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SUBJECT III

FARMING SYSTEMS IN THE POST-GREEN REVOLUTION BELT

Farming Systems Approach to Research*

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It is a bit confusing as to what constitutes the 'Post-Green Revolution Belt' since the entire country is under the spell of Green Revolution for the last two decades in varying degrees. Perhaps, the 'belt' refers to the core northern regions of Punjab, Haryana and Western Uttar Pradesh which led the country to rapid growth in agricultural production and productivity, mainly in wheat and rice.

To confess, this paper is a sort of loud thinking to share some of the ideas with fellow researchers on systems study, one of the subjects of the Conference. This, therefore, is neither a research paper nor a review paper with the usual academic rigour, thorned with notes and references. My purpose is a humble one: to introduce the concept of the General Systems Theory and the purpose of farming systems studies, nature and usefulness of models used in the farming systems research, their relevance in the Indian context, and of course, some conjectures about the future farming systems in the agriculturally advanced regions.

THE EVOLUTION OF GENERAL SYSTEMS THEORY

The concept of systems dates back to antiquity. One could perhaps dig up Indian philosophical schools for the purpose. But the origin of the systems thinking in the West may be traced in the statement credited to Aristotle: "The whole is more than the sum of its parts." The dictionary meaning of system, for instance, by Webster, is "an assemblage of objects united by some form of regular interaction or interdependence". Thus a system could be defined as an organised unitary whole composed of two or more interdependent and interacting parts, components or sub-systems delineated by identifiable boundary or its environmental super-system. It is a set of inter-related elements each of which is associated directly or indirectly with other elements and no subset of which is unrelated to any other subset. In fact, the *interdependence, connectedness* and *interaction* among the sub-systems are the fundamental characteristics and the distinguishing features of a system.

The credit of founding the General Systems Theory goes to the biologist von Bertalanffy (1950, 1972). According to its exponents, a system is more of a philosophy of approach or paradigm rather than an operational formula. It involves the natural method of investigation of any problem by decomposing the problem into constituents and studying each of them in an integrated manner.

Systems approach emphasises the indivisible whole and implies that the system's behaviour is not reducible or predictable from the behaviour of its parts considered in isolation. This approach is *holistic* and it gives an intimate understanding of the working of the system not in terms of how the individual components work separately but in terms of how they interact with and depend on each other to satisfy the goal of the overall system.

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The understanding of the system through the knowledge of interdependent and interacting sub-systems provides a system operator with the insight necessary to manipulate and manage the system with a view to improving its efficiency. This has profound methodological implications especially when interactions among sub-systems in explaining phenomena for the purpose of manipulation do not result in value-free judgements. Systems are normally classified in different ways: physical or mechanical, biological, human, social, etc. Alternatively, systems may be classified as static or dynamic, close or open, abstract or concrete, deterministic or stochastic and so on.

FARMING SYSTEMS

Without going into the details of the classificatory schemes, it may be pointed out that farming is a stochastic dynamic, biological and open system with human or social involvement. Being primarily biological with a high degree of dependence on weather variables and changing socio-political environments, farming system is inherently more risky than any other system. The farming system specifically refers to a crop-combination or enterprise-mix in which the products and/or the by-products of one enterprise serve as the input for the production of other enterprise(s). It takes into account the consumption need of the family, the economic factors like relative profitability of the technically feasible enterprises, availability of farm resources, infrastructures and institutions such as irrigation, marketing facilities including storage and transportation and credit, besides the agro-biological considerations, namely, interdependence, if any, among various technologically feasible enterprises and the preference of the individual farmers. Alternatively, a farming system is defined as the way in which farm resources are allocated subject to the needs and priorities of the farmer in his *local circumstances* which include *(i)* agro-climatic conditions, such as the quantity, distribution and reliability of rainfall, soil type and topography, temperature, etc., and *(ii)* economic and institutional circumstances like market opportunities, prices, institutional and infrastructural facilities and technology (Collinson, 1979). It is important to note that the farmer has limited freedom to control most of these circumstances and therefore, can exert little influence to effect any change in them.

In the systems approach, the whole farm rather than the individual crops/enterprises is considered before any decision relating to the choice of enterprise and/or technology is made. Thus crops or technologies which are found to be high-yielding or highly profitable on isolated evaluation may not necessarily find their place in the cropping pattern or the technology-mix of the farm which follows a systems approach simply because the crops/technologies may not be compatible with the resource endowment, aspirations and preferences of the farmer.

Studies on farming systems became popular during the last few decades precisely for the purpose of gaining adequate knowledge of the system as a whole necessary for designing relevant research to improve the efficiency of the system. Sometimes the term 'Cropping system' is used synonymously with the 'Farming system' even though the former is only a sub-system of the latter. The vastness and complexities of the farming systems at a relatively macro level render it difficult to bring out the micro level interdependence and interaction which play crucial role in decision-making at the farm level. Farming systems are best studied on *representative case farms* to identify research gaps, to generate new knowledge and to narrow the zone of ignorance through farming systems research (FSR). The objectives of any farming systems study, therefore, should be to distinguish the various levels of understanding required for various purposes which include operation of the system, the repair and improvement of the system, and construction of new system (Spedding, 1975).

The farming system can best be described and understood by its structure and functioning. The structure in its wider sense includes among others, the land use pattern, production relations, land tenures, size of holdings and their distribution, irrigation, marketing including transport and storage, credit institutions and financial markets, and research and education. The functions of these structures should also be described in detail to discern the interdependence of these structures and functions.

The dynamics of farming system can be studied by analysing the changes in the structural parameters and functional characteristics of the system. The changes can be studied either in terms of direction or magnitude or both. It may be recognised that some changes in the behaviour and attitude of the farmer, the principal operator of the system, may not be subjected to easy and precise measurement. Nevertheless, reasonably reliable inferences and working knowledge on such changes can be derived from the changes in the physical and other measurable entities of the structures, functions, infrastructures and institutions. The impact of public policies on the structures and functions of the farming system need to be studied in the systems theoretic frame so that the changes brought about in these structures and functions can be examined not in isolation but in terms of their overall effect on the efficiency or goal of the system. Figure 1 shows a diagrammatic representation of the determinants of a farming system.

MODELLING THE FARMING SYSTEM

Because of multi-disciplinary nature of the farming system, economics being an indispensable component, it is important to explore the potential values and usefulness of bio-economic models in describing, analysing and assessing the economic and ecological consequences of manipulation of the underlying agro-biological processes. It is argued that a multi-disciplinary team consisting of economist, agriculturist, sociologist and ecologist is required for formulation of a system model. Some economists feel the need for a holistic farming system approach to the problem but formal modelling is beyond their competence. They, however, prefer to describe, explain and understand the agricultural environment and its interaction with the complex process of farm-level decision-making in an informal manner.

Attempts have been made to use planning models for commercial agriculture. Gross margin analysis and partial budgeting with market price to value the inputs and outputs have also been used. Extensive development of farming system models has, however, taken place only with the advance of modern computers. This is because of the complexity of the farming system and the nature of models used to simulate and optimise management of these systems. Biological processes do not only vary over time and space but are subject to stochastic variations. Social and economic considerations further complicate the system. Keeping these in view, model builders have used linear programming (stochastic, chance-constrained and deterministic), simulation models and Monte Carlo methods in representing a given farming system. It is often claimed that simulation modelling is the only analytical technique which could indicate the effect of an innovation on a number of independent objectives but the scope of the model for simulating biological system is limited. The impact of a change in the input-output relations resulting from technological breakthrough, prices (including

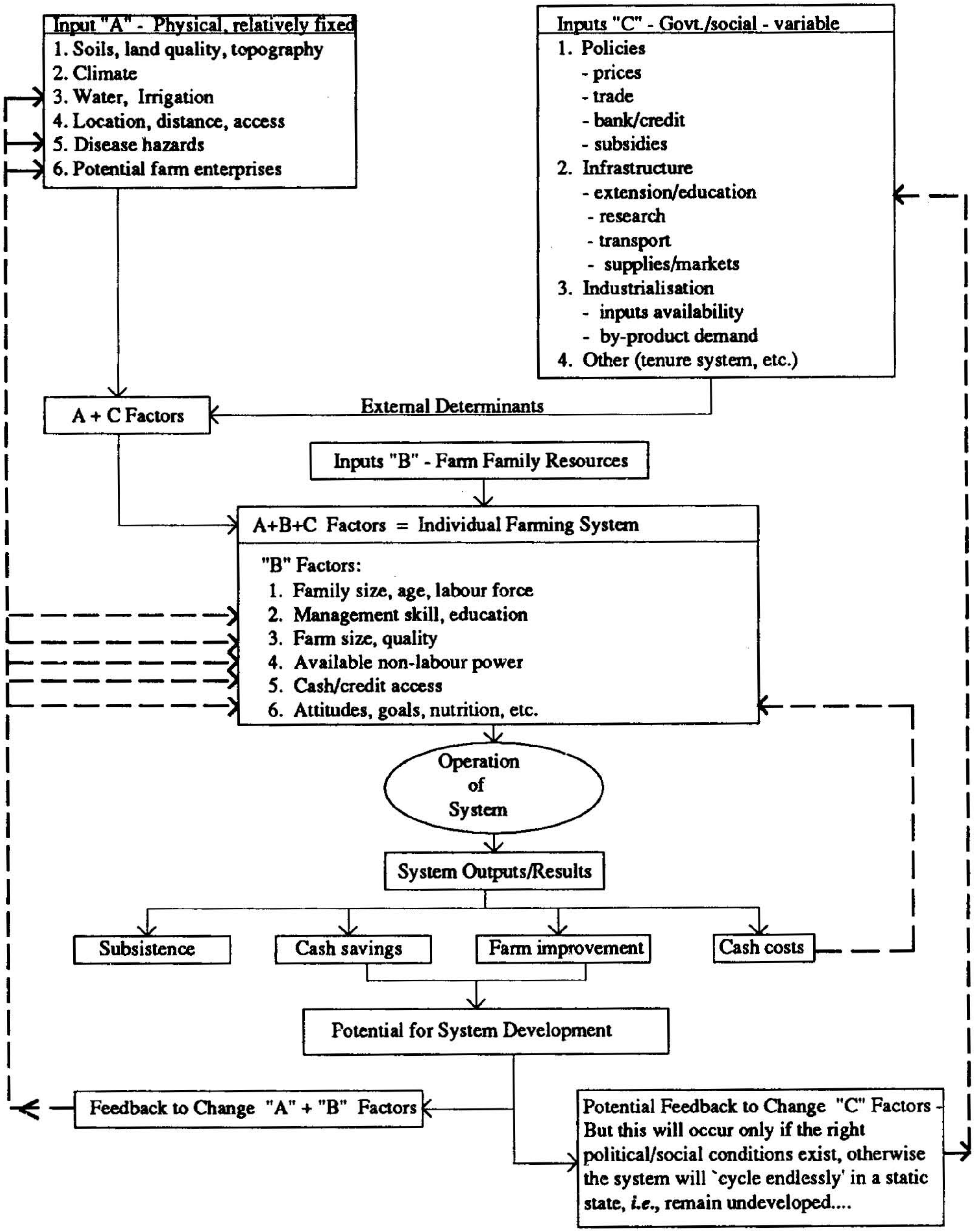

Figure 1. Determinants of a Farming System
Source: Carpenter and McConnel.

subsidies and taxes), resource endowment, preferences, infrastructure and institutions and public policies can be investigated with the help of suitable linear programming (deterministic or stochastic) models through sensitivity analysis/parametric programming with a reasonable degree of accuracy.

The models of farming systems are criticised as they are formulated according to the interests of their constructors rather than the need of their potential users. Besides, most of these models have often failed to adequately represent the technologies of the farming system due mainly to lack of communications with the researchers and the farmers and also the lack of appreciation of the structure and functioning of the various interdependent biological sub-systems. However, it should be kept in mind that there is no fool-proof general model to study farming system. The nature of the problem under study and the type of empirical data dictate the specific model to be used despite the fact that often non-availability of reliable and relevant empirical data limit the scope of mathematical modelling in farming systems studies.

FARMING SYSTEM AND AGRO-CLIMATIC ZONING

Ideally, farming systems research (FSR) should focus on the individual farms, *e.g.*, case studies. However, at an aggregate level it is appropriate to study the farming systems in relatively homogeneous agro-climatic regions for the purpose of planning for agricultural development of the specific regions in keeping with the natural endowments and factors which are normally not subject to change. It is necessary first to delineate agro-ecological zones and then to superimpose these zones with physiography and soil conditions for any meaningful study on the farming system that takes the best advantage of the location-specific agro-ecological factors. The Planning Commission has divided the whole country into 15 agro-climatic regions for the purpose of planning. These regions, being too large, are not as homogeneous as desirable and include more than one farming system in any given region. The Indian Council of Agricultural Research (ICAR) under its National Agricultural Research Project (NARP) has divided the country into 126 agro-climatic zones for 17 major states and six states/Union Territories of the north-eastern hill regions. The National Bureau of Soil Survey and Land Use Planning, Nagpur, of the ICAR delineated 54 agro-ecological zones. The basic objective of the agro-ecological zonings is to acquire first-hand knowledge of the strength and weakness of the natural endowments and of the comparative technological and economic advantages of the concerned zone as well as the problems associated with it so that an improvement in the system can be brought about by removing some of the binding constraints through design of appropriate research and/or public policies. The study of farming system needs to be, therefore, based on small agro-ecological zones which are homogeneous at least in respect of endowments of natural resources, cropping pattern and socio-economic situations.

GREEN REVOLUTION AND FARMING SYSTEM

Owing to their open nature, farming systems interact with the environment. The nature and extent of these interactions vary with the type of farming system as well as the specific environment. Besides the environment, research for generation of technology also influences the farming system, specifically, the enterprise/crop-mix and allocation of scarce farm resources. To be sure, technical innovations invariably change the level and type and quality of output and change the quantity and type of inputs needed for production. Besides an increase in production, the consequences of a breakthrough in production technology are shortage of specific types of land, shortage of labour at the peak seasons and inadequate supplies of credit and infrastructural facilities. Increased use of scarce resources by the crops/varieties benefited by the Green Revolution is likely to create an imbalance and sub-optimality in the use of these resources. An assessment of both the short-run and the long-run impact of a change in one or more determinants of the farming system (Figure 1) in terms of both direction and magnitude induced by innovation in agricultural production technology in specific regions should be undertaken. Specifically, increased use of sub-surface water, high dose of chemical fertilisers, herbicides, pesticides, which constitute the principal components of Green Revolution should be examined in terms of their ability to contribute to the process of sustainable development. It is also necessary to investigate what contribution, positive or negative, the Green Revolution makes to other important productive processes commonly used by the farmers to solve their major problems.

As the description of a farming system includes the enterprise pattern and end uses, food supply and preferences, cropping pattern and crop calendar, sources of credit and use, husbandry practices, besides identification of resource constraints with particular reference to land, labour, irrigation and credit, the involvement of the farmers in the farming systems research is crucial. In addition, yield variability, quantity and distribution of rainfall, incidence of pests and diseases should also be discussed in detail so that the inherent inconsistencies in the means-ends scale can be identified. Finally, the biological, physical and economic interdependence among farm activities should be brought to surface. It is needless to mention that economists are not equipped with *all* the necessary expertise and skills required to undertake such a comprehensive study on the farming system. A multi-disciplinary team of scientists including an agricultural economist is frequently suggested for undertaking any farming systems research (FSR). However, in actual practice, because of strong orientation to a single discipline, individual scientists of the 'multi-disciplinary' team can hardly understand the language of each other. This often results in ineffective communication and a virtual chaos. Practical experience suggests that it is the farmer who is alone the multi-disciplinary man even though he is almost ignored in designing the problem-solving farming systems research.

Farming system being dynamic and open does respond to changes in one or more variables listed in Figure 1. The impact of an innovation in agricultural production technology on the structure and functioning of the farming systems in the 'Post-Green Revolution Belt' of India is substantial. In fact, it is the superior agricultural production technology which is primarily responsible for transformation of traditional/subsistence farming system into a commercial/capitalistic farming system. The extent of the technological impact, however, varies from one region to another depending on the endowment of natural, physical and financial resources and the state of infrastructures and institutions. For example, the farming system evolved during the last two decades of Green Revolution in the country, particularly in the Punjab, Haryana and Western Uttar Pradesh is quantitatively and qualitatively different from the one observed in the pre-Green Revolution period. Specifically, in the Punjab the intensity of cropping and the area under irrigation (both net and gross) have increased substantially after the Green Revolution. There has also been an increase in the area and production of food crops, specially cereals, while those of non-foodcrops have declined during the Green Revolution period. It may be noted that production and area under food legumes have gone down since 1970-71. The area and production of chickpea in the Punjab decreased despite an increase in yield. Again, the area under pigeonpea increased in spite of its declining yield. The area and production of cotton increased while those of oilseeds and coarse grains, particularly maize and pearl millet, decreased. However, the area, production and yield of wheat, the principal beneficiary of Green Revolution, recorded a high rate of growth, even though the resource productivity seems to have declined in recent years. The higher demand for labour (and hence for wage rate) resulted from the adoption of the new technology impelled the farmers to take to large scale mechanisation at least in the peak seasons. These apparently irrational changes cannot be adequately explained simply by considering the concerned crop(s)/enterprise(s) in isolation and need to be analysed in the framework of a farming system where the interactions and interdependence of the elements of the sub-systems and the technology may provide a rational explanation. The impact of green revolution on the cropping pattern, resource productivity, input use, demand for labour, wage rates, pace of mechanisation, allocation of scarce farm resources between the sub-sectors in the agricultural sector such as crops, livestock, fisheries as well as among enterprises within the sub-sectors need to be studied and their probable consequences on future agricultural organisation examined.

Given the public policies in respect of pricing of inputs and outputs, technological innovations in the production of crop/enterprise is likely to change the cropping pattern/enterprise-mix and hence the farming system. Similarly, given the technology of production, a change in the enterprise-mix of a farm may be induced by government policies. The change is dramatic when favourable policies combine with improved technology. The phenomenal growth in wheat in West Bengal in the seventies and rapeseed and mustard in the eighties provide empirical evidence to such a dramatic change. Similarly, the extensive cultivation of rice in the Punjab, a non-traditional rice-growing area, also lays support to the power of technology and public policy, particularly support price and precurement network, to bring about a rapid change in the farming system. The change in the enterprise-mix, in turn, necessitates specialised types of infrastructures and institutions to provide for additional service to the farming system. Studies on such changes in the farming system are immensely helpful in the formulation and implementation of appropriate agricultural policies and to remove imbalances in the research priorities, enterprise-mix and hence in the allocation of farm resources.

The increased demand for crucial inputs like fertilisers, irrigation, credit, labour and mechanisation has to be analysed in relation to their long-term consequence on the sustainability of agriculture. On the one hand, the country needs to be self-sufficient in food and fibre production through intensive agriculture and chemical farming. On the other, the natural resource base of the country which is being gradually eroded by the modern methods of farming must be protected from irreversible degradation. It has been reported (Randhawa, 1990) that 7.31 per cent of the culturable command area (CCA) of Indira Gandhi Nehar Pariyojana is waterlogged and salinised and that 24 per cent of the CCA will be adversely affected and will be unfit for cultivation of any crop if the rise in water table is not arrested. The percentage of CCA waterlogged is 14 in Hirakud. In Sharda Sahayak Command Area about 50,000 ha area is damaged by waterlogging and salinity and in Ramganga Command Area, out of 12 lakh ha of CCA, 3.5 per cent is affected by waterlogging and salinity. In

Ukai-Kakrapar project, an area of 1.2 lakh ha out of about 4 lakh ha of CCA is degraded and has become agriculturally unsuitable. Such examples are galore in India. The present irrigation policy seems to be more demand-oriented and needs to be reviewed in the light of degradation of soil and water, the most important agricultural resources.

Virmani and Eswaran (1990) have suggested some criteria for evaluating the sustainability of agricultural system. These include assessment of risk, assessment of production performance of the technology, stability of the system, impact of the farming system on degradation of natural resources, particularly soil and water and the profitability of the system. The ecological soundness and other factors relating to infrastructures and institutions are also included in the suggested criteria. The technological innovation that has brought about the Green Revolution and increased production base of food crops, particularly cereals, has its concomitant ill-effects on environment and ecology and therefore, needs to be studied from the point of futuristic agriculture leading to a sustainable development of the country. The systems approach provides a useful tool not only for evaluating the sustainability of agriculture but also for testing and designing appropriate systems to suit the natural endowment, limited resource base and the socio-economic situation of the farmer.

Earlier the process of change in its determinants was rather slow to bring about any appreciable change in the farming system. Now with rapid changes in research, technology and public policies the farming system is undergoing fast changes, for instance, from subsistence to commercial farming, low-valued cereals crops to high-valued horticultural crops, from dependence on human labour to emphasis on mechanical power, etc. Therefore, the future research in farming system will have to keep in view these changes for a better understanding of the coming events and a more meaningful plan formulation.

EPILOGUE

If the experience of Green Revolution over the past two decades in the hardcore green revolution belt is any guide, we could perhaps be satisfied with the higher productivity where economic rewards have reached a high plateau for individual farmers. But at what cost? Published research materials have repeatedly pointed to the distortions in the economic and ecological factors and suggested the need for appropriate policies for correcting the imbalances and reversing this process of distortion.

Our main concern should be to take lessons from micro-level farming systems research and incorporate these lessons in the future plan for a sustainable agriculture by striking a judicious balance between appropriate use of natural resources to meet our present needs without jeopardising the future potentials. Future research strategies should be geared to develop new farming system that has a built-in capacity to *naturally* recycle the 'wastes' and the undesirable by-products of one or more sub-systems in order to make them 'useful' to other sub-systems. The hindsight about our failures in introducing many a new innovation in various regions of the country definitely reveals that we have never involved farmers in the research and development process right from the planning stage. This is a major omission since the farmer is the only multi-disciplinary man so far as his farm is concerned. He combines in himself the expertise of an agronomist, economist, microbiologist, meteorologist and so on. Therefore, a narrow approach in terms of commodity planning (for example, maximising the output of a crop like wheat or rice) or cropping system research, technology adoption, etc., albeit important, is only partial and creates distortion within the various farming systems. Our focus has to be on environment and ecology rather than merely on production, on people rather than on technology alone, on preservation of the resource base for the long-term benefits rather than on its exploitation for a limited short-term gain. Given the wide variation that exists in Indian farming, the only methodology for a sustainable agriculture lies in adopting the farming systems approach which allows individual farmers to play their participatory role and helps in assessing the potential created by bio-fertilisers, biological methods of pest control, etc., as well as their impact on the system variables.

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