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A COMPUTERIZED INFORMATION SYSTEM FOR AGRICULTURAL SECTOR*

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I

NEED FOR A COMPUTERIZED INFORMATION SYSTEM

The agricultural sector is the most important sector in India's economy as nearly 45 per cent of the GNP originates in this sector. Though it is a very traditional sector, it has now become a sector in which technological progress in production techniques has become very rapid. More or less a continuous flow of new technology is coming out of the research and experimental stations. For getting the best results, information on this new technology and its implications for production decisions and general agricultural policy should be made available to the concerned people as soon as possible.

Very few countries have been able to manage and develop the agricultural sector satisfactorily. This is due to a number of reasons. Firstly, conventional economic theories of development and planning concentrate largely on the industrial sector. Not much thought is given by academic economists to developing techniques of planning and managing the agricultural sector.

Secondly, the agricultural sector has a very large number of producers each with his own production possibility which is affected by the soil types, irrigation availability, and knowledge of the available technology with reference to seeds, fertilizer, pesticides, etc. Moreover, different crops can be grown from the same land. Any satisfactory consideration of this variability requires analysis of vast amount of data.

Thirdly, in many developing countries as in India the bulk of agriculture is dependent on weather (monsoon), variations in which affect significantly the production of foodgrains. The monsoon does not seem to follow any predictable pattern—at least not one which can be discerned from 50-100 years' data. It becomes necessary to resort to a more extensive analysis to bring into consideration the effects of unpredictable monsoon in policy-making.

All these involve vast amount of data, and data which have to be updated frequently. A large computerized information system is a necessary

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pre-requisite before any satisfactory analysis can be made to manage the agricultural sector in a country such as India.

A computerized system is vital for yet another set of reasons. The data required for a successful management of the sector are collected by many different organizations. For example, the data on climate, rain and moisture availability and need are collected by the meteorological department. The data on areas devoted to different crops are collected by the Ministry of Agriculture. Information on yield response of different crops to the availability of water in different periods of crop season is likely to be available with the Indian Council of Agricultural Research (ICAR). But the irrigation systems are operated by the irrigation department. Most often this is done without the benefit of the data available with other organizations. Optimal irrigation releases can make significant difference to agricultural production. In determining optimal irrigation releases, the data on all the above are required. A large central computerized information system can provide the data from many sources to the various operating agencies. However, not only such data are required, but they are required in time so that irrigation releases can be changed in response to changing cropping pattern and the unfolding behaviour of the monsoon. Such a responsive system can be made to work only in the context of a central computerized information system. At present in the operations of many irrigation systems the pattern of releases are based on cropping pattern which prevailed in the command area some years ago. This leads to grave inefficiencies in the use of irrigation water, as under the impact of new varieties the cropping pattern changes substantially from year to year.

Timely processing of large amount of data is also essential for improving the reliability of forecasts and hence policy which in real world has to be based on forecasts of coming events.

For example, in 1974, it was predicted by the meteorological department that the monsoon will be delayed by two weeks. The various State Governments were warned and asked to take corrective actions, either to release more water from irrigation reservoirs during the normal sowing period, or to be ready for a second planting or to sow a different variety which can be sown late in the season.

Even in the analysis of past data, where timeliness may not be crucial, the need to bring all data at a common place accessible to all is great. Today we have vast amount of data, collected at enormous expenditure, lying unprocessed or partially processed. These data would become even more valuable when processed together with the data collected by different organizations.

For example, the climatological data from the meteorological department can be used along with the experimental data collected under various programmes of the ICAR to estimate production functions with climatic factors as explanatory variables along with seed variety, fertilizer dosages, etc. Similarly, the forecasts of agricultural production being attempted solely on climatological data by the meteorological department can be improved by using the yield production functions estimated from the various experiments.

As yet another example which can be cited is the question of evolving cropping patterns for arid zones. Based on climatological data one can build up a profile of expected soil moisture availability for a given zone. This information can be used along with the production functions estimated from the ICAR experiments to select optimum cropping patterns for the zone.

Both the Institute of Agricultural Research Statistics (IARS) and the Indian Meteorological Department (IMD) plan to get computer systems of their own. These systems, however, will be fully employed in routine bulk data processing. It is thus necessary to establish a higher order computer centre to integrate the data coming from these and other organizations for effectively aiding policy in the agricultural sector. In fact, without such a central computerized system and the analysis that is made possible by it, full and effective use of the information generated by the IARS and IMD computer systems would not be possible. An integrated wholistic view of agricultural planning would become possible only if such a system is established and made operational.

In fact, but for these computers and the small computers that are being planned by some State Governments, it would be a near impossible task to build up the data base for a computerized information and management system. For then, the vast amount of data gathered by many primary agencies all over the country would not be available in machine readable form. To make these data machine readable would be an impossible task for a single organization without unlimited resources.

The purpose of this paper is to outline an up-to-date information system, and to show what can be done in this area with the help of such a system. We first identify the users of such a system and the objectives of agricultural policy and the decisions that various actors have to take in this sector. Next, we outline the various analytical frameworks relevant for taking these decisions. We will then survey the data sources, the channels and frequency of flow of data. Finally, we will identify the various analyses that may be performed and decisions that may be taken better at different stages in the development of the system with available data and as data availability improves in the future. Finally, we determine the computing power required for the system.

II

THE USERS OF THE AGRICULTURAL INFORMATION SYSTEM

The Ministry of Agriculture is in overall charge of the agricultural sector. However, the Planning Commission and the Ministry of Finance are involved in determining the size of its various programmes. The irrigation systems which were till recently managed by the Ministry of Irrigation and Power are now under the control of the Ministry of Agriculture. Under the Constitution, agriculture is a State subject and the programmes are administered by the State Governments. Important policy decisions have to be taken in consultation with the State Governments. For example, the fixing of the procurement support prices of agricultural commodities is a very important annual issue between the Central Government and the State Governments.

The performance of agriculture affects the operations of other ministries of the Government. The public food distribution system and other relief measures have to be operated by the Ministry of Civil Supplies. The extent of required imports of agricultural commodities affect foreign exchange budget and the national budget itself is affected by agricultural output.

The proposed agricultural information system would be used by these various ministries of the Government of India. In the absence of such a system these decisions are, at present, based on the work of many inter-ministerial committees, and special study commissions. These groups have experts in the various areas and their judgement and expertise are brought to bear on the work of the committees. At this level the computerized information system can very effectively help in quantitative decision-making and improve government policy in agriculture and areas affected by it.

On the other hand, the role that such a system can play at the farmer's level is also very large and by itself can justify such a system.

The farmers in India have tasted the fruits of the new technology of agriculture. They are now keen to adopt newer technologies almost as fast as they come out of the research stations. The extent to which farmers in India have adopted the new technology can be seen from Table I which shows the growth in the use of fertilizers, and High-Yielding Varieties (HYV).

The figures in Table I do not fully reflect the farmers' willingness to adopt the new technology as there are substantial excess demands for fertilizers and improved seeds. In spite of the recent doubling of fertilizer prices, there is still a black market of fertilizers and a premium of 100 per cent or more is demanded and paid.

TABLE I—AREA UNDER HYV AND USE OF FERTILIZERS

Year	Area under HYV ('000 hectares)		Fertilizers distributed ('000 tonnes) ($N+P_2O_5+K_2O$)
	Paddy	Wheat	
1961-62	—	—	383
1962-63	—	—	478
1963-64	—	—	574
1964-65	—	—	653
1965-66	—	—	757
1966-67	888	541	1,203
1967-68	1,784	2,958	1,739
1968-69	2,628	4,793	1,750
1969-70	4,519	6,100	1,407
1970-71	5,588	6,480	1,814
1971-72	—	—	2,382
1972-73	—	—	2,589
1978-79 (target)	16,500	15,000	8,000

A computerized system which can provide to the cultivators up-to-date data in a form in which they can understand them and use them for taking rational decisions can at this stage prove to be of enormous value in solving India's food problem at minimal cost.

III

OBJECTIVES OF AGRICULTURAL POLICY

Stated very broadly, the objective of agricultural policy is to assure adequate availability of agricultural products at reasonable stable prices. These prices should be high enough to be remunerative to the farmers and low enough to be acceptable to the consumers. To ensure stability in the context of uncertain weather, buffer stock operations have to be carried out. Since carrying buffer stocks is expensive, an optimum policy has to be designed.

To provide adequate food for the increasing population means to increase the productivity of land by promoting efficient practices and spreading the knowledge of new possibilities. A whole range of options are available for this: Increase irrigation; increase the use of fertilizers (chemical or organic) and pesticides; use different varieties of seeds, etc. With limited resources, these and other inputs must be optimally used and policies have to be devised to promote optimal uses.

Similarly, with limited water resources, a better management of available irrigation systems can substantially affect output. With a given quantity of irrigation water, which crop to irrigate, when to irrigate and with how much water, are important questions.

Apart from increasing the productivity of agriculture, a proper distribution of income generation in the agricultural sector is also desirable. Agricultural development should not lead to increasing inequality in the rural economy.

On the other hand, from the farmer's point of view, what crop to grow, what variety to select, how much inputs to put in, and when to sell the output, are the crucial questions. These are affected by his expectations of prices, his knowledge of technology, his resources and the weather. In all this, the farmer's main objective is to maximize his expected profits.

IV

ISSUES IN AGRICULTURAL POLICY

The issues in agricultural policy can be classified into two groups as decisions by cultivators and decisions of policy-makers.

1. Decisions by Cultivators

Specifically the following decisions on agricultural operations are of importance:

(*a*) What crop and variety to sow in what areas?
(*b*) What should be the level of inputs?
  —Fertilizers
  —Water
  —Pesticides
(*c*) When should the inputs be applied?
(*d*) What other cultural practices are of importance?
  —Timing
  —Spacing, seed rate
  —Soil treatment, etc.
(*e*) When to sell the output?
(*f*) What type of animals to keep? How many of each type to keep?
(*g*) What to feed the animals?
(*h*) Should one go in for poultry keeping?
What should be the level of operation?

2. *Decisions of Policy-Makers*

(*a*) Short-Term Management

(*i*) Estimate output to help in budget making.
(*ii*) Estimate import needs and if necessary, provide for in foreign exchange budget.
(*iii*) Determine advance action required in setting up public distribution system and fixing procurement targets.
(*iv*) How much buffer stock to be carried over to next year?
(*v*) Support prices to be announced.
(*vi*) Prices of inputs such as fertilizers to be fixed.
(*vii*) If necessary, inputs to be imported in time.
(*viii*) Identify drought areas, to take relief measures in time.
(*ix*) Determine policy for operating irrigation systems. What is the trade-off between irrigation and power generation? How much water to release? When, to which crop? Modification in the policy in the light of actual rainfall and inflows.
(*x*) Detect in time incidence of pests and diseases so that control measures are taken in time.

(*b*) Medium-Term Policy

(*i*) Set targets of food availability to meet nutritional needs.
(*ii*) Determine optimal cropping pattern for irrigated, rainfed and arid zones.
(*iii*) Set targets for area under High-Yielding Varieties.
(*iv*) Increase potential for production through efficient use of fertilizers, irrigation, etc.
(*v*) Determine optimal allocation of fertilizers to different crops and agro-climatic zones.
(*vi*) Determine optimal allocation of irrigation resources to different crops.
(*vii*) Determine priority areas for extension work.

(*c*) Long-Term Policies

(*i*) Set targets for irrigation development to insure against droughts.
(*ii*) Set priorities for development of irrigation systems.
(*iii*) Design irrigation system—what is the irrigation intensity? Storage capacity? How to mitigate the effects of floods?
(*iv*) Set targets for availability of fertilizer.
(*v*) What should be the policy towards mechanization? Is it land augmenting?
(*vi*) Are there economies of scale in agriculture? What should be the size of a family's holding?

(*vii*) Set research priorities—what new seeds to be developed for which crop and which zone and with what characteristics?

(*viii*) What measures to take to preserve or improve general long-term productivity of the system.

In order to take these decisions rationally research involving large amount of data processing is required in many areas. Some of the important areas are listed below.

3. *Useful Research for Decision-Making*

(*a*) *Research in the Technology of Agriculture and Animal Husbandry*

(*i*) Estimate production function of different crop varieties in different agro-climatic regions when independent variables are fertilizers, and/or water and climatic variations.

(*ii*) Identify optimum techniques to irrigate, fertilize, sow, etc. (Mechanization or not?)

(*iii*) Develop improved breed of animals. Maintain data bank of yield performances of progeny.

(*iv*) Estimate production functions in animal husbandry. What feeds give best results for which breed?

(*b*) *Ecological Considerations*

(*i*) What practices are good for soil-fertility maintenance?

(*ii*) Bio-system studies to identify measures to preserve them for all users.

(*iii*) Toxicity of chemicals—what pesticides, weedicides and other agro-chemicals are acceptable.

(*iv*) Toxic residues in food and the long-term acceptability of chemicals.

(*c*) *Climate and Weather Fluctuations*

(*i*) Can one forecast yields and output from climatological data?

(*ii*) What is the expected date of arrival of monsoon in different parts of the country? Or what is the expected date of having enough moisture in the soil to begin sowing?

(*iii*) What is the variability of rainfall and climate? What is the expected soil moisture availability over the year? What is a suitable crop cycle for the area?

(*iv*) What is the relationship, if any, between the occurrence of diseases and pests and climate?

The above list is not exhaustive. Moreover, many questions are overlapping and repetitive. Yet these have been separately listed to emphasize to a large number of people the usefulness and need for an information system.

People from different disciplines might view a problem from different perspectives. Nonetheless, the basic theoretical framework for analysis can be common to most of these questions. We now turn to analytical frameworks appropriate for decision-making in the agricultural sector.

V

ANALYTICAL FRAMEWORK FOR POLICY-MAKING

1. Analytical Framework for Farmers' Decisions

In developing the analytical framework for farmers' decisions, we assume that farmers are rational and act in such a way as to maximize expected profits as perceived by them. Because of uncertainties of weather, effectiveness of new technology, etc., and their different endowments of resources, different farmers behave differently. Yet within their constraints they maximize their profits.

For rational decisions at the farm level one needs to know the following:

(*a*) Technological production functions which relate expected yield for his soil and climate to the levels of various inputs.
(*b*) The prices and costs involved in using various inputs.
(*c*) The expected price of various produce.

Thus if proper input and output prices are fixed in advance, a farmer can
(*a*) Allocate his land to different crops, and
(*b*) Decide on the levels of application of different inputs.

Formally, the farmer's decision problem is a non-linear programming problem as described below:

Maximize profit,

$$\sum_{i=1}^{C} \left\{ P_i a_i y_i - c_i(a_i, y_i) \right\}$$

where P_i = price of output i,

a_i = area devoted to crop i,

y_i = yield of crop i (output per unit land),

e_i = cost of cultivating crop i on area a_i to obtain yield y_i,

C = number of crops which can be grown on that land (different variety to be considered as a different crop).

Subject to the constraints:

(*a*) Area Constraint

$$\sum_{i=1}^{C} a_i \leq A$$

Area devoted to crops cannot exceed total land area available with him, A.

(*b*) Production Functions

$$y_i = y_i (N_i, P_i, K_i, w_i^1, w_i^2, \ldots . w_i, R^1, R^2, R^J,$$

$$PET^1, PET^2 \ldots .. PET^3, PEST_i)$$

where N_i, P_i, K_i are fertilizers applied per unit area to crop i,

$PEST_i$ is the pesticide applied to crop i,

w_i^1, w_i^2,. . . . , w_i^J are water applied in periods 1, 2, . . . J of the i crop's life cycle.

R^1, R^2 , . . ., R^J are the expected rainfalls over the periods, 1, 2,. . . , J.

PET^1 ,. . ., PET^J are potential evapotranspiration over these periods.

(*c*) Cost Functions

$$c_i = c_i (a_i , y_i)$$

(*d*) Water Availability Constraints

$$\sum_{i=1}^{C} W_i^j \leq T^j \qquad j = 1, \ldots , J$$

where T^j is the water available in period j from either tubewells or run-off the river schemes, or planned irrigation releases.

(*e*) Fertilizer Availability

$$\sum_{i=1}^{C} F_i \leq \bar{F}$$

If fertilizers are scarce and a rationing system is followed, such constraints may be required. This also applies to other inputs.

In the above the policy variables which can be controlled by the central authority are prices of inputs and outputs and the irrigation releases planned.

The technological information is embodied in the production function y_i's, and the cost function c_i's.

The production functions, y_i's, have to be estimated based on experimental data. For examples of these, see Parikh, *et. al*[1] and Minhas, Parikh and Srinivasan.[2]

Similarly, the cost functions have to be estimated on the basis of farm management surveys. Cost is a function of the levels of various inputs. Either a detailed cost function can be introduced and levels of these inputs determined in the solution, or as a second best solution, the cost functions can be pre-processed to give a summary cost as a function of only area and desired yield as used above.

It should, however, be realized that these production and cost functions have to be estimated separately for each soil and climatic regions. The fineness of this classification can be improved over time when more data become available.

The above is a simplified model which neglects the problems of uncertainty of yield performance, of rainfall, of climate and of prices of output. A dynamic programming model can be constructed to take into account these variabilities. However, the data available for estimating the various frequency distributions are not likely to be available for some time. Thus the above framework or even a still simpler model can be used in the early stages.

2. *Decisions of Policy-Makers*

How such an analytical framework can be used to take important decisions in the management of the agricultural sector is described in Minhas's article.[3] Briefly his scheme is as follows:

(*a*) Determine normatively a requirement vector of agricultural products.
(*b*) Fix a set of input and output prices.
(*c*) Solve the above model for all the different agro-climatic zones.
(*d*) Compare the resulting output with the normatively determined requirements.
(*e*) Adjust prices and iterate through steps 2 and 5 till a consistent solution is obtained. This gives a set of output and input prices which produces the desired output.

1. K. S. Parikh, T. N. Srinivasan and Others: Optimal Requirements of Fertilizers for the Fifth Plan Period, Indian Statistical Institute, Planning Unit, New Delhi, 1974.
2. B. S. Minhas, K. S. Parikh and T. N. Srinivasan, "Towards the Structure of a Production Function for Wheat Yields with Dated Inputs of Irrigation Water," *Water Resources Research,* Vol. 10, No. 3, June, 1974.
3. B. S. Minhas, "Growth with Stability: A Framework for Agricultural Planning," *Economic and Political Weekly,* Vol. III, Nos. 26-28, Special Number, July, 1968.

The same basic model can be modified to determine 'optimal' allocation of scarce inputs such as fertilizers. As an example, see Parikh, *et. al.*[4] It can also be used to project agricultural potentials for a distant future to identify the need and importance of various technical changes.[5]

3. *Analytical Framework for Water Management*

In order to study the question of economically optimal use of water, we need to know the responses to different quantities of water used by the crop throughout its growth cycle. For instance, consider a large reservoir system. The problems of scheduling of the operations of the system include decisions on timing of water releases and the allocation of water among crops. The later decision is also relevant for the operation of tubewells or run-off the river irrigation systems. Unless one has the knowledge of the marginal productivity of water allocated to each crop at different stages of its growth, one cannot arrive at an optimal set of decisions. This knowledge is also required in determining the extent of the command area of an irrigation system. A production function for each crop in which yield is related to dated inputs of water will provide such knowledge.

(*a*) Suppose the reservoir has a given amount of water per hectare, W. Assume also that only one crop is grown. We want to maximize the production

$$Y = Y(W^1, W^2, \ldots, W^J)$$

where Y is yield per hectare, and

$W^1, W^2, \ldots, W^J$ are water releases in the 1st, 2nd,. . . Jth period:

Subject to the constraint that

$$W^1 + W^2 + \ldots + W^J \leq W$$

The conditions for optimality are

$$\frac{\partial Y}{\partial W^1} = \frac{\partial Y}{\partial W^2} = \ldots = \frac{\partial Y}{\partial W^J}$$

In order to solve this problem we need to know the production function Y. On how to estimate Y, see Minhas, Parikh and Srinivasan.[6]

(*b*) Suppose we have a limited amount of water available in period j, I^J, and that crops 1, 2, . . ., C are grown in areas $a_1, a_2, \ldots, a_C$.

4. *op. cit.*
5. K. S. Parikh, "India in 2001," Paper presented at the International Economic Association Conference on Economic Aspects of Population Growth, Velascure, France, September, 1973.
6. *op. cit.*

We want to maximize the value of output:

$$V = \sum_{=1}^{C} P_i . \, a_i . \, y_i \, (W_i^1, W_i^2, \, , \ldots , \, W_i^J)$$

Subject to

$$\sum_{i=1}^{C} W_i^j \, a_i \leq I \quad j = 1, \ldots, J$$

The conditions for optimal allocation of water across crops and over time are as follows:

$$P_1 \frac{\partial Y_1}{\partial W_1^j} = P_2 \frac{\partial Y_2}{\partial W_2^j} = P_c \frac{\partial Y_C}{\partial W_C^j} \quad j = 1, 2, \ldots J$$

Again knowledge of the production function Y_i is essential.

(*c*) A problem which is a combination of the problems (*a*) and (*b*) above. Though the algebra gets involved the essential approach is the same. Once again knowledge of the production function Y_i is essential.

(*d*) Consider the problem where water in the reservoir is W_j and inflows of the remaining seasons are $I^1, I^2, \ldots, I^J$ with their probability distributions $p^1(I^1), p^2(I^2) \ldots$ given. The cropping pattern in the command area is $a_1, a_2, \ldots a_C$ (area devoted to crops 1, 2,.... C). Also the water releases from the reservoir generate power and the variations in the requirement of power over the year do not in general coincide with the variations in the need for irrigation releases. Thus, to some extent more irrigation means less power and vice versa. In scheduling the operation of such multipurpose system it is necessary to decide:

(*i*) schedule of irrigation releases and power generation, and

(*ii*) the year-end dead storage level.

For a detailed treatment of this set of problems and a case study of the Bhakra System, see Minhas, *et. al.*[7]

(*e*) In the above problems we have neglected the essential stochastic nature of moisture availability and requirements. A dynamic programming framework is required to satisfactorily take these into account. We now describe such a model.

7. B. S. Minhas, K. S. Parikh and T. N. Srinivasan, with S. A. Marglin and T. E. Weisskopf: Studies in the Operation of the Bhakra System, Statistical Publishing Society, Calcutta, 1972.

Suppose: We have a reservoir with water RW^i in period i. The inflows are I^i with probability distributions $p^i(I^i)$. The PET's are PET^i with probability distribution $p^i(PET^i)$. The areas devoted to different crops are $a_1, a_2, \ldots, a_c \ldots a_C$ and their yield responses are $Y_c\,(AET^i, PET^i)$.

State variables are the soil moistures in different plots, $SM_1^i, \ldots, SM_C^i$;

Crop yield indexes to reflect history till now, $YC_1^i, \ldots YC_C^i$; and water in reservoir, RW^i.

Policy variables are $W_1^i, \ldots, W_C^i$, the irrigation water releases for each crop in period i.

The value at the beginning of period i of all standing crops, reservoir level and soil moistures is given by a function V^i.

$$V^i\,(SM_1^i \ldots SM_C^i,\ a_1YC_1^i \ldots a_cYC_C^i \ldots a_cYC_C^i,\ RW^i)$$

$$= \underset{W_1^i \ldots W_C^i}{\text{Max}} \left\{ E \sum_{c=1}^{C} (V_c^i\,(YC_c^i, AET_c^i\,(W_c^i) + V^{i-1}\,(YC_c^{i-1}, AET_c^{i-1}\,(W_c^{i-1})\,)\right\}$$

where E is the expectation operator and V_c^i is the gains function in the value of crop c due to irrigation operations in period i. The various relationships are as follows:

(*a*) $SM_c^{i+1} = SM_c^i - E(AET^i) + E(R_c^i) + W_c^i$

(*b*) $AET_c^i = f_c\,(SM_c^i,\ PET_i)$

(*c*) $YC_c^i = E\,Y_c^i\,(AET_c^i \ldots AET_c^n,\ PET^1, \ldots PET^n)$

where $AET_c^i \ldots AET_c^n$ are set to their optimum levels depending upon $PET^i, \ldots PET^n$ which are stochastic variables and

$AET_c^1 \ldots AET_c^{i-1}$ and $PET^i \ldots PET^{i-1}$ are known.

(*d*) $RW^{i+1} = RW^i + E\left\{ [\,(I^i) - \sum_{c=1}^{C} a_c W_c^i]/A\,(RW^i) \right\} - PET^i$

where A (RW^i) is the area of reservoir as a function of water in the reservoir.

This is a formidable problem and even then it is not the most general one as the areas devoted to different crops are not considered policy variables as in fact, they are. To actually carry out computation for such a model requires collection and pre-processing of large amount of data. However, one need not start with such a super model. Simplified partial models such as those described above can be used meanwhile. For a description of stochastic partial models of water management, see the series of articles by Dudley, *et. al*[8] and the article by Hall and Butcher.[9] In fact, in the first stage one would use such partial models, and as more data become available, let the system evolve and grow to the model described above or beyond that to more complex ones such as would determine area allocations internally.

VI

DATA REQUIREMENT AND AVAILABILITY*

As is obvious, large amount of data are required. These may be grouped under the following broad headings:

(*a*) Actual area, yield, production.
(*b*) Soil type and characteristics.
(*c*) Acceptance of improved practices.
(*d*) Various agronomic experiments for input-output relationship.
(*e*) Costs of cultivation, investments and credits.
(*f*) Prices of output.
(*g*) Income, consumption and nutrition.
(*h*) Animal husbandry, fishery and forestry.
(*i*) Climatological data.
(*j*) Irrigation availability by schemes—canals and command area details.
(*k*) River inflow data.
(*l*) Water tables.

All these data are required for as long a time-series as possible for building up expectation functions and frequency distributions.

Vast amount of data are collected in India. Moreover, the data for many years are available. We now examine in detail the present availability of data and the form in which these are available as well as the volume and frequency of collection. We will also consider the limitations of these data.

8. (*i*) N. J. Dudley, D. T. Howell and W. F. Musgrave, "Optimal Intraseasonal Irrigation Water Allocation," *Water Resources Research*, Vol. 7, No. 4, August, 1971, pp. 770-788; (*ii*) N. J. Dudley, D. T. Howell and W. F. Musgrave, "Choosing Optimal Acreages Within a Season," *Water Resources Research*, Vol. 7, No. 5, October, 1971, pp. 1051-1063; (*iii*) N. J. Dudley, W. F. Musgrave and D. T. Howell, "The Best Size of Irrigation Area for a Reservoir," *Water Resources Research*, Vol. 8, No. 1, February, 1972, pp. 7-17; and (*iv*) N. J. Dudley, "Optimal Intraseasonal Water Allocations," *Water Resources Research*, Vol. 8, No. 3, June, 1972, pp. 586-593.

9. W. A. Hall and W. S. Butcher, "Optimal Timing of Irrigation," *Journal of the Irrigation and Drainage Division, American Society of Civil Engineers*, Vol. 94, No. 2, 1968, pp. 267-275.

* This section is prepared with the help of the members of the project team, and especially with the help of Dr. Yayathi.

1. Crop Area Statistics

Practically 93 per cent of the country's geographical area, excepting the hilly and inaccessible areas and the occupied area of Jammu & Kashmir, are covered by some reporting agency or other. The data on area devoted to various crops are collected every season by complete enumeration of all plots in every village excepting for the States of West Bengal, Orissa and Kerala where the data are collected on the basis of a random sample.

These data are available for more than last 20 years. Districtwise data are published and can easily be put on punched cards. (One year's data would require about 1,000 cards.) Villagewise data are available at the tehsil headquarters and tehsilwise data are available at the district headquarters. These may also be easily obtained and transferred on the punched cards (four cards per village per year). Plotwise data are available at the village level and would be voluminous. If and when these data are computerized, they can provide scope for a variety of studies at the micro level which would be extremely useful for their implications for welfare-oriented policies.

The data on area under different crops for the current season are also available soon after sowing is completed under the Timely Reporting System (TRS) on a sample basis (one out of every five villages). Thus the data on area can be kept almost up-to-date making it possible to analyse issues of short-term policy.

The data on area and production of plantation crops like coffee, tea, rubber, cardamom, etc., are available in very great detail in the records of the Boards which control the cultivation of these crops. The data recorded annually are available for individual cultivators.

2. Yield and Production Statistics

The estimates of yield and production are based on crop-cutting experiments. At present about 1,50,000 crop-cutting experiments are conducted annually on food and non-food crops. Along with the data on yield auxiliary information is also collected in these experiments. These data on yields can be readily computerized and the system be made up-to-date. The data from past crop-cutting experiments are available for almost 20 years. One year's data would require 0.6 million cards.

In addition, as a part of its study on the impact of HYVs, the IARS conducts around 20,000 crop-cutting experiments a year over 80 selected districts. In this programme information on other cultural practices is also collected. It has been going on for the last four years and these data are already on nearly one million punched cards.

10. There are roughly 350 districts and 3,500 tehsils in the country.

3. *Soil Resources Data*

The all-India soil survey and various co-ordinated schemes for studies on soil salinity, irrigation, drainage, soil science and water management collect large volume of information on soil data. A large number of soil testing centres distributed throughout the country analyse more than 11,00,000 soil samples each year under the soil test crop response studies. About 2,00,000 soil samples are collected each year under the All-India Soil Survey Scheme.

4. *Improved Seeds, Use of Fertilizers and Other Improved Practices*

The data collected in periodic sample surveys do provide some information on these aspects. However, more reliable and comprehensive schemes to collect these data have recently been taken up. In addition to the IARS Scheme on Impact of HYVs mentioned above, the National Sample Survey Organisation (NSSO) canvasses 30,000 fields a year as a part of the Scheme to Improve Agricultural Statistics (IAS Scheme). Other surveys are also carried out by the Ministry of Agriculture and organizations such as Fertilizer Association of India.

5. *Input-Output Relationships*

The crop-cutting surveys provide estimates of yields per unit area in the irrigated and unirrigated land in different States. A large volume of data relevant to the estimation of input-output relations is generated by the various all-India crop improvement programmes of the ICAR. The simple fertilizer trials conducted as a part of national demonstration programme have accumulated a vast body of information on yield responses to fertilizers. On the basis of these, yardsticks of response of major crops to irrigation and fertilizers in the irrigated and unirrigated conditions have been evolved. In general these yardsticks are related to the effect of particular inputs on yields. However, in the case of HYVs a composite yardstick intended to reflect the additional production from the application of the recommended package of inputs and management practices have been estimated.

Specifically, the following major IARI and ICAR projects provide vast amount of data, most of which are available on punched cards.

(*a*) Co-ordinated Scheme on Micronutrients of Soils:

Objectives:

(*i*) Study of micronutrient deficiency, symptoms and their uptake by indicator crops most sensitive to these nutrients.
(*ii*) Establishment of critical limits for the micronutrients in important crops.

(*iii*) Relationship and determination of micronutrient needs of crop requiring high dose of fertilizers.
(*iv*) Delineation of the areas of micronutrient deficiency.
(*v*) Response of added micronutrients on the representative soil of the region and their relationship to micronutrient content of plant and the available micronutrient content of soils.

Locations: 8; Period: from April 1, 1969 to March 31, 1974 (data available from 1-4-67 at some centres).

(*b*) Co-ordinated Scheme on Microbiological Decompositions of Organic Matters in Indian Soils under Different Climatic Conditions:

Objectives:

To investigate the types of micro-organisms associated in the decomposition of organic matter and course of decomposition in Indian soils, the influence of organic matter on soil structure and crop growth and yield.

Locations: 6; Period: from August 14, 1967 to March 31, 1974. Five-year project.

(*c*) Co-ordinated Agronomic Experiments Scheme (Model Agronomic Experiments Scheme and Simple Fertilizer Trials Scheme):

Objectives: For Third Plan, 1967-68 to 1972-73:

(*i*) To obtain scientific information on the individual aggregate and cumulative effects of a number of growth factors (fertilizers, variety, cultural practices, etc.).
(*ii*) To study the relative efficiency of nitrophosphates, ground rock phosphate and other phosphatic fertilizers as compared to superphosphate or ammonium phosphate and also response of acid soils to liming.
(*iii*) To determine the maximum intensity of cropping possible in different agro-climatic regions.
(*iv*) To obtain any information on any aspect dealing with fertilizer use as might be required by the ICAR.

Locations: 75

Objective: For Fourth Plan:

(*i*) To work out the response surface for N,P,K for different crops in different agro-climatic regions of the country with emphasis on newly introduced HYVs.

(*ii*) To work out the relative efficiency of different phosphatic fertilizers (of varying citrate and water solubilities) for legumes and their residual effect on cereal crops.

Model Agronomic Experiments: at 46 Centres, start of project different at different centres, the earliest being from May 1, 1956.

Simple Fertilizer Trials: HYVs at 30 locations. Rainfed 20 locations.

(*d*) All-India Co-ordinated Research Project on Soyabeans:

Objectives:

To evolve HYVs of soyabean suitable for different agro-climatic conditions.

Locations: 11; Period: from April 1, 1967 to March 31, 1971 extended to March 31, 1974.

(*e*) All-India Co-ordinated Research Project on Cotton:

Objectives:

To intensify the research work for increasing the average yield in cotton growing tracts and fibre quality of indigenous varieties.

Locations: 29; Period: from April 1, 1967 to March 31, 1971 and extended to March 31, 1974.

(*f*) Co-ordinated Scheme on Soil Test Crop Response Correlation:

Objectives:

To conduct research on the fundamental and applied aspects of soil test crop response correlations on district and agro-climatic basis with a view to improve the prediction of soil tests.

Locations: 13; Period: April 1, 1967 to March 31, 1974. Five-year project.

(*g*) Co-ordinated Scheme for Studies on Measurement, Evaluation and Improvement in Soil Structure—Fourth Plan Scheme:

Objectives:

To standardise certain basic techniques for evaluating soil structure with a view to work out a simple value index of soil structure that correlates best with crop yield.

Locations: 9; Period: from April 1, 1969 to March 31, 1974. Five-year scheme.

In addition, there are a large number of other projects conducted by the various agricultural universities. These are reported and published in the National Index of Agricultural Field Experiments. The data from past experiments can be computerized with modest effort, and a scheme can be organized to get data from new experiments for the information system.

6. *Cost of Cultivation*

The Farm Management Surveys sponsored since 1954-55 by the Directorate of Economics and Statistics of the Ministry of Agriculture give the cost of production of field crops on per hectare and per unit of production basis. The surveys also provide data on the extent of employment and unemployment of family labour and availability of capital equipment on farms. These surveys in the past have covered only a limited part of the country and were not frequent. However, a programme to cover the country regularly is started and the data on sample basis are being collected in different States on a continuing basis. More than 7,000 farms are covered every year and the data on daily expenditures and inputs are collected. Monthly summaries of these data are put on punched cards and one year's data require nearly 5 million cards.

In addition, cost data are also available from many surveys conducted by the IARS as also from surveys of the National Sample Survey Organisation.

The Farm Management Survey data for the last three years are already on computer cards and the future data are also be to processed on a computer.

7. *Machinery, Implements and Investments*

In the Livestock Census, the data are also collected in respect of ploughs, carts, sugarcane crushers, oil engines used in irrigation, electric pumps, Persian wheels, tractors and *ghanis*.

The Rural Credit Surveys of the Reserve Bank of India provide data for estimating gross and net investment and the sources of finance. Comprehensive data on annual basis are available for credit given by the institutional credit channels.

8. *Price of Output*

Weekly data on market arrivals, trade stocks, sales, prices and market situation are being collected from about 1,000 markets in all the States. Though the total number of markets as well the distributions of their number among crops has varied over time, all the important markets are covered.

Retail price data on about 72 commodities from 100 centres in the country are also collected, and from about 70 markets the data on trader's margins are collected. For eight weeks around harvest times, the data from all districts are collected for farm harvest prices.

9. Distribution of Land Holdings, Tenancy and Income, Consumption and Nutrition

The Agricultural Census, 1971 carried out by the Ministry of Agriculture has collected information on a variety of items such as size, tenancy rights, etc., for nearly 70 million operational holdings in the country. The data for many States are already available on magnetic tapes. The total number of cards for this Census data would be around 70 million cards.

It is also proposed to regularly update these data through sample surveys in the future.

The data on inequalities in income, consumption and savings and pattern of employment and wages are available from the NSS and Farm Management Surveys. Information on nutritional status is available from the dietary intake surveys carried out regularly by the National Nutrition Monitoring Bureau of the National Institute of Nutrition. These can be further supplemented by appropriate processing of the NSS consumption data.

10. Animal Husbandry

Livestock Census has been carried out in India every five years since 1920. The data on size and composition of livestock as well as age distribution of livestock are collected. Though village level data are available at the tehsils, only tehsilwise data are published.

The data on output of milk, eggs and other animal products have been estimated so far only on *ad hoc* basis. However, systematic sample surveys are now conducted every year to collect these data regularly. The animal husbandry division of the Directorate of Economics and Statistics (DES) of the Ministry of Agriculture collects data on livestock products. The IARS also conducts livestock products survey in selected States. These data are transferred on to 0.25 million punched cards per year.

Research in animal husbandry is reported in the National Index of Animal Experiments. Input-output relationships for livestock operations can be estimated from these experiments. The data on the economics of cattle and buffalo keeping and daily operations are collected from selected districts by the IARS. Under the dairy impact survey the data are collected on various aspects of the economy of the selected districts. These surveys generate 0.5 million cards a year.

11. Fishery

The Central Marine Fisheries Research Institute collects data on catch of marine fish since 1950 on a sampling basis. Varietywise catch, type of equipment, duration of fishing, etc., are reported.

No systematic data are available for catch of inland fishing.

12. Forestry

The data on area and type of forests are collected by the State Forest Departments. The data are available on the volume of standing timber and firewood as well as out-turn of these, as also of other minor forest products.

Though the data for forests under Forest Departments are fairly reliable, the data for forests controlled by corporate bodies, civil authorities, and private owners are not complete.

13. Climatological Data

The Indian Meteorological Department completed 100 years in 1975. Vast amount of data have been collected over the past hundred years. The IMD maintains an extensive network of observatories to record systematic and regular observations relating to weather elements, like rainfall, pressure, temperature, wind, etc., to detect and track storms and cyclones; to monitor cloud pictures and other data from satellites and to record earthquakes. The observational organisation as on April 1, 1974 consists of, among others (for complete details, refer to the publications, Observational Organisation, Indian Meteorological Department, Government of India, New Delhi), the following:

Type of observatory	Number	Elements observed	Frequency of observation
Surface observatory	504	Some or all of the elements atmospheric pressure, air temperature, maximum and minimum temperature, relative humidity, wind speed and direction, rainfall, evaporation, sunshine and occurrence of weather phenomena according to the class of the observatory.	One to eight observations a day according to the class of the observatory.
Agrimet observatory	123	Meteorological and biological. Meteorological elements observed include rainfall, air temperature, humidity, soil temperature and moisture, wind speed and direction, evaporation and occurrence of weather phenomena like thunderstorm, hailstorm, frost, etc.	Twice a day.
Hydromet observatory	320	Some or all the elements, rainfall, temperature, humidity, wind speed and direction, evaporation and sunshine.	One or more observations a day.
Raingauge	4,000	Rainfall	Once a day.

There are 47 surface observatories for which data for 100 years or more are available.

The data from 1945 onwards are on 25 million punched cards. Annual addition of data is at present 3 million punched cards. In addition, the IMD has a special division on agro-meteorology, which has collected data under the following programmes:

(a) *All-India Co-ordinated Crop Weather Scheme:* The data on crop stage and growth along with weather parameters are collected at 50 centres on experimental farms. These data are available for 5 to 30 years for different crops. The data are on one million cards.

(b) *Soil Moisture Evapotranspiration Studies:* Lysimetric observations are being made at a number of agromet stations, and the programme is to set up nearly 200 such stations with 2 to 3 lysimeters each.

14. Irrigation

The data on various irrigation projects are available with the Central Water and Power Commission. These include complete details of reservoirs, canal network, culturable and command areas. The data are also available on the cropping patterns, soil type, etc., for the command area.

15. Water Availability in Rivers

The data from 1,003 gauges and 1,862 gauge discharge sites are available for many years. The gauges measure water levels, three times a day whereas the gauge discharge sites provide discharge twice a day. These data are being transferred on computer cards and will take 1.5 million cards.

16. Ground Water Availability

The Ground Water Board as well as the various State tubewell organizations have data on ground water potential and its exploitation. These data could easily be computerised.

VII

SUMMARY ON DATA AVAILABILITY

The above is a brief description of available data. The details of sample frames, etc., are described by Saluja.[11] Comments on the limitations of these data are given by Srinivasan and Vaidyanathan.[12] The major limitations of these data arise from the incomplete coverage of the country. Nonetheless,

11. M. R. Saluja: Indian Official Statistical System, Statistical Publishing Society, Calcutta and the Indian Econometric Society, Hyderabad, 1972.

12. T. N. Srinivasan and A. Vaidyanathan, "Agricultural Statistics" in C. R. Rao (Ed.): Data Base of the Indian Economy, Statistical Publishing Society, Calcutta and the Indian Econometric Society, Hyderabad, 1972.

TABLE II—SUMMARY OF DATA AVAILABILITY

Data	Basis (Organization)*	Detail	Volume	Frequency of collection	Form in which to be stored	Updating frequency	Limitations of data
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Crop area	Mostly Census, Partly Sample (DES)	Area devoted to different crops plot-wise, villagewise, tehsilwise, districtwise (published)	70 million holdlings .55 million villages 5,000 tehsils 350 districts	Every season	Grouped by agro-climatic zones based on districts in stage 1, tehsils in stage 2, villages in stage 3.	Every season	Treatment of mixed crops is not uniform in the country. Intensity and quality of irrigation not differentiated.
	Sample basis Timely Reporting System (DES)	,,	20 per cent of above	,,	,,	Middle of every season	,,
	Sample basis Improvement of Agricultural Statistics-(IAS) Scheme (DES)	,,	10,000 villages a year	,,	,,	Every season	Carefully collected data up to 1971.
2 Yield and production	Sample of crop-cutting experiments (DES)	Yield/hectare of different crops	1,50,000 cuts a year	Every season	Frequency distribution of yields of different crop varieties in different agroclimatic zones.	Every season	Upto 1971-72 there are two sets of unreconciled estimates due to different treatment of mixed crops. Only one estimate since then.
	Sample basis IAS scheme (NSSO)		30,000 cuts a year	,,		,,	
3. Soil resources	Sample Survey (ICAR)		13,00,000 samples a year	Every season	Area of different soil types in each zone.	Every season	Does not fully cover the country.

(*Contd.*)

TABLE II—(*Contd.*)

Data	Basis (Organization)*	Detail	Volume	Frequency of collection	Form in which to be stored	Updating frequency	Limitations of data
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
4. (*a*) Adoption of new technology	Sample Survey (IARS), (PEO) (MOA, FAI)	Area under HYV, pesticides used, etc., fertilizer applied	50,000 farmers/year	Periodic	Area under different varieties in the zone; Frequency distribution of fertilizer dosages, amount of pesticides, etc. applied to different crop varieties in each zone.	Periodic	Sample size too small to get detailed regional data. Fertilizer data based on distribution and changes in stocks are not accountd for. HYV data do not cover HYV seeds grown by farmers.
(*b*) Agricultural practices	Sample IAS Scheme (NSSO)	30,000 fields a year	Every year	,,	Every year		
(*c*) Area under HYV	Selected districts (DES)	30 to 35 districts/year	,,	,,	,,		
5. Input-Output relationship for crops	Experimental schemes (ICAR, Agricultural Universities) IAS Scheme (NSSO)	For different crop varieties yield response to —fertilizers —micro-nutrients —cultural practices —soil type, structure —irrigation	30,000 plots a year	Every season	Estimated cropwise varietywise yield response functions for different years grouped by agro-climatic zones.	Every season	Not all crops and all areas are covered. Water-yield relationship experiments almost absent. Responses in experimental plots not representative of responses on farmers' fields.

(*Contd.*)

TABLE II—(*Contd.*)

Data	Basis (Organization)*	Detail	Volume	Frequency of collection	Form in which to be stored	Updating frequency	Limitations of data
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
6. Cost of cultivation	Farm surveys and Comprehensive Scheme (DES)	Daily cost and amount of inputs on the different plots of selected households	More than 7,000 households per/year. Monthly summaries alone need 5 million cards/year	Every season	Estimated output-cost functions for different crop varieties for different years grouped by agro-climatic zones.	Every season	Data not yet available for all crops and States.
7. Prices (*a*) Wholesale	Market intelligence (DES)	Daily/weekly market prices, wholesale and retail prices	About 1,000 markets and 72 commodities	Weekly	Frequency distributions of prices over the year. Price forecast functions.		
(*b*) Retail	,,	Retail prices of foodgrains and other essential commodities	100 markets	Weekly			
(*c*) Harvest	,,	Farm harvest prices	All districts	Weekly			
8. Market arrivals/ disposals	Market intelligence (DES)	Daily/weekly data	1,000 markets	Weekly	Frequency distribution of weekly data.	Every year	
9. (*a*) Land Holdings and tenancy	Agricultural Census (ACC)	Household's holding size, tenancy status irrigation facility	70 million holdings	Periodic (every 10 years) (every 5 years on a sample basis)	Distribution of size of holdings by irrigation, soil type and agro-climatic zones.	Whenever new data are available.	
	Periodic Sample Surveys (NSSO)	,,		Regularly, every year(?)			
(*b*) Income	Sample Surveys (NSSO)	Household's income, consumption, savings, employment	30,000 households/year consumption survey in recent years	Every year	Distribution of incomes, employment, savings, consumption, nutritional level by agro-climatic zones.	Every year	

(*Contd.*)

TABLE II—(*Contd.*)

Data	Basis (Organization)*	Detail	Volume	Frequency of collection	Form in which to be stored	Updating frequency	Limitations of data
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
10. (*a*) Animal husbandry	Livestock Census(DES)	Livestock size and age composition by households	5,50,000 villages	Every 5 years	Distribution of livestock, etc., by agro-climatic zones.	Every 5 years	Data on quality or breed of livestock not available.
(*b*) Milk, eggs, wool and meat	Sample Surveys (IARS), (NSSO) (Animal Husbandry Division of DES)	Livestock products	0.25 million/year	Periodic every year	Distribution of production of different breeds. Animal performance histories.		
(*c*) Input-output relationship for livestock products	Experimental Schemes (ICAR)	Yield of different species to different feeds, etc.	0.5 million /year	Continuing experiments	Estimated yield response functions for animals of different breeds, age, etc., to different feeds in different climates.	As and when new data are available.	Inadequate experiments to derive yield functions.
11. (*a*) Machinery and implements	Census (part of Livestock Census) (DES)	Ploughs, carts, crushers, oil engines, pumps, etc., for households	5,50,000 villages	Every 5 years	Distribution of households by size class of holdings and implements by agro-climatic zones.	Every 5 years	Quality data on implements not collected.
	Sample (part of Agricultural Census) (NSSO)	,,					
(*b*) Investment and credit	Rural Surveys (RBI)	Credits advanced for different purposes, investment made		Periodic		Periodic	Surveys are not regularly conducted for data on investment from farmers' own resources.

(*Contd.*)

TABLE II—(*Contd.*)

Data	Basis (Organization)*	Detail	Volume	Frequency of collection	Form in which to be stored	Updating frequency	Limitations of data
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
12. Fishery	Sample basis (CMFRI)	Catch of marine fish variety, duration, type of equipment		Every year		Every year	No reliable data on inland fishing.
	(NSSO)	Catch of inland fish		Occasional		Occasional	
13. Forestry	Survey (DES-MOA)	Area, volume of standing timber and firewood and out-turn of various products		Every year		Every year	Data from only government forests available. Production functions for different bio-systems not available.
14. Climatological data							
(*a*) Rainfall	Observation network (IMD)	12 hourly rainfall	4,000 stations, nearly 100-year series for many stations	Every day	All data and weekly frequency distribution of rainfall by agro-climatic zones.	Every year	
(*b*) Pan evaporation and other determinants of evapotranspiration	,,	12 hourly readings		,,	All data and frequency distributions of PET by agro-climatic zones/stations.	,,	Pan evaporation network is too coarse.
(*c*) Consumptive use of water	Lysimetric observations network (IMD)	Daily readings of soil moisture, PET and actual ET	200 stations	Every day	For different crops yield response to dated inputs of water at different stations.	,,	Only a short time-series available.
(*d*) Yield and climate	Experimental farms (IMD)	Daily readings on crop growth and weather parameters	50 centres 30 years' data	Every day	For different crops yield response to different climates at different stations.	,,	

(*Contd.*)

TABLE II—(*Concld.*)

Data	Basis (Organization)*	Detail	Volume	Frequency of collection	Form in which to be stored	Updating frequency	Limitations of data
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
15. Irrigation							
(*a*) Irrigation projects physical data	Project reports (CWPC)	Reservoir capacity, etc., canal network command area		Whenever a project is completed	Command area by agro-climatic zones and canals.		
Water inflows	Observations (CWPC)	Acre-feet/day		Every day	Frequency distribution of inflows for different weeks. Prediction formulae.	Every year	
(*b*) Water availability in rivers	Observations network (CWPC)	Thrice a day water levels discharge per day	1,003 gauges 1,862 gauge discharge sites, many years data	Every day	Frequency distribution of inflows for different weeks. Prediction formulae.	Every year	Long time-series not available for all rivers.
(*c*) Ground water availability	Survey (GWB)	Water table	—	—	Potential of ground water by agro-climatic zones/districts/tehsils.	,,	Incomplete coverage.
(*d*) Ground water exploitation	— (STO's)	Tehsilwise tubewells by types	—	Every year	Use of ground water by agro-climatic zones districts/techsils.	,,	Incomplete coverage.

* (DES) Directorate of Economics and Statistics, Ministry of Agriculture.
(ICAR) Indian Council of Agricultural Research.
(PEO) Programme Evaluation Organization, Planning Commission.
(MOA) Ministry of Agriculture.
(ACC) Agricultural Census Commissioner.
(IARS) Institute of Agricultural Research Statistics.
(CMFRI) Central Marine Fisheries Research Institute.
(CWPC) Central Water and Power Commission.
(FAI) Fertiliser Association of India.
(NSSO) National Sample Survey Organisation.
(RBI) Reserve Bank of India.
(IMD) Indian Meteorological Department.
(GWB) Ground Water Board.
(STO) State Tubewell Organization.

complete coverage of the country is not always required and the data are capable of providing very useful guidance in policy-making. The data availability is summarised in Table II.

From this review of data, it is quite clear that enough data are available in machine processable forms so that an information system can be made to function productively within a short time. It would be reasonable to expect analyses which will help in decision-making within 6 to 12 months after the project is undertaken. Some of the data gaps may take some years to fill. Till then the analyses that may be carried out can only be less sophisticated. However, these analyses would still be better than what are possible without such an information system, and would lead to substantial improvements in policy decisions.

VIII

OUTLINE OF THE SYSTEM

We can now outline an information system which will help in decision-making in a series of policy issues. Our attempt would be to outline a system which starts producing results as soon as some data are in and not a system which has to wait to produce results till all the data are in.

1. The Data Storage

The data available are enormous and not all of them are required in raw form for analysis. Pre-processing will certainly be done and only processed data will be stored in files of high accessibility.

The data organization for many files would be on the basis of agro-climatic zones/districts/tehsils/villages in progressive stages. For each of these regions the data stored in the processed form is described below:

Data Stored by Agro-Climatic Zones

Agricultural data

1. Irrigated/rainfed area under crops.
2. Soil resources, type, characteristics, fertility status.
3. HYV spread, area under different crops.
4. Pesticide, etc., use, intensity, extent.
5. Fertilizers, use, intensity and extent.
6. Frequency distribution of yields of different crops, varieties for irrigated and rainfed cultivation.
7. Fertilizer dosages applied in the past.
8. Residual fertility in soil.
9. Yield response functions to fertilizers, pesticides, etc., for crop varieties for irrigated, rainfed cultivation.
10. Expected output-cost functions for different crop varieties and input levels.

11. Price forecast functions.
12. Expected prices. Frequency distribution of prices over the years.
13. Distribution of size of holdings by irrigation and soil type.
14. Distribution of income, consumption, savings, employment, unemployment by size class of holdings.
15. Distribution of households by size class of holdings of implements, machinery, engines/pumps.
16. Distribution of livestock.
17. Milk yield and egg out-turn function for different feeds of different breeds.
18. Growth feed functions for different feeds of different breeds.

Climatological data

19. Frequency distribution of rainfall by weeks and conditional prediction formulae.
20. Frequency distribution of PET by weeks and conditional prediction formulae.
21. Frequency distribution of soil moisture availability by weeks.
22. Yield response functions to dated inputs of water for different varieties in different soils.
23. Acreage prediction regressions based on climatic data.
24. Yield prediction formulae based on climatic data.
25. Pest incidence prediction formulae based on climatic data.
26. Ground water exploitation and potential and recharge frequency distributions.

In addition, the following sets of files will be grouped by irrigation projects:

27. (*a*) Physical details of project.
    (*b*) Command area by different agro-climatic zones.
    (*c*) All the data for the various zones of command area.
28. Frequency distributions of inflows at the reservoirs/weirs by weeks and conditional prediction formulae.

2. *Use of Data*

These data files are required for specific purposes of analyses for decision-making. Additional data files should be added whenever they are required in any decision-making problem. One should avoid the temptation to store data for their own sake or for some possible future use. This may not only clutter up the system but would waste resources in data transcription at the cost of data analyses.

The general flow chart in Figure 1 shows the flow and use of data in the system.

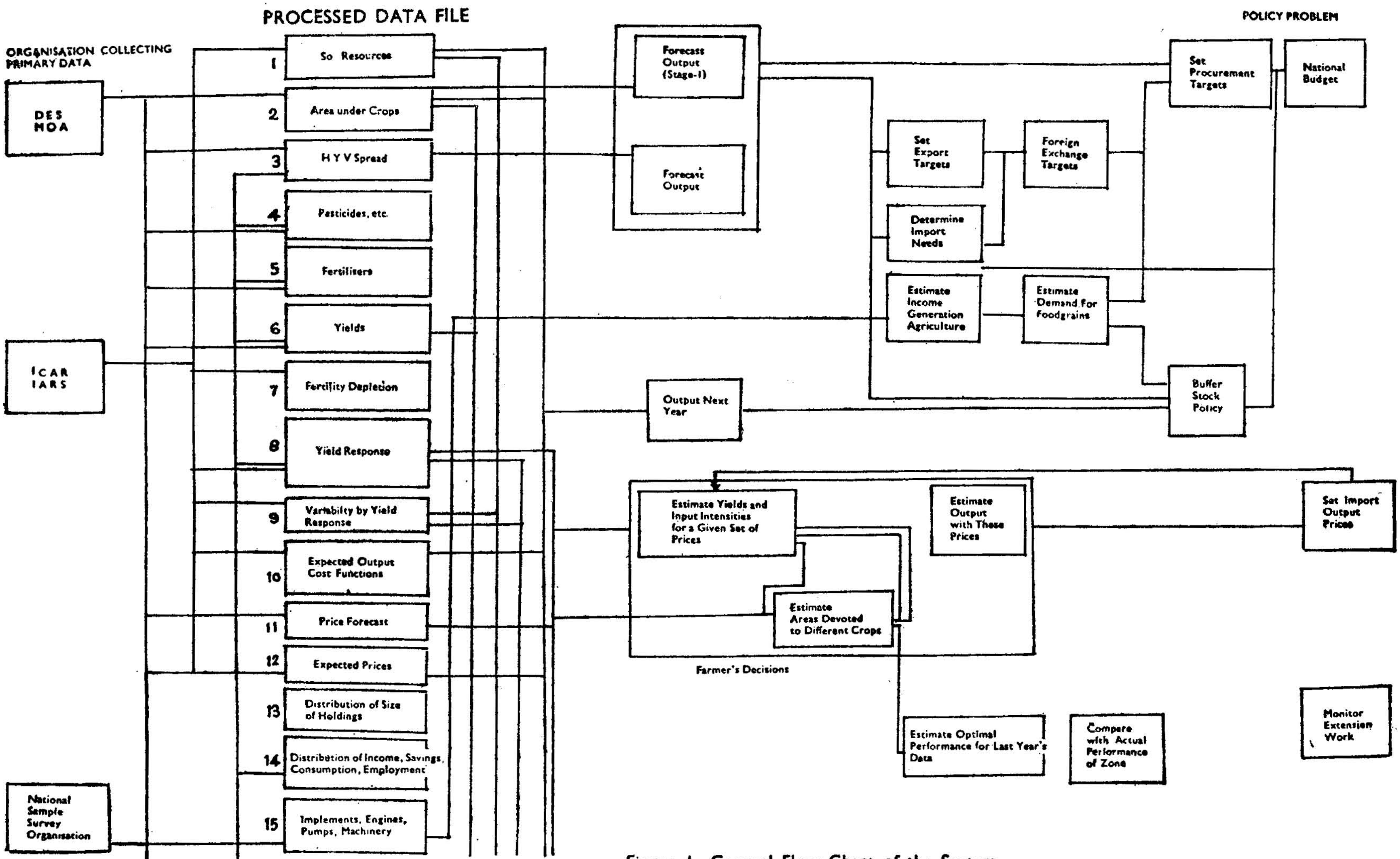
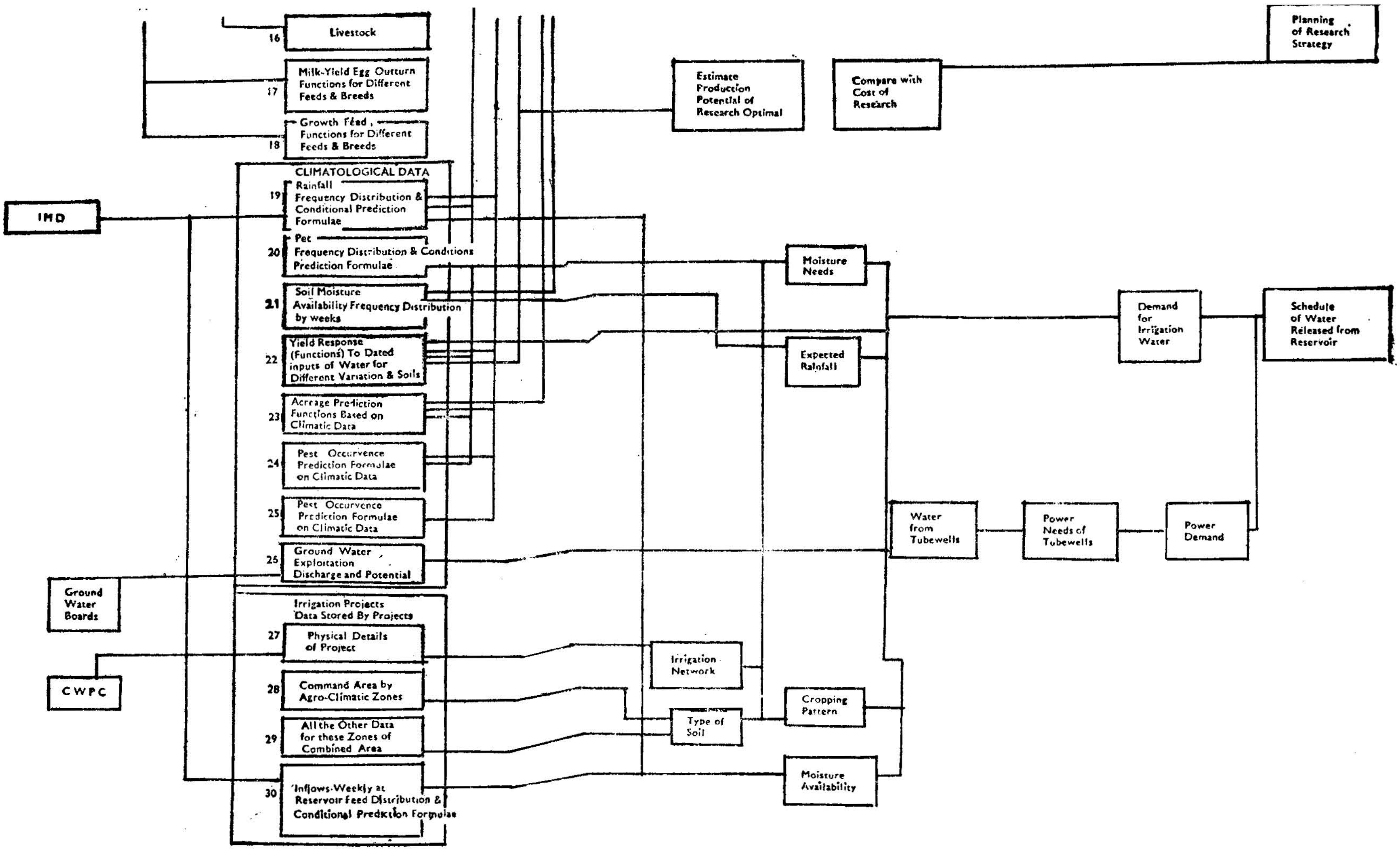


Figure 1—General Flow Chart of the System



Figure—1 General Flow Chart of the System