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TAC REVIEW OF PRIORITIES FOR THE CGIAR SYSTEM

FIRST DRAFT

TAC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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1. INTRODUCTION

1.1. Priority setting in the CG System

The periodic assessment of priorities is an essential condition for rational decision-making on resource allocation in any organization. For the CGIAR this is particularly relevant. The increasing breadth and depth in the range of the System's activities, the heterogeneity of Centers' mandates and its particular place as one of the components in a global research effort make this essential. Clear ideas about priorities are necessary if the System is to achieve its long-term objectives, to maintain high level of quality and relevance of its programs, to operate in true complementarity with NARS and to maximize both impact and the returns to investment in international agricultural research for the benefit of LDCs.

Its terms of reference require the CGIAR to "undertake a continuing review of priorities and research networks related to the needs of developing countries, to enable the Group to adjust its support policies to changing needs and to achieve economy of effort."

The main institutional mechanism available to CGIAR to assist the Group in its task of priority setting is its Technical Advisory Committee (TAC). This is reflected in TAC's Terms of Reference 1/ which open with the statement that TAC will "advise the Consultative Group on priorities in agricultural research related to the problems of the developing countries, in both the technical and socio-economic fields, based on continuing review of existing national, regional and international research activities."

This implies a continuing role for TAC. TAC has consequently, from its first meeting on, been conscious of the need to maintain a current awareness of the changing global situation concerning agricultural research requirements and research potentials.

During its initial years the Committee's approach to selection of priority areas for CGIAR support was essentially pragmatic with primary attention being given to pipeline proposals available for inclusion in the CG System. At that stage priorities were considered more in terms of gaps to be filled than in terms of competition for limited resources among various fields of research. However, as the System grew and the number of activities funded by the Group increased, a more systematic approach to priority selection was required.

TAC's earlier efforts at priority setting: scope, methodological approach, outcome. So far TAC has prepared and submitted to the CGIAR three systematic reviews and recommendations on priorities for support to international agricultural research, in 1973, 1976 (in conjunction with the First Review of the CG System) and in 1979. All three papers were endorsed by the Group and served as basis for resource allocation in the System. In line with the System's growth, its increasing complexities and growing linkages, TAC's priority review exercises have become increasingly complex.

1/ Second Review of the CGIAR.

Scope and complexity of review exercises were also influenced by the underlying assumptions regarding future funding and System growth. In both the 1973 and 1976 versions of its priorities paper, TAC had made the assumption that there would be a continuing modest expansion of funding in real terms which admitted the inclusion of new proposals as well as further growth of some of the ongoing activities. For the 1979 priorities exercise the basic assumption was somewhat different. The earlier expectation of continued program expansion was gradually replaced by a more restricted outlook regarding future growth in resource availability. Resource limitations constituted a new dimension and had to be considered.

TAC's evolving role in the resource allocation process in the CG System. Originally TAC's role was seen as providing the Group with a broad set of criteria and priorities on which decisions regarding resource allocation could be taken. Over time this role has changed somewhat; it became more specific and more demanding. In line with the System's growth, its increasing complexity and, particularly, with resource limitations more specific advice was required on resource allocation among activities competing for scarce resources. Increasingly such questions had to be answered as:

- what are the relative priorities among ongoing activities;
- how do these relate to priorities for activities not presently included in the CG System;
- which among the ongoing activities should receive additional support - which, if any, can be reduced;
- what new activities should be undertaken; at what levels of funding; to what extent could this be achieved by economies in the present System and the reduction of existing activities;
- how best can shifts among and within commodities be arranged in order to maintain the necessary flexibility of funding for the System, to accommodate new activities without adding to the overall commitment and to avoid the risk of petrification of the existing program structure;
- how should the System evolve.

As regards TAC's role in the resource allocation process today, TAC is involved at two levels; both are closely inter-related.

(a) Overall priority setting for the CG System. TAC is the key adviser to the Group. This is its long-term function and its original role. This implies periodic overall assessment of priorities for international support to agricultural research for development. Such assessments are made against the background of overall research needs, research potentials, the respective comparative advantage of the other components of the global research system (NARS and DCRCs) as well as

assumptions on the likely level of resources. It is broad based and assess priorities among ongoing activities as well as priorities between ongoing activities and activities not presently covered by the CG System.

(b) Annual resource allocation process. In recent years TAC has become increasingly involved in the annual resource allocation process. It conducts an annual review of Centers' P&B documents and makes recommendations to the Group on the relative priority rating and the respective program levels. While such involvement of TAC is necessary, legitimate and in line with its comparative advantage, great care must be taken to avoid its getting involved at the level of management decision-making. Here the linkage between the Committee's two advisory functions at the overall priority level and the level of annual resource allocation is important. To deal satisfactorily with level (b) clear ideas are required regarding the Group's overall priorities and policies.

1.2. Scope of the Study

Origins of present priorities review. At TAC 28 in June 1982, the Committee decided to embark on a broad-based study of "Strategic Considerations regarding the CG System". The objectives of this study were to identify the changes which should be brought gradually into the System to make it more effective and responsive to meeting the present and future demands of the developing world while, at the same time, placing in a broader perspective the problem of adjusting the P&Bs of Centers to the resources made available by the CGIAR. The issue was to define an appropriate path for the development of the System under the given resource constraints, so as to keep it lively and efficient in an evolving environment. This proposal was supported and actively endorsed by both the Centers and the members of the Group.

From its initiation this priority review has been a part of TAC's comprehensive exercise on strategic considerations. When embarking on its broad-based study of Strategic Considerations regarding the evolution of the CG System, TAC decided to address a number of key issues, all of which are inter-related:

- an assessment of priorities for CGIAR support;
- the question of the global and regional mandates of Centers, their operational interpretation and compatibility;
- arrangements for inter-center cooperation;
- the evolving relationships of Centers with national programs and their respective comparative advantages;
- role and place of Farming Systems Research in Centers programs; its comparative merits *vs.* the commodity approach;
- role and place of training in Centers' programs; the adequacy and impact of present efforts.

All of these areas have received the Committee's attention over the last two years. Progress made varies from issue to issue. This is fully in line with TAC's initial perception of pursuing a step-wise approach. While the present study concentrates on the issues of priorities, it addresses - both implicitly and explicitly - a number of the other issues. Further reports on the remaining issues will be issued separately.

Scope of this study. The scope of the present review of priorities differs from earlier efforts in three respects:

(a) The breadth of the approach: it constitutes a comprehensive review of priorities among ongoing activities and activities/commodities not presently included in the System;

(b) Its analytical/methodological approach: it uses a somewhat more formal approach and employs a resource allocation model which is then supplemented by TAC's collective judgement;

(c) The time horizon: it works with a dual time horizon regarding both the short and the longer-term. It introduces the long-term perspective regarding the evolution of the CG System and uses this as a framework for rational decision making regarding short-term priorities.

Process and participants involved. In view of its complexity and the many inter-related issues involved, this study was conducted as a step-wise process. It was carried out in close interaction with all elements/institutions in the global agricultural research system directly concerned:

(a) The Centers: both Center Directors and Board Chairpersons participated actively in the various stages of formulation and conduct of the review. Centers provided many of the key inputs such as resource allocation data, their programs, and the long-term plans for the evolution of Centers and their programs.

(b) The clients. NARS leaders participated in the process of consultation in both formal and informal ways. They provided important insights into future research needs, the evolving capacities of national systems and future demands of the CG System.

(c) The CGIAR donor community. Donors provided the much needed feedback to periodic progress reports on the study and thus helped to ensure the relevance of the final product.

(d) Resource persons. A small group of leading scientists and research managers, comprising members of TAC, Center Directors, Board Chairpersons, leaders of NARS and technical cooperation agencies and the CGIAR Secretariat, all attending in their personal capacities, assisted TAC through their participation in a two and a half day brainstorming session on the long-term evolution of the System.

Inputs into study. In addition to the contributions made by those mentioned above, important inputs were provided by:

- FAO: A paper on "Quantitative Indicators for Priorities in International Agricultural Research";

- Dr. M. Pineiro: A discussion paper "An Analysis of Research Priorities in the CGIAR System";

- individual TAC Members and others who contributed a number of discussion papers on various aspects of the exercise (see Bibliography).

Outcome of the present effort: The 1985 TAC Review of Priorities. The outcome of this exercise conducted in response to the needs of the Group is:

- a comprehensive assessment of research priorities for CG System support in both short and long-term, based on a systematic review of evolving research needs and potentials in the context of the global agricultural research system. Obviously, the analysis includes ongoing activities and research areas not presently covered by the CG System;

- a set of guiding principles for the future evolution of the CG System, its priorities, programs and institutional arrangements. These aim at maintaining the high levels of vigor, relevance and impact of CGIAR activities and programs;

- a set of recommendations for priorities and priority shifts including those that are required now to set in motion a gradual process of change leading to the attainment of the System's long-term objectives and evolving priorities.

Rationale and structure of the paper

Background to TAC priority review (Chapter 2). One of the basic assumptions underlying this paper - in particular those parts dealing with the review of priorities for short and medium term - concerns the "nature" of the CG System. This is defined by its objectives, its place in the global system of agricultural research efforts,its institutional/organizational characteristics and its resource endowment. It has implications for the scope of the System's activities. The assumption is that the CG System constitutes one of the components of an emerging global agricultural research system and that in view of its nature and the resources at its disposal it can perform effectively only if it concentrates on a limited number of research problems for which it has a comparative advantage.

This assumption has important methodological consequences for the review of priorities. By restricting the number of issues that need in-depth consideration, it allows a concentration of effort on the

analysis of those areas/problems which are compatible with the concept of the System and its comparative advantage and hence qualify for consideration among the System's priorities.

Chapter 2 presents the background to this priority review. It establishes the framework for the discussion of priorities and defines a set of guidelines that delimit the scope of this discussion. In doing this it describes the main characteristics of the System its place in the global setting and some of the guiding principles that have guided its evolution. It briefly discusses institutional arrangements at the Center level, Centers' mandates, programs and the main thrusts of current activities.

Evolution of the CG System - a long-term perspective (Chapter 3) Chapter 3 looks at the System's evolution over time. It considers long-term changes in research needs and research potentials. It attempts to define the most likely scenario regarding the development over time of the other components of the global system and the resulting implications for the long-term evolution of the CG System, its programs, priorities and institutional/organizational arrangements. This analysis of the long-term perspective serves a dual function. It intends to stimulate thought and discussion on the direction of the System's future development; and it helps to set the stage for the consideration of and rational decision-making on short and medium priorities. This latter function is essential in view of the intimate links between short and long-term considerations, particularly in the case of research with its extended time-lags and gestation periods.

The analytical approach to priority setting (Chapter 4). In this review of the System's priorities TAC has approached the issue of priority selection in a systematic way with the assistance of a set of criteria/indicators.

A few quantitative indicators are used in this process as proxi for attaining the System's goals. This quantitative analysis is complemented by a clearly structured discussion of qualitative indicators. This discussion brings into the process the collective scientific judgement of TAC.

Chapter 4 describes this approach and discusses its rationale. It starts out by discussing some of the conceptual issues involved in priority setting, and then continues by defining concepts and procedures used in this review. It finally discusses the choice of appropriate indicators and argues their relevance in the context of this exercise.

Comprehensive review of activities for CG support (Chapter 5). Chapter 5 constitutes the centerpiece of this priority review for the short term. It presents a systematic assessment of priorities, based on a unified discussion of each commodity/activity in which TAC applies in a structured manner all criteria selected for this exercise (both quantitative and qualitative) as well as its collective judgement on scientific grounds. The outcome of this review is a set of recommendations regarding relative levels of future CGIAR support to specific commodities and activities.

TAC's recommendations regarding priorities, priority shifts and resource allocation (Chapter 6). Chapter 6, finally, presents TAC's recommendations on priorities, priority shifts and future resource allocation. TAC's recommendations, while aiming essentially at the short and medium term, are made against the background of an evolutionary process and in the longer run imply changes at various levels. Hence the recommendations include those priority shifts that are required now to set in motion the processes which will eventually lead to the attainment of the System's long-term goals.

Recommendations are made at various levels. At the global or System's level they deal with coverage of research areas and the appropriate balance among regions. At the operational or Center level they deal with the priority coverage of activities and programs. At the institutional/organizational level they deal with considerations regarding the evolution of Center's programs, size and structures.

2. THE CG SYSTEM IN WORLD AGRICULTURE

This chapter presents the necessary background to TAC's review of CG priorities. It sets the stage and establishes a framework for the discussion of priorities. It helps to delimit the scope of discussion to those areas and issues that are relevant to the System. In doing this it describes the main characteristics of the CG System, its conceptual basis, its place in the global setting and the evolution it has taken so far.

The discussion is presented at two levels, the conceptual and the operational level. It starts out by analysing the conceptual basis of the CG System (sub-chapter 2.3). It discusses the main characteristics of the System as well as a set of guiding principles that are commonly accepted as important in guiding the System's evolution and choice of priorities. It thus attempts to establish a common framework for the discussion of the System's future priorities.

Sub-chapter 2.4 focusses on the operational level of the CG System. It briefly discusses structure and implementation of IARC mandates and then presents an overview of present thrusts of the System's programs.

2.1. Research and agricultural development

As regards the place of research in the framework of agricultural development, it has long been accepted that research - or more precisely the products it generates: technology - is only one of the factors that contribute to agricultural development.

The evolving role of research and technology in facilitating future progress in agriculture. The world is approaching during the closing decades of the 20th century the end of one of the most remarkable transitions in the history of agriculture. Prior to the beginning of this century most increases in agricultural production occurred as a result of increases in the area cultivated. By the end of this century there will be no significant areas where agricultural production can be expanded simply by adding more land to production. Expansion of output will have to be obtained almost entirely from intensified cultivation. Increases in food and fiber production will depend in large measure on continuous advances in agricultural technology. It is imperative therefore to have in place as soon as possible an appropriate and effective research capacity for each (food) commodity of major economic significance for each major agro-ecological region of the world.

An effective response to this challenge is the emerging global agricultural research system with the CG System as one of its key components.

The following paragraphs briefly review the recent history of international support to agricultural development and describe the origins and evolution of the CG System.

2.2. Origins and evolution of the CG System

History of international support to agricultural development of the newly independent nations of the developing world. In the period following World War II a considerable flow of resources started moving towards the developing world. Efforts were directed at the transformation and modernization of agriculture following the experience of the more advanced countries.

The main objectives were to transfer and adapt the technology that had brought about the enormous productivity increases in the industrialized countries and - initially, to a lesser extent - to develop indigenous institutions capable of sustaining in the long run the research needs of these countries.

From the institutional point of view these efforts were characterized by a multiplicity of approaches. In the initial phase the key institutional response to the concern for development was the creation of a set of global technical and development agencies, in particular FAO and UNDP. Their extensive actions - innovative at that time - were complemented by important programs of bilateral assistance agencies, the foundations and other private organizations.

Their activities were directed at both the transfer and adoption of technologies that had been successful elsewhere and institution building. The outcome were numerous success stories and some failures.

From a thematic point of view these activities represented a widely heterogenous array of programs covering a broad number of crops, regions, types of research and complementary activities such as training, and technology transfer. They had been conceived in response to specific needs at the country level and hence were not guided by any global effort directed at the design of an overall scheme of priorities.

Origins of the CG System. Somewhat later - in the late 1950s and early 1960s - the focus changed and a systematic effort was started at the global level by several multilateral and bilateral assistance agencies and national governments, to build the research capacity needed to sustain agricultural development in the developing world. This development had been sparked off by the convergence of three factors: (a) concern about meeting world food needs, (b) experience in advancing technology in food grain production in the tropics, and (c) a more adequate analysis of the role of agriculture and of advances in agricultural technology in the development process 1/.

This development and the new system of international agricultural research institutes that eventually emerged from it constitutes one of the more remarkable advancements in international development assistance.

1/ V.W. Ruttan.

Creation of the original IARCs. The creation of the original Centers in the early sixties in itself represents a notable institutional innovation in international agricultural research. It responded to a number of previous experiences in international research, mainly the great tropical research institutes developed by some of the colonial powers and the more recent experiences of the Rockefeller Foundation wheat program in Mexico and the Ford Foundation rice program in the Philippines.

A number of perceptions and ideas were behind the creation of these first two Centers: IRRI and CIMMYT. First there was the diagnosis that food supply conditions in the developing world were deteriorating and that national reearch institutions would be unable to cope with pressing research problems at least for some years to come. Secondly, there was a conviction about the effectiveness of multidisciplinary programs organized around important agricultural commodities where resources and carefully selected manpower could be concentrated in the generation of technology adapted to tropical conditions. Finally, there was an implicit belief that much of the wealth of basic research that had been accumulated in the developed countries through years of research in these two crops could be effectively utilized in the development of biologically led technology that would be applicable to tropical conditions.

Two other Centers were created a few years later responding to a different set of ideas. In the words of one of the founders: "This Center (CIAT) and a sister institution, IITA, were conceived in the mid-sixties. Those of us who were involved saw these initiatives as experiments to test a different type of international center. Each of these institutions would deal with several commodites not focussed exclusively on one or two. Systems would be stressed. No tested blueprint for international centers of this type existed but if the underlying concepts were reasonably correct, the payoff would be great."

Establishment and evolution of CG System. Following the creation of CIAT and IITA a number of other Centers were either created or incorporated into the evolving CG system. A number of them (ICRISAT, ILCA and ICARDA), following the philosophy that guided the creation of CIAT and IITA, others following new perspectives and perceived needs for international agricultural research or its application (IFPRI, ILRAD, IBPGR, ISNAR). CIP followed the narrow commodity focus approach of the original two Centers. WARDA is a regional organization concerned with rice development and was admitted to the CG System with a view to facilitating the testing and adaptation in West Africa of IRRI generated rice technology.

The creation of a number of Centers following a different research philosophy and their amalgamation into an evolving system responded to a range of interests and perceptions. Among the most important were the attraction of the Center concept following the success of the original Centers, the philosophy of gap filling and supplementing efforts at the national level as well as payoff expectations.

The outcome of this development is the evolution of an increasingly complex system with a broad range of institutions responding to different demands. They represent a range of institutional objectives and consequently a heterogeneity of mandates. Yet, there is unity of purpose and basic philosophy. They all deal with global problems concerning food production in developing countries that can be effectively addressed through concentrated research effort supported internationally.

2.3. Main characteristics and guiding principles

This sub-chapter reviews the main characteristics of the CG System and a set of guiding principles that have guided its evolution. They describe the System's strengths and its comparative advantage relative to the other components of the global system of agricultural efforts, i.e. NARS and DCRCs. They constitute a conceptual basis for the System and the range of activities it has adopted. Similarly, they provide the background for thinking about the System's future evolution and serve as framework for rational decision making on such issues as type and scope of activities and priority selection.

It should be noted that this conceptual basis is the outcome of an evolutionary process involving wide ranging discussions. It represents a growing consensus within the System and is supported by TAC.

(i) Objectives of the CG System

The definition of the objectives of the System and the Centers that form part of it has evolved over time and gained in clarity and specifity. Clearly there has been a convergence of originally different ideas and perceptions. TAC has adopted the following as a working definition for the purpose of this paper. Through research and research related activities the CG System shall contribute to:

- increasing the amount, quality and stability of food supplies in the LDCs and meeting the total world food needs;

- meeting the nutritional requirements of the less advantaged groups in LDCs;

- an overall improvement in the welfare of the less advantaged sectors of society in LDCs through the design of technologies that will improve the efficiency in the utilization of resources at their disposal.

This definition of the System's overall objectives is in line with the broad range of its activities and represents a balance between efficiency and equity considerations.

(ii) Its place in the global system of agricultural research efforts

The concept of gap-filling was an essential part already of the Hill-Harrar philosophy which guided the establishment of the initial Centers. It was understood that the Centers would fill (on a temporary basis) those gaps in research and technology generation that could not be filled by NARS. This concept assigned to the Centers a specific role and implied close collaboration with both NARS and DCRCs. Centers would work in close complementarity with these other components of the global system. The division of labour among these elements would be organized in accordance with the specific comparative advantage of each of them.

Development elsewhere in the global system, in particular increasing research capacities in NARS obviously have their bearing on relative comparative advantages and the future division of labour.

In discussing the CG System's role and place in this global system it is important to consider the respective scales of effort. It should be noted here that the CG System's share in total global public sector spending in agricultural research in 1980 represented a modest 1.6%. Related to LDC efforts its share was in the vicinity of 5%.

(iii) Its time frame

The issue concerning the System's life-span is closely related to the question concerning its place in the global system. The original perception was that the Centers would generate urgently needed technology but after some time national programs would grow sufficiently strong to take over that function and allow the phasing out of the IARCs.

This view of the CG System as an instrument designed to substitute weak NARS on a temporary basis has gradually been replaced by the concept of an indefinite time horizon. The consensus is that IARCs will continue to be needed to complement and support NARS in those areas for which they have a comparative advantage. At a meeting in Bellagio in 1977 already NARS leaders endorsed this concept of (more) permanence and suggested as priority areas for the long run the following activities:

- collection, conservation, cataloguing and distribution of germplasm;
- organization of path-breaking research designed to raise the ceiling of yield and to impart greater stability to yield (i.e. research which can lead to the development of high-yield and high-stability varieties with desired quality);
- development of improved research techniques;
- organization of relevant training programs;
- organization of information and bibliographic services; and
- organization of symposia, seminars and monitoring tours.

The fact that the CG System is now viewed as a permanent component of the global system does not imply obviously, permanence for all the System's elements - the Centers and their programs - in their present form. Changes will occur in program structure and emphasis and this requires continuing reassessment of research needs and potentials in the light of evolving situations.

(iv) Its international dimension

The IARCs are truly international in several respects: staffing, governance, program design, program execution and funding. This has several positive effects on program development, such as absence of politicization, independence of bureaucratic structures, continuity in funding and other support, relative stability in operations, continued access to information germplasm and other resources as well as international mobility of staff and materials.

This international dimension in Centers' structure, governance and programs constitutes one of the key elements of their comparative advantage. This holds true for both the global centers and the regional centers with an agro-ecological zone focus. The only exception in this is WARDA on account of its different structure in governance.

It shold be mentioned here, that according to the earlier vision of the CG System, with its limited time frame, the regional Centers were understood to evolve eventually into more independent regional organizations more closely associated with the countries of the region which would assume responsibility for their financial support and governance. While user orientation is undoubtedly an important element for ensuring the relevance of programs, an appropriate balance will have to be struck if Centers' independence and some of their functional advantages are to be maintained.

(v) Its institutional/organizational characteristics

These are important factors in determining the System's comparative advantage for certain types of research and related functions.

Center autonomy. An important characteristic of the System - innovative at the time of its establishment - is that each institute is governed by an independent board and operates as an autonomous institution. This structure, which combines decentralized decision making with respect to scientific programs with centralized oversight regarding funding and overall program direction is considered fundamental in accounting for the productivity of the System. This balance between the Centers' independence and centralized controls is crucial for the System's success and needs to be conserved in the interest of continued effectiveness and cost efficiency.

Development of a more integrated System. Recent trends point to a gradual transformation of the System from a lose confederation of largely autonomous Centers into a more integrated System. Several factors have contributed to this development:

- increased consultation and concertation among the various components of the System: Center boards and management, TAC, CG Secretariat, as well as donors;

- increased inter-center cooperation, particularly at the regional level, linked with a general increase in the complexity of Centers' programs;

- intensified linkages and cooperation with the other components of the global research system (NARS and DCRCs);

- increasing complexities affecting the System, caused inter alia by funding constraints. These tend to increase the tendencies towards centralization.

These developments obviously have implications for the further evolution of the System. TAC welcomes and fully supports the evolution towards a system of integrated objectives and a high degree of concertation and cooperation at various levels (System, Center board and management as well as program levels). It noted that this trend is well underway. TAC is fully conscious, on the other hand, of the need to maintain the appropriate balance between Center autonomy and integration. It emphasizes, therefore, the need to resist excessive tendencies towards central planning and management which might result in bureaucratization and the stifling of innovative forces and ideas at the Center level.

(vi) Its problem orientation

An important feature common to all Centers is their focus on specific problems that appear to require a technological or institutional solution. Their programs concentrate on the removal of key constraints to the development of food production. This problem focus, inherent in the philosophy of the founders of the System, represents an innovative approach for agricultural research institutions. The programs in most Centers are multi-disciplinary and based on team work. Most other research organizations follow different organizational patterns and use the discipline approach.

An implicit feature of this problem focus is a certain flexibility over time in program design and structure. Programs are result oriented and this implies that, as certain problems are solved and constraints removed, programs must shift and therefore require adjustment and reorientation.

(vii) Focus of IARC mandates and programs

Clarity of focus and continuity of effort have been broadly recognized as two of the main conditions for the success of any research effort. Both are inherent in the CG concept. They have been circumscribed as follows:

- concentration on a set of well defined problems of high priority;

- absence of undue influence of national policies that are unrelated to global needs;

- application of the highest standards of professional performance. This is implied in the center-of-excellence concept;

- availability of long-term funding for specific research efforts.

A careful look at real life in the CG System to see how the Centers have fared so far in terms of these two conditions, clarity of focus and continuity of effort, shows a rather diverse picture. To make any meaningful comment on clarity and continuity one needs to look at Centers' programs rather than their formal mandates as stated in their charters. Programs represent the operational interpretation of mandates. And this interpretation in itself tends to take time; relatively little time in the case of clearly formulated mandates in the field of crop improvement, more time in the case of those mandates that aim at the improvement of farming systems and the removal of agro-ecological constraints on a regional basis.

The CG System is a young system, particularly by research standards. Yet, Centers differ in age and their programs even more. This is due to the fact that some programs predated the formal foundation of the System. Hence continuity so far is varied. Similarly the clarity of focus differs among Centers. It is important to note, however, that the situation is evolving steadily.

With regard to mandates one can distinguish three groups of Centers:

- the initial Centers with a narrow commodity improvement mandate on a global scale for one or a small number of crops;

- the subsequent Centers with a regional mandate focussed on a specific agro-ecological zone, including a number of commodities of considerable importance to the region;

- those Centers that deal with the removal of important constraints (biological or institutional) to agricultural production.

In the case of commodity Centers established in accordance with original concept, the conditions for success were given. They had clearly defined mandates for crop improvement at the global level for a small number of important commodities. Their programs were clearly focussed on technology development through the removal of yield constraints. They concentrated first on areas of high impact potential; i.e. genetic improvement for broad application on a global scale. Continuity of effort was ensured inter alia through the availability of a fair amount of relevant research results from effort that predated the establishment of the CG System.

Their success so far has undoubtedly proved the validity of the concept. For the remaining tasks - the upkeep and further advancement of yield potentials as well as the removal of further constraints - a clear focus and continuity will be equally important. Yet, the constraints are different - they are increasingly complex, more agro-ecological and more site specific - and they may require a different approach. Certainly they will require increased attention to regional problems with the resulting effects on the Centers' operational structure and their arrangements for collaboration with NARS.

Continuity may have a slightly different meaning in this context. It will continue to apply to the efforts on a specific set of problems. What may change is the distribution of responsibilities among the actors involved, i.e. IARCs and NARS and the mode of cooperation among them.

In the case of the regional agro-ecological Centers with multi-crop responsibilities the original mandates were less clearly defined. While their crop specific responsibilities were clear and allowed the development of clearly focussed crop improvement programs, the agro-ecological aspects of their mandates were less apt for speedy development of clearly focussed research programs. They were interpreted as requiring far greater emphasis on environmental constraints, on farming systems research, adaptive research and agronomic practice related to site specific problems. The results were more complex research programs with longer gestation periods. Over time, however, there has been a trend towards the evolution in these Centers of more clearly focussed programs oriented towards the components of the respective farming systems (commodities) with a strong regional focus.

With respect to continuity of effort, these Centers clearly benefitted less from research efforts predating their establishment and from research done elsewhere in the global system. The majority of crops in question had not been the object of any major research efforts by either NARS or DCRCs and the more basic aspects of research concerned had not received much attention either. Furthermore, previous attempts based on technologies developed in temperate zones had mostly failed.

On balance, it can be argued that the conditions for early success and impact were less ideal in the case of the regional centers. The actual success stories there are spread more thinly so far. They are mainly found in the crop improvement area although certain programs in integrated resource management have been highly successful despite the short time lapse since their initiation.

Basically, the findings of this discussion on focus of IARC programs seem to validate the concept that clarity of focus and continuity of effort are essential elements for the success of any research program.

(viii) Its scope of activities

When discussing the scope of the System's activities it is important to remember its limitations in size. In 1980 the aggregate core budgets of the CG Institutions ($120 millions) represented 1.6% of

total public sector spending for agricultural research on a global scale ($7.4 billion) 1/. In terms of scientific manpower for agricultural research the CG's share (750 scientists at Ph.D. level in 1983) was well below 1% of the world's total (148,000 in 1980).

Despite its limited size in both absolute and relative terms the CG System has contributed substantially to the advancement of agricultural research and technology generation for the developing countries. It has contributed in several respects: improved technologies including germplasm, advancement of knowledge and research methodologies, institution building of NARS; advancement of NARS's scientific capacities through training of research staff and, to some extent - acting as a catalyst - to the improvement of linkages among NARS and specialized research and training institutions in the developed countries and elsewhere.

The fact that the CG System has been able to contribute and make an impact well beyond its size is due among other things (discussed elsewhere in this chapter) to selectivity and concentration of effort on those activities that are important. It has concentrated on areas that represent the key constraints to sustained progress in food production in the developing world. In dealing with these problems it has used the center of excellence approach and thus attempted to bring to bear on them in a systematic manner the most advanced knowledge and the best expertise available.

By design, therefore, the CG System is an incomplete system. It is incomplete in at least two respects, (a) with regard to its coverage of research areas (commodities and regions) and (b) with regard to its coverage of research functions in the overall process of research and technology generation. This implies, of course, that choices have to be made on a continuing basis to ensure that the System's efforts are concentrated on the important things with reasonable impact expectations.

<u>The System's coverage of research areas (commodities, regions, activities)</u>. In terms of areas covered, the System concentrates on a limited number of globally important food commodities, which in aggregate contribute roughly 90% to people's diets in the developing world. It deals with them in the major agro-ecological regions in the world. The System's work on crop improvement through plant breeding (8 Centers), on livestock research (two Centers) and pasture improvement (three Centers), and on the improvement of production systems in specific agro-ecological zones (four Centers) is complemented by extensive training activities (all Centers), by systematic efforts at facilitating the collection, documentation and conservation of plant genetic resources (one lead Center) and by two institutions, dealing with non-biological constraints in the fields of food policies (one Center) and institution building of NARS (one Center).

1/ Data from Evenson's et al. "Investing in Agricultural Supply"

The resulting balance in terms of research areas covered is interesting in several respects. Efforts are balanced between:

- plant breeding for the improvement of crop yield potentials and the removal of specific agro-ecological constraints;

- areas of early pay-off/impact and (presently one) high risk venture involving basic research and longer time horizons;

- the removal of constraints to production and productivity in the biological and non-biological (institutional) fields.

Obviously this balance is likely to shift as problems are solved, as the relative importance of constraints shifts and as NARS grow stronger.

The System's coverage of research functions. As regards the System's coverage of research functions in the overall process of research and technology generation, it is important to recall that it works in complementarity with NARS and DCRCs. It has concentrated on those aspects of the research cycle for which it has a comparative advantage and which are not adequately covered by these other components of the global system. It has generally focussed on applied research, leaving adaptive research to NARS (wherever the capacity existed) and relying essentially on DCRCs for the supply of strategic and basic research results. Its products were intended to be intermediate products rather then finished technology.

It is obvious that in real life the division of labour along these ideal lines is not always feasible. In practice the lines that separate these functions are neither straight nor tidy. Centers' involvement was and still is necessary on many occasions in the area of adaptive research, ideally assigned to NARS. The capacity of NARS varies greatly and the rates of development of their capacities vary even more. Facts are that in most developing countries there are still important constraints to the utilization of existing technologies. Yield gaps are enormous. Average farmer yields in many crops in most areas are still well below the biological potential of existing plant varieties.

As regards the supply of strategic and basic research results required by Centers, this varies greatly among crops and research issues. This is due in part to the fact that strategic research in the industrialized world tends to be concentrated on those crops that are important to their own countries. Consequently, the supply of new ideas and tchniques specifically related to tropical commodities is likely to continue to be a limiting factor in breaking important barriers to increased food production in developing countries.

This points to the need for systematic monitoring on the part of IARCs of research requirements in strategic and basic research relevant to their crops. Additional efforts in this field may indeed be necessary. This particularly applies to those crops with a relatively

short research history, where the big quantum jumps in yield levels have not yet been achieved and where there is potential for impact. It also applies, however, to those crops with a longer research history where high yield levels have been attained and further efforts are planned at pushing those levels further.

In more general terms, additional basic/supporting research will be required in all those areas where present lack of knowledge inhibit progress towards technology development. Here such practical questions as who does what, which institutional/organizational arrangements etc. need to be considered.

Looking ahead at the evolution of the System in terms of its scope of activities it appears essential that:

- the System remain an incomplete System concentrating its efforts on those areas that are important (in terms of needs and impact potential), that lend themselves to a CG System type approach and for which the System has a comparative advantage;

- careful attention be given to the continuing assessment of what is important, what constitutes the key constraints at a given time. The outcome may well be a shift upstream; it may also require the retention of substantial downstream activities for a certain time;

- all efforts be resisted which try to convert the System into an all-purpose instrument for the solution of all kinds of development related rural welfare problems;

- an effort be made to maintain an appropriate balance among activities (e.g. high risk vs. early pay-off activities).

(ix) Its research strategy

The preceding paragraphs have shown that - in retrospective at least - the System's scope of activities is reasonably balanced and in line essentially with research needs and its resource endowment. This is the result of continued efforts, at both the Center and the System level, towards concentrating attention on important areas and thus avoiding the spread of resources too thinly. Serious efforts will be required now to identify those changes that will be required to maintain the System's responsiveness and its impact potential.

Equally serious efforts were required in the past and will be required in the future to define an appropriate research strategy for the System. Such a research strategy defines at the System level:

- its specific functions in the overall process of research and technology generation;

- the degree of regionalization and site-specificity of research efforts in the commodity improvement area;

- role and place of FSR in the CG System;

- role and place of factor research in the CG System.

IARC functions in the overall process of research and technology generation. As regards the System's specific functions in the overall research process it was stated earlier that in accordance with the basic concept IARCs would closely collaborate with NARS and DCRCs and essentially concentrate on applied research. NARS and DCRCs would be concentrating on the adaptive and more basic/strategic parts of the research process respectively. This "ideal" division of labour is fully in line with the original purpose of the IARCs, to contribute to technology generation through research.

Real life is complex, however, and the division of labour does not always follow the ideal concept. There are gaps in research coverage at both ends of the spectrum, with regard to basic research (for the reasons mentioned) and - much more so - with regard to adaptive research. Despite substantial improvements in recent times many NARS are still weak and require continued assistance of IARCs in a broad range of fields, particularly those of smaller and less developed countries. Such demands for assistance tend to cover the fields of training, technical cooperation in institution building, establishment of linkages with others and, above all, adaptive research; they require technologies that are more readily applicable to their specific local conditions.

Undoubtedly such assistance by IARCs is both legitimate and necessary, if the System is to have an impact. The issue is not yes or no but to strike the appropriate balance. The build up of ISNAR is likely to contribute to the strengthening of NARS but it will not remove the demands from Centers.

With regard to future trends it appears that assumptions concerning the System's move upstream must - at least for the immediate future - be balanced against the need for continued downstream activities. While the problem of yield gaps must be solved in the short run, attention must be given in the medium term to further advances in yield potentials. And the medium term has started already. On balance therefore, the move upstream must start and serious efforts are required to convince NARS of the need to take on the downstream functions. The development assistance programs of multilateral and bilateral donor organizations are likely to play an important part in this process.

Regionalization and site specificity of research programs. As regards the issue of site specificity and regionalization in research programs, particularly in crop improvement - an issue closely related in practical terms to that discussed in the preceding paragraphs - there has been a noticeable trend in Centers' programs towards decentralization/regionalization of their efforts. The degree of regionalization in Centers' research operations varies enormously among Centers. Obviously there are differences in functional needs for decentralization and - even more so - there are differences among Centers' philosophies and operational strategies.

It should be stressed at the outset that regionalization at the operational level is perfectly compatible with the concept of global crop improvement mandates. In most cases a regional focus, to ensure specific requirements of new technologies is an essential condition for final success.

Needs for decentralization and site-specificity in commodity improvement programs are determined by several factors:

- First and foremost, the crops itself. Obviously the concept of wide adaptability does not lend itself to application with many of the System's crops.

- Secondly, the conditions under which the crop is grown. A high level of homogeneity in production conditions - e.g. under irrigation - demands less site specific research then heterogeneous environments, e.g under upland conditions.

- The stage of progress reached in crop improvement programs. While for some crops at least, the initial breeding for yield potential can be done very effectively at central sites drawing on the Centers' comparative advantage in utilizing their extensive germplasm collections, the following stages tend to require more site specific work. For the final development of improved technologies, region-specific constraints need to be considered and the respective tolerance/resistance characteristics incorporated to ensure the success of the resulting technologies. There is need for increasing attention to genotype/environment interactions and this may well require additional efforts at the more basic levels of research.

- Last but not least the strength of cooperating NARS in the region. According to the ideal division of labour NARS should - some time in the future - take the leadership in handling this part of the research process, the fine-tuning of technologies in accordance with site specific requirements. It is generally accepted, however, that much work remains to be done for the Centers, in close cooperation with NARS.

In operational terms, as was mentioned alrady, the degree and mode of decentralization varies greatly among Centers. Different approaches have been followed. One Center decentralized its research operations to a high degree by involving NARS on the basis of collaborative ventures including extensive use of networking arrangements. This approach is characterized by the Centers' increased reliance on NARS as equal partners in the overall research process.

Another Center regionalized its program through the establishment of one regional Center catering for the specific needs of its agro-ecological zone and a number of sub-regional programs which serve other agro-ecological zones. Yet another Center had decentralized its operations to such an extent that well beyond half of its staff and

resources were deployed outside its campus. Most Centers have established regional operations by outposting staff to regional locations within the agro-ecological zone to be served, including the location of other IARCs.

There are three issues to be considered in this context, and they are best handled by the Centers themselves, since the answers are largely Center specific.

The first refers to the optimum degree of regionalization of Centers' research programs. The answer is likely to be influenced by such factors as functional needs, efficiency considerations, the strength of NARS concerned and the requirements of balance among headquarters and regional operations.

The second concerns the approach to regionalization and the evolving relationships between IARCs and NARS. The ideal concept of the System's evolution and the resulting division of labour between the two clearly calls for increased involvement of NARS (hopefully strengthened in the process) and progressive take-over by NARS of downstream functions. This will allow the IARCs to gradually phase out their involvement in that part of the process, thus freeing resources for other more productive activities for which they have a true comparative advantage. Obviously the speed of this development is likely to vary among Centers, commodities and regions. What is important is the trend of this development and the effort devoted to it. What should be avoided is the creation of conditions which will perpetuate the status quo rather than contribute to change, i.e. the build-up of regional programs along the lines of the IARC model.

The final issue concerns the concept and modalities of inter-center cooperation regarding both the sharing of responsibilities for specific crops and cooperation at the regional/country level to coordinate their approaches to specific problems. Required here is a mode of operations which facilitates the necessary cooperation and coordination while maintaining Centers' individuality in their approaches to research. Such an approach, if appropriately balanced, will on the one hand avoid unnecesssary duplication of effort and conflicting advice to NARS and on the other prevent attempts at creating a "perfect" system with the resulting bureaucractic structures and its negative effects on innovative forces and initiatives at Centers.

Role and place of farming systems research in the CG System. The farming systems perspective as a valid approach to agricultural research is fully endorsed by Centers and TAC. Its holistic approach contributes to a better understanding of production conditions and constraints and to the identification of the most relevant research problems. It emphasizes the importance of environment technology interactions and the relationships among different components and thus contributes to better understanding for the adjustment of new technology components to specific production conditions.

There is agreement, however, that in view of the location specificity involved this is not an area for which the IARCs have any

comparative advantage. IARCs tend to concentrate on component research and leave the execution of FSR to NARS. Some Centers have been working on the development of improved FSR methodologies and have made substantial contributions to the advancement of the conceptual basis.

Role and place of factor research in the CG System. There is general agreement that the commodity-approach is the most appropriate for the CG System. It is in line with both the System's objectives, as defined in section (i), and its basic strategy of concentrating its efforts on the removal of key constraints holding back food production and productivity in the developing countries. It is equally in line with the needs and demands of NARS. This strategy of focussing on commodity improvement is effective, in accordance with the System's comparative advantage, cost efficient and on the whole successful.

An integral part of this strategy is the System's approach to factor research. Applied research on the common factors limiting crop production is generally conducted in the context of commodity research. Problems are mostly crop and location specific and are therefore best addressed by Centers in collaboration with NARS and specialized expertise outside the System. Requirements for strategic and basic research are often dealt with through collaborative and contractual arrangements with other institutions, both international and DCRCs.

For the short and medium-term future TAC endorses this strategy. As commodity improvement continues to be the central thrust, continued emphasis on germplasm activities is both necessary and appropriate. Strong programs will be required, in the context of agro-ecological constraints and with adequate support of the physical, biological and social sciences. The rationale for this is obvious. The Centers have clearly built up a comparative advantage in this area, new varieties still represent the most easily transferable technology at the farmer level; there is still great scope for both raising and stabilizing levels of production, through plants with more productive structures (improved harvest index), with greater resistance to hazards (pests, diseases, drought, etc.) that can more effectively benefit from improved agronomy, and that can exploit natural supplies of nitrogen through biological fixation.

In the longer run these activities in the commodity improvement area are likely to reach new barriers at higher yield levels and to identify new constraints which will require additional efforts in basic and strategic research. These requirements may well go beyond what is presently available both internationally and in DCRCs. Hence new initiatives may be required at the international level - outside the CG System - with which IARCs would collaborate.

(x) Its linkage mechanisms

In performing their functions as described Centers cooperate with impressive numbers of partners in research and training; their clients (NARS), other IARCs, institutions performing basic/strategic research (DCRCs and Universities), and other research and training institutions. Obviously modes of cooperation vary among Centers, depending on purpose and function, commodity specific requirements, regional characteristics

and funding. Linkages are both formal and informal, bilateral and multilateral. They normally serve a common purpose. They constitute an essential element in the functioning of the CG System and their effectiveness determines to a large extent the overall effectiveness and cost-efficiency of the System.

In Centers' collaboration with NARS on specific aspects of the research process networking arrangements have proved to be effective means for organizing such multilateral cooperation. This applies to the wide scale testing of seeds in the case of Centers dealing with cereal improvement, to cooperation on more site specific aspects in root and tuber research as well as the handling of many other common problems. In many cases networking arrangements serve a double purpose, that of conducting research in an effective and cost-efficient manner and that of strengthening NARS in the process, thus preparing the way for eventual take-over by NARS of essential parts of the resarch process (initially the downstream functions). This presupposes, of course, that such collaboration is conducted in a spirit of true cooperation among equal partners with clear responsibilities assigned to each and the Center assuming essentially the role of the technical/scientific back-stopping agent.

There is much scope for cooperation among Centers on common problems concerning commodities, agro-ecological constraints or other research issues and there are various operational modes for conducting inter-center cooperation. One issue that was mentioned already concerns practical arrangements for adequate regional coverage of resarch programs, to ensure adequate service to clients in the respective regions. As was pointed out the practical needs for such regional focus in Centers' programs vary among crops, among regions and they evolve over time as problems shift and NARS grow stronger. Centers will continue to define their operational strategies in the light of the objectives and constraints given.

Cooperation of Centers with DCRCs, Universities and other specialized institutions is equally problem oriented, frequently bilateral and based on specific agreements/contracts. Sources of funding vary. This area, mostly concerned with basic/strategic research should receive increasing attention as NARS grow stronger, Centers move upstream and the issues involved become more complex.

(xi) Its comparative advantage

The System's present comparative advantage is defined by a number of inter-related factors which have been discussed in the preceding paragraphs:

- its international dimension in scope and governance;
- its institutional and organizational characteristics;
- its resource endowment in terms of scale and continuity;
- its problem oriented approach to research and technology generation;

- its concentration on important problems representing key constraints to food production on a global scale;

- its clarity of focus and the Center of excellence concept;

- its research strategy and the implicit division of labour with NARS, DCRCs and others.

In the light of these factors the System appears to have a clear advantage for those aspects and activities in research and technology generation which deal with:

- important food commodities on a global scale;

- the removal of important constraints to increased food production;

- research that has large scale application at the global level, or for large agro-ecological zones.

This confirms the notion that under present circumstances the CG System does well in concentrating on commodity improvement with the objective of raising yield potentials as yield stability while incorporating other desirable characteristics in accordance with region specific requirements. Its advantage in the area of germplasm collection, utilization and testing over large areas and different agro-ecological conditions qualify it uniquely for this work. Implicit in this statement is the System's advantage for applied research. It clearly does not have any comparative advantage for site specific work such as the downstream phases of adaptive research, although it may have performed such work on a temporary basis.

It must be stressed, however, that as needs evolve and NARS develop the System's comparative advantage requires reassessement.

2.4. Present thrusts and programs

Present patterns of program thrusts are the result of an evolutionary process through which Centers' original or formal mandates were interpreted in operational terms, translated into action programs and have since then evolved further in response to needs and opportunities. This process and the dynamics involved reflect the basic philosophy of the CG System, that of serving and assisting NARS in the process of technology generation and the build-up of their capacities. It has been responsive to evolving needs and has thus affected the System's priorities, functions and activities. This process also proves that the CG System mandate structure is by no means static; there is scope for the kind of adjustments needed.

As was indicated earlier in this chapter, there were substantial variations among Centers as regards the kinds of adjustments required in operationalizing formal mandates. This is due to a considerable extent to the enormous heterogeneity of formal mandates. These vary from broad

and general statements of purpose to high levels of specificity enumerating most of the functions and activities to be performed.

The kind of variability referred to concerns the definition, at various levels, of Centers primary objectives in terms of commodity improvement, agro-ecological constraints on systems development, of regional boundaries (if any) to these objectives and of specific activities such as training, germplasm activities, information and documentation services, etc.

While some Centers have short and concise statements clearly defining their responsibilities for specific commodity/activities at the global or regional levels, others have complex mandates implying concurrent responsibilties at various levels (global and regional) for different commodities as well as farming systems research and cooperation with NARS in mid- and downstream activities. In one Center's mandate the central thrust is on the development of improved production systems. For a number of Centers the complementary activities mentioned above (training, information services, etc.) are explicitly stated, for others they are implicit.

The process of operationalizing mandates has been guided by Centers' Boards. These have been responsive to the needs of clients (NARS), to the policies of the Group and to requirements of the research process. Annex Table 24 gives a summary presentation of IARC mandates, both formal and operational.

The most common patterns, established by the earlier Centers with global commodity improvement mandates, was to concentrate initially on a centralized breeding operations based on the concept of wide adaptability. This concept has proved to be a highly useful strategy for the early phases of crop improvement work. Its application, of course, was limited to those crops that lend themselves to this approach and to those Centers that deal with global crop improvement mandates.

This centralized approach to plant breeding was complemented eventually by research efforts at the regional level. Progressive decentralization at the operational level has permitted Centers a better fulfillment of their global mandates for specific crops.

The growth and spread of regional operations, thus motivated, combined with the operations of the "regional" Centers with their systems improvement mandates for specific agro-ecological zones, are providing for an increasing regional coverage of CG System operations.

Resulting from this decentralization - more the trend so far than actual levels reached in view of resource limitations - are two potential issues that may require attention at the System level.

One is the risk of duplicating effort. This is essentially limited to the area of commodity improvement where two or more Centers share responsibilities for a specific crop. The number of potential cases is limited, however, and satisfactory agreements have been concluded for inter-center cooperation on many of them. The trend is positive, therefore.

The other concerns the potential risk of conflicting advice flowing from IARCs to NARS. It is limited to those cases where two or more Centers cooperating with a NARS deal with common problems, e.g. the development of appropriate research methodologies in farming systems research. As Centers mature and the System develops, the level of consultation and cooperation among Centers on common problems is increasing and the apparent risk of conflicting advice tends to diminish.

In this context it should be stressed, however, that the objective of increased inter-center cooperation should not be total uniformity of approaches and methods. Some of the diversity, dynamic tension and spirit of competition among scientists sharing common objectives, which have characterized the System and contributed to its success should be maintained.

Main thrusts. The bulk of CGIAR activities are concentrated on the removal of constraints to increased food production in developing countries. Work on biological constraints, i.e. commodity improvement in the larger sense, constitutes close to 90% of the total effort. The System's efforts related to non-biological constraints (including training) amount to just over 10%. While training clearly receives the most important share (roughly 7%), economic and policy research capture some 3% and efforts directed towards institution building amount to roughly 1.5% of the System's total resources.

The System's efforts towards commodity improvement are concentrated on the world's main food commodities. The commodities covered by CGIAR programs presently account for over 80% of total food commodities or roughly 74% of total agricultural production (in terms of value) in developing countries (Annex table 1).

The allocation of CGIAR efforts by main commodity groups (Annex table 15) shows that the main thrust goes to cereals (51% of total funds directly attributed to commodity improvement programs, i.e. excluding administrative and general operating costs). The other three groups, roots, tubers and starchy foods (15.4%), pulses (18.0%) and livestock products (15.6%) share among them - in allotments of similar size - the other 49% of the total.

With regard to individual commodities Annex table 23 indicates that largest shares go to rice (23.0%), livestock products (15.6%), wheat (8.2%), maize (8.05%), cassava (7.1%) and potato (7.0%). The allocation of commodity improvement efforts by regions (Table 17 for commodity groups and tables 18 - 20 for individual commodities)shows a number of interesting constellations. These are discussed in Chapters 5 and 6, when the present allocation is compared with projected regional needs.

An analysis of CGIAR thrusts by region (tables 14 and 16) shows that Africa (37.5%) is the region most benefitting from CG commodity improvement efforts. It is followed by Asia (26.0%), Latin America (22.0%) and North Africa/Near East (14.4%).

3. EVOLUTION OF THE CG SYSTEM - A LONG TERM PERSPECTIVE

The need to look ahead. Important parts of this paper - particularly Chapters 4 and 5 - address in detail commodity and regional priority needs and the congruence of CGIAR research to these global needs in the short to medium term. They focus on a time horizon of approximately 10 years. The analysis conducted there deals with the appropriateness of the present balance of the System's activities and shifts required in view of changes in food requirements in the developing world. Its essential outcome is to recommend a continuation of the System's main thrust, focussed on commodity improvement of the world's main food crops, and to confirm, with some adjustments, the current balance of activities and Center mandates.

But clearly an organization as large, dispersed and long term as the CGIAR needs also to look ahead for even longer time horizons. It needs to orient its plans for both the short and the long term in accordance with the long term trends of those factors that are important in determining its program of activities: food needs, production potentials, technology requirements and research capacities. Such planning appears to be crucial now. The next 40 years will see the largest absolute increase in human numbers of all time. There will be increasing pressure of population on natural resources, particularly land. Energy resources will become increasingly scarce; hence the need for renewable forms of energy. All of this will have important effects on technology requirements for agriculture.

Process for the analysis of the System's long term evolution. At its 34th meeting in June 1984 initiated a process of systematic thinking about the long term evolution of the System's priorities. It was since assisted in this process by a discussion paper prepared by one of its members and by a brainstorming session in which a small group of scientists, research administrators and friends of the System came together for two and a half days to think about the evolution of the System. The result of this process so far is this chapter on the long term perspective. It focusses on a time horizon of some 25 years.

TAC considers this as a first step in a longer process. More discussions will need to follow and the time horizon will need to be extended to approximately 50 years. Obviously these discussions will need to involve all components of the System as well as representatives of NARS.

This chapter first looks at evolutionary trends in world agriculture and analyzes those elements of change that will define the likely scenario in the first decade of the next century (3.1). It then looks at global research needs and changes in CG priorities resulting from the long run scenario (3.2). It comments on some of the implications of these changes on the System's organization and operating structures (3.3), and finally presents some concluding comments (3.4).

This analysis of the long term perspective also fulfills an important function in relation to TAC's review of short term priorities.

It provides the background to this exercise and gives the appropriate guidance for the evolution in the longer run of short term priorities.

3.1. Scenario for world agriculture in the first decade of the next century

This subchapter essentially deals with the information requirements for long term planning and priority setting. It attempts to draw a scenario for world agriculture in the first decade of the next century and this to provide the information needed for the discussion of future research needs and changes in CG priorities. It takes a balanced look at those factors that are important in defining research needs and in determining the role and place of the CG System in helping to meet these needs. In this analysis TAC is mindful of the specific position of the CG System as an important yet small segment of the global research effort for developing countries. Hence the question regarding the System's comparative advantage in the longer term needs to be kept in mind as the System's future role in the global set-up is analyzed.

The following factors are analyzed:

(i) Population pressure on natural resources. A discussion of trends in population growth, food demand, food production capacities in developing countries and the population carrying capacity of land in different countries and regions. This analysis is conducted at both the global and regional levels and thus highlights specific problem areas and points to critical needs for future research.

(ii) The international economic context. A discussion of projected economic and policy developments relating to food production, food supply and trade and to self-sufficiency considerations. These considerations constitute the overall policy framework that will guide future production and resource utilization goals and policies and hence affect research and technology development.

(iii) Characteristics of the technology generation process. A discussion of changes over time in both the process of technology generation and in the respective capacities of all those components of the global research system involved in this process (NARS, DCRCs and private sector research).

(iv) Structure of production and demand. A discussion of changes in demand and production structures that will have a bearing on research needs. Particular attention will be given to the obvious need for intensifying agricultural production and the implications thereof for research.

3.1.1. Population pressure on natural resources

In any attempt to define the future scenario for the evolution of the CG System population growth and food demand are the key variables. They help to define the size of the problem. In a next step the food

requirements are set in relation to resource availability for the production of the food needed. Here technology comes in. To determine the future role of technology in food production and to define research requirements a number of indicators are used.

An important factor in determining future research needs is the extent to which technology combined with input use is needed to enhance the productivity of scarce factors of production, in particular land, water and energy. Population pressure on natural resources is a useful indicator in this respect. This requires a careful look at both sides of the balance, population size and growth on the one side and population carrying capacity of land in terms of sustainable food production at given levels of technology and input use on the other. Obviously such analysis is meaningful only if conducted at the regional level.

(i) Demographic growth

The next 40 years (1980-2020) will bring about the largest annual population growth in history with 93% of that growth occuring in developing countries whose populations are projected to grow from 3,300 to 6,450 million during that period (UN sources). One of the disturbing features of this growth is the fact that it will be faster in those areas where land resources are least adequate to meet food needs.

The fastest growth rates will be found in those regions with most countries that appear critical in the year 2000 according to FAO's AT 2000: Middle America, Africa and Southwest Asia. In Middle America present high rates of growth will eventually come down to 2.13% per year by 2000. Population nevertheless is expected to reach by 2025 two and a half times the 1980 level. In Southwest Asia growth rates will be similar and by 2025 population will reach 2.7 times the 1980 level. The most rapid growth is expected in Africa whose 1980 population of 470 million (excluding South Africa) is projected to grow to 853 million by the end of the century and to 1,542 million by 2025.

The effects of population growth on food demand are obvious. They are less clear with regard to rural production structures, where they have an impact on labour supply as well as the size and efficiency of holdings.

These rates of growth are accompanied in many regions by equally dramatic rates of urbanization with the resulting effects on food demand; i.e. changes in the structure of demand which in many cases are not compatible with the regions' production potentials.

(ii) Pressure on renewable resources

As a result of population growth, population pressure on the land will increase in all regions. The effects of this will vary, however, in the light of widely differing population carrying capacities of regions. AT 2000 estimates that by the end of this century the entire lands of developing countries - almost three times the present cultivated area - would barely be sufficient to feed their expected

populations if traditional methods of farming continued to be used. No less than 64 countries, 29 of which in Africa would be unable to feed their projected populations from their own land resources. Some 2,450 million ha, almost two-fifth of the land area with 60% of the total population would be carrying more people than they could support, thus representing a serious threat to human welfare and the environment.

Land reserves are limited. While the overall potential land base for rainfed crop production is large, land reserves are unevenly distributed among regions and countries. In addition, the bulk of high potential land reserves is concentrated in the humid tropics, with all the wellknown obstacles to rapid exploitation. According to AT 2000 the average arable area per person is expected to decline in the 90 countries studied from 0.37 ha per person in 1975 to 0.25 in 2000.

The potential overloading of certain zones poses a very serious ecological threat. Along with other factors involved, such as soil erosion caused by excessive cultivation of marginal areas, the fuelwood crisis has a powerful impact on the environment. Two studies by FAO show a disturbing degree of correspondence between the areas of risk of desertification and deficiency in fuelwood and those areas having inadequate land resources to feed their populations at low levels of technology and input use.

Population supporting capacities of land and the resulting potentials for self-reliance in food production vary enormously among regions, among countries and within countries. Hence aggregations have to be treated with care. Imbalances between the distribution of populations and the potential of land resources occur at all levels.

In Africa, for example, the prospects of feeding future populations seem most clouded. Despite the continent's massive land area with a large area of potential rainfed crop land and the existence of large unused land reserves, fast population growth and an uneven distribution of potentials give rise to serious concern. There are several critical zones and countries.

The Near East is the region with land resources most inadequate to meet food needs of expected populations. With only 7% of the land area suitable for rainfed crop production it is the least favoured of all regions in terms of soils and climate. Only at high levels of inputs and technology would the region as a whole be able to feed its future populations.

In Southeast Asia high population pressure is compensated by favourable conditions regarding soil resources, climate and levels of productivity already achieved. Population growth has been reduced and further increases in irrigation are likely to improve the population supporting capacities.

South America, on the other hand has the lowest incidence of critical areas and countries of any region and the highest proportion of land area suitable for rainfed agriculture.

3.1.2. The international economic context

Here, several developments are relevant in determining the scenario for world agriculture which in turn defines research needs and opportunities. Among others these developments relate to:

- the expansion of international trade in food commodities and its influence on consumption patterns and demand;

- the economic and political climate in the industrialized world and its influence on technical cooperation policies and research funding;

- changes in the economic and political climate in developing countries with regard to economic and technical cooperation among these countries;

- the growing inter-dependence among developing countries, particularly at the sub-regional level;

- food policies, food security considerations and their influence on food supplies.

The latter two appear to be particularly relevant in the context of this discussion.

(i) Growing inter-dependence at the sub-regional level

The majority of developing countries are facing a set of complex problems with regard to their agricultural development. Some of these problems require solutions that apparently can only be achieved through cooperation. The recognition of this has sparked off three inter-related trends:

- an increased awareness in developing countries of needs and opportunities for cooperation (TCDC). Development assistance activities and research cooperation have undoubtedly had a catalytic effect in promoting this development;

- an improvement in the political climate towards cooperation with the consequence that joint action is being initiated in an increasing number of fields;

- growing inter-dependence resulting from this, particularly at the sub-regional level.

Cooperative action so far has concentrated on common problems of a short term nature. The overwhelming pressure of short term needs in the area of food production has largely detained attention from long term problems which cut across national boundaries.

Many of these "long term" issues are pressing needs that require short term attention if serious problems are to be avoided. Many of

them have important effects on future food production capacities in many of the developing countries. They concern such crucial issues as:

- resource conservation requirements (deforestation, long term erosion, siltation of rivers and reservoirs);
- environmental concerns;
- the management of large river systems;
- energy problems (alternative fuel supplies);
- employment issues;
- trading patterns and food policy considerations.

A limited number of actions have been initiated to deal with such issues on a sub-regional basis with initiatives emanating partly from within the region partly from external stimuli. Much more is needed. Requirements go well beyond the financial and technical capacities of national systems concerned, even if they combine their forces. Hence innovative institutional approaches may be required to deal with these pressing issues.

(ii) Food policies and their influence on food supply and utilization

Any consideration regarding future food supply and utilization at the global or regional level is strongly affected, among other things, by the assumptions regarding future trends in food trade. Trends point to an increase of trade in food commodities, particularly cereals. This trend is likely to be constrained, however, in the medium term by two factors, the foreign debt problem presently faced by many developing countries and national policies directed at self-sufficiency in food.

There is increasing recognition, however, that national self-sufficiency in food is a complex issue with numerous problems. There is equal recognition of the potential benefits of cooperation at the sub-regional level. FAO's AT 2000 provides evidence that the potential for regional self-sufficiency in food is good in four of the five regions analyzed. It is likely, therefore, that - in accordance with trends elsewhere - such cooperation will increase and self-sufficiency goals are redefined in a regional context. This would, of course, have implications on research needs and opportunities.

3.1.3. Characteristics of the technology generation process

It is clear from earlier chapters that there will be important changes in technology requirements regarding both type and quantity of technologies required. Expectations are that:

- demand for technology will increase over time;
- the role of technology in the production process will be enhanced;

- technologies required will be more complex due to the intensification of agriculture and related developments;

- the range of technologies required will broaden in view of increasing needs of location specific technologies for particular agro-ecological zones.

As regards the process of technology generation there will equally be a number of changes. These are related to changing technology requirements and to institutional developments on the part of the actors involved in this process. It is assumed that the main elements of change are affected by the following four developments:

(i) Growing complexity of technology development;

(ii) The evolution of NARS;

(iii) Increased interventions of the private sector;

(iv) Development of the global research system.

Regarding the research process it is expected that the bulk of technology generation will continue as a joint venture of cooperation among the various partners in the global system of agricultural research efforts: NARS, IARCs, DCRCs and other research institutions in both the developed and developing regions. As the system evolves and NARS grow stronger, the relative weights and functions are likely to shift, with certain functions being transferred to NARS. In short, the division of labour among the various partners will shift in accordance with the evolving comparative advantage of each of them. An element of considerable importance will be the emerging role of the private sector in this process.

(i) Growing complexity of technology development

As population pressures grow and arable land resources are increasingly depleted trends of intensification in agricultural production will necessarily increase further.

Equally, depending on the extent of these pressures on natural resources, agricultural production will increasingly move into more difficult areas including eventually marginal zones. Both developments, particularly as they relate to rainfed agriculture, require more complex technologies. In the design of these technologies more attention will be required on a number of factors:

- genotype/environment interaction so as to mobilize the full yield potential of new technologies;

- efficiency in resource utilization concerning both renewable resources and inputs into the production process;

- environmental concerns, in particular land and water conservation;

- related concerns such as employment, energy and nutritional aspects.

The kinds of complexities involved in future technology requirements become apparent in a (rather schematic) comparison between the needs of Africa and Asia.

For Africa the situation is characterized by the urgency of needs (a fast growing food deficit), a difficult resource base in terms of soils, climate and irrigation potential, a highly uneven distribution of resources, a serious shortage of labour supply in agriculture despite high rates of population growth and the lack so far of appropriate technologies. Research efforts so far have, with a few exceptions, not yielded the results required. Efforts at importation of technologies from elsewhere were largely unsuccessful. These technologies had been developed for different environmental conditions (essentially the more favoured areas) and for different land/labour ratios (land saving technologies). What is required for African conditions are labour saving technologies for the more difficult conditions of rainfed agriculture.

Asian technology requirements are different. While here, too, agriculture increasingly moves into upland areas, high population pressures and rural poverty require land saving and employment generating technologies that maximize the output per land unit.

Such differences in technology requirements obviously require different research strategies. They equally require the application of the entire spectrum of knowledge and research capacities ranging from basic research down to adaptive research. This implies the increasing mobilization and use of the most advanced techniques and institutions in the areas of basic science. On the other hand it implies increased location specificity of both research and technologies generated. This will clearly be an obstacle to rapid diffusion of technologies across broad regions.

The increasing complexity of technology generation, the growing involvement of basic science in this process and the resulting move upstream will put a heavy burden on NARS. Assuming that NARS - in accordance with their resource endowment - will increasingly wish to take the lead in the technology generation process, they will have to continue developing their capacities in the more sophisticated areas of research. In the meantime the bulk of NARS will remain heavily dependent on research results from DCRCs, IARCs and others. The IARCs will play an important bridging function in this process while at the same time bringing in their contributions, particularly in the domains of their comparative advantage.

(ii) <u>The evolution of NARS</u>

NARS must be the principal actors in the generation of technology for the agricultural development of their countries. They should lead the process. This is the basic philosophy accepted by all components of the global system.

The enhancement of national research systems and the strengthening of their capacities has been a major issue in international development. The major development assistance agencies, both multilateral and bilateral, as well as the CGIAR have strongly supported this goal.

Possibly the most important development in this context was the change in the policy climate in developing countries themselves. There has been in recent times a stronger commitment to the build-up of adequate national research capacities.

Recent trends in the build-up of NARS are positive. Investment in agricultural research has grown substantially during the past two decades. While in absolute terms the industrialized regions of the world continue to spend most on agricultural research, the developing regions have increased their share in global public sector spending. Their aggregate growth rate (5.5% per annum for the period 1970-1980) compares favourably with that of the industrialized regions (2.6%).

While there has been growth in research expenditure and manpower in all developing regions, there have been marked differences among regions and even more so among countries within regions. Two regions (Asia and Latin America) have substantially increased their shares in global spending whereas one region (Africa) has maintained its position.

The growth of national systems has been highly variable. This is illustrated by the fact that in Latin America by 1980 two NARS (Brazil and Mexico) accounted for slightly over half of all public sector research expenditure in that region. In Africa the degree of variability was similar; one country (Nigeria) accounted for almost 30% of total research expenditure. In Asia growth was more evenly distributed with a number of NARS expanding substantially.

With regard to future trends, expectations are that the overall growth of national systems will continue. Differences in growth rates will equally continue. The bulk of expenditure will continue to be concentrated in a few countries. In practical terms this means that present differences among research capacities are likely to increase further. The spectrum is likely to broaden. The more affluent countries are apt to spend more on research both in absolute terms and in relation to the value of their agricultural product.

While the effectiveness and cost efficiency of NARS is likely to improve further over time, a serious issue remains the build-up of an appropriate research capacity in the poorer and smaller countries. It should be noted here that research capacity requirements of developing countries are not necessarily tied to size or income level. They are largely dependent on the country's heterogeneity in terms of its agroecological zones and its production structure and potential. And the poorer countries are often those with the more difficult agro-ecological conditions and hence increased research requirements if any progress is to be made.

Any comment about the future role of NARS in the technology generation process must obviously keep in mind the broad, and probably increasing, heterogeneity of their capacities. As a general guideline it must be expected, however, that NARS - particularly those strengthened in the process - will increasingly pursue the trend towards take-over of part of the present functions of IARCs i.e. activities at level III, in addition to level IV.

Speed and intensity of this development will depend on a number of factors. As experience has shown, however, the establishment of cooperative research networks has proved to be an effective instrument for the gradual transfer of responsibilities in this field. Such networking arrangements, with the initial backstopping by IARCs, tend to accelerate this trend and facilitate the effective participation also of the weaker NARS.

In the case of more progressive NARS with good resource endowments it may be expected that they will succeed in narrowing the gap to the advanced institutions of basic science in the industrialized regions. By developing more sophisticated scientific capacities they are likely to benefit more fully and more directly from the potentials offered by these advanced institutions.

For some time to come, however, most NARS including many of the more advanced will have to rely on IARCs and DCRCs to bridge the gap presently separating them from the cutting edge of science.

(iii) Increased interventions of the private sector

The third factor of change likely to have a substantial impact on the technology generation process is the development of the private sector.

This development has two aspects. Both are interrelated and both are based on the condition that private appropriation of research benefits is possible under given circumstances.

The first concerns the increasing role of the private sector in the development and diffusion of technology in the developing countries, particularly seeds. The phenomenon per se is not new. It has some history already in the development of successful private seed industries. The trend is there. New is the extent to which this development is likely to accelerate along this trend. A main characteristic of this aspect is that so far activities have concentrated essentially on the downstream phases of research; i.e. adaptive research with some level III activities.

The second aspect concerns the increasing engagement of the private sector in the upstream functions of research. This phenomenon is relatively new. So far it is limited essentially to the industrialized world, where private sector institutions engage into activities of basic science with the objective of developing improved varieties, the benefits of which would accrue to the industry. This represents an effort at technology development in which the full

spectrum of activities involved in the research process - ranging from basic science down to adaptive research at level IV - is concentrated in the hands of one organization. Typically, organizations of this type are located - initially at least - in industrialized countries, bear the cost and risk involved in such long term engagements and attempt to appropriate the research benefits through commercial marketing of technologies produced in both industrialized countries and - as far as possible - in the developing world.

Both developments obviously have a common basis and both have important implications for the process of technology generation and the actors involved. They raise the issue of scientific knowledge as a public good.

(a) Development of the private seed industry. Past trends show important growth in the development of the private seed industry in a number of developing countries. This development has been based largely on trans-national corporations and has been particularly fast in the case of hybrids (maize and sorghum) where the nature of the breeding process facilitates the private appropriation of research benefits. It has been much slower or non-existent in other species such as roots, tubers, pulses and other cereals, where conditions are less favourable in view of different breeding processes and/or the distribution of seeds.

It is interesting to note that the development of the private sector in hybrids has been based on an organizational structure that takes advantage of the same principles that explain the success of the IARCs: (i) research guided by clearly defined objectives focussed on commodity improvement; (ii) an international structure that facilitates rapid access to genetic variability and massive selection procedures in a large number of screening sites with different kinds of stresses; and (iii) the possibility of more than one crop per calendar year.

With regard to future trends, it is expected this development will accelerate. The conditions for this are increasingly improving. New legislation is emerging in many countries that provides better and more easily enforceable protection to breeding materials in the self-pollinating species. The likelihood of success with commercial hybrids in some of the most important self-pollinated species is And finally, along with economic growth, the development of infrastructure and an increasing share of commercial agriculture, the institutional conditions will be met in a growing number of countries. Notwithstanding these developments there will of course continue to be great variability among crops and countries in the rates of growth of the private sector.

This development will undoubtedly have implications for the technology generation process in the public sector and for the institutions involved, principally NARS and IARCs. These will need to be responsive to a changing situation from the institutional point of view and to changes in demand for specific technologies. IARCs will continue to be faced with high levels of demand from cooperating NARS. At the same time they will need to monitor the adequacy of their

policies regarding collaboration with the private sector with a view to enhancing the effectiveness of the overall technology generation and transfer process and to "socializing" some of the costs of more risky research.

(b) Scientific knowledge as a public good. The concept of the present system of technology development involving essentially DCRCs, IARCs and NARS is based on the assumption of a rational division of labour among these institutions with the IARCs concentrating on applied research. The logic of this concept implies that the required basic knowledge is available to them from other sources, particularly universities and DCRCs. This assumption is correct as long as all or most of the basic research is conducted by such public sector institutions.

The recent involvement of the private sector in upstream research and advances made in biotechnology suggest, however, that this situation may change. Two trends are likely: (i) an increasing proportion of this research at the cutting edge of science being developed by the private sector and (ii) increasing collaboration of public sector institutions with the private sector through joint ventures, contract work or other arrangements. Both imply restrictions to free availability of research results.

A continuation of this trend towards privatization of research in these advanced areas could have important implications for the Centers and their partners. It might preclude or delay their access to certain types of basic information. The magnitude of the problem will depend on a number of factors, including the future strength of DCRCs and universities and the extent to which these public sector institutions develop research programs in these areas in collaboration with IARCs.

The obvious conclusion from this development for Centers is the need to move upstream, stay close to the cutting edge of science and develop enough capacity in these areas of research to be aware of developments, to utilize results as they become available and to initiate collaborative ventures with specialized institutions as needs and opportunities arise.

(iv) Development of a global research system

An objective generally accepted by those dealing with development assistance policies is to have in place as soon as possible a fully functional system for agricultural research which is capable of handling the technology needs of world agriculture in the next century. An implicit part of the acceptance of this objective is a continuing commitment to international support for agricultural research in the developing countries. The purpose here is to assist and complement NARS in two respects i.e. in technology generation and in the further build-up of their own research capacities. The CG System obviously constitutes one important element of this commitment.

What is ultimately needed is a coherent system of effective research organizations with complementary and interrelated functions.

These organizations would be clearly focussed on important problems and be responsive to needs and opportunities in developing countries. They would be independent in structure and governance but grouped into loose confederations.

Past trends are clearly pointing into this direction. Expectations regarding future developments basically confirm this trend.

A first step of key importance in this direction is the completion of the build-up and the subsequent consolidation of the CG System. This includes the final build-up of those Centers that have not yet reached their optimum size and maturity and the attainment of the System's final coverage of commodities/activities that is considered desirable and optimal for the medium term. In this context, the notion of selectivity and an incomplete system is maintained, of course. The CG System will continue to concentrate on a limited number of globally important areas and issues for which it has a comparative advantage.

A second and related step is the growth in recent years in number and size of international Centers outside the CG System. These centers, heterogeneous in scope, focus, and function all address important research issues in the developing world. Expectations are for a continuation of this trend, implying further growth and consolidation of these efforts. As their objectives and activities are complementary to those of the other components of the global system, further growth and expansion of their capacities will increase the opportunities for fruitful cooperation.

The third issue to be considered here concerns the future growth and development of DCRCs, another key component of the emerging global support system for agricultural research in developing countries. The two key questions here concern (i) future funding prospects which obviously are the key determinants of their research capacities in general terms and (ii) the extent to which they will provide in future the basic research most relevant to LDC conditions as well as the strategic/post-technology research needed by IARCs and the more advanced NARS.

Expectations are for limited growth, if any, of research and training capacities and of research output which is immediately relevant to IARC technology generation activities. In this respect a compensatory stimulus could well be the increasing demand for collaboration from the private sector. The main implications for IARCs would appear to be the need to increasingly orient its activities upstream, maintain a critical awareness of basic research needs and opportunities and expand further its cooperation with DCRCs and universities through contracting arrangements.

A fourth issue worthy of consideration and discussion is the desirability, functional necessity and feasibility of developing in the medium term a system of basic research and training centers in the

tropics. The rationale for such a basic research system in the tropics, as argued by V.W. Ruttan 1/, is based on the following assumptions:

- an existing lack of knowledge in a number of areas, which inhibits the effective technology generation efforts;
- enhanced intellectual commitment to the solution of scientific problems, if scientists working on these problems are part of the environment in which the problem exists;
- a more effective dialogue between basic research efforts in the tropics and those in temperate regions;
- full complementarity with current efforts in this field undertaken by those DCRCs that maintain research capacities related to tropical agriculture.

These institutions would probably be governed by an international body similar to the CGIAR and integrated into a coherent system of basic research centers rather than emerge as a set of free standing institutes.

A final issue concerns the development and further improvement of an effective linkage system which connects the various elements of this global research system and improves the communication among its units. This is likely to contribute substantially towards enhancing the overall productivity of the system.

3.1.4. Structure of production and demand

Most of the developments and trends discussed so far that will define the future scenario of world agriculture are inter-related. It is obvious that population growth, increasing population pressure on the land and changes in the economic context will have an impact on future structures of production and demand. These in turn will determine research needs and CG priorities. The areas where the most relevant changes are likely to occur in the long term relate to:

(i) The intensification of agricultural production;

(ii) Evolution of farming structures;

(iii) Changes in the composition of food demand.

Trends and intensities of these developments will vary among regions, among countries and within countries. The level of change will obviously depend on specific circumstances. The degree of variability will be high and may well increase further.

1/ Vernon W. Ruttan: "Toward a Global Agricultural Research System" University of Minnesota, July 1984.

(i) Intensification of agricultural production

Projected rates of population growth and the resulting increase in food demand at the global, regional and country levels immediately raise the question of potential sources for the necessary growth in food production to meet demand. Of the two sources available globally, expansion in area or intensification of production, future trends will be directed towards the latter.

The trend towards intensification will follow two paths. Wherever this is feasible from the technical and economic point of view irrigation will be used. Here the potentials are very unevenly distributed among the regions. By the end of this century the area equipped for irrigation is expected to constitute 34% of total arable area in the Far East, 27% in the Near East, 7% in Latin America and only 2% in Africa. The alternative is intensification of rainfed agriculture. In a growing number of countries this alternative will have to produce the bulk of additional food requirements. This is a complex task with a high demand for appropriate technology which is not available at present. It represents a major challenge to research.

Such intensification under either condition has important implications. The intensive use of land combined with increasing levels of inputs and high yielding crop varieties carries increased risks such as land degradation, loss of soil fertility, environmental problems due to increased input use and high vulnerability of genetic materials to pests, disease and climatic stress.

Land degradation is a serious threat to the future potential land base for food production. Erosion, salinization, depletion of plant nutrients and organic matter, deterioration of soil structure and pollution are the main factors of risk. FAO (AT 2000) has estimated that without appropriate conservation measures the are of rainfed cropland would shrink over the long term by 18% or 544 million ha, an area greater than the active potential cropland of Southeast Asia.

The implications of this trend for research are obvious. What is required are technologies appropriate to national social and ecological conditions. Translated into research needs this has numerous facets. In terms of plant breeding it implies the development of varieties with higher yield potentials and stability particularly for rainfed agriculture at varying input levels. Site specificity of such research will have to increase in the interest of finding the optimum plant genotype/environment combinations. The needs for maintenance research will grow in order to defend yield levels and keep up the essential mechanisms of resistance and tolerance.

In relation to increasing levels of input use there will be important research needs. In many of the developing countries, particularly the poorer areas, the availability of inputs at the required levels constitutes a serious problem, both economic and logistic. The high cost to farmers of such inputs obviously is the key problem. Hence an important research objective must be to increase the

efficiency in input use. More effective ways will need to be found for increasingly complementing (and eventually replacing) fertilizer use by biological fixation of nitrogen and organic recycling.

(ii) Evolution of farming structures

Population growth, undoubtedly the key factor of change in all considerations regarding future trends in world agriculture has various effects on agricultural development and the production structure. It creates additional food demand to which agriculture has to respond. It adds to population pressure on the land and thus has a powerful direct impact on agriculture. It can often stand in the way of efforts to improve the productivity of land. Excessive subdivision of small-holdings and excessive growth of rural labour supply in certain areas may slow down the rate of progress. Urbanization tends to compensate such trends by taking off some of the pressures. Growing urban markets for food may contribute greatly to the process of commercializing and modernizing agriculture. They induce the increasing use of technology and the rationalization of production processes and farming structures implying the use of economies of scale wherever possible.

With regard to future size of land holdings there is no single trend. Conditions in terms of population pressure, urbanization rates and factor availability (land, labour and capital) vary enormously among regions and countries. Similarly varied are national strategies for agricultural development and technology generation.

For the densely populated areas in large parts of Asia with a clearly high intensity of land use, abundant labour supply, and less propensity toward urbanization, the scope for consolidation of land holdings into larger units is limited. However, intensification of the production process through increased use of technology and inputs will clearly proceed further. This points to technology requirements in terms of increased efficiency of input use at high levels of land productivity.

On the other hand, in countries like Brazil with land reserves and high urbanization rates the strategy for modernization of agriculture and the resulting technology requirements will differ. Increasing demand from urban and export markets and the resulting economies of scale will induce production patterns with larger units and rapidly increasing levels of mechanization and input use.

While there is no common global trend in terms of farm size and mechanization, farming structures will progressively evolve. The intensification of agriculture brought about by population growth urbanization and the resulting food demand is likely to progressively transform farming units into commercial operations producing for the

market and combining effectively the production factors at their disposal with increased levels of inputs and technology. The rate of progress will obviously vary in accordance with technical, economic and social circumstances and government policies.

As numerous examples from all three continents - Asia, Africa and Latin America - clearly show, under reasonably favourable conditions even small and initially resource-poor farmers tend to develop quickly into small scale entrepreneurs. Under more unfavourable conditions this transformation, if any, is undoubtedly much slower. Large numbers of subsistence farmers may therefore continue to exist well beyond the time horizon of this study.

(iii) Changes in the composition of food demand

Changes over time in the structure of food demand are brought about by two main factors, income growth and urbanization. A third factor that could have some impact in the long term is the increasing shortage in fuelwood.

Along with economic progress and rising income levels, demand tends to shift to higher quality food. Preferences are high for animal products (meat, milk, eggs and poultry), fruit, vegetables and certain types of cereals. These commodity groups are likely to benefit most from shifts in food demand related to income growth. Indirect effects will be felt in terms of ir those commodities that serve as animal feed (pastures, certain cereals and fibres).

Urbanization tends to produce similar shifts in food demand. Favoured by this trend are those commodities that lend themselves - in technical and economic terms - to storage, handling, transport and/or processing, particularly cereals. Trends are accelerated by trade and aid. A spectacular example for such developments is the increase in consumption and demand for wheat and rice.

Projected rates of urbanization and projected shares of urban population indicate the magnitude of the potential impact. Both vary substantially among regions. In 2025 South Asia - despite its high rate of urbanization of 2.3% - is expected to occupy the low end of the spectrum with 40.7% urban population, while Temperate South America will be at the high end with 92% despite a low rate of urbanization by then (0.2%). Most regions in Africa occupy the middle ranks with estimated shares of urban population between 50 and 60%.

The evolving patterns of demand are in a number of cases not compatible with the regions' production potentials and current cropping patterns. The most striking example again is wheat with high levels of current and projected demand and close to no production potential, at present levels of knowledge, in the lowland tropics. Trade is likely to provide only a partial answer, for well known reasons.

This discrepancy represents a true challenge for research. The issue is to create the conditions over time for narrowing the gap between demand and production potentials. The magnitude of the problem would appear to justify in the long run a sustained research effort conducted from two sides. One would be directed at adapting over time, with the help of the latest advances of science, those crops of high demand to regions where at present levels of knowledge they do not have a comparative advantage (e.g. tropicalizing wheat). The other would be directed at increasing over time the attractivity to the consumer of those crops that do have a comparative advantage in terms of regional production potentials but in view of other characteristics of the commodity compete less favourably on the markets.

This spirit of competition is healthy, productive and fully in line with the spirit of the CG System. Probably it has even accounted for some of its success. Obviously, in terms of resource allocation to such efforts one has to keep in mind the need for balance between the pressing needs of today and the potentials for tomorrow.

In addition to the type of changes in the structure of food demand urbanization tends to increase food processing requirements. The food production process grows longer and more complex. This obviously has implications for research.

The third and final factor that may have long term implications for the structure of food demand is the energy crisis. According to present estimates the number of people without adequate fuelwood supply is expected to rise from 1,395 million in 1980 to 2,986 million by the end of the century. The magnitude of this problem is such that it is likely to have some impact on the evolving structure of food demand.

The final conclusions of this discussion on long term changes in the structure of food demand and its implications for research requirements are by no means clear. Clear are the trends of projected changes in food demand. They will be directed towards quality food, particularly animal products with important implications for feed grains, pastures and other feed stuffs. They will also favour fruits, vegetables and the two main cereals. Among the roots and tubers the potato is likely to maintain its upward trend. Processing of food will be an area of increasing importance.

The implications of these projections for research and technology requirements are manifold. Three main thrusts will be required:

- sustained efforts at further improvements in yield potentials and stability particularly for those commodities most favoured by long-term changes in the structure of food demand resulting from population growth, urbanization and income growth;

- efforts at further improving the post-harvest characteristics of many of the commodities (storability, etc.);

- efforts at the development of improved technologies in the post-harvest area (processing, etc.).

By far less clear are longterm shifts among commodities competing for consumer preferences (and feed of course). Interesting examples of such competition in specific target areas are those of millet, sorghum and maize in the semi-arid tropics, of maize and cassava in large areas of the tropics and of rice, wheat and other cereals in the temperate zones. The long term evolution of comparative advantages and the resulting chances of success in the competition among commodities for food and feed markets will obviously depend to a large extent on the success of research programmes.

3.2. Evolving research needs and changes in CG priorities resulting from the long run scenario

The discussion of a long-term scenario for world agricultural developments has pointed to a number of developments and trends that have important implications on technology requirements and research needs. It has also confirmed that, while many issues of the past and present will continue to be relevant, the future is not a simple extrapolation of past trends.

The main findings in this discussion have a bearing on some of the central issues relating to the future of the CG System. They confirmed:

- a continued need for the CG System as an important component of the global system of agricultural research efforts for the developing world;

- a need for reassessment of the System's future functions within the global system in the light of evolving needs and capacities of the other components of this System;

- continued validity of most of the points that characterize the CG System and that determine its comparative advantage;

- continued relevance of the System's basic orientation, its focus on commodity improvement and the removal of constraints, particularly technological but also institutional, to food production and productivity;

- a need for reassessment of priorities with regard to the System's commodity coverage;

- a need for reassessment of the System's priorities in terms of major research thrusts:

  -- on different agro-ecological zones

  -- on different production ecologies (irrigated vs. upland)

-- on different intensities of resource utilization and levels of technology

-- on different levels of NARS development

-- on upstream vs. downstream activities

-- on efforts at further increase of yield potentials vs. the reduction of yield gaps.

This chapter looks at evolving research needs against the background of evolving research potentials and capacities within the global system. It attempts to define the long term priorities for the CG System. In doing this TAC is conscious of the need to arrive at an optimal division of labour and complementarity among the various components of the global system in accordance with their changing strengths and comparative advantages. It is mindful of course of those specific characteristics of the CG System that contribute its strength, its specificity in purpose, its catalytic role, its concentration of effort, its limited size and capacity, its selectivity.

This discussion concentrates on the following areas:

1. Need for high productivity of resources
2. Service to NARS - the evolving long-term functions of the CG System
3. Greater involvement in basic and strategic research - the upstream function
4. Protecting yield gains - maintenance research
5. Research demands related to the production of quality food
6. Research related to the use and conservation of natural resources.

3.2.1. High productivity of resources

Future technology requirements of developing countries obviously are the primary factor in determining the direction of future research thrusts for the CG System. The preceding discussion has shown some likely trends in technology requirements. Demand for technology will tend to increase. The range of technologies needed will broaden. Technologies required will be more complex, more site-specific and more responsive to specific agro-ecological as well as socio-economic circumstances.

Improvements in resource productivity and in resource utilization will be an area of high priority. Resource efficient technologies will be required for a broad range of conditions, including varying levels of input use. Although the long term trend clearly points towards a general increase in intensity and input use, the velocity of change is likely to vary among regions, countries and crops. Hence the need to cater for a broad range of conditions.

Related to this thrust is the need for increased efforts towards improving the cost-efficiency of the production process by means of supplementing and eventually substituting the traditional inputs, in particular agro-chemicals, by alternative biological solutions.

Past research attention has concentrated essentially on areas of high impact potential and short-term pay-off, i.e. on production technology for irrigated and favoured upland conditions. Major success stories are limited therefore to those conditions.

For the reasons mentioned earlier a concentrated effort will now be required to deal with the more difficult areas in terms of agro-ecological and socio-economic constraints, in particular rainfed agriculture in the more difficult environments. Despite a substantial increase of effort needed in this area, the need obviously persists for an appropriate balance of resources allocated to both conditions. This balance will be influenced by a number of considerations, such as:

- The magnitude and urgency of the problem, which will strongly affect the allocation of efforts among regions in view of their differing population pressures and production potentials;

- Expected impact in terms of the potential contribution to development in both favoured or unfavoured areas;

- Expectations of impact and pay-off in both the short and long term. For the obvious reasons a shift to more difficult areas would tend to increase the time horizon of impact expectations. Yet, the System continues to need results in the short and medium term;

- Recognition that contributions of the private sector, if any, are likely to concentrate on high potential areas. It will remain for CG-supported efforts in collaboration with NARS to cater for the needs of unfavoured areas including attention to the problems of the resource poor farmer.

The future strategy for the System's work on productivity improvement would continue to be based on the commodity approach. In order to accommodate the new thrusts, the present approach to commodity improvement would have to be broadened in four respects.

First, the research agenda would have to be expanded to include more specific attention to particular environmental constraints to commodity improvement.

The second concerns an expansion in the scope of commodity improvement work. The commodity focus would be broadened beyond the traditional concerns with the crop per se and shift towards a more

comprehensive concern for total biomass production and utilization. This would mean looking at such issues as post harvest concerns, potentials for recycling of biomass, the utilization of by-products, the generation of additional feed stuffs, etc.

The third area concerns the integration into productivity improvement programs of additional objectives and concerns. These concerns relate to five major groups of factors mentioned before:

- Ecological concerns related to gene and soil erosion, desertification, pollution, etc.

- Energy concerns related to the dependence of fossil fuels, the neglect so far of renewable energy, etc.

- Economic concerns: high cost of inputs; need for subsidies; difficulties in developing and applying pricing policies which stimulate production and consumption; cost, risk and pay-off to technology generation.

- Employment: Are the new technologies likely to lead to a famine of jobs?

- Equity concerns: Are the technologies generated neutral in terms of socio-economic indicators or do they have built-in seeds of discrimination? Are women adversely affected?

Most of these concerns are becoming increasingly relevant in most countries and should be taken into account in the development of future technologies. At the same time the issues of scale neutrality and resource neutrality of technologies need to be considered. Public policies may be required to enable all farmers irrespective of their innate input mobilizing potential and risk taking capacity to profit from new technologies.

The fourth and final area concerns an enlargement in the scope of the tools used in conducting research on productivity improvement. This will increasingly include the application of the newest tools of advanced science comprising such areas as biotechnology. The application of these tools will be built into the research process within the overall framework of commodity improvement.

On balance, therefore, the traditional commodity focus would thus move towards a more comprehensive approach taking due account of the additional concerns and research objectives. It should be stressed, however, that the proposed shift in focus to more difficult areas which require new research tools will undoubtedly imply lengthening the time-frame of the research programs and hence a slower pay-off.

3.2.2. Service to NARS - the evolving long-term functions of the CG System

The preceding sub-chapter has shown how changes over time in research needs and research potentials within the framework of the global research system influence CG priorities. This sub-chapter looks at the effects of those changes on the future role of the CG System within that framework, its evolving long-term functions and the development of future relationships with NARS.

All CG activities directed towards technology generation, the strengthening of NARS and the removal of important constraints in the economic, policy and institutional areas are oriented towards NARS. This implies, of course, that NARS' future needs are the key determinants of the future direction level and intensity of IARC/NARS collaboration. Hence the need to conduct the planning process which will lead to future programs in a spirit of true collaboration following the principle of "bottom-up" and involving NARS as equal partners.

This approach is fully in line, of course, with the basic philosophy of the CG System, according to which the purpose of CG System activities is essentially conceived as service to NARS. It also implies the principle of "universality" i.e. openness to collaboration with all NARS seeking such collaboration.

Strategy for future cooperation with NARS. Planning at the System level of future priorities for cooperation with NARS in the areas mentioned is a complex task and further complicated by the fact that present differences in the strength of national research systems will continue to persist or even grow. NARS will differ in the progress made in bridging the gaps between potential and actual yield at given levels of available technology and they will differ regarding their needs.

To give an indication of their needs, developing countries can be broadly grouped under the following three categories using the yield gap analysis method:

(i) Group I LDCs. The gap between actual and potential yields is low. For example, in China the average yield of rice is now about 5 t/ha, while the potential yield is about 6 to 7 t/ha. In such countries the needs are for: (a) raising the ceiling to potential yield further, a factor which influenced China to take to hybrid rice in a big way and (b) achieving stability to yield through greater attention to soil and plant health care and to contingency planning to suit different weather conditions.

(ii) Group II LDCs. These are countries where the current national average yields represent about 30 to 50% of what can be achieved. In India, for example, the current average yields in wheat and rice represent abut 40% of what can be realized with the presently available technologies. But within India, there are areas like the Punjab where Group I conditions prevail. Apart from factors like area under irrigation, input-output pricing policies etc., which influence

the size of the yield gap, there is also the problem of raising the purchasing power and thereby the consumption capacity of the rural and urban poor. Further advances in several Group II countries will depend upon success in developing technologies which can help to generate more on-farm and off-farm employment. This calls for a farming systems approach (multiple cropping, crop-livestock, crop-fish integrated production systems, etc.) in research and testing.

(iii) Group III LDCs. These are countries where hardly 10 to 20% of the potential yields are being obtained at the national level. Many countries in Sub-Saharan Africa may fall under this category, despite the fact that even in such countries, there are examples where in small areas Group I or Group II conditions may prevail. By and large, what is urgently needed in such nations is the undertaking of a multidisciplinary constraints analysis which can help to identify the precise ecological, technological, economic, institutional and socio-political constraints responsible for the gap. A carefully designed malady - remedy analysis will help in the formulation of both short-term and long-term research and development strategies.

This classification is indicative of the diversity of needs that have to be considered in decision making regarding the System's future strategy concerning cooperation with NARS. As a result of this IARCs will have to tailor the components of their cooperative programs to match the needs and potentials of NARS. In short, their approach should be geared to the "multiple choice" principle in response to the diversity of needs, both technological and institutional/socio-economic.

This "multiple choice" approach, while fully in line with the basic philosophy and nature of the CG System in terms of its global approach and the "universality" of access, has two shortcomings that need to be mentioned. One concerns the fact that it does not help those countries where NARS are too weak to benefit. Some NARS may indeed remain unable in the medium term to reach the shelf and grasp the products on the shelf. Center's training programs and specific institution building efforts - the latter led by, but certainly not limited to ISNAR - will continue to play an important role in this respect.

The other concerns the inherent danger of spreading the System's resources too thinly. Excessive diversity in research programs obviously needs to be avoided. Equally, a conscious planning effort will be required to improve a balanced move upstream of the System's total research effort and a parallel scaling down of downstream activities. The projected increases in both quantity and diversity of demand for collaboration is likely to counteract the ideal allocation of the System's resources. Hence the need for planning in favour of the proper balance.

The resulting array of collaborative arrangements is expected to cover a broad spectrum ranging from full partnership to continuing assistance. Obviously this is an area that offers scope for increaed cooperation among NARS with the stronger ones assuming the responsibi-

lity of assisting the weaker ones. Similarly there is ample scope for increased trilateral cooperation involving Centers, one or more NARS and development assistance agencies.

Direction of future research. The twin major blessings of CG System are access to diverse political frontiers and to the vast pool of knowledge and materials available in developing and developed countries. IARCs constitute bridges between knowledge and material pools in developed and developing countries. Their principal value to national research systems in LDCs is their ability to help in appropriate technology development. Their value is likely to increase with increasing commercialization in developed countries of research and research products - techniques and materials increasingly protected through patent rights - with the resulting implications for LDCs' access to such research products. Therefore, they should take the lead in bringing to LDCs the benefits of the latest tools of science - whether it be in genetic engineering or other areas.

At the same time, they should continue their global research support and information dissemination services. Increasingly, they should undertake joint training programs with Agricultural Universities in LDCs. What kind of blend between commodity and factor research that may be needed will have to be determined with regard to the nature of the production constraint to be solved. Flexibility in research strategies will be necessary to maintain relevance in response to the felt needs of LDCs at a given point of time.

The System's overall effort in support of NARS will obviously continue to be concentrated on technology oriented research and the build-up of national research capacities. It will cover the four key areas of activity mentioned earlier: research/technology generation, research support services, training and work on the removal of socio-economic policy and institutional constraints.

All four areas of activity are expected to be important long-term functions for the Centers, in response to continuing NARS needs. While research oriented towards technology generation will clearly continue to be the central thrust, the relative weight among those functions is likely to vary over time. To predict clear trends is difficult, however. The great and yet increasing diversity of needs from a large group of increasingly heterogeneous NARS at different levels of institutional development and differing velocities of build-up of their research capacities makes such predictions difficult. What is needed is a balanced approach with enough flexibility for Centers to be responsive to NARS demand.

The need for specific institution building efforts is likely to increase further in the medium term, presenting a broad range of opportunities for cooperation among the NARS concerned, the CG-supported service for the strengthening of national research systems, other IARCs and multilateral as well as bilateral development assistance agencies. In the long term the needs for specific CG-supported efforts are expected to return to more normal levels. By then mechanisms should be in place - in the form of networks or other arrangements - to facilitate

cooperation among NARS with the backstopping of CG System and other efforts.

The need for training is likely to continue at sustained levels. Demand for IARC training is expected from a broad range of NARS for an even broader range of subjects. Orientation and contents of training programs will, for the obvious reasons, tend to move along with research.

The System's long-term linkage function. All along, in conducting their research, training or institution building programs in the pursuit of their primary objectives, IARCs have generated, sometimes as a by-product of the process, a number of linkages. Such linkages occur at various levels and intensities. They tend to connect all those involved in the technology development process, NARS, IARCs, advanced research institutions throughout the world, and technical assistance agencies. These linkages were both necessary and useful in the past; they will be crucial in the future in the light of developments described.

The success of future technology development will increasingly depend on adequate supplies of basic knowledge from advanced institutions around the world in either the public or the private sector. The building and up-keep of bridges linking NARS (and others) with the sources of basic knowledge will hence continue to be an essential function of IARCs.

While in the short to medium term the effects of this linkage function will be a temporary filling of the existing gaps in research potentials, the long term objectives are obviously directed at an eventual reduction and closure of this gap. This implies that over time the bridges will move upstream. A number of success stories of national systems appear to confirm this trend. Yet, in the large majority of cases sustained efforts will be needed to achieve this goal and avoid a widening of gaps.

The scope for IARC activities in the area of linkages is considerably broader, of course, than the building of upstream bridges per se. There will be ample opportunities for Centers to play an important catalytic role in stimulating cooperation among the potential partners in the research process, in mobilizing support in terms of resources and research capacities required, in integrating activities towards a common set of goals and in orienting the efforts of potential contributors towards the key problems and constraints identified. In short, IARCs will continue to have an important function for some time to come in linking technology development and basic science and in helping to direct adequate attention to the key problems.

As regards the operational implications of this long term linkage function it should be stressed that this activity, while clearly part of Center's service function to NARS, needs to be closely linked to research. Just as in the case of training its success will largely depend on relevance, level and quality of the centers' research programs. Hence networking arrangements and other linkage modalities

used to increase the effectiveness and promote horizontal as well as vertical cooperation need to be based on sound research programs of high scientific calibre. They clearly could not be perceived as simple logistic functions of facilitating contacts and networks. The emphasis needs to be on the quality of contents rather than on the functionality of mechanisms.

3.2.3. Greater involvement in basic and strategic research - the upstream function

The issue here is to determine the System's long term strategy with regard to the level of its involvement in the research/technology generation process, i.e. to define those areas in the overall process (in terms of levels I to IV) on which the System intends to concentrate its efforts. A discussion of this issue obviously involves consideration of evolving research needs and expected shifts in the comparative advantage of all partners involved in this process.

With regard to research needs, all three areas of effort, namely (a) reduction of yield gaps, (b) defense of attained yield levels (maintenance research), and (c) work on further development of yield potentials, compete for CG attention in response to NARS demand. Demand for cooperation in all 3 areas is expected to continue at high levels from a large group of vastly heterogeneous NARS for some time to come.

Yet, the progressive strengthening of NARS will allow the gradual transfer of downstream activities, thus eventually freeing CG capacities for other, including upstream, functions. Obviously there will be practical limitations to that transfer process: a continued high level of demand from NARS, particularly the weaker ones. To help solving this problem Centers may require a deliberate strategy to facilitate this transfer process. Collaborative research networks involving different NARS at varying levels of research capacity have been recognized as a useful modality for facilitating this transfer and for involving the stronger NARS in the process of strengthening the weaker ones.

This gradual transfer of downstream functions should allow Centers to eventually shift resources to high priority areas such as creating the conditions for future breakthroughs. The pressing needs for further advances in yield levels were stressed before, particularly for the more difficult areas. Work should start soon to prepare the basis for the next technical revolution.

This obviously requires the build-up of a sound basis of relevant basic knowledge. Yet, it appears that present knowledge reserves in the relevant areas are limited and adequate future supplies from the traditional sources (DCRCs) are not guaranteed. Sources in the private sector are not likely to become easily available, for the reasons mentioned. Hence the need for IARCs to give active consideration to this vital area.

The kinds of issues involved concern the full range of ecological constraints, i.e. constraints related to production factors (soil, water, energy) as well as constraints related to pest and disease

incidences. The kinds of activities concerned are fundamental physiological and biochemical studies of pests and diseases, of host/pest and host/disease interactions, as well as genetic engineering, wide crosses, embryo rescue, specificity of gene action to improve plant resistance/tolerance to biotic and abiotic stresses.

All of these research areas obviously are complex, risky, cost-intensive and possibly slow in terms of time requirements and pay-off. Yet, they should be considered within the broadened framework of IARC's commodity focus.

As regards the optimal strategy for dealing with these issues, it appears that the Centers' present approach is fully appropriate and should be continued. They essentially rely on collaborative arrangements with whatever qualified institution has the relevant capacity and is available for such collaborative ventures (DCRCs, universities in either LDCs or DCs as well as private sector institutions). In this case Centers essentially play a catalytic function, articulate the problem, attempt to stimulate the interest of others and mobilize the appropriate research capacity. The bulk of funding normally comes from other sources, such as bilateral donor agencies. In some cases Centers provide the seed money, in others they will have to fund the entire project.

An alternative modality, in cases where collaborative arrangements may not be available in future, might be the purchase of specific items of knowledge or technology. This may be the case in areas where private sector institutions have produced the research results required but protected their findings through patent laws.

Yet another alternative, of course, is for Centers to conduct the research required. This would imply considerable investment in equipment, staff and operating costs. Such investment could be shared among several Centers where the type of problem lends itself to inter-center cooperation. This is likely to be the case in a number of areas, where common constraints cut across several Centers' programs. The kinds of research in question could concern the mechanisms of salt tolerance in cereals, the mechanisms of plant resistance to nematodes or similar problems.

Whatever the operational modalities may be, Centers will need to continue building up and maintaining the expertise and knowledge base that is needed to monitor attentively latest developments at the cutting edge of science and utilize their products. They will need to remain at the forefront of science if they are to discharge successfully their long term function of linking basic science with technology development and of directing basic research towards important issues in technology development for the developing countries. Hence the need to move upstream. This move is well under way at certain Centers. Its velocity will vary among Centers, depending on needs and opportunities. It is important to note, however, that in the light of developments in basic science and institutional changes - the increasing weight of the private sector and patent laws - the possibilities of free riding are likely to diminish further and the dangers for late comers are likely to increase.

3.2.4. Protecting yield gains - maintenance research

Intensive agriculture, characterized by high yields is the result of a delicate combination of improved germplasm, industrial inputs and management. It is well known that with the narrowing of the gene base the resistance to pests can and does break down as a consequence of pathogens' genetic variability. Additionally, soil and water supplies may deteriorate under intensive use and negatively affect yield levels. For these reasons the protection of high yields obtained under intensive agriculture tend to require a substantial amount of research and monitoring.

The kinds of work involved include a range of activities:

- a continued process of germplasm characterization, evaluation and documentation;

- identification of new sources of resistance/tolerance;

- incorporation of new genes into parental/carrier lines for use by breeders;

- adaptation to specific needs of broad agro-ecological conditions.

This is a complex process which involves the utilization of results of basic research. So far it has been carried out by IARCs in collaboration with NARS. The rationale for IARC involvement is obvious. Their comparative advantage is based on their free access to a global pool of knowledge and materials available across diverse political frontiers, on their free (with some exceptions) transferability of materials and on the existence of a monitoring system which allows speedy action in the case of need.

Future trends in NARS/IARC cooperation in this area will be influenced by two factors. One relates to increasing research needs as a result of intensification trends in world agriculture. The other concerns the development of NARS capacity. The latter will allow the transfer of an increasing share of total research needs to NARS. Yet, total needs are likely to be high and the number of countries that cannot yet absorb this function will remain substantial for some time to come. Hence the continuing need for the CG System to set aside some of its resources for this type of activity. This will obviously imply hard choices in view of competing demand for these resources from other priority areas.

3.2.5. Research demand related to the production of quality food

Obviously expected trends in world food demand are a useful indicator of future research needs. Considered in conjunction with a number of other factors they will indicate the type of shifts required in research priorities to respond to future needs of production technology.

A preceding chapter (3.1.4.) briefly looked at the evolving structure of world food demand and discussed some of the main factors determining changes in that structure: population growth, urbanization and income growth. It also considered some of the factors affecting the availability of food to satisfy demand, adaptation of production potentials, with the help of research, as well as trade and aid.

Expected trends in food demand point to increases of high quality and high density foods, particularly animal products, fruits,vegetables, and certain cereals. They point to changes in the post-harvest characteristics, to processing requirements, to an extension of the production process.

As was mentioned above, any assessment of future research needs and the resulting long term commodity priorities for the CG System will have to take into consideration, apart from trends in food demand, a number of additional factors. Such factors could be the indicators used for the short term assessment of priorities. It is obvious, however, that such a procedure would tend to reiterate many of the biases inherent in the System. A broader view should therefore be taken of CG System objectives, potentials and research needs, reflecting the changing conditions in world agriculture.

This implies defining more broadly the System's goal structure. The System's target groups will obviously include - explicitly - the urban consumer in addition to the farming population. Its target commodities should be defined more broadly to include crops used as animal feed as well as the by-products of the production process. The trends towards intensification of agriculture and high density commodities will make this necessary. Similarly, the trend towards commercializing agriculture will increasingly convert food crops into cash crops.

Expected trends in long term food demand will have varying effects on CG research needs. In the following paras the main commodity groups are briefly reviewed with regard to likely trends in CG System research demand.

Cereals. Global long term demand for cereals for both food and feed is expected to grow substantially on account of population growth, urbanization and income growth. Rice and wheat are likely to remain the world's two most important staples for a long time. Other cereals too, particularly maize and sorghum, are expected to face substantial growth in demand for food and feed.

Research needs are equally impressive. Important efforts are required on a number of fronts: (a) work on specific constraints in the more difficult areas in order to realize the full yield potential of existing genotypes in specific environments, (b) the defence of yield gains, (c) work towards new frontiers in terms of yield potentials so as to prepare the next quantum jump in cereal yields.

While an increasing share of this work will be done by others (NARS, DCRCs and the private sector) CG involvement is essential at sustained, high levels, to stimulate such work and integrate the various efforts. CG efforts are likely to shift among regions, commodities and levels of emphasis (upstream). Yet the overall effort should be maintained at present high levels. The tendency should be to concentrate increasingly on the constraints of tomorrow, gradually shifting the other functions to NARS.

Roots, tubers and starchy foods. Long term growth in global demand for this group of commodities is likely to be moderate. Much will depend on progress regarding post-harvest technology for use as both food and feed. While its share in global food demand is likely to decrease on account of urbanization and income growth, demand for feed purposes is likely to increase. Obviously, there will be important differences in trends among the individual crops and among the regions. In some regions, particularly Africa, this group will maintain an important share in diets for some time to come. And some of the individual crops may continue their upward trend (e.g. the potato).

Research needs and potentials are much influenced by the importance of some of the commodities as key components of sustainable cropping systems in some regions, by the fact that most crops have a rather short research history with little work done elsewhere, and by the open questions concerning the potential impact on post-harvest technology. An additional consideration of some importance is the need to maintain on a global basis the basic variety of diets.

The CG System effort would be expected to continue at present levels for some time with important shifts among commodities, regions and the direction of research thrust. In the longer term, as NARS grow stronger, much of the work on roots and tubers should be transferred to NARS with a resulting decrease in CG involvement.

Livestock products are expected to face substantial demand increase resulting chiefly from income growth, to a lesser extent from population growth and urbanization. Growth rates will vary among regions and will affect all species/commodities of interest to the CG System, i.e. beef, milk and small ruminants. Induced demand will strongly affect the need for pasture improvement (intensification of pasture use and development of integrated production systems) and production of feedstuffs (cereals, roots and tubers, and pulses, including their by-products). It will equally affect rural production systems in terms of drought power, manure and other by-products.

The CG System response to this trend would be expected to benefit those areas not adequately covered by others for which it has a comparative advantage, i.e. the improvement of livestock-based production systems in areas with limited alternative opportunities. It would continue to concentrate on beef, milk and small ruminants assuming that poultry and swine continue to be adequately covered elsewhere. It would equally concentrate on pasture development for those areas where an impact is likely in the light of other developments competing for land, in particular marginal lands.

In view of high demand for this type of technology which the CG System is working on, particularly for production systems in marginal areas, a sustained CG System effort will be required. Obviously the situation needs to be reviewed in the light of developments regarding the animal disease situation in Africa.

Pulses. Long-term trends of growth in pulse demand appear to be moderate, essentially in line with population growth, with limited effects of urbanization and income growth. Most of the present factors determing the importance of this group of commodities are likely to keep their relevance. Pulses are likely to maintain their role as an important supplement to cereal-based and other diets, representing a low cost alternative to animal protein. They will equally maintain this role as providers of green vegetables (to a limited extent), animal feed (essentially the by-products), fuelwood (principally pigeonpea) and soil nutrients through biological nitrogen fixation. Their global importance as a group is based on essentially regional crops, with the exception of field beans and groundnuts.

Research needs are influenced by the relatively short research history, of this group, by the apparent potential of substantial gains in productivity, by the fact that research elsewhere is limited so far (with the exception of the oil producing pulses) and by the expectation that pulses will continue for some time to be essential components of cropping systems in low input agriculture. The continued relevance of this latter aspect at the global level in the long term will obviously depend on a number of external factors, such as energy prices.

The CG effort devoted to pulses as a group should therefore be maintained at present levels. In the short run a minor increase could be justified to even out regional imbalances in reseach coverage (e.g. better coverage of African research needs in bean technology) and to bring up to comparable levels of effort those species that presently have a limited regional importance. This would allow determination for most species of their future potential and long-term role in both their regions of traditional use and in new areas where with the help of research they might build up a comparative advantage.

Tropical vegetables. Long term growth in demand is likely to be influenced by all three factors, population and income growth as well as urbanization. Important parts of global research needs are expected to be covered by AVRDC, with the bulk of efforts being directed towards Asia. On the other hand, an increasing share of technology development and diffusion, particularly for those species with global distribution and large market shares such as tomatoes and onions, will be taken over by the private sector. In view of rising demand and in the interest of contributing to an improvement in nutritional balance, a supplementary CG effort would appear to be indicated. Such an effort would be closely linked and strictly complementary to the AVRDC program, it would focus on needs in Africa and Latin America and would concentrate on those species that are important but not adequately covered elsewhere.

Vegetable oils. Global trends in long term demand are clearly upward; so are the trends of production, with much of the expected increase coming from large scale commercial operations - partly based on small holder schemes. Technology requirements are essentially taken care of by "others", national as well as international organizations in both the public and the private sector. These concern both the main perennials (oilpalm and, to a lesser extent, coconut) and the main annual crops (soybean and groundnut). Hence the scope for additional CG System initiatives beyond maintaining its fully justified involvement in groundnut improvement is limited.

While the CG System might have a role to play in the improvement of a number of relatively minor species not adequately dealt with elsewhere, in the context of an expanded regional focus, the limited global importance of these species would not appear to justify spreading the System's already thin resources even further.

3.2.6. Research related to the use and conservation of natural resources

Existing trends towards resource and environmental deterioration clearly are the cause of serious concern. Intensification of agriculture and the expansion of agricultural frontiers will reinforce these trends. The kinds of issues involved relate to:

- use and conservation of natural resources, i.e. land and water management to avoid irreversible losses;
- management of large river basins (Amazon, Nile, Ganges, etc.) in terms of long term sustainable production;
- the problem of fuelwood. In large parts of the world this issue is reaching dramatic dimensions;
- long-range socio-economic and ecological consequences of large scale loss of tropical forest cover.

All of these issues are long term in nature, transcend national boundaries and go well beyond the scope of food production. They represent pressing needs and call for urgent action.

A similar set of issues of global relevance concerns the economic and policy sphere of food production. Here the kinds of issues involved relate to the design of sustainable patterns of food trade, the attainment of food security and the solution of pressing problems caused by massive growth of food import requirements.

Action is needed at various levels. At the global level there is need for concerted international action which may help to orient and coordinate appropriate research agenda on global resource problems. Such action would equally contribute towards reaching consensus among

those concerned on priorities for both research and action programs. It would help to focus larger efforts on environmental problems through increasing public awareness, promoting action and facilitating linkages among the various parties.

At the technical level needs are for the design and execution of appropriate research programs which address the key issues. This will require both specific research programs on specific environmental problems as well as research efforts focussing on specific environmental or resource issues in the context of commodity production.

As regards the potential role of the CG System in this area, it is obvious that action requirements at both levels go well beyond the System's present scope and capacity in terms of size, structure, and resource endowment. Yet, in the light of needs it should have a continuing role to play. It would be expected to cooperate with NARS and those international organizations that have the lead in the respective fields, in an effort to raise awareness and to orient action programs into the appropriate direction.

Areas for IARC involvement would be to cooperate with both NARS and others in the planning and design of appropriate research programs. This would involve problem identification, program orientation, the designation of executing agencies, as well as facilitating linkages among all partners involved (NARS, donors, etc.). It should be noted in this context that Centers have been involved in such activities at the regional level.

In the somewhat narrower context of agricultural research and technology generation, i.e. the System's area of activities and comparative advantage, IARCs will obviously have a leading role to play in promoting and facilitating the development of environmentally sound technologies.

Many of the research activities relating to the issues mentioned lend themselves to cooperation at the regional/subregional level, cutting across national boundaries as well as commodities. This appears to offer ample scope for inter-center cooperation in collaborative ventures with NARS and other specialized institutions. This seems to be an area where IARCs, particularly those with an agro-ecological zone focus can make important contributions without necessarily going beyond their comparative advantage in commodity research.

3.3. Some organizational implications

Changes over time in priorities and functions tend to have organizational and resource implications. Adjustments are likely to be required at various levels to remove possible constraints to the implementation of long term objectives. They concern broad concepts, organizational structures as well as management and operating procedures.

The purpose of this chapter is to review some of those implications and identify the kind of adjustments that would be required to facilitate implementation of changes envisaged in the System's long term priority structure. In accordance with TAC's comparative advantage which clearly lies at the conceptual or strategic level rather than that of management and operational procedures, this chapter concentrates on three issues of strategic relevance:

1. Flexibility to adjust to diverse and changing needs of NARS;
2. The center of excellence concept;
3. Inter-center cooperation.

It should be noted at the outset that some of the adjustment processes are already well under way at several Centers. The issue then is one of reinforcing ongoing trends rather than starting from zero. This proves two things, that for the CG System in some respects the long term has already started and that the borderline between long term and short term is rather fluid. Processes of change tend to occur stepwise.

3.3.1. Flexibility to adjust to diverse and changing needs of NARS

Discussions in the preceding chapters pointed out the increasing diversity of NARS, the varying velocity of their institutional development and the resulting increase in the diversity of demands from NARS facing the Centers. The range of demands for cooperation is likely to increase further, with the more advanced NARS requiring cooperation at the middle and upper levels of the spectrum and the weaker ones demanding cooperation at the lower end. The obstacles to scaling down and eventually phasing out downstream activities were mentioned as well as the needs for increased IARC involvement in upstream activities.

The central issue has been and will continue to be competing demands at various levels in the research process with the resulting difficulties for Centers in making choices between pressing needs and opportunities. What is needed is to create the conditions which will allow Centers to respond to the need for change and to move forcefully towards the important problems of tomorrow while satisfying the pressing needs of weaker NARS.

To achieve the kind of flexibility required several measures will be needed. Increasing use will undoubtedly be made of the mechanisms already discussed to facilitate and accelerate the transfer of downstream functions to NARS (networking). Funding mechanisms tend to be a useful instrument to facilitate change, e.g. the use of fixed-term funding for specific research programs/projects. Finally, additional resources will probably be required for fixed periods of time to allow the implementation of program changes before the corresponding amounts of resources have been freed elsewhere from activities to be phased out.

3.3.2. The center of excellence concept

Several of the long term trends discussed earlier in this chapter regarding evolving functions and activities of IARCs in the research and technology generation process imply the maintenance of strong science based units at the Centers. Only strong multi-disciplinary teams, linked to institutions of basic research, will be able to perform the increasingly complex functions of properly serving the needs of their clientele. Hence the confirmation of the center of excellence concept with the implicit move upstream.

The velocity of this move upstream will obviously be center specific. It will depend on the commodities in question, the region served as well as developments related to the build-up of NARS' capacities. There will essentially be three inter-related developments or trends.

The first, concerning the short and medium term, is likely to reinforce past and present trends towards decentralization of Centers' breeding and agronomy programs which has resulted in rapid growth of outposted staff. This increase in outposted staff is expected to continue for some time. It is an effective way for Centers to serve their clients on a regional or subregional basis and thus to take charge of their mandates. The functions thus performed are essentially at level III with some (decreasing) involvement at level IV.

The second development, concerning the long term is a reversal of this trend. The transfer to NARS of downstream activities related to site-specific activities and the creation of collaborative networks would be expected to allow greater concentration of resources at headquarters. This would serve as basis for the performance of the kinds of service functions to NARS mentioned earlier, including of course the maintenance of germplasm collections, research-based training programs, etc.

The third development, likely to take place simultaneously, concerns the long term trend towards the decentralization of plant breeding. Future plant breeding, at high levels of science, will increasingly be taken over by NARS with an important involvement by IARCs.

This trend towards decentralization in plant breeding - already far advanced for certain crops - will undoubtedly be favoured by two factors:

- The recognition that the concept of "wide adaptability" is likely to give way eventually to breeding for closer local adaptation. This trend is likely to be reinforced by the move to rainfed areas. Wide adaptability has been a useful strategy for the early phase of the Green Revolution, and it justified the large-scale centralized breeding programs; but these will be less suited to the next phase of greater emphasis on local adaptation;

- The consideration that the building of an increasing number of objectives into breeding programs works well up to a point and then becomes cumbersome, so that some objectives begin to suffer and smaller local programs become more effective.

These decentralized breeding programs increasingly handled by strengthened NARS and linked through networks will place a heavy demand on Centers in terms of the functions mentioned earlier, i.e. germplasm, research methodologies, basic knowledge, training, information and facilitating linkages with basic research institutions. Centers' capacity to respond or even lead this process will determine to which extent they are able to maintain the status of true centers of excellence.

3.3.3. Inter-center collaboration

It appears that past and present trends, pointing to growth in inter-center collaboration are in perfect harmony with likely future trends and oportunities, resulting from long term objectives and shifts in functions. The trends are expected to continue in the future. What will change are contents and levels of cooperation: the level will move upstream.

Present trends, essentially related to the regionalization of Centers activities at mid- and downstream levels are expected to continue for some time. For the reasons discussed earlier IARC activities at the regional level are necessary in the short run and hence expected to expand. There is ample scope for inter-center cooperation in areas where Centers share responsibilities for commodities in specific regions, in areas where various Centers work on the improvement of research techniques and methods and in those cases where various Centers cooperate with specific NARS in downstream functions.

As in the longer run Centers' involvement in downstream functions decreases and the research process moves upstream, opportunities for inter-center collaboration will shift. Although the research process will continue to be related to commodity improvement and conducted within the framework of an enlarged commodity focus, the opportunities for fruitful cooperation are likely to expand. Numerous basic issues and constraints cutting across commodities and Center programs will lend themselves to joint research action.

Common objectives as well as considerations regarding the high cost in investment and staff time of such operations will favour joint action such as the sharing of capacities, equipment and staff. The formation of joint reseearch teams of a task force type to concentrate on specific problems during a fixed period of time could become a common feature. These teams would obviously link up with external sources of knowledge (and funding) in an attempt to mobilize all possible resources for the solution of the problem.

To facilitate this kind of collaboration a broad range of organizational mechanisms is available, many of which - including contracting arrangements - are being used already at Centers.

This discussion of inter-center collaboration confirms that expected trends regarding the System's evolution in terms of objectives and organizational mechanisms are quite in line with the original concept of the System as a loose federation of independent Centers with an integrated set of objectives. Much in terms of inter-center collaboration has been achieved already without the creation of an "integrated System" and the attainment of future objectives appears to be equally feasible.

3.4 Concluding remarks

This discussion of the likely scenario for the long-term evolution of the CG System has pointed to a number of trends and changes that will influence the System's future priorities. These changes concern both the needs, in terms of technology requirements, to ensure adequate food production in developing countries, and the potentials to deal with these needs, i.e. the total research capacity available to cater for LDC's long-term research requirements.

Trends regarding overall demand for technology point to a dramatic increase, due essentially to the projected intensification of agriculture. Complexities of technology requirements will further increase as production moves into the more difficult areas, particularly under rainfed conditions.

Specific regional needs are likely to have an important bearing on the allocation of efforts. For example the urgent needs of Africa, in the light of that region's pressing food problems, are expected to place a heavy demand on available research capacity for some time to come. Asia's technology requirements, not as pressing in the short run due to good advances made, will equally require attention in view of still persisting rural poverty and high population pressure on the land.

Changes in the global research capacity are reflected by three developments, an increase in the number of actors involved (particularly the growing involvement of the private sector), the progressive development of NARS and the continued evolution of the global research system. All three developments are expected to contribute to a further enhancement of the global research potential that is available to cope with these needs.

As regards the future role and priority functions of the CG System, this discussion of trends points to a substantial increase in overall demand for cooperation from an increasingly heterogeneous group of NARS. This demand for cooperation in the areas of research/ technology generation, training and institution building covers a yet growing range of products and services, well beyond the System's limited size and resource endowment. Hence the System's capacity to respond is

conditioned by the need for continued selectivity and concentration on the areas of its comparative advantage.

In the light of the growing strength of NARS and the progressive take-over by NARS for downstream functions the focus of IARC activities will gradually shift upstream. Along with this move upstream Centers will increasingly be called upon to take on an expanded linkage function. Besides facilitating the linkages among NARS, Centers of advanced science throughout the world, and interested donors, they are likely to play an important catalytic role in stimulating research efforts, in promoting cooperation, in mobilizing resources and in orienting these efforts towards the key problems facing technology development. In short, for some time to come the CG System is expected to make an important contribution in terms of facilitating scientific linkages between the developing world and advanced institutions in industrialized countries and elsewhere.

The implications of these evolutionary trends on program structure, organization and resource requirements indicate the need for a number of gradual adjustments.

The long-term program structure and orientation, determined essentially by NARS needs is not expected to require any major changes. The focus of the research/technology generation process remains on commodity improvement, broadened in the light of additional concerns and increased regional emphasis.

While the System's commodity structure is expected to evolve gradually with shifting emphasis in food demand, the regional distribution of efforts is likely to require more important adjustments over time. These shifts in emphasis may in the longer term have implications on both the concept and actual distribution of IARC mandates. A notion of flexibility regarding operational mandates within time-frames (long enough to justify investment and short enough to allow the kind of flexibility required) could facilitate the adjustments needed.

With regard to organizational implications three trends are likely to emerge, (a) reinforced emphasis on the center-of-excellence concept with the concurrent build-up of some capacity in basic science, (b) a further increase in inter-center cooperation, gradually moving upstream, and (c) continued (or even expanded) emphasis on regional operations, with the same tendency to move upstream.

As regards the future size of Centers, there is no common trend. Developments are likely to be center-specific and determined by such factors as mandated commodities and regions; size, structure and needs of clients (NARS); extent of involvement in upstream areas; as well as any specific functions that might in future be assigned to Centers in the System-wide context. It is assumed, however, that following a period of further growth in the short to medium term which would allow the Centers - particularly the younger ones - to complete the build-up of their programs at both the headquarters and regional level, a kind of ceiling would be reached. Additional or new functions would thereafter

be funded from internal shifts in resources, facilitated essentially through the transfer of functions to other partners in the global System (particularly NARS in the case of downstream activities). This notion of a long-term ceiling has in fact been instituted by a few Centers already.

A final comment on the System's resource endowment - or the problem of choice and balance. The CG System has been conceived as a small group concentrating on a few important areas, fulfilling a catalytic function and assisting NARS by means of filling gaps. It has remained small in relation to the magnitude of the problem. It is minute in relation to expectations of others regarding its performance and impact potential.

The question of size is intimately connected with the issue of reconciling research needs and legitimate demand from the System's partners/clients (NARS) with its performance potential in terms of its resource endowment. This need of reconciling growing demands and limited potentials obviously raises problems of choice and balance at various levels, at the Center level as well as at the System level.

4. ANALYTICAL APPROACH TO PRIORITY SETTING IN THE CG SYSTEM

This chapter discusses TAC's approach to priority setting. It first points out some of the issues involved in such an exercise and then considers the pros and cons of a formal model-based approach. It presents a compromise procedure, using a set of indicators as proxy, which is feasible in terms of data requirements and yet satisfies the need for a systematic analytical approach based on quantitative and qualitative information. It finally discusses the application of this procedure.

4.1. Some conceptual issues regarding priority setting

Priority assessment is a key condition for decision making on resource allocation. The establishment of relative priorities is particularly relevant for the CG System in the light of increasing demand for the System's services and products and the resulting pressure on its scarce resources.

Priority setting in the context of the CG System has been acknowledged repeatedly to be a complex exercise. It involves a variety of issues and considerations at various levels. One of the basic problems is the difficulty of comparing in a systematic manner a set of widely heterogeneous commodities/activities which all relate - in different ways - to the System's objectives and all compete for scarce resources.

Like any other problem of policy choice the key issue here is to relate in a clear and structured manner the activity to be supported and the goals to be attained. This obviously requires a clear definition of the System's objectives, its goals and the weights assigned to different - some times conflicting - goals. It also requires reasonable knowledge about the functional relationship between the activities considered for support and the goals pursued. This presupposes a fairly clear idea about the expected impact of research and other CG activities on the desired goals, in terms of removing specific constraints. The knowledge of both is less than perfect.

There is no doubt that the definition of the System's objectives and its goal structure have evolved over time and gained in clarity and specificity. There has been a convergence of initially less specific and at times diverging ideas regarding the System's goals, the weights assigned to them as well as specific target groups. Yet, the definition of objectives relating to food production, food security, equity considerations, nutritional concerns and others leaves room for potential conflicts and requires further clarification.

Far more limited yet is the knowledge base regarding the linkage between research expenditures and stated goals. The lack of quantitative information regarding those links, the absence of an appropriate data base regarding both research expenditures and impacts as well as the lack of precision already mentioned in the definition of the System's goal structure, are in fact the main reasons for the absence so far of a quantitative resource allocation model.

Such a model would allow rational decision making on the basis of a clearly defined, coherent set of parameters. The outcome of model analysis would of course be subject to complementary discussion based on informed judgement and the collective wisdom of those in charge of decision making.

While recognizing that the application of a complex model in the context of CGIAR priority setting is not likely to be feasible for some time to come, TAC nevertheless feels that a reasonable effort should be undertaken by all parties concerned to gradually improve the data base. This would improve the conditions for both the formal approach based on a coherent analytical framework and TAC's collective judgement.

In the absence of a quantitative model, TAC in its earlier priority reviews essentially relied on a set of criteria to define priorities. Since the majority of criteria available did not lend themselves to quantitative application, those reviews were based on qualitative assessments. The kinds of criteria used can be grouped in four categories related to (a) research needs, (b) research potential, (c) efficiency considerations and (d) impact considerations, especially those related to equity.

4.2. TAC's approach to priority setting

TAC has opted for a formal analytical approach based on a set of indicators to discuss in a structured and explicit manner all those elements that are relevant and need to be considered. It has identified a set of indicators which attempt to relate the System's effort (in terms of resource allocation to specific activities) to the System's goals.

In view of the complexity of the System's goal structure, of the linkages between goals and activities and the heterogeneity of its activities/commodities the set of indicators to be used as proxy had to be fairly broad. They all relate to the System's objectives (either direct or indirect), they are compatible with its basic concept and they address a broad range of priority-related issues. A few of them lend themselves to quantitative analysis, the others are brought in through a clearly structured discussion.

Choice and relevance of priority indicators

In considering the choice of indicators for this priority review TAC was conscious of the need to address in a systematic manner three sets of issues dealing with (a) the direct relations betwen the System's goals and research efforts, (b) the issue of research potentials and opportunities, and (c) efficiency and research productivity considerations.

In relation to the System's goals (food supplies, nutritional concerns and equity considerations) the indicators should address the question of the importance of the commodity/activity in terms of its

potential contribution to the attainment of these goals. They would therefore consider such things as value of production, dietary contribution, present and future gaps, areas cropped, the number of countries producing the commodity to any substantial extent, etc. They would equally address its potential contribution to equity concerns and hence consider such issues as expected research benefits to low income groups (both producers and consumers) and potential impact on productivity and welfare on areas/regions with particular resource constraints (agro-ecological, social, etc.). Finally, they would consider potential impact on such additional concerns as employment and income generation, resource conservation, the generation of by-products, etc. that have been accepted as complementary goals.

As regards the issue of research opportunity and research potential consideration should be given to such concerns as (a) the potential contribution of CG System research to the removal of critical constraints (technological as well as institutional); (b) impact expectations including pipeline considerations, (c) research opportunities including unexploited areas of research, (d) opportunities for breakthrough and the existence of research potential which is likely to yield returns.

Finally a series of efficiency considerations should be addressed such as the existence of a genuine comparative advantage for the CG System to undertake the kind of research in question, the existence of true complementarity of effort with the System's partners, in particular NARS, and the existence of a reasonable level of cost-effectiveness for the operations considered (in terms of resource requirements).

All of the concerns listed are relevant. Their relative importance varies in accordance with commodities, regions and circumstances. As was mentioned earlier, a few of them lend themselves to quantitative analysis; the others - not necessarily less important - will be simultaneously applied in a unified discussion by TAC of each commodity/activity at the global and regional level (Chapter 5).

Quantitative indicators

The three indicators chosen for quantitative analysis relate to:

(i) calory and protein contribution of commodities to diets
(ii) value of production
(iii) trends in yields, production, food consumption and degree of self-sufficiency.

(i) Calory and protein contribution of commodities to diets

There are two basic reasons for using this indicator: (a) It can directly be related to the goal of enhancing the welfare of poor people in developing countries by increased food production/availability of food. (b) It helps to overcome a shortcoming of the second indicator, value of production, which is based on actual purchasing power and does not take into account unequal income distributions in developing

countries. Monetary values, therefore, tend to overrate rich people's food and underrate poor people's food. Dietary patterns, then, may help to identify people's needs which are not properly revealed on markets.

The shortcomings of using dietary patterns to identify priorities in research, of course, has to be acknowledged. It is due to the fact that people's preferences with respect to food do not only reflect dietary contents. People not only buy calories, but commodities and, therefore, dietary patterns will not always reflect people's actual economic behaviour.

This indicator can be used to identify priorities among commodities on a global and regional scale. In Table 2 calory contributions to diets are calculated, and Table 3 presents protein contributions to diets corrected by the amino-acid quality of individual commodities. Table 4 provides the arithmetic average of calory and protein contributions to diets. This presents an approximate but integrated view of nutritional aspects for priority setting. Based on this table, commodities have been ranked according to their global importance and taking into account particularly high regional needs. The information is summarized in Tables 5 and 6.

(ii) Value of production

For commodity-oriented research the value of production is an important priority indicator as it roughly allows to compare the economic importance of different commodities on a global and regional basis. There are two main arguments that support the use of this indicator: (a) It is explicitly derived from the CG System goal to enhance the living standard in developing countries by increased food production. Hence it captures the basic intention of the CG System; and (b) It takes explicitly into account the needs and desires of people as revealed by their economic behaviour.

TAC is aware of course of the fact that the use of prices ideally requires the existence of non-distorted markets and the acceptance of the actual distribution of income and, thus, purchasing power 1/.

A relatively simple way to avoid this problem of price distortions at the national level is to base the calculations on world market prices. These prices more adequately reflect the comparable value of production of given commodities in given countries, independent of their participation in international trade. They reflect people's needs and desires, their actual economic behaviour and opportunities. It is acknowledged, of course, that differring transport costs facing individual countries cannot be taken into account. A certain distortion remains, therefore. Comparability is ensured, however.

1/ The following example of Zaire helps in visualizing one of the problems. For several commodities domestic producer prices have been far lower than the relevant world market prices - the average export unit values. This is particularly true for sorghum, cowpeas, and beans. Hence, government intervention may heavily distort domestic prices from the international level. As a consequence, the value of production based on domestic producer prices would clearly underrate the importance of sorghum, cowpeas, and beans.

The problem related to the income distribution is difficult to solve. Due to the unequal distribution of purchasing power prices tend to undervalue poor people's food and overvalue rich people's food. Correcting prices in this respect clearly is not feasible.

By comparing different values of production, priorities can be identified on a global and regional scale. In Table 1 such figures have been calculated for 12 regions and for all developing countries. The figures refer to the average of 1979/81 and cover individual commodities as well as commodity groups. Constant world market prices - FAO's average export unit values - have been used for the calculations. Based on this table commodities have been ranked according to their global importance and taking into account particularly high regional needs. Table 5 shows the ranking for commodity groups whereas Table 6 refers to individual commodities.

(iii) Trends in production, food consumption and degree of self-sufficiency

Priority setting is a dynamic process which needs to be responsive to change. It should be based therefore on future needs and opportunities rather than past or status quo considerations. Accordingly, to the extent possible future production patterns (in terms of value) and future dietary patterns should be taken into account. TAC has therefore chosen to look at trends of important variables. Past trends, if properly interpreted, represent a first indication of future developments whereas projections directly try to describe future changes.

Yield levels and trends may give good indications of the production of research activities. Comparisons among countries with similar agro-ecological conditions may indicate where research could be effective in overcoming constraints. Increasing trends in yield levels could be a measure of research success, the strength of NARS and their extension services or the importance attached by a government to a crop through provision of incentives and inputs. Static yields may indicate that further research could bring about increases slowly or rapidly depending on whether or not a yield threshold has been reached. Declining yields may mean lack of production incentive or depletion of the resource base. Using yield as an indication of research success or potential payoff from research requires, like the other indicators, sound judgement and knoweldge of the circumstances but they can provide valuable insights.

Another important indicator in this respect is the production trend. It may demonstrate how production structures evolve over time in response to future needs. It may also help to identify past successes of research and research potentials for the future. In Table 7 production trends over the period 1969/71-1979/81 are listed.

In Table 8 consumption trends are calculated for the same period. These figures demonstrate how dietary patterns evolve over time. In addition, they give some insight into the relationship between the nutritional value of different commodities and actual food demand.

To a certain extent, the information contained in production and food consumption trends can be condensed in trends of degrees of self-sufficiency. Such trends reflect the traditional "gap" approach in agricultural research funding. They illustrate the commodities for which gaps are opening and for which they are expected to close.

In Table 8 trends in the degree of self-sufficiency for 1979/81 to 2000 are shown. The data are based on FAO's perception of a year 2000 scenario which uses a modest growth rate both in agriculture and in the overall economy. In its AT 2000 study FAO elaborated policies and measures necessary for agricultural development to be consistent with its scenario. Hence the figures of Table 8 also demonstrate changing gaps in the context of a reasonably realistic development strategy.

In addition to this, past developments of the degree of self-sufficiency have been calculated on a regional scale for some important commodities. This is shown in Figure 1. The figure refers to the period 1969/71 to 1978/81 and underlines the importance of regional gaps by relating them to the regional production level. Obviously the importance assigned to such gaps tends to increase as they refer to regions with a relatively high share in global production. In this case, it would be more difficult to cover regional gaps by trade than in the case of large gaps in small production areas.

In interpreting evolving gaps a word of caution is necessary. There are two different ways of relating changing gaps to research needs. On the one hand, in cases of low degrees of self-sufficiency a widening of the gap may point to the need of increased research efforts. This interpretation is in line with the idea of import substitution which may be appropriate for countries at a very low development stage.

On the other hand, the same situation might indicate a comparative disadvantage in producing the commodity. In this case it would be a waste of resources to fill the gap by corresponding research funding instead of increasing research efforts for other commodities having a comparative advantage. This interpretation is in line with the export promotion argument which is often considered to be the appropriate development concept for countries at a higher level of development. In fact, many success stories of research with respect to non-food commodities point to the fact that comparative advantages should not be totally neglected in considerations concerning the funding of food commodity research.

In any case, caution is required in the interpretation of degrees of self-sufficiency and changes in trends. The interpretation will depend on such factors as time horizon and development stage and requires a sound understanding of the circumstances. Nevertheless TAC considers trends in the degree of self-sufficiency a useful indicator which covers on a quantitative basis some of the dynamic aspects in priority setting.

Regional analysis

While, in accordance with the System's nature and set-up, the resource allocation process is concentrated at the global level, priority assessment clearly requires disaggregation. It can only be meaningful if needs and potentials of regions/agro-ecological zones are given adequate consideration in the context of a balanced discussion.

In the light of this need, all statistical information used in this paper to support TAC's indicator-based discussion of priorities has been presented at both the regional and global levels. This facilitates the simultaneous consideration, based on the various indicators used, of the importance of commodities at the respective levels. It allows the kinds of comparisons required from various perspectives among commodities and regions.

The regional grouping chosen (based on data availability) comprises 12 regions (cf. Appendix). They are composed of 90 developing countries used in FAO's AT 2000 but also include China. Hence, these regions almost entirely cover the world's developing countries. Because of their magnitude India and China represent individual regions. The rest of Asia is aggregated into South-Asia, South-East Asia, and a region comprising dry aras in North Africa and the Near East. Tropical Africa is a very heterogeneous continent with highly different regional needs. This is why four regions have been selected to represent this continent though their magnitude appears to be rather small as compared to other regions. The regions considered are East/South Africa, Equatorial Africa, Humid West Africa, and Semi-Arid West Africa. Finally, Latin America is represented by Temperate South America, Tropical South America and by Central America. Table 10 summarizes some of the more important indicators to characterize the economic and agricultural situation in these regions.

In addition to a set of self-explanatory tables containing the relevant information for TAC's indicator-based discussion at both the regional and global levels, three sets of figures are presented in the Annex. They will facilitate particularly the regional analysis against the background of the global picture. They allow comparisons among commodities and regions with regard to needs, potentials and gaps.

The first set of figures presents a dynamic gap analysis. It relates the relative importance of some principal commodities (value of production shares) in specific regions to recent trends in self-sufficiency.

The second (dealing with groups of commodities in aggregated form) and the third set (individual commodities) describe the relative importance of commodities in their respective regions as well as the relative weight of specific regions in the light of the global situation. They indicate such points as:

- the importance of a given commodity in terms of its contribution to diets in the region;

- its importance in terms of its contribution to the total value of food production in that region;

- the regions' share in the global production and consumption of that commodity.

Finally, a set of tables (No. 14-23) presents some information on the present pattern of CGIAR resource allocation (by commodity and region) and relates present funding levels to the apparent importance of commodities or groups of commodities as expressed by the quantitative indicators (contribution to diets and shares in production value). This will also provide an input into TAC's discussion of priorities.

The use of indicators in priority assessment

For its review of activities for CGIAR support (Chapter 5) TAC has opted for a unified discussion of each commodity/activity. This discussion, building on TAC's collective judgement, will be structured by the use of the broad range of indicators discussed earlier (quantitative as well as qualitative) and will be conducted at the global and regional levels simultaneously. It will use as inputs the information presented in tabular form as well as the Committee's own knowledge base.

5. REVIEW OF ACTIVITIES FOR CGIAR SUPPORT

The pattern for the long term evolution of the System was set out in Chapter 3 and in so doing set the stage for a discussion of the current activities and the changes which would need to be initiated over the next 5 - 10 years to meet the needs that are forecast for the future. The commodities are the centerpiece of the CG System activities but there are as well a number of other activities not directly related to commodities concerned with removing in one way or another some of the constraints inhibiting increased food production and one additional activity considered fundamental to all crop improvement, the collection, evaluation, maintenance and distribution of germplasm.

In the discussion on research devoted to commodities an introduction to the commodity group is given followed by the discussion of the individual crops within the commodity group. After those commodities supported by CG System are discussed, there is a short discussion on some other commodity groups which may merit CG System consideration.

This is followed by a discussion of CG System research and other activities devoted to removing constraints. This is a rather heterogeneous group of activities which are not really related to one another by any common thread. They are supported by the CG System because they point to ways of removing problems not related to commodities directly, but rather to socio-economic and other factors which prevent realization of potential food increase.

There has not been breakout of CG System resources applied to policy research, institution building, farming system research or training but most of the same indicators used for commodities cannot be applied to these activities in the same way as for commodities. Most of these activities and programs have not been in operation as long as the commodity research programs and therefore results are not yet obvious. An additional factor is the problem of what indicators to use in socio--economic research as the linkages between research expenditure and increased food production are even more tenuous than for the commodities.

Lastly there is a short discussion on germplasm.

Thus in this chapter TAC considers all those activities undertaken by the CG System to help increase food production in LDCs and makes an assessment at the relative importance of current activities and of the adequacy of current support. In so doing it considers the feasibility of deleting some efforts and of adding others.

In the consideration of the commodities, indicators were selected, the use of which has been discussed in chapter 4. Suffice to say here that two indicators were used, the value of production of a particular commodity and its contribution to diet, to show the congruence of the current level of funding with each indicator. These were

the only areas for which there was sufficient hard data to try to relate the level of effort with the global importance of the crop.

The use of the congruence of funding with the two indicators assumes that the opportunity for research in the generation of new technology is equal for all commodities and for all regions. However given the fact that the commodities supported by the CG System are heterogeneous with regard to regional importance, research history (stock of knowledge), consumption patterns, extent grown by small, marginal or subsistence farmers, involvement of the private sector, capacities of interested NARS, the dynamics of the crop (strength of demand) etc., bring other considerations to bear on TAC's deliberations at the same time.

With respect to the matter of the data base TAC wishes to record its appreciation for the generosity of FAO in providing the data which has been used. The Centers' Program and Budget documents for 1985 were used as the source of information for the 1983 funding allocations and extra information was provided. TAC appreciates the cooperation of Center Directors in these endeavours.

A series of "rules" were devised to bring some consistency into the presentation and distribution of CG System resources as follows:

- total research and research support funds available to the centers, core and special project, were allocated among commodities and regions following guidance given by the centre;

- farming systems and economics research funds were distributed as appropriate among commodities, recognizing that some of the results of farming systems and economics research go beyond commodities research entirely;

- allocations to genetic resources were distributed among a center's commodities;

- research support expenses were distributed first among regions according to research fund allocation to region and then among commodities according to the proportion of research funds for each area.

Some centers supplied additional information to clarify the meaning of the Programme and Budget distributions and these were of great help. It must be emphasized however that the Programme and Budget documents were the primary source of information. TAC recognizes that some of the results of these distributions may not be accurate and therefore wishes to make quite clear that the distributions given in Table 14 are indicative only. Corrections and explanations based on the actual 1983 Programme and Budget figures for preparation of revised tables would be appreciated.

A final note on the results of TAC's deliberations. TAC has used the indicators and its collective scientific judgement to assess the appropriateness of the current relative effort directed to each

commodity at the global and regional level within a commodity group, and the appropriateness of the global effort directed to each commodity group. Where the Committee considers it appropriate proposals have been made for relative changes in emphasis in the short to medium term taking into consideration TAC's perspectives on the long term.

5.1. Commodity-oriented research

5.1.1. Cereals

Cereals are the most important of all staple crops providing at least 28% to the diets of LDCs and in many regions over 60% (Figure 2a). Over 1,660 million ha, that is over 50% of the world's arable lands are devoted to their culture and they provide directly half of the global food needs, and indirectly through animal conversion, such foods as meat, milk, eggs and other animal products. The most widely grown cereal is rice, produced mainly in LDCs and mainly in Asia. The next are wheat and maize which in terms of global production are almost equal with rice but in LDCs, the two together do not equal the rice total (Table 11). The other cereals supported by the CG System are barley, sorghum and millet which account for about 12% of the LDC cereal production and have significance only in specific regions.

Cereals will continue to be in heavy demand. Increases in demand for rice is likely to parallel population growth in most of the world except for Africa where demand is far exceeding population growth. The demand for wheat is also increasing faster than population growth and this demand is being increased by the large amounts available for trade and its use as food aid. Other cereals, maize, sorghum, millet and barley, will also be subject to continuing demand. The demand for animal products which results from increased income will result in requirements for increased feed as intensification of animal production takes place. Maize, sorghum and barley among the cereals are likely to be under particular pressure to fill animal feed formulations and thus will become income generators for the farmers.

A number of factors contribute to making cereals the global staples. They are easily cultivated as annuals, are easily adapted to mechanization, as grasses they are adaptable to a wide range of soils, climates and cropping systems and the seed is easily harvested, cleaned, stored and handled whether in small quantitites or in bulk.

The most intensive cropping patterns are applied to rice and farmers with under 5 ha may produce 2-3 crops per year. The available inputs are usually first directed to rice, but wheat which is not usually as intensively cropped as rice, also receives more inputs than most other crops with the exception of vegetables. The other cereals in the LDCs are all grown under much more marginal conditions with many biotic and abiotic constraints. Cropping intensity, levels of inputs and production are all much less than the average for wheat or rice. Research station yields are far above average farmers yields for all

crops but most of the constraints facing farmers are location specific and normally not suitable to international effort. Nevertheless there is considerable potential for increased production from appropriately applied current technologies.

It was the recognition of the role of cereals in the global diet and the necessity to increase production in the LDCs which led to the setting up of the first centers with concentration on rice, wheat and maize and the successes amply demonstrate the wisdom of the decision. These crops, paricularly rice and wheat already had a long research history so that the capability of the crops and the centers of expertise were well known.

The addition later of barley, sorghum and millet was done on the expectation that the successes of wheat and rice could be repeated. With the possible exception of barley, these other cereals had a much shorter research history to build upon and so far fewer sources of knowledge and expertise. In addition sorghum and millet are grown in regions where there is no other choice of cereal crop. Nevertheless in spite of the limited CG System history and limited effort in comparison with the major cereals, considerable improvement in the productive capacity of these cereals has been achieved in 10 years and there are excellent developments in the pipeline. However they are grown under rainfed conditions where there is much more instability of environment and greater efforts are needed to increase the stability of yield and in others ways to ameliorate the difficulties of rainfed agriculture.

The main products of CG System cereal research have been two, improved cultivars and a tremendous increase in the research capacity of the NARS. The capacity of NARS of those countries where rice and/or wheat are the chief staples is such that most are now capable or are on the verge of capability of looking after their own cereal breeding and other related research. Their capacity for extension is confirmed by the increase in their national yields. This strength and capacity will allow fairly rapid transfer of many responsibilities for level III and IV activities presently held by the IARCs to these NARS, allowing the IARCs in cooperation with advanced institutions to prepare the way for the next increase in yield level similar to the increase brought about by the dwarfing genes of wheat and rice. Such an increase will be necessary in the future to meet the needs arising from population growth.

The LDC self-sufficiency trends during the seventies show close to self-sufficiency for rice in Asia and a lack of self-sufficiency elsewhere. With respect to wheat, apart from a sharply positive trend in Temperate South America and the increase in India, most other LDC regions are far from self-sufficient with only South Asia having significant increases but from a small base. Wheat is however a surplus commodity produced in temperate climates and is the world's most traded cereal. Most regions are closer to self-sufficiency for maize but apart from Temperate South America self-sufficiency trends have been negative.

The regions where the self-sufficiency trends are most strongly negative for all cereals is in Africa but this is the region where the

roots and tubers largely take the place of cereals and have their comparative advantage. Research on cereals for African conditions has not yet had great success. This is due in part at least to the difficulties of transfer of technologies from other regions and indicates that special efforts are needed for Africa if substantial increases in cereal production are to be realized.

The original level of CG System effort and extending through most of the 70s, has been most intense in Asia where the need was greatest at the time. This effort has also been focussed on the best available growing conditions and availability of high inputs. Under these conditions, spread of modern varieties has been fastest for wheat and rice. During the middle 70s research into cereals was considerably strengthened with the addition of other cereals which started from smaller research base. It was at this time that the research focus began to move more towards Africa. Development of modern varieties has been slower for sorghum and millet but in many cases are only now beginning to appear. As yet, modern varieties are not yet used to any great extent in rainfed agriculture but with new varieties appearing and more in the pipeline, higher and more stable cereal yields under rainfed agriculture are in the offing.

Land suitability (Table 12) shows that for cereals under low inputs there is still considerable potential for all cereals although less for wheat than the others. The same situation holds true for the high input level.

The CG System gives highest priority to the cereals with an allocation of 51% of its resources. This gives a positive deviation by value of production and a negative value by dietary contribution. TAC recognizes the overwhelming importance of cereals but considers that the level of CG effort is appropriate when compared with the level of effort given to other commodity groups and when the total amount of research on cereals by countries and institutions outside the System is taken into consideration. In taking this position TAC is mindful of the fact that because of the importance of cereals much more effort could with benefit be applied to cereals and in the long run they may require increased CG System support.

Rice

Globally rice is the most important crop both in terms of contribution to diet for which it contributes 27% and by value of production. It is the staple food for more people rich and poor than anyother commodity.

Within the CG System rice was allocated US $24,253,000 in 1983 distributed as follows: Africa $7,369,000, Asia $13,709,000, Latin America $1,993,000 and North Africa/Near East $1,182,000.

Rice is primarily a tropical and sub-tropical crop with its main area of production (with the exception of China), lying between the Tropics of Capricorn and Cancer. It is harvested from 145 million

hectares globally of which less than 5 million hectares are in developed countries. Rice lands occupy about one third of the area planted to cereals in LDCs which represents a production area 50% larger than for wheat. Thirty-six countries harvest more than 100,000 hectares of rice, 15 in Asia, 9 in Africa, 3 in Central America, 5 in Tropical South America and 4 in Near East/North Africa. In total, Asia has 126 million hectares which represents 87% of the global rice producing area, while Latin America has 8.2 million hectares and Africa 4.6 million hectares (Table A) in rice production.

Water is a major factor in cropping intensity. With year round water control there are fewer abiotic constraints and with the availability of day length insensitive materials maturing in 90-100 days, the production of 2 to 3 crops per year is becoming more common. It is under these regimes that the farmers' yields are highest, and where there is most chance of bringing present productivity closest to practical productivity 1/. It has been estimated that current yields farmers are achieving under irrigated conditions are about half the practical level they could achieve using current technologies. The major problems for irrigated rice appear socio-economic and largely location specific.

Rice is grown under five major cultural regimes: irrigated, shallow rainfed (non irrigated rice with good rainfall but which may have soil constraints, e.g. salinity, fluctuating water table, iron toxicity, etc.) dryland, deepwater and floating rice cultures. In developing countries rice is most often produced by farmers with less than 5 ha of land. It is a highly labour intensive crop. In Asia, 56% of the rice is produced under irrigated conditions (Table A) and 23% under shallow rainfed conditions. Although only 25% of the global production is from dryland, deepwater and floating rice regimes, half of the rice production area of Africa is dryland with a further 17% deepwater, and in Latin America 74% of the area is dryland, most of which is in Brazil.

The differences among these regimes are such that rices grown under dryland, deepwater or floating conditions could be considered as totally different from rice grown under irrigated and shallow rainfed regimes. To date most gains have been made from irrigated rice but substantial yield improvement has also been achieved under the shallow rainfed conditions for which irrigated rice varieties are suitable. Research to improve yield under deepwater conditions has started and some modern varieties are now under test. Little attention within the CG System has been given so far to improving rices for dryland culture or for floating conditions.

1/ IRRI LTP Yields:

present productivity	- current yields achieved by farmers
practical productivity	- yields achievable by farmers using known technologies within environmental limits
potential productivity	- yields achievable within the environmental limits if optimum practices are used

Table A

Estimated Rice Growing Areas Classified by Dominant Water Regimes ('000 ha)

	Total Area 1978-80	Irrigated	Rice Area by Type of Water Control			
			Rainfed			
			Shallow	Dryland	Deep Water	Floating
Developing Asia	126,000	70,200 1/	29,000	10,700	11,200	4,950
% of Reg. Total		55.7	23.0	8.5	8.9	3.9
Latin America 2/	8,200	1,200	0	6,100	900	0
% of Reg. Total		14.6		74.4	11.0	
Africa	4,600	800	700	2,300	700	0
% of Reg. Total		17.4	15.2	50.0	17.4	
Developed Countries 3/	4,800	4,800	0	0	0	0
TOTAL	143,500	77,000	29,700	19,100	12,800	4,950
% of World Total		53.7	20.7	13.3	8.9	3.4

1/ of which 8,800 (7%) is dry season irrigated area.

2/ Brazil has 6,200,000 ha.

3/ Japan has 2,500,000 ha - USA has 1,250,000 ha.

Source: A Plan for IRRI's Third Decade, 1982.

Overall, the average yields of rice in developing countries have increased by about 20% over the last 10 yrs. (FAO 1981 Production Yearbook) and over approximately the same time the real costs of rice production have dropped, which has resulted in a price decrease of 18-20%. This impact has been made on irrigated rices and massive increases in production have been achieved in Asia coming from yield (20% increase), and increasing the intensiy to 2 to 3 crops per year. Self-sufficiency has been achieved for several countries and Asia is now a net exporter of rice. Most of the equity from these successes is going to farmers with under 5 ha of rice and to the rice labourers needed for the intensive production.

Smaller yield increases have also been recorded in the Near East and in Latin America and both regions increased production. In Africa yields have dropped by about 4% but because of increased area harvested, production has risen by about 14%. Despite this increase in African production, the demand, especially in West Africa, is outstripping both population growth and production and imports are rising rapidly. However, the area in Africa currently planted in rice is only about 10% of the total crop area harvested. It is estimated that there are 61 million ha suitable for low input rice production and 133 million ha for high input production in Africa (Table 12).

In the future 1/ the area producing irrigated rice is expected to increase from 21% in 1980 to 26% of the total rice area by 2000 and the area producing two irrigated rice crops to increase from 19% in 1980 to 25% by 2000. By modifying the architecture of the rice plant, it 1/ has estimated that 2.2 t/ha in the wet season and 3.5 t/ha in the dry season could be added to the research station yields of irrigated rice bringing them up to approximately 8 t/ha and 12 t/ha respectively.

The problems associated with shallow rainfed rice are similar to those faced by irrigated rice production except that many of the biotic and abiotic constraints assume greater importance as water control becomes less reliable. The proportion of area shallow rainfed rice is expected to drop from 30% in 1980 to about 23% of the rice culture area by 2000 as much of it becomes irrigated.

Dryland rice is currently the least productive of rice regimes. It comprises in total 19.1 million hectares of the world's harvested rice areas, most of which is in Asia. The area under dryland cultivation is expected to drop from 12% to 11% of the total between 1980 and 2000.

The main problems associated with deepwater rice is the necessity to have materials which can tolerate both drought and submergence, elongate sufficiently in response to deep-water conditions and still yield well.

1/ IRRI LTP

Like deepwater rice, the main problems concern increasing the toleration to periods of submergence and ability to elongate quickly in response to rising flood waters but an additional requirement is the ability to produce a crop even through the stems may have been separated from the roots, and have become free floating. Despite the fact that culture of floating rice comprises only 3.4% of the global total and is found only in Asia, it is grown on a larger area than the total rice production area of Africa.

The CG System puts 23% of its resources of research into rice with a result that there is a small positive deviation by value of demand and a small negative deviation by value of production (Tables 21 and 22).

Rice contributes over 30% to the diets of all Asian regions, between 10 and 20% in Humid West Africa, Equatorial Africa and Tropical South America and elsewhere less than 7% (Table 4). It is thus Asia where the commodity is most important and where over the past 10 years self sufficiency has been attained. Increases in production and consumption were recorded through the 70s and the extrapolations to 2000 indicate negative trends in self sufficiency in Temperate South America, Central America, Near East/North Africa, South and South East Asia.

Most of the CG System has been directed towards irrigated rice and the success of this strategy is amply demonstrated both by the production increases and the strong NARS of the major producing countries. However little consideration has yet been given to the other regimes. TAC considers that the dryland conditions are in need of more intense effort as it is in these areas especially in Asia and Africa that some of the poorest and most disadvantaged farmers are situated. In addition, the size of the dryland rice area alone merits particular attention. The most important constraints in this culture are pests, diseases and weed control. Blast is a disease which can cause serious damage whenever the crop is grown.

In considering the priorities to be given to rice and its various cultures, TAC recommends that the overall effort should be maintained but that there should be some reallocation of effort. With respect to irrigated rice, the strength of the NARS of the major producers is such that most aspects of level III and IV activities can be transferred to the national level with backup from the CG System. This will make way for reorienting work into aspects of level I and II research which should be initiated now to prepare for the next level of major impact.

It is expected that as this recommendation is implemented there will be some small amount of effort available for a reorientation to other rice research problems.

TAC notes that resources in Latin America have already been shifted from irrigated rice to shallow rainfed and dryland culture and strongly supports this move. TAC considers that the level and allocation of effort in Latin America is appropriate.

With respect to activities in Asia and Africa a rather different picture emerges. It is clear that the original idea that technology could be transferred from Asia to Africa has been shown to be wrong as discussed in Chapter 3 and that because of the differences in land/labour ratio in Asia and Africa special consideration needs to be given to Africa to develop appropriate technologies. TAC therefore recommends that despite the small proportion of the global supply of rice produced in Africa, the overwhelming demand requires substantial efforts.

TAC considers that the current allocation of effort to Africa is appropriate but recommends, that in line with the relative importance of the different regimes that there be a shift of focus away from the problems of irrigated rice to those of rainfed especially dryland production. TAC expects that many of the components of technologies developed for African conditions could be adapted to Asian dryland conditions for example, blast resistance.

Finally TAC considers that the overall level of effort in Asia is appropriate but recommends that some shifts of emphasis to strengthen research on rainfed cultures, particularly dryland culture, be implemented. In making this recommendation to increase the effort on dryland rice at the expense of irrigated rice, TAC recognizes that success is likely to take time but nevertheless is convinced that for the next 10 years a major effort in this area is required.

Wheat

Wheat is the second most important global crop according to diet contribution, preceded by rice and followed by maize (Table 22). In value of production wheat ranks fourth after rice, sweet potatoes and beef and buffaloes (Table 21). Twenty-six LDCs harvest over 100,000 hectares of wheat, with China producing 38%, North Africa/Near East 30%, India 22% and Temperate South America 6% of LDC production. For Temperate South America and North Africa/Near East wheat is the number one food crop in both dietary contributions and value of production.

Table 23 shows that wheat (durum wheat and triticale included) occupied the third position according to the level of 1983 CG System funding, receiving a total of US$ 8.5 million (Table 15). This level of funding for wheat took 8.2% of the total CG System budget implying deviations by -117% from its dietary contribution and by +39% from its value of production.

As shown in Table 15, the CG System 1983 funding for wheat was distributed as follows. Africa and Near East 54% (with North Africa/ Near East receiving 74% and East-South Africa 26%), Latin America 29% approximately (evenly distributed among Temperate South America, Tropical South America and Central America) and Asia 17% (evenly distributed among India, South Asia and South East Asia).

Bread wheat is a complex commonly known as Triticum aestium and contains spring and winter, hard and soft types. Pasta and many mediterranean foods are derived from durum wheat, T. durum. Durum wheat is important primarily in the Near East/North African region where it accounts for 50% of the wheat crop. Triticale is a man made cereal derived from crosses between wheat and rye with considerable potential for areas which are marginal for wheat as it has greater cold and drought tolerance and outperforms wheat on poor soils. In general triticale has a milling quality close to wheat and in some areas is preferred by millers because of the large grain and ear-size. It sometimes goes by the name of "big wheat".

Most wheat is grown as a sole crop in temperate climates by farmers with some access to inputs but also in tropical conditions in the cooler seasons or at higher elevations. Wheat growers range from small partially subsistence farmers to large commercial high technology users. Wheat is the cereal mostly regarded as the basis of modern urban foods, levels of wheat consumption in many LDCs have been influenced by the availability of wheat as a tradable commodity and by food aid programs.

There are now available broadly adapted modern wheat varieties for majority of production environments but there is increasing concern abourt the vulnerability to attack from pests and diseases throughout the wide use of genetically similar materials. In general, as with rice in the better production environments, the improvement of farmer yields are now mainly limited by location specific production agronomy factors. To ensure NARS can make use of the yield potential already built in improved materials, the CG System has an important role to fulfill in providing national programs with research procedures (or methodologies) and orientation to develop more appropriate production technologies for farmers.

Overall for bread wheat it is estimated that very satisfactory yield levels have been achieved. Potential yields for rainfed wheat are up to 6 ton/ha in farmers' fields, but actual average is less than 2 ton/ha. For durum wheat, and particularly for the North Africa/Near East region, additional research is needed to raise yields (though some lines are now approaching the best bread wheats), and develop increased tolerance to drought, heat and especially to frosts for high altitudes of the Middle East. Incorporation of desirable genes from new sources into useful modern varieties is becoming an important NARS strategy to reduce the genetic uniformity of the national wheat crop. With regard to triticale, its real potential in developing countries has not yet been fully appreciated. The ability to recover from grazing shortly after germination and still produce a good grain crop, is an important characteristic that will benefit marginal wheat growing areas where animals are part of the farming system.

For the mid-term, much of the CG System level III and IV wheat research will diminish as it is transferred to the stronger NARS since most constraints to increased yields are location specific. Germplasm enhancement to protect current yield potentials, will continue at the Centers but more fundamental research using bio-engineering and other

bio-technologies (including wide crosses) will be required before any quantum leap in wheat yields or expansion into new agro-ecological zones can be attained.

Figure 3.b shows the relative importance of wheat for the different developing country regions. North Africa/Near East and China are the two most important regions producing close to 70% of total wheat in LDCs, and dietary contribution of 40% and 19% respectively. India follows with approximately 20% contribution in both total production and dietary contribution. Temperate South America is in the fourth place with 6% contribution to total production and 25% to diet within the region. Finally, three regions, Tropical and Central America and South Asia, have low values of production but high dietary contributions.

Temperate South America, India and China have already strong national programs which are in general able to handle early generation materials and hence need less direct attention from the CG System. Moreover, for these regions self-sufficiency ratios indicate gaps only for China (85%) and trends are positive for the three of them. The picture is different for North Africa/Near East, for which self-sufficiency ratio is of 73% and trends slightly negative (Figure 1.b).

Hence, India and Temperate South America are prime candidates for a progressive transfer of level III research.

For the case of those regions where wheat production is small but consumption (and hence imports) are relatively high - Tropical South America, Central America and South Asia - research opportunities exist for the CG System to develop wheat technologies, perhaps mainly for rotations, in spite of the fact that other crops are relatively more suitable for these agro-ecological zones. CG System's efforts in pushing the limits of wheat into more marginal areas are clearly needed, given the expected increase in the demand for this crop and the little relevance of research underway outside the System.

From the previous discussions on the different NARS capabilities and the relative importance of wheat across regions, TAC considers that the distribution of CG System's efforts are appropriate with the exception that the effort directed to the East/South Africa appears too high (Table 18).

TAC therefore recommends that CG System's efforts for wheat should be maintained to its present level. The importance of research efforts made in the developed world and in particular by the private sector, along with the increasing capability of some NARS in taking some responsibilities for level III research, are the main arguments for maintaining the current level of effort in spite of the fact that demand for this crop is expected to grow substantially with population growth, urbanization and income growth.

In addition TAC recommends the transfer to stronger NARS of down-stream research activities, particularly those related to breeding for the protection of yield levels and for further resistance to diseases and tolerance to some environmental constraints. In the immediate

future the CG System will need to concentrate on countries with weaker NARS assisting them in obtaining the materials they require and in developing appropriate technologies for farmers.

Finally TAC recommends that through appropriate cooperation with more specialized institutions, the CG System engage in upstream or more fundamental research to overcome constraints inhibiting further crop improvement.

Maize

Maize is a cereal crop ranking third in diet contribution after rice and wheat, and fifth in value of production after rice, sweet potato, beef and buffaloes and wheat (Tables 21 and 22). Maize provides more than 28% of total diet in two regions, and between 5 and 11% in six other regions (Table 4). Fifty-two countries harvest maize from 100,000 ha or more annually, more countries than for either wheat or rice.

Table 23 shows that maize occupied the fourth place according to the CG System's 1983 funding, receiving a total of approximately US$ 8.45 million distributed as follows: Africa 53%, Near East/North Africa 3%, Asia 15% and Latin America 29%. This represents 8% of total CG System's budget which implies a deviation of +18% by the maize dietary contribution, and of +53% by its value of production.

Maize is a naturally long-season, cross-pollinated crop. There are three different grain types: (a) flint, with kernels of hard starch; (b) dent, with kernels of hard starch capped with soft starch; and (c) floury, which have soft starch kernels and there are strong preferences among some people for particular types. In addition the colour may vary, but breeding is generally confined to white and yellow. Besides the grain produced from maize, the remaining stalks (stover), to a much greater extent than rice or wheat, has an important use as cattle fodder in many areas where it is grown.

Maize provides calories for the poorest of rural populations in those areas where it is used as human food. In addition it is widely grown in mixed cropping systems by subsistence farmers under marginal conditions.

Except for China and Temperate South America, yields of most LDCs are low and close to 1.5 t/ha. Production of open pollinated materials has received the greatest CG System attention and generated varieties with yield potential above 4.5 t/ha. Some developing countries using modern inputs and with appropriate infrastructure are interested in the development of inbred lines to produce hybrids. As this trend is likely to increase it will mean that even greater attention should be given to national competence in certified seed production and delivery needs.

Many of the constraints inhibiting maize yields are biological/ecological ones, such as susceptibility to certain diseases, to insects and lack of sufficient drought tolerance, and can be ameliorated by germplasm enhancements.

In order to close the actual yield gap, the main constraint is seen in lack of appropriate production technologies for farmers. Accordingly, there are CG System opportunities for developing production research procedures that national programs could use in generating more suitable technologies for their clientele. In general the strength of NARS of those countries which produce the highest quantities of maize is not as great as those producing similar quantities of wheat or rice, and much work remains to bring them to suitable strength so that they can maintain the productivity of good materials and maize contains considerable genetic variability which can still be utilized to good effect in improving materials. However, further improvement of yield potential and the overcoming of certain constraints, will require more fundamental upstream research.

Among cereals maize is the grain of greatest importance for animal feed. In many areas of developing countries even small farmers are producing maize for feed in response to increasing demand for higher quality food with economic progress and rising income levels. Use of hybrid maize can be expectd to increase rapidly as a consequence of the rather active grain trade related to the intensification of animal production.

Figure 3.c shows the relative importance of maize for the different developing country regions. Central America, Tropical South America and China are noticeable since the three together produce more than 65% of total maize in LDCs, and have dietary contributions of 28%, 8.6% and 6.5% respectively. Then come East South Africa and South East Asia producing close to 15% of total maize, having dietary contributions of 35% (the highest in maize consumption) and 5.9% respectively. The case of Temperate South America producing 6.5% of total LDCs is unique in the sense that it has the lowest dietary contribution but third position in value of production with almost all maize used as animal feed. Six other fall other six regions (four from Africa, India and South Asia) produce together around 12% of total maize production and have dietary contributions ranging from 2.3% for South Asia to 10.8% for Humid West Africa.

The LDCs increase in maize production by 60% during the seventies can be mostly attributed to China with yield gains of 48% (70% of its area in improved varieties). Latin America as a whole increased maize yields by 28% in the same period. Figures for other regions show much more modest gains, Africa being noticeable with 9% increased in production all coming from area expansion. The lack of improvement in East Southern Africa is particularly remarked. Central America and North Africa/Near East are the two regions with lowest and declining self-sufficiencies, 81% and 69% respectively (see Figure 1c). Trends in self-sufficiency are negative for Central America and Semi Arid West Africa (-0.6%) and for East/South Africa (-0.5%) (Table 9).

From an analysis of the allocation of CG System funds and with reference to Figure 3.c Equatorial Africa and Humid West Africa rank first equal each with 18% of the effort followed closely by Central america and Tropical South Africa with 15% and 14% of the effort, then Semi Arid West Africa with 11% and East/Southern Africa 7%. The

distribution of CG System efforts for maize is reasonably balanced within Latin America and Asia but not for Africa. East/Southern Africa, as the largest maize producing region within Africa and the number one region among all LDCs in maize contribution to diet and value of production, should be receiving more effort. North Africa/Near East may be receiving effort below and Humid West Africa, Equatorial Africa and Semi-Arid West Africa receiving effort above their relative importance according to value of production.

TAC therefore recommends that even through the current CG System effort for maize, shows a positive deviation in relation to its dietary and production value contributions the level should be moderately increased because of its importance in more countries than any other crop, and because its high potential has not yet been reached due to the later start of research.

TAC also recommends that additional effort should be allocated to Africa, particularly to East/South Africa, and in general to those areas were the main use of maize is for human food.

<u>Barley</u>

Barley occupies the nineth position equal with cassava in calories-protein contribution to LDC diets and the sixteenth in value of production (Table 21 and 22). Nineteen LDCs harvest over 100,000 ha of barley annually but 62% of total production is located in just one region: North Africa/Near East.

Table 17.3 shows that barley occupied the twelveth place in the ranking by the CG System 1983 funding receiving US $2.9 million. This amount took 2.75% of total CG System budget which implied deviations of +53% by its dietary contribution of and of +78% by its value of production.

As shown in Table 14, the CG System 1983 funding for barley was distributed among regions as follows: North Africa/Near East 65%, Tropical South America 19%, Central America 7% and the rest in East/South Africa and Asia. This distribution seems to be fairly well adjusted to barley importance across regions, although the level of effort allocated to Latin America is somewhat large.

Available technology in barley consists of materials showing improved plant type, improved straw strength and earlyness coupled with high yield and semi-dwarf habit. In addition there is a range of high-lysine materials with suitable grain characteristics for both hulled and hulless grain types. Because the likelihood of grazing in early stages of growth where most of the grain goes for human consumption, there is need for dual purpose materials. The nutritional quality of the straw also needs some attention.

Figure 3d shows that barley is only important for the North Africa/Near East region which produces 62% of LDCs barley and where barley contributes 2.95% to the diet. India, South Asia, China and Tropical South America follow where barley contribution to diet is less than 0.5% and the grain is used mainly for brewing and animal feed.

Since barley does not form a significant proportion of the diets in any region of the developing world, it seems to be better for the CG System not to concentrate exclusively on barley as grain for human food. Given the importance of barley for grazing, it is appropriate to transfer efforts to its improvement for forage and feed. After all, in many areas of the developing world brewing companies are already providing farmers with barley varieties that, if not entirely acceptable as food, farmers consume anyway.

TAC recommends that the current level of CG System efforts on barley be gradually decreased because of the relative importance of barley as a feed that the main effort be transferred from a focus on grain to the development of dual purpose high quality barley materials for North Africa/Near East.

Sorghum

Among those commodities with CG System support, sorghum ranks sixth in calories/protein contribution to LDC diets preceded by sweet potato and followed by millet and in value of production sorghum occupies the thirteenth place equal with millet (Table 21 and 22). Thirty-five LDCs harvest over 100,000 ha of sorghum annually, 17 of which are in Africa, 10 in Asia and 8 in Latin America.

Table 23 shows that sorghum occupied the seventh position according to the level of CG System 1983 funding, receiving approximately a total of US$ 5 million (see Table 14). Sorghum took 5% of the total CG System budget which implied a deviation of +52% byits dietary contribution and +82% from its value of production.

Sorghum was probably domesticated in Africa fairly recently. It is genetically a highly variable crop adapted to cultivation in conditions with as much as 250 mm rain to as little as 25 mm. However pearl millet usually replaces it at the dry end and root crops in the moister areas. There is some competition with maize over part of its agro-ecological range.

In comparison with maize, sorghum is of less importance globally in dietary or value contribution but it grows in areas so dry that the choice of cereals is limited and the people who live there are among the poorest in the world. Although it is a crop with a short history in well focussed research, it has ample genetic variability and excellent drought and heat tolerance, and therefore rapid improvement in yield and stability has already been realized. The materials now in the pipeline give promise of greatly increased productivity in the future.

In those countries where sorghum is used as a human food, average actual yields are below 1 ton/hectare. Applied research results for those areas indicate that from available technology yields above 3 tons/hectare are possible from open pollinated materials. Yield increases of 40% above the best open pollinated varieties have been achieved from sorghum hybrids.

The primary objective of CG System support to sorghum is the development of high-yielding, stable varieties and hybrids with acceptable food grain quality, tailored to the several ecological conditions of the semi-arid tropics. Most of the sorghum is produced for human consumption, and research faces problems to which little attention has been given outside the System. Yields of LDCs in the last decade have risen by 28% and production by 23% while the area harvested dropped slightly although they have remained almost stable over the past decade in Africa. India has nearly doubled its yield and increased its area planted. Temperate South America and Central america have shown important yield and production gains over the same period. These problems may very well justify the actual level of funding for sorghum which exceeds its contribution to food and to value of production.

Figure 3.e shows the relative importance of sorghum for the different developing country regions. Both Semi-Arid West Africa and India rely on sorghum for food (13.1% and 5.8% respectively). Sorghum production is important not only in these two regions but also in Latin America where it is basically used for animal feed. East and Southern Africa and North Africa/Near East rank next and are equal with respect to sorghum's contribution to diet, 3.1%. China is an important producer (17% of total) but the diet contribution is quite low. Finally the other three African regions together contribute less than 5% to total sorghum production, but where the crop is still of some importance as food. Taking into account only those regions relying on sorghum mainly as food, North Africa/Near East and East South Africa, have self-sufficiency ratios close to 100, but are the two regions forecase to have larger negative trends in self-sufficiency, -1.4% and -0.7% respectively. (Figures are given for trends to "millet and other cereals" in Table 9.)

This discussion suggests that, from the CG System's viewpoint, research potential opportunities is greatest in Africa. India, China Central and Temperate South America due to either the relatively strong national programs or the development of the private sector seed industry, have less need of assistance from the CG System.

As shown in Table 14, CG System 1983 funding for sorghum was basically distributed among three regions as follows: 49% to Africa, 43% to India and 8% to Latin America. Having in mind the data within Figure 3.e, it is clear that such a distribution reflects fairly well the priorities. Semi-Arid West Africa received the highest level of funding and ranks first in both dietary contribution and value of production. India ranked second by funding, second in dietary contribution and fourth in value of production, and Central America ranked third by funding, third by value of production and eighth in dietary contribution. (Table 18).

TAC recommends that the current level of CG System effort for sorghum be maintained so as to continue the research on those problems found mainly in semi-arid tropics of Africa, and that given the strong NARS of India and the participation of the private industry in the sorghum improvement, there be an increase in effort for Africa.

Millet

As seen in Table 21 and 22, millet occupies the seventh place after sorghum with respect to dietary contribution among those commodities being funded by the CG System. In value of production millet ranks thirteenth equal to sorghum.

Table 14 shows that millet ranked nineth by the CG System 1983 funding, receiving approximately US $4.2 million. This represents 4% of the total CG System research funds and implies a deviation of +50% by the dietary contribution, and +77% by the value of production.

Twenty-four LDCs harvest 100 000 hectares or more annually, 19 of which are in Africa, 4 in Asia and 1 in Latin America. There is no significant millet production in either Central America or Tropical South America. The production of Temperate South America is used only for animal feeding.

Pearl millet *Pennisetum* is the most important millet grown in the semi arid tropics. There are however a number of other genera which are also termed millet (minor millets) but are not dealt with by the CG System. It should be noted that in the African continent both pearl millet and sorghum may be termed millet and hence in published figures millet may be over estimated.

Millet is a crop of the semi-arid tropics where it can produce under conditions to dry for sorghum. Like sorghum, millet is a food crop grown by poor subsistence farmers. Both are usually planted and farmers will expect some yield from one of them no matter what the total rainfall or its distribution may be in any one year. For the driest end of the agro-climatic range of semi-arid tropics there is no alternative cereal crop.

Before the CG System involvement, there had been little research conducted on pearl millet. With the demonstration in 1966/67 in India that early maturity hybrid millets could give high grain yields (7.5 ton/ha in 85 days), the potential of millet as a food crop was established.

The primary objective of CG System support for pearl millet has been similar to that of sorghum and oriented to develop high yielding materials and hybrids with acceptable food quality. Pools from Africa and India have been used to undertake massive intercrossing and, for Africa particularly, to further cross the resulting improved germplasm with suitable materials to retain the local pest and disease resistance. Improved farming practices, especially those to reduce effects of water deficiency, are underway and can have a major impact. CG System opportunities regarding millet research are mainly related to development of technologies for very marginal areas and pose specific research problems that have not received much attention outside the System. The justification for the actual level of CG System efforts devoted to this crop devolve from these facts.

Figure 3.f shows the relative importance of millet for the different developing country regions. As was the case for sorghum, Semi Arid West Africa and India are the two most importantregions producing more than 60% of total LDCs millet production. Contribution of millet to human diet in Semi Arid West Africa is as high as 20% making a total of 32% along with sorghum. The same total is of 11% for India. China is also an important millet producer with more than 20% of total production. The other three African regions produce about 7% of total millet in LDCS and all these regions, the dietary contribution is between 2.5% and 5%. In addition North Africa/Near East produces 7% of the millet but its contribution to diets is about 1% (Table 4).

The global area harvested, yields and production of millet have all declined during the past 10 years. Within LDCs yields have remained stable. Trends in self-sufficiency for millet in Semi-Arid West Africa is of -1%, followed by India (-0.7%) and Equatorial Africa (-0.3%). (Figures are given for trends to "millet plus other cereals" Table 9).

As shown in Table 15, the CG System 1983 funding was basically distributed to two regions as follows: India 51% and Semi-Arid West Africa 49%. This distribution could have been slightly different according to the indicators, since 42% of total millet production comes from the semi-arid tropics of Africa, compared to about 35% from India. Furthermore in Semi Arid West Africa millet is much more important in terms of both dietary contribution and value of production than in India.

TAC recommends that the current level of CG System efforts be slightly increased so as to hasten results from the pipeline and pursue research opportunities in the semi arid tropics.

TAC also recommends that more attention be given to Semi Arid Africa, where millet is the most reliable crop.

5.1.2. Roots, Tubers and Starchy Foods

Plants which produce roots, tubers or starchy fruits are plants well adapted to tropical conditions and have for a very long period been the staple foods in areas where cereals were not grown. There has been considerable interchange among tropical countries of the various species cultivated and many are now far more important outside their region of origin then inside it. Africa, particularly Western and Central Africa rely for their primary energy source on these foods and nowhere else do such foods play a major dietary role except for many island nations of the Caribbean and Pacific and for the Andean region of South America.

They are all vegetatively propagated, are capable of large yields, are commonly grown in mixed cropping systems by subsistence farmers in marginal areas but may also be sole cropped. They may all be found in kitchen gardens even when a minor component of a cropping system. Cassava, yam, sweet-potato and plantain/banana all have a role in the bush fallow cultivation system of Africa with cassava being the last crop planted before the return to fallow, and the

others planted in the early part of the rotation. All are capable of yielding when grown on poor soils, but cassava is the most tolerant of such conditions and generally has a wider ecological amplitude than the others. Although any single variety of cassava can grow successfully only in a fairly narrow range. Cassava is also more resistant to pests and diseases then the other species with tuberous roots. It is also the insurance crop against starvation. Potato, plantain/banana and cocoyam are somewhat different from the other starchy crops.

Potato with its long research history has, apart from the Andean highlands where it originated, been a temperate country staple. However, its rapid growth rates and high yields make it attractive as another crop in many countries and regions where the staple cereal or root crop have long maturity times. Propagation using rue seed technologies may make potato competitive with some starchy root crops and would certainly add variety to a diet. Plantain/banana is confined to humid conditions but has a much wider world distribution and unlike any of the others has considerable international trade as a cash crop. Africa is the main producer of plantains. Cocoyam is also generally confined to the humid tropics and in Africa, to the western coastal regions.

All these crops have a short storage life after harvest and some may be difficult to prepare for consumption. The protein content and quality is variable and ranges from very low (cassava and banana) to more or less equal to cereals (potato, sweet potato, yam). Legumes do not supplement the proteins of starchy roots and fruits as they do cereals as the same amino acids (methionine and cystine) are missing. They do provide cheap protein to diets based on starchy roots and fruits, although these diets still need further supplementing from a wide range of foods.

China is the largest producer of roots and tubers (predominatly sweet potato) with 49% of LDC production, but they contribute 8.6% to the diet while in Africa as a whole they provide much more. Besides Africa, where roots and tubers have their greatest dietary significance on a world scale, they are also of fundamental importance to peoples of the Caribbean and Pacific Islands. There sweet-potato is generally the staple supplemented by cassava and cocoyam. Plantain/banana is also important. Generally CG System has given little attention to these regions of the world.

The land area from which roots and tubers are harvested is minimal (Table 5.6 Indicators) and for most regions is 1% or less of the regional total. Exceptions are China which has 6% of its cultivated land in sweet-potato, the main cassava producing areas of Tropical America (4%), Equatorial Africa (15%), Humid West Africa (4%), East and Southern Africa (9%) and Semi-Arid West Africa (2%) and Humid and Semi-Arid West Africa both of which have almost 3% in yams. The changes foreseen in land use (Table 7.1, Indicators) devoted to root and tuber cultivator indicate annual increases for all regions except Temperate and Tropical South America of between 1.5% and 0.1%. Tropical South America is expected to increase by 2.6% and Temperate South America to decrease by 0.1%.

There is a great genetic variability among existing cultivars in resistance to biotic and abiotic constraints and progress can be made from selecting among them and diffusing the superior materials. However, for effective long range programs, flowering and seed production is necessary to hybridize and increase variability. Many cultivars of all these species do not flower regularly and are difficult to induce. This applies particularly to some yam, cocoyam and to sweet potato cultivars. In addition most of these crops have a long maturity time so only one generation (or less) per year is possible. Thus there is a slow rythm to selection and improvement.

Because the main method of propagation is vegetative there are difficulties in exchanging germplasm as well as in breeding. Introduction of virus indexing and tissue culture methods for preparing and testing "clean" materials for distribution and propagation is making more rapid the distribution of desirable cultivars across national boundaries, but quarantine regulations still do not permit entirely free movement of germplasm by this route. These restrictions have meant that NARS research scientists have had to deal with seed instead of vegetative materials requiring accelerated development of NARS scientists enabling them to work more independently than would normally be the case with scientists dealing with crops propagated only by seed. This fact has been noted and encouraged in the CG System and has resulted in building up NARS strength with most of the root and tuber crops.

Cassava, sweet potato, plantain/banana and yam and cocoyam are important as food items primarily in Africa (Annex 2g) although in Latin America and in Asia some provide a small dietary contribution more in terms of calories than protein (Tables 2 and 3) for which other commodities are much more important. They do however contribute to the economies of some countries through export trade or for animal feed.

Total roots and tubers within the LDCs over the last 10 years have shown an increase in production of 16% to a total of 345.6 million mt, but regionally there are important differences. In Africa 1/ and Asia total production of roots and tubers has increased substantially during the last 10 years (Table 7) while in Latin America production has declined. This result for Latin America is strongly influenced by Brazil which is the largest producer of roots and tubers (over 27.3 million mt in 1979/81) and has shown declines in production of 19%, area 4% and yields 16% (FAO 1981 Production Yearbook) otherwise the region has been more or less stable.

The self sufficiency of most LDC countries (1971/81) for roots and tubers (excluding plantain/banana) is close to 100% (Table 3.2 Indicators) but East and Southern Africa where roots and tubers contribution to the diet is 13.2% is only 86% self sufficient. South Asia and Central America also show less than 100% self sufficency but the root and tuber contribution to diet is only about 1%.

1/ The data relating to roots and tubers are unreliable, especially for Africa.

The CG System allocations to the root, tuber and starchy food group show a positive deviation with respect to both global value of production and contribution to diets (Table 15). However with few exceptions the root tuber and starchy foods are of importance only in Africa where they provide a substantial proportion of the calories, 46% in Equatorial Africa, 35% in Humid West Africa (where cereals provide 37.5%), 23% in East and Southern Africa and 21% in Semi-Arid West Africa. In no other region do they provide more than about 12% of the calories (Table 3). They are not so important with respect to protein although in Humid West Africa they provide 16% of the protein, the largest single source except "other food commodities".

Continuation of support by the CG System despite this positive deviation at the global level can be justified by the importance of the commodities within this group for their dietary contribution to populations in Africa. Further, most of them have had very short research histories because, except for potato, they are unimportant in temperate regions. In spite of their limited research histories and the limited funding some of the commodities have received, progress is good and pipeline developments are promising.

With respect to the future, hard data is incomplete. However for Africa at least the group will continue to be the main staples because most can yield well under marginal conditions with few inputs and are well suited for shifting cultivations, and some have excellent nutritional qualities and are in high market demand.

There are many unknowns. Food processing technology could provide products or product ingredients from this group for urban consumers and also low cost animal feeds. TAC recognizes the need to reduce post harvest losses in storge and sees considerable benefit from research into food and feed technologies. Developments here would mean more income for the grower from current production and probable savings in hard currencies through reduction in imports or increased exports. Apart from cassava these crops all have a high value of production and are in demand by urban consumers from all strata of society.

TAC considers that the current effort on roots, tubers and starchy foods is appropriate given the importance of these staples to the diets of many of the world's poorest people who live in the agroecological zones where they have a comparative advantage over cereals.

TAC further considers that within 10 years a reappraisal of the situation with respect to research on roots, tubers and starchy foods should be undertaken. By that time the use and progress in root and tuber post-harvest storage and processing technologies will be clear and the demand can then be assessed and the research needs identified.

Cassava

On the global level cassava ranks 9th equal with barley in its caloric/protein contribution to LDC diets and 17th with respect to value of production (Tables 21, 22).

The CG System, in 1983 allocated US$ 7,491,000 to cassava ranking it in 5th place. The funds were distributed as follows: Latin America 44%, Africa 52% and Asia 3% (Table 19).

Cassava is harvested on more than 14 million ha 1/, all of which is in developing countries. In terms of LDC area cultivated cassava ranks 7th and in terms of total LDC production 5th after maize and sweet potato. In Africa there are more than 7 million ha. 1/; in Latin America almost 3 million, Middle East 45 thousand and Asia 3 million ha. Brazil is the major producer harvesting 2 million ha with Zaire next with almost 2 million ha. Other countries which harvest over 1 million ha annually include Nigeria (1.2 million), Indonesia 1.4 million, Thailand 1 million. Twenty-one countries harvest over 100,000 ha annually with 12 in Africa, 3 in South America and 6 in Asia.

It has high potential yields (e.g. over 40,000 kg/ha). It is generally a less labour-demanding crop than sorghum or yam and is capable of producing a crop from soils too poor and degraded to produce anything else. Yields are lowest in Africa, averaging about 6,600 kg/ha. In Latin America yields are close to 9,000 kg/ha (Table 5.7 Indicators).

Africa ranks highest in importance for the use of cassava as a source of food. Populations of Equatorial Africa derive 19.8%, and from Eastern and Southern Africa 12% of the dietary contribution from cassava. Elsewhere in the world cassava contributes less than 1% of the diet with the exception of Tropical South America (3.5%) and SE Asia (2.7%). Cassava although with less than 1% usable protein plays a very special role in the diets and survival strategies of the rural peoples of Africa. It is capable of producing a harvest in very poor and degraded soils, it needs no special storage if it is left in the ground till needed, the roots will survive in the ground uninjured by fire, the planting materials are the above ground stems, the plant can regenerate after insect attack and still produce and in general it is not labour intensive to grow. Its leaves provide a vegetable green rich in protein (30%). Although not a highly valued crop in comparison with the other starchy roots and fruits (Table 1), it is the survival crop, the insurance against starvation.

1/ IITA estimates that cassava is harvested from at least 10 million ha in Africa.

During the period 1969/71 to 1979/81 LDCs yields have remained stable. Area harvested has increased by 27% and production by 26%. In Africa the average yields decreased 4%, area harvested has increased by 26%, and production increased by 21%. Part of the yield drop in Africa could have been caused by cassava mealy bug (CMB) and green spider mite (GSM), but this has been more than offset by the 26% area increase. CMB and GSM together are estimated to reduce yields by about 30%.

In other parts of the world, Latin America has shown a yield decrease of 16%, an area increase of 4%, and a production decrease of 12%; and Asia has shown a yield increase of 31%, an area increase of 42% and a production increase of 87% and China a yield increase of 7%, an area increase of 47%, and a production increase of 58% but from a small base (FAO 1981 Production Yearbook).

The CG System has led the research into the improvement of cassava and has concentrated on the development of stable, pest resistant materials with high dry matter yield. Development of improved agronomic technologies have led to increases in production even using traditional varieties. In Africa research into the biological control of certain pests has been an important strategy.

The main problems constraining cassava production in Africa are lack of sufficient pest and disease resistance and pipeline developments promise benefit from research into biological control of the main pests. Changes are occurring but the difficulties of distributing vegetatively propagated crops slow the spread of disease resistant materials. In Latin America and Asia the situation is entirely different. Suitable technologies are available but the disease problems have limited exchange of materials with Africa.

Land suitable for cassava production at low inputs is estimated at 433 million ha (Table 12) while at high inputs is 645 million hectares, substantially more than currently used. This increase is largely accounted for by Africa which with high inputs could increase the area cultivated by more than 600%. Increases in area of cultivation of cassava in other areas is minimal and in South East Asia high input agriculture would result in reducing the area devoted to cassava.

The future demand for cassava is problematic. It is in Africa where annual increases in cassava consumption of between 1.3% and 3.5% over the last 10 years from a much higher base would signify a continuing demand for cassava well beyond 2000. The demand for cassava from food processing industries or for animal feed in Africa cannot be predicted at this time but could be substantial. Rising incomes, however, appear to reduce demand for cassava as indicated by the decline in consumption, production and area harvested over the last 10 years in Latin America. Demand for animal feed especially for export has led to significant increases in production especially in SE Asia and this trend could be expected to continue. It is largely farmers on marginal lands who are benefitting from this trend. There has also been a 6.4% annual increase in consumption of cassava in

South East Asia (Table 8) but it is from a very low base comprising less than 3% of the diet.

Analysis of the resource allocation to cassava on a global basis shows a positive deviation in terms of both dietary contribution and value of production, but given the relatively short research history and the dependance of some of the world's poorest populations, it is TAC's view that some positive deviation has been required.

On a regional basis there are some important imbalances (Table 19). Tropical South America receives the greatest amount of effort but ranks 7th with respect to value of production and 6th for dietary contribution while Central America which ranks 3rd by allocation ranks 9th for both factors. This would indicate that a reduction of effort would be warranted for Latin America because of its small dietary contribution and value of production in comparison with its importance in Africa.

TAC recommends that in the short term the level of effort be maintained but in the longer term, the total level of effort be phased down. For the immediate future TAC recommends that the focus of attention should be Africa and that a small increase in effort should be directed to the problems of Asia at the expense of Latin America. In the longer term, if food processing or other industries do not create increased production, TAC recommends that the CG System should phase cassava research to a minimal level sufficient to meet the long term African needs.

Potato

On a global scale potato ranks 12th overall in its contribution to LDC diets and 8th with respect to value of production (Tables 21, 22).

Within the CGIAR-funded activities, potato ranks 6th in terms of allocation. In 1983 US$ 7,353 million were allocated to potato research which were distributed as follows: Latin America 37%, Africa 21%, North Africa/Near East 21%, Asia 21% (Table 19).

Globally potato is harvested from 18 million hectares of which 4.6 million hectares are in LDCs. Eleven LDC countries harvest over 100,000 hectares of potatoes. China produces 31% of LDC production, followed by India with 19%, North Africa/Near East 16% and Tropical South America with 14%. Potato, so far, makes no substantial contribution to the diet of any LDC. In Temperate South America potato has the highest contribution but provides less than 3% of the diet, Tropical South America is next where it provides 1.5%, but in most regions it contributes less than 0.5% to the diet. It would appear to be used as a vegetable rather than primary staple and therefore to be important for variety and nutritional qualities. In those LDCs where production is large (e.g. China, India), exports are also considerable and even some of the small country producers export a substantial amount of their production. Overall there is a small net import of potatoes into all other LDC regions (Indicators 3.4).

Over the last 10 years developing countries have achieved increases in area, yield and production. For example in India yields have increased by 41%, area harvested by 48% and production by 108%. For Asia as a whole has increased yields by 28%, the Near East by 18%, Africa by 12% and Latin America by 24% (FAO 1981 Production Yearbook). Production for each of these regions is also increasing, both Asia and Africa have almost doubled their production. Potato has the fastest growing demand from LDCs which cannot as yet be satisfied. There is still considerable area of LDC land suitable for increasing potato production under low inputs or high, but in comparison with other crops the amount is small with 65.6 million ha suitable at low inputs and 79.6 at high inputs. Most of this however is in South America (Table 12).

One of the factors in potato production is the price of seed tubers which have to be renewed regularly and are expensive imports for many LDCs. The recent progress within the CG System on the use of true (botanical) seed and the substantial savings the associated technology realizes, could make potatoes a much more attractive crop for small farmers both for their own use and for a cash crop directed to urban markets. Although the crop originated in tropical highlands it has become well adapted to temperate lowlands and now, considerably assisted by the CG System, is rapidly moving back into tropical climates and to lower elevations. It is only within the CG System that research into growing potatoes under tropical conditions - short day length, warm to hot temperatures, etc. has occurred. Although subject to a wide range of pests and diseases, substantial progress is being made in building up resistance as well as increasing yields under a variety of agro-ecological conditions. A particular aspect of the potato research within the CG System has been the successful strategy employed to increase NARS capacity to deal with vegetatively propagated crops which at the same time has resulted in developing dynamic and confident NARS. Another aspect has been the generally low cost and highly efficient and productive methods for ensuring research progress. There is still within the World Potato Germplasm Collection held by the CG System considerable genetic variability to be exploited and from which TAC confidently expects even more impressive results.

The potato is an easily digested and versatile food with a high protein content of good quality. It has a longer shelf life than either sweet potato or yam, and can, when dried, be the basis of a wide range of easily stored and prepared foods. Although with limited LDC areas suitable for its production under either high or low inputs there is still sufficient land to allow considerable expansion in its production to meet the growing demands. There are no figures for self sufficiency but consumption trends through the seventies were high in many regions, e.g. 7.1% in Central America, 12.5% in Humid West Africa and 8% in India and these are likely to continue (Table 8). The self sufficiency levels in 1979/81 in Humid West Africa and Semi-Arid West Africa were 53% and 77%. The high value of production and the limited space required to produce yields sufficient for both family needs and the market, the relatively short generation time making it suitable for a variety of cropping patterns, indicate that demand for potato will continue to increase in LDCs.

The allocation of funds to potato by the CG System indicate a substantial positive deviation by the two main indicators. However, given the foregoing discussion on the demand trends and the potential of the true seed technolgies, this level is totally justified. The potato research program is highly decentralized resulting in an appropriate regional allocation.

TAC therefore considers that the high effort devoted to potato is appropriate and should be maintained for a limited period before phasing down to a lower level as suggested by the center responsible and accepted by the CG System.

Sweet Potato

Globally sweet potato ranks 5th in its contribution to the diets in the LDCs and 2nd respect to its value of production (Tables 21, 22).

With respect to CGIAR funded activities sweet potato received in 1983 US$ 629,000 from the CGIAR System placing it in the 19th place. The funds were distributed as follows: 25% each to East and Southern Africa, Equatorial Africa, Humid West Africa and Semi-Arid West Africa.

The area from which sweet potato is harvested globally has remained stable over the last 10 years at 12 million ha. Of this total, 11.8 million ha are in LDCs with Asia harvesting 10.4 million ha. Seven LDCs harvest over 100,000 ha, of which 5 are in Asia and 2 in Africa 1/.

China which harvests 9 million ha produces 88% of the LDC production. South East Asia grows about 5% of the LDC production and Equatorial Africa 2%. Sweet potato provides 8% of the diet to China, 4% to Equatorial Africa, 0.8% to South East Asia and Eastern and Southern Africa. The average yield of all LDCs is currently 8 t/ha. Many countries have average yields of twice that amount and yields of over 40 t/ha have been obtained in four months. Although in global terms the proportions are small, sweet potato is the staple calorie source for many Caribbean and Pacific Island nations.

The demand for sweet potato is increasing in Africa, especially in Equatorial, Eastern and Southern and Semi-Arid West Africa where area is small, and although average yield is only 7.0 t/ha, some countries average over 10 t/ha. Production increased by 25% from 1969/71-1979/81 to over 5 million mt in 1981 and is now twice that of Latin America (Table 3.1 Indicators).

The crop is well adapted to those tropical lowlands with average temperatures above 24^{o}C. Its production costs and labour input are relatively low, especially in relation to the production

1/ FAO 1981 Production Yearbook

costs of yam. Sweet potato makes a substantial contribution to the nutrition of the poor in terms of calories, protein and especially vitamin A. Both roots and leaves are eaten. In much of Asia the roots are eaten as a vegetable rather than as a staple.

Concentrated research on the sweet potato as a tropical crop is of fairly recent date and two separate international efforts - one within the CGS and one outside - have programs devoted to the improvement of its yield and quality.

Over the past 10 years (1969/71-1979/81) yields have risen in LDCs less than 6%, but this masks the drop of 27% in Latin America, a drop of 8% in Asia and stable a situation in China. In Africa as a whole, yields have increased 9% with increases in both area harvested and production. Nigeria, for example, recorded a 42% increase in yield and with very little increase in area, has increased production by 70% 1/.

Among problems which need solution are the susceptibility of the tubers to attack by sweet potato weevel (for which the mechanism of resistance has now been identified) and nematodes which affect storability, and the difficulty of floral induction and therefore seed production for breeding purposes. There is tremendous genetic variability yet to be tapped, but within the CGS collection of germplasm available to the breeders from the area of diversification is still in need of enlargement. The base collections of sweet potato germplasm are located in USA and in Taiwan and quarantine regulations to safegard against disease spread are a constraint to germplasm exchange even through meristem tissue culture. TAC notes this situation and encourages efforts in overcoming these problems.

The high value of sweet potato, the excellent food quality, the very large amounts that can be raised from small areas and the relatively short research history which has given positive results, all indicate that there is potential for substantial gains to be made from continued research. In addition its high value should be a spur to develop suitable processing technologies for convenience food or food components.

With respect to the CG System allocation of resources, on a global basis sweet potato has a strong negative deviation with respect to both dietary contribution and value of production. Since China is the largest sweet potato producer and AVRDC also has a mandate for sweet potato, TAC recommends that the CG System confine its activities and to Africa and Central America. Considering the small CG System allocation to the commodity and the fact that consumption trends through the 70s (Table 7) in Africa showed larger annual increases than any other region, TAC agrees that most of the effort should be focussed on African problems. However, TAC further recommends that the CG System research efforts should be carried out in close cooperation with other institutions also working on sweet potato improvement.

1/ FAO 1981 Production Yearbook

Yam

Yam ranks 17 in its contribution to LDC diets and 6th equal with plantain/banana with respect to its value of production (Tables 21, 22). It is thus a crop like sweet potato which has a high market value in comparison to its contribution to the diet.

Among CGIAR funded commodities yam ranks 20th by allocation. In 1983 it received US$ 564,000 distributed as follows: Humid West Africa 50%, Semi-Arid West Africa 50% (Table 19).

Ninety-nine percent of 21.3 million metric ton global yam production is from Africa, harvested from 2.3 million hectares. Nigeria is the largest producer among the 12 African countries producing over 100,000 metric tons in 1981.

Yam contributes 8% of the caloric/protein shares in diets of populations in Humid and Semi-Arid West Africa, 0.55% to the diets of Equatorial West Africa and 0.05% to the diets of North Africa/Near East, Central America and Tropical South America. In West Africa the white yam Dioscorea rotundata is most highly prized and the species receiving most attention by CG System. It appears to be complementary to sweet potato in Africa, being of greater importance in Humid West Africa and Semi-Arid West Africa while sweet potato is more important in Equatorial and East and Southern Africa (Table 19).

The research base for yam diseases and yam improvement breeding is fairly recent. Yam, with cocoyam, commands the highest market prices. It is usually planted in the second and later years of the shifting cultivation cycle.

The main difficulties with yam are the high labour requirement for staking and other production processes, the requirements for planting material (25% of the harvest), the susceptability to nematodes and fungal diseases, the short storage life, and the difficulty of inducing flowering in some species.

Within the CG System "non stake" yam lines capable of producing 20 t/ha have been produced and the new techniques for the production of planting materials should reduce the drain on stored roots. These techniques have started a small seed yam production industry in Nigeria among the yam growers.

With respect to CG System funding of yam at the global level there is a strong negative deviation with respect to value of production but a small positive deviation with respect to dietary contribution (Table 23).

On the regional level yam has not only the highest value of production for any individual commodity produced in the regions of its highest production, but also outranks most other commodities on a regional basis despite the fact that the area from which it is harvested is under 3% of the total harvested in both Humid West Africa and Semi-Arid West Africa (Table 5.6 Indicators). These figures would

indicate that there is likely to be a steadily increasing demand for yam in these regions but it may be less elsewhere.

TAC therefore recommends that because of the demand for yam, the short research history, and the production and storage problems relating to labour and to pests and diseases, that an increase in effort be devoted to yam. In recommending this action TAC also recognizes that research that is presently focussed in Africa should also be of importance to other parts of the world particularly Asia and the island nations where yam is grown.

Cocoyam

Cocoyam, on the global scale, ranks 18th equal with 4 other crops in its contribution to LDCs diets and 18th with faba bean in value of production (Tables 21, 22).

Within the CG System cocoyam ranks 22 by level of funding. In 1983 it received US$ 63,000 from the CG System with all funds distributed in Semi-Arid and Humid West Africa (Table 19).

The area from which cocoyam is harvested in Africa is estimated at 1.5 million hectares with the major production coming from a few West African countries. Statistics are difficult to obtain but cocoyam tends to be a basic staple in Africa, where it is grown, a vegetable in Asia and a supplemental food in Tropical America. It is a highly prized food and is important for variety in humid tropical regions of the world. There are two main species: *Colocosia* originating in Asia and *Xanthosoma* from Central America. *Xanthosoma* is the preferred species in West Africa.

There has been less research on cocoyam than on most other root or tuber crops but three African NARS do have national cocoyam programs. Cocoyam blight, the most important problem affecting the crop, specifically *Xanthosoma* in forest areas, is the only aspect which has been the subject of CG System research. Much of this research is carried out collaboratively with NARS.

On both value of dietary contribution and value of production, cocoyam has a negative deviation within the CG System with respect to resource allocation.

TAC notes that cocoyam has only limited world importance and therefore recommends that CG System effort be phased out to allow greater concentration on other root and tuber crops.

Plantain/Banana

Globally plantain/banana ranks 6th equal with yam by value of production and 16th by contribution to diet (Tables 21, 22).

Within the CG System plantain/banana ranks 21st by funding. In 1983 plantain/banana received US$ 238,000 from the CGIAR distributed as follows: Humid West Africa 50% and Semi-Arid West Africa 50% (Table 19).

The world production of plantain/banana is about 60.25 million mt annually with all but about 2% coming from LDCs. Plantain makes up about one third of the total production (FAO 1981 Production Yearbook). Of the two crops, plantain is more important for Africa and banana for the Central and South America and Asia although all areas produce both. This discussion will focus on plantain and bananas for local consumption.

Plantain/banana as a significant source of calories is important primarily in Equatorial Africa and Humid West Africa. Elsewhere the importance in terms of caloric sources is much less (Table 2). The crop is however significant for its value of production especially in Equatorial Africa (17.3%), although elsewhere it is not as high, approximately 5% or lower in Tropical South America, Central America and in other parts of Africa (Table 1).

Production trends with respect to plantain/banana have been positive during the seventies (Table 7) with consumption also positive but at higher rate. Thus projections to 2000 indicate declining self sufficiency for nearly all regions.

Quite clearly plantain/banana is a crop of world wide significance with a high value of production. It does not have the position of a staple although in most regions is important for diet variety.

The CG System effort is clearly negligible but it is concentrated in the region of highest dietary significance. Breeding of plantain/banana has not been undertaken because it is highly complex and would require considerable space and other resources not currently available. Instead the current strategy is to work with the crop from the perspective of its role in farming systems of the humid tropics and not for its food value though some screening of cultivars for suitable materials could be undertaken.

The threat of diseases in many areas of the world and their spread to other areas is great and increasing. This aspect, together with the possibility of loss of some valuable germplasm collections has led to a proposal for the establishment of INIBAP (International Network for the Improvement of Bananas and Plantains) outside the CG System but to be supported by many CG System donors.

TAC welcomes this initiative and stresses its support for the limited involvement of the CG System (but no leadership role) in the activities of the Network. TAC continues to take the position that the CG System should not become involved in breeding plantain/banana but continue its work in the context of farming systems for the humid tropics.

From this point of view, although effort by the CG System in is very low either by the value of production or contribution to diet, TAC is of the opinion that there should be no increase of CG System effort on plantain/banana.

TAC therefore recommends that CG System effort in plantain/banana remain at its current level and that the CG System take every opportunity to cooperate actively with INIBAP on banana/plantain research.

5.1.3. Pulses

Pulses or food legumes are somewhat less important than cereals, as far as quantity is concerned, but are important for the quality of the food value they provide. Unlike the cereals the importance of individual legume species is difficult to determine as they all play rather similar roles in the diet and in the farming systems where they occur. The legume family is widespread through the world and domestication of different species has taken place in different regions. There is thus an array of species which are potentially capable of fitting into a range of ecological niches in farming systems ranging from regions of reasonable soil fertility and low water stress to regions with infertile acid soils and considerable drought stress. Some species are complementary in a given system, others may replace one another.

Although all legume crops show ability to nodulate with *Rhizobium*, the efficiency and quantity of nitrogen fixation varies greatly, some species freely nodulating with naturally occurring rhizobia, others requiring specific inoculation at the time of planting.

All the legume species included in the CG System can be grown as sole crops but most are grown in the tropics as components of mixed rainfed systems requiring few inputs by farmers on small areas and who may also be farming under marginal or subsistence conditions. The crops are host to a wide range of pests and diseases but there are considerable differences in degree of susceptibility to various insects among legumes. Like cereals grain legumes are relatively easy to transport and store except that the seeds are highly susceptible to insect (bruchid) attack reducing the value of the stored product for both food and seed. Most are a source of income as a cash crop.

Besides their production as human food, legumes have several other important roles. Those with high nitrogen-fixing ability can help reduce the nitrogen requirement for a subsequent cereal crop. Further additions of nitrogen and organic matter can be made to the soil by their use as green manure. Many of the species are fed to livestock after harvest and some, particularly soybean, are important ingredients for feed concentrates, especially for chickens. Part of the need for fuelwood in semi-arid areas can be met by pigeonpea.

Most legumes used as food are relatively easy to prepare but some may require prolonged cooking, or special preparation (e.g. soybean) before consumption is possible. It is characteristic of some species that the fresh green pods, leaves and the dried seeds all being used for food. The protein content of legume seeds is much higher than in cereals and range from 20-40% so that in regions where animal protein is scarce or expensive leguminous crops provide an inexpensive and generally high quality substitute. Of particular importance, the aminoacids of the legumes are supplementary to those of cereals and when eaten together improve the total amount of protein available. It is usually recommended that 5-10% legumes are sufficient to supplement a cereal-based diet. The aminoacid complement of root and tuber crops (exception cassava and plantain both with very low protein content) and legumes is similar so the effect is not supplementary as for cereals. Legumes remain important for their protein, but the situation requires that populations using starchy roots as the main staple are dependant on a much wider range of foods to ensure adequate nutrition. Two leguminous species soybean and groundnut are widely grown for their oil content which is particularly important where animal fats are not available as the available foods are made more palatable. Where animal protein is sufficient legumes provide additional calories and variety to the diet.

Apart from those legumes which are of importance to the industrialized world, that is bean (Phaseolus vulgaris), pea (Pisum sativum), broad bean (Vicia faba), groundnut and soybean, little attention had been given to improvement of tropical leguminous species until the establishment of the international centers. Because of the lack of germplasm and basic information about the biology of most species, time has been spent on amassing collections, working out strategies and evaluating materials. Sufficient unexploited genetic variability has been identified within each crop so more stable yields can be attained through genetic resistance but there is some evidence that there may be a yield penalty. Improved varieties and breeding lines are beginning to appear in each of the crop species showing various levels of resistance and tolerance to biotic and abiotic production constraints. In addition changes in plant architecture and growth patterns give promise of increasing yields, reducing some disease problems and raising the possibility of machine harvesting in areas of labour scarcity. Many species are being selected for a range of maturities to fit specific cropping situations. These new materials together with developments in the pipeline give promise of considerable improvements still to come.

Use of improved cultivars of peas and beans (species and varieties unspecified) varies considerably. Although data are very incomplete (Table 6.3 Indicators), South Asia is planting 96% of its area to improved cultivars, Africa varies from 25% to 0.1% while Latin America ranges from 12% to 0%. With respect to leguminous oil seeds, the situation is somewhat different and generally greater use of improved varieties is made in the regions of largest production. Irrigation is not used to any great extent now in pulse production except for Near East/North Africa (32%) and Temperate South America

(26%) and in both the proportion of irrigated pulses are expected to decline by 2000. India is the exception and it is predicted that 35% of the pulse crop will be irrigated. No other region will have more than 12% of the pulse area under irrigation (South Asia) and most will be under 3% of the pulse area irrigated (Table 7.5 Indicators).

Excluding ground nut and soybean but taking all the pulses as a group 29.5 million tons were harvested by LDCs in 1982 (Table 3.1 Indicators). During the seventies yields decreased 1% and production increased 2% (1981 FAO Production Yearbook). Asia is the largest producer with highest production but yields have been falling except for China. Africa and Latin America have similar productions but whereas area and yields are increasing in Africa, yields and total production are almost stable in Latin America. Africa, South East Asia, China and the Near East have all been net exporters of pulses over the period 1979-81 while Latin America has been a net importer (Indicators 3.4).

The discussion on legumes is based on figures given for the dried seeds. There are no estimations included for the amount that is eaten green and for such species as field bean, cowpea, faba bean. At least the quantity consumed green might be considerable and mean that for some species and regions the figures are all under estimated.

Throughout most of Africa and Asia, where animal products are expensive and not widely available to the poor, and total protein intake is lower than 29 g, (the LDC average), the importance of the protein contribution from pulses as supplement cereal protein becomes clearer. It is those regions where total calories intake is lowest that pulses are most important even though their dietary contribution is relatively small. Furthermore in those diets where animal products do not play a major role, variety in the diet is essential. It is clear, however, that especially Humid West Africa and Equatorial Africa but also some other regions "Other food commodities" provide a substantial protein contribution. Only in India and China does this category supply less than 10% of the intake. It is especially interesting that for most of the African regions and South Asia this category is more important for protein than calories (Tables 3 and 4).

Looking at the regional situation (Annex 2c) except for Temperate South America and South Asia, pulses provide at least 3% of the total diet so are important throughout the LDCs. In most diets it is the protein factor rather than the caloric factor which is most important, although for India, Tropical America and China the contribution of calories is also likely to be important.

In summary, pulses are a small but vital component of the diet of poor people. Although the major proportion is used and traded as dried seeds, a considerable amount is also consumed as a vegetable. Legumes are an excellent source of high quality protein, are also a concentrated source of calories, they are readily transported and stored although subject to storage insect damage. Many species are easily transformed into snack food and could probably be included in new convenience foods. They may be grown by farmers on large or small

areas and may provide important cash income. They are important for their role in cropping systems and for the value of materials produced for livestock fodder and fuelwood. In this respect the grain legumes may complement the forage legumes at particular times of the year. Furthermore research on tropical pulses has had a short history and few other organizations work on these crops. Their role in the future is likely to be two-fold: a) continued source of high quality low cost protein and b) expansion of the use as a green vegetable particularly for the urban markets.

Chickpea

Globally chickpea ranks 12th equal with groundnut by its contribution to diets and 15th for value of production (Tables 21 and 22).

In 1983 chickpea received US $2,064,000 from the CG System, ranking it in 13th place by funding. The funds were distributed as follows: Asia 67%, Near East/North Africa 23% (Table 20).

All 10 million hectares of world production are within LDCs. Five LDC countries harvest over 100,000 hectares and another 12 harvest between 10 and 100,000 hectares.

Asia has by far the largest area in production with 9 million hectares harvested of which nearly 7 million hectares are in India. Two of the South Asian Countries each harvest over 50,000 hectares. Other Asian countries harvest areas of less than 10,000 ha while China has no major chickpea production. The Near East/North Africa region harvests more than 700,000 ha. Where 3 countries harvest more than 100,000 ha and another 4 harvest more than 50,000 ha. Latin America harvests 250,000 ha most of which is in Mexico. In Africa 57,000 ha are harvested mainly in Eastern and Southern Africa. The total LDC harvest is 6.0 million mt, second to field bean (excluding oil legumes).

Chickpea provides India with 4% and the Near East/North Africa with 1% contribution to the diet. The other regions where chickpea provides a small proportion of the diet are Eastern and Southern Africa, South Asia and South East Asia, all of which have cereal-based diets and Temperate South America and Central America where caloric and varietal value is probably more important than protein.

The crop is moderately drought resistant, adapted to warm semi-arid climates where it is generally considered a crop of the cool season. It is relatively free from insect attack during growth but seeds are subject to bruchid attack in storage. Although there is only one species there are two distinct types, the small seeded "desi" preferred in India and Ethiopia and the large seeded "kabuli" preferred in the Near East/North Africa and Mexico. LDC yields average about 600 kg/ha over most of its major production area but reaching 1,090 kg/ha in Central America (Table 5.7 Indicators). Yields can be doubled from 1,500 kg/ha to over 3,000 kg/ha in India by

limited irrigation. Even without supplementary irrigation, yields can be stabilized and it is expected that they could increase to 1,000 kg/ha by the end of the decade.

There has been a yield drop of 6% over the last 10 years within the LDCs. Asia had a 17% decrease with a large variability from year to year. In Eastern and Southern Africa countries on the other hand there have been yield increases of between 7-60% with, in some cases, the production stable because the area harvested has been reduced. Latin America has seen a yield increase of about 45% but it has been in the Near East/North Africa region where the most substantial yields have been attained (20%-200%) despite the yield drop in Pakistan due apparently to recent devastating *Ascochytia* blight attacks.

TAC notes that the level of CG System resources devoted to chickpea, when the crop is considered apart from other pulses, appears too great considering the region of production is confined primarily to one country. It is, however, the main protein source of that country after cereals. TAC considers that chickpea may become more important in East and Southern Africa, and in other parts of Asia.

TAC considers that the potential payoff from chickpea research is high. The recent initiation of concentrated research and the progress already made would indicate that there are good potentials for increased production not only in India and the Near East/North Africa, but also in Eastern and Southern Africa where it is too dry for field bean. Production increases in South Asia and South East Asia would also be expected especially as a result of the recent interest of many of these countries in improving legume production. TAC welcomes the establishment of the Asian Regional Grain Legume Programme. Some limited effort on chickpea in Central America may be beneficial in demonstrating its potential in areas marginal for field bean as it is the chief alternate to field bean in that region.

Even given overwhelming importance of chickpea to India, TAC considers that continued research is justified. However, since the Indian NARS is particularly strong, varietal breeding for India should not be a priority and future efforts should be shifted toward the solution of problems in other regions. The effort for the Middle East/North Africa region is probably low because the dietary contribution, value of production and the proportion of the harvested area devoted to chickpea make it the most important pulse of the region, and therefore further effort on chickpea for the region would be warranted. TAC also recommends that efforts should be strengthened for the rest of Asia and for Eastern and Southern Africa.

Cowpea

Cowpea ranks 18th equal with cocoyam in contribution to LDC diets and 20th equal with lentil and pigeonpea in value of production (Tables 21, 22).

With respect to the CGIAR-funded activities, cowpea ranks 10th. In 1983 it received US$ 3,860,000 from the CGIAR system distributed as follows: Africa 85%, Latin America 15% (Table 20).

Cowpeas are grown widely through the humid to semi-arid regions of Africa and to a lesser extent in Asia and Latin America. Together Nigeria harvests 1.7 million ha, Brazil 1.7 million ha and Niger 1.1 million ha and are responsible for 70% of the world's production. Average yields are 630 kg/ha but in marginal inter-cropping systems cowpea yields maybe as low as 150-200 kg/ha.

The best varieties so far developed are capable of 2,500 kg/ha on the research station and the short duration cowpea can achieve this in 60 days. There is potential for this short maturity legume crop in African rice fallows and considerable Asian interest in its potential to fit into rice-based cropping systems where a short maturity legume is needed.

Cowpea is an aggressive crop of the semi-arid to humid tropics able to grow on poor soils and with the ability to nodulate with a wide range of rhizobia and to contribute satisfactory amounts of fixed nitrogen to the soil. It is however a crop with poor plant type and vulnerable to many pests and diseases. Systematic work has resulted in breeding lines with multiple resistances, some improvement of plant type, and the release of superior varieties for commercial use. The potential for continued improvement of resistance to multiple pests and diseases is considerable. Its main uses are as a green vegetable (leaves and pods) and a fast cooking low sulphur grain legume for human food, but use as fodder in the subhumid and Sahalian zones is also important.

Cowpea is the most important pulse in Semi-arid West Africa, an area which has a lower intake of calories and protein than the LDC average and therefore the level of effort there is justified.

TAC considers that despite the short research history on cowpea there is excellent potential for a marked impact in the sub-humid and semi-arid regions of legume production from cowpea, as progress already achieved and technologies in the pipeline amply demonstrate. The short maturity type has particular importance because of its multiple uses and because it can yield a crop before the main harvests. There is also potential for its use in a number of other regions where a short duration legume is needed because of time constraints in the crop cycle.

TAC recommends that the effort devoted to cowpea research should remain at its present level with its focus on Africa. It however welcomes and encourages the efforts to improve cowpea production in areas outside of Africa such as in Latin America and Asia.

In the longer term, TAC also considers that some of the other crop species of Vigna important in the tropics may also benefit from CGIAR supported research. At the same time it notes that AVRDC is conducting research on murgbean Vigna radiata and would not wish to duplicate other activities.

Faba Bean

Faba bean ranks 15th overall in its contribution to LDC diets and 18th equal with cocoyam with respect to value of production (Tables 21, 22).

Among the CGIAR commodities, faba bean ranks 15th by funding. In 1983, it received US$ 1,704,000 which was entirely allocated to North Africa/Near East (Table 20).

Faba bean is harvested from 3.7 million ha of which 3.3 million are within LDCs. China harvests 2.3 million ha while the Near East/North African region harvests 791,000 ha and Latin America almost 300,000 ha where Brazil harvests 170,000 ha. Faba bean is not grown to any extent in Asia (apart from China). In total five LDCs harvest over 100,000 ha, 3 of which are in the Near East/North African region. LDC total production of faba bean is 3.5 million metric tons, 3rd in amount after field bean and chickpea (Table 3.1 Indicators).

The faba bean contributes 0.8% to the diets of the Near East/North African region ranking just after chickpea (0.95%) and just ahead of field bean (0.65%) in that region. Its value of production is 0.6%. In China, faba bean provides 0.7% to the diet 1/. It plays a minor role in the diet of both Tropical South America (0.05%) and Central America (0.1%).

This is the least drought resistant of all the legumes and subject to a number of pests and diseases. It is primarily a crop of temperate and subtropical regions and is therefore grown as a winter crop in the subtropics or at high altitudes in the tropics. It is often irrigated. It does not set seed under high temperatures. LDC yields average 1,634 kg/ha.

There has been an overall increase of LDC yields of 20% during the last 10 years. China has achieved a 34% yield increase, increased production by 5%, while reducing area cropped. Latin America has achieved a 15% increase overall but Brazil the largest producer has had declining yields and production. It is in the North African part of the Near East/North African region where much of the crop of that region is grown, that some yields are increasing substantially allowing some area reduction while maintaining production. However, other countries, such as Ethiopia and Morocco are experiencing declining yields.

The total effort of the CG System on faba bean has been directed to the Nile Valley supported by special project funds and has been of considerable benefit in the strengthening and backup of national systems of the region. The level of effort has been appropriate for the short term but may not be appropriate for the

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1/ The same is also reported for India, which means that the crop is imported as there are no production figures reported.

longer term. TAC notes that faba bean is grown in this area entirely under irrigation, competes with other pulses, and does not appear to have a significant potential for expansion to LDCs except under irrigated conditions.

TAC therefore recommends, because the faba bean is of only minor interest to LDCs outside the Near East/North African Region, that at the conclusion of the Nile Valley special project, the situation be reassessed with a view to determining future action.

Field Bean

Globally field bean is ranked 8th with respect to the proportion of calories and protein it provides LDC diets and 12th with respect to value of production (Tables 21, 22). In Equatorial Africa it has the highest value of production.

Among those commodities funded by the CGIAR, field bean ranks 8th overall by order of funding. It received US$ 5,078,000 in 1983 from the CGIAR which were distributed as follows: Latin America 80%, Africa 20% (Table 20).

Twenty-one LDC countries harvest more than 100,000 ha of which 6 are in Latin America, 9 are in Africa, 2 in the Near East/North Africa and 4 in Asia including China. Its area of major production is Latin America followed by India (Table 3.1 Indicators). Eleven million tons are produced by LDCs.

However, the dietary importance of the crop is highest in Equatorial Africa where it provides over 7% to the diet and provides after the cereals the most important single sourse of protein (Table 3). Field bean provides almost 6% of the diet for both Tropical South America and Central America and although perhaps important among the poorest people in complementing the cereal amino acids, is of less nutritional significance overall because of the high proportion of livestock and livestock products in the diet (nearly 26% for Tropical South America and 22.6% in Central America). In Eastern and Southern Africa and in India, field bean provides almost 2.5% of the diet.

Field bean is the only non-oil pulse crop with substantial production in all LDC regions and has a longer research history than any of the other pulses grown under tropical conditions. It needs good moisture and is subject to high temperature, frost and drought stress. There is great variety in seed size, colour and coat type for which there are specific preferences among different populations and ample genetic variability which is still to be exploited for the many areas where it is grown. Field bean may be eaten either as a staple or as a green vegetable (pods and leaves), but there are no estimates on the level of this use.

There has been almost complete stability at the global level over the past 10 years with respect to yields and production. It is in China where yields which have increased most (18%), but the area

has decreased keeping production stable. African yields have increased by 9%, while Latin American yields have declined by 8%. The other regions have remained more or less at the same level.

Average LDC yields are 630 kg/ha, close to cowpea (Table 5.7 Indicators) and have remained stable over the last 10 years. As yields of some LDCs are much higher there is reason to believe that higher stable yields should be achievable. Experimental yields of 5 t/ha have been achieved. It was noted however in a recent EPR that "Beans are among the most susceptible of the world's crops to diseases" and "have a low inherent capacity for nitrogen fixation" 1/.

In the LDCs there are some 338 million ha (Table 12) suitable for growing field bean under low input conditions and under high input conditions some 588 million ha. Most of the potential land is in Africa, but high inputs would double the potential of South America. There is less land available in South East Asia but under high inputs would amount to 116 million ha. The current LDC area producing field bean is approximately 11 million ha.

The level of effort devoted to field bean by the CG System is appropriate according to its overall importance. TAC notes that demand for field bean exists, is expected to increase wherever it is grown, and is greatest in Equatorial Africa and Eastern and Southern Africa.

TAC recommends that the global effort directed to field bean be maintained at the current level but also recommends that some effort be redirected towards solving the problems associated with bean production in Equatorial Africa.

Groundnut

On a global basis groundnut ranks 12th equal with chickpea in its contribution to the diets of LDCs and 11th in value of production (Tables 22, 22).

Among the CG System supported activities groundnut ranks 12th by level of funding. In 1983 it received US$ 2,688,000 distributed as follows: East and Southern Africa 11%, Semi-Arid West Africa 18%, and India 71% (Table 20).

Groundnut is harvested globally from 19 million hectares of which 17 million are in LDCs. There are 24 LDCs harvesting over 100,000 ha of which 16 are in Africa, 2 in South America and 6 in Asia. India is the major producer harvesting 38.9% of the LDC groundnuts from 7.2 million hectares. China produces 14% and

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1/ CIAT EPR

Semi-Arid West Africa 11% of the LDC production. All other LDC regions produce less than 10% each. Groundnut like field bean grows in all LDC regions and in terms of total LDC production ranks 2nd to field bean (Table 3.1 Indicators).

Groundnut grows best in sandy soils. The average yields of LDCs are about 900 kg/ha although many countries average more than twice that amount. Over the past 10 years the average yields have increased by 7% while area harvested and total production have each declined by about 2.5%. There are large fluctutions from year to year. In India, for example, production area and yield have all remained stable, while Nigeria despite a slight increase in yield has decreased area and production by about 30% each. Most of the largest producers with the exception of China have had decreases.

Groundnut is used for direct human consumption and also for oil production. The press cake remaining after oil extraction is a valuable animal feed. In India about 60% is used for oil. It is an important cash crop for the small farmer and a source of national export income for many LDCs.

The greatest constraint to groundnut production is the instability of yield. Thus the CG System general objective is to develop high yielding breeding lines and varieties that give stable resistance or tolerance to the major production constraints and to reduce factors causing storage losses. India has been the main focus of CG System activity because of the importance of the crop there. However because Africa has a large number of groundnut producing countries some shift of resources has occurred.

Currently groundnut improved cultivars are planted on over 90% of the area harvested in East and Southern Africa, South Asia and China. Equatorial Africa plants 60% to improved cultivars and South East Asia 44%, while other areas range beetween 39% and 5%. Changes in land use from 1980 to 2000 indicate that apart from Temperate South America, other regions will increase in land used for groundnut production of between 1% and 4.5%, except for South Asia with the trend in 9% increase. Temperate South America is expected to reduce the area by 2.6% annually (Indicators Table 7.1). The trends in self sufficiency for oil seed indicate overall increases for LDCs but decreasing self sufficiency for Semi Arid West Africa, where groundnut is an important crop.

TAC considers that the level of effort within the CG System devoted to groundnut is probably high when the efforts of other organizations are taken into consideration. The CG allocation to groundnut is concentrated in India, the region of its highest production. However, in terms of dietary contribution its importance is much higher in all the African regions (where its value of production is also high) and in Central America. Analysis of the distribution of groundnut production would indicate that more effort be expended on solving the problems of the crop in Africa where both value of production and contribution to diet are almost equal with field bean.

TAC recommends that the level of effort on groundnut be maintained at the current level in the short term but because of the strength of other organizations in the longer term the level should be phased down somewhat. TAC also recommends that there be a greater focus on the problems outside of India, principally in Africa.

Lentil

Lentil ranks 18th equal with 3 other crops in its contribution to LDC diets and 20th equal with 2 other pulses in value of production (Tables 21, 22). Lentil is produced in significant quantities by 23 LDCs and in the region of largest production contributes to some countries' exports. Total LDC production is just over 1 million metric tons.

Lentil within the CGIAR ranks 17th by level of funding. It received in 1983 US$ 1,288,000 from the CGS placing it in the 17th place. The funds were distributed as follows: Near East/North Africa 82%, India 18% (Table 20).

Three LDC countries harvest more than 100,000 hectares of lentil annually while another 11 harvest more than 10,000 hectares. Of these 14 countries, 8 are in the Near East/North Africa region including two with over 100,000 ha. India harvests over 100,000 hectares, while one country in South Asia harvests over 50,000 ha and several countries in Central America, Tropical and Temperate South America have smaller but significant productions.

Clearly the crop has its major importance in North Africa and the Near East where it contributes 0.6% of the diet and 0.4% of the value of production 1/. India and South Asia are next (0.1%) followed by Central America and Tropical South America next (0.05%).

Lentil is able to withstand cool temperatures and has good drought tolerance and therefore is a crop of higher altitudes or the cool season in the tropics and subtropics. It is more resistant to pests and diseases than faba bean or chickpea but is not frost hardy nor suited to wet tropics. The seeds are usually eaten directly but may also be ground to extend cereal flour. The vegetative parts are used for forage and green manure.

Concentrated research on lentil in the Near East and North Africa started with the ALAD Program in 1971 and was transferred to the CGS in 1977. Lentil was another pulse included in the Indian research program on pulses and there existed some research experience in some Mediterranean countries. Thus although there was a base to build upon much remained to be done. Average LDC yields at about 570 kg/ha are the lowest of the CG System pulses.

1/ Value of production probably does not include the value of lentil straw for fodder which is often worth more than the seeds.

During the last 10 years lentil yields have remained stable. A few individual countries, Syria and Turkey, have made gains but generally increases in production have come from increases in area. Two serious problems in the region of its major production are the tendency of the pods to shatter and the labour intensive nature of the harvest (in a region where labour is scarce and expensive).

Lentil has had a relatively small percentage of resources devoted to research within the CG System and substantial impact has yet to be shown. However good potential for increasing crop yields and stability has been demonstrated. Pipeline developments for production of lines with shatterless pods and for improving the plant type to reduce the labour demand at harvesting, indicate that significant improvements are possible within a short time. These developments may raise the potential of lentil, because of its relative freedom from pests and diseases, as a crop in other areas of the world where drought and cool temperature tolerances are required.

While TAC recognizes that the level of effort devoted to lentil has not been entirely appropriate according to its importance at the global level, the severity of the problems under study justifies this action. The level of success possible with the developments now in the pipeline suggest that continuation at the same level is warranted until the current research program has been concluded.

TAC therefore recommends that the current level of effort be continued with the focus on the Near East/North Africa but in the medium term a gradual reduction in effort should be considered

Pigeonpea

From a global perspective, pigeonpea ranks 18th equal with 4 other crops with respect to its contribution to LDC diets and 20th equal with 2 other pulses with respect to value of production (Tables 21, 22).

With respect to CGIAR supported commodities, pigeonpea ranks 16 by allocation of funds. It received in 1983 US $1,479,000 from the CG System which were distributed as follows: Asia 74%, North Africa/Near East 17%, and East and Southern Africa 8% (Table 20).

There is no complete information on the total LDC planted to pigeonpea. India produces 90% of the World's pigeonpea on some 2.5 million hectares. However 300,000 hectares are harvested in South East Asia (2 countries), Near East (1 country), Eastern and Southern Africa (4 countries), and in Central America another 400,000 hectares are harvested. Although known to be grown in the Nile Valley and West Africa no figures are available. Pigeonpea contributes 1.2% to India's diet and a 0.2% to the diets of Eastern and Southern African populations and 0.05% of the diets in Equatorial Africa (Table 4).

Pigeonpea is a plant of the semi-humid to humid tropics, tolerant of high temperatures, more drought tolerant than chickpea, remarkably free from pests and has a wide range of seed colour, size and shape. It is susceptible to frost and waterlogging and to a number of diseases.

Research indicates it would be capable of considerable yield increase both as a sole crop and in a range of cropping systems requiring differing and widely ranging maturity dates (110/130 - 140/160 - 200/270 days). Average yields (590 kg/ha) approximate those of chickpea. In addition, hybrid pigeonpea holds considerable promise for increasing production. As a perennial crop which is often treated as an annual one, pigeonpea is capable of producing a second or third harvest after the major crop is taken. The green pods are often used as a vegetable. It also provides a source of fuelwood, green manure and forage. Although it contributes little nitrogen to associated crops, after sole cropping pigeonpea has been shown to leave up to 40 kg/ha for a succeeding cereal crop.

Although pigeonpea is currently of limited importance outside India, there is considerable potential for it in Eastern and Southern Africa, Equatorial Africa and in Central America where it could complement field bean or chickpea in crop rotations for dryer situations. The range of seed colour, size and shape make it potentially more acceptable to some populations than those pulses with a limited range of these characteristics. Its fuelwood production capability would similarly be an advantage in dryer situations. The research history of pigeonpea is short but results so far and pipeline developments indicate considerable improvements in yield potential and yield stability.

Among the pulses supported by the CGS pigeonpea ranks 6th after faba bean but TAC is of the opinion that there is good potential for greater use of pigeonpea in LDC cropping systems because of its tolerance to drought and high temperatures, and its relative freedom from insect pests. TAC is encouraged to learn of the improvements in the pipeline and of the more active interest being shown by other countries in Asia and in Eastern and Southern Africa.

TAC therefore recommends continuation of the current effort on pigeonpea and supports the continued exploitation of its potential in those cropping systems in Africa and parts of Asia and the Near East where drought and heat tolerance are important considerations.

Soybean

Soybean ranks 11th in the proportion of its contribution to LDC diets and 9th with respect to value of production (Tables 21, 22).

Among the CGIAR supported commodities, soybean ranks 18th with respect to the allocation of funds. In 1983 it received US$ 782,000 from the CG System all of which were distributed in Africa (Table 20).

The area from which soybean is harvested globally is 51 million hectares of which 21 million hectares are in LDCs. In the last 10 years the global area has increased by 74% and the LDC area by 95%. Tropical South America, produces 49% of the LDC total (most of which is from Brazil which has a large export trade) followed by China with 28%, Temperate South America with 12.7% and S.E. Asia with 5%. There are 11 LDCs with over 100,000 ha of soybean of which 1 is in Central America, 3 in South America, 6 in Asia and 1 in Africa. It is reported that 7 African countries are undertaking new production campaigns.

Soybean provides 3% of the diets in both South-East Asia and China, and in all other regions where it is grown, less than 0.1%. This would indicate that where substantial quantities are grown as in Tropical South America and Temperate South America the major proportion is not for direct human consumption but is processed for oil and animal feed.

The crop was introduced into Nigeria at the turn of the century and has been shown to be readily adapted to tropical conditions and cropping systems in other West African countries but yields are very low 787 kg/ha, much below LDC coverage of 1,225 kg/ha. For use it is processed into a fermented paste or in villages in Zaire into flour. It is a rotation crop with maize in the more humid regions and does not compete with groundnut which is in the sorghum and millet regions where less than 700 mm rain falls. In areas where the two cropping systems overlap groundnut is planted and harvested before soybean. Research on soybean outside the CG System has been underway for some time and for the most part is effectively served by AVRDC and INTSOY.

The CG System soybean program is limited in scope, African based and strictly focussed on three aspects: increase in the ability of soybean to nodulate with naturally occurring rhizobia, improvement in the viability and storability of the seed, and development of appropriate cultural and management practices for pure stands or mixed cropping systems. Excellent progress in reaching these goals has been made but no new CGS produced varieties have yet been released.

In Africa a number of countries have started soybean production, but apart from Nigeria with 195,000 ha, Egypt with 42,000 ha, Zimbabwe with 35,000 and Ivory Coast with 15,000 ha, the other 6 Africa producers harvest less than 10,000 ha a piece. Use of improved cultivars is minimal. Information is available only for Equatorial Africa (Cameroon, Madagascar and Rwanda) where 13% of the area is planted to them. The annual rate of increase in land area for soybean in this region is expected to be 1.1%, but the total area currently is only 0.1% of the area harvested in the region.

It is the opinion of TAC that the small amount of resources the CGS is putting into soybean in Africa is justified and the development of breeding lines by the CGS in collaboration with interested NARS containing improvements in the selected aspects will make an impact on collaboration with interested NARS containing improvements in the selected aspects will make an impact on African soybean production

with economic gain for small farmers. In addition soybean substitution at oil mills when groundnut is in short supply would be useful.

Despite the increasing LDC demand for soybean, TAC considers that an increase in the CG System level of effort is not justified as it is geographically too limited and other institutions have a greater comparative advantage. AVRDC is successfully serving the needs of Asia while INTSOY is coordinating international efforts. TAC recognizes that there are valuable materials in the CG System pipeline and supports the completion of the current program. In the mid to long term, however, TAC recommends that CG System research in soybean be terminated and the efforts redirected to another pulse crop.

5.1.4. Livestock

Livestock (milk, beef and buffaloes) on a global scale rank 4th with respect to contribution to LDC diets and 3rd by value of production. Sheep and goats are counted separately and rank 18th equal with 4 other crops with respect to C/P contribution to diets and 10th for value of production.

Within the CGIAR, livestock receives US$ 11,738,000 putting this commodity in second place. The funds are distributed as follows: Latin America 26%, Africa 54% and North Africa/Near East 18%. Of the total allocated by the CG System approximately 20% is directed to pastures/forages utilized primarily by sheep and goats while the rest is directed to the control of trypanosomiasis and theileriosis and to the improvement of pastures for bovines. There are no CG System allocations to non-ruminant livestock or to livestock breeding.

The importance of animal products (meat, milk, eggs) is undisputed, especially the increased demand associated with rising incomes and urbanization. There are many problems associated with improving production which are not necessarily in the comparative advantage of the CG System to help solve.

Research by the CG System into various aspects of beef and swine production in Latin America during the early years established that for beef the major constraints to production were not diseases but rather poor nutrition and that emphasis on better quality pasture/forage would provide a faster and more long lasting payoff. With respect to swine, technologies for a range of production systems became available and after formulations of feed requirements based on locally available materials had been established, the swine program was phased out.

Following these findings in Latin America, it was established in Africa and in the Near East that a major limitation to livestock production, whether bovines or sheep and goats was also closely associated with their nutrition, especially in the dry season. Thus one major focus of the CGIAR System is on livestock production systems and especially the improvement of animal grazing land (pasture, forage, browse) appropriate to the agro-ecological zone under consideration.

In Africa another major constraint for a large part of the continent are two specific diseases, trypanosomiasis and theileriosis, which severely constrain cattle production. These diseases are also found in other parts of the world but not with the same severity. Because of the difficulties in dealing with these diseases, and their economic importance, an animal laboratory was established with its first priority being to contribute to the control of these two diseases. The work is of a fundamental scientific nature (upstream level 1 and 2) and progress is expected to be slow because of the complexity of the problems but the payoff from success would be difficult to exaggerate.

Animals are of great importance beyond their use as a source of high protein food. All animals perform a specific role in soil nutrient cycling and land conservation practices. They are a source of fuel and in some instances animal feed. There are also a variety of end products besides meat, milk and eggs. Additionally cattle and buffaloes are a source of traction for farmers who have no access or cannot use other forms of power. Their use for farm traction is expected to decline in Latin America but to increase substantially in Africa and to a lesser extent in Asia (Table 7.7 Indicators). In parts of the world animals have the role of capital savings and may be the outward sign of social status. They are also a generator of prosperity.

In marginal areas, large and/or small ruminants are the only efficient way of converting range land browse into human food as the soils are either too poor or too dry for effective cropping. CG System studies have shown that most farmers tend to place any gains from increased animal production into improving their cropping systems thus success in livestock research can lead to substantial payoffs in crop production. Work with respect to increasing browse for livestock by planting fast growing trees particularly leguminous species, is showing that livestock can be raised on smaller areas. Trees can supply not only high quality fodder for the animals but, if deep rooted, can be interplanted with crops and play a vital role in mineral recycling benefitting both animals and crops. Such practices also assist in conserving soil and water and in providing fuelwood.

On a regional basis, livestock and livestock products are most important for all regions in terms of consumption (especially if the protein contribution alone is considered - Table 3) as these products provide at least 6.5% of the protein contribution. With respect to numbers, India has the highest population (205 million animal units, AU), followed by China (159 million AU, Near East/North Arica with 137 AU, and Tropical America with 126 AU. No other LDC region has more than 57 million AU. The changes in self sufficiency over the 10-year period 1969/71 - 1979/81 show close to self sufficiency for most regions. There has however been a decrease in self sufficiency in Semi Arid West Africa, SE Asia and North Africa/Near East. (Figure 18). All projections to the year 2000 indicate an increase in demand for meat, milk, eggs and other animal products. Decreasing levels of self sufficiency for all types of animal products are forecast in

India and in semi-arid West Africa; otherwise, for beef and buffaloes, there are trends towards increasing self sufficiency for the rest of Asia and Central America.

The CG System allocations (Tables 21, 22) to livestock research show an apparent positive deviation at the global level with respect to both value of production and contribution to diet. However the cause of this deviation is the long term effort directed to solving disease problems. As the demand for animal products is expected to increase rapidly and as they are also, like the legumes, of far more importance within the farming system than their food value alone would indicate, TAC considers that the deviation of the CG System allocation to livestock is well justified.

TAC recommends that the level of effort in livestock research continue at least at the current level, and that the current focus on the improvement of livestock production systems for those regions where crops are not an alternative to livestock, and on the diseases trypanosomiasis and theileriosis, be maintained.

TAC notes that CG System efforts are currently concentrated in Latin America, Africa and the Near East and that there are no research efforts directed to Asian problems. given the problems experienced in Africa and the growing demand in Latin America, the current focus is appropriate but in the long term as successful pasture forage/range-land improvement technologies are developed and success is achieved in controlling diseases, consideration should be given to problems of more marginal areas, the possible CG System role in intermediate technology generation for production systems including small ruminants and non ruminants. Sources of feed for animals under intensive production systems also should receive some CG System attention. TAC considers that the CG System has no comparative advantage for breeding of large ruminants and that such activities are well taken care of elsewhere. Nevertheless TAC supports the strategy of considering the feed quality aspects of those commodities already used for dual (food and feed) purposes and encourages efforts in the transformation of other crop byproducts into animal feed.

5.1.5. Oil Seeds

Globally oilseeds rank 6th after vegetables with a dietary contribution of 1.5% and 6th after pulses with a value of production of 2.1% (Table 15).

The world production of vegetable oil is difficult to determine. Leaving soybean and groundnut aside (see pulses) the total production of vegetable oils is US $11.6 million (excluding linseed and castor oil) in 1979/81 (Table 1). The production trends through the seventies were positive except for Equatorial Africa and South Asia. The consumption trends through the seventies were also mostly positive, and generally higher than for production (Tables 7 and 8). The self sufficiency trends (including groundnut and soybean) to 2000 indicates that trends are negative for Temperate South America,

Central America, Semi-Arid West Africa and South Asia while the rest are positive. There is an overall positive self-sufficiency trend for all LDCs in oil seeds until 2000 (Table 9).

Vegetable oils are important in diets to provide energy, fatty acids essential for human nutrition and for their ability to improve the palatability of diets based almost exclusively on cereals or roots and tubers.

Oil seed production and use is clearly of global proportions but the group of plants producing oil are heterogeneous and range from large perennials (oil palm and coconut) to a variety of annuals including legumes (groundnut and soybean), cereals (maize) and a range of other species with differing regional importances (safflower, sesame, sunflower, mustard and rapeseed).

The role of the CG System in research on oil producing plants is minimal and concerns primarily groundnut and soybean, (discussed under pulses), and maize (see cereals) and is small in relation to the size of demand. However these are three crops in a whole panoply many of which quite have considerable research support from bilateral, large industrial or multinational institutions. This is true particularly for oil palm and for most of the non-leguminous oil producing crops.

The situation with coconut would appear to be an exception. It is of importance not only as a primary source of edible oil, but also of livestock feed and fibre, especially in the humid tropics of South and South East Asia and the Pacific and its use in the humid tropics to help create more stable ecological conditions for continuous cropping. It is, where ever it is grown, a source of income for small holders. Technologies are available for its successful production but some problems do exist, especially diseases, which are hampering development.

In reviewing this situation in light of the indicators and of additional information, TAC decided that the CG System had no comparative advantage in undertaking research on any additional oil producing crops and no compelling reason to develop such advantage.

It is to be noted that the CG System already supports research on groundnut and soybean which also have strong support outside the CG System and for this reason is not advocating any redirection of effort in their direction. Maize is a third crop from which oil may be extracted and which could be an appropriate use for oil extraction when other needs have been filled.

TAC therefore recommends, despite the importance of vegetable oils in LDC diets, that no additional CG System effort be expended in this area.

5.1.6. Tropical Vegetables

Vegetables from a global perspective are high by value of production (7.6%) and rank 4th after roots, tubers and starchy foods. Their dietary contribution is much less (2.3%) ranking them 5th after pulses (Table 15).

Vegetables are important in the diet in all areas of the world for the vitamins, minerals, amino acid balance and fibre they provide. There are strong social preferences affecting the choice of species used as vegetables and many are highly location specific. There is a tremendous array of vegetables and the kinds vary considerably from region to region. The green and leafy vegetables are probably of greatest importance but the red and yellow ones are hardly less significant. Among examples are: Amaranthus, Chenopodium (leafy greens), Solanum (eggplant and relatives), Capsicum (chillies), leguminosae (green beans and peas).

Vegetables as a group become much more in demand as incomes and urbanization increase. They are well adapted to small scale operation if markets are close, and to large scale operations as infrastructure improves (transporation, cold storage, refrigeration, etc.).

Among the NARS there is little effort devoted to vegetables. AVRDC, which has a limited regional mandate, is the only international institution devoted to vegetables. It works on 6 crops including pulses, leafy vegetables, fruit and roots. However it can serve only part of the need. Another factor in vegetable research is the role of the multinational institutions, which produce seed and work on a contract basis with growers but usually with a limited number of crops.

The CG System does not work directly with vegetables but some crops play a dual role and have been mentioned elsewhere. In addition, work on rice based cropping systems is leading to a search for vegetables which are suitable for particular periods in the rice cropping cycle. This activity involves IARCs, AVRDC and NARS which are all providing materials for testing.

TAC strongly supports the work of the AVRDC and urges that there be increased collaboration between the CG System and AVRDC with respect to the current vegetable crops now under intense effort and particularly for the range of crops which may be considered in the future. In this respect TAC welcomes the current collaboration of AVRDC in the activities surrounding rice-based cropping systems for Asia.

Despite the importance of these efforts in Asia, they are small in relation to the large and growing need for additional research on vegetables there and in Africa and Latin America. TAC considers that the CG System could assist in meeting that need. AVRCD should have the leading role in any such endeavour but the CG System could for instance assist in a type of network operation for both sensiting and strengthening NARS with respect to the importance of vegetables.

TAC therefore recommends that mechanisms be explored for increasing vegetable research for the LDCs.

5.1.7. Aquaculture

Aquaculture is of very great importance for increasing the production of fish as has been demonstrated in many LDCs and particularly in Asia by the development of new technologies, their spread and the increased production of both salt and fresh water fish. The subject is highly complex due to the numerous species, the high location specificity of needs and constraints and the regional and local preferences for particular species.

There has been a great diversity and multiplicity of ongoing research activities at the national, regional and global levels that clearly needed appropriate coordination. In response the "Interregional Network of Aquaculture Centers" has been established under the auspices of FAO funded by UNDP which functions within the framework of Technical Cooperation of Developing Countries (TCDC). It builds heavily on activities carried out by existing national and regional institutions which are closely linked through technology exchange arrangements. ICLARM, the International Center for Living Aquatic Resources established in the Philippines in 1977, is an important link in this network as is SEAFDEC, the South East Asia Fisheries Development Center.

TAC had identified aquaculture as of first priority level for international support and continues to give high priority to research investment in this field because of the high potential for substantial impact on production and the need for basic research to develop principles mehodologies and production models which can be locally adapted.

TAC is still convinced of the importance of aquaculture and its potential for supplying high quality protein by relatively cost-effective methods but because of the complexity of the problems and their location specificity does not consider that the CG System involvement is justified.

TAC welcomes the development of the Interregional Network of Aquaculture Centers and considers this an important international initiative. However TAC, because of the lack of any comparative advantage, recommends against direct involvement of the CG System in the support of aquaculture research at this time.

5.1.8. Conclusions

Consideration by TAC of the present CG System allocation of effort with the relative importance of commodities according to the application of selected indicators suggest that in total the proportions allocated to each commodity group was appropriate and should not be subject to drastic or sudden change. However within the commodity groups and among regions certain imbalances were found.

Cereals

TAC has recommended that cereals, for which all indicators point to increasing demand, should continue to receive the major proportion of the CG System effort to a level of at least 50% of the funds. Given the level of resources devoted to cereals outside the CG System by some of the NARS, the developed countries, private industry, it is TAC's position that the CG System continuing effort will ensure continuity of high quality research. The IARCs are expected to concentrate on research to increase productivity of the more marginal environments and are also expected to have greater involvement in upstream activities to ensure that research devoted to further increasing the yield potentials for the more favoured environments is undertaken.

For rice and wheat, the two cereals which will remain the most important, TAC recommends that the current level be maintained but that emphasis should shift to more upstream research on overcoming current yield constraints. In addition TAC recommends progressive transfer of Level III research to the stronger NARS, a more intense focus on the development of technologies for rainfed rice production (particularly dryland rice), and for wheat in more tropical climates.

For maize, TAC recommends that the current level of effort be increased because of its shorter research history and the tremendous potential for greater productivity which has not been realized. Greater effort should be focussed on Africa where relatively little has been achieved by the CG System and where close to 15% of the total LDCs maize is produced.

With respect to sorghum, millet and barley TAC recommends that more effort be directed to solving the production problems of the semi-arid tropics of Africa. The total level of effort devoted to millet should be increased while that devoted to sorghum should be maintained at current levels and for barley TAC recommends reduction of resources and concentration on dual purpose (food/feed) materials for Near East/North Africa.

Roots, Tubers and Starchy Foods

As a whole this group of commodities is expected to have a lower global demand in the long term although over the short term there may be increased regional demands. Progress in post-harvest storage and processing technologies is likely to be a major determining factor influencing global demands. It is in Africa where this group of commodities makes its greatest contribution to human diets currently with cassava the most important, but yam gives indications of a strong future demand.

Potato is a special case and as the crop with the fastest growing demand, commands special attention by the CG System. It should continue to be supported in the short term at its current high level before decreasing in the medium term in line with the strategy approved by the CG System.

TAC recommends that the actual level of the CG System effort at about 15% should be maintained at least for the next 10 years when demands resulting from progress in post-harvest food processing technologies can be assessed. In this sphere, TAC encourages research into the uses of root and tuber crops for processed and convenience foods and where appropriate for animal feed.

TAC considers that the level of effort devoted to cassava is appropriate only for the short term and that a decrease in effort is warranted. However, TAC also considers that there is an imbalance in the allocation of effort, therefore, recommends that the level of effort devoted to African and (to a less extent) Asian problems be increased at the expense of effort devoted to Latin America.

With respect to the other crops in this commodity group, TAC recommends increase in yam research, maintenance of sweet potato and plantain/banana research, and termination of support for cocoyam.

Pulses

TAC in considering the pulses both separately and as a group notes that the current effort amounts to about 18% of the CG System funding. As a group the pulses are important as a cheap protein source for poor people but as incomes rise generally become less important. TAC has also noted that there is considerable variation in the research histories of the different crops, some are long while others are very short and scarcely predate the formation of the CG System. TAC notes and supports the small amount of research on the vegetable types of some CG System pulses being undertaken by the centers as an appropriate activity. There is also considerable variation in the level of research activity devoted to pulses outside the CG System and unlike the cereals the effort is not high. These factors together with research potential, regional distribution and the importance for other qualities, were evaluated in reaching TAC's overall recommendation that the current level of the CG System activity should be maintained.

This conclusion has been reached while at the same time making recommendations relating to the total level of effort and to changes in regional effort for individual crops. These changes are influenced by two main factors, relative to the strengths of the NARS and the pipeline developments.

In summary TAC recommends that the current level of effort be maintained on chickpea, cowpea, field bean and pigeonpea but that the focus should be broadened to give more adequate weight to African needs, and additionally for chickpea to North Africa and the Near East. With respect to the faba bean, groundnut and lentil TAC considers that the current level be maintained to allow technologies currently under development and in the pipeline to be completed. At the time of completion of the current programs reassessment should be undertaken to determine future effort. Lastly, with respect to soybean TAC recommends the phasing out of effort when the current program objectives are met.

Livestock

Although TAC recommends maintenance of current levels in livestock research in the short term, it also considers that in the medium term consideration should be given to increasing the CG System resources devoted to livestock production systems, including intermediate technology generation for small ruminant and non-ruminant animals which are not addressed by others. In addition, TAC considers that greater attention will have to be given to feed quality and feed conversion technologies of various crops already supported within the CG System.

Other commodities

In considering the merits of oil seeds, tropical vegetables and aquaculture for support from the CG System, TAC noted the high demand and potential for all these commodities but also noted that there were other institutions with greater comparative advantages than the CG System. TAC therefore recommends that except for tropical vegetations none of these commodities receive CG System support at least in the short term. With respect to tropical vegetables TAC considers that CG System involvement in response to high demand is appropriate and the mechanisms for CG System support be explored with due involvement of AVRDC.

5.2. Constraints -oriented research/activities

5.2.1. Factor-Oriented Research

Chapters 2 and 3 dealt with factor-oriented research in a more global fashion. TAC recognized the importance of appropriate efforts in this field and discussed institutional/organizational arrangements with a view to defining its role and place in the CGIAR System. In doing so the overall comparative advantage of the System in the light of its structure, governance, operating procedures and its resource endowment was examined. TAC concluded that the System's comparative advantage was highest in the systematic improvement of a limited number of globally important food crops/products.

With regard to factor-oriented research TAC agrees with the recommendations on this subject of the Second Review of the CGIAR, which state that

- applied research on the common factors limiting crop production should be built-up within the context of the commodity approach;

- the requirements for strategic research on the common factors of crop production should be built-up partly within the multi-disciplinary approach to Center programs, but mainly through collaborative and contractural arrangements with other institutions;

- the CGIAR should not create new International Centers that focus on a single common factor of productivity, unless there is no other way of doing the work.

(i) Plant Nutrition

In 1982 (TAC 27) TAC conducted a review of plant nutrition research requirements in developing countries which assessed the needs and priorities for international support to this area. As regards the adequacy of research coverage TAC confirmed its earlier assessment (1979 Priority Paper) that plant nutrition research in the narrow sense 1/ (i.e. research on the mechanisms of nutrient uptake by plants) is not a neglected field.

The IARCs and several other institutions, both national and international, are active in this field (FAO, IFDC, etc.). TAC gave support to the continuation of these activities and suggested that upon request it would be ready to examine the needs for "accelerated programs" of the IARCs in plant nutrition research. This might become necessary in the light of changing demands and priorities within the CGIAR System.

1/ For a discussion of broader concerns regarding plant nutrition research in the overall context of soil constraints see para. on Soil Resources Management and Conservation.

In view of its high degree of location and crop specificity plant nutrition should continue to be dealt with in a decentralized manner. Activities conducted at the national level appear to be particularly relevant.

The present system whereby several of the IARCs cooperate with IFDC and other specialized institutions in this area appears to be effective in covering existing needs.

TAC gave its support to this cooperation and encouraged members of the CGIAR to continue their support individually or collectively to these activities as part of the special projects and other parallel activities which complement and enhance the Centers' work in this field. Clearly there is no need for an additional international initiative in this field.

(ii) Crop Protection

The management and control of plant pests and diseases is another important factor applying to all commodity groups. Integrated pest control involving all possible control mechanisms including chemicals is for obvious reasons the favoured approach.

Crop protection constitutes an important part of Centers' programs and receives an important share of their resources. According to the TAC 28 report some 160-170 professionals or roughly one third of the Centers' scientific staff are engaged in pest control.

Centers favour the multidisciplinary approach to this complex issue and continue sustained efforts at breeding varieties with durable resistance.

TAC considered the issue of crop protection (TAC 28), examined the adequacy of present international efforts, as well as the appropriateness of institutional arrangements and concluded that a new (additional) initiative by the CGIAR is not required.

TAC noted that "crop protection research is and should continue to be an important facet and an integral part of the diverse crop improvement programs and farming systems research activities at the IARCs. It should remain distributed among Centers as a component of their multidisciplinary programs at Headquarters and off-campus. The close inter-action of researchers in crop protection and those in other fields at the IARCs and in national programs is considered mutually beneficial in the development of integrated methods of crop protection and other improved technologies for specific crops and production systems in diverse agro-ecological zones.

TAC considers that this strategy is sound and effective, and it would not favour the development of a specialized international institute covering the multiple aspects of crop protection research. The IARCs should continue to rely on specialized centers of excellence, such as ICIPE to address some aspects of fundamental research and seek highly specialized services".

(iii) Soil Resources Management

This is another research area with a high degree of location specificity. As a general operating principle earlier recommendation (1979 Priorities Paper) remains valid whereby "soil (and water) management should form an integral part of the concerns and the existing programs of the IARCs, insofar as these are directly relevant to their work on crop improvement and farming systems research". The IARCs are encouraged to continue their effective collaboration with both national programs in developing countries and those specialized institutions in this field that have the expertise required for highly specific research tasks.

As regards the adequacy of overall research coverage of this field it appears that good progress has been made through the development under FAO leadership of regional inventories of soils and agroclimatic conditions. These help identify the major soil and climate constraints as well as resource potentials for the generation and transfer of improved agricultural technologies.

The recent TAC review of plant nutrition research requirements mentioned above (para. (ii)) brought out a number of broader concerns regarding plant nutrition research in the overall context of soil constraints in different ecological zones and stressed the needs for further research on soil-plant nutrition constraints.

TAC recognizes the need for increased cooperation in this field between the IARCs, national programs and international institutions. It welcomes the establishment of the International Board for Soil Resources Management (IBSRAM) which would enhance and better coordinate the efforts required. With regard to institutional considerations TAC confirms that it favours the strengthening of relevant programs at the existing IARCs over supporting a new initiative in this field under the CG System.

(v) Water Management

In its 1979 Priorities Paper TAC confirmed its earlier recommendation that (soil and) water management should form an integral part of IARCs' programs. It recognized however that additional international support might be required for certain aspects of research in this field.

In the meantime TAC spent considerable time and effort in discussing practical proposals for the establishment of an international initiative in irrigation management. At TAC 27 in early 1982 the Committee reiterated its full strong conviction that irrigation management is a subject of highest importance and priority, justifying international attention through the CGIAR. A similar view had been held by the Second Review of the CGIAR System which had actively recommended group action in this field.

In considering the relative importance of water management in the CG System context TAC noted that:

- inefficiency of many water management systems continues to be a matter of concern;

- most problems concerning water management are site and crop specific and require a decentralized approach;

- CG System priorities are gradually shifting towards rainfed agriculture;

- the capacity built up within the CG System constitutes a sound basis for dealing with the System's crops and for cooperating effectively with more specialized institutions as the need arises.

TAC welcomes the establishment of the International Irrigation Management Institute (IIMI) and encourages Centers to cooperate actively with IIMI in appropriate activities.

TAC therefore considers that additional CG System effort in water management at this time is not a high priority.

(vi) Mechanization

In its 1979 Priorities Paper TAC recognized the crucial role played by mechanization in the intensification of cropping systems. It recognized that the type of research required to promote appropriate mechanization does not lend itself easily to an international effort. Yet it noted that some aspects thereof have been successfully incorporated in the programs of some of the IARCs programs. TAC recommended that international research in this field should remain limited in scope and be confined to the development of innovative approaches, in particular those which can be used by small farmers. Most of this research should remain a national responsibility.

The Second Review of the CGIAR took a yet more restrictive approach and suggested that "further work on mechanization by the System should be limited to testing new complements and machinery.... The development of appropriate machinery should be undertaken primarily in cooperation with manufacturers".

TAC endorses the low priority assigned to mechanization research in the CG System. The work required is highly location-specific and can better be carried out by cooperating national institutions.

(vii) Post-harvest technology

Efforts to prevent post-harvest losses and to improve post harvest technology have received icnreasing attention by numerous international organizations. Several of the CGIAR Centers have made important contributions to technological processing in their areas of concern.

It is TAC's opinion that post-harvest technology will need increased attention in the future for almost all commodities, but particularly for roots and tubers. These needs go beyond harvesting, drying, storage and milling at the farm and village level and include both simple village and industrial level processing. Impact could be substantial as the roots and tubers could provide large amounts of food on a year-round basis for both urban and rural populations in many parts of the world, but especially in Africa, should suitable food processing technologies be developed.

TAC therefore recommends that the CG System should increase its efforts on post-harvest technology. Such efforts should be in close collaboration with interested NARS and with specialized institutes to develop a range of processed foods or convenience food components appropriate and acceptable to local tastes.

(viii) Energy

In the Second Review of the CGIAR is the statement: "We recognize the importance of all aspects of the energy crisis that impinge on agriculture in developing countries, but we do not think that there is any specific aspect of energy *per se* that would be an appropriate activity for the CGIAR System. In making a case for strengthening the multi-disciplinary approach to commodity research we have problems related to energy clearly in mind."

TAC in considering the matter of energy and its use for agriculture, has come to the conclusion that the problems related to energy should be identified more specifically by the CG System within the multi-disciplinary approach. Matters of fossil fuel use in mechanization and fertilizer production will in the main be handled by institutions outside the CG System and the extent of its use by farmers will be dependent on prices, policies, etc.

There is however in contrast to fossil fuels a variety of sources of renewable energy including wind, sun, water, animal manure, plant by-products and trees. For the most part animal manure, plant by-products and trees are the most important on-farm sources of fuel, but there are considerable differences in supply in different parts of the world. It is the unsatisfactory supply of wood that leads many people to use crop plant and animal by-products as fuel, by-products for which other uses may be more beneficial. Besides its use as fuel,trees provide other products as wood for farm buildings, tool handles and farm equipment, fences (or hedges) are almost as vital. Trees also play an important part in mineral recycling,protecting soils, increasing water infiltration and providing shelter and animal forage or browse.

TAC is of the opinion that more attention should be paid by the CG System to the appropriate use of fast growing multi-purpose trees in the context of the farming system.

TAC notes that there are a number of international organizations concerned with the matters discussed above and recognizes in particular the work of FAO and ICRAF. TAC also notes that there are some good examples of linkages already made between the Centres and some of these other organisms. TAC encourages this trend.

5.2.2. Farming Systems Research (FSR)

Research into farming systems was instituted in response to the observation that apparently good and profitable technologies were not being adopted by farmers. An additional factor was the belief that before there is an attempt to change a particular system of farming/cropping patterns the principles by which it works should be understood. Farming systems research is therefore a holistic approach to identifying the problems and constraints and recognizes that changes in a single component brings about changes throughout the whole system and some could have unexpected consequences. The focus is usually the single farm but may be extended to much larger, (i.e. regional) groupings of farms which although different are interdependent. The approach is comprehensive and the subject matter complex.

FSR is usually considered as having two main aspects, an upstream long-term aspect concerned with the identification of major problems and constraints and the undertaking of research and development of technologies to solve or ameliorate them,and the downstream short-term aspect concerned with the adaptation of new technologies to specific farm and production circumstances. Both are highly site specific.

Within the CG System, FSR is an activity which has received considerable attention. The funding allocated by the CG System to FSR in 1983 was approximately US$ 12 million distributed among Centers as follows: ILCA 35%, IITA 25%, ICARDA 15%, ICRISAT 15% and IRRI 15%. In addition CIAT, CIMMYT and CIP all focus on crop improvement activities from a FSR perspective. These cannot be separated out financially from the main commodity orientation of each Center's research.

TAC in analyzing the types of research carried out under the label of FSR has been struck by the diversity of activities and the number of important component or factor research projects undertaken. In addition TAC found that what was classified in one Center as FSR might be classified as something quite different in another. In some instances certain research projects are classified as FSR simply because there is no other place for them.

This variety of approach and subject matter and terminology has become more obvious recently as several Centers have begun or have followed one another in FSR in the same countries but from differring crop perspectives. Therefore Center Directors have instituted consultations in order to harmonize the CG System approaches.

TAC considers that the site specificity of FSR precludes CG System involvement in FSR per se because the CG System has no comparative advantage over NARS. However, TAC considers that the approach used in FSR is an essential

tool in the development of new component technologies. TAC also considers that the development of FSR methodologies for the use of NARS scientists is an important activity because it serves the purposes of assisting NARS in identifying those constraints which the CG System can help solve, and in adapting resultant technologies to the specific areas of need.

TAC does not intend to make any specific stand on these matters pending the outcome of the Center Directors consultations so has used this discussion to present some ideas about FSR in the context of the CG System.

5.2.3. Policy Research

The policies of actors outside and within the CG System - client countries and other countries, donors and sponsors, and financial and technical institutions for development - can and do influence the possibilities of increasing food production in developing countries through improved technology. The availability of information on these policies and of analyses of alternative development strategies with regard to food is essential for the sound review and discussion within the System of its priorities, and for the continual re-evaluation and re-alignment required to maintain or adjust the comparative advantages of the IARCs.

TAC decided in 1979, and the CGIAR accepted, that there was a need for food policy research to be done in the perspective of the aims of the System.

Developing nations can and do adopt different approaches in their efforts to increase food production. Agricultural research and training is one of these approaches. It can be effective and is often a necessary basis for proceeding. Other approaches may be needed to enable or ensure its effectiveness. Among these are (a) adequate investment in or support for development of land, water, other inputs and infrastructure; (b) provision of incentives to producers (prices, consumer goods and services); and (c) stimulation of offtake (consumer subsidies, establishment of food industries, promotion of exports and other marketing arrangements).

The allocations to national agriculture/agricultural research may reflect the competition for resources among the different approaches. Where the allocations have been lower than might be expected from government statements of the priority accorded, some of the reasons have been, for different countries and at different times:

- An awareness of the causes of inefficiency of domestic food production, distribution (transport, storage), and marketing arrangements the removal of which would take too large a share of available resources in the short or medium term.
- One or more constraints in the endowment of a country for food production, including land, water, energy and labour resources.
- The judgement that the promotion of export products (including industrial and non-food agricultural ones) is more important or promising for national development than the promotion of food production.
- Failure in attempts to generate foreign exchange through food exports because of changing world market conditions (including changing import policies).
- Inflow of food as aid or by way of trade on concessional terms.
- Various other reasons, including the valuation of currencies, the availability of credit or the cost of borrowing, changes in governments or their policies, and disasters caused by nature or man.

Policy research has already been done, in some countries or on some aspects, on most of the policy-linked decisions that can and do influence the utilization of IARC generated or sponsored knowledge in developing nations. Examples are research on rice policies and on investment in irrigation for food production (southeast Asian countries); research on food subsidy costs, benefits and effects (Egypt and Sri Lanka); research on means to achieve improved food security for developing countries; research on effects of fertilizer availability (India); research on effects of food aid (WFP); research on coarse grains demand (SAT West African countries). Some of this research involves collaboration among several Centers.

TAC has agreed that, in the short and medium term, policy research should place emphasis on (a) defining policies and adjustments to policies to permit technological change to raise food production in developing countries, and to stimulate growth of income and employment of the rural poor; (b) exploring suitable responses to rapid growth in food import demand by developing countries; (c) how to achieve food security for the world's poorest people; (d) farm product incentives to achieve both growth and equity; (e) the relative importance to be assigned to different agricultural commodities in future production patterns; (f) international coordination of food trade and aid; (g) food policy roles of public investment and of competition for funds; and (h) effects of alternative agricultural and food policies on other sectors of the economy and the implications for rural and national development.

All of these topics bear importantly on the possibility for the CGIAR to be effective in achieving improvements in food production and availability in developing countries through agricultural research. All of these topics contain elements addressing the concern of the CGIAR that among the benefits of its contributions should be an increase in equity and in the ability of countries to solve their different problems. All of these topics are amenable to analysis by methods of policy research to provide the guidance needed by the CGIAR System to set and adjust its priorities so as to maximize the benefits from its activities for the developing countries.

TAC recently recommended a modest increase in the resources devoted to food policy research. It proposes that the effort be allowed to continue at the recommended level.

5.2.4. Training

The organization of training programs by Centers has high priority for CGIAR support. The purpose of the training is to help strengthen the NARSs and to facilitate the dissemination and adoption of useful research results. Its most visible impact to-date has been the vast number of trials of varieties and practices conducted in the IARCs client countries. These have laid the foundations for many of the successes achieved. The professional cadre which has benefitted from training at an IARC has grown to above 14,000.

The strengths of the NARSs vary greatly among countries and also within a given NARS. The need for manpower development therefore is along a broad front: from adaptive and applied research understanding and capability, to competence in sophisticated techniques, and to ability in the design and management of research programs. There will be unmet needs in this whole spectrum for some time to come. A particular expressed need is for degree related research training.

The contribution the IARCs can and do make through training is anchored in their research, in the programs and the scientists who work in them. With growth in research activities and changes in research goals, training too has grown and changed and must continue to do so.

Because of the heterogeneity of the NARSs, the range of training offered has had to be expanded. Some training activities can appropriately be carried out at in-country locations and by national institutions. IARCs support and facilitate such activities where feasible. In very few instances has such transfer permitted dropping of a training activity by an IARC. Degree related training is viewed by IARCs as helping the transfer effort and, perhaps even more important, as leading to closer and more fruitful collaboration with national institutions including universities.

While continuing to respond to the range of training needs of the NARSs at the different stages of their development, the IARCs should concentrate on those aspects where they can contribute from a point of comparative advantage and/or which are relevant to the better utilization of technology generated or sponsored by the System. Training receives support from many sources. There should be scope for improving efficiency, for sharing and saving resources, through cooperation with activities external to the IARCs supported by extra-core funding (mostly from CG donors), and through inter-Center cooperation. But new or expanded activities will have to be undertaken.

The IARCs have devoted to training an estimated 7% (± 2%) of a core budget which now approaches $ 200 million. The TAC Study of Training in the CGIAR System is expected to give guidance concerning the effort and resources which the System should allocate to training. In view of the high priority of the activity TAC is expected to recommend that the allocation be at least maintained at the current level.

5.2.5. Institution Building

The CG System was established with the philosophy that food production constraints could be ameliorated by the development of new technologies resulting from well focussed research. However limitations became apparent to the development and spread of the new technologies among which were the relative weaknesses of national institutions. Many multi-national, bilateral and other international assistance agencies have been active in trying to remove these limitations through efforts in strengthening national institutions, directly through technical and financial assistance and indirectly through the provision of the training and new technologies.

Gradually it became clear that the problems being experienced included low absorptive capacity of NARS which could not be solved through provision of money and people alone. Another way had to be found if the real needs of the institutions concerned were to be met.

This led the CG System to establish a special CG System service to engage directly in specific activities related to institution building. The focus of the service activities is on building the national institutional capacity in a systematic way to organize, plan and manage its agricultural research system from its own national resources. Studies are only initiated on the invitation of a national government which participates fully throughout the process. A unique feature of this CG System service is the monitoring of the implementation of changes in close collaboration with the host government.

Sufficient time has not elapsed to show specific impact of this approach but invitations received by the CG System indicate that this service is held in high demand. Experience indicates that the status of agricultural research and research scientists within their own countries is being enhanced.

The comparative advantage for the CG System service is based on the knowledge base which is being accumulated. Systematic and comparative research into the organization and management of national agricultural research systems is being undertaken and broadly based concepts developed. Analysis of the information gives valuable feedback to not only the CG System but also to technical assistance agencies and helps both the country and agencies to identify with greater precision the real needs for financial, technical or training assistance. In addition the feedback to the CG System makes the the transfer and adaptation of new agricultural technologies more effective. TAC considers that this research program acts as an important focal point. The results from such activities are likely to reach far beyond the CG System.

TAC considers that this program of activities is of highest relevance in helping national governments help themselves. The payoff will be seen as the constraints limiting food production are ameliorated. TAC recognized that this is primarily a catalyzing activity and in the long run will become increasingly concerned with developing improved linkages among NARS and with other institutions for mutual benefit.

TAC therefore recommends that the program of activities covered by this service be allowed to grow to meet the level originally proposed and them to continue at that level.

5.3. Germplasm

The fundamental tool for the plant breeder is the genetic variability contained in the crop, its wild relatives, primitive cultivars and land races. Thus the collection, preservation, characterization, evaluation and distribution of germplasm are essential activities associated with the development of improved plant varieties.

Concern followed the recognition that valuable materials containing great variability were being lost with increasing speed as the pace of modernization of agriculture accelerated following World War II. The concern for this process of loss of genetic variability (genetic erosion) had two major results: CG System assigned responsibility to Centres for the collection and maintenance of the germplasm related to the crops supported by the CG System; and the CG System created a mechanism to promote greater awareness and coordinate germplasm activities worldwide to ensure that the variability of species valuable to agriculture were adequately represented in germplasm collections (germplasm banks) and that collections of species threatened with extinction were made on a priority basis. Germplasm collections, as part of the heritage of mankind, were to be conserved, made freely available to researchers, and for safety duplicated for storage and maintenance in another germplasm bank elsewhere.

The same concerns which stimulated CG System interest in germplasm conservation resulted in the adoption by the FAO Conference in 1983 of the International Undertaking on Plant Genetic Resources which calls on governments to take particular responsibility in assuring protection and freedom of access to collections of germplasm and sets out procedures as to how this can be achieved. In the implementation of this activity, CG System is expected to be an important partner responsible for scientific leadership.

For seed propagated crops, there are three types of collections: "base" collections, which are for long-term conservation and do not hold materials for general exchange; "active" collections, which are samples held in medium storage and provide materials for evaluation, documentation and exchange; and "working" collections, the commonest type, which are usually in the hands of breeders. Vegetatively propagated crops are subject to more conservation difficulties and often require field plantings. Gradually working collections are being placed in tissue culture thus saving time, energy and space. However there is no similar method yet devised which could adequately take care of the long-term conservation of vegetatively propagated crops.

In the period since the CG System started stimulating conservation of materials valuable to agriculture, long-term germplasm banks have increased from three or four to more than 30 and a network of germplasm activities that includes more than 80 countries and 50 crop species has been created. In addition some of these germplasm banks have been designated as holding base collections of crop species important world-wide and regionally. The designated base collections of most of the crops the CG System supports are held by its Centres which in addition, also hold important collections of other crops.

The responsibility of a germplasm bank concerns not only the collection and conservation which also means periodic regeneration of the collections, but also the characterization, evaluation, documentation and exchange of the materials in its charge.

The total spent by the CG System in 1982 is estimated as being about US$ 13 million but because of difficulties in separating conservation and breeding this figure represents only an order of magnitude.

Collecting activities were of the highest priority at the early stages of CG System involvement but they are beginning to be phased down as the range of global variability conserved in germplasm banks reaches a satisfactory level for each species. The focus of activity both inside and outside the CG System is beginning to shift at differential rates towards characterization and evaluation of collections. Currently research into long-term conservation of vegetatively propagated crops by cryo preservation and into the problems of recalcitrant seeds (seeds which do not store or generate well) is currently being supported by the CG System. Preliminary results are promising.

It is estimated that approximately 12% of the materials held in germplasm banks have been evaluated so much still remains to be done. Clearly the responsibility for these activities is with the germplasm bank that holds the materials. Thus the question of who should bear the cost of these activities becomes of interest in light of the importance of these materials. Information about the stored materials must also be available if these materials are to be used effectively. It has been suggested that all collection should cease (except for emergencies) unless the costs of characterization and evaluation are included and guaranteed. While much evaluation can be done by a germplasm bank, only the breeders can effectively evaluate materials in relation to characteristics of interest to specific crop improvement goals.

TAC considers that germplasm conservation, characterization, evaluation, documentation and exchange are a fundamental responsibility of the CG System not only for its mandated crops but for all the associated wild relatives and other species which may provide useful variability for breeding. Furthermore, TAC considers that the CG System retains responsibilities for the continuing needs of the germplasm of those crops which may be phased down or discontinued within the CG System, or which has been given to the CG System for safekeeping.

TAC also considers that the CG System continues to have the responsibility of assisting NARS with germplasm activities not only by providing scientists with materials with specific characteristics but also by backstopping the NARS in undertaking their responsibilities associated with germplasm bank management.

These functions all require continuing CG System leadership in path-breaking research for increasing the efficiency and effectiveness of the long-term storage of germplasm and in particular for vegetatively propagated crops and recalcitrant seeds and for formulating guidelines for germplasm bank management.

TAC therefore recommends that in keeping with the fundamental importance of germplasm conservation and the activities associated with the effective management of germplasm collections, the CG System increase substantially in the short term its efforts in this field, so that satisfactory levels of characterization, evaluation and documentation, and standards in the operation of germplasm banks, can be achieved with the least delay in the CG System.

APPENDIX

Country Groupings

The following grouping of countries is used throughout the report. In some cases exceptions to these groupings had to be accepted due to data available. These exceptions are marked in the tables.

Temperate South America

Argentina, Chile, Uruguay

Tropical South America

Bolivia, Brazil, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Venezuela

Central America

Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua

East/South Africa

Angola, Botswana, Kenya, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia, Zimbabwe

Equatorial Africa

Burundi, Cameroon, Central African Republic, Congo, Gabon, Madagascar, Rwanda, Uganda, Zaire

Humid West Africa

Benin, Ghana, Guinea, Ivory Coast, Liberia, Sierra Leone, Togo

Semi-Arid West Africa

Chad, Gambia, Guinea-Bissau, Mali, Mauritania, Niger, Nigeria, Senegal, Upper Volta

North Africa/Near East

Afghanistan, Algeria, Cyprus, Egypt, Ethiopia, Iran, Iraq, Jordan, Lebanon, Libya, Mongolia, Morocco, Pakistan, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, Turkey, Yemen A.R., Yemen P.D.R.

India

South Asia

Bangladesh, Nepal, Sri Lanka

South-East Asia

Bhutan, Burma, Indonesia, Kampuchea, Korea P.R., Korea Rep., Laos, Malaysia, Philippines, Thailand, Vietnam

China

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LIST OF ANNEX TABLES

Annex table 1: Value of production in developing country regions [a/] by commodity, 1979/81, in percent of total regional value of production.

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China	All Developing Countries
Cereals	18.7	12.9	14.6	19.4	11.6	9.1	14.2	25.3	42.8	60.6	45.9	34.4	30.8
Rice	0.9	6.3	2.3	2.0	6.7	6.1	2.3	4.7	29.1	57.8	42.2	22.8	19.6
Wheat	7.5	0.9	1.8	1.1	-	-	-	13.5	8.0	1.8	0.1	5.6	5.0
Maize	6.5	5.4	7.7	13.7	2.3	2.0	1.5	1.9	1.2	0.8	2.9	4.6	3.8
Barley	0.3	0.1	0.3	0.2	-	-	-	3.6	0.4	0.1	0.4	0.3	0.6
Sorghum	3.2	0.2	2.5	1.2	0.8	0.4	3.2	1.0	1.8	-	0.1	0.5	0.9
Millet	0.2	-	-	1.2	1.7	0.7	7.1	0.6	2.2	0.2	0.2	0.6	0.9
Roots, tubers and starchy foods	2.9	9.0	7.4	12.5	39.8	35.2	50.0	3.4	4.0	7.1	8.2	19.0	13.0
Cassava	-	1.2	0.1	3.3	4.7	1.4	1.6	-	0.2	0.1	1.3	-	0.5
Potato	2.4	2.1	0.9	1.4	1.4	-	0.1	2.4	2.2	1.8	0.9	1.5	1.6
Sweet potato	0.4	0.4	0.7	2.7	8.1	0.6	0.6	0.1	0.5	1.9	2.9	17.2	6.6
Yam	-	0.3	0.2	-	4.1	23.2	41.8	0.3	-	-	-	-	1.9
Cocoyam	-	-	0.1	-	0.9	4.9	4.5	0.1	-	-	0.1	0.3	0.3
Other roots and tubers	-	0.2	0.1	0.1	3.3	-	0.1	0.3	-	0.2	0.3	-	0.2
Plantain/banana	0.1	4.8	5.3	5.0	17.3	5.2	1.4	0.2	1.1	3.1	2.7	-	1.9
Pulses	6.4	9.2	4.3	5.1	6.9	2.3	6.5	3.2	9.9	0.9	2.1	2.7	4.8
Chickpea	-	-	0.6	0.2	-	-	-	1.0	3.6	0.4	0.1	-	0.7
Cowpea	-	-	-	0.2	0.1	-	2.4	-	-	0.1	-	-	0.1
Faba bean	-	0.1	0.1	-	-	-	-	0.6	-	-	-	0.5	0.3
Field bean	0.8	2.2	2.8	1.8	4.1	0.3	0.1	0.4	1.8	0.2	0.5	0.5	1.0
Groundnut	1.0	0.4	0.2	2.2	2.6	2.0	3.9	0.8	3.2	0.1	0.9	0.5	1.1
Lentil	0.1	-	-	-	-	-	-	0.4	0.3	0.2	-	-	0.1
Pigeonpea	-	-	-	0.4	0.1	-	-	-	0.9	-	-	-	0.1
Soybean	4.5	6.4	0.6	0.3	-	-	0.1	0.1	0.2	-	0.6	1.2	1.4
Livestock and livestock products	52.0	32.3	33.8	27.6	12.3	5.3	15.1	30.6	15.0	12.6	13.6	28.1	25.2
Beef and buffaloes	32.6	11.8	9.3	14.2	6.0	1.6	5.6	6.5	0.5	3.7	2.8	2.5	5.6
Sheep and goats	1.5	0.4	0.3	1.8	0.9	0.6	3.0	5.9	0.9	0.9	0.2	0.7	1.3
Milk	9.7	8.1	11.4	6.8	1.5	0.4	2.4	13.7	12.0	5.8	0.5	1.2	5.8
Other livestock b/	8.3	12.1	12.8	4.8	4.0	2.6	4.2	4.5	1.6	2.0	10.1	23.7	12.5
Vegetables	3.2	2.6	3.7	6.2	3.8	3.9	4.6	10.4	11.9	2.5	7.5	8.6	7.6
Oilseeds	2.0	0.8	1.8	1.9	2.1	3.6	3.5	2.5	1.6	2.0	6.3	0.9	2.1
Coconut	-	0.1	0.4	0.7	0.1	0.4	0.1	-	0.5	1.6	3.0	-	0.5
Oil palm	-	0.1	0.1	0.3	1.5	2.3	2.1	-	-	-	2.8	0.1	0.5
Other oilseeds	2.0	0.6	1.3	0.9	0.6	0.9	1.3	2.5	1.1	0.5	0.5	0.8	1.1
Other food crops c/	11.6	16.2	19.2	8.0	8.4	25.8	4.1	16.5	7.5	3.2	6.2	2.0	8.2
Non-food crops d/	3.2	17.0	15.2	19.2	15.1	14.8	1.9	8.1	7.3	11.0	10.3	4.3	8.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total in billion US$	22.1	60.1	27.2	8.7	10.8	8.3	18.1	61.5	77.0	12.7	66.3	187.6	560.3

a/ For country groupings, see appendix. This table is based on 90 developing countries of FAO's AT 2000 study plus China.
b/ Pigmeat, poultry, eggs.
c/ Sugar, citrus fruit, fruit, cocoa.
d/ Coffee, tea, tobacco, cotton, jute and hard fibres, rubber, fodder crops.

Source: FAO, AT 2000 and ICS data files; FAO, The State of Food and Agriculture 1981, FAO Agriculture Series, No. 14, Rome 1982.

Annex table 2: Calory contributions to diets in developing country regions a/ by commodity, 1979/81, in percent

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China	All Developing Countries
Cereals	33.6	37.3	47.6	46.9	26.2	37.5	48.2	58.5	66.6	80.9	67.9	65.0	60.1
Rice	1.3	14.9	5.1	3.0	9.5	18.3	6.8	6.0	33.2	68.0	56.1	35.4	29.3
Wheat	30.7	12.8	11.4	5.7	2.3	4.5	4.6	39.6	18.5	9.9	4.7	18.4	17.5
Maize	1.4	9.3	30.5	33.6	8.4	10.6	5.6	5.8	3.1	2.5	6.1	7.7	7.6
Barley	0.2	0.3	-	-	0.1	-	0.1	2.6	0.7	0.1	0.6	0.6	0.8
Sorghum	-	-	0.6	3.2	2.1	1.9	13.1	3.5	5.8	-	0.1	1.5	2.6
Millet	-	-	-	1.4	3.8	2.2	18.0	1.0	5.2	0.4	0.3	1.4	2.3
Roots, tubers and starchy foods	4.7	11.9	4.0	23.0	46.4	35.2	20.9	1.7	2.5	3.7	7.6	12.1	9.1
Cassava	0.2	5.7	0.5	18.1	31.4	16.0	8.4	-	0.9	0.5	4.0	0.2	2.6
Potato	3.3	2.0	0.7	0.7	0.7	0.1	0.1	1.3	0.9	0.8	0.5	0.7	0.9
Sweet potato	0.6	0.3	0.5	1.6	4.5	0.5	0.3	0.1	0.3	0.9	1.5	11.1	3.9
Yam	-	0.1	0.1	-	1.1	9.5	9.4	0.1	-	-	-	-	0.5
Cocoyam	-	-	-	-	0.3	3.4	1.3	-	-	-	-	0.1	0.1
Other roots and tubers	-	0.1	0.1	-	0.8	-	0.1	0.1	-	0.1	0.2	-	0.1
Plantain/banana	0.6	3.7	2.1	2.6	7.6	5.7	1.3	0.1	0.4	1.4	1.4	-	1.0
Pulses	0.9	4.4	5.4	3.5	7.7	2.7	5.4	2.4	5.4	0.8	2.5	3.2	3.7
Chickpea	0.1	-	0.3	0.1	-	-	-	0.7	2.5	0.3	0.1	-	0.6
Cowpea	-	-	0.1	0.3	0.1	-	2.9	-	-	0.1	-	-	0.1
Faba bean	-	0.1	0.2	-	-	-	-	0.7	-	-	-	0.8	0.4
Field bean	0.5	4.1	4.4	1.4	4.2	0.4	0.1	0.4	1.4	0.2	0.3	0.6	1.1
Groundnut	0.1	0.1	0.4	1.3	3.2	2.2	2.2	0.2	0.1	-	0.8	0.6	0.6
Lentil	0.1	0.1	-	-	-	-	-	0.3	0.2	0.2	-	-	0.1
Pigeonpea	-	-	-	0.4	0.1	-	-	-	1.1	-	-	-	0.2
Soybean	0.1	-	-	-	0.1	0.1	0.2	0.1	0.1	-	1.3	1.2	0.6
Livestock and livestock products	22.6	11.5	10.2	5.1	2.9	2.5	3.0	5.0	3.0	2.6	3.1	8.5	6.2
Beef and buffaloes	13.6	3.7	2.0	1.9	1.1	0.8	1.0	1.1	-	0.5	0.4	0.5	1.0
Sheep and goats	-	-	-	0.2	0.1	0.1	0.3	0.4	0.1	0.1	-	0.1	0.1
Milk	4.7	4.1	4.6	2.1	0.7	0.7	1.0	2.6	2.6	1.6	0.3	0.4	1.7
Other livestock b/	4.3	3.7	3.6	0.9	1.0	0.9	0.7	0.9	0.3	0.4	2.4	7.5	3.4
Vegetables	1.7	0.9	0.8	0.9	1.0	1.7	1.0	1.7	1.8	0.4	1.4	1.7	1.5
Oilseeds	6.0	1.6	3.1	3.3	4.3	7.6	7.3	4.8	3.0	1.7	3.0	1.4	2.9
Coconut	-	0.1	0.1	0.9	-	0.3	0.1	0.1	0.3	0.6	1.8	-	0.4
Oil palm	-	0.4	0.2	0.8	3.6	6.4	5.2	0.7	0.7	0.1	0.8	-	0.7
Other oilseeds	6.0	1.1	2.8	1.6	0.7	0.9	2.0	4.0	2.0	1.0	0.4	1.4	1.8
Other food commodities c/	30.5	32.4	28.9	17.3	11.5	12.8	14.2	25.9	17.7	9.9	14.5	8.1	16.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total, in calories	3178	2514	2655	2047	2153	2120	2290	2594	2056	1898	2414	2428	2349

a/ For country groupings, see appendix. This table is based on 90 developing countries of FAO's AT 2000 study plus China.

b/ Pigmeat, poultry, eggs.

c/ This group comprises other food crops and all other commodities that contribute to nutrition. The contribution of other food crops in all developing countries, e.g., is 2.3 percent.

Source: FAO, ICS data files.

Annex table 3: Protein contributions [a/] to diets in developing country regions [b/] by commodity, 1979/81, in percent

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China	All Developing Countries
Cereals	21.4	32.6	42.4	51.0	31.8	40.5	49.6	58.1	67.7	82.3	61.5	55.5	54.4
Rice	1.0	12.9	5.0	2.9	11.8	20.3	6.9	5.1	32.3	69.2	51.4	28.6	25.3
Wheat	19.7	12.9	11.9	6.4	2.1	5.7	5.2	40.7	21.0	11.1	4.5	18.9	18.1
Maize	0.7	6.8	25.5	36.3	10.8	11.0	4.8	4.8	3.5	2.0	5.6	5.3	5.5
Barley	-	-	-	-	-	-	-	3.3	-	-	-	-	1.7
Sorghum	-	-	-	2.9	1.5	1.3	11.3	2.7	3.9	-	-	1.0	2.1
Millet	-	-	-	2.5	5.6	2.2	21.4	1.5	7.0	-	-	1.7	1.7
Roots, tubers and starchy foods	2.4	3.6	-	5.9	12.9	15.9	9.7	0.9	-	-	1.4	5.0	2.7
Cassava	-	1.3	-	5.9	8.2	5.3	1.6	-	-	-	1.4	-	-
Potato	2.4	1.0	-	-	-	-	-	0.9	-	-	-	-	1.0
Sweet potato	-	-	-	-	2.6	-	-	-	-	-	-	5.0	1.7
Yam	-	-	-	-	-	6.6	6.1	-	-	-	-	-	-
Cocoyam	-	-	-	-	-	2.2	2.0	-	-	-	-	-	-
Other roots and tubers	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantain/banana	-	1.3	-	-	2.1	1.8	-	-	-	-	-	-	-
Pulses	0.5	7.7	8.3	5.4	17.0	5.3	10.1	3.9	10.9	-	6.3	7.0	7.9
Chickpea	-	-	-	-	-	-	-	1.2	5.2	-	-	-	1.4
Cowpea	-	-	-	-	-	-	6.5	-	-	-	-	-	-
Faba bean	-	-	-	-	-	-	-	0.9	1.3	-	-	-	1.0
Field bean	0.5	7.7	7.1	3.4	10.3	1.3	-	0.9	3.1	-	-	1.0	2.4
Groundnut	-	-	1.2	2.0	6.7	4.0	3.6	-	-	-	1.4	1.3	1.4
Lentil	-	-	-	-	-	-	-	0.9	-	-	-	-	-
Pigeonpea	-	-	-	-	-	-	-	-	1.3	-	-	-	-
Soybean	-	-	-	-	-	-	-	-	-	-	4.9	4.7	1.7
Livestock and livestock products	58.0	40.0	33.0	19.1	13.4	8.3	13.3	16.5	7.9	6.5	10.4	19.2	19.1
Beef and buffaloes	38.1	13.2	8.3	10.3	7.2	3.1	5.7	4.2	-	3.5	2.4	2.3	4.8
Sheep and goats	-	-	-	-	-	-	2.8	2.1	-	-	-	-	-
Milk	8.3	9.7	10.7	5.9	3.1	2.6	2.4	5.4	7.9	3.0	-	-	4.1
Other livestock c/	11.6	17.1	14.0	2.9	3.1	2.6	2.4	4.8	-	-	8.0	16.9	10.2
Vegetables	1.6	1.6	1.5	2.5	4.6	4.0	2.0	2.7	3.9	-	3.1	4.7	3.1
Oilseeds	-	-	-	-	-	-	-	-	-	-	-	-	-
Coconut	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil palm	-	-	-	-	-	-	-	-	-	-	-	-	-
Other oilseeds	-	-	-	-	-	-	-	-	-	-	-	-	-
Other food commodities d/	16.1	14.5	14.8	16.1	20.3	26.0	15.3	17.9	9.6	11.2	17.3	8.6	12.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total, in g protein	58	31	34	20	20	23	25	33	23	20	29	30	29

a/ Corrected by the aminoacid quality of proteins.

b/ For country groupings, see appendix. This table is based on 90 developing countries of FAO's AT 2000 study plus China.

c/ Pigmeat, poultry, eggs.

d/ This group comprises other food crops and all other commodities that contribute to nutrition.

Source: FAO, ICS data files.

Annex table 4: Calory/protein contributions to diets a/ in developing country regions b/ by commodity, 1979/81, in percent

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China	All Developing Countries
Cereals	27.5	35.0	45.0	49.0	29.0	39.0	48.9	58.3	67.2	81.6	64.7	60.3	57.3
Rice	1.2	13.9	5.6	3.0	10.7	19.3	6.9	5.6	32.8	68.6	53.8	32.0	27.3
Wheat	25.2	12.9	11.7	6.1	2.2	5.1	4.9	40.2	19.8	10.5	4.6	18.7	17.8
Maize	1.1	8.6	28.0	35.0	9.6	10.8	5.2	5.3	3.3	2.3	5.9	6.5	6.6
Barley	0.1	0.2	-	-	0.1	-	0.1	3.0	0.4	0.1	0.3	0.3	1.3
Sorghum	-	-	0.3	3.1	1.8	1.6	12.2	3.1	4.9	-	0.1	1.3	2.4
Millet	-	-	-	2.0	4.7	2.2	19.7	1.3	6.1	0.2	0.2	1.6	2.0
Roots, tubers and starchy foods	3.6	7.8	2.0	14.5	29.7	25.6	15.3	1.3	1.3	1.9	4.5	8.6	5.9
Cassava	0.1	3.5	0.3	12.0	19.8	10.7	5.0	-	0.5	0.3	2.7	0.1	1.3
Potato	2.9	1.5	0.4	0.4	0.4	0.1	0.1	1.1	0.5	0.4	0.3	0.4	1.0
Sweet potato	0.3	0.2	0.3	0.8	3.6	0.3	0.2	0.1	0.2	0.5	0.8	8.1	2.8
Yam	-	0.1	0.1	-	0.6	8.1	7.8	0.1	-	-	-	-	0.3
Cocoyam	-	-	-	-	0.2	2.8	1.7	-	-	-	-	0.1	0.1
Other roots and tubers	-	0.1	0.1	-	0.4	-	0.1	0.1	-	0.1	0.1	-	0.1
Plantain/banana	0.3	2.5	1.1	1.3	4.9	3.8	0.7	0.1	0.2	0.7	0.7	-	0.5
Pulses	0.7	6.1	6.9	4.5	12.4	4.0	7.8	3.2	8.2	0.4	4.4	5.1	5.8
Chickpea	0.1	-	0.2	0.1	-	-	-	1.0	3.9	0.2	0.1	-	1.0
Cowpea	-	-	0.1	0.2	0.1	-	4.7	-	-	0.1	-	-	0.1
Faba bean	-	0.1	0.1	-	-	-	-	0.8	0.7	-	-	0.4	0.7
Field bean	0.5	5.9	5.8	2.4	7.3	0.9	0.1	0.7	2.3	0.1	0.2	0.8	1.8
Groundnut	0.1	0.1	0.8	1.7	5.0	3.1	2.9	0.1	0.1	-	1.1	1.0	1.0
Lentil	0.1	0.1	-	-	-	-	-	0.6	0.1	0.1	-	-	0.1
Pigeonpea	-	-	-	0.2	0.1	-	-	-	1.2	-	-	-	0.1
Soybean	0.1	-	-	-	0.1	0.1	0.1	0.1	0.1	-	3.1	3.0	1.2
Livestock and livestock products	40.3	25.8	21.6	12.1	8.2	5.4	8.2	10.8	5.5	4.6	6.8	13.9	12.7
Beef and buffaloes	25.9	8.5	5.2	6.1	4.2	2.0	3.4	2.7	-	2.0	1.4	1.4	2.9
Sheep and goats	-	-	-	0.1	0.1	0.1	1.6	1.3	0.1	0.1	-	0.1	0.1
Milk	6.5	6.9	7.7	4.0	1.9	1.7	1.7	4.0	5.2	2.3	0.2	0.2	2.9
Other livestock c/	8.0	10.4	8.8	1.9	2.1	1.8	1.6	2.9	0.2	0.2	5.2	12.2	6.8
Vegetables	1.7	1.3	1.2	1.7	2.8	2.9	1.5	2.2	2.9	0.2	2.3	3.2	2.3
Oilseeds	3.0	0.8	1.6	1.7	2.2	3.8	3.7	2.4	1.5	0.9	1.5	0.7	1.5
Coconut	-	0.1	0.1	0.5	-	0.2	0.1	0.1	0.2	0.3	0.9	-	0.2
Oil palm	-	0.2	0.1	0.4	1.8	3.2	2.6	0.4	0.4	0.1	0.4	-	0.4
Other oilseeds	3.0	0.6	1.4	0.8	0.4	0.5	1.0	2.0	1.0	0.5	0.2	0.7	0.9
Other food commodities d/	23.3	23.5	21.9	16.7	15.9	19.4	14.8	21.9	13.7	10.6	15.9	8.4	14.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

a/ Arithmetic mean of calories and protein shares.
b/ For country groupings, see appendix. This table is based on 90 developing countries of FAO's AT 2000 study plus China.
c/ Pigmeat, poultry, eggs.
d/ This group comprises other food crops and all other commodities that contribute to nutrition.

Source: Calculations based on Annex tables 2 and 3.

Annex table 5: Ranking of food commodity groups a/ by value of production and calory/protein contributions to diets

According to value of production	According to calory/protein contributions to diets
Cereals South Asia, South East Asia, India	Cereals South Asia
Livestock and livestock products Temperate South America, Central America, Tropical South America	Livestock and livestock products Temperate South America, Tropical South America, Central America
Roots, tubers and starchy foods Semi-Arid West Africa, Equatorial Africa, Humid West Africa, China	Roots, tubers and starchy foods Equatorial Africa, Humid West Africa, Semi-Arid West Africa, East/South Africa, China, Tropical South America
Vegetables India, North Africa/Near East	Pulses Equatorial Africa, India, Semi-Arid West Africa
Pulses India, Tropical South America, Equatorial Africa, Semi-Arid West Africa, Temperate South America	Vegetables China, India, Humid West Africa
Oilseeds South-East Asia, Humid West Africa, Semi-Arid West Africa	Oilseeds Humid West Africa, Semi-Arid West Africa, Temperate South America, North Africa/Near East, Equatorial Africa

a/ Excluding the groups of "other food crops" and "non-food crops" as mentioned in other tables.

This table is based on the value of production and the calory/protein contributions to diets as main priority indicators for commodity groups on a global scale. In the particularly identified regions the shares are at least 25 p.c. higher than the global figure.

Source: Cp. annex tables 1 and 4.

Annex table 6: Ranking of individual food commodities by value of production and calory/protein contributions to diets

According to value of production

First category c/

Rice
: South Asia, South-East Asia, India

Second category c/

Sweet potato
: China

Milk
: North Africa/Near East, India, Central America, Temperate South America, Tropical South America

Beef and buffaloes
: Temperate South America, East/South Africa, Tropical South America, Central America

Wheat
: North Africa/Near East, India, Temperate South America

Maize
: East/South Africa, Central America, Temperate South America, Tropical South America

Third category c/

Yam
: Semi-Arid West Africa, Humid West Africa, Equatorial Africa

Plantain/banana
: Equatorial Africa, Central America, Humid West Africa, East/South Africa, Tropical South America, South Asia, South-East Asia

Potato
: Temperate South America, North Africa/Near East, India, Tropical South America

Soybean
: Tropical South America, Temperate South America

Sheep and goats
: North Africa/Near East, Semi-Arid West Africa, East/South Africa

Groundnut
: Semi-Arid West Africa, India, Equatorial Africa, East/South Africa, Humid West Africa

Field bean
: Equatorial Africa, Central America, Tropical South America, India, East/South Africa

Sorghum
: Semi-Arid West Africa, Temperate South America, Central America, India, East/South Africa

Millet
: Semi-Arid West Africa, India, Equatorial Africa, East/South Africa

According to calory/protein contributions to diets

First category c/

Rice
: South Asia, South-East Asia

Wheat
: North Africa/Near East, Temperate South America

Second category c/

Maize
: East/South Africa, Central America, Humid West Africa, Equatorial Africa

Third category c/

Milk
: Central America, Tropical South America, Temperate South America, India, East/South Africa, North Africa/Near East

Beef and buffaloes
: Temperate South America, Tropical South America, East/South Africa, Central America, Equatorial Africa

Sweet potato
: China, Equatorial Africa

Sorghum
: Semi-Arid West Africa, India, East/South Africa, North Africa/Near East

Millet
: Semi-Arid West Africa, India, Equatorial Africa, Humid West Africa

Field bean
: Equatorial Africa, Tropical South America, Central America, East/South Africa, India

Barley
: North Africa/Near East

Cassava
: Equatorial Africa, East/South Africa, Humid West Africa, Semi-Arid West Africa, Tropical South America, South-East Asia

Soybean
: South-East Asia, China

Potato
: Temperate South America, Tropical South America

Chickpea
: India

Groundnut
: Equatorial Africa, Humid West Africa, Semi-Arid West Africa, East/South Africa

According to value of production	According to calory/protein contributions to diets
Fourth category c/	Fourth category c/
Chickpea India, North Africa/Near East	Faba bean
Barley North Africa/Near East	Plantain/banana Equatorial Africa, Humid West Africa, Tropical South America, East/South Africa, Central America, Semi-Arid West Africa, South Asia, South-East Asia
Cassava Equatorial Africa, East/South Africa, Semi-Arid West Africa, Humid West Africa, South-East Asia, Tropical South America	Oil palm Humid West Africa, Semi-Arid West Africa, Equatorial Africa
Coconut South-East Asia, South Asia, East/South Africa	Yam Humid West Africa, Semi-Arid West Africa, Equatorial Africa
Oil palm South-East Asia, Humid West Africa, Semi-Arid West Africa, Equatorial Africa	Coconut South-East Asia, East/South Africa, South Asia
Cocoyam Humid West Africa, Semi-Arid West Africa, Equatorial Africa	Cowpea Semi-Arid West Africa, East/South Africa
Faba bean North Africa/Near East, China	Lentil North Africa/Near East
Cowpea Semi-Arid West Africa, East/South Africa	Pigeonpea India, East/South Africa
Lentil North Africa/Near East, India, South Asia	Sheep and goats Semi-Arid West Africa, North Africa/Near East
Pigeonpea India, East/South Africa	Cocoyam Humid West Africa, Semi-Arid West Africa, Equatorial West Africa

a/ Excluding the aggregates "other roots and tubers", "other livestock", and "other oilseeds" as mentioned in other tables.

b/ This table is based on the value of production share and the calories/protein share in the diet as main priority indicators for individual commodities on a global scale. In the particularly identified regions the shares are at least 25 p.c. higher than the global figure.

c/ The following shares mark individual categories:

Category I : share $\geq$ 10 p.c.
Category II : 3 p.c. $\leq$ share $<$ 10 p.c.
Category III : .9 $\leq$ share $<$ 3 p.c.
Category IV : share $<$ .9 p.c.

Source: Cp. annex tables 1 and 4.

Annex table 7: Production trends in developing country regions a/ by commodity, annual rate of change 1969/71-1979/81, in percent

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China	All Developing Countries
Cereals	1.7	3.5	3.4	0.4	0.9	1.3	1.9	2.8	2.2	2.0	3.1	3.7	3.0
Rice	2.7	3.4	4.4	4.8	1.3	1.6	5.8	2.0	1.7	1.9	3.1	2.9	2.7
Wheat	2.1	3.3	2.0	2.1	3.8	-	1.6	3.6	5.2	14.1	0.6	7.2	5.0
Maize	0.9	3.1	2.6	1.5	1.2	0.4	2.6	2.4	0.6	-1.4	4.6	6.5	3.8
Barley	-4.3	-	8.5	19.8	-	-	18.9	2.5	-2.7	-2.7	-2.9	1.8	1.3
Sorghum	4.0	20.1	5.8	-0.3	1.4	0.9	0.7	2.9	2.8	-	6.5	-2.0	2.2
Millet	3.9	-	-	-1.6	-1.5	0.7	1.0	-1.0	-1.1	-0.6	-	-4.6	-1.5
Roots, tubers and starchy foods	-1.5	-	1.9	2.5	2.4	1.2	1.4	5.0	3.7	4.2	5.9	0.8	1.8
Cassava	-3.8	-1.5	1.0	3.3	2.5	1.3	1.3	-	1.7	3.3	8.1	7.2	2.4
Potato	-0.6	1.9	7.3	4.5	3.9	-	2.7	5.8	7.6	1.2	5.4	2.3	3.7
Sweet potato	-4.2	-8.2	-0.5	2.9	2.5	-1.3	4.5	1.8	-4.1	0.2	0.9	0.5	0.4
Yam	-	5.1	-	1.3	3.3	1.3	2.2	0.3	-	-	-2.3	-	2.0
Cocoyam	-	-3.2	10.5	-	0.1	-3.2	1.8	8.6	-	-	4.0	2.9	0.9
Other roots and tubers	-	-1.5	4.3	2.5	2.0	-	1.2	6.6	-	3.0	-10.1	-	-1.0
Plantain/banana	-4.3	1.8	1.7	3.1	2.2	1.4	2.8	2.0	3.7	7.4	6.0	0.8	2.8
Pulses b/	8.8	-0.7	1.8	0.1	1.1	1.0	2.0	0.9	-0.8	-1.8	2.8	0.2	0.2
Chickpea	2.7	-4.2	4.8	-0.4	-	-	-	0.6	-1.1	-1.5	0.8	-	-0.6
Cowpea	-	-	-1.1	2.8	-9.5	-	2.3	-6.7	-	15.6	0.7	-	1.9
Faba bean	2.3	-2.8	5.3	-	-	-	-	0.8	-	-	-	0.4	0.5
Field bean	11.5	-0.6	1.3	0.4	2.2	0.9	1.3	-	1.8	-3.3	3.6	-0.2	0.9
Groundnut	4.4	-5.5	-0.2	-1.5	-0.9	1.8	-5.2	6.8	0.3	-4.6	2.0	5.4	0.4
Lentil	6.7	-7.3	8.2	-	-	-	-	2.1	0.6	-1.2	-6.7	-	1.3
Pigeonpea	-	-8.1	-4.1	2.1	-6.1	-	-	-	0.1	-	-1.2	-	-
Soybean	56.7	25.1	8.5	30.2	-	-	2.4	20.9	-	-	3.1	0.2	11.1
Livestock and livestock products	1.5	3.7	4.2	2.1	3.0	4.9	2.5	3.1	4.0	2.8	4.4	4.6	3.8
Beef and buffaloes	1.4	2.1	2.2	2.1	2.2	1.0	0.9	2.3	2.6	2.1	2.6	1.8	1.9
Sheep and goats	-4.8	0.5	1.4	2.9	2.5	3.9	1.8	3.5	2.0	3.2	4.3	2.1	2.3
Milk	1.3	2.7	5.1	1.4	3.3	4.2	0.3	2.6	3.8	3.6	8.2	5.0	3.2
Other livestock c/	3.5	6.6	6.2	4.2	4.0	6.4	6.7	7.9	8.2	2.5	5.3	5.0	5.4
Vegetables	0.6	3.6	5.3	2.0	2.4	1.5	4.0	4.3	3.5	-0.2	3.7	2.5	3.2
Oilseeds d/	3.7	1.8	1.5	1.5	-1.7	2.9	1.3	1.0	1.0	-1.1	8.6	7.2	4.3
Coconut	-	-0.3	0.8	1.2	14.9	1.0	-0.6	-	-0.2	-1.5	3.3	1.3	2.1
Oil palm	-	10.8	1.2	0.2	-1.4	4.7	1.3	-	-	-	17.0	4.8	11.0
Other oilseeds	3.7	0.6	1.8	2.3	-2.9	-0.4	1.4	1.0	1.5	0.4	10.7	7.5	3.2
Other food crops e/	2.0	6.4	2.8	3.2	0.5	0.7	-2.1	2.7	1.8	-0.4	6.3	5.1	3.4
Non-food crops f/	1.5	2.3	2.0	-0.9	-1.3	1.9	-	0.2	2.5	-0.6	2.9	3.5	1.9
Total	2.0	3.5	3.1	1.2	1.2	1.5	0.9	2.7	2.3	1.6	4.0	3.5	3.0

a/ For country regions, see appendix. This table is based on 90 developing countries of FAO's AT 2000 study plus China.
b/ Excluding groundnut and soybean.
c/ Pigmeat, poultry, eggs.
d/ Including groundnut and soybean.
e/ Sugar, citrus, fruit and cocoa.
f/ Coffee, tea, tobacco, cotton, jute and hard fibres, rubber, fodder crops.

Source: FAO, AT 2000 and ICS data files

Annex table 8: Food consumption trends in developing country regions [a/] by commodity, annual rate of change 1969/71-1979/81, in percent

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa Near East	India	South Asia	South-East Asia	China	All Developing Countries
Cereals	1.3	4.2	3.5	2.9	2.4	4.1	4.7	3.9	2.6	2.0	3.1	3.7	3.3
Rice	-1.5	4.0	4.0	9.0	3.1	4.6	10.3	3.3	2.6	13.7	2.8	3.5	4.4
Wheat	1.2	5.2	5.0	5.8	5.3	8.5	13.3	4.7	4.8	4.9	4.9	7.6	5.6
Maize	5.9	2.5	2.4	3.2	2.5	1.6	6.2	3.6	0.1	-0.5	6.0	0.2	2.0
Barley	4.4	2.8	8.8	-	-	-	29.6	1.8	-2.6	-1.9	-14.0	1.8	-0.3
Sorghum	-	-	-1.0	-1.2	4.7	2.2	1.8	2.0	0.4	19.6	6.5	-2.2	0.5
Millet	-	-	-	-1.7	0.5	1.2	1.3	-0.7	-	-0.9	0.2	-4.8	-1.0
Roots, tubers and starchy foods	-0.9	0.7	3.0	2.7	2.3	1.8	1.5	6.2	3.4	3.5	4.3	1.2	2.0
Cassava	-4.3	-1.3	-0.3	3.5	2.4	2.4	1.3	-	1.7	3.2	6.4	2.9	2.2
Potato	-0.5	2.1	7.1	4.5	4.1	12.5	2.1	7.1	8.1	1.4	5.2	2.1	4.0
Sweet potato	-4.3	-7.5	-0.8	2.8	2.9	-1.4	4.5	1.4	-4.1	-0.1	0.1	1.1	0.9
Yam	-	5.2	-0.2	1.3	2.8	1.2	2.7	0.2	-	-	-3.7	-	2.3
Cocoyam	-	-3.4	10.7	-	0.2	-2.3	1.8	9.7	-	-	3.4	2.9	1.2
Other roots and tubers	-	-1.6	4.5	3.1	1.3	-	1.0	6.7	-	3.8	-	-	3.3
Plantain/banana	0.2	2.5	3.0	3.3	1.7	1.8	2.9	5.8	4.2	6.3	5.4	2.9	3.3
Pulses [b/]	1.4	-0.5	3.0	0.7	2.0	1.0	3.2	2.2	-0.7	-3.3	2.6	0.6	0.5
Chickpea	1.3	-1.5	9.5	-1.5	-	-	-	0.8	-0.9	-3.5	1.3	-	-0.6
Cowpea	-	-	-1.2	3.2	-7.8	-	4.0	-5.9	-	14.1	0.7	-	3.2
Faba bean	2.3	-4.6	5.5	-	-	-	-	2.3	-	-	-	0.7	1.0
Field bean	3.5	-0.7	2.7	3.0	3.3	1.0	1.3	2.4	2.0	-5.5	2.6	0.1	1.2
Groundnut	-1.2	-10.7	0.6	-0.8	0.3	2.8	3.4	8.3	1.3	-5.0	2.6	5.0	2.1
Lentil	7.8	-0.8	8.0	-	-	-	-	2.8	1.5	-3.8	-1.3	-	1.6
Pigeonpea	-	-1.5	-10.1	3.8	-0.8	-	-	-	0.1	-	3.6	-	0.1
Soybean	16.0	10.8	16.3	34.5	-	3.6	24.8	10.8	22.1	0.9	6.5	2.3	8.2
Livestock and livestock products	2.2	3.8	5.0	3.1	2.9	4.1	3.8	4.8	4.0	3.1	4.4	4.7	4.2
Beef and buffaloes	2.2	2.4	2.6	2.9	1.9	2.2	1.8	3.4	1.1	2.1	3.1	1.8	2.4
Sheep and goats	-4.9	-0.1	1.6	2.9	2.5	3.1	1.8	3.8	1.9	3.2	5.2	2.1	2.6
Milk	1.9	2.9	5.7	2.0	3.1	3.0	3.0	3.2	3.9	3.6	4.6	5.5	3.7
Other livestock [c/]	3.6	6.3	6.4	4.6	4.2	6.4	7.7	10.5	8.1	2.4	4.8	5.1	5.4
Vegetables	0.7	3.6	5.6	2.0	2.3	1.7	4.0	4.6	3.5	-0.4	3.6	2.7	3.3
Oilseeds [d/]	-1.1	-0.9	4.5	7.4	3.7	3.5	4.6	5.3	5.0	0.1	4.1	8.2	4.5
Coconut	-	3.4	2.6	11.0	-4.0	-3.1	1.7	6.8	0.3	0.7	2.2	-0.3	1.6
Oil palm	-	9.5	2.1	8.5	3.6	3.2	1.7	22.2	-	24.6	19.9	7.2	8.5
Other oilseeds	-1.1	-3.1	5.0	5.1	4.2	13.7	22.4	4.0	4.2	-2.1	6.6	8.5	4.5
Other food crops [e/]	0.5	3.1	4.1	1.9	1.4	0.6	5.5	4.0	2.2	-0.5	5.6	5.3	3.4
Non-food crops [f/]	1.5	-0.4	1.5	4.6	5.4	15.2	12.3	5.4	3.1	3.8	7.4	8.6	2.8
Total	1.6	3.0	4.3	2.9	2.4	2.7	3.7	4.6	2.9	1.8	3.8	3.7	3.5

a/ For country regions, see appendix. This table is based on 90 developing countries of FAO's AT 2000 study plus China.
b/ Excluding groundnut and soybean.
c/ Pigmeat, poultry, eggs.
d/ Including groundnut and soybean.
e/ Sugar, citrus, fruit and cocoa.
f/ Coffee, tea, tobacco, cotton, jute and hard fibres, rubber, fodder crops.

Source: FAO, AT 2000 and ICS data files.

Annex table 9: Trends in the degree of self-sufficiency in developing country regions [a/] by commodity, annual rate of change 1979/81-2000, in percent

	Temperate South America	Tropical South America	Central America	East/South Africa b/	Equatorial Africa	Humid West Africa	Semi-Arid West Africa c/	North Africa/ Near East	India	South Asia	South-East Asia d/	China	All Developing Countries b/c/d/
Cereals	0.4	0.4	-0.1	-0.2	0.1	0.6	-0.4	-0.3	0.3	-0.3	-0.4	n.a.	-0.1
Rice	-2.3	0.3	-0.3	2.3	0.6	-	1.6	-0.9	0.4	-0.3	-0.3	n.a.	-
Wheat	0.8	1.2	0.6	0.6	3.5	-	2.1	-0.1	0.4	1.0	-3.4	n.a.	-0.1
Maize	-0.2	0.3	-0.6	-0.5	-0.4	-1.0	-0.6	0.7	0.4	-0.1	-0.2	n.a.	-0.1
Barley	0.1	-0.3	-2.6	-0.6	-	-	-	-0.8	-2.1	-3.1	-4.0	n.a.	-1.3
Millet and other cereals	0.8	0.3	1.2	-0.7	-0.3	0.1	-1.0	-1.4	-0.7	-2.0	-2.3	n.a.	-0.5
Roots, tubers and starchy foods	0.2	-0.1	-0.3	-	-	0.1	-	0.2	-	-	-0.4	n.a.	-0.1
Roots and tubers	-	-	0.1	-	-	0.1	-	0.2	-	0.1	-0.5	n.a.	-0.1
Plantain/banana	5.4	-0.3	-0.5	-	-0.1	-0.1	-	0.3	-	-	-0.1	n.a.	-0.1
Pulses e/	-0.7	0.1	-0.3	-0.4	0.4	-0.6	-0.3	0.1	-	-0.8	0.3	n.a.	-0.1
Livestock and livestock products	0.1	0.1	0.2	0.3	0.5	0.4	-0.4	0.2	-0.1	0.1	0.2	n.a.	0.1
Beef and buffaloes	0.1	0.1	-0.5	0.1	0.6	-	-0.8	0.3	-1.1	-0.2	-0.1	n.a.	-0.1
Sheep and goats	0.2	-0.5	-1.9	-0.1	0.3	-1.1	-1.7	-0.7	-0.1	0.1	-2.0	n.a.	-0.6
Milk	-	0.3	0.5	0.7	0.8	0.4	-0.1	-	-0.1	0.2	-	n.a.	0.1
Vegetables	-	-	0.7	-0.1	0.3	0.3	-0.2	0.2	-0.1	0.1	-	n.a.	0.1
Oilseeds f/	-0.8	1.4	-0.2	1.0	0.6	0.8	-1.5	1.0	0.4	-1.6	0.7	n.a.	0.4
Food commodities g/	0.3	0.1	0.1	-	0.1	-0.5	-0.4	0.2	0.2	-0.2	-0.2	n.a.	0.1
Non-food crops h/	1.0	-0.9	-2.5	-1.1	-0.6	-1.1	-1.8	-0.2	-0.4	-1.0	0.6	n.a.	-1.3

a/ For country regions, see appendix. This table is based on 90 developing countries of FAO's AT 2000 study and uses FAO's scenario B perception of the year 2000.
b/ Excluding Lesotho, Swaziland, and Botswana.
c/ Excluding Guinea-Bissau.
d/ Excluding Bhutan.
e/ Excluding groundnut and soybean.
f/ Including groundnut and soybean.
g/ Cereals, roots, tubers and starchy foods, pulses, livestock and livestock products, vegetables and oilseeds.
h/ Coffee, tea, tobacco, cotton, jute and hard fibres, rubber, fodder crops.

Source: FAO, AT 2000 data files.

Annex table 10: Economic and agricultural sector indicators for developing country regions,[a] 1979/81 for levels, 1969/71-1979/81 for trends

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China	All Developing Countries
GDP/caput, US$	1451	1273	1243	291	240	374	507	742[b]	154	150	415[c]	310	510[b/c]
GDP, annual growth rate, p.c.	2.5	6.2	6.5	2.0	2.2	2.6	5.6	5.4[b]	3.4	3.9	7.7[c]	5.6	5.4[b/c]
Population, m.	41	199	114	74	72	36	109	377	685	117	413	978	3215
Population, ann. growth rate, p.c.	1.3	2.6	2.9	3.2	2.5	2.9	3.0	2.8	2.2	2.4	2,2	1.7	2.2
Undernourished population, in p.c. of total population	4.5	14.6	12.8	23.1[d]	17.4	23.2	24.0[e]	14.7	33.3	32.0	19.0[c/f]	n.a.	n.a.
Agricultural popul., in p.c. of total popul.	14.5	36.0	40.3	72.2	78.4	64.4	61.8	55.1	63.4	81.0	57.6	n.a.	58.0[g]
Rural popul. below absolute poverty income level, in p.c. of rural popul.	n.a.	68.6[h]	43.3[i]	61.3[j]	71.0[k]	65.0[l]	45.4[m]	41.6[n]	n.a.	55.5[o]	42.4[c]	n.a.	n.a.
Food imports, billion US$	0.7	4.2	3.6	0.9	0.5	0.7	1.8	14.1	2.6	0.9	5.1	3.0	38.0
Food imports, in p.c. of GDP	1.3	1.7	2.6	4.0	2.8	5.1	3.3	4.8[b]	2.5	5.0	3.2[c]	0.9	3.1[b/c]
Agr. GDP, in p.c. of total GDP	12.2	11.0	11.5	30.7	28.7	30.8	27.9	13.4	39.5	51.7	25.3	n.a.	20.8[g]
Agr. GDP/caput of agr. popul., US$	1362	364	275	114	80	204	174	183	93	90	158	n.a.	143.8[g]
Agric. GVP, billion US$	22.1	60.1	27.2	8.7	10.8	8.3	18.1	61.5	77.0	12.7	66.3	187.6	560.3
Agric. GVP/ arable land, US$/ha	443	590	754	280	312	256	169	431	477	863	882	n.a.	485[g]

a/ For country groupings, see appendix. This table is based on 90 developing countries of FAO's AT 2000 study plus China. Undernourished population data refer to 1977.
b/ Excluding Lebanon, Yemen A.R., Yemen P.D.R.
c/ Excluding Kampuchea, Korea P.R., Laos, Vietnam.
d/ Excluding Lesotho, Swaziland, Botswana.
e/ Excluding Guinea-Bissau.
f/ Excluding Bhutan.
g/ Excluding China.
h/ Excluding Brazil, Colombia, Peru, Venezuela, Guyana. Suriname.
i/ Excluding Mexico, Costa Rica, Cuba.
j/ Excluding Zambia, Zimbabwe.
k/ Excluding Central African Republic, Congo, Gabon, Uganda.
l/ Excluding Ghana, Guinea, Ivory Coast, Liberia, Togo.
m/ Excluding Guinea-Bissau, Mauritania, Nigeria, Senegal, Upper Volta.
n/ Excluding Algeria, Cyprus, Iran, Lebanon, Libya, Syria, Turkey, Saudi Arabia, Yemen A.R.
o/ Excluding Sri Lanka.

Source: FAO, AT 2000 and ICS data files; World Bank, World Bank Development Report, Washington; World Bank, Social Indicators Data Sheets, Washington 1983; FAO, Fourth World Food Survey, Rome 1977.

Annex table 11: Production in developing country regions [a/] by commodity, in percent of production in all developing countries, 1979/81

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China	Total	Total in mio. t.
Cereals	2.4	4.5	2.3	1.0	0.7	0.4	1.5	9.0	19.0	4.5	17.6	37.2	100.0	173.3 b/
Rice	0.2	3.4	0.6	0.1	0.7	0.5	0.4	2.6	20.4	6.7	25.5	38.9	100.0	366.2
Wheat	5.9	1.9	1.8	0.3	-	-	-	29.5	21.9	0.8	0.4	37.5	100.0	157.7
Maize	6.7	15.1	9.7	5.6	1.2	0.8	1.2	5.4	4.3	0.5	9.0	40.7	100.0	149.1
Barley	1.9	2.0	2.4	0.5	-	-	-	62.0	9.5	0.2	6.8	14.7	100.0	21.3
Sorghum	13.4	2.6	12.7	2.0	1.6	0.6	11.1	12.2	26.5	-	1.0	16.3	100.0	43.0
Millet	0.9	-	-	2.1	3.8	1.1	25.9	7.0	34.8	0.5	2.0	21.9	100.0	26.4
Roots, tubers and starchy foods	0.9	7.5	2.8	1.5	5.9	4.0	12.5	2.8	4.2	1.3	7.5	49.2	100.0	72.6 b/
Cassava	0.2	24.2	0.7	9.4	16.5	3.7	9.3	0.1	4.9	0.4	27.9	2.7	100.0	122.1
Potato	5.8	13.7	2.7	1.4	1.6	-	0.1	15.9	18.8	2.6	6.3	31.1	100.0	49.8
Sweet potato	0.3	0.7	0.5	0.6	2.4	0.1	0.3	0.2	1.1	0.6	5.3	87.9	100.0	140.1
Yam	-	1.7	0.6	-	4.2	18.5	72.9	1.8	-	-	0.1	-	100.0	21.3
Cocoyam	-	1.1	3.2	-	5.0	20.3	40.7	2.0	-	-	2.8	24.9	100.0	4.9
Other roots and tubers	-	8.8	3.6	0.7	32.6	-	1.6	32.8	-	2.8	17.1	-	100.0	2.7
Plantain/banana	0.2	27.6	13.8	4.1	17.8	4.1	2.4	1.1	7.9	3.7	17.1	0.2	100.0	57.0
Pulses	5.3	20.5	4.4	1.6	2.8	0.7	4.4	7.4	28.4	0.4	5.1	19.0	100.0	26.9 b/
Chickpea	0.2	0.2	4.2	0.4	-	-	-	16.5	75.8	1.2	1.3	-	100.0	5.9
Cowpea	-	-	2.5	4.5	1.4	-	88.9	0.4	-	1.2	1.1	-	100.0	1.4
Faba bean	0.1	2.5	2.0	-	-	-	-	25.8	-	-	-	69.5	100.0	3.8
Field bean	3.0	22.9	13.0	2.7	7.6	0.4	0.4	3.7	24.2	0.4	5.7	16.0	100.0	10.6
Groundnut	3.3	4.0	1.0	3.0	4.4	2.6	11.0	7.8	38.9	0.2	9.2	14.6	100.0	8.2
Lentil	4.2	0.8	1.3	-	-	-	-	45.3	43.0	5.3	0.1	-	100.0	0.9
Pigeonpea	-	0.2	0.9	5.1	1.1	-	-	-	91.4	0.2	1.1	-	100.0	2.0
Soybean	12.7	49.1	2.0	0.3	-	-	0.3	0.8	1.4	-	5.0	28.4	100.0	29.0
Livestock and livestock products	8.2	13.8	6.5	1.7	0.9	0.3	1.9	13.4	8.2	1.2	6.4	37.5	100.0	140.7 b/
Beef and buffaloes	23.1	22.6	8.1	4.0	2.1	0.4	3.3	12.9	1.3	1.5	5.9	14.9	100.0	15.0
Sheep and goats	4.4	3.4	1.1	2.2	1.3	0.7	7.4	49.5	9.2	1.5	1.8	17.6	100.0	4.2
Milk	6.6	15.0	9.6	1.8	0.5	0.1	1.3	26.1	28.7	2.3	1.0	7.1	100.0	108.0
Other livestock [c/]	2.6	10.4	5.0	0.6	0.6	0.3	1.1	4.0	1.7	0.4	9.6	63.7	100.0	69.8 b/
Vegetables	1.7	3.6	2.4	1.3	1.0	0.8	2.0	15.1	21.6	0.7	11.7	38.1	100.0	42.5 b/
Oilseeds	3.8	4.1	4.1	1.4	2.0	2.6	5.5	13.4	10.8	2.2	35.9	14.3	100.0	11.6 b/
Coconut	-	1.5	3.5	2.2	0.2	1.1	0.4	-	13.2	7.0	70.8	0.2	100.0	4.0
Oil palm	-	2.8	0.7	0.9	5.5	6.8	13.7	-	-	-	65.8	3.8	100.0	5.0
Other oilseeds [d/]	7.4	5.9	6.0	1.3	1.1	1.3	4.0	26.0	14.8	1.0	5.3	26.0	100.0	6.0 b/
Other food crops [e/]	5.6	21.1	11.3	1.5	2.0	4.6	1.6	22.0	12.5	0.9	8.9	8.0	100.0	46.1 b/
Non-food crops [f/]	1.5	21.9	8.8	3.6	3.5	2.6	0.7	10.7	11.9	3.0	14.6	17.2	100.0	46.7 b/
Total	3.9	10.7	4.9	1.6	1.9	1.5	3.2	11.0	13.7	2.3	11.8	33.5	100.0	560.3 b/

a/ For country groupings see appendix. This table is based on 90 developing countries of FAO's AT 2000 study plus China.
b/ In million US$.
c/ Pigmeat, poultry, eggs.
d/ Castor and linseed excluded.
e/ Sugar, citrus fruit, fruit, cocoa.
f/ Coffee, tea, tobacco, cotton, jute and hard fibres, rubber, fodder crops.

Source: FAO, AT 2000 and ICS data files; FAO, The State of Food and Agriculture 1981, FAO Agriculture Series No. 14, Rome 1982.

Annex table 12: Land suitability in developing country regions for selected crops, in million ha [a]

	Africa	Central America	South America	Southwest Asia [b]	Southeast Asia	All developing countries	Input level index [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
	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	283.3	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

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/ For 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; excerpt from Jahnke, H.E. and D. Kirschke, Quantitative Indicators ..., op. cit.

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Annex table 13. 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**
Millet & other cereals	-.17	-.22*	.08	.27*	.39***	.05	-.30**
Roots	-.08	-.17	.01	.14	.25*	.01	-.16
Bananas	-.01	.01	-.03	.11	.11	.09	-.12
Pulses	-.28**	-.34**	-.04	.42***	.43***	.18	-.27*
Vegetables	.20	-.05	.15	-.21*	-.17	.10	.09
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
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; excerpt from Jahnke, H.E. and D. Kirschke, Quantitative Indicators ..., op. cit.

Annex table 14. CG System allocation to developing country regions by commodity

	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China	All Developing Countries
Cereals	715	3,873	3,265	3,702	3,441	3,441	7,217	7,107	7,138	4,093	7,811	1,815	53,618
Rice		1,395	598	1,879	1,945	1,945	1,600	1,182	1,814	3,181	6,899	1,815	24,253
Wheat	715	753	868	1,129				3,777	441	441	441		8,565
Maize		1,165	1,299	581	1,496	1,496	915	258	421	421	421		8,473
Barley		560	199	113				1,890	50	50	50		2,912
Sorghum			301				2,645		2,239				5,185
Millet							2,057		2,173				4,230
Roots, tubers and starchy foods	540	3,410	2,080	1,743	2,385	1,369	1,453	1,550	517	517	775	-	16,339
Cassava		2,329	999	811	1,453	811	830				258		7,491
Potato	540	1,081	1,081	775	775			1,550	517	517	517		7,353
Sweet potato				157	157	157	158						629
Yam						282	282						564
Cocoyam							64						64
Other roots and tubers													
Plantain/banana						119	119						238
Pulses	405	2,714	1,497	704	1,356	334	3,605	3,634	4,694	-	-	-	18,943
Chickpea								667	1,397				2,064
Cowpea		280	280	280	140	140	2,740						3,860
Faba bean								1,704					1,704
Field bean	405	2,434	1,217		1,022								5,078
Groundnut				302			471		1,915				2,688
Lentil								1,006	282				1,288
Pigeonpea				122				257	1,100				1,479
Soybean					194	194	394						782
Livestock and livestock products c/	-	3,767	941	1,635	2,577	2,273	2,349	2,904	-	-	-	-	16,446
Beef and buffaloes		3,767	941	1,179	2,577	1,479	1,422	1,252					12,617
Sheep and goats				456		794	927	1,652					3,829
Total by region	1,660	13,764	7,783	7,784	9,759	7,417	14,624	15,195	12,349	4,610	8,586	1,815	105,346

a/ Core funding and special projects (IBPGR, IFPRI and ISNAR not included) (Research support, Economics, FSR and Genetic Resources expenses prorated among regions and among commodities were appropriate. FSR expenses attributed to commodity research as follows: ICARDA 66%, ICRISAT 100%, IITA 50%, ILCA 75% and IRRI 75%).

b/ See appendix for country grouping.

c/ Forage and disease expenses. All CIAT forage to beef, all diseases to beef, ICARDA and ILCA forage distributed 1/3 to beef and 2/3 to sheep and goats.

Annex table 15. Value of production, calory/protein contribution and CG System allocation by food commodity groups, in percent

Food Commodity Groups	Value of Prod. (1)	Dietary Contr. (2)	Funding Level	Deviation from (1)	Deviation from (2)
Cereals	30.8	57.3	51.0	+40	-12
Roots, tubers & starchy foods	13.0	5.9	15.4	+16	+62
Pulses	4.8	5.8	18.0	+73	+68
Livestock and liv. products	25.2	12.7	15.6	-62	+19
Vegetables	7.6	2.3	-	-	-
Oilseeds	2.1	1.5	-	-	-
Other food	16.4	14.7	-	-	-
TOTAL	100	100	100		

Annex table 16.[a/] Value of production[b/] and CG System allocation by developing country regions, in percent

Regions	Value of Production (%)	Funding Level (%)	Deviation from Value of Production (%)
Temperate South America	4.3	1.6	-168
Tropical South America	9.3	13.1	+ 29
Central America	4.0	7.4	+ 46
East/South Africa	1.4	7.4	+ 81
Equatorial Africa	1.9	9.3	+ 79
Humid West Africa	1.0	7.0	+ 86
Semi-Arid West Africa	3.8	13.9	+ 73
North Africa/Near East	9.3	14.4	+ 35
India	13.4	11.7	- 15
South Asia	2.6	4.4	+ 41
South East Asia	10.9	8.1	- 35
China	38.3	1.7	-2150
TOTAL	100	100	

a/ From Table 11 and 14.

b/ Vegetables, oilseeds, other food crops and non-food crops not included.

Annex table 20. Value of production, calory/protein contribution, CG System allocation and ranking, by developing country regions for pulses, in percent

Food Commodity \ Region	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China
Chickpea												
Value of production	-	-	0.6	0.2	-	-	-	1.0	3.6	0.4	0.1	-
Dietary contribution	0.1	-	0.2	0.1	-	-	-	1.0	3.9	0.2	0.1	-
Funding level	-	-	-	-	-	-	-	33.0	67.0	-	-	-
Ranking by:												
Value of production	-	-	3	5	-	-	-	2	1	4	6	-
Dietary contribution	5	-	3	5	-	-	-	2	1	3	5	-
Funding level	-	-	-	-	-	-	-	2	1	-	-	-
Cowpea												
Value of production	-	-	-	0.2	0.1	-	2.4	-	-	0.1	-	-
Dietary contribution	-	-	0.1	0.2	0.1	-	4.7	-	-	0.1	-	-
Funding level	-	7.0	7.0	7.0	4.0	4.0	71.0	-	-	-	-	-
Ranking by:												
Value of production	-	-	-	2	3	-	1	-	-	3	-	-
Dietary contribution	-	-	3	2	3	-	1	-	-	3	-	-
Funding level	-	2	2	2	-	5	1	-	-	-	-	-
Faba bean												
Value of production	-	0.1	0.1	-	-	-	-	0.6	-	-	-	0.5
Dietary contribution	-	0.1	0.1	-	-	-	-	0.8	0.7	-	-	0.4
Funding level	-	-	-	-	-	-	-	100.0	-	-	-	-
Ranking by:												
Value of production	-	2	2	-	-	-	-	1	-	-	-	-
Dietary contribution	-	3	3	-	-	-	-	1	2	-	-	-
Funding level	-	-	-	-	-	-	-	1	-	-	-	-
Field bean												
Value of production	0.8	2.2	2.8	1.8	4.1	0.3	0.1	0.4	1.8	0.2	0.5	0.5
Dietary contribution	0.5	5.9	5.8	2.4	7.3	0.9	0.1	0.7	2.3	0.1	0.2	2.8
Funding level	8.0	48.0	24.0	-	20.0	-	-	-	-	-	-	-
Ranking by:												
Value of production	6	3	2	4	1	10	12	9	4	11	7	7
Dietary contribution	9	2	3	5	1	7	11	8	6	11	10	4
Funding level	-	1	2	-	3	-	-	-	-	-	-	-
Groundnut												
Value of production	1.0	0.4	0.2	2.2	2.6	2.0	3.9	0.8	3.2	0.1	0.9	0.5
Dietary contribution	0.1	0.1	0.8	1.7	5.0	3.1	2.9	0.1	0.1	-	1.1	1.0
Funding level	-	-	-	11.0	-	-	18.0	-	71.0	-	-	-
Ranking by:												
Value of production	6	10	11	4	3	5	1	8	2	12	7	9
Dietary contribution	8	8	7	4	1	2	3	8	8	-	5	6
Funding level	-	-	-	3	-	-	2	-	1	-	-	-
Lentil												
Value of production	0.1	-	-	-	-	-	-	0.4	0.3	0.2	-	-
Dietary contribution	0.1	0.1	-	-	-	-	-	0.6	0.1	0.1	-	-
Funding level	-	-	-	-	-	-	-	78.0	22.0	-	-	-
Ranking by:												
Value of production	4	-	-	-	-	-	-	1	2	3	-	-
Dietary contribution	4	4	-	-	-	-	-	1	2	2	-	-
Funding level	-	-	-	-	-	-	-	1	2	-	-	-

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Annex table 20 (cont'd) - page 2

Food Commodity / Region	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China
Pigeonpea												
Value of production	-	-	-	0.4	0.1	-	-	-	0.9	-	-	-
Dietary contribution	-	-	-	0.2	0.1	-	-	-	1.2	-	-	-
Funding level	-	-	-	8.0	-	-	-	17.0	74.0	-	-	-
Ranking by:												
Value of production	-	-	-	3	4	-	-	-	1	-	-	-
Dietary contribution	-	-	-	2	4	-	-	-	1	-	-	-
Funding level	-	-	-	3	-	-	-	2	1	-	-	-
Soybean												
Value of production	4.5	6.4	0.6	0.3	-	-	0.1	0.1	0.2	-	0.6	1.2
Dietary contribution	0.1	-	-	-	0.1	0.1	0.1	0.1	-	3.1	3.0	3.0
Funding level	-	-	-	-	25.0	25.0	50.0	-	-	-	-	-
Ranking by:												
Value of production	2	1	4	5	-	-	8	8	7	-	5	3
Dietary contribution	4	-	-	-	4	4	4	4	-	1	2	2
Funding level	-	-	-	-	2	2	1	-	-	-	-	-

Annex table 21. Congruence of CG System allocation and value of production by commodity, in percent

Commodity (Ranked by value of production)	Value of Production	Funding Level	Deviation
1. Rice	19.6	23.00	+ 15
2. Sweet potato	6.6	0.60	-1000
3. Beef and Buffaloes	5.6	12.00	+ 53
4. Wheat	5.0	8.20	+ 39
5. Maize	3.8	8.05	+ 53
6. Yam	1.9	0.50	-280
6= Plantain/banana	1.9	0.20	-850
8. Potato	1.6	7.00	+ 77
9. Soybean	1.4	0.70	-100
10. Sheep and goats	1.3	3.60	+ 64
11. Groundnut	1.1	2.55	+ 57
12. Field bean	1.0	4.80	+ 79
13. Millet	0.9	4.00	+ 77
13= Sorghum	0.9	5.00	+ 82
15. Chickpea	0.7	1.95	+ 64
16. Barley	0.6	2.75	+ 78
17. Cassava	0.5	7.10	+ 93
18. Faba bean	0.3	1.60	+ 81
18= Cocoyam	0.3	0.05	-500
20. Cowpea	0.1	3.65	+ 97
20= Lentil	0.1	1.25	+ 92
20= Pigeonpea	0.1	1.40	+ 93

Annex table 22. Congruence of CG System allocation and calory/protein contribution by commodity, in percent

Commodity (Ranked by dietary contribution)	Dietary Contribution	Funding level	Deviation
1. Rice	27.3	23.00	- 19
2. Wheat	17.8	8.20	-117
3. Maize	6.6	8.05	+ 18
4. Beef and Buffaloes	2.9	12.00	+ 76
5. Sweet Potato	2.8	0.60	-366
6. Sorghum	2.4	5.00	+ 52
7. Millet	2.0	4.00	+ 50
8. Field bean	1.8	4.80	+ 62
9. Barley	1.3	2.75	+ 53
9= Cassava	1.3	7.10	+ 82
11. Soybean	1.2	0.70	- 71
12. Potato	1.0	7.00	+ 86
12= Chickpea	1.0	1.95	+ 49
12= Groundnut	1.0	2.55	+ 61
15. Faba bean	0.7	1.60	+ 56
16. Plantain/banana	0.5	0.20	-150
17. Yam	0.3	0.50	+ 40
18. Cocoyam	0.1	0.05	-100
18= Cowpea	0.1	3.65	+ 97
18= Lentil	0.1	1.25	+ 92
18= Pigeonpea	0.1	1.40	+ 93
18= Sheep and goats	0.1	3.60	+ 97

Annex table 23. Congruence of CG System allocation and calory/protein contribution and value of production, in percent

Commodity (Ranked by funding level)			Deviation (dietary contrib.)	Deviation (value of prod.)
1.	Rice	23.0	- 19	+ 15
2.	Beef and Buffaloes	12.0	+ 79	+ 59
3.	Wheat	8.20	-117	+ 39
4.	Maize	8.05	+ 18	+ 53
5.	Cassava	7.10	+ 82	+ 93
6.	Potato	7.0	+ 86	+ 77
7.	Sorghum	5.0	+ 52	+ 82
8.	Field bean	4.8	+ 62	+ 79
9.	Millet	4.0	+ 50	+ 77
10.	Cowpea	3.65	+ 97	+ 97
11.	Sheep and goats	3.60	+ 97	+ 64
12.	Barley	2.75	+ 53	+ 78
13.	Groundnut	2.55	+ 61	+ 57
14.	Chickpea	1.95	+ 49	+ 64
15.	Faba bean	1.60	+ 56	+ 81
16.	Pigeonpea	1.40	+ 93	+ 93
17.	Lentil	1.25	+ 92	+ 92
18.	Soybean	0.70	- 71	-100
19.	Sweet potato	0.60	-366	-1000
20.	Yam	0.50	+ 40	-280
21.	Plantain/banana	0.20	-150	-850
22.	Cocoyam	0.05	-100	-500

Annex table 24. Formal and Operational Mandates of IARCs

Centers	Formal Mandates		Operational Mandates	
	Commodity/Activity	Region/Agro-ecological Zone	Commodity/Activity	Region/Agro-ecological Zone
CIAT	Food crops Animal products	Tropical lowland with emphasis in Latin America	Field beans Cassava Tropical pastures	World World Latin America, lowland tropics
CIMMYT	Wheat Maize Sorghum Rice Other food crops	World World Undefined Undefined Undefined	Wheat Maize Triticale Barley	World World World Regional
CIP	Potato Other root crops	World World	Potato	World
ICARDA	Dry subtropical or temperate climate primarily Near East, North Africa and Mediterranean Barley Lentils Broad beans Other crops Wheat Chickpea	World World World World N. Africa/N. East N. Africa/N. East	Same as formal with concentration on non-irrigated agri-culture Farming Systems	Dry areas of region
ICRISAT	Sorghum Millet Pigeonpea Chickpea Groundnut Low rainfall unirrig. seasonally dry and semiarid tropics	World World World World World	Sorghum Millet Pigeonpea Chickpea Groundnut Farming systems semi-arid tropics	World World World World World Asia, Africa
IITA	Tropical agriculture	World	Rice Maize Cassava Cocoyam Soybean Sweet potato Yam Cowpea Farming systems humid and subhumid tropics	Africa Africa Africa Africa Africa World World World Africa
ILCA	Livestock production systems in Africa	Africa	Livestock production systems in Africa	Africa
ILRAD	Trypanosomiasis Theileriasis Other diseases		Trypanosomiasis Theileriasis	
IRRI	Rice	World with emphasis on Asia	Rice	World with emphasis on Asia
WARDA	Rice	West Africa	Rice	West Africa

LIST OF ANNEX FIGURES

REVISED

Annex table 17. Value of production, calory/protein contribution, CG System allocation and ranking, by developing country regions and food commodity groups, in percent

Food Commodities \ Regions	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/ Near East	India	South Asia	South-East Asia	China
Cereals												
Value of production	18.7	12.9	14.6	19.4	11.6	9.1	14.2	25.3	42.8	60.6	45.9	34.4
Dietary contribution	27.5	35.0	45.0	49.0	29.0	39.0	48.9	58.3	67.2	81.6	64.7	60.3
Funding level	1.3	7.2	6.1	6.9	6.4	6.4	13.5	13.3	13.3	7.6	14.6	3.4
Ranking by:												
Value of production	7	10	8	6	11	12	9	5	3	1	2	4
Dietary contribution	12	10	8	6	11	9	7	5	2	1	3	4
Funding level	12	6	10	7	8	8	2	3	3	5	1	11
Roots, tubers and starchy foods												
Value of production	2.9	9.0	7.4	12.5	39.8	35.2	50.0	3.4	4.0	7.1	8.2	19.0
Dietary contribution	3.6	7.8	2.0	14.5	29.7	25.6	15.3	1.3	1.3	1.9	4.5	8.6
Funding level	3.3	20.8	12.8	10.8	14.6	8.4	8.9	9.5	3.1	3.1	4.7	-
Ranking by:												
Value of production	12	6	8	5	2	3	1	11	10	9	7	4
Dietary contribution	8	6	9	4	1	2	3	10	10	12	7	5
Funding level	9	1	3	4	2	7	6	5	10	10	8	-
Pulses												
Value of production	6.4	9.2	4.3	5.1	6.9	2.3	6.5	3.2	9.9	0.9	2.1	2.7
Dietary contribution	0.7	6.1	6.9	4.5	12.4	4.0	7.8	3.2	8.2	0.4	4.4	5.1
Funding level	2.1	14.3	9.5	3.7	7.2	1.8	19.0	19.2	24.8	-	-	-
Ranking by:												
Value of production	5	2	7	6	3	10	4	8	1	12	11	9
Dietary contribution	11	5	4	7	1	9	3	10	2	12	8	6
Funding level	8	4	5	7	6	9	3	2	1	-	-	-
Livestock and livestock products												
Value of production	52.0	32.3	33.8	27.6	12.3	5.3	15.1	30.6	15.0	12.6	28.1	25.2
Dietary contribution	40.3	25.8	21.6	12.1	8.2	5.4	8.2	10.8	5.5	4.6	6.8	13.9
Funding level	-	22.9	3.9	9.9	15.7	13.8	14.3	17.7	-	-	-	-
Ranking by:												
Value of production	1	3	2	6	11	12	8	4	9	10	5	7
Dietary contribution	1	2	3	5	7	11	8	6	10	12	9	4
Funding level	-	1	7	6	3	5	4	2	-	-	-	-

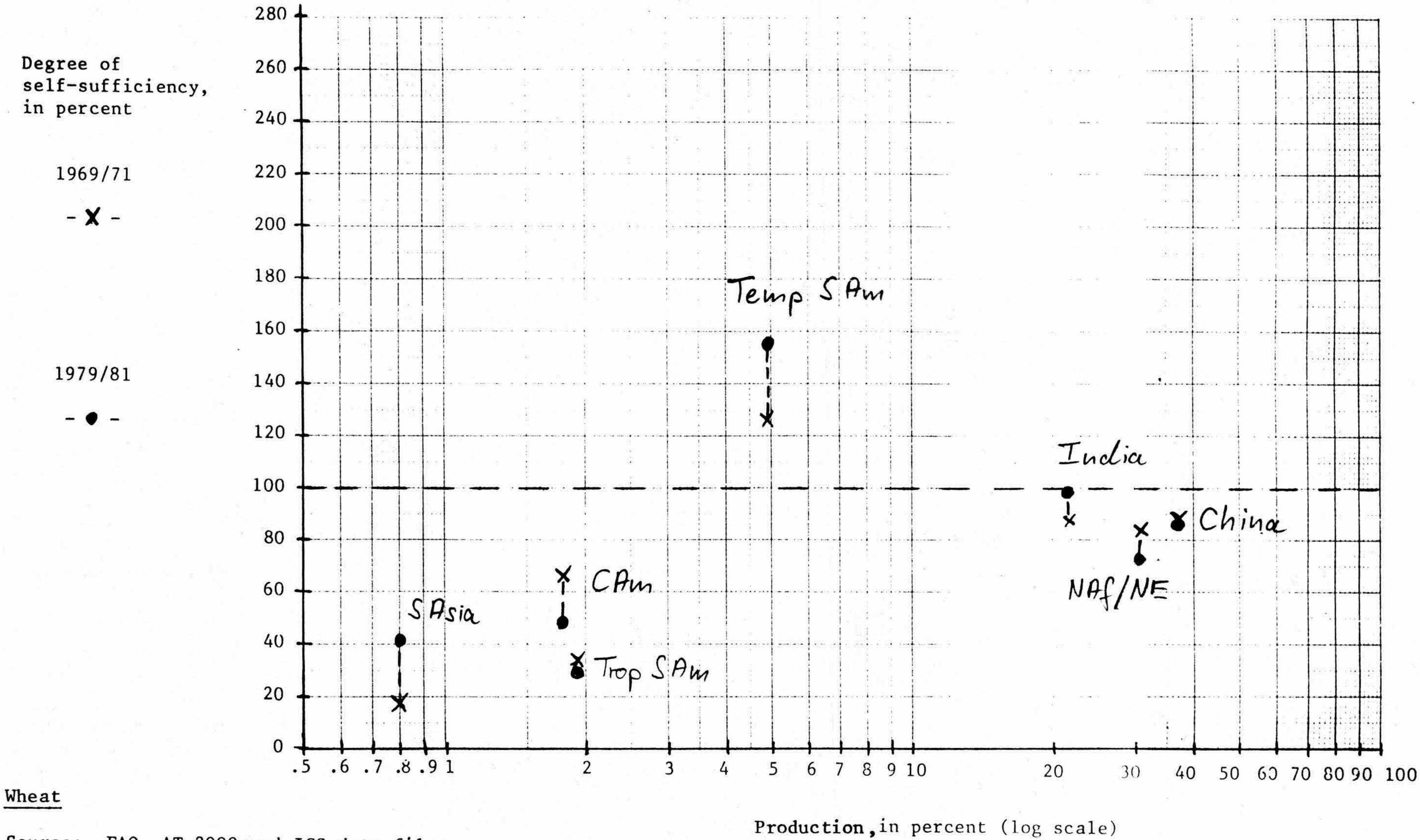
Annex table 18. Value of production, calory/protein contribution, CG System allocation and ranking, by developing country regions for cereals, in percent

Food Commodity \ Region	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/Near East	India	South Asia	South-East Asia	China
Rice												
Value of production	0.9	6.3	2.3	2.0	6.7	6.1	2.3	4.7	29.1	57.8	42.2	22.8
Dietary contribution	1.2	13.9	5.6	3.0	10.7	19.3	6.9	5.6	32.8	68.6	53.8	32.0
Funding level	-	5.8	2.5	7.7	8.0	8.0	6.6	4.9	7.5	13.1	28.5	7.5
Ranking by:												
Value of production	12	6	9	11	5	7	9	8	3	1	2	4
Dietary contribution	12	6	9	11	7	5	8	9	3	1	2	4
Funding level	-	9	11	5	3	3	8	10	6	2	1	6
Wheat												
Value of production	7.5	0.9	1.8	1.1	-	-	-	13.5	8.0	1.8	0.1	5.6
Dietary contribution	25.2	12.9	11.7	6.1	2.2	5.1	4.9	40.2	19.8	10.5	4.6	18.7
Funding level	8.5	8.8	10.1	13.2	-	-	-	44.1	5.1	5.1	5.1	-
Ranking by:												
Value of production	3	8	5	7	-	-	-	1	2	6	9	4
Dietary contribution	2	5	6	8	12	9	10	1	3	7	11	4
Funding level	5	4	3	2	-	-	-	1	6	6	6	-
Maize												
Value of production	6.5	5.4	7.7	13.7	2.3	2.0	1.5	1.9	1.2	0.8	2.9	4.6
Dietary contribution	1.1	8.6	28.0	35.0	9.6	10.8	5.2	5.3	3.3	2.3	5.9	6.5
Funding level	-	13.6	15.3	6.9	17.7	17.7	10.8	3.0	5.0	5.0	5.0	-
Ranking by:												
Value of production	3	4	2	1	7	8	10	9	11	12	6	5
Dietary contribution	12	5	2	1	4	3	8	9	10	11	7	6
Funding level	-	4	3	6	1	1	5	10	7	7	7	-
Barley												
Value of production	0.3	0.1	0.3	0.2	-	-	-	3.6	0.4	0.1	0.4	0.3
Dietary contribution	1.1	0.2	-	-	0.1	-	0.1	3.0	0.4	0.1	0.3	0.5
Funding level	-	19.2	6.8	3.9	-	-	-	64.9	1.7	1.7	1.7	-
Ranking by:												
Value of production	4	8	4	7	-	-	-	1	2	8	2	4
Dietary contribution	2	6	-	-	-	-	-	1	3	7	4	5
Funding level	-	2	3	4	-	-	-	1	5	5	5	-
Sorghum												
Value of production	3.2	0.2	2.5	1.2	0.8	0.4	3.2	1.0	1.8	-	1.0	0.5
Dietary contribution	-	-	0.3	3.1	1.8	1.6	12.2	3.1	4.9	-	0.1	1.3
Funding level	-	-	5.8	-	-	-	51.0	-	43.2	-	-	-
Ranking by:												
Value of production	1	10	3	5	7	9	1	6	4	-	6	8
Dietary contribution	-	-	8	3	5	6	1	3	2	-	9	7
Funding level	-	-	3	-	-	-	1	-	2	-	-	-
Millet												
Value of production	0.2	-	-	1.2	1.7	0.7	7.1	0.6	2.2	0.2	0.2	0.6
Dietary contribution	-	-	-	2.0	4.7	2.2	19.7	1.3	6.1	0.2	0.2	1.6
Funding level	-	-	-	-	-	-	49.0	-	51.0	-	-	-
Ranking by:												
Value of production	8	-	-	4	3	5	1	6	2	8	8	6
Dietary contribution	-	-	-	5	3	4	1	7	2	8	8	6
Funding level	-	-	-	-	-	-	2	-	1	-	-	-

Annex table 19. Value of production, calory/protein contribution, CG System allocation and ranking, by developing country regions for roots and tubers, in percent

Food Commodity / Region	Temperate South America	Tropical South America	Central America	East/South Africa	Equatorial Africa	Humid West Africa	Semi-Arid West Africa	North Africa/Near East	India	South Asia	South-East Asia	China
Cassava												
Value of production	-	1.2	0.1	3.3	4.7	1.4	1.6	-	0.2	0.1	1.3	-
Dietary contribution	0.1	3.5	0.3	12.0	19.8	10.7	5.0	-	0.5	0.3	2.7	0.1
Funding level	-	31.0	13.0	11.0	19.0	11.0	11.0	-	-	-	3.0	-
Ranking by:												
Value of production	-	7	9	2	1	4	3	-	8	9	6	-
Dietary contribution	11	6	9	2	1	3	5	-	8	9	7	11
Funding level	-	1	3	4	2	4	4	-	-	-	7	-
Potato												
Value of production	2.4	2.1	0.9	1.4	1.4	-	0.1	2.4	2.2	1.8	0.9	1.5
Dietary contribution	2.9	1.5	0.4	0.4	0.4	0.1	0.1	1.1	0.5	0.4	0.3	0.4
Funding level	7.0	15.0	15.0	10.0	10.0	-	-	21.0	7.0	7.0	7.0	-
Ranking by:												
Value of production	1	4	9	7	7	-	10	1	3	5	9	6
Dietary contribution	1	2	5	5	5	11	11	3	4	5	10	5
Funding level	6	2	2	4	4	-	-	1	6	6	6	-
Sweet potato												
Value of production	0.4	0.4	0.7	2.7	8.1	0.6	0.6	0.1	0.5	1.9	2.9	17.2
Dietary contribution	0.3	0.2	0.3	0.8	3.6	0.3	0.2	0.1	0.2	0.5	0.8	8.1
Funding level	-	-	-	25.0	25.0	25.0	25.0	-	-	-	-	-
Ranking by:												
Value of production	10	10	6	4	2	7	7	12	9	5	3	1
Dietary contribution	7	9	7	4	2	7	9	12	9	6	4	1
Funding level	-	-	-	1	1	1	1	-	-	-	-	-
Yam												
Value of production	-	0.3	0.2	-	4.1	23.2	41.8	0.3	-	-	-	-
Dietary contribution	-	0.1	0.1	-	0.6	8.1	7.8	0.1	-	-	-	-
Funding level	-	-	-	-	-	50.0	50.0	-	-	-	-	-
Ranking by:												
Value of production	-	4	6	-	3	2	1	4	-	-	-	-
Dietary contribution	-	4	4	-	3	1	2	4	-	-	-	-
Funding level	-	-	-	-	-	1	1	-	-	-	-	-
Cocoyam												
Value of production	-	-	0.1	-	0.9	4.9	4.5	0.1	-	-	0.1	0.3
Dietary contribution	-	-	-	-	0.2	2.8	1.7	-	-	-	-	0.1
Funding level	-	-	-	-	-	-	100.0	-	-	-	-	-
Ranking by:												
Value of production	-	-	5	-	3	1	2	5	-	-	5	4
Dietary contribution	-	-	-	-	3	1	2	-	-	-	-	4
Funding level	-	-	-	-	-	-	1	-	-	-	-	4
Plantain/banana												
Value of production	0.1	4.8	5.3	5.0	17.3	5.2	1.4	0.2	1.1	3.1	2.7	-
Dietary contribution	0.3	2.5	1.1	1.3	4.9	3.8	0.7	0.1	0.2	0.7	0.8	-
Funding level	-	-	-	-	-	50.0	50.0	-	-	-	-	-
Ranking by:												
Value of production	11	5	2	4	1	3	8	10	9	6	7	-
Dietary contribution	9	3	5	4	1	2	7	11	10	7	6	-
Funding level	-	-	-	-	-	1	1	-	-	-	-	-

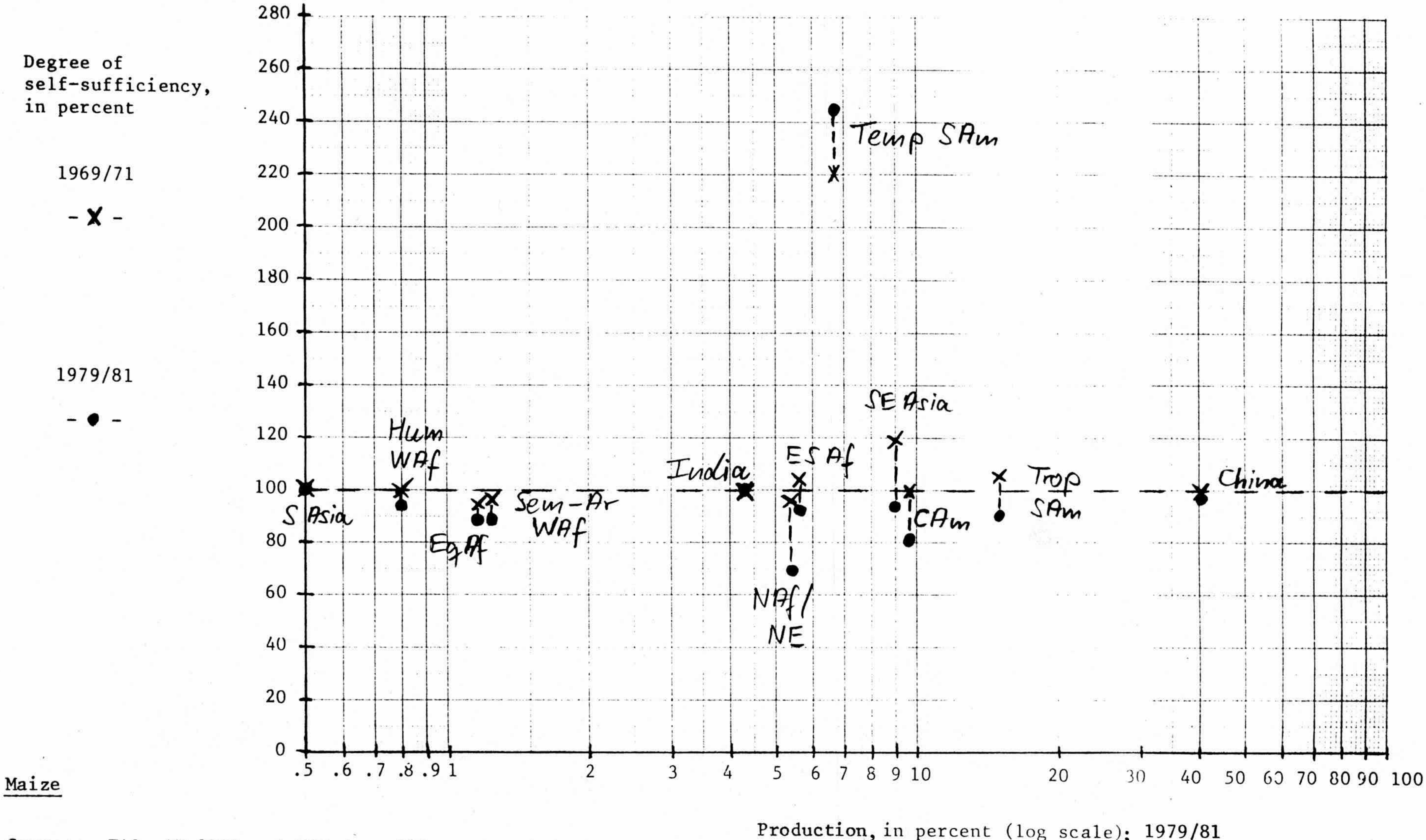
Annex figure 1.b : Production and degree of self-sufficiency by developing country regions for wheat



Wheat

Source: FAO, AT 2000 and ICS data files.

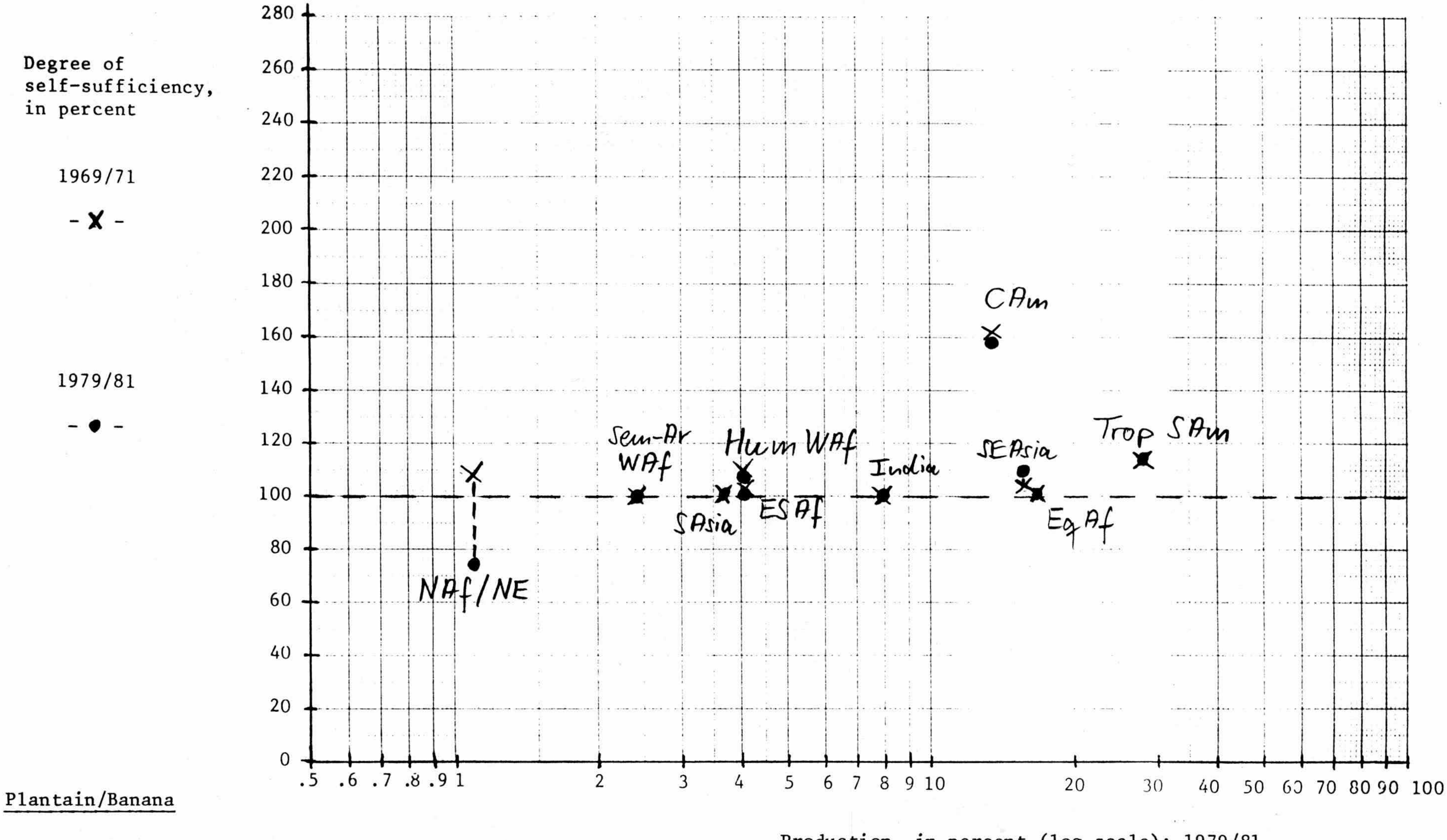
Annex figure 1.c : Production and degree of self-sufficiency by developing country regions for maize



Maize

Source: FAO, AT 2000 and ICS data files.

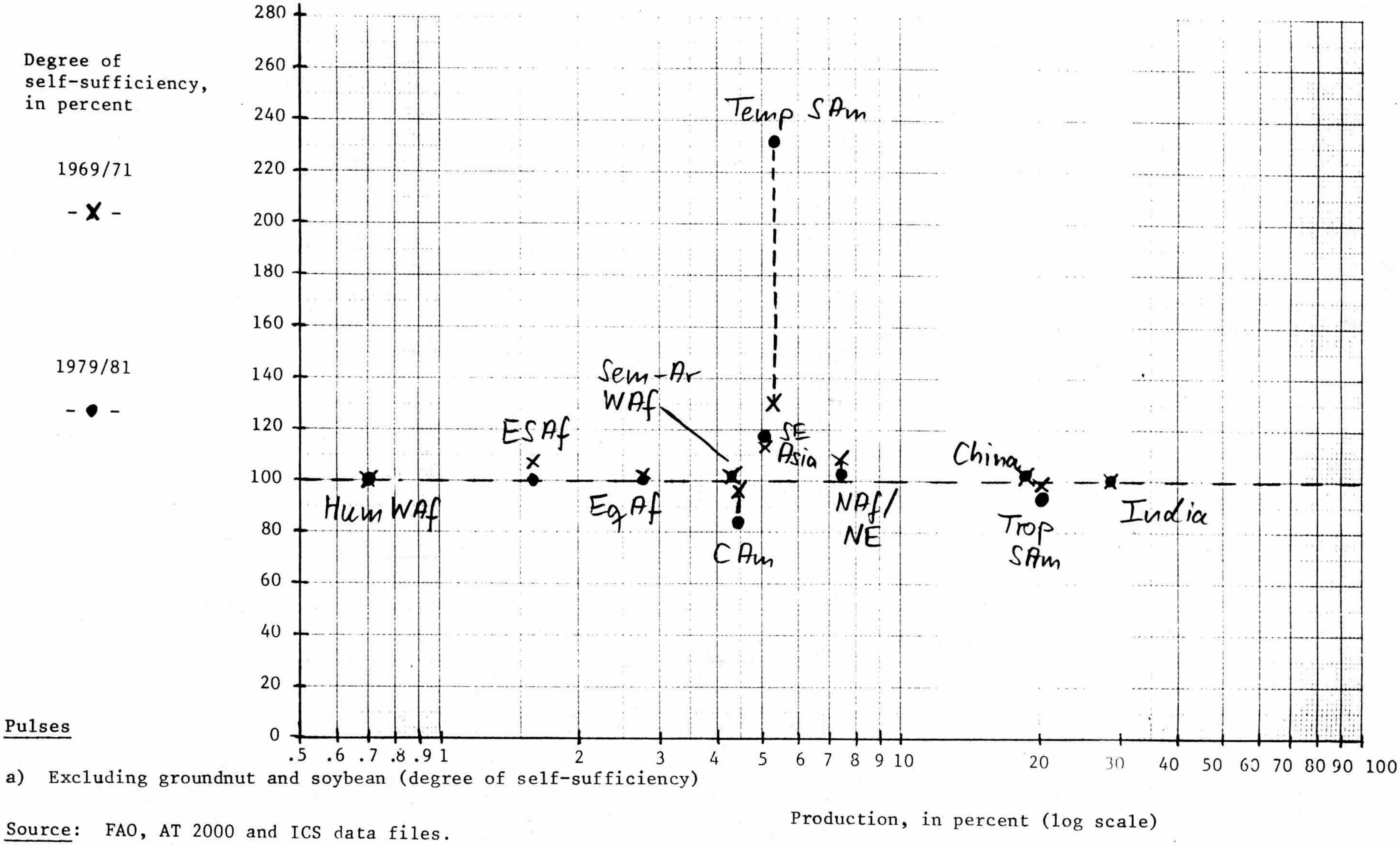
Annex figure 1.d : Production and degree of self-sufficiency by developing country regions for plantain/banana



Plantain/Banana

Source: FAO, AT 2000 and ICS data files.

Annex figure 1.e : Production and degree of self-sufficiency by developing country regions for pulses a)

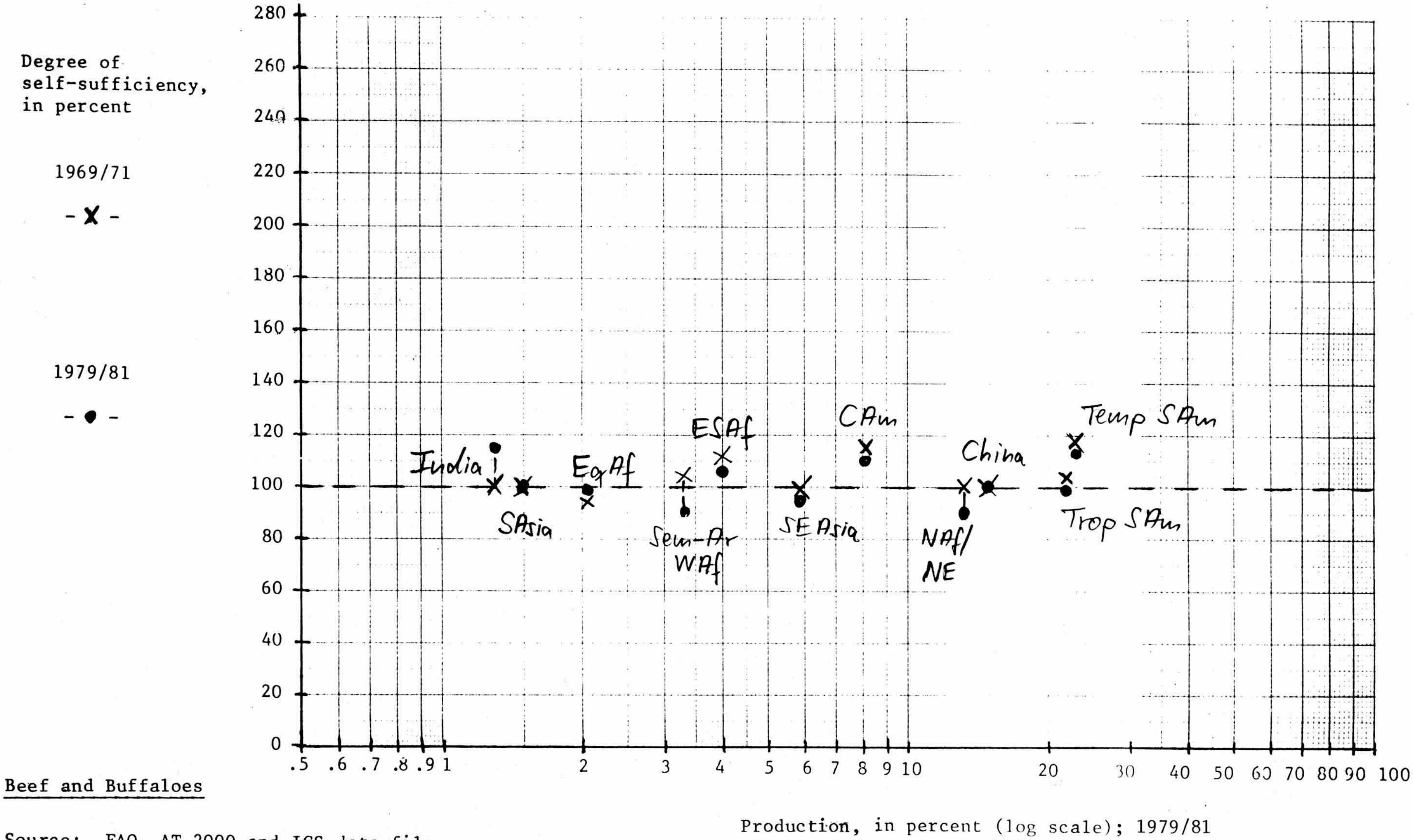


Pulses

a) Excluding groundnut and soybean (degree of self-sufficiency)

Source: FAO, AT 2000 and ICS data files.

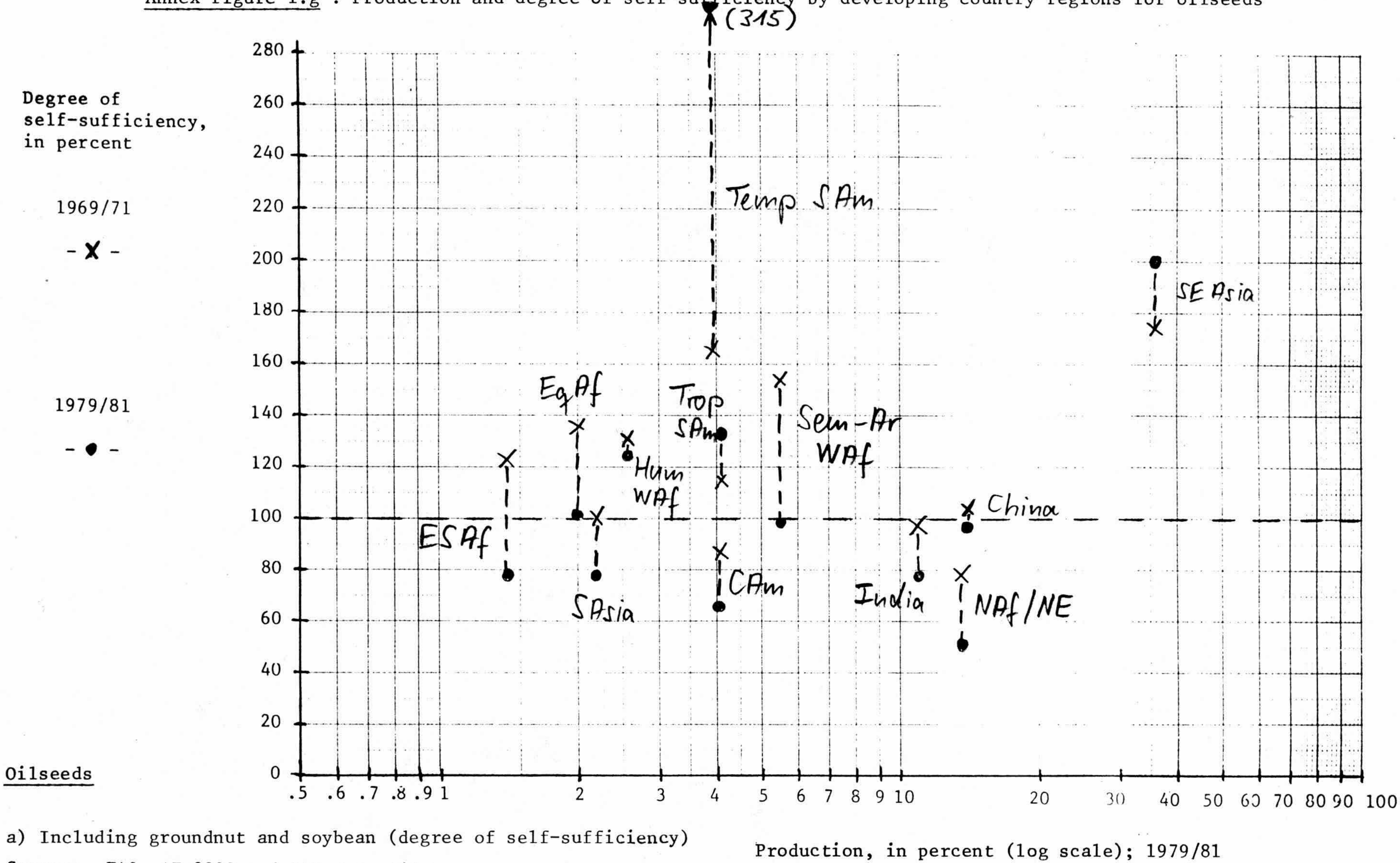
Annex figure 1.f : Production and degree of self-sufficiency by developing country regions for beef and buffaloes



Beef and Buffaloes

Source: FAO, AT 2000 and ICS data files.

Annex figure 1.g : Production and degree of self-sufficiency by developing country regions for oilseeds a)



a) Including groundnut and soybean (degree of self-sufficiency)

Source: FAO, AT 2000 and ICS data files.

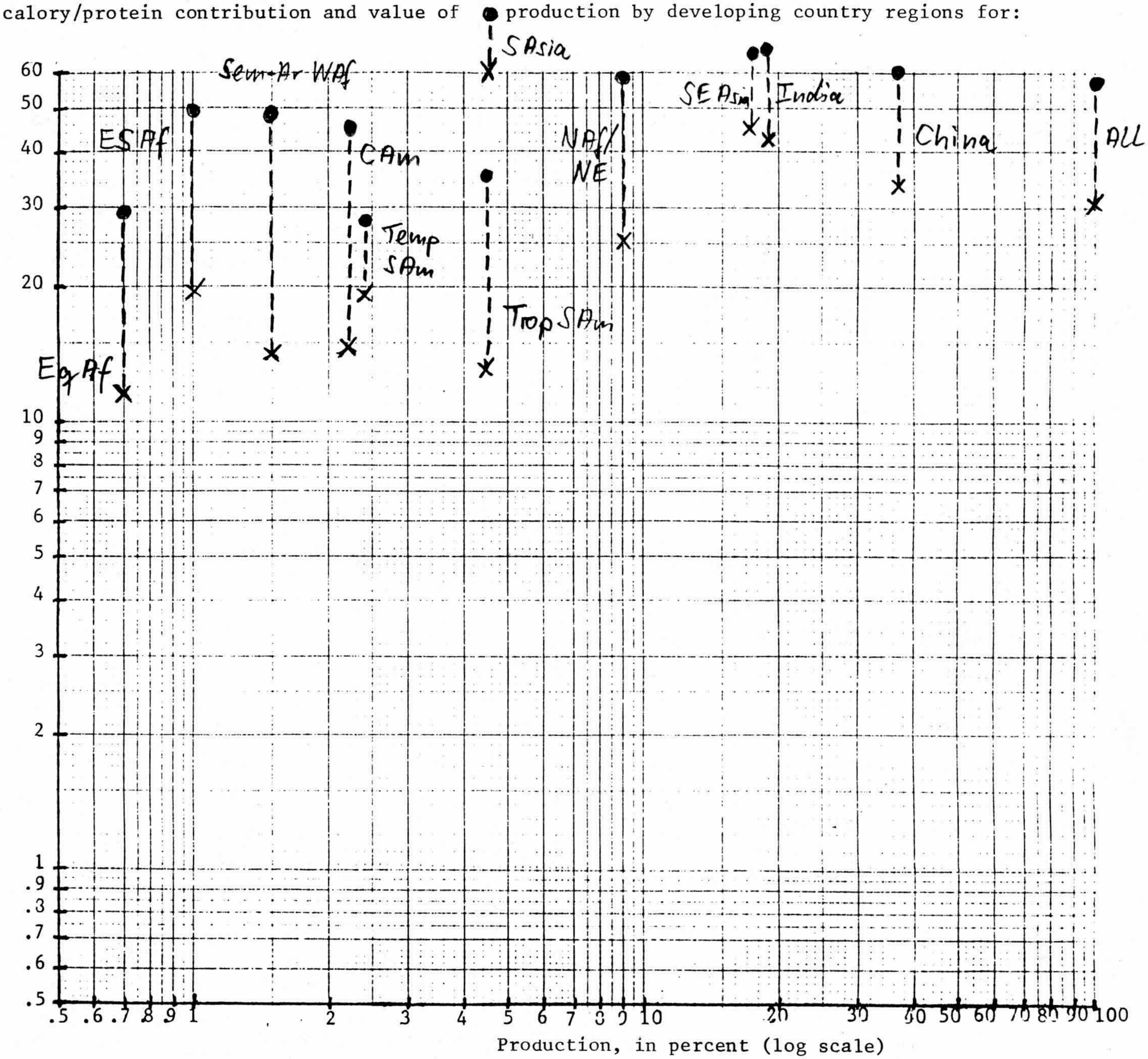
Annex figure 2.a : Production, calory/protein contribution and value of production by developing country regions for: Cereals

Value of production, in percent - x -

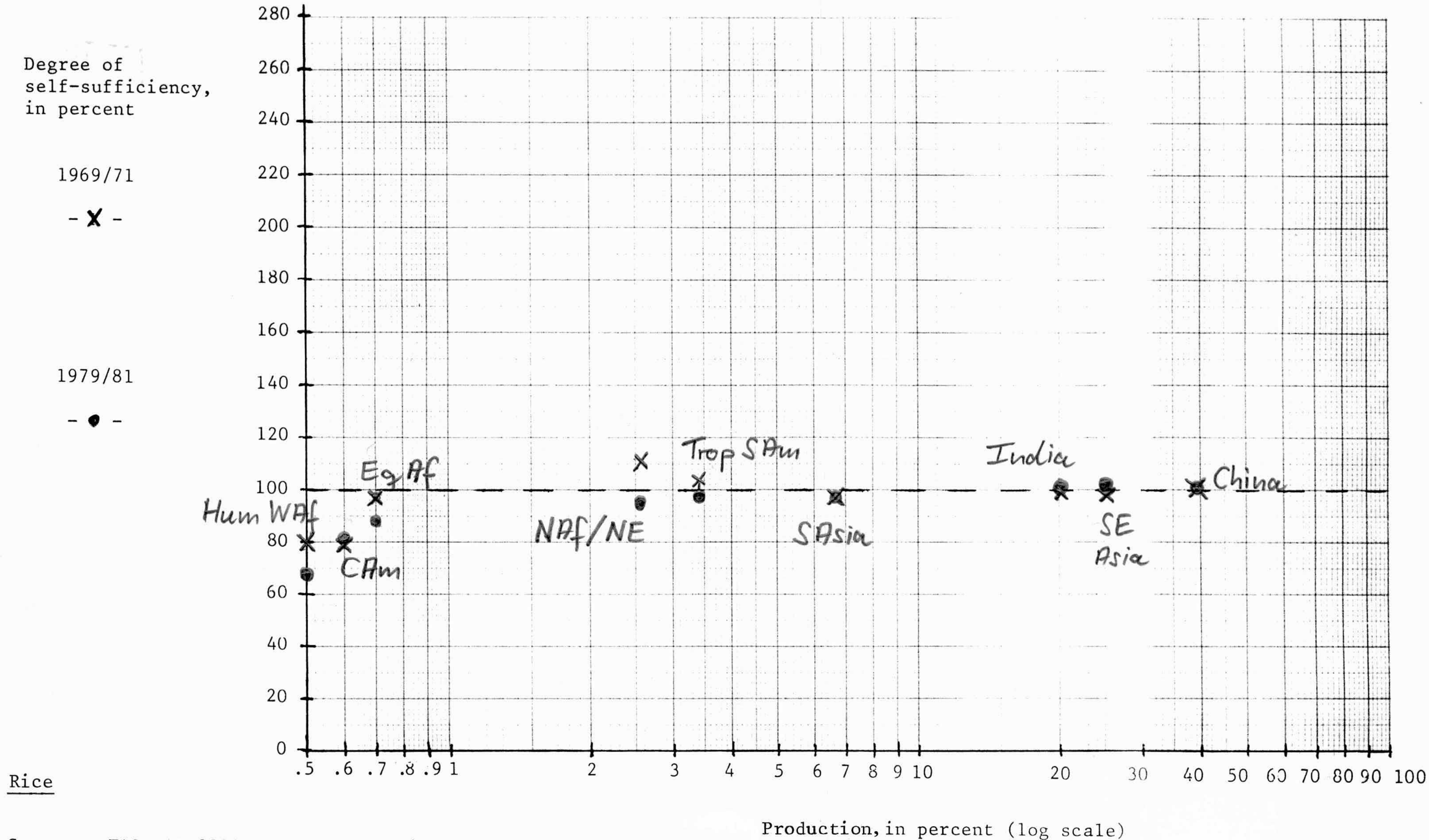
Calory/protein contribution, to diet, in percent - ● -

(log scale)

Cereals

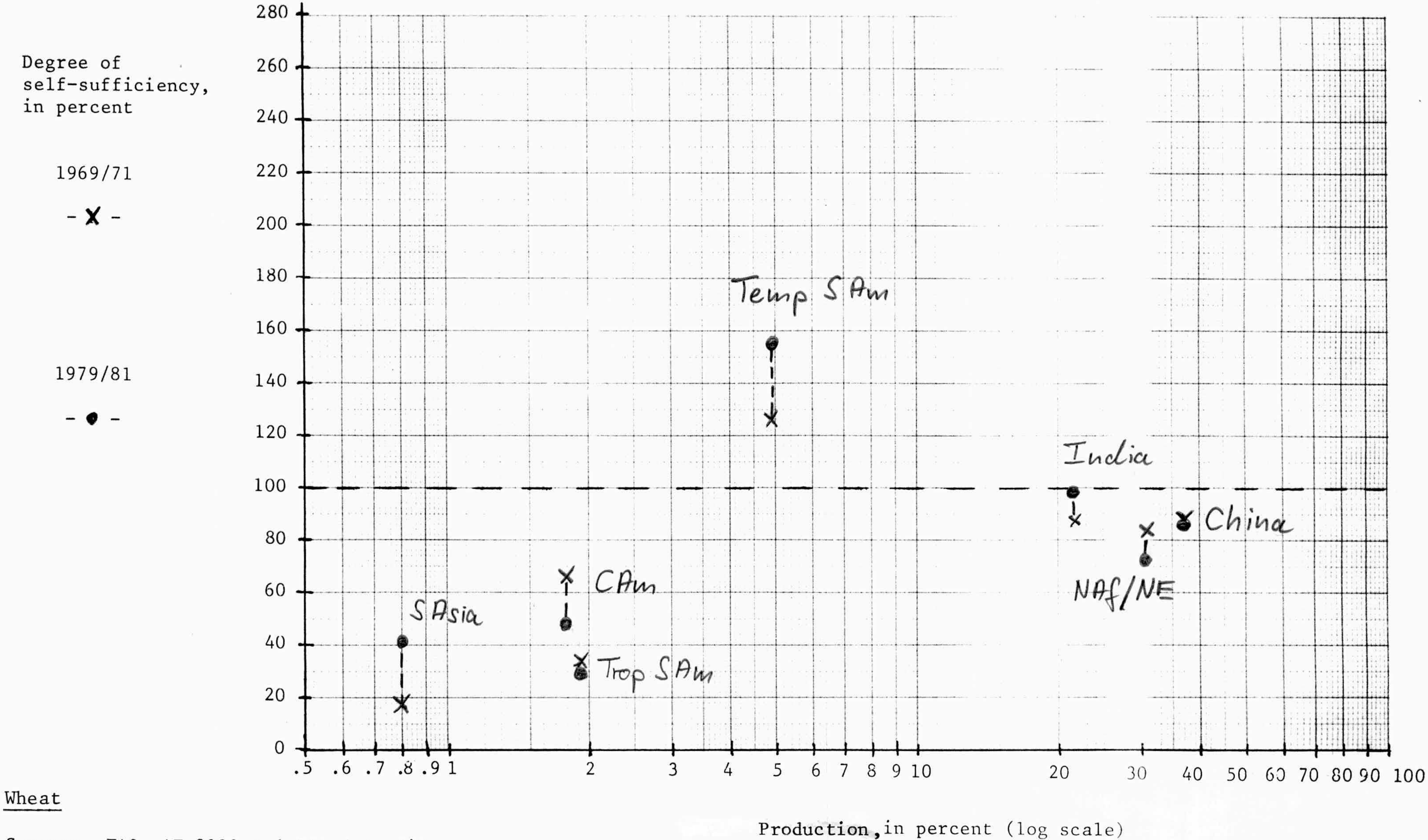


Annex figure 1.a : Production and degree of self-sufficiency by developing country regions for rice



Source: FAO, AT 2000 and ICS data files.

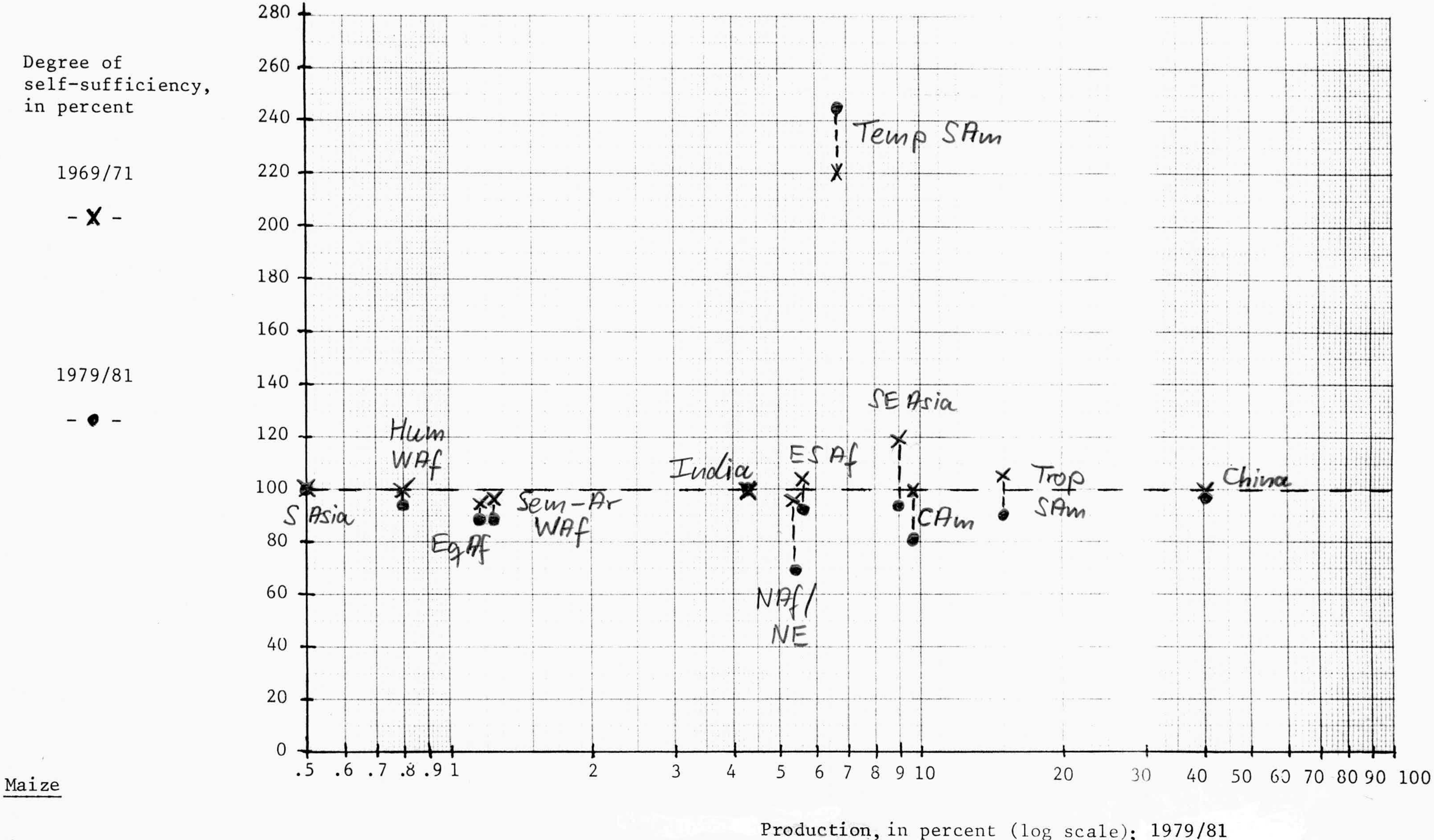
Annex figure 1.b : Production and degree of self-sufficiency by developing country regions for wheat



Wheat

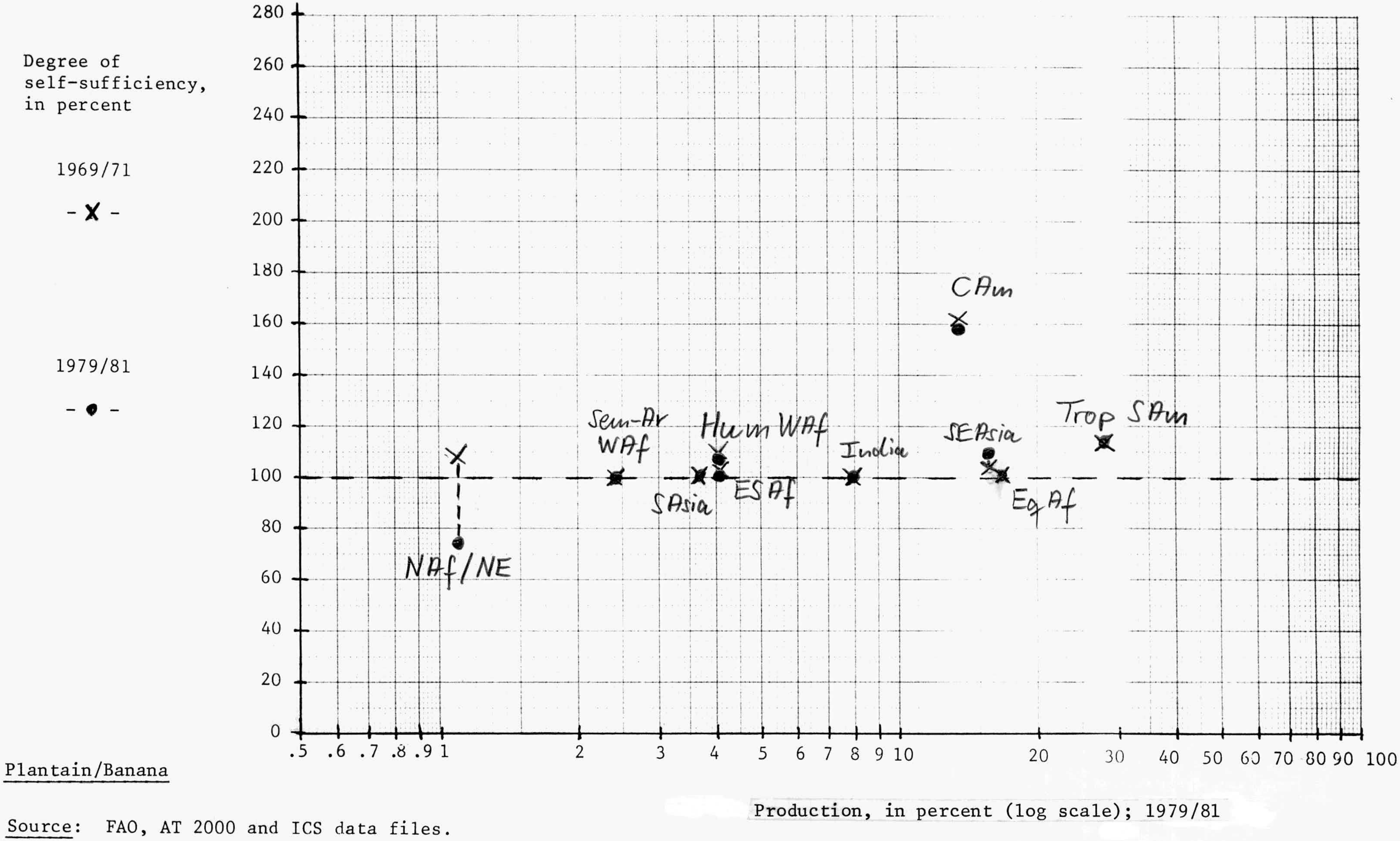
Source: FAO, AT 2000 and ICS data files.

Annex figure 1.c : Production and degree of self-sufficiency by developing country regions for maize



Source: FAO, AT 2000 and ICS data files.

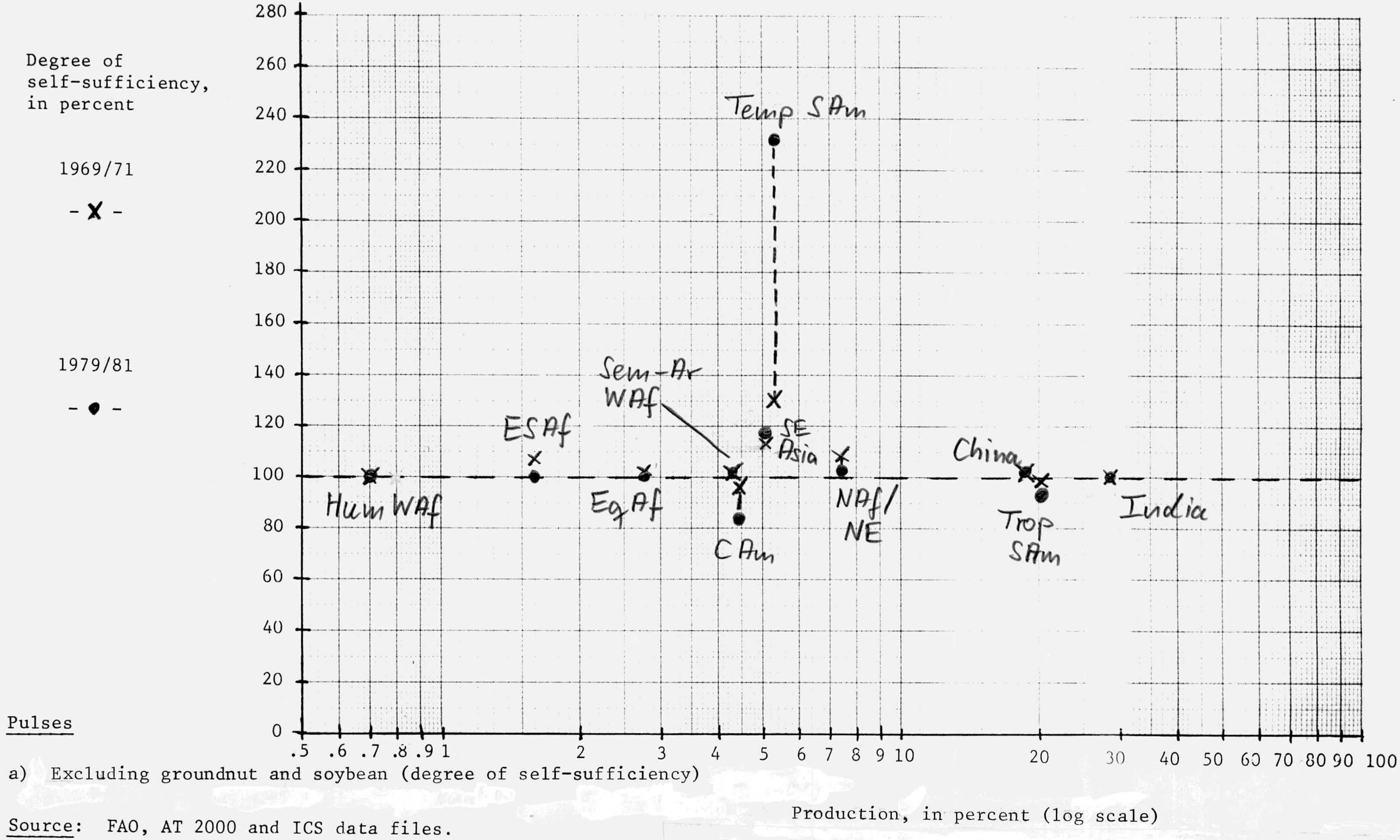
Annex figure 1.d : Production and degree of self-sufficiency by developing country regions for plantain/banana



Plantain/Banana

Source: FAO, AT 2000 and ICS data files.

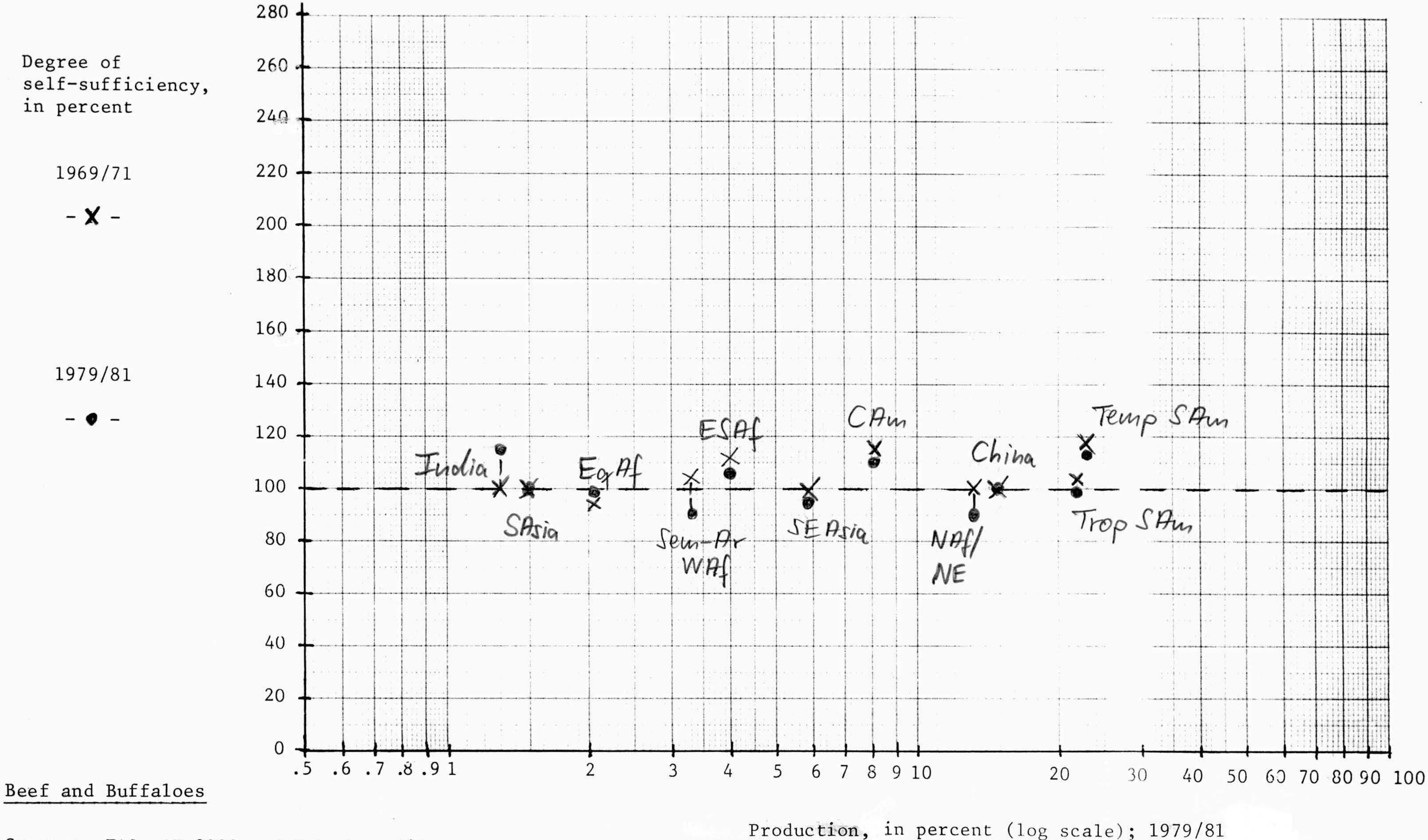
Annex figure 1.e : Production and degree of self-sufficiency by developing country regions for pulses a)



a) Excluding groundnut and soybean (degree of self-sufficiency)

Source: FAO, AT 2000 and ICS data files.

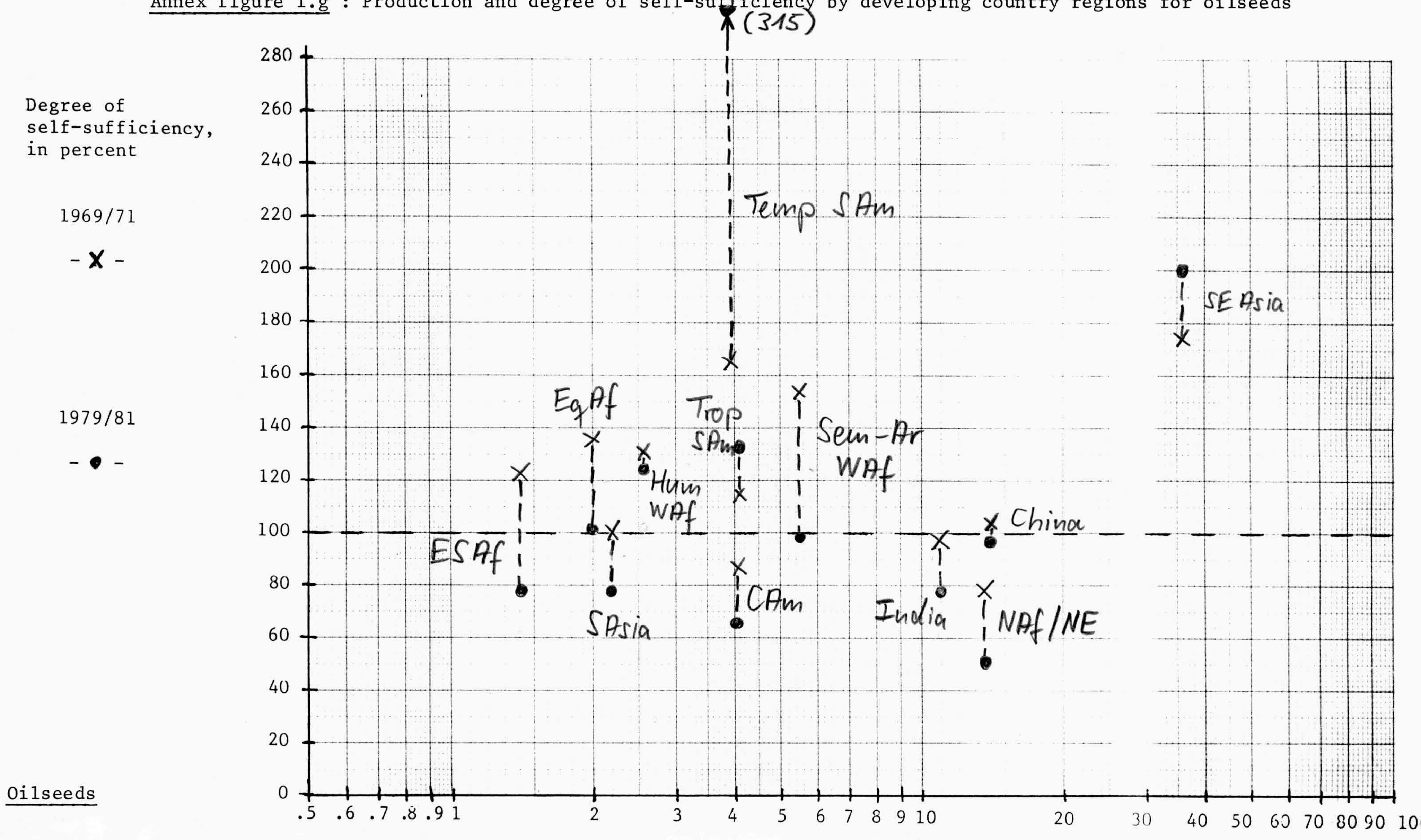
Annex figure 1.f : Production and degree of self-sufficiency by developing country regions for beef and buffaloes



Beef and Buffaloes

Source: FAO, AT 2000 and ICS data files.

Annex figure 1.g : Production and degree of self-sufficiency by developing country regions for oilseeds a)



a) Including groundnut and soybean (degree of self-sufficiency)

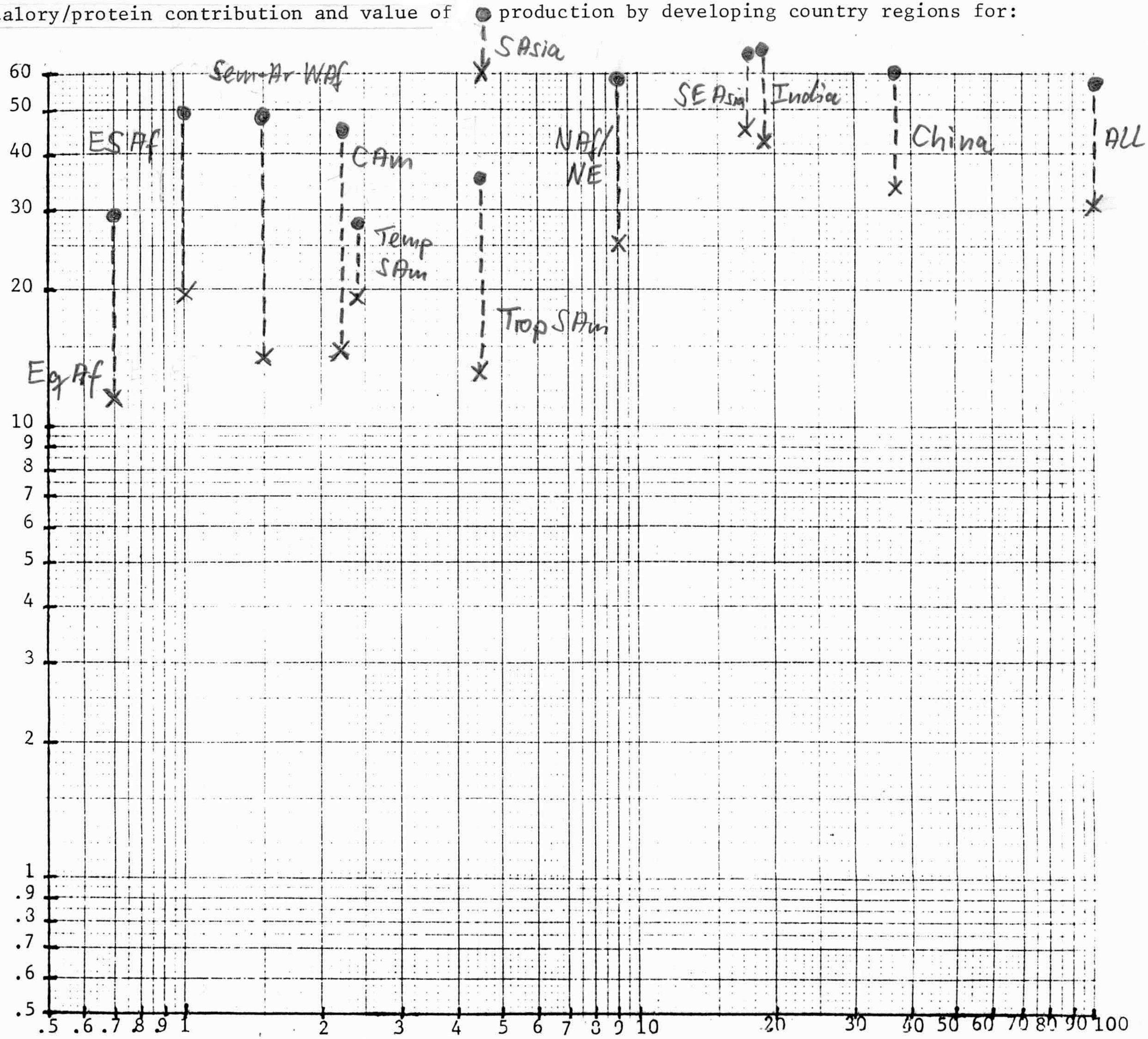
Source: FAO, AT 2000 and ICS data files.

Annex figure 2.a : Production, calory/protein contribution and value of production by developing country regions for:
Cereals

Value of production, in percent
- x -

Calory/protein contribution, to diet, in percent
- ● -

(log scale)



Production, in percent (log scale)

Cereals

Annex figure 2.b : Production, calory/protein contribution and value of production by developing country regions for: Roots, Tubers and Starchy Foods

Value of production, in percent

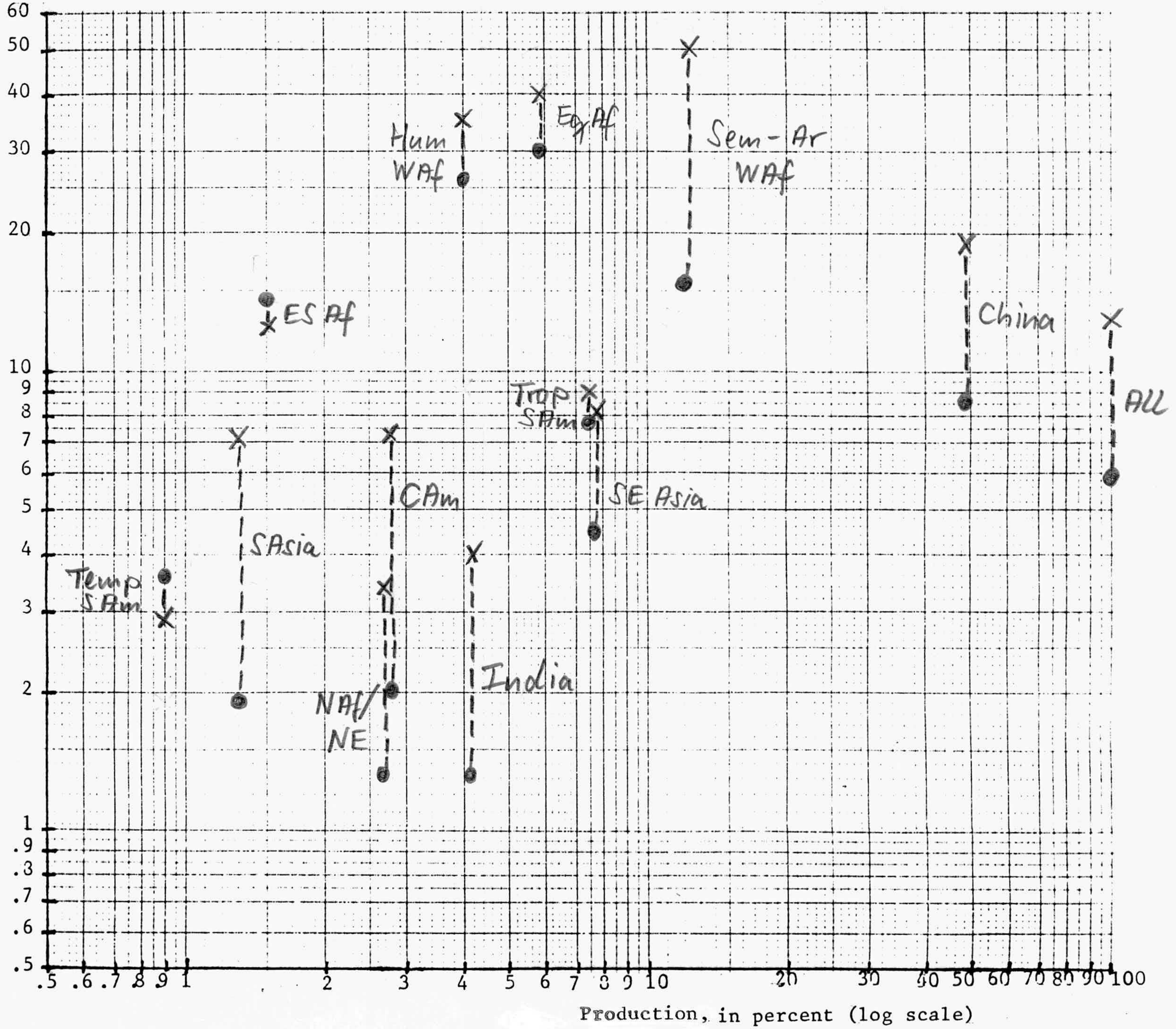
- x -

Calory/protein contribution, in percent

- • -

(log scale)

Roots, Tubers & Starchy Foods



Annex figure 2.c : Production, calory/protein contribution and value of production by developing country regions for:
Pulses

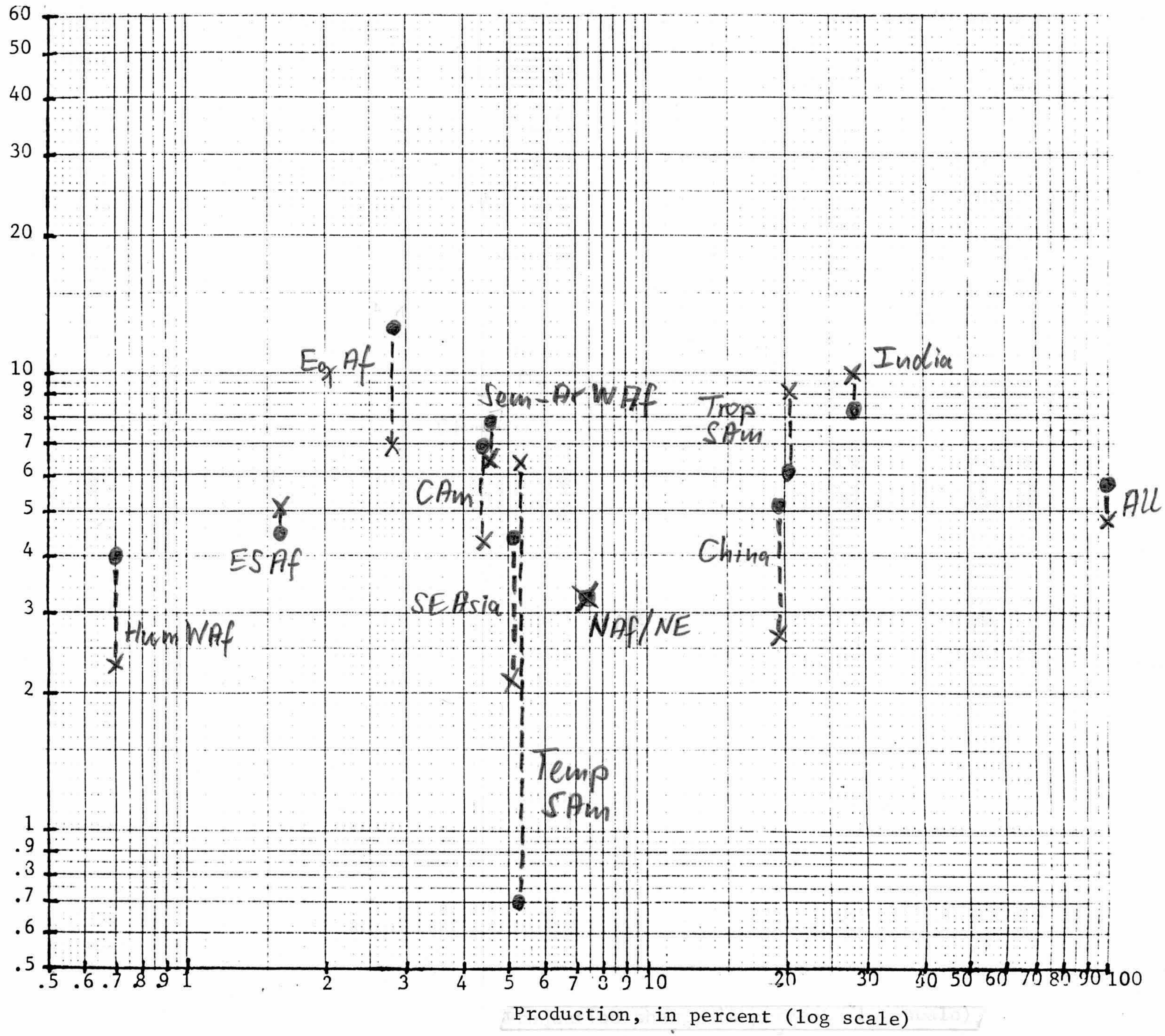
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



Pulses

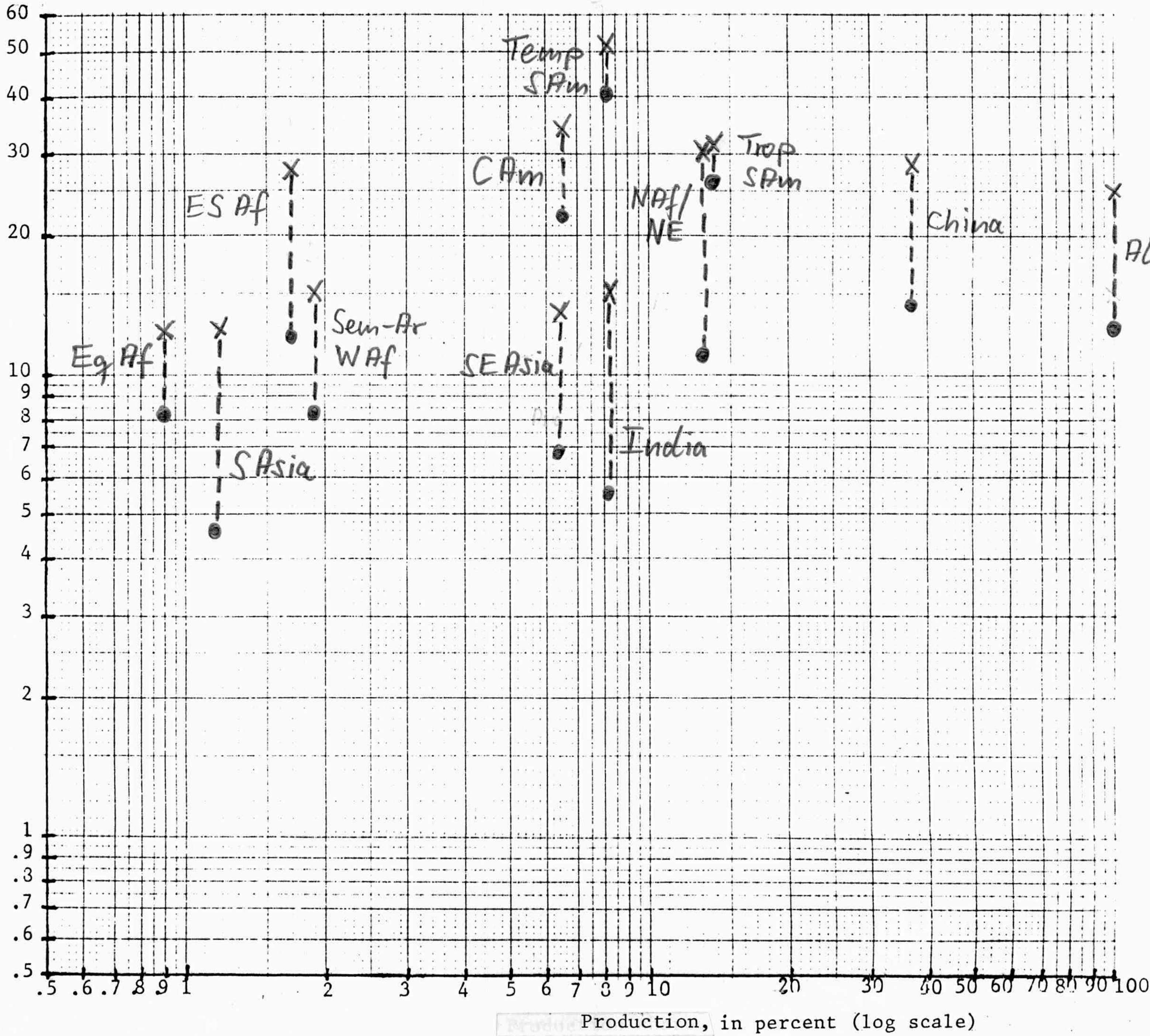
Annex figure 2.d : Production, calory/protein contribution and value of production by developing country regions for:

Livestock and Livestock Products

Value of production,
in percent
- x -

Calory/protein contribution,
in percent
- ● -

(log scale)



Livestock and Livestock Products

Annex figure 2.e : Production, calory/protein contribution and value of production by developing country regions for: Vegetables

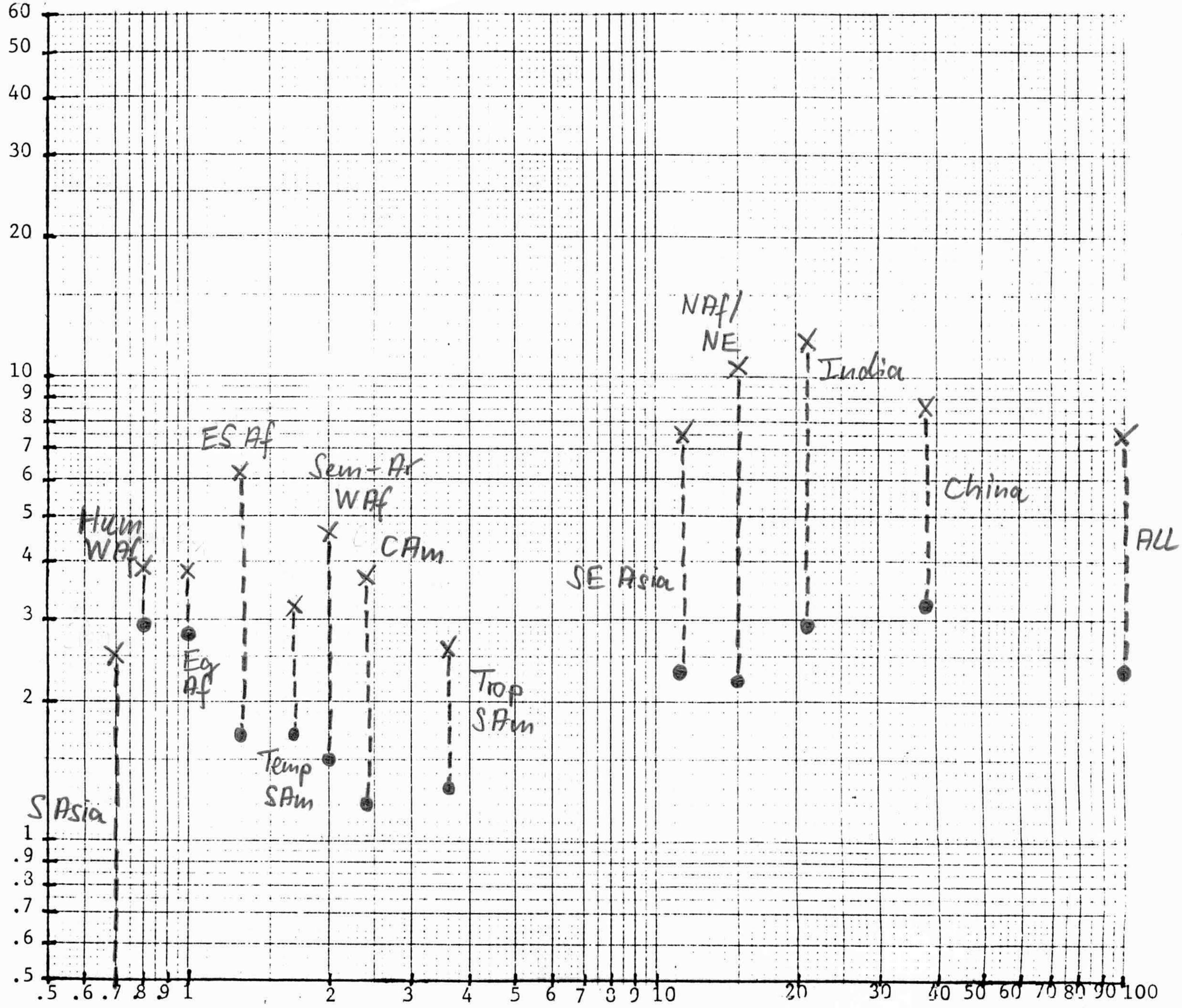
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



Production, in percent (log scale)

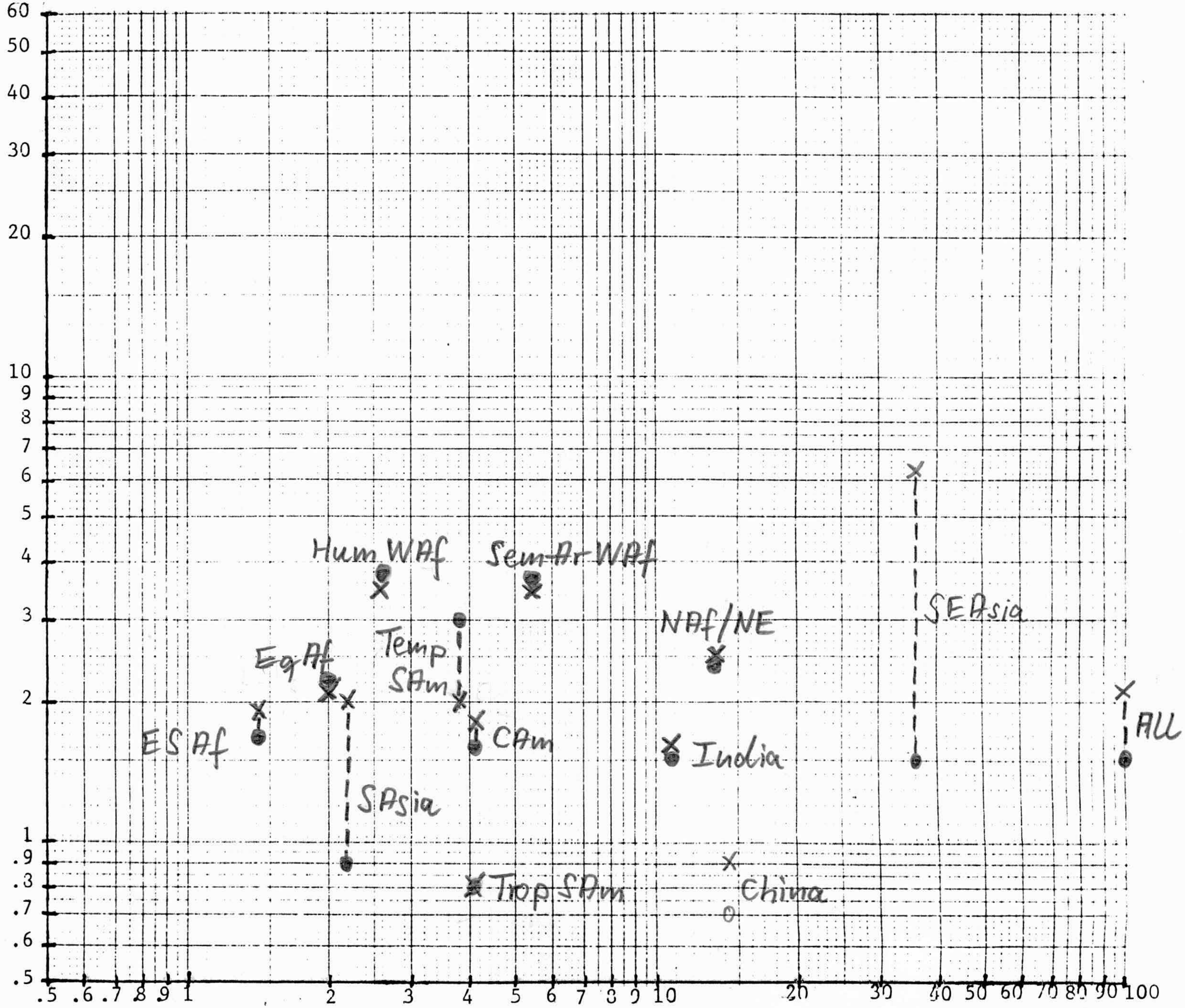
Vegetables

Annex figure 2.f : Production, calory/protein contribution and value of production by developing country regions for:
Oilseeds

Value of production, in percent
- x -

Calory/protein contribution, in percent
- ● -

(log scale)



Production, in percent (log scale)

Oilseeds

Annex figure 3.a : Production, calory/protein contribution and value of production by developing country regions for : Rice

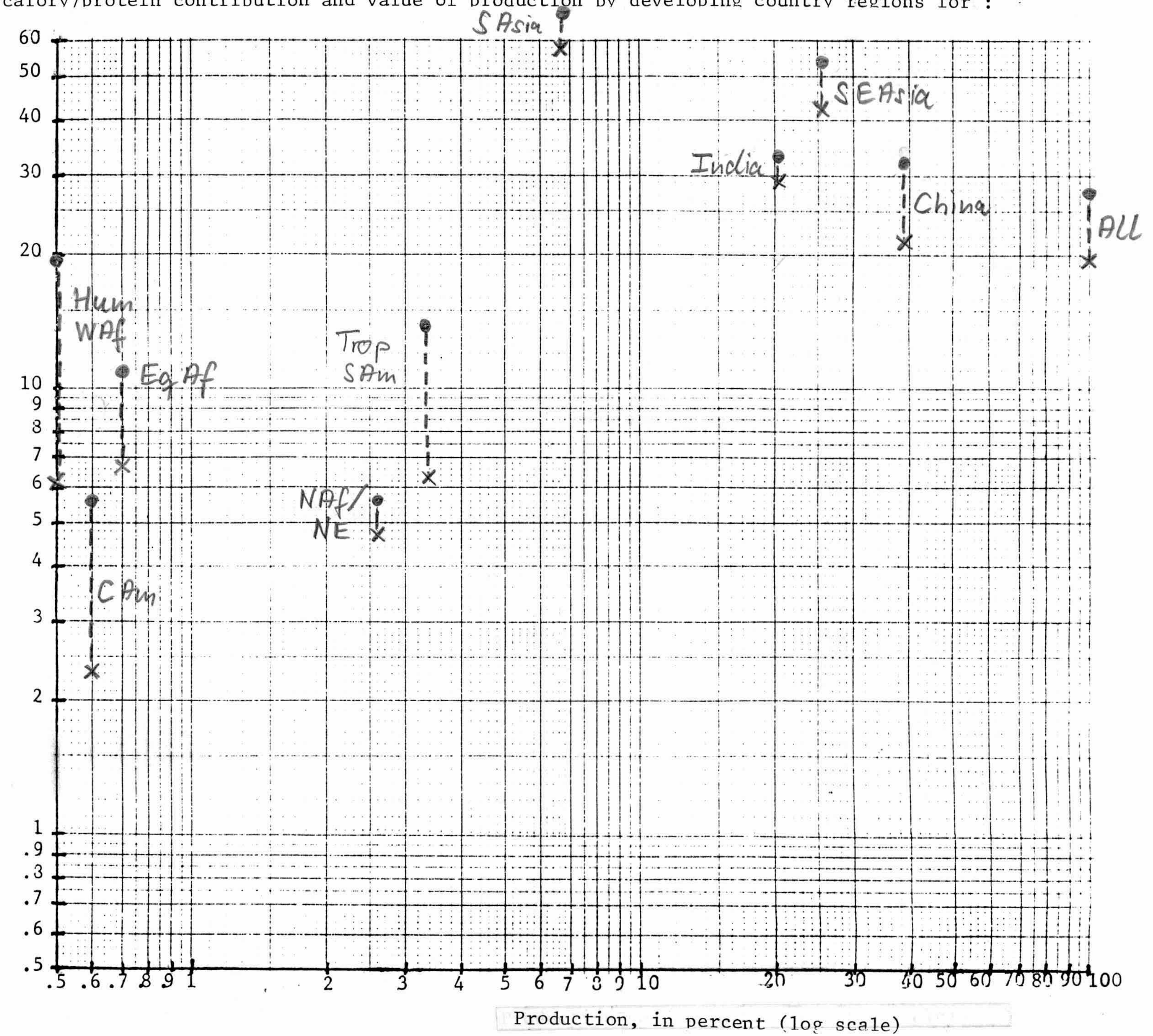
Value of production, in percent

- x -

Calory/protein contribution to diet, in percent

- ● -

(log scale)



Rice

Annex figure 3.b : Production, calory/protein contribution and value of production by developing country regions for : Wheat

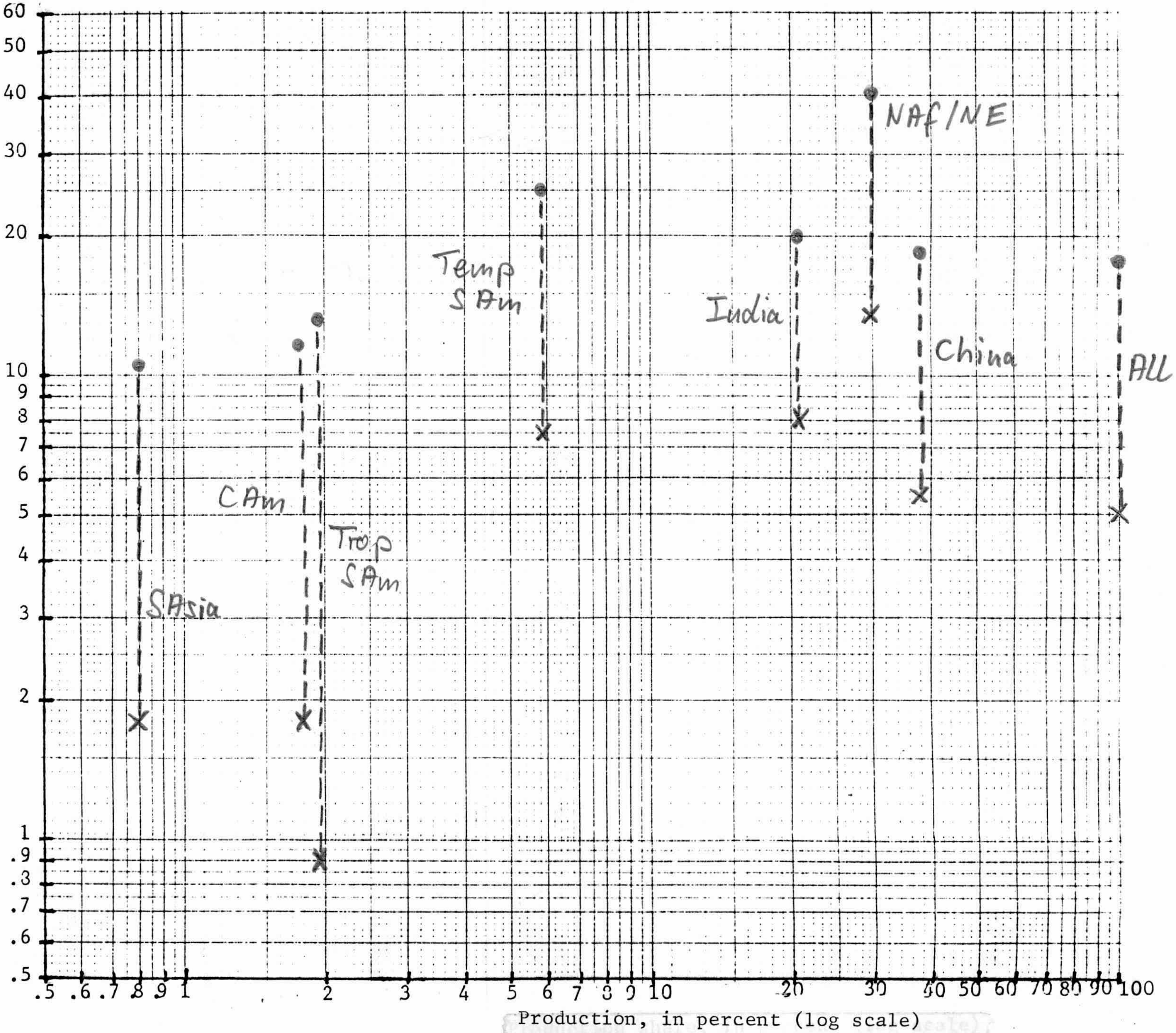
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



Wheat

Annex figure 3.c : Production, calory/protein contribution and value of production by developing country regions for : Maize

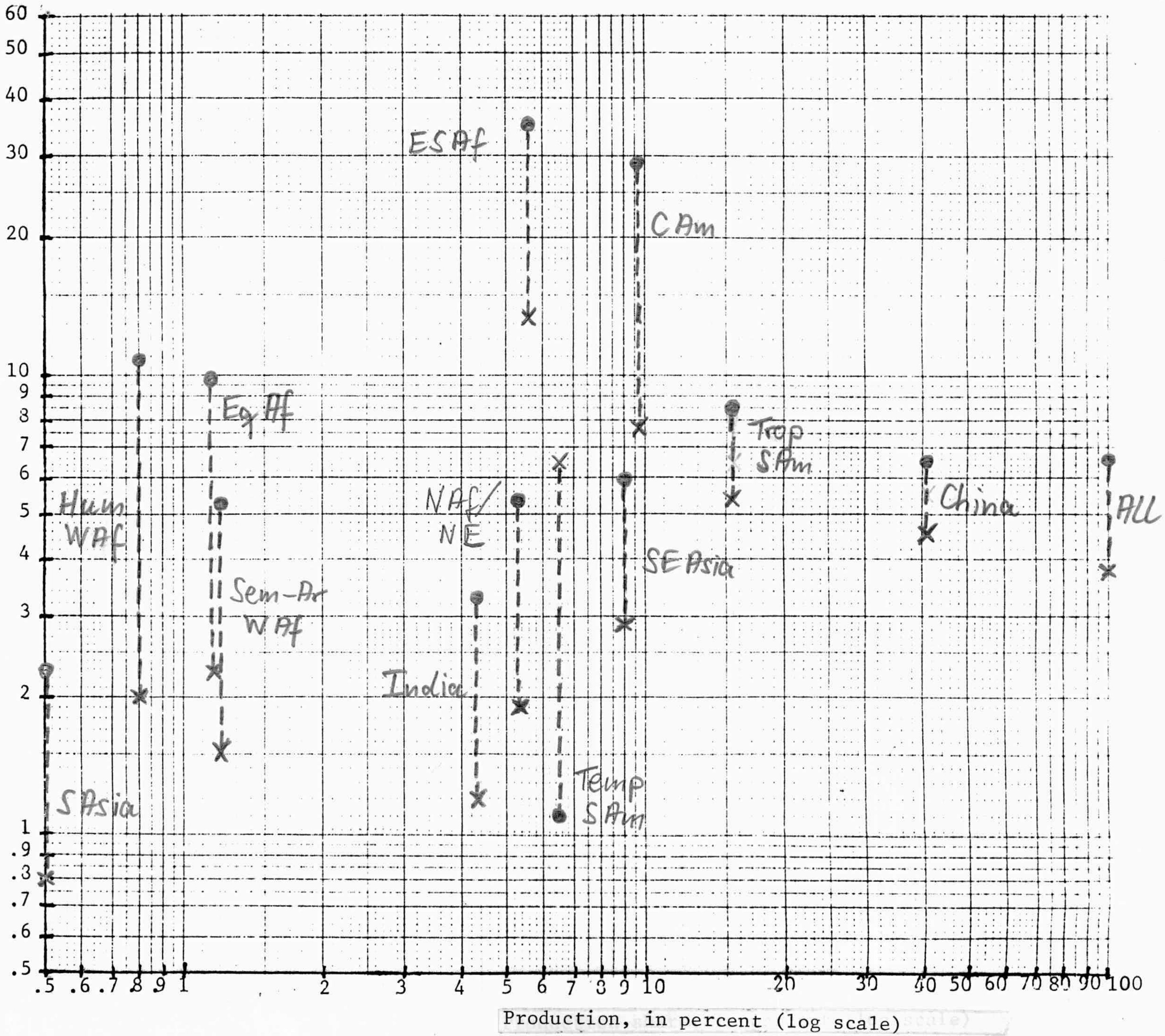
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



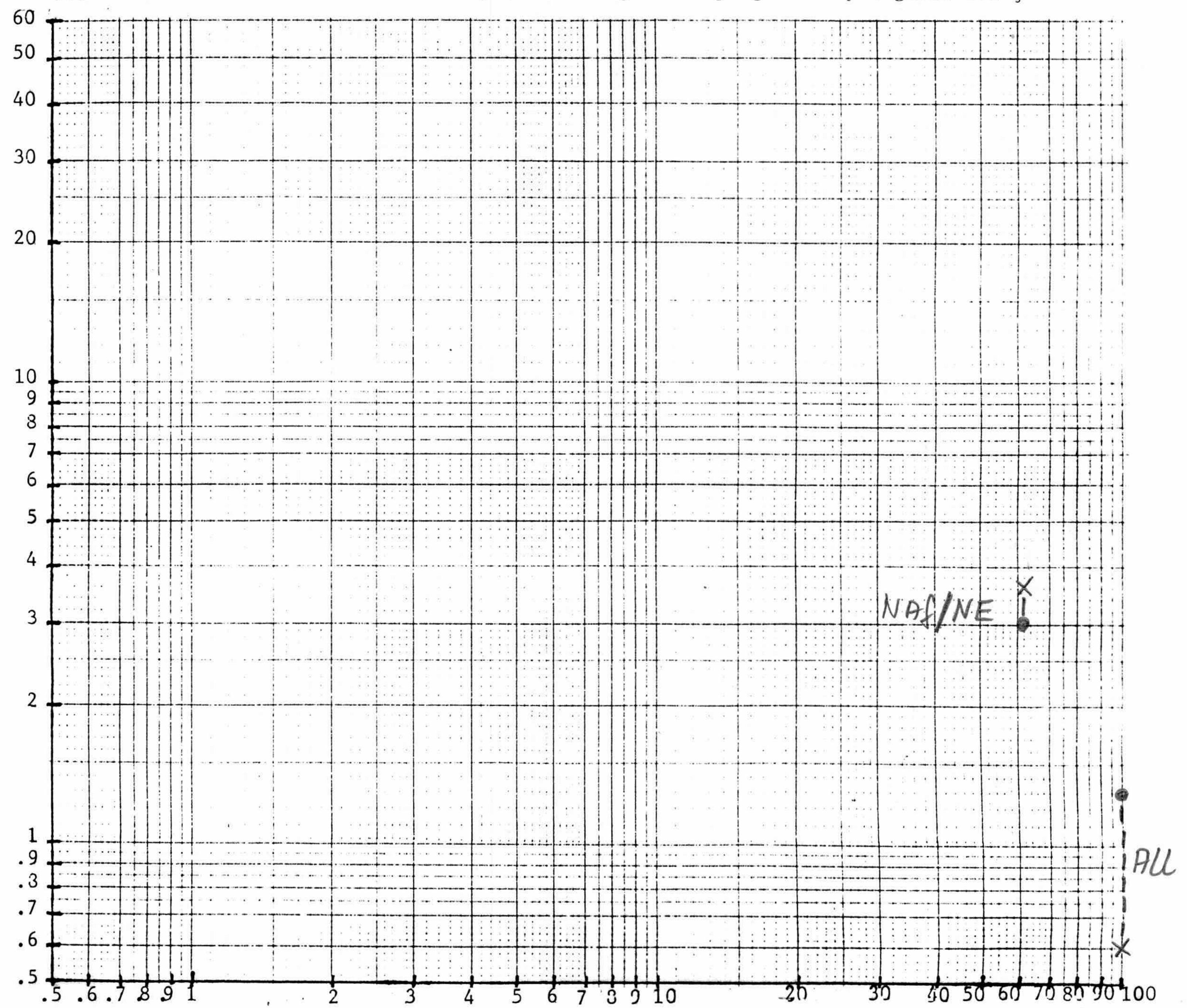
Maize

Annex figure 3.d : Production, calory/protein contribution and value of production by developing country regions for : Barley

Value of production, in percent - x -

Calory/protein contribution, in percent - ● -

(log scale)



Production, in percent (log share)

Barley

Annex figure 3.e : Production, calory/protein contribution and value of production by developing country regions for : Sorghum

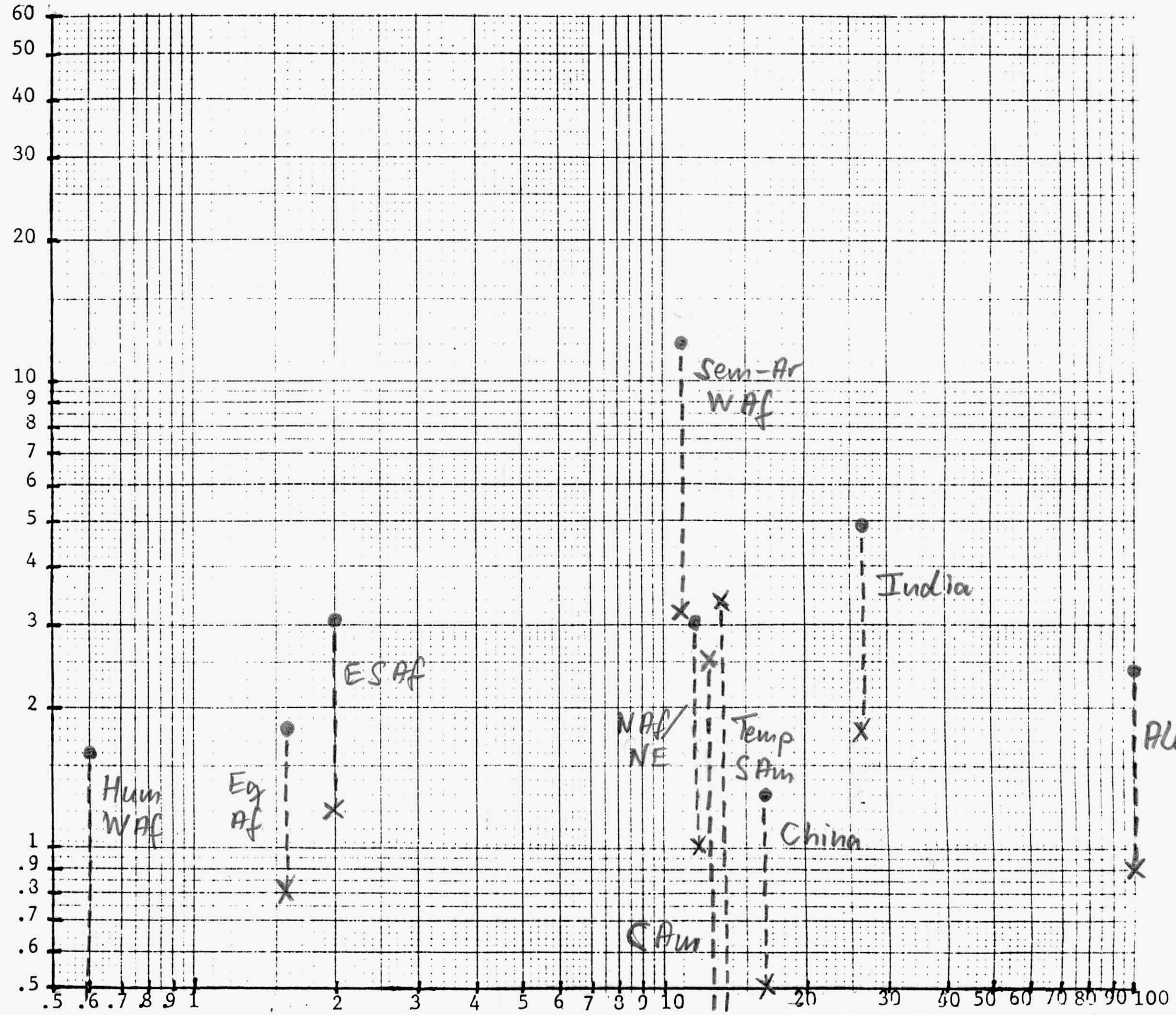
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

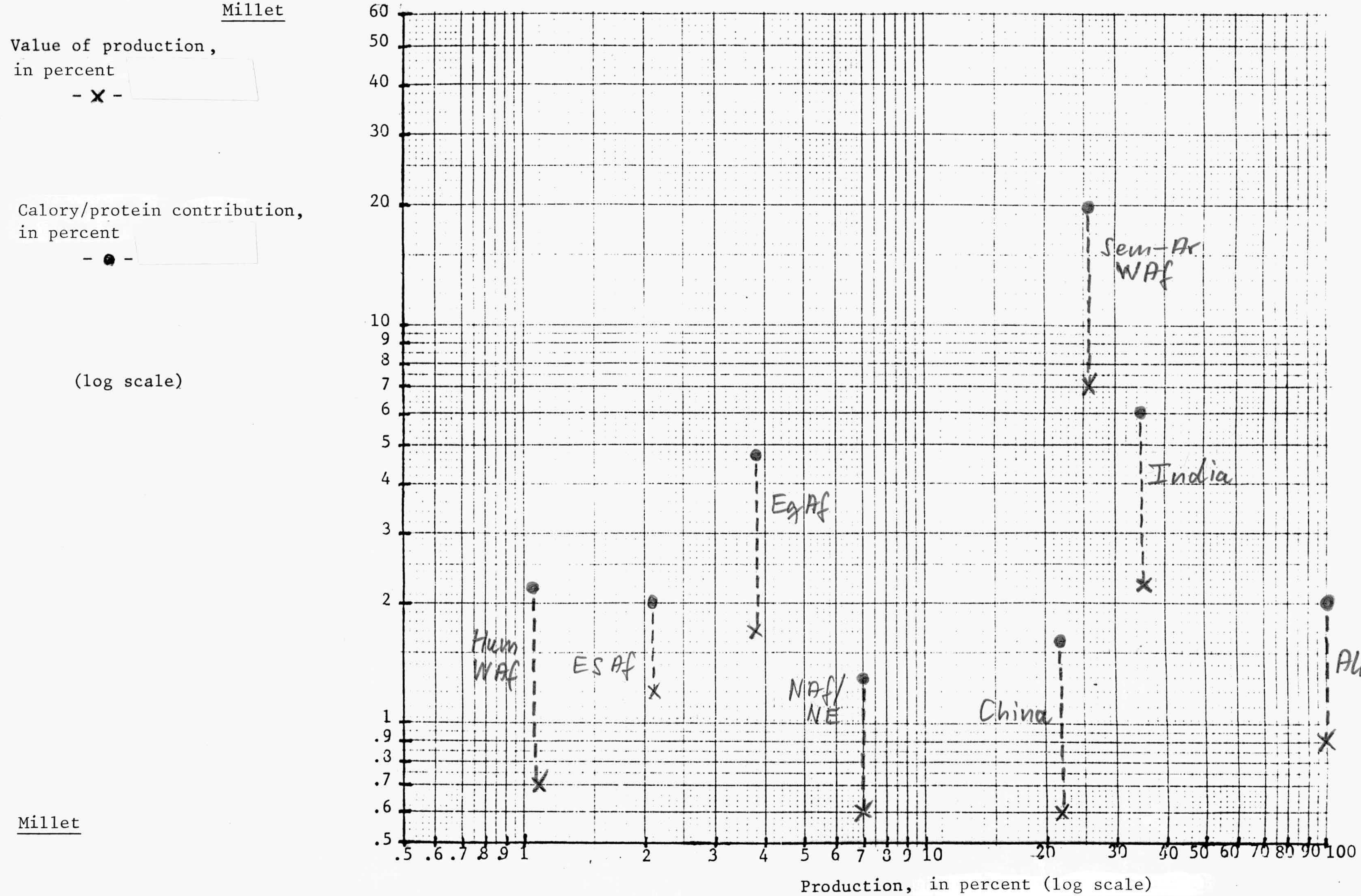
(log scale)



Production, in percent (log scale)

Sorghum

Annex figure 3.f : Production, calory/protein contribution and value of production by developing country regions for : Millet

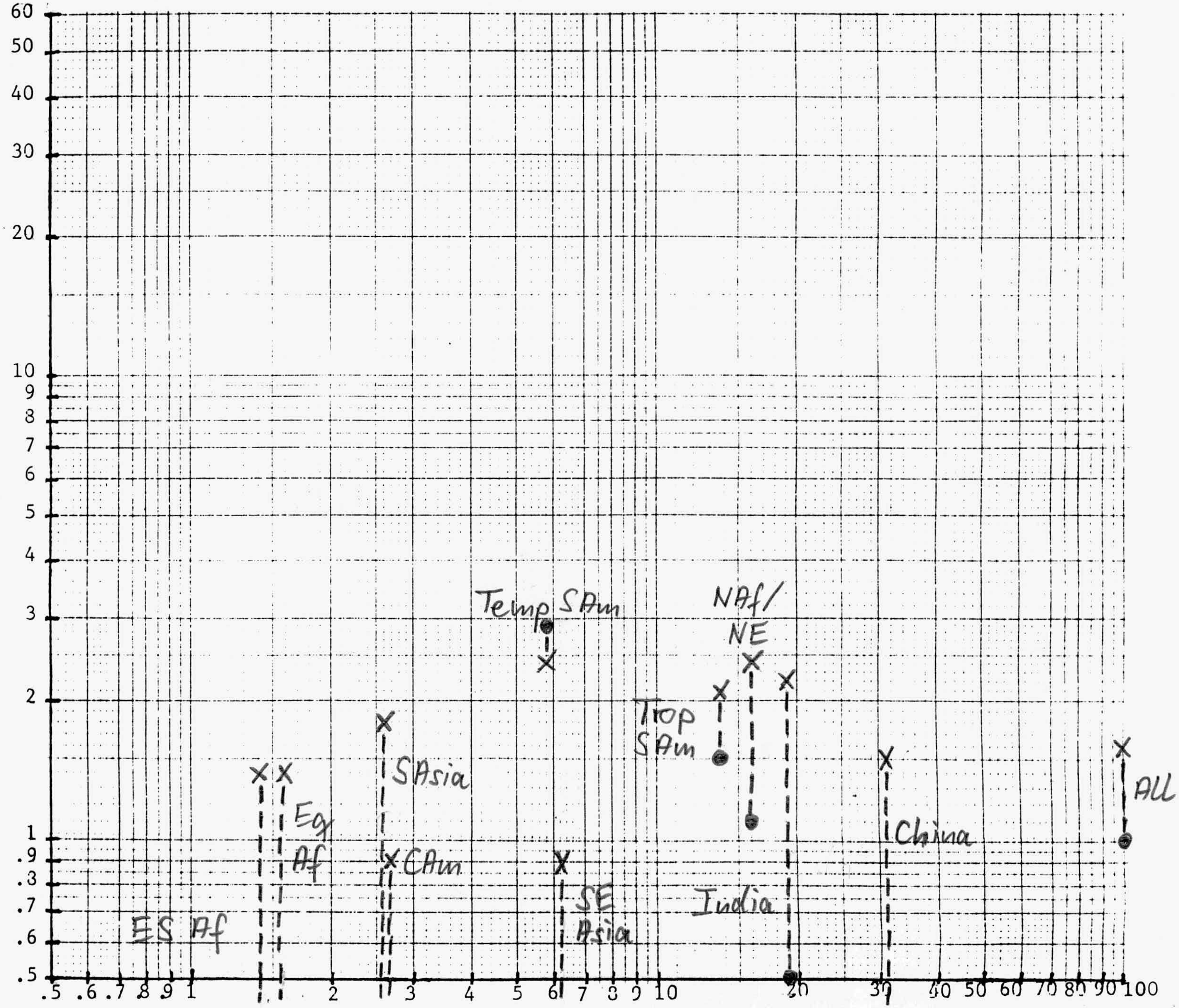


Annex figure 3.h : Production, calory/protein contribution and value of production by developing country regions for : Potato

Value of production, in percent - x -

Calory/protein contribution, in percent - • -

(log scale)



Production, in percent (log scale)

Potato

Annex figure 3.i : Production, calory/protein contribution and value of production by developing country regions for : Sweet Potato

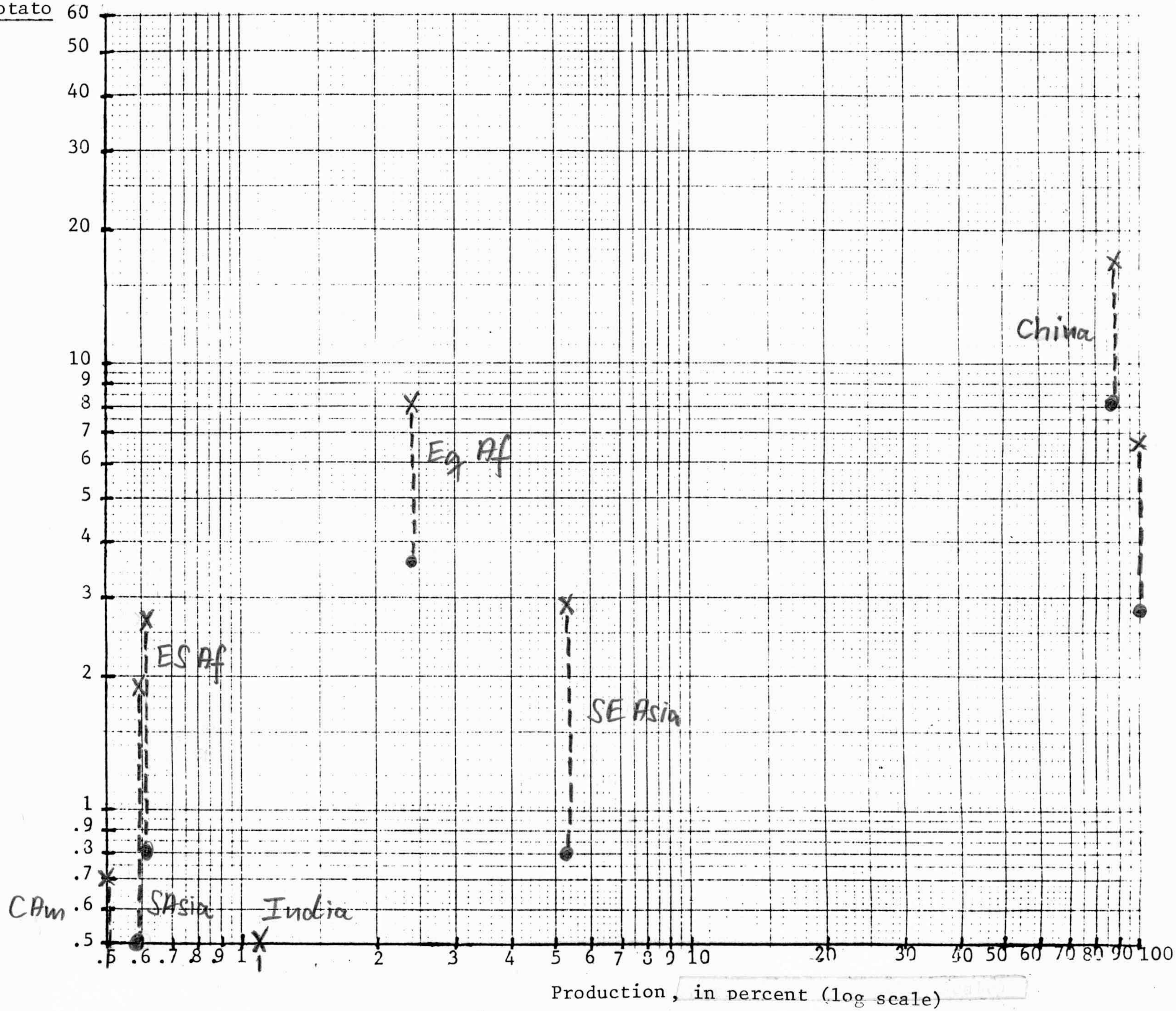
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



Sweet Potato

Annex figure 3.j : Production, calory/protein contribution and value of production by developing country regions for : Yam

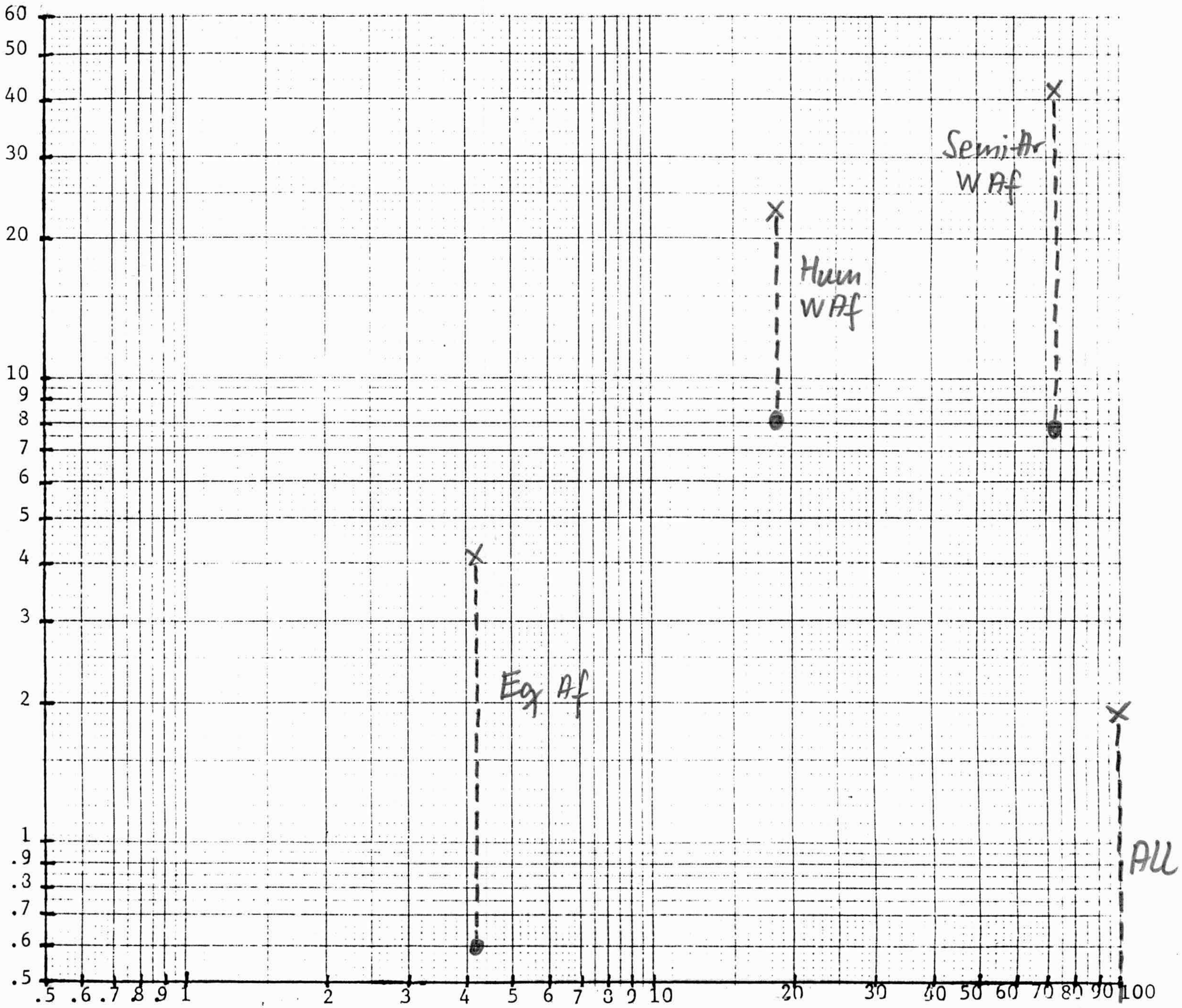
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



Production, in percent (log scale)

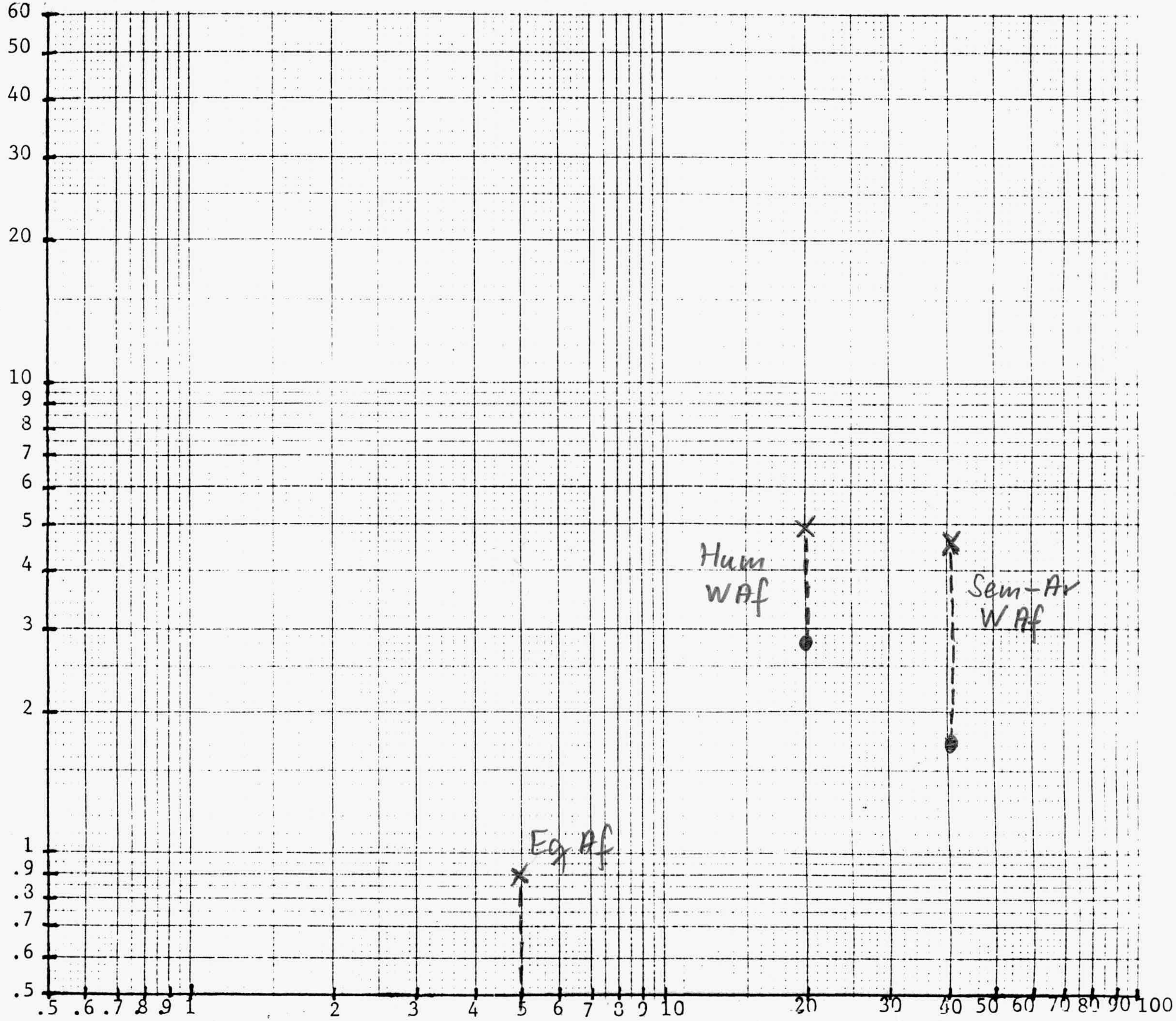
Yam

Annex figure 3.k : Production, calory/protein contribution and value of production by developing country regions for : Cocoyam

Value of production, in percent
- x -

Calory/protein contribution, in percent
- ● -

(log scale)



Production, in percent (log scale)

Cocoyam

Annex figure 3.1 : Production, calory/protein contribution and value of production by developing country regions for : Plantain/Banana

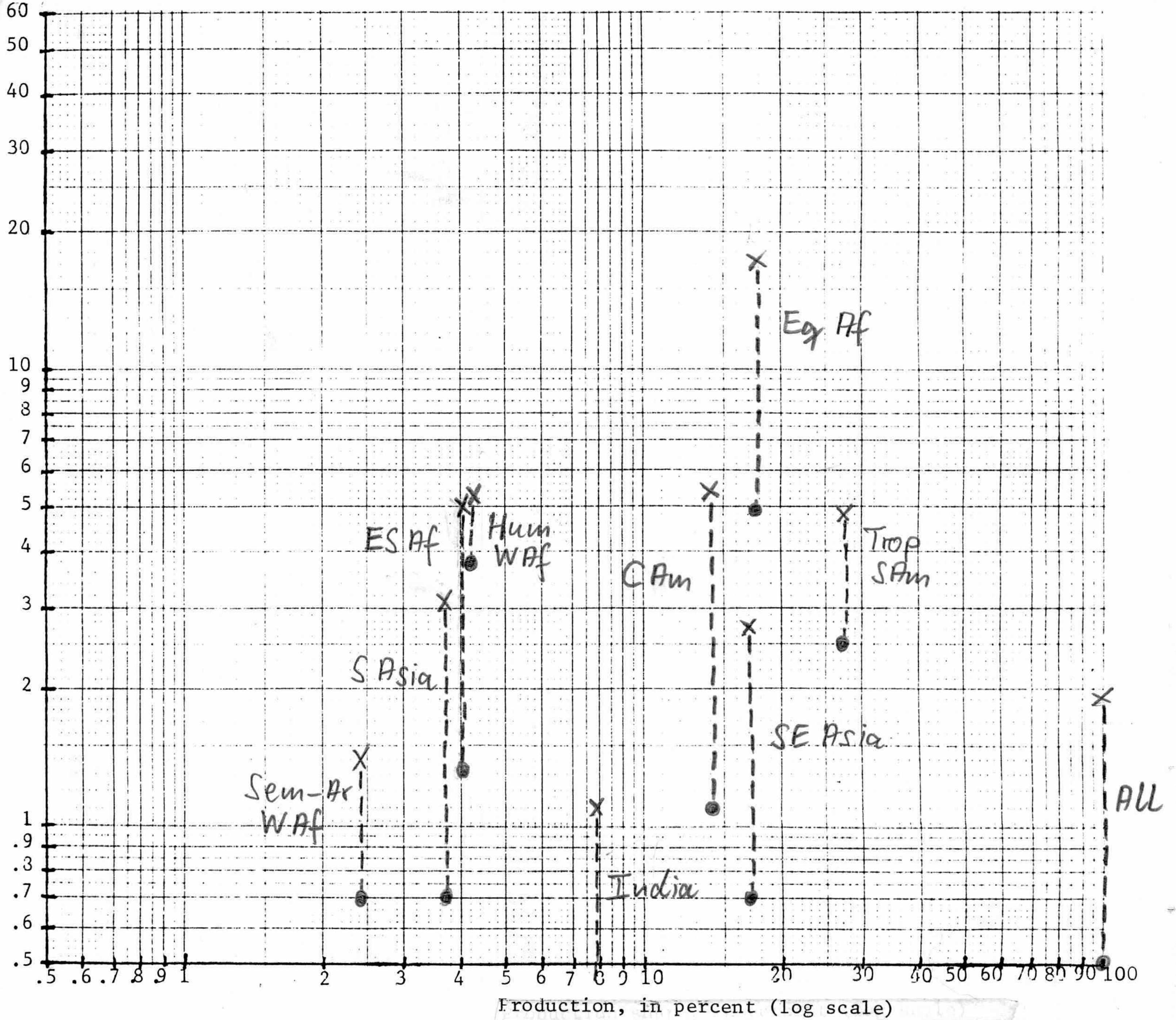
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



Plantain/Banana

Annex figure 3.m : Production, calory/protein contribution and value of production by developing country regions for : Chickpea

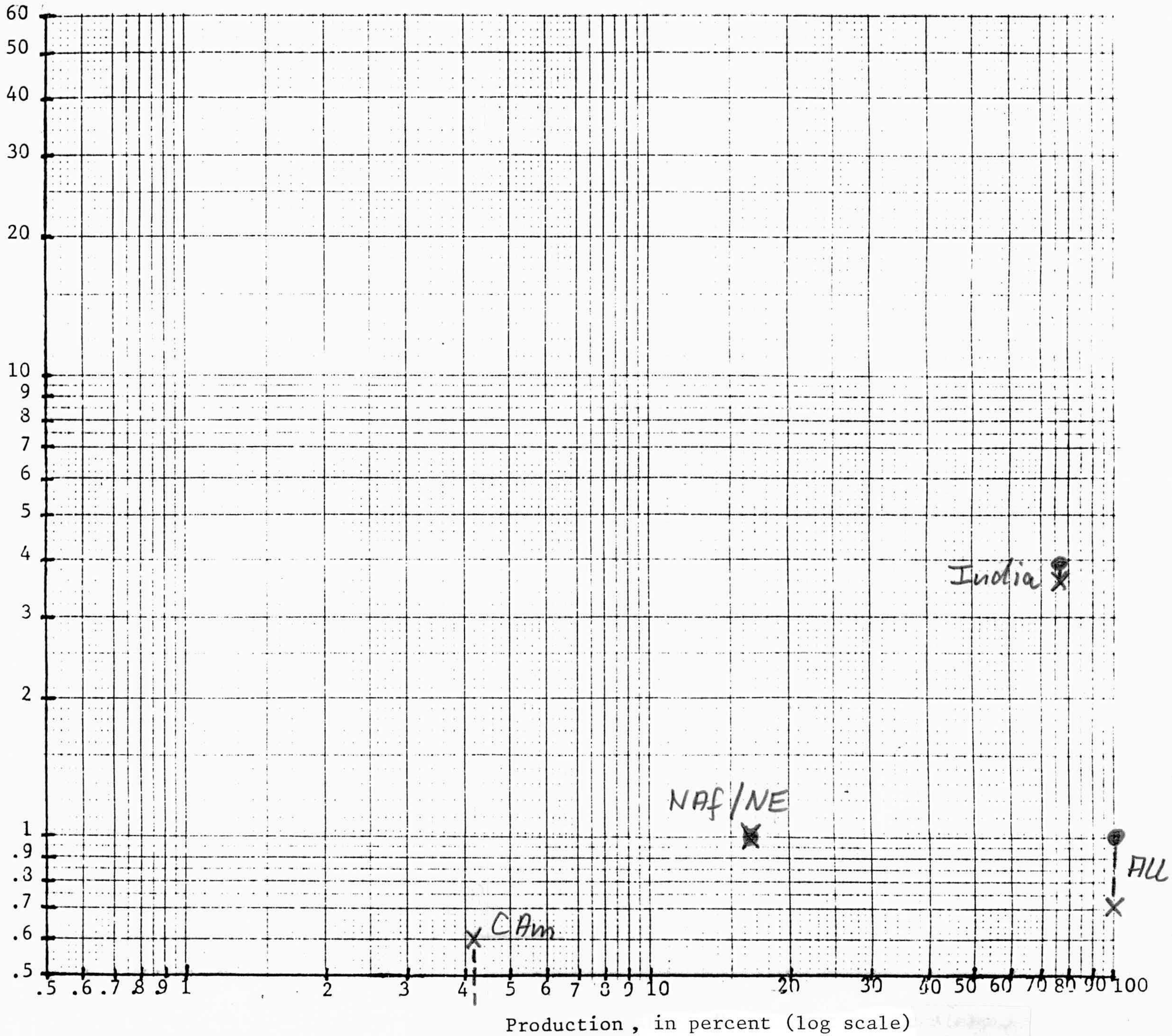
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



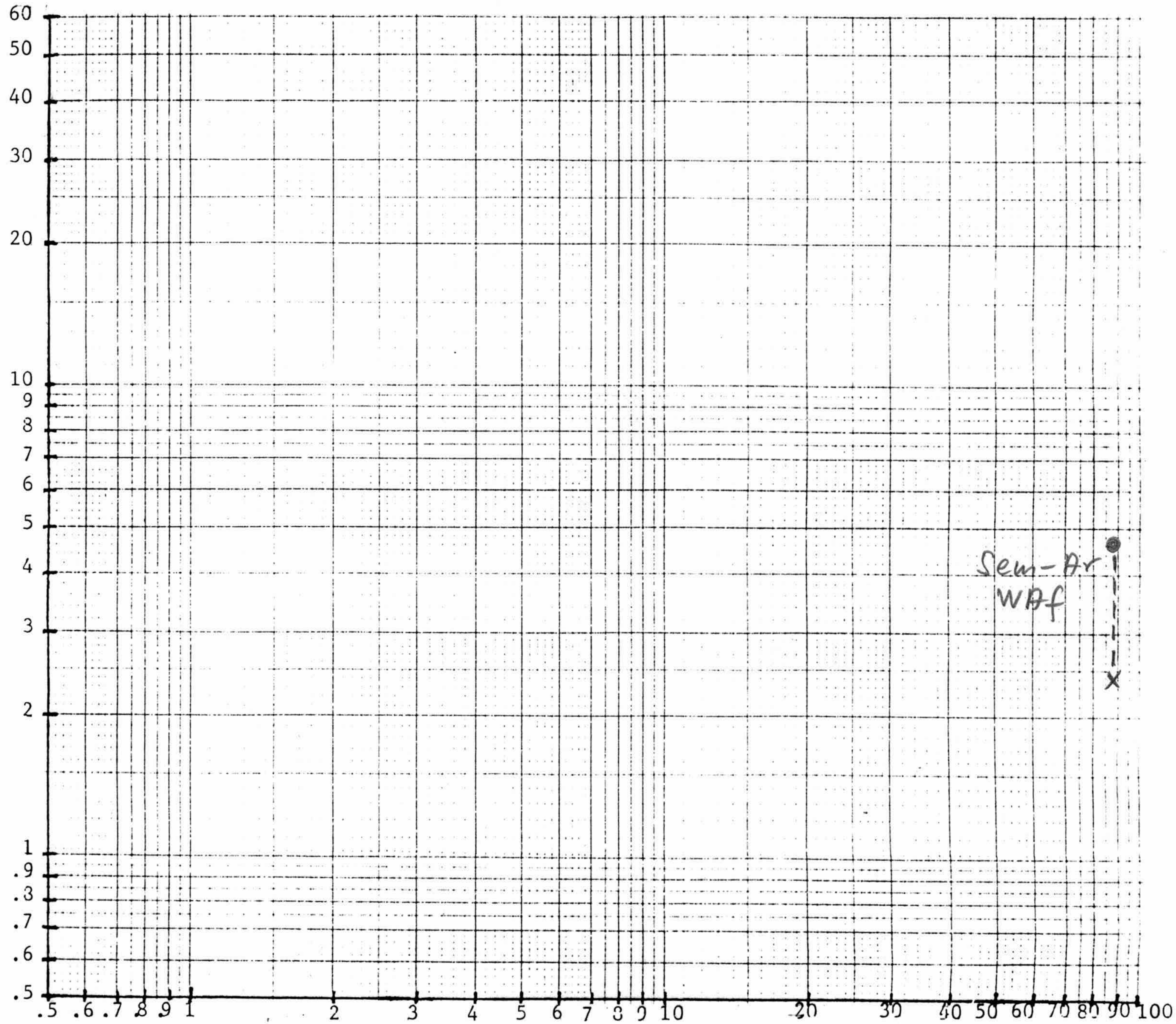
Chickpea

Annex figure 3.n : Production, calory/protein contribution and value of production by developing country regions for :
Cowpea

Value of production, in percent - x -

Calory/protein contribution, in percent - ● -

(log scale)



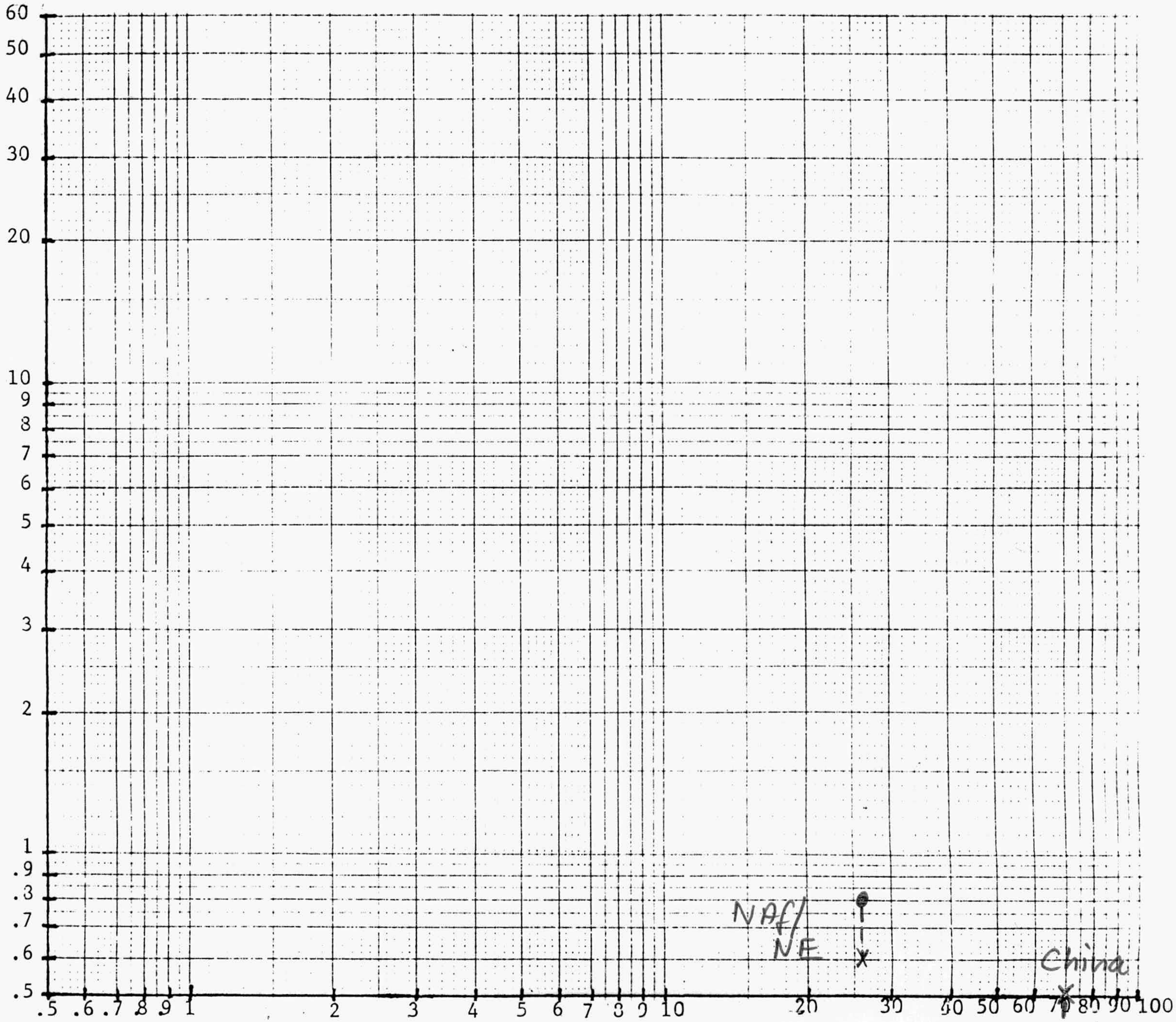
Cowpea

Annex figure 3.o : Production, calory/protein contribution and value of production by developing country regions for : Faba bean

Value of production, in percent - x -

Calory/protein contribution, in percent - ● -

(log scale)



Production, in percent (log scale)

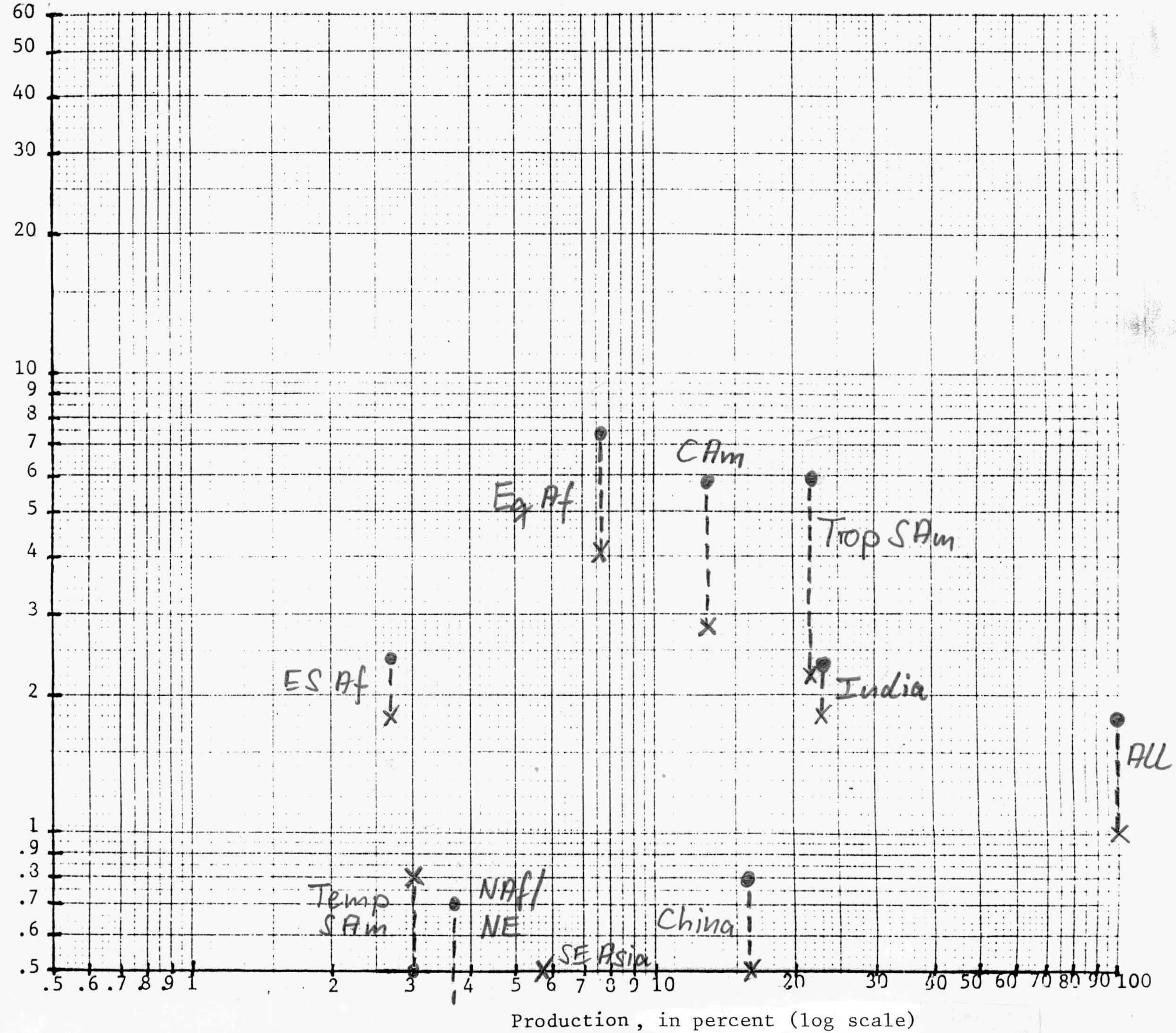
Faba bean

Annex figure 3.p : Production, calory/protein contribution and value of production by developing country regions for : Field bean

Value of production, in percent - X -

Calory/protein contribution, in percent - ● -

(log scale)



Field bean

Annex figure 3.q : Production, calory/protein contribution and value of production by developing country regions for :

Groundnut

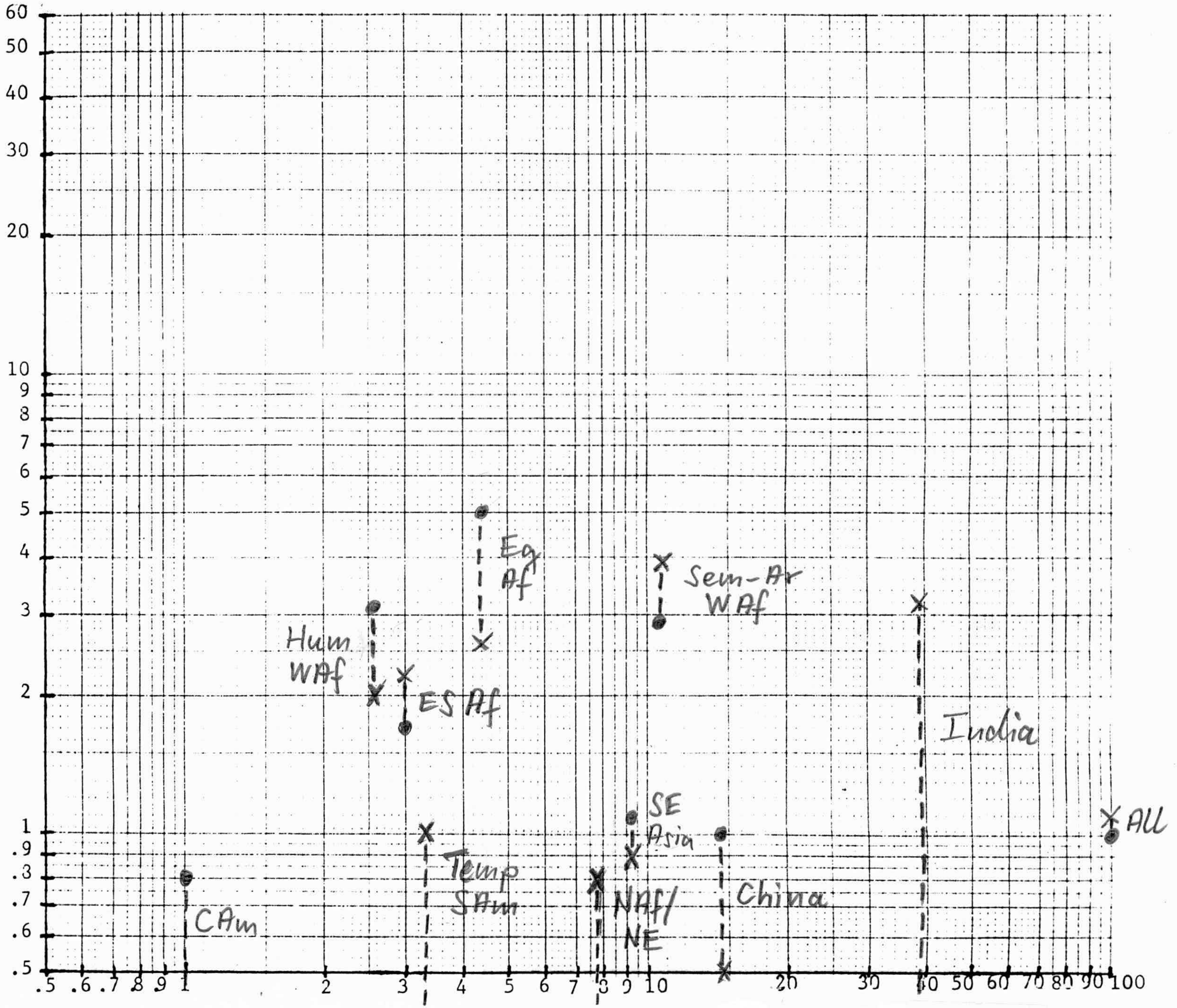
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



Production, in percent (log scale)

Groundnut

Annex figure 3.r : Production, calory/protein contribution and value of production by developing country regions for : Lentil

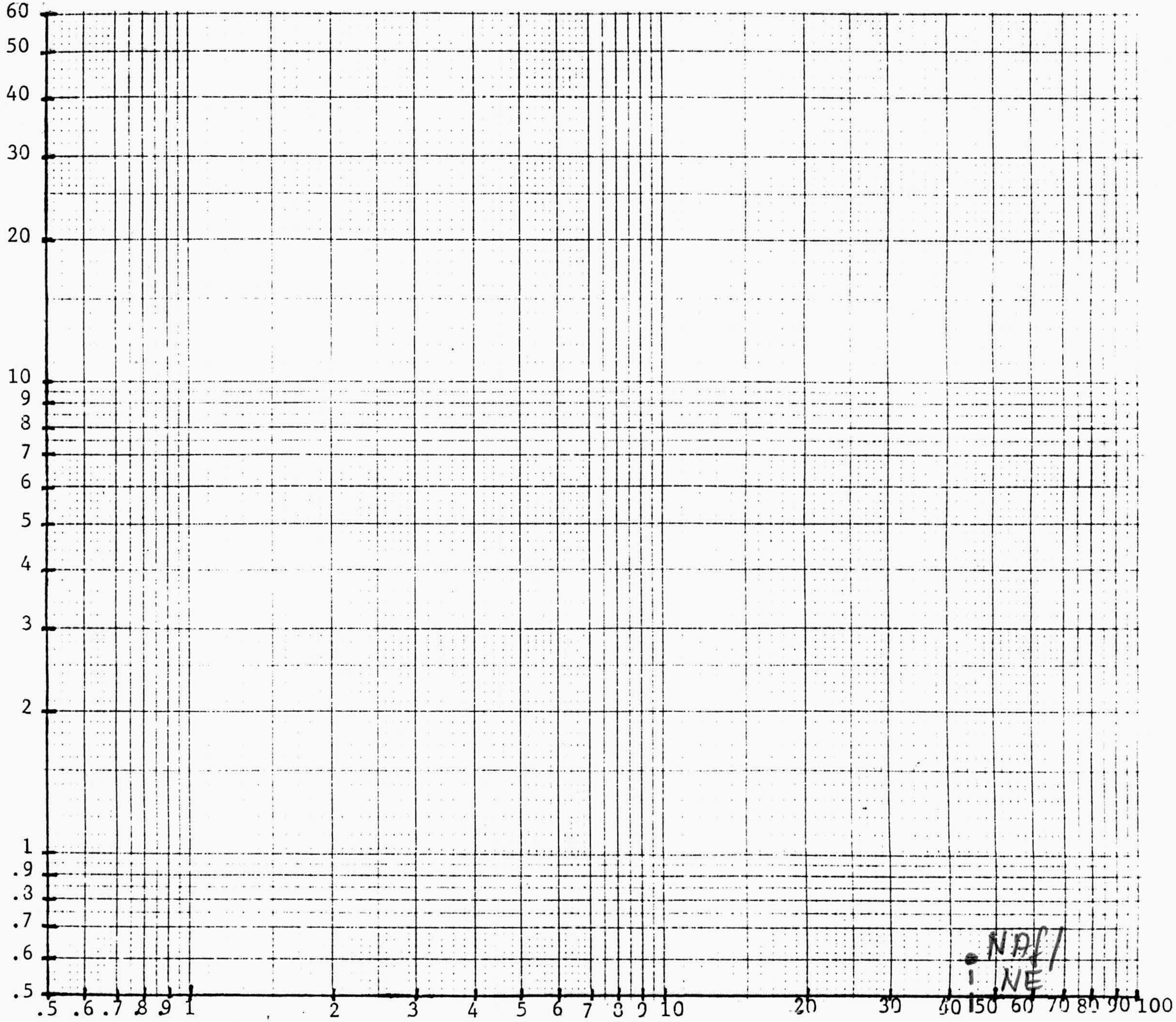
Value of production, in percent

- X -

Calory/protein contribution, in percent

- ● -

(log scale)



Production, in percent (log scale)

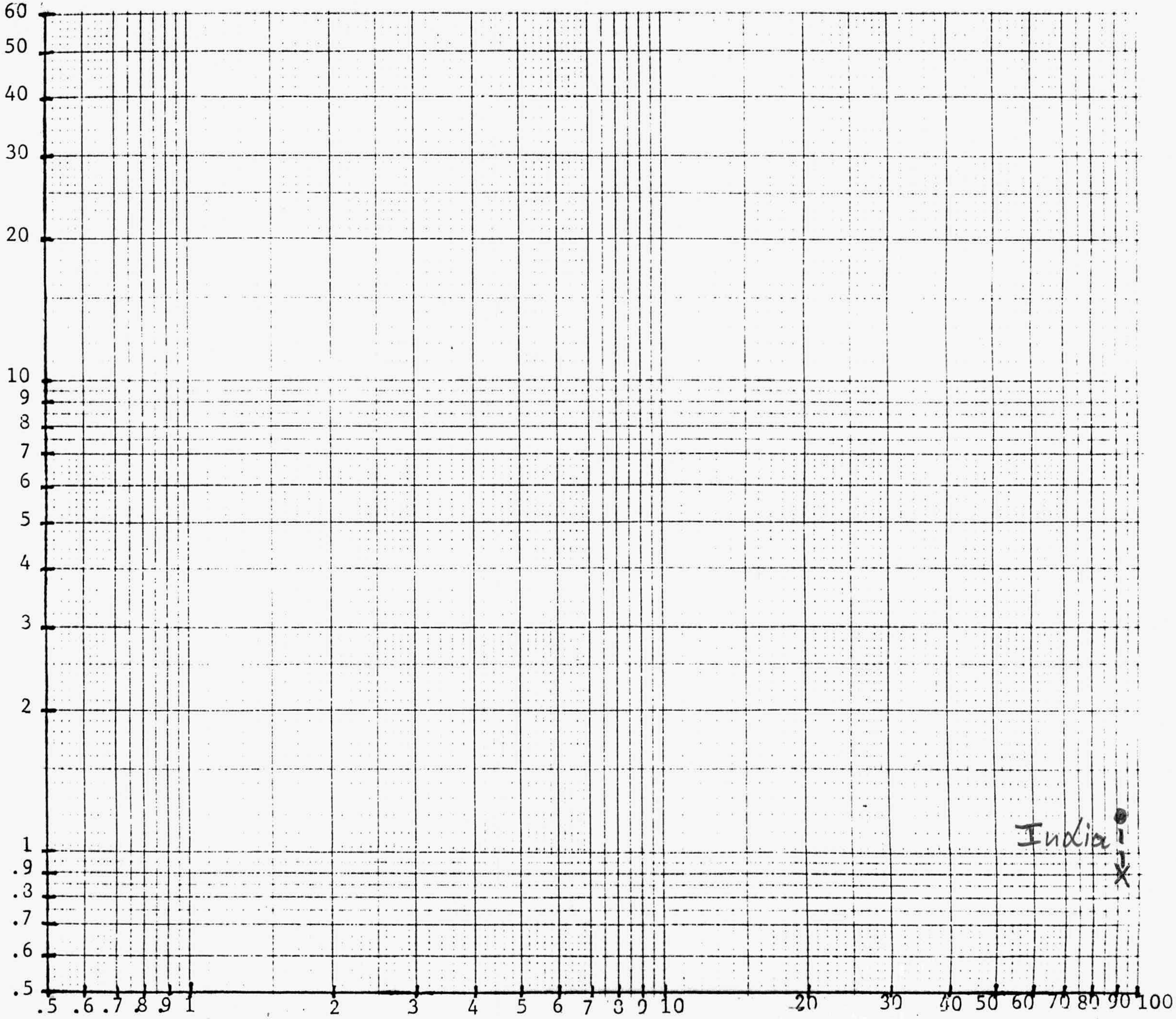
Lentil

Annex figure 3.s : Production, calory/protein contribution and value of production by developing country regions for : Pigeonpea

Value of production, in percent
- x -

Calory/protein contribution, in percent
- ● -

(log scale)



Pigeonpea

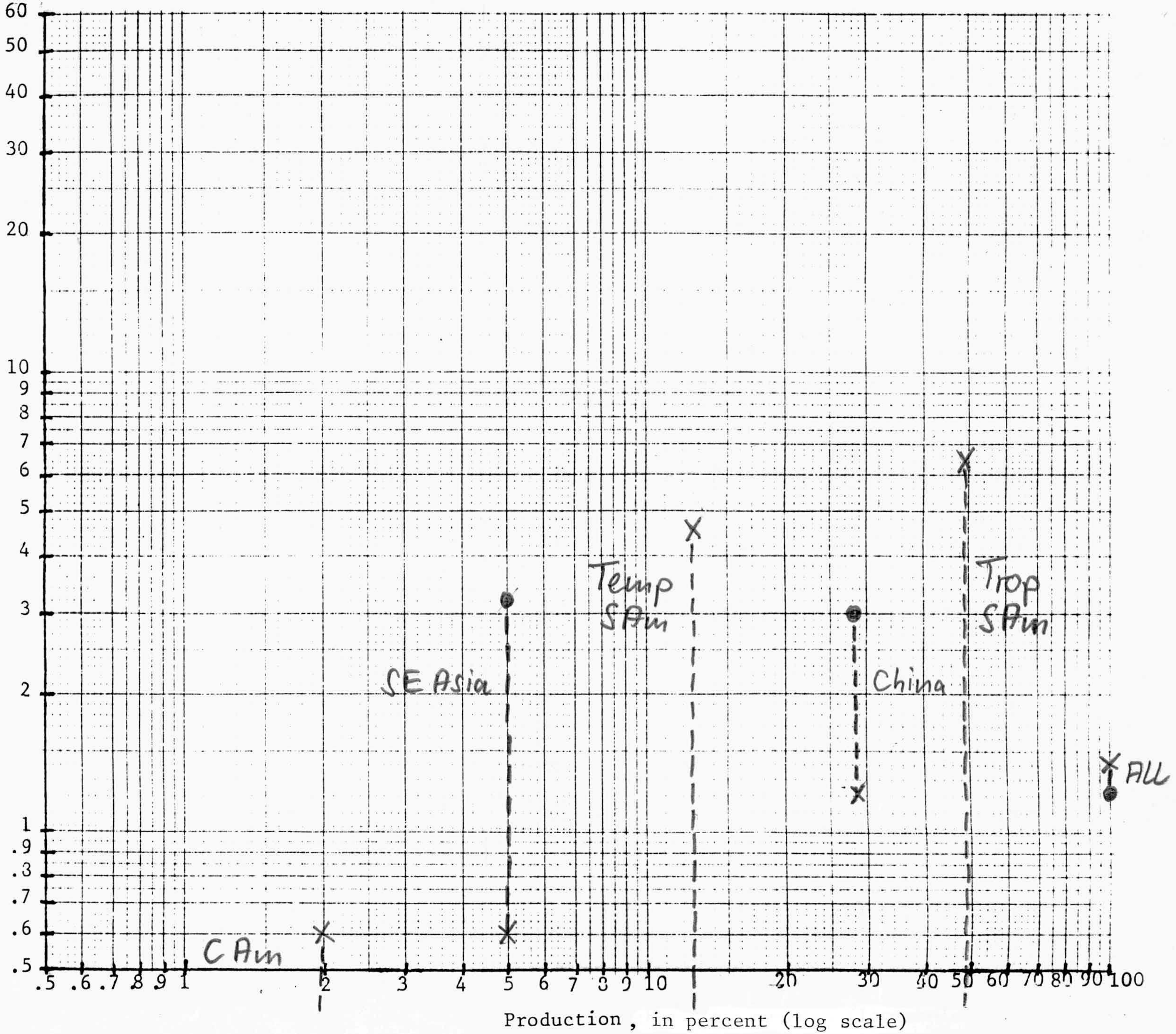
Production, in percent (log scale)

Annex figure 3.t : Production, calory/protein contribution and value of production by developing country regions for : Soybean

Value of production, in percent
- x -

Calory/protein contribution, in percent
- ● -

(log scale)



Soybean

Annex figure 3.u : Production, calory/protein contribution and value of production by developing country regions for : Beef & Buffalo

Value of production, in percent

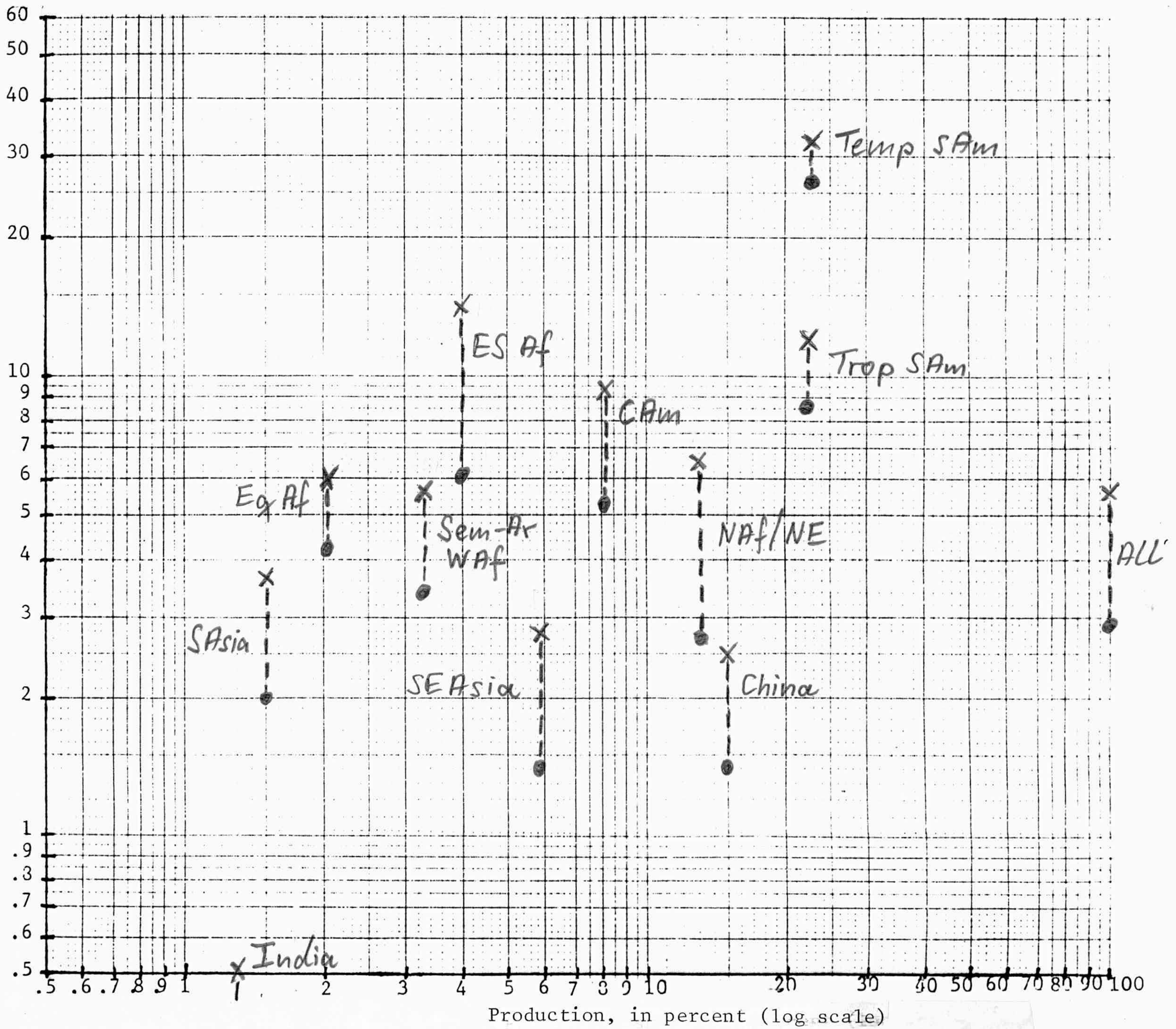
- x -

Calory/protein contribution, in percent

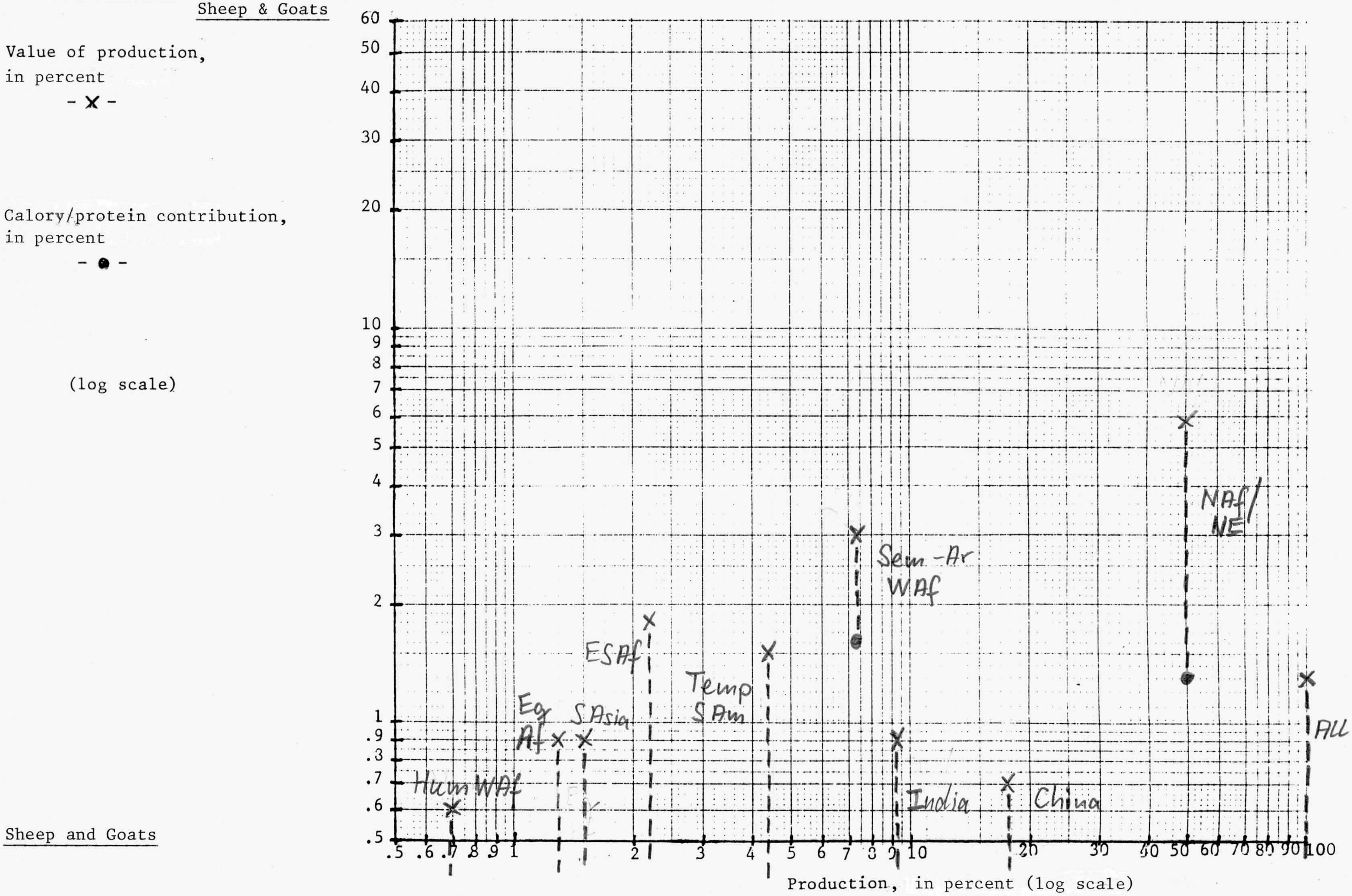
- ● -

(log scale)

Beef and Buffalo



Annex figure 3.v : Production, calory/protein contribution and value of production by developing country regions for : Sheep & Goats



Annex figure 3.x : Production, calory/protein contribution and value of production by developing country regions for : Coconut

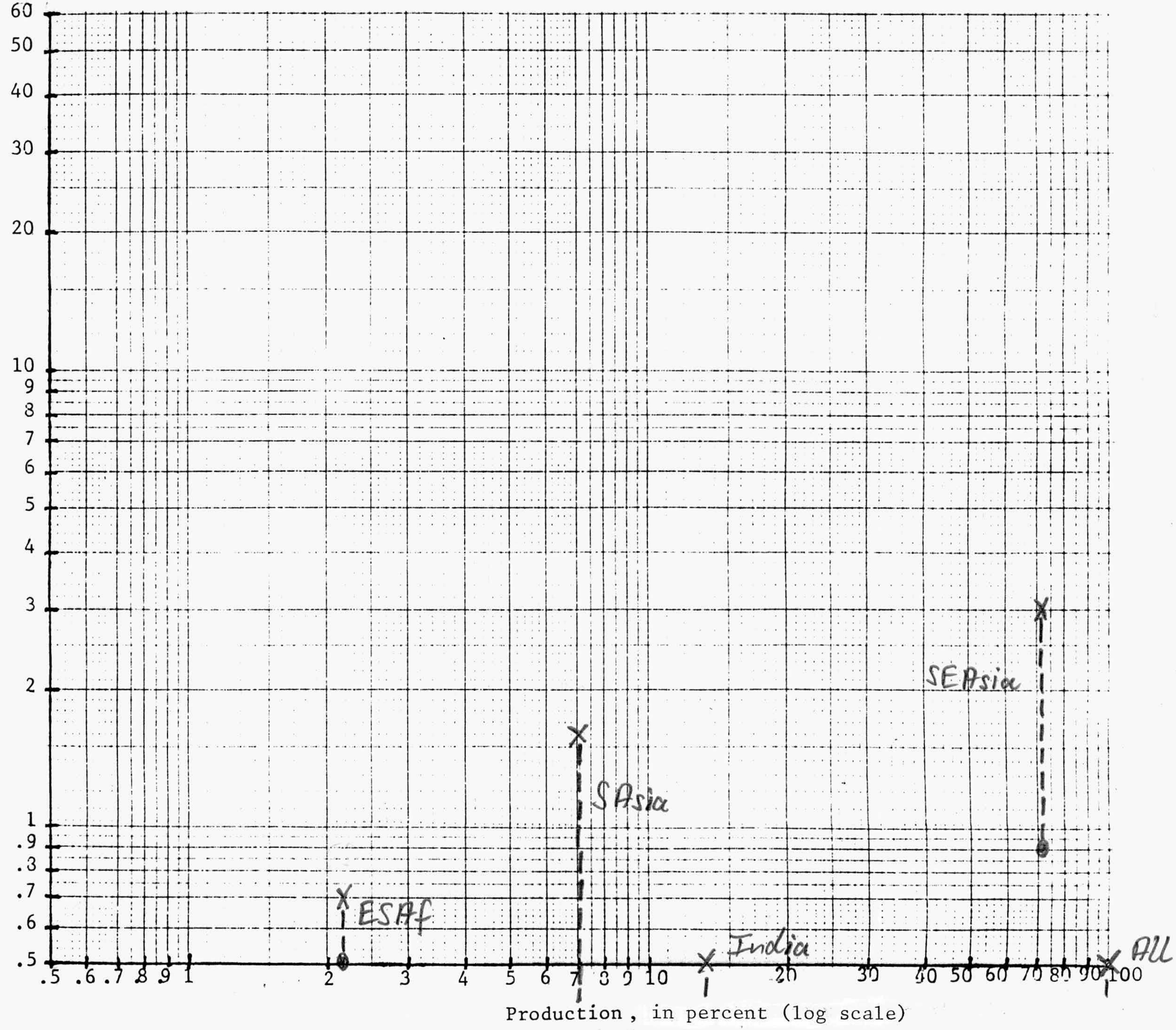
Value of production, in percent

- X -

Calory/protein contribution, in percent

- ● -

(log scale)



Coconut

Annex figure 3.w : Production, caloty/protein contribution and value of production by developing country regions for : Milk

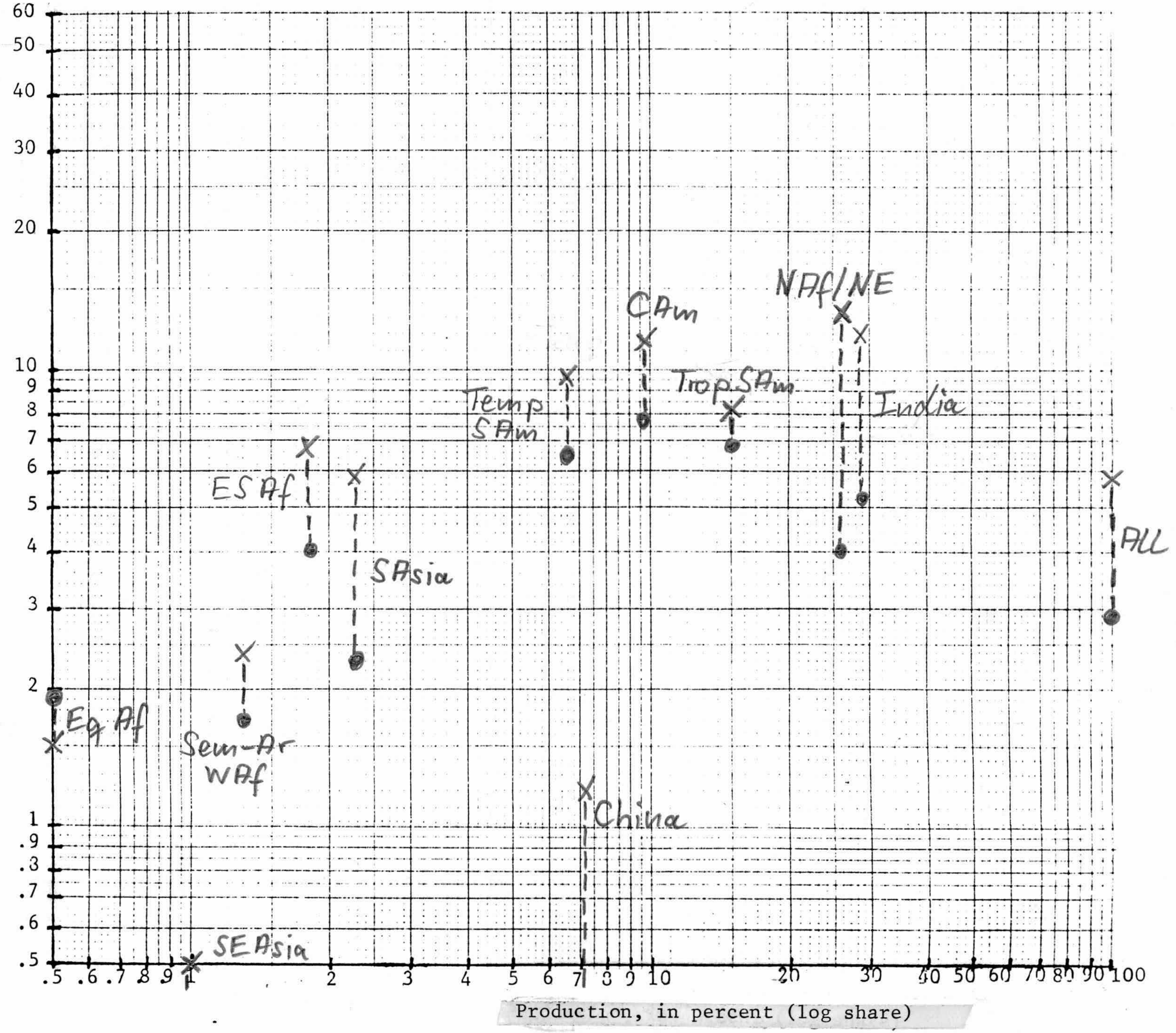
Value of production, in percent

- x -

Calory/protein contribution, in percent

- ● -

(log scale)



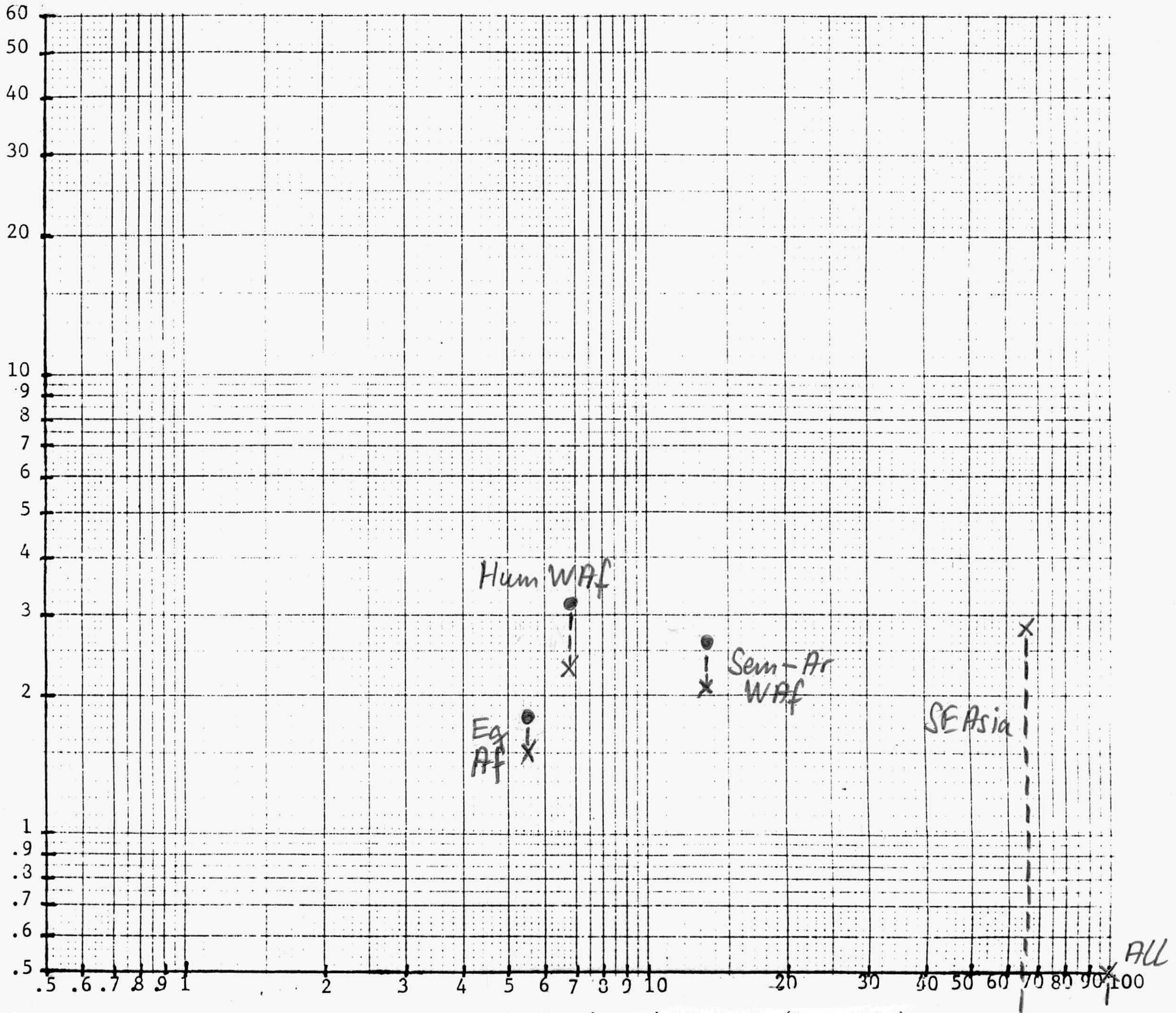
Milk

Annex figure 3.y : Production, calory/protein contribution and value of production by developing country regions for : Oil Palm

Value of production, in percent - x -

Calory/protein contribution, in percent - ● -

(log scale)



Production, in percent (log scale)

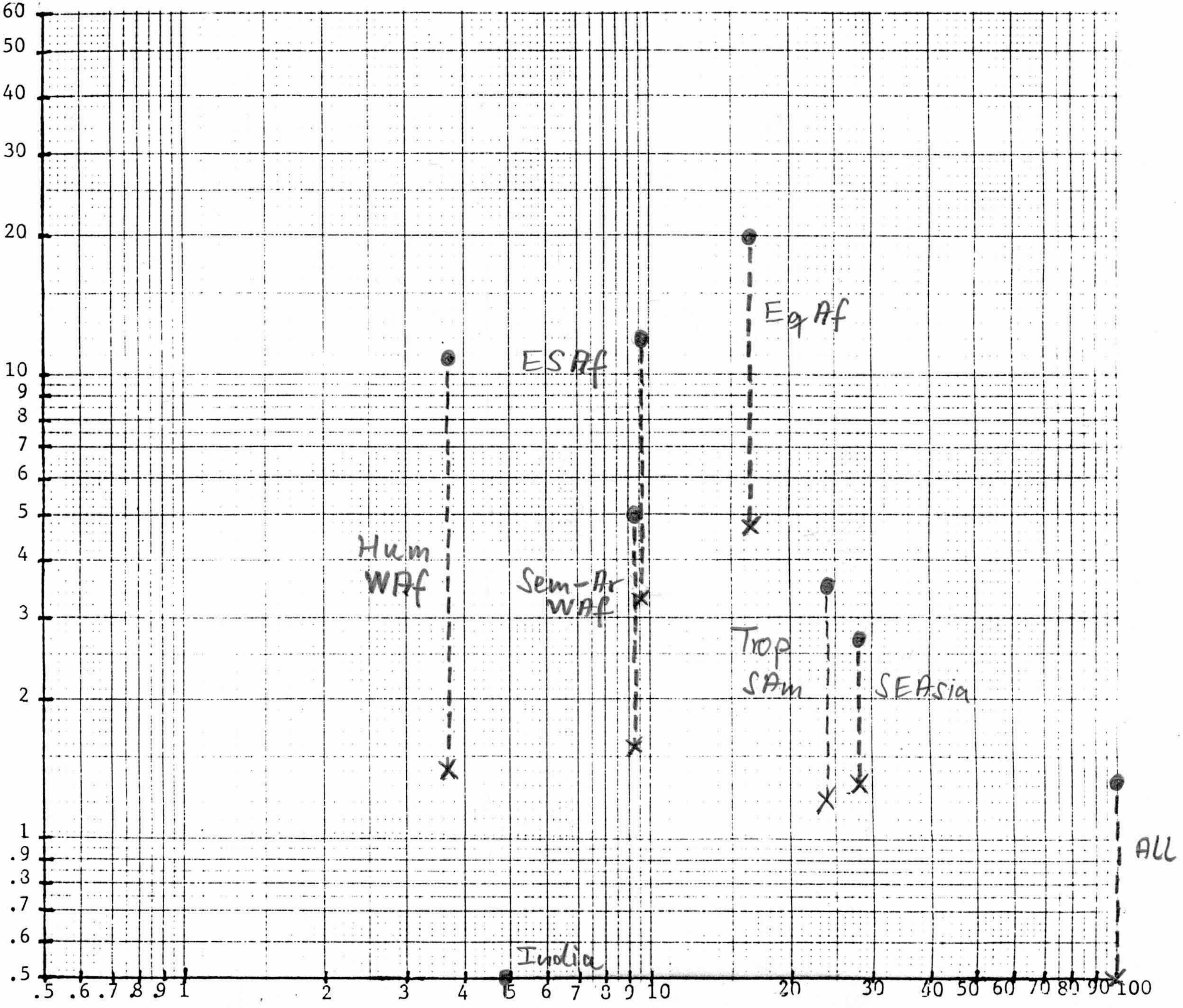
Oil Palm

Annex figure 3.g : Production, calory/protein contribution and value of production by developing country regions for for : Cassava

Value of production, in percent - X -

Calory/protein contribution, in percent - ● -

(log scale)



Production, (in percent (log scale)

Cassava

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