8.1 The use of agronomic information in the socio-economic models of the Centre for World Food Studies

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8.1.1 Introduction

Although the world produces sufficient food for the total population, and although it has been estimated that agricultural output can be increased at least twenty-fold (Buringh & van Heemst, 1979; see also Chapter 1), more than 400 million people suffer from less than adequate nutrition, and many of them from starvation. To get to the root of this hunger and poverty problem an agro-technical and socio-economic analysis must be made in a global context. In particular, the mechanisms that determine the distribution of resources and purchasing power, through productive employment, have been found to cause an unbalanced distribution of available food (Linneman et al., 1979). To improve the food situation, efforts should therefore be directed towards reduction of income inequalities between rich and poor countries, as well as between different income groups within countries. Policies to influence that distribution could be initiated at the international level, while interdependence of national policies should also be taken into account (see Chapter 1). Global policy analyses have indicated the general direction of solutions but have not been able to quantify the effects of such measures. A necessary starting point of an investigation into the nature and causes of the hunger problem therefore lies in the development and construction of a set of individual country models, that interact through international markets and are linked through international agreements.

The focus on relationships between agro-technical factors and economic processes, and on national policies and linkage of nations, which together determine the characteristics of the food market, requires a multi-disciplinary approach. This approach necessitates starting such an analysis with a detailed description of the physical environment determining actual and potential agricultural production, and its limitations (as outlined in this monograph), as well as an inquiry into the socio-economic structure of the agricultural sector and its interrelationships with the rest of the economy. Such economy-wide models will not be used to forecast or to make predictions (Meadows et al., 1972), but rather to enable the analysis of possible alternative futures. Quantitative modelling of these relationships and interactions can contribute to increased insight into the causes of the hunger problem, which in turn may lead to the formulation of useful policy proposals. At the national level, it is particularly important that such models are applicable for medium- and long-term planning and that they contain all elements that may influence the national food market. At the international level, the model system should provide explicit and reliable suggestions for international policy coordination. Before the explicit linkage between the physical factors and socio-economic structure is discussed, the general structure of the full model is outlined.

8.1.2 Characteristics and structure of the study: a modelling approach

The pursued research objectives are decisive for the choice of the methods to be used. First, the complex system of interacting economies in a world market must be described. Second, at the national level, economy-wide models are needed to describe the agricultural and food sectors in their appropriate context. Third, the formulation of the intricate interrelationships between physical factors that determine agricultural production and the socio-economic factors that govern behaviour require an in-depth study.

Three main components, the main characteristics of the model structure that are considered in line with these objectives can be distinguished:

- the general structure, describing the interaction among country models
- the agricultural supply model
- the physical crop and livestock growth models.

The general structure

The international system – or linkage system – comprises a number of country models connected through the world market. The system contains all countries, some of them explicitly modelled, others aggregated to a 'rest of the world' group. It thus describes world trade. Linkage of models requires a set of stringent conditions and agreements to be followed in the formulation and development of each individual model. Each national model must distinguish four levels of analysis:

- an international market
- a national government and a national market
- classification of the population in producers and/or consumers of agricultural and non-agricultural commodities
- agronomic information at a subregional level.

The unique feature of this approach is that it attempts to model and analyse the mutual dependence between each and all of these levels (Figure 72).

The country model

In the national model, the government, the agricultural and the non-agricultural population groups are the main actors, i.e. the government and each of the socio-economic groups are decision makers and can act and react independently in the model. It is essential, therefore, that a country model describes realistically the behaviour of the actors and their reactions to a changing

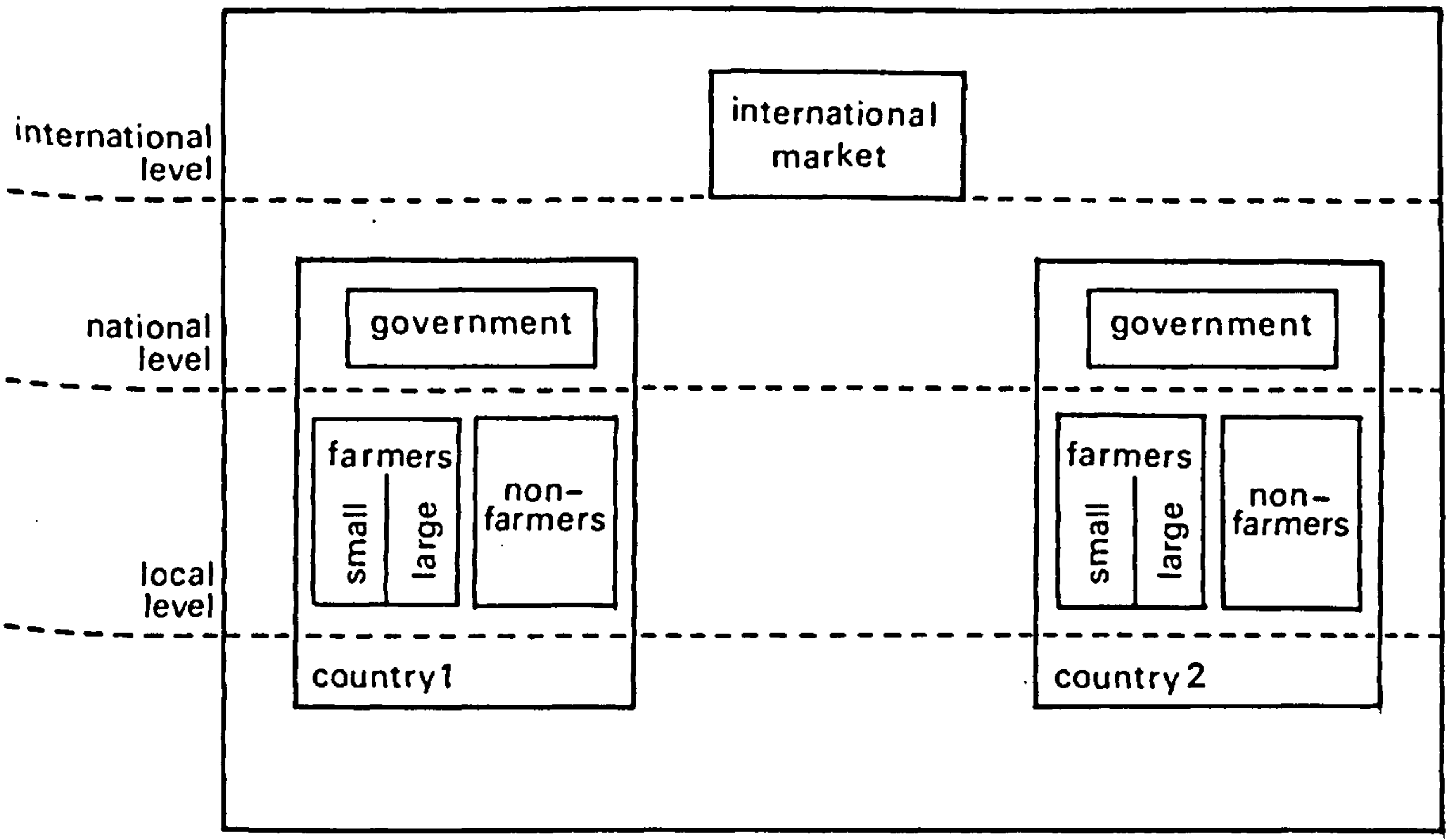

Figure 72. The international linkage system; actors in the economic model.

and fluctuating environment, and a pattern of relationships between the actors. A main feature of the national model is the role played by each actor – including the government – given his endowments (resource structure) and the constraints governing their use. Thus the government must use its instruments – taxes, tariffs, quotas, public investment – to influence the behaviour of the other actors to achieve pre-stated objectives, such as growth, stability and distribution. The production and consumption behaviour of the other actors is governed by the physical and economic environment to which they are exposed.

The agricultural supply model

Within the national model, the agricultural production model describes the farmer's behaviour that is relevant for the determination of agricultural output. Income maximization and/or satisfaction of subsistence requirements are pre-defined objectives and act, therefore, as driving forces in this model. The output of the crop growth model (the production of both marketable yield and crop residues of a given crop) and the necessary farm and non-farm inputs to achieve that yield on the specified land type are then transferred to the input file of a linear programming tableau. The linear programme* is an optimization technique used for maximizing revenues of the agricultural sector (over regions and farm sizes) subject to a number of physical and socio-economic constraints. Part of the information required for the LP tableau is

* See for instance R.R. Benneke & R. Winter (1973) for a popular description of the linear programming technique.

shown in Table 89 (this information and other exemplary material given in this subsection are derived from ongoing research to develop suitable socio-economic models for Bangladesh). The output of the linear programming model consists of the level of production, production pattern and input requirements, where the production pattern is determined by the relative prices, resource structure, agro-technical possibilities and the socio-economic environment.

Agricultural activities – i.e. feasible enterprises that can be undertaken by a farmer, for example the planting of a paddy crop in the *aman* season, is one activity, and the planting of a paddy crop in the *boro* season another – can be distinguished by type. The two main ones, closely interrelated in traditional agriculture, are crop and livestock production, to which processing of agricultural products and household activities can be added (trade, non-agricultural production, renting and hiring of production factors, etc.). Within the agricultural sector distinctions can be made between (agro-ecological) regions, farm sizes and applied technology level. For each region, each farm size and

Table 89. Example of output of the crop growth model and required farm and non-farm inputs for a specific crop on a specified land type under three types of management.

1310

R1/Aman paddy local /transplanted /start: 21/177 days
18 3

	C7IWL2 1306	C7IIWL2 1307	C7IIIWL2 1308
YLDPADDY1373	−1931.00000	−2006.00000	−5236.00000
PADSTRAW1374	−4754.00000	−4936.00000	−12678.00000
FERTEQVS1322	0.00000	16.00000	192.00000
FRTCPT011323	0.00000	1.00000	1.00000
FRTCPT021324	0.00000	0.00000	1.00000
FRTCPT031325	0.00000	0.00000	1.00000
WEEDCT011328	1.00000	1.00000	1.00000
WEEDCT031330	1.00000	1.00000	1.00000
DRAINCAP1369	0.00000	0.00000	0.00000
IRRCAPDS1371	0.00000	0.00000	0.00000
LODGPREV1372	0.00000	0.00000	1.00000
PDCTRCAP1346	0.00000	0.00000	1.00000
PRRCCT151361	1.00000	1.00000	1.00000
PRRCCT161362	1.00000	1.00000	1.00000
SGSDCAP 1306	1.00000	1.00000	1.00000
HCARCT171431	1.00000	1.00000	1.00000
HCWRCT171493	1931.00000	2006.00000	5236.00000
HCSRCT171555	4754.00000	4936.00000	12678.00000

Table 89. (continued)

1336

R1/Cotton	/sown/loc	var/start:	26/233 days
	C16IOL2	C16IIOL2	C16IIIL2
	1476	1477	1478
COTTSEED1394	−770.00000	−1015.00000	−3213.00000
COTSTALK1395	−3217.00000	−4241.00000	−13419.00000
YLDCOTTN1393	−415.00000	−547.00000	−1730.00000
FERTEQVS1322	0.00000	108.00000	451.00000
FRTCPT011323	0.00000	1.00000	1.00000
FRTCPT021324	0.00000	1.00000	1.00000
FRTCPT031325	0.00000	0.00000	1.00000
WEEDCT011328	1.00000	1.00000	1.00000
WEEDCT031330	1.00000	1.00000	1.00000
WEEDCT051332	1.00000	1.00000	1.00000
DRAINCAP1369	1.00000	1.00000	1.00000
PDCTRCAP1346	0.00000	1.00000	1.00000
CTSDCAP 1315	1.00000	1.00000	1.00000
THINCT021337	1.00000	1.00000	1.00000
THINCT041339	1.00000	1.00000	1.00000
HCACOT221460	1.00000	1.00000	1.00000
HCWCOT221522	415.00000	547.00000	1730.00000
HCSCOT221584	3217.00000	4241.00000	13419.00000

each level of technology a set of activities, as mentioned above, is constructed. Thus as the degree of detail increases, the number of activities within the agricultural supply model increases at an exponential rate. For example, two paddy growing activities (Aus – HYV and *aman* broadcast paddy) in two agro-ecological zones (Northwest and Sylhet), on small-owner operated and large-owner operated farms, with hand and animal traction technology under two levels of management (no fertilizer and 100 kg fertilizer per ha) would represent 32 individual activities in the model (2^n, $n = 5$). However, the many combinations may for the larger part be generated in a systematic way, as shown in the treatment of the physical crop-growth model.

The physical crop-growth model

In the physical crop-growth model, environmental characteristics such as soil type and climate are taken as points of departure for a step-wise calculation of possible outputs by crops (already outlined in previous chapters of this monograph). This, in combination with information on options for land development and production technologies, provides the basic information needed to model actual and potential agricultural production activities. The physical crop-growth model, providing the inputs used in the country model is characterized by the hierarchical structure as outlined in Chapters 1-4 of this monograph.The distinguished levels account for all physical factors that influence crop production and yields. The relationship between crop growth, nutrient uptake by the crop and nutrient application by the farmer is described in the fieldwork and management component and is accounted for, together with the other required farm inputs, in the supply model.

The type of information generated by the physical crop-growth model and the field work and management module is presented in Table 89. The heading of the first set of activities in the table indicates the region (R_1), the crop and variety (a local variety of *aman* paddy), the date the crop has to be transplanted (the 21st ten-day period) and the length of the growing period (177 days). The column codes, e.g. C7IWL2, indicate the crop species (C7), Activity Level (I) (i.e. lowest production level), water supply limited (W), and Land Unit (L2). The third column, C7IIIWL2, indicates Activity Level III, the highest production level, where production is only limited by radiation and temperature. In the second set of activities the same information is generated for cotton under optimal water conditions, as indicated by the O in the column headings, e.g. C16IOL2. The three columns give information on yields that can be obtained under specified conditions, indicated by a negative (−) sign on a hectare basis and on the required inputs per ha to achieve that yield, indicated by a positive sign. Most inputs assume the value 1, indicating that for that particular input the physical resources, such as man-hours of labour and a certain type of equipment are being requested from another data file called OPERAT for various levels of technology as specified in Section 6.1.

In this particular case, *aman* paddy will yield under the specified conditions 1931, 2006 and 5236 kg ha^{-1} of paddy and 4754, 4936 and 12678 kg ha^{-1} of paddy straw, respectively, if supplied with the specified required inputs, e.g.:

FERTEQVS 0.0000 16.0000 192.000

This means that at Activity Level I no fertilizer is required, while at Activity Level II and III 16.0 and 192.0 kg, respectively of pure N must be applied. The line

WEEDCF01 1.0 1.0 1.0

indicates that at all three activity levels weeding is required, where the coefficient (1.0) is a transfer coefficient calling for the appropriate technical coefficients of weeding 1 ha of *aman* paddy.

The livestock model

The farming systems in, for example, South and South-East Asia have been developed over a very long period in balance with the environment. Under the present circumstances, in which these regions are subject to a number of destabilizing influences such as, for example, high rates of population growth and economic recession, the sustainability of agriculture and, therefore, the environmental balance is being endangered. To be able to recommend better management options to redress this situation, the interrelationships that exist between the two sub-sectors of arable cropping and livestock and the socio-economic environment must be analyzed and, if possible, quantified because they are of considerable importance for the analysis of the problems and potentials of such farming systems.

Therefore livestock is modelled in close relation to the arable farming sector, both in terms of energy provided to cropping as draught power and manure and in terms of consumption of crop by-products, residues and waste. Moreover, grazing of range, forest and waste lands are considered in terms of area and yield (Figure 73). The livestock simulation model itself specifies the individual factors that determine feed intake and the conversion of feed into animal growth, production, and offspring. The model describes the individual animal as a system that converts energy into traction, weight gain, livestock products (milk, wool, meat), offspring or heat loss. These functional relationships provide an insight into the growth characteristics of an animal or herd and yield the estimated quantities of concentrate feed and roughage necessary to achieve the specified growth rates.

The type of data used in the supply model's linear programme consists of feed requirements for maintenance, growth, etc. for different types and age of

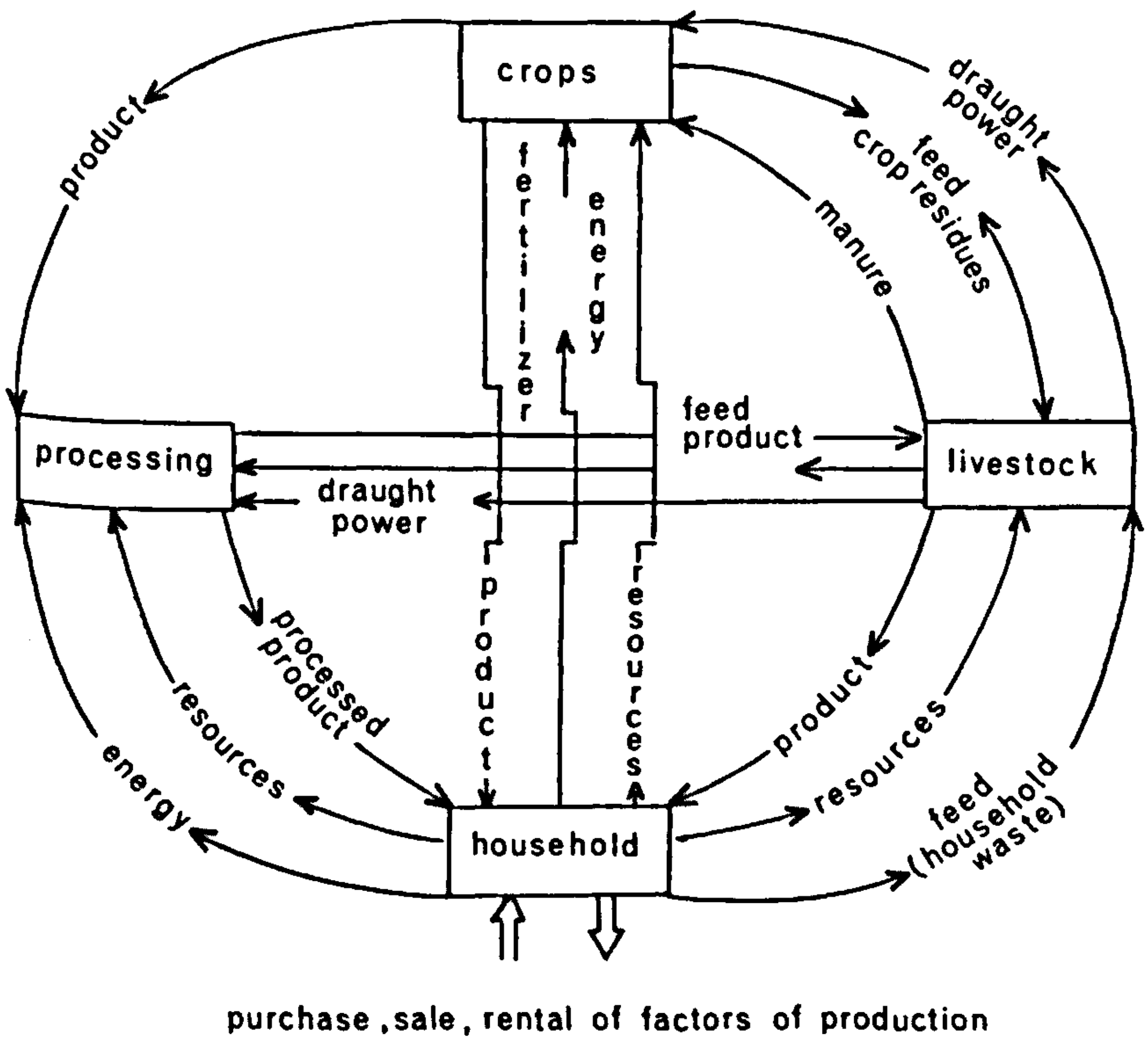

Figure 73. A schematic representation of interaction within the agricultural sector.

livestock. For example, Table 90 shows that the activity COWYMNGA – a young cow, male or female, on a maintenance and growth ration – requires COWYOUNG, i.e. one newborn animal, and will yield an animal one-year old of 55 kg. The FEEDDAYS indicate the number of days the animal needs to be kept on the indicated ration. DMINTAKE, CPINTAKE and MEINTAKE indicate the required dry matter (kg d^{-1}), digestable protein (g d^{-1}) and metabolizable energy (MJ d^{-1}) intake, respectively, on a daily basis. Finally, MANUREPR and NIMANURE indicate the daily manure production in kg of dry matter per day, and the pure nitrogen content in the produced daily manure in g d^{-1}.

The other activities, COWGMSGM, COWGMNGM, etc. define production and requirements for a growing animal (older than one year) that reaches mature weight at different rates of growth. COWGMSGM indicates slow growth of males (1870 days to reach mature weight) and COWGMNGM shows the requirements for normal growth of a male animal. The last activity refers to female animals. The energy and protein content of the various feeds and by-products, as well as waste, are also defined. These data are then linked with the feed availability for the domestic livestock. In this fashion the model will eventually find an equilibrium between the total required feed and roughage stock and the size of the livestock herd.

The integration of the crop and livestock model components into a comprehensive analytical system that is governed by the behavioural relationships of the farm households, is a unique characteristic of this modelling approach. Such a synthetic modelling approach that can subsequently be validated by field experiments, is particularly valuable as it permits quantitative description of alternative methods of crop and livestock production and enables the analysis of alternative and feasible farming systems. The integrated research on crop and livestock production in various farming systems under defined environmental and socio-economic conditions provides a basis for quantitative land evaluation, which obviously goes far beyond the pure agronomic or technical assessments undertaken elsewhere.

8.1.3 Farm energy

The agronomic modelling effort of the Centre attempts to describe a complex system of mutually dependent factors representing the agriculture and food sector. One important dependency, increasingly recognized today in agriculture, is the food-energy nexus. Current research at the Centre emphasizes the role played by traditional energy sources, such as manure, twigs, leaves and firewood, as well as that of alternative energy sources in the rural economy. There is no doubt that the food-energy relation is a significant consideration in the choice of farming systems and technology to be used in them.
Three energy functions can be distinguished:

– energy as agricultural input

Table 90. Activities for livestock growth in Bangladesh.

410
Feed requirements for Bangladesh cattle
9 5

		COWYMNGA	COWGMSGM	COWGMNGM	COWGMFGM	COWGMSGF
		450	451	452	453	454
COWYOUNG	430	1.00000	0.00000	0.00000	0.00000	0.00000
COWGROWG	431	−1.00000	1.00000	1.00000	1.00000	1.00000
COWADULT	432	0.00000	−1.00000	−1.00000	−1.00000	−1.00000
FEEDDAYS	500	365.00000	1870.00000	611.00000	266.00000	1661.00000
DMINTAKE	433	0.51000	3.61000	3.98000	4.74000	3.16000
CPINTAKE	434	27.60000	110.80000	151.20000	382.10000	98.10000
MEINTAKE	435	3.90000	22.63000	27.36000	40.79000	20.14000
MANUREPR	436	−0.26000	−1.99000	−1.99000	−1.90000	−1.74000
NIMANURE	437	−0.00290	−0.02190	−0.02190	−0.02090	−0.01910

– energy as agricultural output
– energy as domestic fuel.

Their integration in the agricultural modelling system permits a number of innovative analytical linkages. For example, the model can trace the effects of energy prices on production, income and the distribution of income in agriculture, or the implications of agricultural energy-extensive technology on energy and food supply. Furthermore, it can give insight into the production possibilities of 'green' energy, as embodied in wood, biogas and alcohol, and into the effects of relative energy scarcity on the productivity of land and livestock.

8.1.4 The socio-economic factors

The socio-economic factors that play such an important role in the process of resource allocation to various production activities, and in achieving income-maximization, are pervasive throughout the agricultural and rural development process. Land tenure and ownership patterns, farm size, family size, allocation of labour within the family, custom and religious factors, on-farm and off-farm employment opportunities, migration and market and credit facilities are all factors that must be accounted for when estimating and analyzing alternative production possibilities. Thus the socio-economic factors govern and constrain to a large extent the actual agricultural production process. The economic analyses based on these alternatives are necessary to supply sufficient knowledge and information to the government as a basis for its decisions to implement certain policies. Hence the rigorous use of quantitative models and methods can accomplish two things: increased insight in the planning situation and a qualitative improvement of decision making on the basis of existing knowledge.

8.1.5 Regional planning

Planning takes many forms and may serve a multitude of purposes and objectives. It comes about because national leaders are convinced that only part of the government's objectives will be realized if left to the forces of the free market and private enterprise. Regional planning may take place because a government pursues a balanced growth within or among regions. Therefore, regional development plans are formulated because a particular region is considered to have physical or socio-economic development potential, or because that region is poorly endowed physically and therefore lags behind in development relative to other regions. Planning models thus make it possible to analyse certain development opportunities through improved existing technologies or existing technologies, that are unused in the region, or completely new technologies derived from experiment stations. Thus the effect of introducing new technologies on, for example, regional income and employment can be estimated.

Development plans must thus describe the actual situation and formulate alternative courses of action that may lead to alternative development paths. To successfully plan and to be useful for decision making the information supplied must be of relevance to the planning situation of the policy makers and must relate to the instruments that the policy maker is able to apply. For example, if the government wants to increase food production it does not have the tools to physically force farmers to increase agricultural production (at least in market economies), but it can manipulate relative prices of agricultural commodities, or it may subsidize fertilizers or other inputs, or invest in land improvement or infrastructural works and thus stimulate agricultural production. The model should then be able to indicate which of these measures would be more effective in terms of satisfying or meeting the government's objectives. In another situation, if the government wants to increase government revenue by raising direct taxes, it might want to know whether such a measure would adversely affect the poor groups more than the higher-income groups; in other words, would it skew the income distribution in the right direction? Would such a measure affect the terms of trade of agriculture? Planning models must be able to accomodate such questions to be of use to decision makers.

8.1.6 International trade and aid

As C.T. de Wit stated in his introduction to this monograph, the food problem is not only a local or national problem, it is a problem with international political and economic dimensions, because food deficits and hunger do not stop at borders but transcend national boundaries in such forms as food aid and capital flows to achieve a more equal distribution of income between and within countries*.

One of the important features of the modelling exercise presented here is that all such country models can be linked to an international linkage system. The output of that system lends itself for an evaluation and analysis of trade policies. In particular it allows an analysis of the effects of international trade (and commodity) agreements and their impact on trade and balance of payments of developing countries and, even more importantly, on the income distribution effects within developing countries.

At the national level one can analyse the effects of international trade

* An alternative view would be that food aid and capital transfers to chronically food deficient countries are the other side of the same coin, namely international migration of labour to eventually achieve an optimal international division of labour. In other words, development aid can be seen to be some sort of pay-off to keep people within their boundaries.

measures and the resulting costs on developing countries. Thus, modelling the economies of individual countries, where each individual country model has been supplied with the policy instruments that each particular government has at its disposal, has the advantage that the system permits analysis of the effects of one country's or a group of countries economic policies on other countries, and vice versa. Thus, capital flows to developing countries resulting from a negative balance of payment add to the resources for development. The model then can be used to analyse the effects of alternative levels, compositions and allocations of these flows. Upon completion of the linkage system (with all its satellite models), the results may indicate those countries that can be expected to have continued food deficits and those population groups that may continue to be subject to hunger and malnutrition. The advantage of this modelling system over a more fragmented modelling approach is that the effects of any set of policies, both through international agreements and emanating from individual countries, can be analyzed.

8.1.7 Summary

The present national model may be used as a tool for analyzing the food situation and for determining policies conducive to combat hunger. Because national model building is done in close cooperation with local researchers and government institutions, the model should be suitable for transfer to local institutions. The presentation of the methodology in this monograph is an example of the way in which the models can be transferred. One of the Centre's objectives is to make its models fully available to the government of the country in question for use as a tool to make its own policy analyses. Policy analysis with the help of the model does provide government decision makers with a number of choices focussing on increasing food production and the implied growth of income and purchasing power of the lowest income groups. For any developing country such information is of crucial importance. For foreign donors it may also provide guidance in cases where they want to channel more of their resources to rural development and in particular to the basic needs of the lowest income groups.