4.0	4.0	0.4	3.6	3.1	6.7
Partially irrigated use [f)]	0.2	0.5	1.4	4.2	4.6	0.5	3.8	2.5	6.3
Total use	27.9	23.7	12.1	36.3	52.9	16.5	60.3	39.7	100.0 [g)]
Reserve	65.0	71.4	7.1	9.8	63.4	18.4	58.4	94.9	153.3
Total use/caput (ha)	0.64	0.54	0.47	0.23	0.30	0.50	0.36	0.38	0.37

a) According to FAO's AT 2000 project data. Based on arable land in ha

b) Per caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Equipped for irrigation and suitable drainage and not suffering from water shortages

f) Equipped for irrigation, but lacking drainage or reliable water supplies or with low quality and reliability of distribution

g) Total arable land use in all developing countries comprises 728.0 million ha

Source: FAO, AT 2000 data files

Table 5.3.b shows arable land and irrigation in different land classes. Most of the land reserves are situated in so-called problem areas, areas that because of excess rainfall and/or soil characteristics pose problems for agricultural production. Considerable reserves are also to be found in good rainfall areas. Desert land reserves are very low, however, although only those areas are considered which may be made available for irrigation.

These figures reveal that land intensification will not be the only way to increase food production in developing countries. It is important for Asia and problem country groups, such as low income countries and countries with low agricultural growth. In these cases, irrigation may also play a dominant part in intensification.

On the other hand, there are the huge tracts of land - not only the problem areas but also the good rainfall areas in Africa and Latin America - whose development would constitute an important development path. Such a development would not be without hinderances, however. The classical problems of rainfed arable land use in the tropics have to be overcome. Shifting cultivation systems achieve relatively high yields at minimal inputs. The movement to more permanent farming systems tends to be accompanied by declining yields, increasing weed problems, and reduced productivity of land and labour to the point where, in a low equilibrium trap, they hardly suffice to support a farmer's family. These problems, often summarized by reference to declining soil fertility, are less pronounced in the drier areas.

In these zones permanent rainfed farming is a possibility to increase production over the years even at a low level of technology although yields in any one harvest are lower in this zone and the potential for increase through modern inputs more limited than in other zones. On the other end of the rainfall scale, the use of tree crops, the practice of garden agriculture, and the use of irrigation are adapted forms of land use in the tropics. There is the phenomenon that the sub-humid zone, the middle belt, - at first sight the zone with the highest agricultural potential - is the zone with the lowest degree of utilization and the lowest population densities.

It has long been recognized that here research has an important role to play. Ley systems, mixed agriculture, zero tillage have to be examined for applicability. No quick answers can be expected for a problem of such size, complexity, and history like the soil fertility problem of the tropics. It can, however, be speculated that the answer does not lie in adaptation of locally available resources (e.g. increased use of organic material). Such attempts must have been made over and over again. Modern inputs, new crops and varieties, and new forms of biological and mechanical technology as a result of research efforts are more likely to provide answers in due course.

5.4 Cropping Pattern

Agricultural land use is, of course, a more complex phenomenon than shown by the proportions used for the different crops. Interactions in space and time determine cropping patterns and these are only inadequately reflected by the aggregate statistics in Table 5.4. Nevertheless some insights can be gained.

Table 5.3.b: Arable land and irrigation in developing country land classes [a] 1974/76, in percent of total arable land use in all developing countries

	Good rainfall [b]	Low rainfall [c]	Naturally flooded [d]	Desert [e]	Problem areas [f]	All developing countries
Rainfed use	40.3	17.0	7.8	-	21.9	87.0
Fully irrigated use [g]	1.5	2.2	0.7	1.3	1.0	6.7
Partially irrigated use [h]	1.2	2.1	0.8	1.3	0.9	6.3
Total use	43.0	21.4	9.3	2.6	23.8	100.0 [i]
Reserve	49.9	9.5	20.5	1.4	71.9	153.3

a) According to FAO's AT 2000 project data. Based on arable land in ha

b) Rainfall providing 120 - 270 growing days, soil quality very suitable or suitable according to FAO's agro-ecological zones project classification

c) Rainfall providing 75 - 120 growing days, soil quality very suitable, suitable or marginally suitable according to FAO's agro-ecological zones project classification

d) Land under water for part of the year and lowland non-irrigated paddy fields

e) Land with less than 75 days growing season and suitable for cultivation only under irrigation. It represents only that share of total desert land for which water is likely to be available

f) Rainfall providing more than 270 growing days, soils of all qualities in this zone, plus that part of the 120 - 270 growing days zone where soil rating is only marginally suitable

g) Equipped for irrigation and suitable drainage and not suffering from water shortages

h) Equipped for irrigation, but lacking drainage or reliable water supplies or with low quality and reliability of distribution

i) Total arable land use in all developing countries comprises 728.0 million ha. The total land use per caput for all developing countries is 0.37 ha

Source: FAO, AT 2000 data files

Well over half of the total cultivated land area is devoted to cereals. Rice as the most important single crop occupies 18% of the land. In actual land use wheat is more important than maize. Here, as for other crops, interesting comparisons with land suitability and potential land use in Chapter 4 can be drawn. While for maize a huge potential for area expansion exists, the potential wheat area, even under high input conditions, would be well below 10% of the total cultivable area.

Each region has its distinct dominant cereal. In Africa it is the millets, in Latin America maize, wheat in the Near East and rice in the Far East.

Food crops other than cereals occupy somewhat over 30% of the cultivated area. Roots (about 4%) and pulses (almost 9%) are the most important, followed by ground nuts (2.9%). Non-food crops account for 11.8% of the cultivated area with fodder crops (4.4%) and cotton (3.5%) standing out. The potential to increase food supplies in developing countries by switching land use from non-food crops to food crops, as sometimes advocated, would from this appear to be strictly limited. An analysis by country would, however, point to important exceptions from this general perspective.

The picture drawn from Table 5.4 differs from that based on production quantities and values of the different commodities. Thus maize and millets are much more important in area than in production value. This is due partly to prices and people's preferences, partly it is the result of different yield levels. The different natural environments also intervene. The millets tend to be grown in the driest areas that would be hardly suitable for any other crop. Judging by production value alone the importance of millets could thus be underestimated. For the identification of research priorities neither land area nor production value are sufficient. They may influence but do not by themselves determine the payoffs of research efforts.

5.5 Crop Yields

Crop yields are important indicators of agricultural productivity. They have been a major focus of research efforts in the past and they have been given close attention in previous papers dealing with research priorities. Table 5.5 gives average yields for the main crops by world region as presented by TAC (1979). The figures are updated to 1982.

The yield differences among the regions are great. It is not so clear, however, what conclusions should be drawn from such differences. The rice yield in China at close to 5 tons is high but most of that rice is produced under non-tropical irrigated conditions. Meaningful comparisons could possibly be made with the Koreas or Japan (where they are higher) but not necessarily with India. On the other hand, the average yield in India at 1.7 tons may be considered low by any standards. Wheat yields provide another example for the difficulty of drawing conclusions. Yields are lowest by far in Australia. Yet some of the most sophisticated technology is applied to achieve production in extremely marginal areas and under drought conditions. The wheat yields in Northern America are a bit more than half of those in Europe, but

Table 5.4.: Land use in developing country groups [a] by crop, 1974/76, in percent of total land use for crops in all developing countries

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	3 percent or over	All developing countries
Wheat	1.1	1.9	4.0	4.7	5.4	0.7	6.6	5.2	11.8
Rice	0.7	1.4	0.2	15.9	14.0	2.4	12.3	6.0	18.2
Maize	2.5	4.6	0.4	2.7	3.8	1.1	4.1	6.0	10.1
Barley	0.7	0.2	1.2	0.7	0.8	0.2	1.5	1.4	2.8
Millets and other cereals	5.0	1.0	1.2	6.8	10.1	3.2	12.0	1.8	13.9
Roots	2.0	0.8	0.1	0.9	1.9	0.6	1.9	1.9	3.8
Raw sugar (beet)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Raw sugar (cane)	0.1	1.0	0.0	0.8	0.8	0.1	1.0	0.9	1.9
Pulses	2.1	1.4	0.3	4.9	6.0	1.0	6.4	2.3	8.7
Vegetables	0.4	0.2	0.3	1.7	1.8	0.2	1.8	0.8	2.7
Bananas	0.2	0.3	-	0.2	0.4	0.2	0.4	0.5	0.9
Citrus fruit	-	0.2	-	-	0.1	0.0	0.2	0.2	0.4
Other fruit	0.2	0.4	0.6	0.7	0.7	0.1	1.0	0.9	1.9
Olive and other oils [e]	0.4	0.1	0.2	1.3	1.4	0.1	1.5	0.5	2.0
Palm (-kernel) oil	0.3	0.1	-	0.1	0.1	0.0	0.3	0.2	0.5
Soybeans	0.1	1.2	-	0.3	0.2	0.0	0.1	1.4	1.5
Groundnuts	1.0	0.2	0.2	1.6	2.2	0.5	2.3	0.6	2.9
Sunflower	-	0.3	0.1	0.1	0.1	0.0	0.4	0.1	0.5
Sesame seed	0.1	0.1	0.2	0.6	0.8	0.3	0.7	0.3	1.0
Coconuts	0.2	-	-	1.2	0.7	0.0	0.3	0.9	1.3
Cocoa	0.6	0.2	-	-	0.1	0.0	0.5	0.3	0.8
Coffee	0.6	0.9	0.0	0.1	0.5	0.2	0.4	1.1	1.6
Tea	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.2
Tobacco	0.0	0.1	0.1	0.2	0.2	0.0	0.2	0.3	0.4
Cotton	0.5	0.7	0.4	1.7	2.3	0.5	2.1	1.4	3.5
Jute and hard fibres	0.1	0.1	0.0	0.5	0.5	0.2	0.4	0.3	0.7
Rubber	0.0	0.0	0.0	1.0	0.5	0.0	0.1	0.9	1.0
Fodder crops	0.2	2.1	0.4	1.7	2.0	0.0	3.6	0.8	4.4
Other crops	0.2	0.0	0.0	0.3	0.4	0.1	0.4	0.1	0.5
Cereals [f]	10.0	9.1	7.0	30.8	34.1	7.6	36.5	20.4	56.9
Other food crops [g]	7.8	6.5	2.1	14.9	17.6	3.2	19.4	12.0	31.3
Non-food crops [h]	1.6	3.9	0.9	5.4	6.6	0.9	6.9	4.8	11.8
Total	19.4	19.5	10.0	51.1	58.3	11.7	62.8	37.2	100.0 [i]

a) According to FAO's AT 2000 project data. Based on cultivated area in ha

b) Per caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Other oils comprise all vegetable oil production with the exception of olive oil, palm (-kernel) oil, soybeans, groundnuts, sunflower, sesame seed, and coconuts

f) Wheat to millets and other cereals

g) Roots to cocoa

h) Coffee to other crops

i) Total cultivated area in all developing countries comprises 544,7 million ha

Source: FAO, AT 2000 data files

Table 5.5.: Yields of major food crops in world regions, 1982, in kg/ha

	World	USA, Canada	Western Europe	Japan, Australia, Oceania	USSR, Eastern Europe	China	South and Southeast Asia (except Japan, China, India)	India	Middle East, North Africa	Central & South Africa	Central America	South America
<u>Cereals</u>												
Rice	2 956	5 315	5 279	5 771	3 801	4 886	2 634	1 744	3 236	1 424	2 911	2 065
Wheat	2 030	2 338	4 001	836	1 797	2 488	1 671	1 696	1 376	1 352	4 186	1 648
Maize	3 495	7 154	5 611	5 116	3 844	3 000	1 618	1 121	2 148	999	1 799	1 958
Sorghum	1 426	3 705	4 682	2 022	1 000	2 500	1 095	675	683	688	3 071	3 014
Millets	660	-	1 958	1 131	711	1 500	924	500	657	604		1 168
Barley	2 064	2 867	3 561	924	1 677	2 560	2 027	1 150	1 141	1 230	1 758	1 021
Total, cereals above	2 378	4 141	4 098	1 577	1 918	3 443	2 440	1 304	1 397	845	2 261	1 954
Total, all cereals	2 328	3 589	3 957	1 507	1 829	3 388	2 436	1 304	1 392	842	2 253	1 932
<u>Pulses</u>												
Cowpeas	232	-	2 394	1 000	-	-	653	-	1 671	222	388	-
Pigeonpeas	744	-	-	-	-	-	500	751	561	651	1 286	537
Chickpeas	602	-	618	-	-	-	665	584	576	779	1 092	501
Dry beans	555	1 577	697	1 601	423	971	706	300	1 012	650	657	538
Lentils	751	1 254	688	-	691	-	644	497	1 403	1 091	833	517
Broadbeans	1 086	-	1 376	588	1 692	1 067	-	-	1 020	1 451	1 080	520
Total, pulses above	582	1 529	862	1 444	491	1 025	682	481	827	391	707	537
<u>Legume oilseeds</u>												
Soybeans	1 805	2 166	2 488	1 581	795	1 129	984	956	2 367	750	1 719	1 646
Groundnuts	698	750	709	683	700	700	657	700	707	684	700	700
<u>Roots and tubers</u>												
Cassava	8 761	-	-	-	-	13 404	11 090	17 948	2 778	6 480	5 842	11 300
Irish potatoes	14 374	29 576	23 280	27 878	12 913	10 345	10 350	13 750	13 022	6 016	12 642	10 567
Sweet potatoes	12 336	14 439	10 527	20 931	-	13 929	6 740	7 317	12 661	6 541	4 513	8 938
Yams	9 035	-	10 556	18 500	-	-	2 941	-	2 875	9 174	3 801	9 564

Source: FAO, ICS data files

this is dictated by differences in socio-economic and natural conditions that lead to completely different production intensities.

For meaningful interpretations yield levels have to be related to the agro-climatic environment and to input levels.

5.6 Yield Variation and Yield Reserves

Table 5.6.a presents results of a first effort to analyse yield differences. Inter-country coefficients of variation of yields are shown by land class. A small figure shows that actual yields do not differ very much among countries. This may indicate that actual yields are close to potential yields. On the other hand, high coefficients of variation demonstrate that actual yields in many countries can still be increased without reaching biological restrictions. In this case considerable yield gaps can be assumed to exist.

Surprising is the relative stability of the coefficient of variation for different crops or different land classes. Obviously, there is a rather constant cross country variation of crop yields which seems to be independent of the crop or the land class considered. These figures suggest that there is some "natural barrier" for actual yield adjustment in developing countries. Appropriate research may help to overcome such a barrier. Alternatively, variability in the developing world may be accepted and efforts directed to increasing potential yields and actual yields within the whole system. In any case, interpretation requires caution because the land classes used cover a wide climatic range.

There are interesting exceptions to the general pattern. Large yield gaps mostly exist in problem areas such as for maize, millets, fruit, palm (-kernel) oil, and cotton. Some large gaps also exist in good rainfall areas for millets, citrus fruit, and cotton. Coefficients of variations on irrigated lands, on the other hand, tend to be relatively low. Considering fully irrigated areas crops like barley, sugar beet, soybeans, ground nuts, coffee, and tea should be mentioned. This impact of irrigation on agricultural production deserves to be emphasized. Irrigation not only increases yields, but also equalizes yields across countries. Hence, it is of primary importance for an intensified and worldwide use of production potentials.

Such a conclusion is also possible by means of Table 5.6.b. This table shows actual and potential yields in developing country land classes. The figures refer to 1974/76 and concentrate on crops. The actual yields reveal the high differences between irrigated land and other land areas. The potential yields, on the other hand, demonstrate that huge yield gaps could still be covered by appropriate adjustments of production processes. This is true for any land class and shows the importance of appropriate innovation research. As indicated by the figures, yield potentials on irrigated lands are, however, already exploited to a larger extent than those on other areas.

In summary, the figures throw light on different aspects of the yield gap problem. Applied research and, especially, irrigation may contribute to increased exploitation of yield potentials, but this is likely to be of different importance for different crops and land classes. Social pay-offs of such a strategy, however, have to be compared to the alternative approach of increasing yield potentials through more basic research. That approach may be rather promising in case of identified small yield gaps.

Table 5.6.a: Coefficient of variation [a] of yields in developing country land classes [b] by crop, 1974/76, in percent

	Good rainfall [c]	Low rainfall [d]	Naturally flooded [e]	Fully irrigated [f]	Partially irrigated [g]	Problem areas [h]	All developing countries
Wheat	42.7	44.2	40.2	46.4	39.7	42.3	58.1
Rice	40.3	-	40.0	38.3	39.1	38.2	53.6
Maize	50.6	49.7	-	44.4	43.0	62.7	57.5
Barley	58.9	33.9	-	29.1	40.3	48.9	61.4
Millets & other cereals	64.9	46.7	32.9	48.0	49.5	60.5	65.3
Roots	44.5	31.8	43.7	35.6	36.3	45.5	46.8
Raw sugar (beet)	-	-	-	25.0	-	-	22.3
Raw sugar (cane)	32.2	-	-	41.8	33.6	40.2	50.3
Pulses	39.1	42.5	61.5	43.7	40.6	42.6	47.8
Vegetables	49.6	31.2	37.4	40.2	40.9	49.0	51.4
Bananas	37.8	-	51.3	32.6	-	41.0	44.1
Citrus fruit	64.1	-	-	39.9	31.3	52.1	55.1
Other fruit	56.2	45.8	69.5	44.4	46.2	71.3	62.9
Olive & other oils [i]	47.4	55.7	-	46.7	56.8	43.6	50.9
Palm (-kernel) oil	-	-	-	-	-	71.4	71.4
Soybeans	36.1	-	-	17.5	-	33.8	36.0
Ground nuts	40.9	35.0	-	30.0	27.8	40.4	43.7
Sunflower	43.3	-	-	-	-	-	53.2
Sesame seed	46.9	49.3	-	-	35.3	45.3	47.2
Coconuts	17.2	-	-	-	-	55.9	57.1
Cocoa	-	-	-	-	-	48.6	48.7
Coffee	39.5	-	-	24.2	-	52.4	53.1
Tea	30.7	-	-	25.5	21.4	39.4	38.3
Tobacco	43.7	-	-	32.3	35.9	51.7	44.4
Cotton	61.7	34.1	-	36.1	34.8	96.8	60.3
Jute & hard fibres	40.9	56.2	33.9	-	-	47.9	43.4
Rubber	-	-	-	-	-	35.3	37.6
Fodder crops	39.9	25.9	-	41.9	35.5	24.5	40.5

a) Standard deviation/mean

b) According to FAO's AT 2000 project data

c) Rainfall providing 120-270 growing days, soil quality very suitable or suitable according to FAO's agro-ecological zones project classification

d) Rainfall providing 75-120 growing days, soil quality very suitable, suitable, or marginally suitable according to FAO's agro-ecological zones project classification

e) Land under water for part of the year and lowland non-irrigated paddy-fields

f) Equipped for irrigation and suitable drainage and not suffering from water shortages

g) Equipped for irrigation, but lacking drainage or reliable water supplies or with low quality and reliability of distribution

h) Rainfall providing more than 270 growing days, soils of all qualities in this zone, plus that part of the 120-270 growing days zone where soil rating is only marginally suitable

i) Other oils comprise all vegetable oil production with the exception of olive oil, palm (-kernel) oil, soybeans, ground nuts, sunflower, sesame seed, and coconuts.

Source: FAO, AT 2000 data files

Table 5.6.b: Yield reserves for cereals in developing country land classes [a] by crop

	Good rainfall [b]	Low rainfall [c]	Naturally flooded [d]	Fully irrigated [e]	Partially irrigated [f]	Problem areas [g]	All developing countries
				Actual yields, 1974/76, in kg/ha			
Wheat	1 156.0	530.0	1 320.0	2 075.0	1 541.0	672.0	1 288.0
Rice	1 534.0	-	1 606.0	3 059.0	2 232.0	1 099.0	1 947.0
Maize	1 402.0	953.0	854.0	3 296.0	1 957.0	957.0	1 377.0
Barley	1 473.0	655.0	1 471.0	1 798.0	1 434.0	850.0	1 156.0
Other cereals	978.0	455.0	815.0	2 676.0	1 636.0	580.0	735.0
				Potential yields [h], in percent of actual yields 1974/76			
Wheat	302.8	377.1	227.3	289.2	227.1	372.0	290.7
Rice	221.6	-	230.2	228.8	257.6	254.8	256.5
Maize	356.6	157.4	351.3	229.1	306.6	418.0	348.6
Barley	339.4	229.0	203.9	278.1	265.0	352.9	308.2
Other cereals	511.3	307.7	184.1	224.2	305.6	431.0	409.1

a) According to FAO's AT 2000 project data

b) Rainfall providing 120 - 270 growing days, soil quality very suitable or suitable according to FAO's agro-ecological zones project classification

c) Rainfall providing 75 - 120 growing days, soil quality very suitable, suitable, or marginally suitable according to FAO's agro-ecological zones project classification

d) Land under water for part of the year and lowland non-irrigated paddy-fields

e) Equipped for irrigation and suitable drainage and not suffering from water shortages

f) Equipped for irrigation, but lacking drainage or reliable water supplies or with low quality and reliability of distribution

g) Rainfall providing more than 270 growing days, soils of all qualities in this zone, plus that part of the 120 - 270 growing days zone where soil rating is only marginally suitable

h) Potential yields reflect a known technology which is applicable to the area considered

Source: FAO, AT 2000 data files

6. Indicators of Non-land Production Factors

6.1 General

The basic rationale for analysing non-land production factors is the same as in the previous chapter. The relative scarcity of different production factors is important in orienting research and determining priorities. While the previous chapter focussed on land this chapter deals with the availability and productivity of other production factors. Beyond inputs into crop agriculture, livestock as an important factor of agricultural production and livestock productivity are specifically dealt with.

6.2 Input Structure in Crop Agriculture

Factor-oriented research intends to change the input structure in agricultural production. The general principle is to find ways to save scarce factors and to extend the use of abundantly available factors. It is impossible, however, to take an isolated view of agricultural production factors without considering commodities. The production process itself constitutes a close link between factors and commodities. Furthermore, also factor-oriented research activities are often directed to specific products. Finally, social pay-off evaluation of different research areas is heavily based on commodities.

If production of certain commodities requires large amounts of scarce inputs research with respect to these commodities may result in considerable input savings. On the other hand, certain commodities may require large amounts of labour. Research-induced extension of such commodities could effectively reduce employment problems which is an essential goal as such in most developing countries. Equally, research could help to make better use of scarce resources in such labour-using production branches. In general, factor-oriented research efforts will have to take into account the current input structure and their possible impact on this structure.

Table 6.2.a shows the use of inputs for different crops in developing countries.Traditional and improved seed, land labour, draught animals, and tractors as power source, fertilizers and pesticides are the inputs dealt with. The figures refer to 1974/76 and reveal remarkable differences in the input structure among crops. Cereal production has a high power demand, using more than half of all available labour, draught animals, and tractors. Most of the fertilizer, on the other hand, is used in the production of food crops other than cereals. The use of pesticides is lowest in cereals production, especially high for the non-food crops. Data for more recent years are incomplete and could not be used here. It is noteworthy, however, that they show substantially increases in the use of all inputs for cereals as a commodity group.

Of the individual commodities rice production absorbs more than one third of labour and draught animal inputs. Its use of fertilizers and pesticides is considerable, too. Other commodities that use large amounts of all inputs considered are wheat, maize, sugar cane, and, to a lesser degree, millets, roots, and cotton. The high use of pesticides in cotton production may not be surprising. Nevertheless, it seems worth pointing out that almost one third of all pesticide use in developing countries is accounted for by that crop alone. The picture

Table 6.2.a: Input use in developing countries [a] by crop, 1974/76, in percent of total input use

	Seed [b]		Power [c]				Fertilizer [e]			Pesticides [f]
	traditional	improved	labour	draught animals	tractors	total [d]	N	P	K	
Wheat	43.1	28.8	4.5	6.5	14.8	5.8	7.0	10.1	6.4	3.3
Rice	25.4	46.3	34.3	38.4	14.4	34.1	22.3	12.1	13.3	11.0
Maize	10.9	7.1	9.0	7.8	12.7	9.0	6.1	5.4	3.2	6.0
Barley	9.4	9.3	0.8	1.3	2.8	1.1	2.1	3.6	2.0	0.0
Millets and other cereals	11.2	8.5	8.4	10.3	6.1	8.8	4.3	4.0	1.6	4.4
Roots	-	-	6.5	4.1	6.4	5.8	2.5	3.2	3.6	10.9
Raw sugar (beet)	-	-	0.1	0.1	0.6	0.2	0.6	0.9	1.7	0.5
Raw sugar (cane)	-	-	5.0	5.3	11.2	5.6	17.6	15.6	21.3	4.3
Pulses	-	-	5.3	7.2	3.7	5.2	2.7	8.3	0.5	1.0
Vegetables	-	-	4.8	3.7	2.1	4.3	2.9	3.6	6.1	1.7
Bananas	-	-	0.4	0.1	0.1	0.3	1.2	1.2	2.0	1.2
Citrus fruit	-	-	0.4	0.2	0.5	0.4	1.4	1.0	3.0	1.9
Other fruit	-	-	1.3	0.5	1.0	1.0	2.0	1.5	4.2	12.2
Olive and other oils [g]	-	-	1.5	1.8	1.4	1.6	3.6	2.9	3.2	0.0
Palm (-kernel) oil	-	-	0.2	0.0	0.1	0.1	0.0	0.0	10.8	0.0
Soybeans	-	-	0.6	0.7	2.3	0.8	6.7	8.6	-	0.0
Groundnuts	-	-	2.8	2.5	1.4	2.6	1.3	1.9	2.0	0.8
Sunflower	-	-	0.2	0.2	1.1	0.3	0.5	0.6	1.4	0.4
Sesame seed	-	-	0.6	0.7	0.0	0.7	0.1	0.1	0.1	0.1
Coconuts	-	-	0.7	0.2	0.1	0.6	0.5	0.5	1.8	0.0
Cocoa	-	-	0.4	0.1	0.1	0.3	0.1	0.1	0.3	0.0
Coffee	-	-	2.1	0.7	0.8	1.6	0.6	0.7	1.0	5.5
Tea	-	-	0.5	0.2	0.2	0.4	2.8	1.4	4.0	0.1
Tobacco	-	-	0.9	0.2	0.7	0.7	0.6	1.3	2.3	0.5
Cotton	-	-	4.8	4.3	6.8	4.8	5.6	4.2	1.1	32.2
Jute and hard fibres	-	-	0.8	0.6	0.2	0.7	1.5	1.3	0.0	0.0
Rubber	-	-	1.2	0.4	0.4	0.9	0.1	0.0	0.4	0.0
Fodder crops	-	-	1.9	1.9	8.0	2.3	3.3	5.9	2.7	2.0
Cereals [h]	100.0	100.0	57.0	64.2	50.6	58.8	41.8	35.2	26.5	24.8
Other food crops [i]	-	-	30.9	27.4	32.4	29.7	43.7	50.0	61.9	35.0
Non-food crops [k]	-	-	12.1	8.4	17.0	11.5	14.5	14.8	11.6	40.2
Total [l]	-	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

a) According to FAO'S AT 2000 project data. Land use for crops is discussed separately in chapter 5.4

b) Based on volume, in percent of cereals

c) Based on man-day equivalence

d) Total power requirement from labour, draught animals, and tractors

e) Fertilizers in N,P,K nutrition content

f) Based on value (US $)

g) Other oils comprise all vegetable oil production with the exception of olive oil, palm (-kernel) oil, soyabeans, groundnuts, sunflower, sesame seed, and coconuts

h) Wheat to millets and other cereals

i) Roots to cocoa

k) Coffee to fodder crops

l) The absolute figures for all developing countries are: in million man-days, labour (48 932), draught animals (20 085), tractors (5 240); in 1 000 metric tons, N (6 333), P (4 929), K (2 223); in million US $, pesticides (1 841)

Source: FAO, AT 2000 data files

for the other commodities and inputs is rather differentiated and difficult to generalize on.

In summary, input use in developing countries varies greatly among crops and does not reflect at all production value or land area occupied. Hence, factor-oriented research cannot simply be based on important commodities, but has to consider differences in input structure as well.

Table 6.2.b shows the aggregated input use for developing country groups. The use of hand labour and of draught animals is prominent in the Far East. As many low income countries are located in this region the same is true for this country group and the group of countries with low agricultural growth. A high share of hand labour in part only reflects a high share in total population but the importance of draught animals is a characteristic feature of the Far East. Tractor use is relatively modest in the Far East and, again, in low income countries. These country groups also use about half of the traditional and the improved seed each. This confirms the well known phenomenon that improved seeds call for increased use of complementary inputs, particularly fertilizer. In general Africa's share in the use of material inputs is rather low whereas the opposite is true for Latin America. This generalization is valid also if one sets input use in relation to the human population or to cultivated area.

As a consequence factor-oriented research will have to consider regional differences in input use and structures. Hence, factor-oriented research, too, cannot simply take a global view, but has to take into account specific country group characteristics.

6.3 Labour Productivity in Crop Agriculture

Factor-oriented research may change the input structure of agricultural production in different ways. Ultimately it has to contribute to increased labour productivity, which is a basic incentive for the adoption of innovations and, thus, for technological change.

Table 6.3. gives monetary labour productivities in developing country groups by crop. Again, the figures refer to 1974/76. They reveal considerable divergences among country groups and crops. In economic terms this is an indication of imperfect labour markets in developing countries. The mobility of labour is imperfect both among countries and among crops.

Labour productivity is relatively high for food crops other than cereals, particularly bananas, citrus and other fruit. Labour productivity in cereal production, on the other hand, is relatively low, especially so in millets, maize, and rice production. As for developing country groups, labour productivity is extremely low in least developed countries. Africa - which comprises most of the least developed countries - and the Far East as well as countries with low income and low agricultural growth also have low figures. High values apply to Latin America, the Near East, and countries with high agricultural growth.

Very low labour productivities exist for maize in Africa and the Far East and for millets in Africa, the Near East, and the Far East. The same is true for sunflower in the Far East and for cotton in Africa and

Table 6.2.b: Input use for crops by developing country group [a)], 1974/76, in percent of total input in developing countries

	Seed[b)]		Power[c)]				Fertilizer[e)]			Pesticides[f)]
	traditional	improved	labour	draught animals	tractors	total[d)]	N	P	K	
Africa	12.3	6.4	18.6	7.1	7.1	14.7	6.6	7.7	6.9	16.4
Latin America	13.1	23.0	12.6	11.2	50.6	14.9	32.1	32.8	28.7	36.7
Near East	25.9	23.0	6.8	4.9	17.8	7.1	13.7	15.6	12.6	12.5
Far East	48.7	47.6	62.0	76.8	24.5	63.3	47.6	43.9	51.8	34.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low income[g)]	52.7	49.7	69.2	79.4	22.8	68.7	39.2	39.0	36.9	42.6
Least developed[h)]	9.1	6.9	14.3	13.2	2.1	13.2	3.3	3.1	2.2	9.7
Agricultural growth[i)]										
- under 3 percent	61.9	60.4	65.5	74.6	48.8	66.8	41.4	42.8	39.9	49.1
- 3 percent or over	38.1	39.6	34.5	25.4	51.2	33.2	58.6	57.2	60.1	50.9

a) According to FAO's AT 2000 project data. Land use is discussed separately in chapter 5.2. The following crops are considered: wheat, rice, maize, barley, millet and other cereals, roots, raw sugar, pulses, vegetables, bananas, fruit, vegetable oils, cocoa, coffee, tea, tobacco, cotton, jute and hard fibres, rubber and fodder crops

b) Based on volume, in percent of cereals

c) Based on man-day equivalence

d) Total power requirement from labour, draught animals,and tractors

e) Fertilizers in N,P,K, nutrition content

f) Based on value (US $)

g) Per caput GDP of US $ 300 or lower in 1975

h) Official UN classification

i) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

Source: FAO, AT 2000 data files

Table 6.3.: Labour productivity in developing country groups [a] by crop, 1974/76, in US $/man-day

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	3 percent or over	All developing countries
Wheat	5.6	15.6	6.7	4.5	4.4	3.0	5.1	7.8	6.1
Rice	2.0	4.2	3.9	2.6	2.4	2.2	2.3	3.5	2.7
Maize	1.4	3.2	2.6	1.8	1.5	1.2	2.0	2.3	2.2
Barley	6.0	10.4	7.4	4.5	3.6	3.3	4.8	8.2	6.2
Millets and other cereals	1.1	5.7	1.9	1.5	1.4	1.2	1.5	2.1	1.6
Roots	3.9	9.9	7.5	5.5	3.9	2.8	4.5	6.0	5.2
Raw sugar (beet)	8.0	25.9	13.1	8.8	6.3	3.9	12.6	13.5	13.0
Raw sugar (cane)	4.6	7.6	5.7	3.4	3.2	3.0	4.0	6.3	4.9
Pulses	2.7	5.5	7.1	3.3	3.2	2.8	3.2	4.8	3.5
Vegetables	5.9	13.6	10.1	7.3	7.0	5.6	7.5	9.0	8.0
Bananas	20.6	37.8	28.7	27.6	20.8	19.5	25.3	30.9	28.0
Citrus fruit	11.3	28.5	17.2	12.3	12.9	11.2	15.2	25.1	20.1
Other fruit	19.7	34.5	22.2	19.2	18.0	16.2	21.2	24.4	22.6
Olive and other oils [e]	2.7	8.6	4.2	2.3	2.2	1.6	2.5	3.8	2.9
Palm (kernel) oil	9.5	17.8	-	30.5	12.5	6.2	8.3	23.6	15.4
Soybeans	2.4	11.2	8.8	4.0	3.6	2.1	8.3	9.2	9.1
Groundnuts	3.1	8.2	6.6	3.2	3.2	3.6	3.2	4.4	3.5
Sunflower	2.6	13.4	5.7	1.9	2.0	1.8	6.3	6.4	6.3
Sesame seed	2.4	5.3	3.3	2.2	2.4	2.8	2.3	4.0	2.7
Coconuts	2.8	8.6	-	5.1	4.4	1.8	3.7	5.9	5.1
Cocoa	9.3	14.2	-	12.3	8.2	5.7	8.9	12.7	10.5
Coffee	4.4	8.9	6.3	6.3	4.7	3.9	4.7	7.8	6.7
Tea	5.1	80.7	7.5	5.2	5.1	5.3	6.1	7.6	6.5
Tobacco	7.8	12.4	6.6	6.8	6.4	5.7	7.6	8.2	8.0
Cotton	1.6	5.6	4.9	1.8	2.0	2.2	1.9	4.7	2.8
Jute and hard fibres	2.4	6.5	-	3.5	2.9	3.6	3.2	4.7	3.6
Rubber	3.6	4.2	-	3.9	2.7	-	2.7	4.0	3.8
Fodder crops	7.9	25.0	8.3	4.3	4.8	4.2	7.2	10.1	7.7
Cereals [f]	1.6	4.5	4.7	2.6	2.3	1.8	2.4	3.5	2.7
Other food crops [g]	4.7	11.7	11.1	5.2	4.7	4.2	5.4	8.5	6.5
Non-food crops [h]	3.5	9.9	5.4	3.3	3.2	3.1	3.9	5.9	4.7
Total	3.2	8.3	6.9	3.3	3.1	2.6	3.4	5.5	4.1

a) According to FAO's AT 2000 project data

b) Per caput GDP of US $ 300 or lower in 1975

c) *Official UN classification*

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Other oils comprise all vegetable oil production with the exception of olive oil, palm (-kernel) oil, soybeans, groundnuts, sunflower, sesame seed,and coconuts

f) Wheat to millets and other cereals

g) Roots to cocoa

h) Coffee to fodder crops

Source: FAO, AT 2000 data files

the Far East. High labour productivities are achieved in the production of bananas in all regions, of citrus fruit and tea in Latin America, of palm (-kernel) oil in the Far East, and of fruit other than citrus fruit in Latin America and the Near East.

For research priorities the interpretation of labour productivities has similar problems as that of yields. High or low values as such do not prove anything. Thus, low labour productivities may be indicative of promising - since so far neglected - research areas. Assuming diminishing returns to research such a choice of priorities might result in higher returns than concentrating on commodities with high labour productivities. On the other hand, low productivities may be indicative of barriers to research which are difficult to overcome; whereas high rates might reflect research successes in the past that can be repeated in future. In this case, research support will have to concentrate upon commodities with high labour productivities. Consequently, reasons for differences in labour productivities are more important for setting research priorities than the labour productivities as such.

6.4 Capital Intensity in Crop Agriculture

As a generalization, factor-oriented considerations in developing countries will tend to stress labour-intensive technologies. Such a general view, however, will have to be specified according to particular commodities and research areas considered. Actual differences in factor intensities for different commodities have to be taken into account. As a consequence there may be different approaches and prospects for research to enhance labour-intensity for specific commodities. For a commoditiy that is already produced in a relatively labour-intensive way, it may be difficult to increase labour-intensity further. On the other hand, concentration of research and development efforts on these products may have considerable employment benefits. Other crops are already now produced in a capital-intensive way for a variety of reasons. A change in factor intensities may be difficult to effect despite its overall desirability. Promising research areas may have to be quite different from those relating to labour-intensive production processes.

Table 6.4. presents indicators of mechanical power use (tractors and draught animals) in developing countries as percentage of total power input. That ratio may be taken as a "proxi" for capital-intensity and gives insight into different technology levels of crop production. Again, the data refer to 1974/76. The methodology of calculating a common denominator for the different sources of power is given in Konandratos et al (1982).

For developing countries as a whole agricultural production is very labour-intensive. Mechanical power accounts for only half of total power. Capital-intensity is extremely low in Africa (les than 20% mechanical power) and considerably below average in least developed countries. On the other hand, it is relatively high in Latin America. Considering commodity groups, capital-intensity is relatively high for cereals and relatively low for non-food crops. Food crops other than cereals take a medium position. It may come as a surprise that the production of non-food crops is relatively more labour intensive than cereal production. This is related to the limited technical suitability of many of the typical tropical non-food crops like tea, coffee, rubber

Table 6.4.: Use of mechanical power in developing country groups [a] by crop, 1974/76, in percent of total power use

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	Agricultural growth [d] 3 percent or over	All developing countries
Wheat	127.5	183.3	96.9	79.4	74.0	47.0	87.1	111.6	95.6
Rice	18.5	64.1	37.4	51.3	52.5	56.8	55.6	37.7	50.5
Maize	24.6	70.4	39.3	55.6	40.4	28.7	53.1	48.3	50.4
Barley	139.5	123.8	108.3	61.4	68.2	72.0	93.9	105.0	98.3
Millets and other cereals	15.3	101.3	49.3	100.2	70.3	30.9	60.5	43.7	58.0
Roots	13.6	91.8	93.8	52.2	29.8	29.0	33.9	39.3	36.3
Raw sugar (beet)	25.0	225.0	95.2	100.0	50.0	-	81.3	97.6	89.7
Raw sugar (cane)	43.9	97.8	43.6	51.9	49.6	51.3	58.8	79.8	66.7
Pulses	25.6	63.5	54.3	80.5	68.3	31.4	67.5	50.0	63.4
Vegetables	7.0	31.6	21.2	47.4	44.6	19.4	45.2	18.8	36.5
Bananas	3.2	21.4	-	27.1	12.3	5.5	15.0	14.4	14.7
Citrus fruit	12.2	36.0	24.3	26.1	20.6	14.3	25.0	31.3	14.7
Other fruit	9.9	39.2	23.4	26.2	22.8	13.0	27.1	23.0	27.6
Olive and other oils [e]	17.0	86.2	31.3	76.9	72.9	26.9	70.9	28.1	50.6
Palm (-kernel) oil	1.9	20.0	-	14.3	3.7	-	2.4	13.2	7.5
Soybeans	14.3	57.3	100.0	39.5	40.0	-	100.0	82.0	83.6
Groundnuts	11.1	82.2	50.9	56.3	44.4	21.5	44.7	26.5	41.3
Sunflower	50.0	160.6	73.3	59.5	57.4	50.0	104.4	71.1	91.1
Sesame seed	30.0	50.0	47.7	67.9	58.2	44.9	57.8	46.9	54.9
Coconuts	5.6	33.3	-	15.3	15.8	7.1	16.1	14.8	15.2
Cocoa	3.5	26.1	-	-	-	-	5.5	13.3	8.8
Coffee	8.8	24.7	-	16.9	11.7	14.5	13.4	18.7	16.9
Tea	5.6	75.0	25.0	18.6	17.0	13.6	19.2	14.5	18.2
Tobacco	27.3	33.3	28.4	26.5	29.3	23.5	35.5	22.4	28.2
Cotton	19.4	92.2	69.0	46.2	41.7	32.9	38.5	79.6	52.2
Jute and hard fibres	10.0	32.4	-	34.6	31.2	50.0	33.6	26.4	31.7
Rubber	2.6	33.3	-	16.3	14.9	-	14.0	16.2	15.7
Fodder crops	106.3	322.0	53.5	48.4	48.0	73.3	85.5	95.5	87.4
Cereals [f]	25.5	78.5	69.8	57.7	55.4	45.4	59.1	48.6	55.8
Other food crops [g]	15.1	79.3	37.9	56.2	47.1	28.3	50.0	43.4	47.6
Non-food crops [h]	16.3	81.6	59.4	36.6	34.4	29.3	43.6	43.0	43.4
Total	19.9	79.3	57.7	55.1	50.6	39.5	54.7	46.1	51.8

a) According to FAO's AT 2000 project data. Mechanical power comprises power of draught animals and tractors; total power includes handlabour in addition. The calculations are based on man-day equivalence

b) Per caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Other oils comprise all vegetable oil production with the exception of olive oil, palm (-kernel) oil, soybeans, groundnuts, sunflower, sesame seed,and coconuts

f) Wheat to millets and other cereals

g) Roots to cocoa

h) Coffee to fodder crops

Source: FAO, AT 2000 data files

for mechanization. Individual crops show considerable differences in capital-intensity. It is high for wheat, barley, sugar beet, soybeans, and sunflower, low for bananas, citrus fruit, other fruit, palm (-kernel) oil, coconuts, cocoa, coffee, tea, and rubber.

The differences among developing country groups are also considerable. Millet production, e.g., is relatively labour-intensive in Africa, relatively capital-intensive in Latin-America and the Far East. Fodder crops, on the other hand, are relatively capital-intensive in Africa and Latin America but relatively labour-intensive in the Near East and in the Far East. Hence, an aggregation over all developing countries would not adequately reflect technology differences, among them. Considerations of research priorities, therefore, would also have to be based on a differentiated view of the developing world.

6.5 Livestock Populations

One of the most important factors in livestock production are the animals of the different species. Table 6.5.a gives the ruminant numbers (cattle, sheep and goats) in the form as contained in the 1979 TAC report (1975 figures) and, in addition, the figures for buffaloes, pigs and chickens. The figures are up-dated to 1981 and the annual rates of change since 1975 are given.

Absolute animal numbers by world region, of course, are a doubtful basis for research priorities. The fact that India has fewer sheep than cattle while for China the reverse applies does not in itself have research implications. Only in an extreme case like the virtual absence of sheep and goats in Japan might one be led to conclude that sheep and goat research should not have a high priority in that country. Conversely buffaloes stand out as a particularly important species in Asia.

Conversion of the absolute animal numbers to percentages would show the different relative importance of the livestock species in the geographical regions as characterized by the share they have in total populations. Relative to the cattle (and buffalo) shares - the most important single species - Africa has a high proportion of sheep and goats, Latin America stands out for the high proportion of pigs and of poultry, the Near East for the virtual absence of pigs and for a high proportion of sheep and goats. The latter two, again, are of relatively lesser importance in the Far East.

In the developing countries livestock populations have generally increased. China is an exception but here there are also particularly grave data inconsistencies. Overall, the variations among regions, on this aggregate level, do not lend themselves to straightforward interpretations.

In Table 6.5.b the world livestock populations have been converted to animal units. For the ruminant species this is a common procedure to allow comparison on a feed requirement basis. The conversion of monogastric animals like pigs and poultry to animal units is less common but does help to get an idea of the relative importance of the different species. Some 60% of the livestock population thus quantified is accounted for by cattle; somewhat more in the developed countries, a bit

Table 6.5.a: Livestock numbers in world regions, 1981 and annual rate of change 1975-1981 [a)]

	1981, million head						1975 - 1981, in percent					
	Cattle	Buffaloes	Pigs	Sheep	Goats	Chickens	Cattle	Buffaloes	Pigs	Sheep	Goats	Chickens
USA and Canada	126.8	-	74.1	13.4	1.4	474.6	- 2.3	-	3.4	-- 2.0	0.0	0.3
Europe	132.5	0.4	174.2	137.1	11.9	1230.4	- 0.3	0.0	1.7	1.5	0.4	- 0.4
Oceania	34.3	-	4.8	204.6	0.4	64.0	- 3.7	-	1.9	- 0.2	12.2	4.1
USSR	115.1	0.3	73.4	141.6	5.9	988.1	0.9	- 4.7	0.3	- 0.4	0.0	4.6
Central America	53.7	0.0	19.1	9.6	9.5	256.6	1.9	-	0.4	1.1	- 2.4	2.3
South America	213.8	0.6	53.9	105.2	19.1	671.7	0.0	20.1	1.2	0.8	0.6	6.1
Africa	170.9	2.3	9.8	184.3	148.9	597.2	1.7	0.7	3.7	2.9	3.0	3.7
Asia (except India, China, Japan)	123.0	37.5	39.5	188.3	117.1	904.7	2.5	0.6	-	2.9	3.7	-
India	182.0	61.5	10.2	41.5	72.1	147.0	0.2	0.4	4.1	0.6	0.7	0.7
China	53.4	18.9	310.3	105.2	82.3	861.4	- 3.0	- 7.4	-	6.2	5.3	-
Japan	4.4	-	10.1	0.0	0.1	286.3	3.4	-	4.6	-	0.0	2.8
World	1209.8	121.6	779.3	1130.8	468.7	6482.2	0.1	- 1.1	2.9	0.0	2.8	1.2

a) Inconsistency of data bases may especially exist for China

Source: FAO, FAO Production Yearbooks 1977 and 1981

Table 6.5.b: Livestock populations in world regions in animal units (AU) [a)] 1981

- million AU -

	Cattle		Buffaloes		Pigs		Sheep		Goats		Chickens		Total	
	AU	%	AU	%	AU	%	AU	%	AU	%	AU	%	AU	%
USA and Canada	88.8	78.4	-	-	18.5	16.4	1.3	1.1	0.1	-	4.7	4.1	113.4	100.0
Europe	92.8	56.6	0.4	0.2	43.6	26.6	13.7	8.4	1.2	0.7	12.3	7.5	164.0	100.0
Oceania	24.0	51.8	-	-	1.2	2.6	20.5	44.3	-	-	0.6	1.3	46.3	100.0
USSR	80.6	65.0	0.3	0.2	18.4	14.8	14.2	11.5	0.6	0.5	9.9	8.0	124.0	100.0
Subtotal dev'd	286.2	64.0	0.7	0.2	81.7	18.2	49.7	11.1	1.9	0.4	27.5	6.1	447.7	100.0
Central America	37.6	80.1	-	-	4.8	10.2	1.0	2.1	1.0	2.1	2.6	5.5	47.0	100.0
South America	150.0	81.9	0.6	0.3	13.5	7.4	10.5	5.7	1.9	1.0	6.7	3.7	183.2	100.0
Africa	119.6	73.1	2.3	1.4	2.5	1.5	18.4	11.2	14.9	9.1	6.0	3.7	163.7	100.0
Asia (exceot India China, Japan)	86.1	49.7	37.5	21.7	10.0	5.8	18.8	10.9	11.7	6.8	9.0	5.1	173.1	100.0
India	127.4	62.3	61.5	30.1	2.6	1.3	4.2	2.1	7.2	3.5	1.5	0.7	204.4	100.0
China	37.4	23.2	18.9	11.7	77.7	48.1	10.5	6.5	8.2	5.1	8.6	5.3	161.2	100.0
Japan	3.1	36.5	-	-	2.5	29.4	-	-	-	-	2.9	34.1	8.5	100.0
Subtotal dev'ing	561.2	59.6	120.8	12.8	113.5	12.1	63.4	6.7	44.9	4.8	37.3	4.0	941.1	100.0
World	847.4	61.0	121.5	8.7	195.2	14.1	113.1	8.1	46.8	3.4	64,8	4.7	1388.8	100.0

a) Conversion factors: Cattle 0.7, buffaloes 1.0, pigs 0.25, sheep and goats 0.1, chickens 0.01

Source: FAO, FAO Production Yearbook 1981 less in the developing countries. Buffaloes play practically no role in the developed countries and in the developing countries of Latin-America and Africa. In Asia (without India, China and Japan) they account for 22%, in India for over 30%. Pigs are the most important species in China. In Central and South America they outweigh sheep and goats taken together. In all other developing regions the small ruminants are more important. Chickens account for 4% on average (34% in Japan, only 0.7% in India as the two extremes).

6.6 Livestock Productivity

Table 6.6.a gives productivity indicators of livestock for developing countries and developed countries each as a group. The first set of figures relates meat production to animal units. It is not to be used for a rigid comparison of the two country groups: The application of uniform conversion factors overrates productivity in developed countries, but a large proportion of the difference is real. Vast differences exist among species. Productivity of small ruminants in developing countries is significantly over that of cattle, mainly as a result of higher reproduction rates. It is several times higher for pigs, and particularly poultry, which is also reflected in the offtake rates. Expressed in terms of annual meat production per animal unit, cattle produce 25 kg, sheep and goats 37, pigs 175 and poultry 225 kg. The comparison of offtake rates, carcass weigths and milk yields between developed and developing countries points to a vast unexploited productivity potential in the latter. Average milk yields per cow are over 3000 kg in developed countries but only 670 kg in developing countries.

These differences, of course, also result from differences in the natural environment, management and input levels. A quantitative differentiation is not possible on this aggregate level.

Table 6.6.b is meant to show the differences among regions and country groups in productivity indicators. Because of its detail it does not lend itself for a text interpretation. It is obvious, however, that the developing countries are by no means uniform and that for different regions and country groups quite different relative gaps and advantages exist.

In no case would any of the figures in themselves be sufficient for the setting of research priorities. Productivity differences would have to be related to differences in the natural environment, the management and the input level. A Zebu cow may produce 250 kg of milk per year over and above the calf's requirements in the drier parts of the Sahel. A Holstein-Friesian may yield 6500 kg under optimum conditions in Europe or the US. The comparison does not necessarily point to possible improvements. Given their environments both animals may be genetically as adapted as possible. And what research can do to improve feeding and general management of livestock kept by traditional societies in marginal environments yet has to be demonstrated. One of the major constraints is that of keeping privately owned animals on common pastures, which makes the introduction of improvements extremely difficult. This may be less a problem of research and more one of political will and power of governments. Similarly it would be difficult to derive conclusions from regional differences. Offtake

Table 6.6.a: Orders of Magnitude of livestock productivity in developed and developing countries by species, about 1980

	Cattle	Sheep and goats	Pigs	Poultry
Meat production (kg) per animal unit and year				
developed	110	73	400	714
developing	25	37	175	225
Offtake (%) a)				
developed	34	54	129	n.a
developing	11	32	78	n.a
Caracass weight (Ls)				
developed	218	15	78	n.a
developing	161	13	58	n.a
Milk yield (kg) b)				
developed	3081	n.a	n.a	n.a
developing	672	n.a	n.a	n.a

n.a not available or not applicable

Note: The figures are to be taken as rough indicators only because a) source data relate to different years between 1979 and 1981, b) the animal unit conversion factors (Table 6.5.b) are problematic when used for non-ruminants and when applied uniformly to developed and developing countries

a) Animals slaughtered divided by number of animals

b) Annual milk production per milking animal

Source: FAO Production Yearbooks and Table 6.5.b

Table 6.6.b: Structure of livestock production in developing country groups [a] by species, 1974/76

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	Agricultural growth [d] 3 percent or over	All developing countries
	Off-take [e], in percent of average species off-take in all developing countries								
Cattle and buffaloes	120.4	157.0	174.2	39.8	54.8	90.3	80.7	134.4	100.0
Sheep and goats	95.3	67.3	105.3	124.9	106.2	89.4	96.6	105.3	100.0
Pigs	131.4	76.0	175.5	137.5	105.5	79.6	104.5	97.8	100.0
Poultry	81.9	126.9	131.0	72.9	66.6	65.0	88.8	109.4	100.0
	Carcass weight, in percent of average species carcass weight in all developing countries								
Cattle and buffaloes	69.8	125.6	72.8	73.8	73.3	65.6	94.9	105.5	100.0
Sheep and goats	89.3	110.7	123.8	82.0	92.6	103.3	93.4	110.7	100.0
Pigs	81.9	116.3	123.1	86.5	87.4	77.1	95.8	102.2	100.0
Poultry	81.8	109.1	100.0	81.8	81.8	72.7	100.0	100.0	100.0
	Milk yield, in percent of average species yield in all developing countries								
Cattle and buffaloes	50.5	155.1	98.7	86.7	80.2	47.1	82.2	133.0	100.0
Sheep and goats	85.6	91.9	111.6	88.4	95.1	114.4	87.2	114.2	100.0
	Egg yield, in percent of average egg yield in all developing countries								
Poultry	50.0	142.3	101.9	96.2	59.6	48.1	76.9	121.2	100.0

a) According to FAO's AT 2000 project data

b) Per caput GDP US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Animals slaughtered divided by number of animals

Source: FAO, AT 2000 data files

rates of cattle herds are higher in Latin America than in the Far East. This reflects differences in resource endowment and management but also, in cultural history, in the purpose for which livestock are kept and, generally, in the functions livestock have for agriculture and for the respective societies. To actually draw conclusions for research priorities would presuppose a much more differentiated and disaggregated view of the research area (Jahnke 1982): One and the same species may be related to quite different products or commodities like meat and milk or meat and eggs. Furthermore, the output function is only one of several. Thus cattle also have an input function in agriculture (draught, manure). Furthermore, livestock are often the venue for savings and investment and they may even play a social and cultural role. This multiplicity of products and functions of livestock makes it particularly difficult to identify research areas in terms of social payoffs.

7. Gap Indictors from FAO's AT 2000 Study

7.1 General

An essential part of the data used in the previous chapters has been based on FAO's project "Agriculture: Towards 2000". That project provides a comprehensive planning framework for agriculture in developing countries. It is a basic source of detailed and quantitative information on agricultural performance in the developing world. However, AT 2000 is not only a positive analysis. It also has a normative element. The study intends to demonstrate necessary changes to meet future needs. It proposes strategies for the development of world agriculture to the end of the century, with particular reference to developing countries.

The normative part of AT 2000 is based on specific views of the future. Two scenarios are used for the evolution up to the year 2000. An optimistic scenario (scenario A) is based on the overall economic growth objectives of the UN International Development Strategy (IDS) and a substantially improved agricultural performance. The alternative scenario is based on more modest growth rates both in agriculture and in the overall economy. The AT 2000 Study elaborates the policies and measures necessary for agricultural development to be consistent with the scenarios. This is based on known technologies and takes into account numerous constraints and possiblities for change of agriculture in individual developing countries. AT 2000 constitutes an extraordinary effort to foresee the challenges to and the constraints and potentials of agriculture in developing countries.

There are a great deal of straightforward implications for research. Differences between scenarios in the year 2000 and the present situation reflect gaps which might in part be overcome by appropriate research efforts. Then there are gaps and deficiencies already in the present situation. They may increase in seriousness unless overcome by new technologies provided by appropriate research activities. Analysing gaps in FAO's AT 2000 project, therefore, helps to identify agricultural research priorities. The fact that projections in AT 2000 are based on known technologies, therefore, does not deny the need for research. Applied research is called for to apply technologies known in principle. Furthermore, research must now try to find new technologies that may be in need in the year 2000.

The main reference in this chapter is FAO's optimistic scenario A for the year 2000. Several variables like cropping patterns, yields, land use and irrigation, inputs and livestock production structure are analysed. Necessary changes in these variables to meet FAO's normative scenario may indicate a need for research. A larger change or gap may call for a higher priority in research planning although this relationship is by no means unambiguous. In any case research possibilities and probabilities of success would need to be taken into account in addition.

7.2 Change in Cropping Patterns

To meet FAO's scenario in the year 2000 an adaptation of the cropping pattern in developing countries is necessary. Table 7.2. shows that these changes are not dramatic as a whole. On average land use is to

Table 7.2.: Change in land use under FAO's AT 2000 scenario A in developing country groups [a] by crop, annual rate of change 1980 - 2000, in percent

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	3 percent or over	All developing countries
Wheat	2.4	1.9	- 0.9	0.2	0.6	3.1	0.6	0.0	0.4
Rice	3.7	2.1	2.1	0.3	0.5	0.8	0.6	0.9	0.7
Maize	2.4	2.4	1.6	2.3	1.9	1.6	2.1	2.5	2.3
Barley	0.6	2.9	1.8	2.4	2.2	1.4	1.6	1.8	1.7
Millets and other cereals	1.7	3.2	1.1	- 0.4	0.3	1.2	0.7	1.9	0.9
Roots	1.0	2.4	1.1	0.6	0.6	0.6	0.8	1.5	1.2
Raw sugar (beet)	1.1	3.9	2.5	23.5	21.3	9.7	8.7	3.2	5.1
Raw sugar (cane)	3.2	2.9	4.3	1.8	1.6	2.9	1.4	3.7	2.5
Pulses	1.3	2.2	2.4	1.1	1.1	1.4	1.2	1.9	1.4
Vegetables	2.1	2.9	2.5	1.6	1.7	1.8	1.7	2.5	1.9
Bananas	0.7	1.8	0.4	1.5	1.1	0.5	1.1	1.4	1.3
Citrus fruit	1.6	2.1	3.2	2.0	3.2	3.0	2.6	1.7	2.1
Other fruit	2.6	3.1	1.7	2.9	2.8	2.8	2.3	2.8	2.6
Olive and other oils [e]	- 0.5	- 1.1	2.5	1.7	1.6	3.6	1.4	0.3	1.1
Palm (-kernel) oil	0.7	6.2	0.0	5.2	3.4	1.9	0.4	5.0	3.1
Soybeans	3.1	2.6	4.5	3.4	3.2	5.7	0.4	3.2	2.7
Groundnuts	2.8	0.3	3.2	2.3	2.6	3.8	2.1	3.1	2.3
Sunflower	3.9	1.8	5.0	6.5	6.1	5.1	3.9	2.8	3.6
Sesame seed	3.7	3.4	3.4	2.0	2.6	3.7	2.5	3.2	2.7
Coconuts	- 1.6	- 3.2	0.0	0.5	0.1	0.2	0.8	- 0.3	0.0
Cocoa	0.6	2.3	0.0	4.5	1.2	6.1	0.1	2.3	1.1
Coffee	0.9	1.3	7.8	1.3	1.3	0.9	1.2	1.2	1.2
Tea	1.8	1.8	1.0	1.9	1.9	2.5	3.0	2.6	2.9
Tobacco	2.6	1.5	1.1	1.4	1.5	2.3	2.0	1.4	1.6
Cotton	2.2	0.9	1.4	0.7	1.1	2.3	0.9	1.4	1.1
Jute and hard fibres	- 0.5	- 2.0	- 1.1	- 0.7	- 0.9	- 1.6	- 1.0	- 0.6	- 0.8
Rubber	1.0	1.6	0.0	2.2	1.6	-	1.4	2.2	2.1
Fodder crops	4.3	2.2	3.6	2.8	2.6	3.9	2.7	2.9	2.7
Other crops	2.5	0.0	1.4	2.7	2.7	3.1	2.6	2.5	2.6
Cereals [f]	2.0	2.4	0.3	0.4	0.6	1.4	0.8	1.4	1.0
Other food crops [g]	1.4	2.3	2.6	1.6	1.7	2.1	1.5	2.3	1.8
Non-food crops [h]	2.0	1.7	2.6	1.8	1.6	1.5	1.9	1.7	1.8
Total	1.8	2.2	1.1	0.9	1.1	1.6	1.9	1.7	1.4

a) This table is based on FAO's AT 2000 project. The calculated figures describe the necessary annual rates of change 1980 - 2000 in cultivated land area to meet AT 2000 scenario A

b) Per caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Other oils comprise all vegetable oil production with the exception of olive oil, palm (-kernel) oil, soybeans, groundnuts, sunflower, sesame seed, and coconuts

f) Wheat to millets and other cereals

g) Roots to cocoa

h) Coffee to other crops

Source: FAO, AT 2000 data files

expand at a rate of 1.4% per year, well below the demographic growth rate during the period concerned. Land used for cereals expands at a rate below average (1.0%), that for "other food crops" and non-food crops above average (1.8%). Maize increases its claim to land relative to other cereals. Other crops with increasing land use shares are sugar cane and beet, citrus and other fruit, vegetable oils, tea, rubber, and fodder crops.

While differences in annual growth rates may appear small, the cumulative effect over 20 years is not insignificant. Thus, maize expanding at 2.3% per year would have increased its area by 50% after 20 years, wheat (0.4%) by less than 10%. These two crops mark about the upper and lower end of the scale of growth rates called for.

The pattern by developing country groups is complex. Considerable expansion is implied for wheat in least developed countries and in Africa (starting from a very small base), for rice in Africa, and for millets in Latin America. Among food crops other than cereals many commodities are destined for expansion in different regions and groups, particularly in the least developed countries. Fodder crops, finally, will require relatively much more land in Africa and the Near East as well as in the group of the least developed countries.

In summary, change in cropping patterns to meet FAO's scenario of the year 2000 are tangible but not dramatic. There is an obvious need to think about research implications of some findings: Wheat area is to increase by 10%, the area of maize by 50%. All other things being equal one would be tempted to put one's eggs in the maize basket.

7.3 Sources of Production Increase

In AT 2000 FAO developed cropping programmes to meet the normative scenario for each country. The results can be aggregated for the different crops. This shows the necessary changes in gross value of production, at constant 1975 prices, for all crops considered to meet the optimistic 2000 scenario. At the same time, the sources of these changes, area expansion, crop mix, yield increase, and cropping intensity, can be analysed.

Table 7.3. shows the necessary annual increases of crop production in developing country groups between 1980 and 2000. The average figure of 3.6% increase per year is higher than recent trends of about 3 percent but not dramatically so either. The necessary increases are especially high, however, for Africa (4.1%) and the group of the least developed countries (4.3%), which are largely synonymous.

To reveal possible starting-points for research the sources of increase are important. At constant prices, the value of production may change as a consequence of changes in area cultivated, land classes used, crop mix, cropping intensity, and yield. Bruinsma et al (1983) developed a method to isolate these influences. Based on this method the figures in Table 7.3. give the percentage contribution of different sources to the overall change in the gross value of production. They show that yield increases are most important to induce changes in gross value of production. For developing countries as a whole they account for about half of the change. Yield increases are somewhat less important in Latin America, but most important in Africa and in the Far East.

Table 7.3.: Change in gross value of production for crops under FAO's AT 2000 scenario A by developing country group [a)]

	Annual rate of change 1980 - 2000 [b)], percent	Sources of growth [c)]				
		Arable land, percent	Land mix, percent	Crop mix, percent	Cropping intensity percent	Yield, percent
Africa	4.1	22	4	2	14	58
Latin America	3.6	48	4	3	10	34
Near East	3.4	2	28	6	18	47
Far East	3.4	12	17	5	13	53
Total	3.6	22	13	4	13	48
Low income [d)]	3.6	12	16	5	11	56
Least developed [e)]	4.3	14	13	3	13	57
Agricultural growth [f)]						
- under 3 percent	3.6	12	14	4	14	56
- 3 percent or over	3.5	33	11	4	12	40

a) This table is based on FAO's AT 2000 project. The following crops are considered: wheat, rize, maize, barley, millet and other cereals, roots, raw sugar, pulses, vegetables, bananas, fruit, vegetable oils, cocoa, coffee, tea, tobacco, cotton, jute and hard fibres, rubber, and fodder crops. The value of production is calculated at constant 1975 prices

b) The calculated figures describe the necessary annual rates of change 1980 - 2000 to meet AT 2000 scenario A

c) Contribution of different factors to the annual rate of change in gross value of production

d) Per caput GDP of US $ 300 or lower in 1975

e) Official UN classification

f) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

Source: FAO, AT 2000 data files

Area expansion is the next important source of increase in gross value of production. It is most important in Latin America, but practically without relevance in the Near East. Other sources of change play a less important role. This is uniformly true for crop mix. There are some regional differences in the importance of land mix and cropping intensity. Both are rather important in the Near East. Land mix changes, on the other hand, can be neglected in the case of Africa and Latin America.

These figures have implications for agricultural research priorities. The most important probably relates to the primordial importance of yield increases as a source of growth. Area expansion can also have important research implications in the sub-humid tropics (compare Chapter 5.2). The other variables like land mix, crop mix, and cropping intensity characterize changes in farming systems and are of different importance for the different regions. Research support will have to take into account such differences. Farming system research would appear to be important to supplement the more traditional research areas.

7.4 Land and Irrigation Requirements

Expansion of arable land has been identified as a major source of production increases in developing countries to meet FAO's 2000 scenario. In this section an analysis is made of the relative importance of total arable land, of irrigated and rainfed land, and of changes in land reserves. Table. 7.4.a refers to different developing country groups, whereas different land classes are considered in Table 7.4.b.

Table 7.4.a shows that total arable land will have to be increased at a rate above average in Latin America and in countries with high agricultural growth. Land reserves will diminish significantly in the Far East and in least developed countries. Irrigation plays a dominant role in land use adaptation; compared with the expansion of rainfed land (0.8% p.a.) the expansion of irrigated land is extremely high at 3.5% p.a. This means that over 20 years the extent of fully irrigated land would have to double. Overall the share of irrigated land use would increase considerably. A structural change in irrigated land use also takes place. For developing countries as a whole partially irrigated land would have to diminish, whereas the extent of fully irrigated land would continue to increase. A rate well above average is called for in Africa and the Far East. The same is true for low income countries, least developed countries, and countries with low agricultural growth.

Table 7.4.b shows the relevant figures by land classes. Overall expansion is above average in good rainfall and problem areas. This is also true for fully irrigated use and for the use of naturally flooded areas. Land reserves diminish significantly in good and low rainfall areas, and in desert areas.

In summary, the view by land resources has many different facets according to type of land, region and country group. This would have to be reflected in considerations of research priorities as well. Overall, there remains the high and growing importance of irrigation if production and development goals are to be met. In comparison, expansion of rainfed production in low-rainfall areas is judged to be of

Table 7.4.a: Change in arable land and irrigation under FAO's AT 2000 scenario A in developing country groups [a], annual rate of change 1974/76 - 2000, in percent

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	Agricultural growth [d] 3 percent or over	All developing countries
Rainfed use	1.0	1.8	- 0.0	- 0.2	0.3	0.8	0.4	1.3	0.8
Fully irrigated use [e]	4.2	2.4	2.6	4.0	4.1	5.1	4.1	2.8	3.5
Partially irrigated use [f]	0.8	- 0.1	- 1.3	1.8	- 1.6	- 0.6	- 1.1	- 1.9	- 1.4
Total use	1.0	1.8	- 0.3	0.4	0.6	0.9	0.6	1.3	0.9
Reserve	- 0.5	- 0.8	- 0.5	- 2.0	- 0.6	- 1.0	- 0.8	- 0.7	- 0.7

a) This table is based on FAO's AT 2000 project. The calculated figures describe the necessary annual rates of change 1974/76 - 2000 to meet AT 2000 scenario A. The calculations are based on arable land in ha

b) Per caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Equipped for irrigation and suitable drainage and not suffering from water shortages

f) Equipped for irrigation, but lacking drainage or reliable water supplies or with low quality and reliability of distribution.

Source: FAO, AT 2000 data files

Table 7.4.b: Change in arable land and irrigation under FAO's AT 2000 scenario A in developing country land classes a), annual rate of change 1974/76 - 2000, in percent

	Good rainfall b)	Low rainfall c)	Naturally flooded d)	Desert e)	Problem areas f)	All developing countries
Rainfed use	0.9	0.1	- 0.1	-	1.2	0.8
Fully irrigated use g)	3.6	2.9	5.9	2.8	3.2	3.5
Partially irrigated use h)	- 0.8	- 1.2	- 1.1	- 3.2	- 0.9	- 1.4
Total use	1.0	0.4	- 0.8	0.7	1.3	0.9
Reserve	- 1.2	- 1.0	- 0.4	- 1.8	- 0.5	- 0.7

a) This table is based on FAO's AT 2000 project. The calculated figures describe the necessary annual rates of change 1974/76 - 2000 to meet AT 2000 scenario A. The calculations are based on arable land in ha

b) Rainfall providing 120 - 270 growing days, soil quality very suitable or suitable according to FAO's agro-ecological zones project classification

c) Rainfall providing 75 - 120 growing days, soil quality very suitable, suitable or marginally suitable according to FAO's agro-ecological zones project classification

d) Land under water for part of the year and lowland non-irrigated paddy fields

e) Land with less than 75 days growing season and suitable for cultivation only under irrigation. It represents only that share of total desert land for which water is likely to be available

f) Rainfall providing more than 270 growing days, soils of all qualities in this zone, plus that part of the 120 - 270 growing days zone where soil rating is only marginally suitable

g) Equipped for irrigation and suitable drainage and not suffering from water shortages

h) Equipped for irrigation, but lacking drainage or reliable water supplies or with low quality and reliability of distribution

Source: FAO, AT 2000 data files

negligeable importance as a source of growth. By implication, one may argue that research on rainfed production and semi-arid areas should be de-emphasized. On the other hand, there may be equity reasons and other social considerations in favour of leaving priorities as they are.

7.5 Input Requirements

One of the most important features of FAO's AT 2000 Study is the comprehensive insight it provides into input structures of developing countries' agriculture, both at present and in its necessary evolution to the year 2000. Such input requirements may point to priorities for factor-oriented research.

Table 7.5.a summarizes the change in input requirements by crop under FAO's optimistic AT 2000 view. Compared to changes in cropping patterns and land use, changes in input requirements are considerably more accentuated. This may have implications for appropriate factor-oriented research, but it certainly also underlines the need to bring about more wide-spread adoption of known technologies.

Of all input categories increases in fertilizer use are of highest importance especially for cereal production. Tractor use and, thus, mechanization will have to expand considerably, too. Cereal production will heavily depend on improved seed, but also on a relatively high increase in the use of pesticides.

Looking at crops individually, the picture is very complex reflecting the great variations in agronomic characteristics, particularly among food crops other than cereals and non-food crops. Commenting individual differences does not appear to be warranted in this aggregate interpretation.

Table 7.5.b shows changes in aggregate input requirements by developing country group. The most substantial increases are necessary in Africa for all production factors considered. Important increases are also called for in the Far East particularly in improved seed, tractors, fertilizers, and pesticides. Similarly it is the groups of low income and least developed countries that are supposed to realize the most essential increases in input use in order to meet the agricultural development objectives of AT 2000.

In summary, and in comparison with the analysis of required changes in cropping patterns and of the sources of production growth, the great importance of increased use of modern inputs becomes apparent. In this view the choice between commodities, say, maize and wheat, is less relevant than the choice between low-input and high-input levels. Of course, the two choices are interrelated. If there are no improved varieties of a particular crop that respond to complementary inputs,there is not much sense in advocating fertilizer use. AT 2000 essentially bases its forward planning on increased application of known technology. Yield increases are only predicted if there is sufficient evidence of viable improved varities and input response. Yet there is still considerable scope for applied biological research and trial work as well as and farming systems research to expand adoption of improvements.

Table 7.5.a: Change in input requirement under FAO' AT 2000 scenario A in developing countries [a] by crop, annual rate of change 1980 - 2000, in percent

	Seed [b]		Power [c]				Fertilizer [e]			Pesticides [f]
	traditional	improved	labour	draught animals	tractors	total [d]	N	P	K	
Wheat	- 3.4	6.1	1.1	- 0.2	4.4	1.6	10.4	9.7	10.0	4.9
Rice	- 4.3	4.8	1.7	0.7	6.9	1.8	9.8	9.6	8.6	4.9
Maize	0.9	6.9	2.2	1.1	7.6	3.0	9.7	9.7	9.8	5.9
Barley	- 0.7	6.1	1.6	- 0.2	5.9	2.5	9.3	9.2	9.6	-
Millets and other cereals	- 0.2	5.1	1.9	- 0.1	6.6	1.7	7.9	7.9	9.8	5.4
Roots	-	-	1.3	0.1	6.4	1.8	6.6	6.6	6.9	2.6
Raw sugar (beet)	-	-	5.6	6.3	7.9	6.5	12.5	12.6	12.5	8.8
Raw sugar (cane)	-	-	2.0	0.8	7.2	3.1	5.6	5.7	5.5	5.9
Pulses	-	-	1.7	0.3	7.1	1.9	8.9	8.7	4.0	6.3
Vegetables	-	-	3.0	1.7	8.3	3.1	7.8	8.3	8.2	5.3
Bananas	-	-	1.7	1.3	9.8	2.1	6.1	6.1	6.1	5.9
Citrus fruit	-	-	2.6	1.4	7.7	3.2	6.7	5.5	4.3	3.9
Other fruit	-	-	2.9	1.9	7.9	3.3	8.7	8.7	8.6	4.9
Olive and other oils [g]	-	-	2.3	1.7	6.2	2.6	5.1	6.0	6.0	0.0
Palm (-kernel) oil	-		3.5	4.5	12.4	4.1	0.0	0.0	8.4	0.0
Soybeans	-	-	0.9	0.4	6.5	3.3	6.0	6.0	0.0	0.0
Groundnuts	-	-	3.0	1.6	7.1	3.0	12.0	11.6	11.5	6.9
Sunflower	-	-	4.0	3.1	6.3	4.6	10.2	7.6	5.7	5.0
Sesame seed	-	-	3.5	2.1	8.7	3.6	15.4	15.4	13.6	7.2
Coconuts	-	-	0.6	0.5	9.4	1.1	13.8	13.8	13.8	-
Cocoa	-	-	1.3	0.8	8.3	1.9	6.0	6.0	6.0	3.5
Coffee	-	-	1.4	0.2	7.9	1.8	6.8	6.8	6.8	4.3
Tea	-	-	2.9	2.0	10.3	3.3	5.4	5.4	5.4	5.7
Tobacco	-	-	1.9	1.1	9.6	2.3	5.7	5.8	5.8	3.5
Cotton	-	-	1.6	- 0.1	5.8	2.0	6.1	6.2	4.8	3.3
Jute and hard fibres	-	-	- 0.8	- 1.9	5.9	- 0.7	5.6	5.5	0.0	0.0
Rubber	-	-	1.9	2.5	10.4	2.7	16.5	16.5	16.5	-
Fodder crops	-	-	3.4	1.7	5.4	3.7	11.0	10.9	11.2	5.7
Cereals [h]	- 2.2	5.6	1.8	0.6	6.5	2.0	9.7	9.5	9.3	5.2
Other food crops [i]	-	-	2.2	1.0	7.1	2.7	7.1	7.4	7.7	4.7
Non-food crops [k]	-	-	1.9	0.6	6.1	2.4	8.3	9.0	8.8	3.7
Total	-	-	1.9	0.7	6.6	2.2	8.6	8.5	8.4	4.5

a) This table is based on FAO'S AT 2000 project. The calculated figures describe the necessary annual rates of change 1980 - 2000 to meet AT 2000 scenario A. Change in land requirement is discussed separately in chapter 8.1

b) Based on volume

c) Based on man-day equivalence

d) Total power requirement from labour, draught animals and tractors

e) Fertilizers in N,P,K nutrition content

f) Based on value (US $)

g) Other oils comprise all vegetable oil production with the exception of olive oil, palm (-kernel) oil, soybeans, groundnuts, sunflower, sesame seed and coconuts

h) Wheat to millets and other cereals

i) Roots to cocoa

k) Coffee to fodder crops

Source: FAO, AT 2000 data files

Table 7.5.b: Change in input requirement for crops under FAO's AT 2000 scenario A by developing country group a), annual rate of change 1980 - 2000, in percent

	Seed b)		Power c)				Fertilizer e)			Pesticides f)
	traditional	improved	labour	draught animals	tractors	total d)	N	P	K	
Africa	0.8	7.1	2.7	1.3	7.2	2.8	11.0	11.3	11.1	5.6
Latin America	0.2	5.0	0.7	- 0.2	6.5	2.9	6.2	6.3	6.2	4.0
Near East	- 1.7	4.4	1.5	- 0.7	5.7	2.3	7.1	7.1	7.3	4.2
Far East	- 3.8	6.3	1.9	0.8	7.3	1.9	9.7	9.7	9.1	4.6
Total	- 2.2	5.6	1.9	0.7	6.6	2.2	8.6	8.5	8.4	4.5
Low income g)	- 3.0	6.5	2.2	0.8	7.6	2.1	10.6	10.2	10.0	4.9
Least developed h)	- 0.5	7.6	2.8	1.6	8.2	2.6	10.4	10.5	10.8	6.1
Agricultural growth i)										
- under 3 percent	- 2.5	6.3	2.2	0.7	6.0	2.2	10.4	9.9	9.5	4.8
- 3 percent or over	- 1.8	4.6	1.3	0.5	7.1	2.4	7.1	7.4	7.6	4.2

a) This table is based on FAO's AT 2000 project. The calculated figures describe the necessary annual rates of change 1980 - 2000 to meet AT 2000 scenario A. Change in land requirement is discussed separately in chapter 8.1. The following crops are considered: wheat, rice, maize, barley, millets and other cereals, roots, raw sugar, pulses, vegetables, bananas, fruit, vegetable oils, cocoa, coffee, tea, tobacco , cotton, jute and hard fibres, rubber, and fodder crops

b) Based on volume for cereals only

c) Based on man-day equivalence

d) Total power requirement from labour, draught animals and tractors

e) Fertilizers in N,P,K, nutrition content

f) Based on value (US $)

g) Per caput GDP of US $ 300 or lower in 1975

h) Official UN classification

i) Annual rate of change of gross agricultural production 1961 - 80. All the commoditites covered in FAO's AT 2000 project are considered

Source: FAO, AT 2000 data files

7.6 Requirements of Livestock Development

Livestock production has to grow at particularly high rates if demand for livestock products implied by the AT 2000 scenario is to be met. Table 7.6.a shows necessary increases in meat production in developing country groups by species.

Meat production as a whole will have to grow at an annual rate of change of 4.4 percent. This is clearly above the growth rate deemed necessary for crops and is equivalent - over 20 years - to an increase by a factor of 2.4 . The rate is even higher for Africa and the Far East. Above average rates of production increase are implied for pigs and poultry while the relative importance of ruminant livestock would be slightly reduced.

The necessary increases in meat production are based on increases in the number of animals, offtake increases, and carcass weight increases. All components contribute to the necessary changes, but numeric increases are particularly important. This reflects a realistic assessment of the feasible rather than the choice of the most desirable development path: The scope for productivity increases is judged to be more limited than in the case of crops. Numeric increases are lowest for the ruminants at 2% p.a. giving recognition to the limited capacity of grazing resources.

For the different developing country groups different development patterns are envisaged. Again the most far-reaching adaptation processes are called for in Africa and the Far East. Thus considerable emphasis is on numeric increase of poultry in the Near East and of pigs in low income countries. Carcass weight is to increase for all species in low income and least developed countries. The increase of cattle and buffalo offtake rates is a particular challenge for the Far East.

Table 7.6.b shows that substantial increases in milk and egg production are also called for. In both cases, again, they are mostly based on animal numbers. Yield increases play a subordinate role.

Milk production increases are put above average for Africa (all species) and Latin America (cows). An above average potential is seen for milk from sheep and goats in the Far East. Above average increases in the number of laying hens and egg yields, finally, will have to take place in the Near East.

In summary, the necessary development of livestock production reflects many specific problems and possible bottlenecks. There are only few general guidelines for global research priorities. A basic distinction appears to exist between crop and livestock production as regards productivity or yield increases. They are deemed very important for crop agriculture as reflected by increases in irrigation and input use. For livestock the potential for yield and productivity increases is viewed much more conservatively. The emphasis is more on numeric increases, albeit of those animals that are more productive in the first place like milk animals, pigs, and poultry.

Table 7.6.a: Change in meat production under FAO's AT 2000 scenario A in developing country groups [a] by species, annual rate of change 1974/76 - 2000, in percent

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	Agricultural growth [d] 3 percent or over	All developing countries
	Number of animals								
Cattle and buffaloes	1.9	1.9	1.3	1.4	1.4	1.6	1.3	2.3	1.7
Sheep and goats	2.1	1.7	1.8	2.2	2.1	2.1	1.9	2.1	2.0
Pigs	3.4	2.0	2.6	3.6	3.3	2.8	2.7	2.7	2.7
Poultry	4.9	3.5	5.7	5.0	4.7	2.9	4.4	4.8	4.6
	Off-take [e]								
Cattle and buffaloes	1.1	1.2	1.3	2.3	1.9	1.5	1.3	1.4	1.5
Sheep and goats	0.9	1.0	0.6	0.4	0.6	0.8	0.7	0.6	0.7
Pigs	1.1	1.5	0.3	0.7	1.0	1.2	1.0	1.3	1.2
Poultry	1.0	1.0	1.0	1.2	1.2	1.0	0.9	0.9	1.0
	Carcass weight								
Cattle and buffaloes	1.0	0.2	1.2	0.6	0.6	0.8	0.4	0.5	0.5
Sheep and goats	1.0	0.8	0.7	1.0	0.9	0.9	0.8	0.8	0.9
Pigs	1.0	0.4	-0.1	0.7	0.7	1.0	0.4	0.6	0.5
Poultry	1.2	0.6	0.7	1.2	0.8	1.3	0.7	0.7	0.7
	Meat production [f]								
Cattle and buffaloes	4.1	3.4	3.8	4.4	3.9	3.8	3.0	4.2	3.7
Sheep and goats	4.0	3.5	3.1	3.5	3.6	3.8	3.5	3.6	3.5
Pigs	5.6	3.9	2.7	5.0	5.1	5.2	4.2	4.6	4.5
Poultry	7.1	5.1	7.5	7.4	7.1	5.4	6.1	6.5	6.3
Total	4.8	3.8	4.7	5.1	4.6	4.1	3.8	4.8	4.4

a) This table is based on FAO'S AT 2000 project data. The calculated figures describe the necessary annual rates of change 1974/76 - 2000 to meet AT 2000 scenario A

b) Per Caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of gross agricultural production 1961 - 80. All the commodities covered in FAO's AT 2000 project are considered

e) Animals slaughtered divided by number of animals

f) Based on volume

Source: FAO, AT 2000 data files

Table 7.6.b: Change in milk and egg production under FAO's AT 2000 scenario A in developing country groups [a] by species, annual rate of change 1974/76 - 2000, in percent

	Africa	Latin America	Near East	Far East	Low income [b]	Least developed [c]	Agricultural growth [d] under 3 percent	3 percent or over	All developing countries
	Milking animals								
Cattle and buffaloes	2.8	2.8	1.5	2.3	2.3	2.6	2.1	3.0	2.4
Sheep and goat	2.9	1.0	1.5	3.0	2.6	2.4	2.5	1.8	2.2
	Milk yield								
Cattle and buffaloes	1.1	1.4	1.7	1.0	0.9	0.8	1.3	1.1	1.3
Sheep and goat	0.3	1.1	0.6	0.6	0.6	0.5	0.4	0.6	0.5
	Milk production [e]								
Cattle and buffaloes	4.0	4.2	3.2	3.3	3.3	3.4	3.4	4.1	3.7
Sheep and goat	3.2	2.1	2.1	3.6	3.2	3.0	2.9	2.5	2.7
Total	3.8	4.2	2.9	3.3	3.2	3.2	3.3	4.0	3.6
	Laying hens								
Poultry	4.0	3.3	5.0	4.5	4.2	3.4	3.8	4.3	4.1
	Egg yield								
Poultry	1.8	1.3	1.5	1.2	1.6	1.7	1.2	1.3	1.3
	Egg production [e]								
Poultry	6.0	4.6	6.6	5.8	5.9	5.0	5.1	5.6	5.4

a) This table is based on FAO's AT 2000 project data. The calculated figures describe the necessary annual rates of change 1974/76 - 2000 to meet AT 2000 scenario A

b) Per caput GDP of US $ 300 or lower in 1975

c) Official UN classification

d) Annual rate of change of grass agricultural production 1961 - 80. All the commodities covered in FAO'S AT 2000 project are considered

e) Based on volume

Source: FAO, AT 2000 data files

8. Concluding Considerations

8.1 General

These concluding remarks are to take up some of the major issues in relating quantitative indicators to research priorities. They are not meant to represent the conclusions from the preceding analyses. In particular they do not depict research priorities as their result. This would be inappropriate: The information provided may in many cases be necessary for rational decision-making about research priorities; it is unlikely to be sufficient, however.

The basic view taken in this paper is that priority identification for international research should be guided by the goals of society. The choice among different research areas should be made on the basis of the different social payoffs. If the goal is to maximize food production the potential benefit from a research project will depend on the probability of success, the time period it is likely to take from the year of decision-making to the time of achievement and implementation in practical agriculture, and the cost of the project in terms of opportunities foregone by devoting resources to this and not to another project. In reality social payoff is more a conceptual device than a measuring rod. Probabilities of success and time frame are hard to predict in research. There is a long and complex way from a research result to production increase in practical agriculture and efficiency is a difficult term to come to grips with in research. Furthermore there is not only one goal in a society but many different ones, often conflicting, and they may vary in their emphasis from one country to the next.

No clear-cut unambiguous conclusion can therefore be derived from the indicators presented. They give an indication of the potential importance of a particular research area with respect to a particular goal. They say nothing about the social payoff and they do not allow the conclusion that international support to agricultural research should go in that and not in the other direction. They are in themselves insufficient for decision-making.

On the other hand, they could serve a number of useful purposes in the process of deriving research priorities. They make clear the need to define the goals more clearly. While most would agree that increased food production in developing countries should be a first order goal for international research, this requires further sharpening. The crops that emerge as the most important by calorie contribution are different from those by value of food production. If one judged that all suitable land should be used for food crop production resulting research priorities are different than if resources are to be put to their best economic use. And if the value of food production now is to be maximized research priorities would be different from those oriented toward values in the future.

The indicators have different meaning for different goals. They also have to be complemented by information on research possibilities to get closer to an estimate of social payoffs. The principal issues involved in this process shall in the following be highlighted under the headings "commodity orientation", "resource orientation" and "orientation by development perspectives". These are the different orientations or emphases of the different indicators. The issues that arise in drawing conclusions for research priorities differ accordingly.

8.2 Commodity Orientation

The shares of a crop in production, demand, trade, or nutrition may be indicators for its importance in attaining a society's goals. Inferences for research priorities, however, have to be drawn with caution. Several problems have to be considered.

(1) Commodity share versus research payoff: The problem that the indicators presented do not relate to the social payoff of a research effort, the ultimate conceptual criterion, pervades all sections. It lends itself particularly well to an illustration with respect to commodities.

Both in production and in demand, rice is by far the most important single commodity with a share of close to 20%. In comparison, maize has a share of 3.8% only. Rice is five times more important than maize. Should one, as a consequence, spend five times more money on rice research than on maize research? Not necessarily, because commodity shares have nothing to do with research possibilities. A dollar spent on maize research may bring a return ten times higher than on rice research, or vice-versa. In either case a 5:1 ratio of commodity shares may be far off the optimal relative allocation. Furthermore, nothing can be deduced about the absolute size of the research effort called for. A threshold value can always be assumed to exist below which efforts dissipate ineffectively. The threshold is likely to be different for different crops as well as the response curve of research to expenditures. This has to do with causality and efficiency but also issues of "researchability" and "location-specificity" come in. All these issues are, to a degree, amenable to rational analysis and even quantification. The point to make here is simply that the indicator of commodity share is in itself insufficient for deciding about research priorities.

(2) Present versus future shares: The share of crop products is around 80% in the total value of agricultural production and in total demand for agricultural products, that of livestock products in the order of twenty percent. Even if one refrains from translating this into numeric weights for research priorities it would appear plausible to conclude that more emphasis should be put on crop research than on livestock research. But that conclusion is oriented to the past, not to the future. Table 8.2 provides a model of the development of demand for food and non-food products over time on the basis of typical values for economic growth, population growth, and income elasticities of demand.

Thus in a country with a per caput income of US $ 200 or less livestock products will not account for more than 10% of total demand for food. Extreme resource endowments or cultural factors can lead to deviations, but the order of magnitude given is representative of the average. In demand, in production value, and in the food consumption budget, crop products are about 9 times as important as livestock products. However, at a 5% growth of the economy and a 2% population growth per annum livestock products will have doubled their share after 20 years (the lifespan of a cow) and after forty years demand for livestock products will account for over one third of total demand. Even more important

Table 8.2: Hypothesized evolution of demand for livestock and crop foods in the course of demographic and economic development

	Year 0 t = 0	Year 20 t = 20	Year 40 t = 40
Popuialtion (million)	10	15	22
annual increase	2%	2%	2%
Per caput income (US $)	200	530	1400
annual increase	5%	5%	5%
Proportion of income spent on			
all food	60%	50%	35%
livestock products	6%	10%	12%
crop products	54%	40%	23%
Income elasticities of demand for			
all food	1.0	0.6	0.4
livestock products	2.0	1.2	0.8
crop products	0.9	0.5	0.2
Growth rate of demand for			
all food	7%	5%	4%
livestock products	12%	7%	6%
crop products	6.5%	4.5%	3%
Actual demand (million US $) for			
all food	1200	3975	10780
livestock products	120	795	3696
crop products	1080	3180	7084
Increase in demand (million US $) from year t to (t+1)			
all food	84.0	199.0	431.2
livestock products	14.4	55.7	221.8
crop products	70.2	143.1	212.5

Note: The proportion of income spent on different foods is interrelated with the respective income elasticities of demand. But here no assumptions are made about the development of elasticities over time. The proportion and elasticity coefficients are not calculated over the years but set at typical values for the years shown.

Source: Jahnke (1983)

than the share may be incremental demand from one year to the next because it is the incremental production that calls for new technology and research. Incremental demand for livestock foods in year forty is higher than that for crop foods. Furthermore, the rate at which livestock production is to move forward to meet demand is much higher. Over forty years the production value has to increase thirty times, for crop foods only 7 times.

These theoretical considerations are fully confirmed by the empirical evidence in Chapters 2 and 3. The share of livestock foods in the diet and in total food demand increases while production hardly keeps pace. Given the dramatic increases called for in livestock production and the long gestation period of livestock research, particularly in the case of the large ruminants, a case can be made for emphasis on livestock research that is out of proportion with the present contribution of livestock to production, income and food consumption.

This reasoning does not only bear on research but is basic to practice and theory of agricultural development as a whole (Mellor 1966). Nor does it only apply to the issiue of livestock versus crops. It is relevant for any choice among products that differ in their income elasticities of demand which means that their future relative importance is foreseeably different from their present one. At given returns to research efforts the commodity with a higher elasticity coefficient deserves greater emphasis in forward-looking decision-making.

<u>(3) Outward and inward-oriented development strategies:</u> Wheat accounts for almost one fourth of the developing countries' import bill, coffee for over 16% of the export bill. They are the most important single agricultural commodities in developing countries' trade. If a country has an inward-oriented development strategy it will attempt to substitute for imports. It would have to try and produce wheat, if necessary at the expense of coffee. The goal of autarchy would prevail over that of income maximization. To the extent that research can help overcome obstacles in that course, priorities would be set accordingly.

If on the other hand the strategy is outward-oriented the country will push all those commodities for which there is a comparative advantage in production. For the tropical countries this applies to the typical tropical crops like coffee. Research would be oriented to enhance the production of coffee rather than that of wheat. The strategy is likely to contribute more to growth in national income, but self-sufficiency in wheat might further drop.

<u>(4) Variation among developing countries:</u> A whole chapter has been devoted to the view of commodity-oriented indicators by country groups. The great variation in the relative importance of commodities, in diets, in income levels etc. is obvious. To average out the indicators over the world may be less desirable than to explicitly take into account regional differences when setting priorities for international agricultural research. This finds further support in the great regional variation in resource endowment.

8.3 Resource Orientation

Essentially all the chapters from 4 on have a resource orientation. Chapters 5 and 6 focus on the actual situation, availability, and productivity. Chapters 4 (agro-ecological zones) and 7 (AT 2000) take a more comprehensive view of resource potentials and how they influence agricultural development into the future. This section focusses on the actual use of resources.

There are at least two different ways in which research may be resource-oriented. On one hand, it may help to exploit availability and productivity of resources used at present by demonstrating the possibilities and limits of certain innovations. Extent of low rainfall land shows the area potential of innovations for a typical low rainfall crop like millet. Availability of lowland humid areas similarly is related to the potential of a crop like cassava. On the other hand, research may be oriented to increasing the availability and/or productivity of a particular resource. This may be achieved indirectly e.g. through the adaptation of a crop to a larger spectre of land conditions. It may also relate to the enhancement of a resource, e.g., the rehabilitation of degraded land which actually increases the availability and productivity of the resource land. It is a basic contention that research and the consequent development of technology is determined by the relative scarcity of the resources (Herlemann and Stamer 1954, Ruttan and Hayami 1969, Binswanger and Ruttan 1978). In the attempt to accelerate the generation of innovations one would try to observe this principle. This ensures that innovations are likely to be in the economic interest of the farmers and of the countries concerned. The following aspects are emphasized.

(1) Relative factor scarcities: Successes of international agricultural research of the past are much associated with high-yielding varieties of maize, wheat, and rice. Such research primarily increases the productivity of land and is particularly relevant in situations where land is the scarcest factor. The indicators show, however, that land scarcity is by no means the typical situation of all developing countries. In fact there is a clear-cut regional differentiation. The Near East (including North Africa) and the Far East have only minimal possibilities of expansion. Practically all cultivable land is already in use. Africa and Latin America, on the other hand, have huge land reserves. Land use could be expanded to two to three times of the present. Development paths and, accordingly, research priorities would appear to have to be different.

Land reserves do not necessarily imply that cultivation can be expanded at known technologies and without research efforts. The reserves that lie in the warm and humid tropics pose some of the most difficult problems of agricultural land use once the low intensities of shifting cultivation are surpassed. This calls for research efforts that may have relatively little to do with the genetic yield potential of a crop and much more with questions of soil fertility. Land scarcity, on the other hand, not only calls for yield increases through higher-yielding varieties but also for other measures of increasing land productivity. Irrigation is a major line of development. The data clearly show that irrigation gains in importance as land gets scarcer. The necessary production increases will have to come largely from irrigated land, an issue taken up again in the context of development perspectives.

(2) Land use and yields: Having recognized land as the central agricultural production factor the proportion of land devoted to a

particular crop can also be taken as an indicator of its importance. Because of differences in land quality and yields that proportion is different from the one in production or demand. Rice at 18% of all cultivated area remains the most important crop, but millets are second at 14%.

A crop that can be grown under marginal conditions, like the millets in low-rainfall areas, makes possible the use of land that would otherwise hardly contribute anything to food production. In this light one might attribute greater importance to the millets than would appear to follow from their weight in production.

The more basic question that arises is whether research should concentrate on the high potential areas or whether a case can be made for the more disadvantaged situations irrespective of lower yields and lower contribution to total production. Such a line of argument could be based on the potential for production increases. The indicators do show that at known technologies the rate at which yields of millets could be increased is similar to that of other crops. There is also no noticeable difference between potential yield increases in low rainfall compared to other areas.

The figures may be considered inconclusive because too general for decision-making. On the other hand they do not in themselves deny that significant production increases can also be achieved in the less well endowed areas.

The expression "at known technologies" does not mean that research has no role to play. First there is always a need for local applied research even for known technologies. Second the difference between actual yields and potential yields at known technologies can be interpreted as an indication of the potential of research to push the frontier even further.

<u>(3) Livestock:</u> Animals are not only a product but also a production factor for crop agriculture (manure, draught) and, of course, for livestock production. The analysis of livestock numbers is therefore important. Such an anlysis should not be limited to cattle, sheep, and goats, as has been the case in the past. It is also difficult to talk about livestock numbers without regard to weight and feed requirements.

The inclusion of buffaloes, and of pigs and poultry and the conversion of all animals to animal units gives a more realistic picture. Buffaloes emerge as the second most important species in developing countries. Pigs and poultry are more important than sheep and goats already in terms of animal units. Their importance is much greater yet in terms of production. Their production per animal unit is several times that of ruminants.

The conclusions for research priorities are not self-evident. Should livestock research concentrate on the most important species in terms of liveweight (cattle and then buffaloes) or on the species that are more productive? Should emphasis be on meat production or on the production of milk and eggs? Do ruminants deserve absolute priority because their feed base is less competitive with human nutrition? Does one only consider the function of livestock as a producer of foods or also that of contributing to crop agriculture (manure, draught) and the important socio-economic functions like that of a savings account. The quantitative indicators of livestock populations and livestock productivity provide only partial answers to these questions.

8.4 Orientation by Development Perspectives

Both, the agro-ecological zones project (Chapter 4) and the AT 2000 study (Chapter 7), combine commodity and resource consideration to scenarios of agricultural production in the future. The complementarity of the two works leads to a number of important issues in research priority setting.

(1) The framework of agricultural potentials: The AEZ project has provided a detailed agro-ecological inventory of the developing world. It sets the limits to what is possible at presently known technologies. A basic question is whether international agricultural research wishes to place itself within that framework. The task would then be to find practical solutions to problems that in principle are already known to exist. The production possibility curve would not be moved outward but made more realistic for practical agriculture in developing countries. Alternatively research would concentrate on moving the limits outwards. This would lead to changes in the assessment of land suitabilities, yield potentials and the like. This raises the question whether research should be applied or basic. Of course, the answer may not simply be yes or no but one that defines degree and complementarity. Still the question has to be answered: Does the orientation of research accept AEZ and AT 2000 as the framework within which to operate or does it aim to change that framework?

(2) Food production versus agricultural development: The AEZ project and the subsequent studies of population supporting capacities take food production, more specifically calorie and protein supply, as the one overriding goal of developing countries and as the only purpose of agriculture. AT 2000, on the other hand, aims at exploiting agricultural potentials also for income and trade. The resulting production structures, in both cases projected to the year 2000, are different. The possible conclusions to be drawn for research are also different. The question is not whether the CG system should include non-food crops. The relative advantage of public international efforts in research on food production has been well established. The question poses itself in a different way: If the aim is to make every country self-sufficient in food production, research would focus on the countries and areas that emerge as critical in terms of population supporting capacities. These are largely the semi-arid and the highland situations. Emphasis on centres like ICRISAT and ICARDA would be increased because they are much directed to agricultural improvement in critical semi-arid zones. In addition the installation of a highland centre would become an important issue. If, on the other hand, the potentials are to be exploited as they exist the warm tropical lowlands would stand in the foreground for research.

(3) Sources of growth: AT 2000 shows a possible path of agricultural development if efforts (and funds) are considerably increased from now to the year 2000. At the same time the development path depicted is realistic in the sense that it is based on known production possibilities only and includes infrastructural, socio-economic, and political constraints. Thus a large body of experience is incorporated in the scenarios and it could justifiably be argued that research orientation should be guided by it. This would refer to the sources of

growth (expansion, yield improvement, changes in land and crop mix, increases in land use intensity), to the inputs required (varieties, power, fertilizer, pesticides), to the different crops and the differences among regions. In consequence priorities would be put on yield increasing innovations on fertilizer use, on rice, and on irrigation. The orientation would be quite different. Livestock would receive a relatively big emphasis because it would be attempted to meet the demand increases. Pigs and pultry would receive greater attention than ruminants simply because of their greater potential to increase production quickly.

8.5 Outlook

The limitations of the quantitative indicators for identification of priorities in international agricultural research have been outlined. These limitations determine to a degree direction and emphasis of the additional requirements for setting such priorities.

The basic incompleteness of the indicators presented relates to the relationship between the cost of research efforts in a particular direction and the benefits in terms of social goals. The social payoff cannot be determined by the indicators presented alone. The example is that a high share of rice in world production and consumption does in itself not mean that rice research has a high payoff. This calls for additional information on cost-benefit relationships, success probabilities and the like to be able to assess more fully the social payoffs of alternative research areas in terms of different social goals.

Present allocation of research resources has to be considered too. This includes the CGIAR system, public national research allocation, and research efforts by the private sector. A relatively recent analysis of the CG system exists (CGIAR, 1982). Annex I contains a compilation of existing data on public national research allocation. It demonstrates how difficult it is to characterize research efforts meaningfully. It also draws attention to the ambiguity of the indicators. If national research efforts focus on a particular commodity or resource, does this mean that international efforts stay away from that research area or that they follow suit and concentrate on the same. The extent to which national and international research are complementary or substitutional is not really known.

Quantitative indicators of the type presented in this paper can be useful and necessary for research planning. They are incomplete and insufficicient to base decisions solely on them. Even if complemented by a great deal of evidence on research possibilities and prospects in different areas and on actual research allocation in the different spheres at present they are likely to remain incomplete and insufficient. This is related to the limitations of a "central planning" approach to research altogether. First, whatever data are presented as a basis for decision-making, even if they constitute extrapolations into the future, they are data from the past and, therefore, orient the view backwards. Research, on the other hand, is a creative venture into the future that can only be inadequately guided by such indicators. Second the international system of agricultural research is an incomplete system. It has to be seen in connection with national research efforts. And even then it is still incomplete. The optimal size of total research efforts is not known and it is very clear that international research cannot include all researchable areas, however important they may be. Research allocation then resembles a second-best problem. In a state of overall imperfection, one cannot be sure that a step towards the optimum represents an improvement. To balance research efforts according to the relative share of wheat and rice in total demand by developing countries is fine. But it could well be that, at given levels of overall expenditures the highest payoff would be achieved by doing research on wheat only, simply because of the respective response curves to research. It could also be that the highest social payoffs would be achieved for a while by concentrating efforts on producing cheap nutrients or on growth hormones. As problem-oriented as one may wish international research to be, it is still research. It is not just the testing of existing cultivars for different purposes and environments. It contitutes a challenge to the intellectual capacity of human minds. If the researcher working in a rice programme has an idea that in practice is only applicable to wheat, surely he would not have failed, although he may appear to be in conflict with the quantitative indicators in this paper. International research should not be viewed in a too mechanistic way. It should retain some elements of basic research. That does not mean that research goes on without controls and reference points. But these controls and reference poins are more subtle and more sophisticated. To illustrate this one can hardly do better than to refer to Arnon (1975) who in the following is cited almost word by word.

Because of the uncertain nature of the output of basic research and its potential impact on agricultural development, it does not appear possible to devise a simple, rational basis for judging or planning the allocation of resources to this sector; nor are there objective criteria for determining priorities. In exploratory research an original idea is investigated, and in the early stages it is not even possible to guess at the probability of something of practical, economic importance arising from it. A certain effort has to be invested before any evaluation can be made. Yet to neglect this type of research is to stifle initiative and perhaps miss important opportunities. Since the success of exploratory research cannot be forecast, the conditions under which it is done and especially who does it assume major importance. The only practical solution is to assign a certain proportion of the total funds available to agricultural research for these and similar kinds of research in the sense of "scientific overhead". Whatever the actual proportion decided on, it is bound to be purely arbitrary.

In assigning priorities among different research proposals that fall in the categories described above, important guidelines can be their scientific promise and feasibility and the reputation of the researcher who submits the proposal. Specific criteria proposed for this purpose are:

1. Whether a scientific answer to the problem proposed can be reasonably anticipated.

2. The reputation of the investigator, or the promise of a young scientist.

3. Whether facilities and support needed for the research are available.

4. Whether the field appears "ripe" for intensive research, and whether there are real opportunities for major progress.

5. Whether the results of the proposed research may contribute to the long-term goals of the agency that provides the support.

6. The originality of the research and its technical soundness.

7. The scientific "significance" of the research in terms of affording new understanding of fundamental laws, providing a critical test of current theory, and exploiting new techniques.

8. The possibility that it will illuminate work in other scientific fields.

It is to the credit of the international research system that in fact it has, both within the individual centres and in its central bodies, much adhered to the principles as spelt out by Arnon.

Finally a word of caution appears appropriate. Solid research needs stability. The priority indicators contained in this paper should not be used to question the existence of any of the present centres. Too much effort is associated with the establishment of such research capacities to sacrifice any one of them on the basis of some aggregate statistics. At most they can be used to guide emphasis in growth and long-term evolution of the system. But also considerations of growth, increment and long-term evolution need not be solely based on centrally planned priorities and on quantitative indicators as contained in this paper. More flexible mechanisms could be introduced by which for instance any future increments in core funding to the CGIAR would be distributed among competing research proposals from the centres, possibly also from national institutions on merit. Merit would be established by TAC on the basis of quantitative indicators but also along Arnon's guidelines. Thus the principle of strong individual centres would be maintained. So would the present system of "special project funding" by individual donors but it would be complemented by central "merit-funding". The latter would be more stable and more long-term than special project funding. It would be designed to reconcile concerns for originality and quality of research with those for coherence and consistency with quantitative indicators of the type presented in this paper.

Annexes

Annex I: Indicators of National Agricultural Research

1. General

Priority choice in international agricultural research support will reflect societal goals in developing countries and research possibilities. So far a general view has been taken and no explicit distinction has been made between international and national agricultural research. National research activities in developing countries, however, exist and increasingly contribute to societal goal realisation in these countries. They have been recognized as key elements in any programme to increase food supplies. Without the collective effort of research and extension in the developing countries themselves, the prospects for increased food and agricultural production in these countries look dim (FAO/UNDP 1983).

As a consequence enhancement of national agricultural research in developing countries is a major issue in international development. FAO and UNDP have actively supported the developing countries in strengthening their capabilities in national agricultural research. Furthermore, international financing institutions and bilateral donors have made substantial financial, material, and intellectual contributions. For the period 1976 - 80, Oram (1982) estimated that total assistance for agricultural research to the developing countries was running, at the rate of constant 1975 US $, at 400 million per year. Support for the CGIAR system accounted for 19 percent of this total and bilateral assistance for 42 percent or US $ 190 million per year. In the period 1970 - 81 UNDP and FAO assisted some 790 national agricultural research projects involving a total commitment by the two organizations of US $ 757 million (FAO/UNDP 1983).

These figures demonstrate the increasing importance attributed to national agricultural research in developing countries. Both international and national research support is, therefore, considered as essential to meet the needs of developing countries. Consequently, priorities in international agricultural research should not be determined in isolation and without explicit regard to national research activities. A thourough understanding of national research in developing countries is a crucial prerequisite to make the best choice in international research support.

In the following the importance of national agricultural research in developing countries for priority choice within the CGIAR system will be illustrated. The theoretical relationships between international and national research activities are briefly discussed and some indicators concerning level, trends, and structure of national agricultural research in developing countries are presented. These indicators take a global view for all developed countries. They are largely compiled from recent studies by Judd et al. (1983) and IFPRI/ISNAR (1981). These indicators convey a rough idea of the problems involved on a global basis. For a more detailed discussion of specific problems based on in-depth analyses of 12 countries the reader is referred to the FAO/UNDP evaluation study on national agricultural research of 1983.

2. Relationship between national and international agricultural research

The usefulness of international agricultural research in a system of different national research activities is widely acknowledged. There are four basic arguments in favour of international efforts (Pinstrup-Andersen, 1982; Ruttan, 1982):

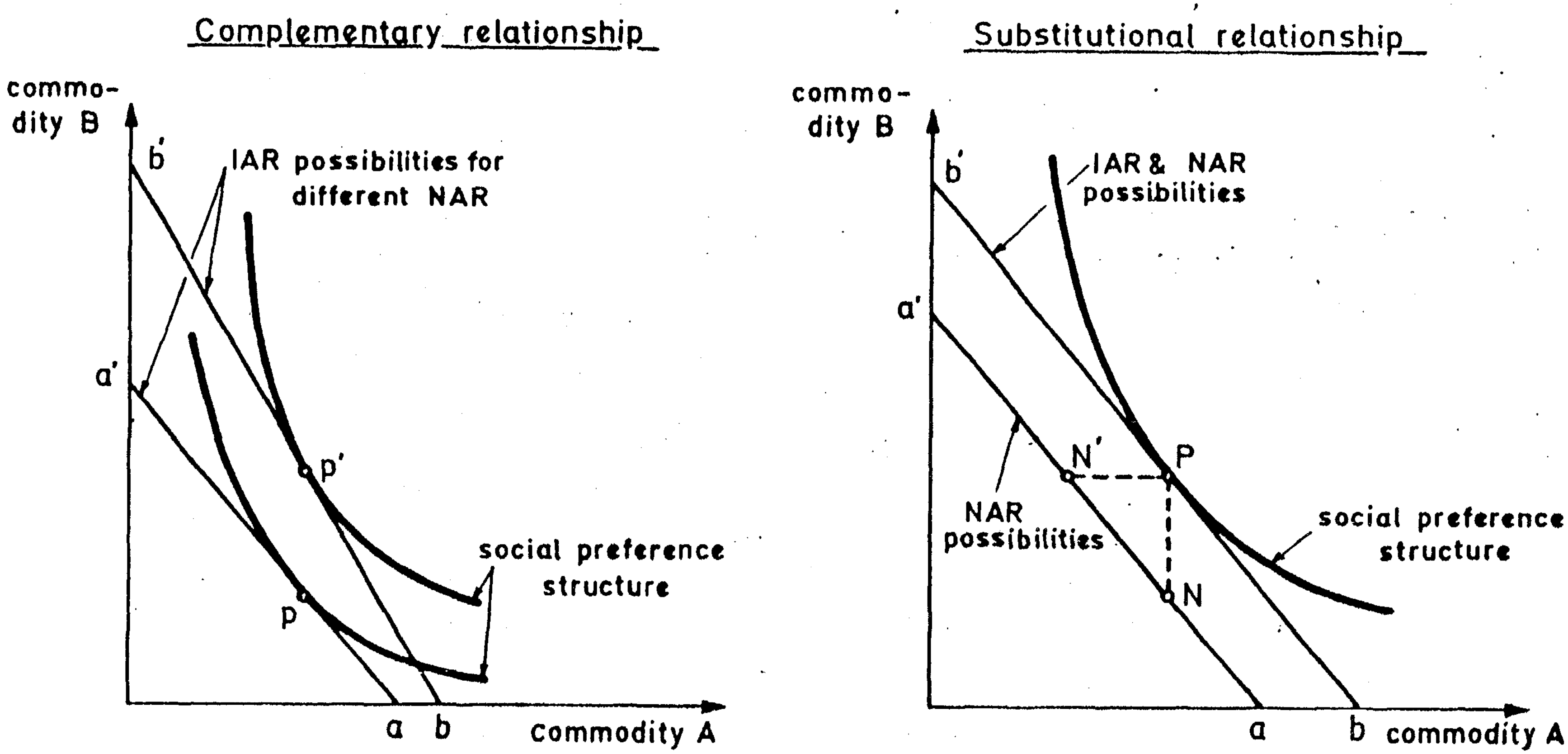
a) the public good character of agricultural research,
b) distortions in developing countries' time preferences,
c) distortions in developing countries' risk preferences, and
d) imperfect markets for agricultural research demand and supply.

For these reasons developing countries will generally underinvest in agricultural research and international efforts are required to fill the gap. But such underinvestment is not uniform across all research areas. Certain areas are covered by national research in developing countries while others are not. It can also be assumed that national and international research vary in their relative suitability for different research areas. National agricultural research activities, therefore, have an important influence on the priorities one sets for international efforts.

The relationship between national and international research activities can be complementary or substitutional. Complementarity exists if national research activities supplement international research; if there is mutual reinforcement in the attainment of social goals. National research may then adopt results from the international level and appropriately transform them to facilitate national implementation. Hence, international agricultural research success and, thus, priority choice heavily depends on level and structure of national research systems.

Complementarity is illustrated on the left-handy side of Figure I. This figure shows the optimal priority choice for international research considering different national research possibilities. For simplicity, the figure refers to commodity-oriented research. Line aa' shows international agriculture research possibilities for a certain national research system. Optimal research support, in this case, Annex Figure I

Relationship between international and national agricultural research and research priority choice



IAR – international agricultural research

NAR – national agricultural research

is characterized by point P. Increases in national research possibilities, now, automatically increase international research possibilities. The new situation is characterized by line bb' and the optimal point P'. Due to a change in the national research system, therefore, priorities in international research will change in favour of commodity B. Hence, priority depends on structure and performance of national research systems.

Some more aspects of the complementarity issue should be mentioned. Schultz (1980) emphasizes that IARCS are not capable of doing more than a small part of required research in a certain area. To take advantage of such advances calls for a corps of highly skilled scientists on the national level. According to Schultz it would be a serious mistake for developing countries to assume that IARCS, along with the on-going agricultural research in high income countries, are substitutes for first-rate national agricultural research enterprises. FAO and UNDP (1983) argue in a similar way:

> "The justification for national agricultural research is based on two main arguments: (i) farming problems are highly location-specific and improved technology can only be geared to tackle these through adaptive research conducted on the spot; (ii) it is essential to create a cadre of local research scientists whose experience and perception of local farm problems make them better qualified to assess the relevance and adaptability of new technology to prevailing farming conditions; this function cannot be delegated to outside scientists or to the CGIAR. In fact, with the establishments of the IARCS, it soon became evident that the transfer of technology from the international centres to the developing countries could only be achieved through strong national research systems. This led to the 'outreach programmes' by the IARCS".

In case of a substitutional relationship between national and international agricultural research priority choice in international research is dependent on national research systems, too. Substitution exists if both international and national research address the same research areas. Such a situation is illustrated on the right-handside of Figure I. Line aa' represents national research possibilities. Adding international research possibilities to this line results in the global research possibilities line bb'. Based on this line and the social preference structure the optimal point P can be identified. This point demonstrates an 'integrated' priority choice from a global point of view. It can be realized, of course, by different allocations for international and national agricultural research. If, e.g., national research chooses an allocation according to point N international research should concentrate on research for commodity B. The opposite is true if national research allocation is characterized by point N'. International research, then, should give resources to commodity A. Several more allocations, of course, are possible and result in different priority choices for international agricultural research.

In summary the crucial importance of national research activities for priority choice in international agricultural research has to be emphasized. In the following section some empirical information about national agricultural research in developing countries is given. This information may help to judge the implications of national research allocation to priority setting for international research.

3. Level of Research Allocation

Agricultural research is a complex process. It is not self-evident that its level can be adequately characterized by a few simple indicators. It is common to concentrate on public sector research and to use expenditures and manpower as quantitative variables. A research structure may then be characterized by these two variables and their relationship. Furthermore, a distinction between agricultural research as such and extension is useful.

Annex Table I.3.a gives indicators of national research structure in developing country groups and for the developded countries as a whole in 1980. It is based on a study by Judd et al. (1983). Research and extension expenditures in all developing countries are considerably lower than in developed countries. There is also less manpower devoted to research; on the other hand, extension manpower is much higher in developing countries than in developed countries. Variation among country groups is considerable and makes it difficult to draw general conclusions. The figures suggest, that an essential part of research activities in developing countries is concentrated in a few countries. In Africa, West Africa stands out which is dominated by Nigeria. Similarly, Brazil is responsible for the high figure of the Tropical South in Latin America. The high concentration of national agricultural research expenditures in developing countries is confirmed by the IFPRI/ISNAR study of 1981. According to this study 50 % of the total sum was spent in five developing countries - Argentina, Brazil, India, Nigeria, and Mexico.

Table I.3.a: Expenditures and manpower of public sector agricultural research and extension by developing country group [a], 1980, in percent of all developing countries

	Expenditures [b]		Manpower [c]		Research / Extension		Expenditures / Manpower	
	Research	Extension	Research	Extension	Expenditures	Manpower	Research	Extension
Africa								
North	3.1	14.7	4.8	9.6	21.2	50.0	64.0	154.0
West	10.3	17.4	5.3	12.6	58.8	40.0	196.0	138.0
East	3.8	9.0	3.4	10.3	41.8	35.0	111.9	88.0
South	4.1	2.6	3.6	1.6	156.5	230.0	114.5	166.0
Latin America								
Central	5.6	4.9	4.6	2.4	114.7	195.0	122.1	206.0
Tropical South	13.5	25.0	10.1	0.7	53.5	150.0	133.6	368.0
Temperate South	4.0	3.8	3.2	0.6	106.5	575.0	127.3	684.0
Asia								
West	6.3	10.0	4.8	7.0	61.8	70.0	130.0	146.0
South	9.5	6.9	12.0	3.5	136.5	35.0	79.8	20.0
Southeast	5.2	5.4	8.6	14.5	94.7	60.0	60.0	38.0
East [d]	2.5	-	3.4	-	-	-	75.0	-
China	32.2	-	36.3	-	-	-	88.6	-
All developing countries [e]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Developed countries	269.3	192.4	210.9	49.2	140.0	435.0	127.9	394.0

a) According to a study by Judd, Boyce, and Evenson
b) Based on const. 1980 US $
c) Based on scientist man-years
d) Excluding Japan
e) The absolute figures for all developing countries are: Expenditures, in million US $, research (2 000.9), extension (1 177.5); scientist man-years, in 1 000 units, research (47.6), extension (234.2)
f) Including East Asia.

Source: Judd, M. A., J. K. Boyce and R. E. Evenson, Investing in agricultural supply, Center discussion paper, no. 442, Economic Growth Center, Yale University, New Haven 1983

Considering the relationship between research and extension, the developing countries as a whole devote relatively more resources to extension than developed countries. This is especially true as measured by manpower. The figures, however, vary greatly between developing country groups. Research expenditures and manpower are very low in North, West, and East Africa, and in West Asia.

Interpretation is limited, of course, by the fact that different populations are involved. A country group with a larger population will, ceteris paribus, have a greater share in overall resource allocation for extension as well as research.

Annex Table I.3.a also shows ratios between expenditures and manpower and between research and extension. There is great variation among country groups. It appears impossible to draw any generalizable conclusion for the country groups considered. The figures suggest, however, some general remarks for the developing countries as a whole. In general, expenditures per scientist are higher in developed countries than in developing countries. The difference is much higher for extension than for research. As a consequence manpower-intensity of research is higher in developing countries than in developed countries. This relationship, however, is reversed in extension.

In Annex Table I.3.b expenditures and manpower of public sector agricultural research are shown for developing country income classes. In addition, these figures are related to agricultural GDP, population, and crop area, to better judge the magnitudes involved. One obvious relationship is that, as the income level of developing countries rises more money is spent on agricultural research per agricultural GDP. The same is true for expenditures per caput and expenditures per area. Poor countries spend .36% of the agricultural GDP on research which is equivalent to US $ 185 per 1000 inhabitants or US $ 0.80 per 1000 ha of crop area. The respective figures for high income countries are 1.07%, US $ 1384 and US $ 3.10. A somewhat simplistic interpretation is that the poorer the country the less it is able to spend on agricultural research. At the same time, of course, its need for agricultural research may be all the greater. This is a well-known fact and the basic starting-point for support of national agricultural research systems in developing countries. Overall, the level of research expenditures in these countries is now slightly above the target of .5% of agricultural GDP as proposed by the UN World Food Conference in 1974 and in a few countries these expenditures have attained the level of one percent of agricultural GDP, e.g. Argentina, Brazil, Kenya, and Nigeria. (FAO/UNDP, 1983).

Considering scientific manpower allocation by developing country income group, on the other hand, the result is not definite. A clear relationship holds for the number of scientists per caput. It is 14 for the low income, 24 for the high income group. The ratio of scientists to crop area, however, does not move in the same direction. One is left with an ambiguity. Differences in population groups might explain the statistical differences as well as different research policies. Finally, the causal relationships are open for different interpretations. One would like to think that higher research efforts result in higher economic growth rates. But the figures may mean nothing more than that richer countries can afford to spend money on research irrespective of research results.

In summary, the data in Tables I.3.a and I.3.b do provide some insights into national agricultural research in developing countries. These countries generally stress extension as compared to research as such. This is especially true for low income countries. Appropriate national research activities, however, are necessary to adopt and transform technologies which have been produced on the international level (Schultz, 1980; Pinstrup-Andersen, 1982; Ruttan, 1983). Hence, performance of national agricultural research may be a severe constraint to success in international agricultural research. The complementarity issue, therefore, has to be carefully considered for different research areas. Again, it is of little help to take a global view. National research possibilities vary greatly among developing countries. This has to be taken into account when determining priorities in international agricultural research.

4. Trends 1970-80

Performance of national agricultural research may change over time. Priority choice on the international level cannot neglect such changes but has to reflect them.

Annex Table I.4 shows trends for expenditures and manpower of public sector agricultural research and extension by developing country group. The figures refer to the period 1970-80 and are based on Judd et al (1983). Between 1970 and 1980 the developing countries as a group have increased their expenditures and their manpower allocations for research at rates of about 5.5% p.a., substantially above the rate in developed countries (over 2%). Extension has expanded at much lower rates, closer to 2% p.a. and closer to the rates in developed countries. Particularly high growth rates for research are shown for West Africa. Central America and South and Southeast Asia. Extension has experienced higher growth rates in Latin America than in any other region but it has also started from a particularly low level.

Table I.3.b: Expenditures and manpower of public sector agricultural research by developing country income group [a], 1980

	Number of countries	Expenditures [b]				Manpower [c]		
		million US $	per agricultural GDP, percent	per 1 000 inhabitants, US $	per 1 000 ha crop area, US $	1 000 number	per million inhabitants, number	per 1 000 ha crop area, number
Low income countries	13	184.70	0.36	185.20	0.80	13.50	13.60	0.06
South Asia	5	139.70	0.32	156.20	0.70	12.30	13.70	0.06
Sub-Sahara Africa	8	45.00	0.58	438.50	1.50	1.20	12.00	0.04
Middle income countries	27	271.60	0.46	542.4	2.40	9.60	19.30	0.08
Southeast Asia	9	105.00	0.35	343.60	2.10	6.00	19.50	0.12
North Africa/Middle East	2	4.00	0.26	339.00	0.60	0.20	17.50	0.03
Sub-Sahara Africa	4	104.90	0.67	1 111.30	3.30	1.70	18.50	0.05
Latin America	12	57.70	0.50	648.90	2.40	1.70	19.50	0.07
High income countries	11	357.20	1.07	1 384.10	3.10	6.20	24.10	0.05
Southeast Asia	1	1.50	0.88	2 178.20	-	-	50.10	-
North Africa/Middle East	1	1.60	1.12	2 419.40	3.60	0.10	84.50	0.13
Latin America	9	354.10	1.07	1 378.80	3.10	6.10	23.90	0.05
Total of 51 countries	51	813.50	0.56	463.30	1.80	29.40	16.70	0.06

a) According to a study by IFPRI and ISNAR. The data comprise 51 selected developing countries

b) Based on constant 1975 US $

c) Number of research scientists

Source: IFPRI/ISNAR, Resource Allocations to National Agricultural Research: Trends in the 1970s, prepared by P.H. Oram and V. Buidlish, Washington and The Hague 1981

Table I.4.: Trends for expenditures and manpower of public sector agricultural research and extension by developing country group [a], annual rate of change 1970 - 80, in percent

	Expenditures [b]		Manpower [c]		Research / Extension		Expenditures / Manpower	
	Research	Extension	Research	Extension	Expenditure	Manpower	Research	Extension
Africa								
North	2.20	- 0.20	7.60	4.30	2.50	3.60	- 5.10	- 4.30
West	8.40	1.20	9.60	3.00	7.00	4.80	- 1.10	- 1.70
East	4.30	2.10	8.60	2.60	2.20	5.80	- 3.90	- 0.40
South	3.00	- 1.90	4.40	1.50	5.20	3.10	- 1.40	- 3.30
Latin America								
Central	14.20	8.80	6.40	10.30	5.00	- 3.70	7.50	- 1.40
Tropical South	7.60	8.00	5.90	7.70	- 0.30	- 1.80	1.60	- 0.20
Temperate South	3.50	0.04	4.10	1.70	3.40	2.40	- 0.60	- 1.60
Asia								
West	5.90	2.10	3.70	- 1.30	3.70	4.50	2.10	3.50
South	10.20	- 0.60	8.20	0.90	10.80	5.80	1.80	- 1.80
Southeast	10.70	1.50	9.20	1.10	9.00	7.20	1.40	0.50
East [d]	7.60	-	3.80	-	-	-	3.60	-
China	2.50	-	3.50	-	-	-	- 0.90	-
All developing countries	5.50	2.40	5.40	2.00	2.70	2.90	0.00	0.40
Developed countries	2.60	2.40 [e]	2.20	1.30 [e]	- 0.10	1.00	0.20	1.10
World, total	3.30	2.40	3.10	1.70	0.70	1.30	0.10	0.70

a) According to a study by Judd, Boyce, and Evenson
b) Based on const. 1980 US $
c) Based on scientist man-years
d) Excluding Japan
e) Including East Asia

Source: Judd, M. A., J. K. Boyce and R. E. Evenson, Investing in agricultural supply, Center discussion paper, no. 442, Economic Growth Center, Yale University, New Haven 1983

As a consequence the relationship between research allocation and extension allocation has slightly changed. Research has been promoted more than extension, both in terms of expenditures and of manpower. Hence, developing countries have changed their research structure towards the structure in developed countries. Again, however, the variation among individual developing countries must be emphasized. The degree to which generalizations can be made over all countries and regions is limited.

Overall, the trends may be taken to indicate that developing countries' agricultural research and extension structure is approaching that of developed countries. Two conflicting conclusions could be drawn. On one hand the growing importance of national agricultural research in developing countries may facilitate the adaptation and transformation of technologies in these countries (Pinstrup-Andersen, 1982). This may enhance success of international research activities. On the other hand, national agricultural research might increasingly become competitive with international research. Substitutional relationships between national and international agricultural research would become stronger. On this general level it is not possible to determine which trend might prevail. While growing resource allocation to national agricultural research in developing countries is encouraging the view should not be too optimistic. Most developing countries still lack an adequate system for planning allocating, and monitoring research resources which results in a misallocation of resources (Daniels and Nestel, 1981). FAO and UNDP (1983) summarize the major constraints and problems for national agricultural research in developing countries. Because of their relevance for priority choice in international agricultural research they deserve to be cited here:

(i) Despite its high economic and social benefits, developing countries still do not devote enough funds to research. This attitude is motivated by the general impression that agricultural research is both a complex and long-term process and its benefits are not as visible as those resulting from other forms of agricultural investment, e.g. irrigation or expenditures on extension.

(ii) The advantages of agricultural research are still not fully grasped by the farming community and perhaps least valued by the general public. The problem is exacerbated by the lack of dialogue between research scientists and policy-makers. All these factors are reflected in the low priority given to agricultural research by planners and policy-makers.

(iii) The planning of research programmes remains weak. The major problems are the lack of balance between short and long-term needs, unclear objectives which fail to provide guidance for resource allocation and lack of commitment to solve the problem of poor farmers. In most developing countries, research continues to be viewed as a scientific discipline operating separately from other closely related disciplines. Its focus is mainly on commodity research; farming systems research is still in its early phases, although some of the IARCs are encouraging the developing countries along these lines. A major difficulty of organizing farming system research is that it is a multidisciplinary effort and requires full cooperation between researchers, extensionists and farmers. Another problem is the lack of involvement of research scientists from universities and colleges in the planning of national agricultural research.

(iv) Research programmes continue to suffer from shortage of funds and their timely provision and from lack of identifying the real beneficiaries. Socio-economic research is invariably lagging behind technical and biological research. Often no systematic effort is made to gain a clear picture of the financial benefits emanating from research which accrue to producers and consumers and among the latter to land owners and landless workers.
Another weakness in programming is the lack of harmonization of research priorities with given resource endowments and the establishment of research priorities so that the best use can be made of available funds.

(v) There is a strong tendency to produce improved technology suited for the areas most favoured by climate and geography. The development of technology for marginal areas, where complex environmental, technical and socio-economic factors are at play, is still not receiving adequate attention.

(vi) The possibility of transfer of research results from one developing country to another is not fully exploited. This is caused by the slow progress in promoting networks among national agricultural research institutions in different regions. Similarly, the services provided by the CGIAR system are not fully utilized in the transfer of technology from country to country.

(vii) Not much attention is being given to the indirect consequences of agricultural research such as the effects on the environment or on other crops resulting from the introduction of a new technology for a single crop.

(viii) In most cases research institutions are not structured to facilitate smooth flows of information. Lack of communication among research institutions prevents the cross-fertilization of ideas and experience, encourages duplication of effort and makes it difficult to fill the gaps in the research system. On the whole, there appears to be a need for restructuring agricultural research organisations.

(ix) The absence of a professional research environment (intellectual stimulation, recognition of success and group interaction) is a constraint, expecially lack of contact with agricultural research scientists in other countries, particularly those with similar climatic conditions.

(x) Trained and experienced manpower is in short supply, especially in the LDCs. In fact, most developing countries do not have a coherent plan for training in research. The creation of additional research stations in response to political pressures has further diluted manpower resources in many countries. Most critical is the shortage of skilled research managers, a function which cannot be handled by scientists or political appointees. It requires qualified personnel who, because of private sector competition, demand higher salaries. Although the training facilities provided by the IARCs are being relatively well utilized the same cannot be said of the facilities offered by the international associations. The retention of manpower in research constitures a major difficulty. The major factors responsable are inadequate career structures, low salaries and poor conditions of work.

(xi) Liaison between research (generation of knowledge) and extension (dissemination of tested technology) is very poor. Instead of interaction, there may be even antagonism, expecially if each discipline is attached to a separate ministry. This situation has prevented dialogue between researchers and farmers and has weakened the diffusion process by which research results are adopted.

5. Allocation by Research Area

A research area can be defined by purpose, commodity or resource involved, and by the scientific field. Available data only allow to differentiate according to commodity and commodity group. Even for that differentiation data base and methodology are by no means straightforward. The following empirical information refers to recent studies in this field.
Judd et al. (1983) determine relative allocations by the proportion of publications. Such a procedure, obviously, is rather arbitrary, but the lack of alternatives has to be recognized. Annex Table I.5.a gives the resulting expenditures on specific commodities as percentages of total research expenditures. Since a considerable part of the publications could not be allocated to a particular commodity, interpretation has to be cautious.

The most important commodity group surprisingly enough are livestock. Livestock research absorbs 36 % of all research efforts or twice as much as cereal research. At 30 % non-food crops are the second most important commodity group.

Of individual commodities cattle rank first but this really is more a commodity group (meat, milk, draught). Wheat and rice come next in importance. Of the different regions West Africa, Tropical South America, and South Asia have similar shares and together account for over two thirds of total research efforts. This reflects the importance of the national research systems in the large countries Nigeria, Brazil, and India. Livestock research is relatively important in Africa, Latin America, and West Asia, while in South, Southeast and East Asia cereal research is in first place. This corresponds with the relative importance of livestock production in these regions.

Table I.5.a: Research expenditures in developing countries by commodity [a], 1976, in percent of total research expenditures in all developing countries

	Africa			Latin America			Asia				All developing countries
	North	West	East	Central	Tropical South	Temperate South	West	South	South East	East	
Wheat	0.53	0.32	0.06	0.23	1.08	1.06	0.32	3.54	0.07	0.20	7.40
Rice	0.08	0.84	0.04	0.06	0.84	0.03	0.01	2.65	2.57	1.24	8.36
Maize	0.08	0.63	0.07	0.05	0.59	0.14	0.03	0.43	0.18	0.05	2.25
Cassava	-	0.31	0.02	-	0.25	-	-	0.02	0.10	-	0.70
Potatoes	0.04	-	-	0.01	0.32	0.11	0.04	0.29	0.06	0.05	0.92
Sweet potatoes	0.01	0.31	-	-	-	0.01	-	0.03	0.01	0.04	0.42
Sugar	0.09	0.23	0.05	0.11	0.76	0.26	0.04	0.47	0.17	0.13	2.32
Beans	0.13	0.16	0.04	0.04	0.77	0.06	0.03	0.12	0.09	0.01	1.44
Vegetables	0.18	0.86	0.03	0.02	0.47	0.08	0.14	0.61	0.26	0.10	2.75
Bananas	0.02	0.15	0.01	0.01	0.17	0.01	-	0.06	0.04	0.01	0.48
Citrus fruit	0.14	0.07	-	0.01	0.31	0.18	0.17	0.22	0.04	0.07	1.21
Soybeans	0.08	0.49	0.08	0.02	1.65	0.20	0.02	0.36	0.45	0.26	3.62
Groundnuts	0.06	0.35	0.02	0.01	0.18	0.03	0.01	0.20	0.14	0.01	1.00
Coconuts	-	0.01	0.01	-	0.06	-	-	0.14	0.34	-	0.55
Cocoa	-	0.84	-	0.01	0.29	-	-	0.02	0.27	-	1.43
Coffee	-	0.49	0.80	0.02	2.33	0.01	0.01	0.24	0.35	-	4.26
Cotton	0.17	0.16	0.05	0.01	0.29	0.02	0.04	0.47	0.07	-	1.29
Other crops	1.18	4.85	0.88	0.34	5.35	2.35	0.78	4.48	2.89	0.96	24.05
Cattle	0.65	8.84	0.98	0.80	3.89	1.28	0.36	1.70	1.03	0.46	19.99
Pigs	0.03	0.72	0.04	0.13	0.82	0.40	0.04	0.32	0.43	0.43	3.36
Poultry	0.20	1.10	0.13	0.11	0.55	0.11	0.10	0.56	0.41	0.21	3.48
Other livestock	0.67	2.58	0.37	0.27	1.50	0.94	0.60	1.12	0.52	0.12	8.70
Cereals [b]	0.69	1.79	0.17	0.35	2.51	1.23	0.35	6.62	2.82	1.49	18.01
Other food crops [c]	1.93	8.63	1.14	0.58	10.58	3.30	1.24	1.03	4.83	1.64	40.91
Non-food crops [d]	0.17	0.65	0.85	0.03	2.62	0.02	0.05	0.72	0.42	0.01	5.55
Livestock [e]	1.56	13.24	1.51	1.31	6.76	2.73	1.10	3.70	2.39	1.23	35.53
Total [f]	4.34	24.31	3.68	2.27	22.47	7.28	2.75	18.08	10.47	4.36	100.00

a) According to a study by Judd, Boyce and Evenson. The study comprises data for 26 large developing countries. These countries account for more than 90 percent of the research undertaken in developing and semi-industrialized countries, excluding China. The calculations are based on 1980 US $

b) Wheat, rice and maize

c) Cassava to cocoa

d) Coffee, cotton, other crops

e) Cattle to other livestock

f) Total expenditure in all developing countries is 898 million US $

Source: Judd, M. A., J. K. Boyce and R. E. Evenson, Investing in agricultural supply, Center discussion paper, no. 442, Economic Growth Center, Yale University, New Haven 1983

Judd, Boyce, and Evenson restricted their analysis to the allocation of research expenditures. In another study ISNAR and IFPRI presented some figures about commodity-oriented manpower allocation in national agricultural research of developing countries. The figures do not permit a global view for a specific time, but inform about selected developing countries. Annex Table I.5.b summarizes the results.

According to that approach the proportion of scientists working in crops research is very high, above 50 % in all but one country, and on average closer to 75 than to 50 %. Research in animal husbandry would account for about 10 % in Asian countries, and around 25 % in Africa and Latin America. The table also lists forestry and fisheries as important research areas in some countries and regions.

Altogether the figures by Judd et al. and by ISNAR/IFPRI are not so different as it may appear at first sight. It is more the grouping that is different. If one groups all the non-livestock research as crop research it accounts for 65 % confirming the figures by ISNAR/IFPRI. Just how reliable these figures are and - more importantly - what they mean is difficult to judge.

In any case the figures provide a global view of commodity-oriented research efforts in developing countries. They will have to be supplemented by specific country studies to gain a detailed view. The comprehensive analysis of national agricultural research in 12 countries by FAO/UNDP (1983) will be very useful in this respect. Summarizing country experiences at an earlier time, Daniels and Nestel (1981) state

> "that crop research was almost always given relatively more resources than its economic importance warranted and fisheries and forestry usually less, with animal reseach varying considerably. There was also, usually, a relatively high allocation of reseach resources for cash and export crops (expecially where research resources were obtained through a producer) cess or export levy. The reasons for such apparent anomalies are often historic".

Table I.5.b: Research scientists in selected developing countries by sector of agriculture [a], in percent of total number of agricultural research scientists

	Year	Crops	Animal husbandery	Forestry	Fisheries	Other sectors
Asia						
Bangladesh	1977/78	79.9	3.2	8.1	1.8	7.0
Indonesia	1974	66.3	11.1	11.7	10.9	-
	1979	54.6	8.0	10.1	9.7	17.6
Malaysia	1980	60.5	13.0	-	1.5	25.1
Nepal	1980	75.9	6.8	14.4	2.7	-
Pakistan	1977/78	81.9	13.7	2.9	1.5	-
Philippines	1974	37.0	10.0	10.0	6.0	37.0
	1978	45.0	7.0	13.0	9.0	26.0
Thailand	1974	69.6	12.2	12.8	5.4	-
	1979	86.5	8.9	0.9	3.7	-
North Africa/Middle East						
Yemen, AR	1977	90.3	-	-	-	9.7
Yemen, PDR	1976	87.1	-	8.1	-	4.8
Sub-Sahara Africa						
Sudan	1977	79.0	13.8	-	-	7.2
Ethiopia	1977	59.0	7.0	-	-	34.0
Kenya	1979/80	57.8	39.8	1.6	0.8	-
Nigeria	1977/78	63.6	16.7	12.1	7.6	-
	1980	57.9	23.3	8.6	10.2	-
Senegal	1975	58.0	23.2	2.9	15.9	-
	1980	56.0	23.0	2.0	19.0	-
Upper Volta	1975	61.7	11.5	-	-	26.8
Togo	1980	59.2	40.8	-	-	-
Latin America						
Barbados	1980	72.2	27.8	-	-	-
Costa Rica	1980	96.0	-	-	-	4.0
Haiti	1980	75.7	18.9	-	-	5.4
Jamaica	1980	76.7	10.0	-	-	13.3
Mexico (Total)	1974	82.5	13.4	4.4 [b]	-	0.3
(INIA only)	1977	91.3	-	-	-	8.7
Nicaragua	1980	75.0	16.7	-	-	8.3
Panama	1980	64.3	-	-	-	35.7
Brazil (EMBRAPA)	1980	73.1	26.9	-	-	-
Colombia (ICA)	1980	53.2	31.2	-	-	15.6
Peru (INIA)	1980	85.2	1.0	7.6	-	6.2
(Universities)	1978	74.7	21.0	4.3	-	-
Uruguay (University)	1980	52.3	17.9 [c]	10.6	-	19.2
Venezuela	1980	72.9	27.1	-	-	-

a) According to a study by IFPRI and ISNAR
b) Including fisheries
c) Refers to pastures

Source: IFPRI/ISNAR, Resource Allocations to National Agricultural Research: Trends in the 1970s, prepared by P.H. Oram and V. Buidlish, Washington and The Hague 1981

Annex II: Country Groupings

Data based on FAO's AT 2000 study use the regions Africa, Latin America, Near East and Far East (or Asia and Far East). In addition country groups are distinguished:

Low income countries: countries with per caput GDP of US $ 300 or lower in 1975;

Least developed countries: multiple-criteria classification by UN;

Country groups according to growth rate of agricultural production: the growth rates are those of gross agricultural production covering all the commodities analysed in the study valued at 1974 - 76 world export unit values; the growth rates have been computed as compound interest rates using the least square method.

The classification of countries according to region and country group are shown in the attached Table "The 90 developing countries of the study and alternative country groupings, by category".

Data based on FAO's agro-ecological zones AEZ project group countries into the following regions: Africa, Southwest Asia, South America, Central America and Southeast Asia. Since these regions correspond with the common geographical concepts and since all countries of anyone region are included a listing by country does not appear warranted except for Southeast Asia. That region is to the east of Afghanistan and comprises of Bangladesh Bhutan, Brunei, Burma, India, Indonesia, Kampuchea DM, Lao, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam.

The 90 developing countries of the study and alternative country groupings, by category

	Low-income countries[1]	Least developed countries[2]	Past growth rate of gross agricultural production[3] 1961-80, % p.a.		
			Low: under 2%	Medium: 2% to under 3%	High: 3% or over
Africa					
1. Algeria			●		
2. Morocco				●	
3. Tunisia					●
4. Benin	●	●		●	
5. Gambia	●	●	●		
6. Ghana			●		
7. Guinea	●	●	●		
8. Ivory Coast					●
9. Liberia					●
10. Mali	●	●	●		
11. Mauritania	●		●		
12. Niger	●	●	●		
13. Nigeria			●		
14. Senegal			●		
15. Sierra Leone	●		●		
16. Togo	●		●		
17. Upper Volta	●	●		●	
18. Angola	●		●		
19. Cameroon	●				●
20. Central African Republic	●	●		●	
21. Chad	●	●	●		
22. Congo			●		
23. Gabon			●		
24. Zaire	●		●		
25. Burundi	●	●		●	
26. Ethiopia	●	●	●		
27. Kenya	●				●
28. Madagascar	●		●		
29. Malawi	●	●			●
30. Mauritius			●		
31. Mozambique	●		●		
32. Zimbabwe				●	
33. Rwanda	●	●			●
34. Somalia	●	●	●		
35. Tanzania	●	●	●		
36. Uganda	●	●	●		
37. Zambia				●	
Latin America					
38. Costa Rica					●
39. El Salvador					●
40. Guatemala					●
41. Honduras				●	
42. Mexico					●
43. Nicaragua					●
44. Panama					●
45. Cuba				●	
46. Dominican Republic					●
47. Haiti	●	●	●		
48. Jamaica			●		
49. Trinidad and Tobago			●		
50. Argentina				●	
51. Bolivia					●
52. Brazil					●
53. Chile			●		
54. Colombia					●
55. Ecuador				●	
56. Guyana			●		
57. Paraguay					●
58. Peru			●		
59. Suriname					●
60. Uruguay			●		
61. Venezuela					●
Near East					
62. Egypt	●			●	
63. Libya					●
64. Sudan	●	●			●
65. Afghanistan	●	●	●		
66. Cyprus				●	
67. Iran					●
68. Iraq				●	
69. Jordan			●		
70. Lebanon			●		
71. Saudi Arabia					●
72. Syria					●
73. Turkey					●
74. Yemen	●	●	●		
75. Democratic Yemen	●	●			●
Asia and Far East					
76. Bangladesh	●	●	●		
77. India	●			●	
78. Nepal	●	●	●		
79. Pakistan	●				●
80. Sri Lanka	●		●		
81. Burma	●			●	
82. Indonesia	●			●	
83. Republic of Korea					●
84. Lao	●	●		●	
85. Malaysia					●
86. Philippines					●
87. Thailand					●
88. Democratic Kampuchea	●		●		
89. Democratic People's Republic of Korea					●
90. Viet Nam	●			●	

Annex III: Map of population supporting capacities in developing countries

Annex III: Map of agroclimatic zones in developing countries

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