NIJHOWNE, T.

Wheat Productivity for some Selected Wheat-Growing Regions of India

INTER-REGIONAL DIFFERENTIALS IN WHEAT PRODUCTIVITY FOR SOME SELECTED WHEAT-GROWING REGIONS OF INDIA

(Abstract of Thesis submitted by Tilak Nijhowne to the Faculty of Graduate Studies and Research at McGill University in partial fulfillment of the requirements for the degree of Master of Arts in Economics)

The study selects five regions and three consecutive years for which relevant data is available. Two computations are attempted: (i) Calculation of total or aggregate productivity ratios by simple statistical procedures aimed at estimating area differentials in the marginal productivities of factors and thus studying resource allocation. (ii) The use of a modified Cobb-Douglas production function involving correlation and regression analysis aimed at measuring the quantitative effects of particular independent variables or classes of variables.

Implicit in the calculations are the estimates of total or general productivity through the relationship pf output to all associated inputs. The calculations of the productivity ratios insert values of physical output and input quantities for subsequent observations. In all cases input quantities are weighted by input prices for a preselected base period. Two sets of productivity ratios were obtained, the first dealing with all sizes of land holding and the second with the overall regional size of holding.

The calculations employing correlation and regression analysis represent changes in nonquantifiable variables through the use of zero-one or dummy variables -- periods (three years); interregional differences (five regions); scale of holding (four classes of size group) and categories of land (irrigated and unirrigated). The data for the three years in question - base period and the subsequent two years provide estimates of technical change in effect. The particular solution selected for weighting inputs employs the covariance matrix method with time-series data. The weights are derived from market values (shares) and fitted production function respectively.

The study attempts to isolate some of the particular problems faced in collecting, processing and selecting data. Some of these problems are unique in reference to India, others most probably affect all mainly agricultural economies.

McGILL UNIVERSITY

INTERREGIONAL DIFFERENTIALS IN WHEAT PRODUCTIVITY FOR SOME SELECTED WHEAT-GROWING REGIONS OF INDIA

[Submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Arts (Economics)]

Montreal [Quebec] Canada

1971 TILAK NIJHOWNE

CONTENTS

PREFACE

The primary objective of this thesis is to shed some light on the matter of wheat production and productivity; highlighting some factors often lost sight of in the application of theory to practical problems in India (and underdeveloped countries more generally). Consequently, this study is an attempt at measurement of inter-regional differentials in wheat productivity for some selected wheat growing regions of India.

The somewhat arbitrary limitations of a thesis subject preclude the investigation of intimately related areas of study e.g. substitution among factors and crops, optimum size, technological change, bias on account of specification and management, etc. These fall under the category of investigation into the nature of the structure of agriculture and factors involving growth.

An understanding of the problem would involve a detailed examination of the agricultural sector, the dynamics of agricultural production and its mechanics, but to a much lesser extent. Better understanding of the problem affects the economist, whose theoretical considerations will ideally influence the content and direction of public policy. It is my hope that this study will contribute to such a better understanding.

These theoretical considerations are largely hypotheses relating to the behaviour and functioning of the economic system under given conditions. Understandably the hypotheses will alter if the given conditions alter. From our observations of certain phenomena we derive relationships and arrive at certain plausible explanations or hypotheses. The organization of these observations and relationships depends upon an assessment of the significance of certain items and their assigned priorities.

The formulation of appropriate public policy is difficult at the best of times, but it is of vital importance in Indian development. If guidelines based on more than general intuitive and political considerations can be established, then the resultant public policy is likely to be more effective. The reallocation of existing resources within agriculture, the allocation of new resources to agriculture and the distribution of resources between the agricultural and non-agricultural sectors are affected by our understanding of the problem.

In this study calculations will estimate: (i) area differentials in marginal productivities of factors, with a view to studying resource allocation; (ii) the quantitative effects of particular independant variables or classes of variables e.g. size of holding, type of land tenure, irrigated and unirrigated land etc.; and (iii) total or general productivity through the relationship of output to all associated inputs in real terms.

Two computations will be attempted. The first is the calculation of total or aggregate productivity ratios by simple (arithmetic) statistical prodedures.[1] The second will use a modified Cobb-Douglas production function, and involves methods of correlation and regression analysis. Both these methods are discussed in Chapter 2, where some attempt has been made to justify their choice.

Chapter 1 examines the problem of productivity in Indian agriculture. A definition of productivity followed by a brief summary of productivity studies elsewhere, some of the special problems involved in its measurement associated with agriculture and finally, a brief note on Indian agriculture. In Chapter 2 the methodology used is discussed. A statement on the technique of measurement of productivity, followed by the techniques chosen and a justification of their choice, closing with a discussion about the problem of data. In Chapter 3, the computations and their results enable some statements about the measured differentials in interregional productivity. The final Chapter 4 is a brief summary and statement of conclusions.

I would like to express my appreciation of the kindness of the library staff and my debt to the faculty in the Department of Economics at McGill University for their patience and understanding. In particular I am grateful

---

1. The inputs - land, family labour, hired labour, fixed capital and working capital - at constant prices are held to a base period. Output is seen as value added at constant prices and to the same base.

Professor C. John Kurien, without whose encouragement and guidance this study would never have been completed.

CHAPTER 1 : PROBLEM OF PRODUCTIVITY IN INDIAN AGRICULTURE

Productivity may be defined as output per unit of input; alternately, as the process of obtaining a larger output from the same input or of getting the same output from a smaller input. Generally speaking, upward changes in productivity are the result of more efficient use of some or all the production factors and/or of improvements in technology.

The term productivity is occasionally used loosely -- and incorrectly -- to signify 'capacity to produce' or merely 'production'. Whereas countries with a shortfall in production should aim specifically at expanding production, the fact that they do effect an increase in output of certain products or even of all products taken together, is not sufficient evidence of an increase in productivity. Another mistaken notion is ".... to regard increased profitability as evidence of a higher productivity". While an improvement in productivity -- a physical concept -- may possibly result in a corresponding improvement in profitability -- concept involving price -- the reverse is uncertain.[1]

The application of the concept of productivity is easier in situations more directly under human control; more applicable to industry than to agriculture. Agricultural production is dependent on biological processes, and is less amenable to control due to the several external factors

---

1. E. O. Saxon "Special Concept of Productivity" Productivity Vol. VI No. 2&3, National Productivity Council, 1965, New Delhi.

conditioning them, e.g. soil, climate and weather, pests and diseases, etc. In addition, the difference between traditional agriculture in an underdeveloped economy and commercial farming in an advanced/developed economy makes for yet another significant difference. Whilst traditional[2] agriculture inputs have their origin on the farm itself, inputs in non-traditional[3] agriculture have their origin in the industrial sector. The mainly subsistence farmer in traditional agriculture is unable to work towards getting the maximum output per unit of input. The commercial farmer in non-traditional agriculture produces mainly for the market and increased productivity reflects itself in lower unit costs.

The extension of the concept of productivity to the Indian situation involves a farm management[4] approach, backed

---

2. traditional inputs include: farm bred livestock, draught and milch; seed stored from previous harvests; animal manure, crop residual and green manuring; local made implements and tools, etc.

3. non-traditional inputs include: chemical products - fertilizers, pesticides, fuels etc.; engineering products - machinery, tools, implements; scientifically raised livestock and improved hybrid seed, etc.

4. A. D. Pandit "Application of Productivity Concept to Indian Agriculture" Productivity Vol. VI No. 2&3, National Productivity Council, 1965, New Delhi, P. 187-189 (Special issue on Agricultural Productivity)
Pandit defines this as an approach based upon "...a sound accounting system to assess the profitability from each unit (person, crop, field, animal and machine)...[and]...involved putting together many and differing agricultural enterprises into an effective overall economic unit...[aimed at]...more efficient utilisation of labour and other inputs."

See also: A. V. Bhuleshkar "Productivity and Technical Change; A Theoretical Analysis" Productivity Vol. VI No. 2&3 National Productivity Council 1965 New Delhi and supported by structural and organisational changes in the agricultural system. The application of scientific research in fields relating to foodgrains, cash crops, dairy and livestock will then make possible continuous increases in productivity.

Until recently, despite numerous references to 'productivity' in several/various definitive studies of the Indian economy, there has been little emphasis on arriving at a conceptual definition and application of the concept towards empirical measurement. This has probably been because of a confusion in regard to profitability, efficiency and productivity, which was also prevalent/extant outside of India. Another possible explanation would lie in the fact that analysts of the economic problems of India have emphasized structural alterations and wide sweeping changes in economic institutions and organisation.

Even in the formulations of the Five Year Plans, there have been no explicit statements about 'productivity', except for hopes that certain policy/policies, when implemented, would contribute to increased productivity. In all fairness it must, however, be admitted that programs/policy formulations for bringing about improved or increased productivity have been formally stated -- implying some general understanding about the problem. Some attempts have been made at discussion of the concept at a theoretical level. It would seem, however, that interest in this area has been created mainly by discussions taking place in international organizations -- ILO, OECD, etc.

There have been a fairly large number of empirical studies in the field of agriculture using production functions and regression analysis. During the last decade there has been an upsurge of interest in the field of agricultural productivity, resource allocation, etc., sparked in part by a combination of the following: 1. The widening gap between food requirements and production. 2. The growing difference in opinion regarding agrarian reform; hitherto considered the overall panacea for most agricultural problems.

An early study[5] of increases in efficiency of the U.S. economy used an arithmetically aggregated composit input to calculate output per unit of input for the U.S. economy. The study, which covered the agricultural, mining and manufacturing sectors for the period 1869 to 1938 (base 1929) concluded that increases in gross national product over the period reflected equally an increase in resources and efficiency. Between 1954 and 1956, Fabricant[6] and Kendrick[7] developed a somewhat narrow definition of input with studies

---

5. Jacob Schmookler "The Changing Efficiency of the American Economy" RES XXIV (August 1952) p. 214-231

6. loc cit

7. op cit Kendrick however made assumptions which were restrictive: (a) constant returns to scale in all industries studied, and (b) use of available stock of capital without any adjustment for capacity utilization - resulting in the mixing up of short run and long run production functions.

at a highly aggregated level. This was achieved employing a total input measure obtained by arithmetically aggregating inputs using market shares as weights.

In 1957, Solow[8] developed his general geometric model, thus introducing a new concept and methodology. Despite the fact that he did not use a Cobb-Douglas function, it is generally agreed that his results would have been identical, if he had. Solow's assumptions were fairly general - perfect competition (factors consequently receiving their marginal product), technical change was Hicks-neutral, and the production function was linear and homogenous; further that there were no errors of measurement.

By 1961 the simple Cobb-Douglas function was being used with geometric weights.[9] From this point on, the Cobb-Douglas function was modified to include a concept which treats technical change as 'embodied' in new capital and implies that capital is a vehicle of technical change.[10] Another modification was to assume relative shares of factors constant over time and measure embodied technical change without using measures of capital.

---

8. Robert M. Solow "Technical Change and Aggregate Production Function" RES XXXIX (August 1957) p. 312-320

9. Evsey D. Domar "On the Measurement of Technological Change" E J LXXl :284(December 1961) p. 707-721

10. R.M. Solow "Investment and Technical Change" Mathematical Methods in Social Sciences (Arrow et al) Stanford University 1959 Stanford p. 89-104

Denison[11] and Schultz[12] sought to introduce 'quality' of labour input (expressed as efficiency of the input and measured by an index of education) and several other sources of increases in productivity. The work by Griliches[13] introduced additional variables to estimate their role in explaining productivity growth; he attempted to adjust inputs for qualitative changes, use estimated production function weights to aggregate inputs <u>and</u> made allowance for economies of scale - estimated on the basis of cross-sectional data. The widely held assumption of constant returns to scale was finally dropped by Westfield[14] in 1966, in the context of embodied technical change.

Another attempt at using a modified version of the Cobb-Douglas function is that of Sahota[15] who uses a covariance (no interaction) matrix to differentiate variations in levels of neutral efficiency combining cross-sectional data with time-series data. Other attempts at using the more

---

11. Edward F. Denison <u>The Sources of Economic Growth in the United States and the Alternatives Before Us</u> (Supplementary Paper 13) Committee for Economic Development 1962 New York

12. T.W. Schultz "Investment in Human Capital" <u>AER</u> Ll (March 1961) p. 1-17

13. Zvi Griliches "The Sources of Measured Productivity Growth: US Agriculture 1940-1960" <u>JPE</u> LXXl (August 1961) p. 311-346

14. Fred M. Westfield "Technical Change and Returns to Scale" <u>RES</u> XLVlll (November 1966) p. 411-432

15. Gian S. Sahota "An Analysis of the Causes of the Secular Decline in the Relative Price of Fertilizer" Unpublished PhD Dissertation, Department of Economics, University of Chicago 1965 Chicago

general production functions will not be discussed here. A fairly comprehensive discussion of these functions is provided by Kurien.[16]

The literature identifies certain "dynamic forces" of economic life which include technological progress, accumulation of capital, entrepreneurial skills and ability and the organizational and changing institutional pattern of the economy. In association with productivity analysis as applied to the agricultural sector, we find certain facets/aspects become highlighted as special or additional problems. The major problems in the measurement of agricultural productivity are:

(A) The difficulties of measuring <u>output</u> due to: (i) the length of the production process i.e. the number of stages in the process. The criteria of 'length' of the production process gives rise to a possible distinction between total or gross agricultural output, net output (output of domestic agricultural resources only) and net

---

16. John C. Kurien "Technical Change in US Manufacturing Industries, 1947-64" Unpublished PhD Dissertation Vanderbilt University 1967 Nashville p. 12-16 and p. 22-46

factor output.[17]

(ii) The 'breadth' of the production process i.e. the number of products that can simultaneously be taken into consideration. This may be a single product, a section of agriculture or the entire agricultural sector. Whereas the output of a single product can be measured because of homogenities, the output of more than one product cannot

---

17. Total or gross output signifies the total amount of final products. The concept of final product depends upon the selected breadth of the sector. When considered separately final products include addable products e.g. fodder used in the stock production sector. Yet arable products are intermediate farm products when taken in the context of the total agricultural sector.
Net output signifies gross output less intermediate agricultural products obtained from outside the domestic agricultural sector. Imported non-agricultural intermediate products like fertilizer are not excluded. Nor are the industrial intermediate products originating in the domestic economy. This concept of net output is not considered very valuable for analytical purposes being only a variant of total or gross output.
Net factor output signifies the result of production in the relevant agricultural sector and deducts the whole amount of products and services (both domestic and imported) used in the agricultural sector but produced outside agriculture, from the total or final product. This concept - actual product of the agricultural sector itself - approximates the concept of net value added used when calculating national product. The selection of the concept of total or gross output or its variant net output affects what is meant by final product. For the single product the concept of total output may be different, without deduction for that part of the product used in its production e.g. seed. This is connected with the measurement of yield, through the relation of total output with a given input factor e.g. crop harvested per acre, and is strictly speaking not a productivity measure.

be measured in simple physical quantities.
(iii) The difficulty of coordinating the selected concept of output with the corresponding input concept to give real meaning to the productivity measurement.

In addition we have difficulties created when the product contains an element of services, or when the production unit makes or can produce different products with the same equipment. The products are either alternative varying widely in respective proportions or the products are simultaneous, in proportion variable within certain limits. Further, the quality of product varies between production units or the quality of product varies over time, either abruptly or slowly over the years. Additional problems arise due to differences of process, due to subcontracting, integration, etc. The same final or end product may be obtained despite diversity of processes. Differences arise due to varying degree of integration between production units, despite similar production processes. Also there are differences due to respective purchases of semifinished and non-agricultural inputs and due to semicontracting for certain operations or subdivision of the processes between different production units. Yet another source of difficulty in this category is the varying degree of integration from year to year.

Another problem is created in the measurement of productivity on account of what is known as the 'index number' problem. Physical quantities are not quite independent of the price component and are intimately connected to change in productivity. The choice of weights is thus extremely important, unless the price and quantity relatives of both output and input remain unaltered each price system will provide different results for productivity comparisons between regions and/or years.

Changes in consumer preferences and income distribution, however caused, affect the relationship of prices of product. Within a region, these changes in price relationships may be small but are not negligible. Between regions, these changes are significant. A steep rise in productivity of a product will generate a relative fall in price, the amounts produced and consumed will increase depending upon price elasticity of demand and vice versa. Products tend to be valued at their marginal importance with prices equal to costs at the point of equilibrium. This applies equally to inputs or factors of production.

Yet another problem arises due to the periodicity of agriculture. One element of this refers to the influences of accidental and seasonal factors which generate supply difficulties or affect variations in demand and include strikes etc. Agriculture is an industry where both the volume of production and productivity are liable to sudden and large fluctuations. The other element refers to the period of production or duration of 'manufacturing' process and the margin of error that occurs in the measurement of agricultural production.

(B) The difficulties arising out of the definition of input: 1. the extreme nonhomogenity of factors. In land due to: (a) differences in soil, topsoil depth, fertility and location; (b) proximity and availability of water or irrigated and unirrigated land by source; (c) period of settlement and length of cultivation; (d) type of tenure; (e) size of holding or scale of operation, etc.

Agricultural land is treated as a separate input but could quite properly be considered a special type of capital item. The annual use of the constant stock of land capital is the input flow from land - farming practices and good husbandry maintain the physical condition of the land at the same level.

One method for calculating amount of land is to calculate the value of the total net land rents, directly or indirectly as the interest of the total capital value in constant prices of all agricultural land. The net land rents include certain other non capital input elements e.g. services rendered by the numerous public drainage, sewage, irrigation, transportation and other systems servicing the agricultural sector. Changes in the price component of the agricultural value of land over a period of time are eliminated to yield the comparative volumes of the input of land use. This method is adopted in the United States.[18]

18. United States Department of Agriculture Technical Bulletin 1238 USDA Washington p. 44

In labour through: (a) differences in skills and experience; (b) sex and age distribution; (c) family or dependents' participation at varying minimum and maximum ages or earners and dependents; (d) classes of personal (family) and hired labour; (e) whether all agricultural labour should be included, or merely labour actually used, or yet again a "reasonable" amount of labour,[19] etc.

For capital: (a) arising out of the fact that buildings, machinery and implements, tools and agricultural land together with livestock are all special/separate types of capital items. Capital input comprises two annual flows emanating from the stock of capital: (i) annual consumption of the item concerned, whole or partial, and (ii) use of all capital invested in the productive factors and work in progress during the process of production. The former is like an intermediate product and to estimate the input flow one would need to know the original amount of the capital goods and to find a key for allocating the total amount over the period according to how it was used.

Improvements made by good farming techniques and husbandry generally maintain physical condition of the land, eliminating input flow as a real consumption of actual land; (b) vast differences in types and nature of capital equipment,

---

19. Concept of Productivity Measurement in Agriculture on a National Scale OECD 1961 Paris p. 17

largely because of their purely local fabrication based on traditional design, materials and customary use; (c) arising out of the component elements - consumption of the capital item wholly or partly during a specified production period and use of all investment in factors and work in progress.

The cost of capital includes the full price of fertilizer, pesticides, etc., and that part of the equipment, tools and machinery that is consumed during the accounting period, the cost of maintenance, upkeep and operation plus the interest on the money used to acquire the non-durables and the durable means of production. Thus the concept capital signifies the total purchasing power invested in production (in the sense of a factor or resource). The input of this factor is just a service, compensated for with interest only and not depreciation.

Both component elements constitute annual flows.

In the case of management: (a) arising out of the nature of the 'general state of the arts'. The relation between managerial skills, decision making and entrepreneurship is affected by extreme immobilities partly due to illiteracy and lack of information. The general level of education, awareness of and proximity of alternatives, the effectiveness of mass media, technical information, services and facilities available all influence the state of the arts; (b) affected by the extent of direct contact with market forces, i.e. product price response; (c) arising out of the degree of subsistence i.e. the amount of surplus left over direct farm subsistence needs. The preponderantly small i.e. limited scale forms, have little or no opportunity to increase size and reduce their numbers, consequently there is a weak product price pressure to cause alterations; (d) affected by the kind of tenure and permanency of holdings, etc.

2. The specific or unique factor mix, which is caused by the local combination of inputs factors which vary, as we have seen, in both quality and nature. These unique input combinations are found not only in different regions, but within regions and/or adjoining farms.

(C) The difficulties arising out of <u>attitudes</u>. A very intimate relation exists between the stage of development[20] of any country with the attitudes towards and the ability to effect change. Part of the picture related to inherited or historical factors that have shaped and conditioned institutions, expectations and patterns of behaviour. Their influence permeates the very structure of the economy. Under near-subsistence conditions, fear of worsening conditions creates an atmosphere of resistance to changes and certain

---

20. There are other difficulties associated with general economic policy, with special reference to growth and agriculture; these will <u>not</u> be considered here. Some of these are: (i) historical or inherited factors, (ii) unique or special situation of the country or region, (iii) status of underdeveloped region - declining, deterioration and stagnation of economy, and (iv) basic strategy adopted and the phased shortrun project adopted, etc.

institutionalised forms of self insurance (e.g. joint family) against shocks of all kinds. Often the institutional and organisational patterns reinforce the status quo, and aim merely at keeping the system surviving/functioning without any reference to efficiency and productivity. Part again relates to the mass or general participation and effectiveness of general economic policy, in that it seeks to both resolve the problem of growth and development and also affect the agricultural sector. This it can do only if the basic strategy, however longterm, expresses itself clearly through the public policy measures in a clear, unambiguous and confident manner. Yet part again deals with the techniques and procedures chosen and the legislative, freemarket and other pressures or mechanisms adopted to effect the phased process of changes outlined in the strategy.

Recurrent phrases like "pathetic contentment"; "apathy" and "weary fatalism" are found in the literature dealing with the agriculturist in underdeveloped economies, to describe his attitudes. The solution to the problem of a backward agriculture and low productivity may lie in the direction of setting up a system of rewards, incentives and assistance opening opportunities of alternate employments; effecting coherent, radical and uniform reforms; and providing an accelerated investment in social and human capital which alters the intersectoral distribution and combination of factors.

(D) Another set of difficulties arise as a consequence of the nature, process and period of production. 1. Even within the limited local alternatives [possible], total output varies a great deal over the period of production. (a) In some measure there is involuntary product substitution, due either to failure or delay in precipitation. Another crop is planted and if the rains fail, yet another.[21] And so on until the only possible crop is some form of animal fodder. The dogged attempts to plant another crop is a form of insurance; the crop has to be cleared in time for the next, and so the period of maturation and harvesting, etc., must be over so as to take timely advantage of precipitation. Farmers cannot afford just one crop, however good the "expectations." As a consequence the specific output we are interested in may vary very sharply. (b) Another form of insurance introduced by the agriculturist, is the practice of planting double or multiple crops. In this manner, the farmer attempts to simultaneously enrich the soil and also obtain some degree of insurance against losses. Another interesting feature of this and similar practices is that because the different components of the crop mixtures mature at different times, there is a phased availability of food and/or cash crops; and in addition a portion of the land under cultivation can be fallow for a short period at least. It may be noted,

---

21. For information on (a) period of production, (b) substitutable crops and crop mixtures see the following chapter.

however, that this introduces the element of time. [timing]

2. Due to the combination of duration of production, scale of operation, limited choice of alternative techniques,[22] immobilities due to intermediaries, etc., there is a cushioning effect on market forces [which in any case alter whilst the product is already under production] affecting both product and factors. There are, consequently significant time-lags in the process of adjustment to disturbance.

3. Under semisubsistence farming conditions, the maximisation principle is largely inoperative. Whether the margin over cost is measured in physical or monetary terms, a factor already mentioned reoccurs here; the element of inelasticity. This is due to the fact that, whatever be the condition of the market and the size of output, a certain minimum of the output [of food] is for domestic consumption.

4. Part of the problem of weather in relation to the nature, process and period of production has been dealt with in another section.

The [last] section above, dealing with the special difficulties in measuring agricultural productivity was intended to serve as some kind of guideline in adopting the measure of productivity best suited to our particular needs. Earlier, the discussion indicated two broad categories of

---

22. On limited choice of alternative techniques see A.V. Bhuleshkar "Productivity and Technical Change; A theoretical Analysis" Productivity Vol VI No. 2&3 National Productivity Council 1965 New Delhi

possible measurements; the first dealing with specific measures, the second with comprehensive measures or ratios. It was suggested that partial measures did not permit accurate measurement of changes in efficiency; whilst they could sometimes permit an indication of basic trends. Consequently the comprehensive ratio was accepted as being more suitable.

Among the more prominent features of the Indian economy may be listed her largely traditional agriculture with a record of low productivity in agricultural production. India's large population creates a gigantic food grain requirement, which apparently cannot be met wholly from domestic production. Expenditures on imported food grains have cut deep into the nation's foreign exchange earnings and potential resources. The problem is becoming progressively more acut and the authorities are faced with the prospect of spending a larger proportion of future foreign exchange resources on importing food.

Investment programs have had to be amended, in many cases cutting back on programs with foreign exchange involvement. Projects and programs, sometimes already in operation, have had to be postponed or terminated due to shortages in investment resources.

On the side of supply, efforts are being made to enlarge the existing vast land areas devoted to food production. Efforts are being made to introduce and extend the use of fertilizers, water and soil conservation schemes; to extend methods of irrigation and introduce improved implements, improved seed varieties and measures against insects, pests and plant diseases.

In some limited measure these efforts are proving successful. Despite adaptation in crop plants and different forms of tillage and the use of manures and fertilizers to compensate for soil conditions, agricultural production remains both variable and hazardous on account of fluctuations in weather. It must, however, be remembered that there is a limit to the amount of cultivated and cultivable land that can be turned over to food production. A large sector of industry depends on non food commercial crops and some of these crops constitute valuable foreign exchange earners.

On the side of demand, efforts are being made to restrain population growth mainly through birth control, and to a lesser extent by changed consumption habits.

These efforts may be less than effective on two counts. One, the question of population restriction is effective only in the longrun. During the interim the question of food is not resolved, nor is the question of larger food intakes and improved nutritional standards. In any case the main issue is obscured by viewing the problem through a population-biassed viewpoint. The sharply falling deathrate and longer and longer life expectancy, both due to medical advances and improvements in preventative medicine, has created a temporary, but nevertheless serious, population imbalance. Perhaps a satisfactory solution to the problem lies in radically altered consumer preferences and habits. This alteration of consumer preferences is unlikely without the existence of a better understanding of the resources available to agriculture and their possible reallocation. In any case, the alteration of consumer preferences, like population restriction, is possible only in the long term.

Approximately three-quarters of the total cultivated land in India is under food crops. The major food crops are wheat and rice which take up ten per cent and twenty-two per cent of the cropped area respectively. The importance of these two crops cannot be overstressed. The choice of wheat was inevitable since I have firsthand knowledge of the wheat producing areas and some direct knowledge of wheat production.

Particularly in the northern half of India, wheat is a major staple. In recent years, wheat has grown in importance as a major cereal grain on account of the fact that its consumption is regarded as being superior to the minor cereals, coarser grains and maize. The wheat "industry", if it may be so called, is a relatively large segment of foodgrain agriculture. The Indian wheat crop occupies some 10 per cent of the total cultivated area, of which less than one-third is irrigated. In domestic terms this adds up to approximately 12 million tons of wheat produced on some 33 million acres; in international terms India produces some 4.3 per cent of the world's wheat.[23]

---

23. Statistical Handbook Central Statistical Organisation, Government of India: 1964 New Delhi
Wheat 1963-64: India 4.3%; USSR 26.9%; USA 12.4%; Canada 7.9%; France 4.1%; Turkey 4.0%; Australia 3.6%; and Italy 3.2%; Other parts of the world 33.6%

In India, as most everywhere else, efforts are being made to introduce and extend the use of fertilizers; water and soil conservation schemes; extend methods of irrigation; and introduce improved implements; improved seed varieties and measures against insects, pests and plant diseases. In some limited measure these efforts are proving successful. Despite adaptation in crop plants and different forms of tillage and the use of manures and fertilisers to compensate for soil conditions, agricultural production remains both variable and hazardous on account of fluctuations in weather.

The choice of major wheat growing regions in India was facilitated by the index provided in the percentage distribution of area under wheat to the area under all cereals and millets. The area under wheat as a percentage of total cropped area was yet another means of highlighting the major wheat growing regions;[24] and confirms the choice indicated by the previous method. In alphabetical order these are: (i) Bihar; (ii) Gujarat and Maharashtra; (iii) Himachal

---

24. The area under wheat in each State is indicated as a percentage of the total cropped area. In addition, the position of the State is indicated as a percentage of the all-India total cropped area.
Area as percentage of total cropped area

Punjab 20.7	India 7.6	Maharashtra 4.4	India 8.2	Bihar	India not available
Rajasthan 9.8	India 9.1	Madhya Pradesh 3.0	India 22.6		
Himachal Pradesh 31.3	India 10.3	West Bengal	India negligible		
Gujarat 4.7	India 8.2	Orissa 0.1	India negligible		

Pradesh; (iv) Madhya Pradesh; (v) Punjab; (vi) Rajasthan, and (vii) Uttar Pradesh. However, for the kind of analysis attempted, data availability restricts the study to Punjab, Uttar Pradesh, Gujarat and Maharashtra (Bombay) and Madhya Pradesh.

CHAPTER 2 : DISCUSSION OF METHODOLOGY USED

Measurement of Agricultural Productivity

The concept "productivity", until quite recently was vague.[1] This confusion was probably because: (i) the rate of productivity change is not a fixed quantity over time, (ii) usage of the term productivity varied among different people, and (iii) statistical data and techniques were deficient. In addition...."productivity affects costs, prices, profits, employment and investment...."[2]; therefore, it is not surprising that confusion persisted. It is also increasingly accepted that the issue of productivity is vastly complicated as it embraces "a host of very complex problems....behind productivity lie all the dynamic forces of economic life: technical progress, accumulation, enterprise, and the institutional pattern of society."[3]

By the early 1950's productivity came to be regarded as a result or effect instead of a faculty or aptitude.[4]

---

1. For a brief discussion of possible origin and development see: K. Sangha Productivity and Economic Growth Asia 1964 London
   E.O. Saxon "Special Concepts of Productivity" Productivity Vol VI Nos 2&3 National Productivity Council 1965Delhi
   J.W. Kendrick Productivity Trends in the United States Princeton University Press 1961 Princeton p. 3 - 6

2. In this connection see S. Fabricant Basic Facts on Productivity Change NBER 1959 Princeton. Fabricant maintains that errors persist through: "...failure to specify methods and the assumptions involved in the process of estimation or failure to understand them..." p. 1

3. W.E.G. Salter Productivity and Technical Change Cambridge University Press 1960 Cambridge

4. Even though "productivity is the measure of means" it is not synonymous with efficiency. Efficiency is "aptitude, capacity; in a word the quality of the entity whose productivity is under review..." Productivity Measurement Vol 1: Concepts European Productivity Agency OECD 1955 Paris p. 26

Productivity began to be generally conceived as a relationship between product and factors; between output and inputs. Various[5] statements in this relationship were put forward and refined; and solutions offered to the problems posed by the definition and measurement of outputs and inputs. The concept admits different kinds of productivity according to whether the measure included one or another of several input factors e.g. labour, capital, power, raw materials, management, etc.[6]

The most widely applied definition of productivity, and perhaps the most authoritative states: "Productivity may be defined as a relation, frequently expressed in ratio form, between output and associated inputs in real terms... The advantage of relating real product to the sum of associated factor inputs, human and material, is that the ratios indicate the net saving of inputs, and thus the change in productive efficiency; ratios of real product to single classes of input, such as labour, reflect the effect of

---

5. cf. Measurement of Productivity Report by a group of European Experts OEEC 1952 Paris
Also see Productivity Measurement Vol I: Concepts (op. cit.) and J.W. Kendrick Productivity Trends (op. cit.)

6. cf. E.O. Saxon "Special Concepts of Productivity"
S.Fabricant Basic Facts on Productivity Change
I. Siegel Productivity Measurement Vol I: Concepts p 44
The earliest statement of which I am aware, was in the French note and by Dr. Laszlo Rostas, between 1952-55,reprinted in Measurement of Productivity OEEC 1955 Paris

factor substitutions as well."[7]

Within the broad limits of the definition are included some special concepts of productivity: (a) gross and net productivity, (b) total and partial productivity, and (c) average and marginal productivity, [8] The concept selected for application depends in large measure upon the use to which the analysis is intended. For our purposes it is necessary only to examine in detail the concept that distinguishes between total and partial measures of productivity (and average and marginal measures.)

The best known partial productivity ratios are (i) productivity of labour, (ii) productivity of capital, (iii) productivity of land and (iv) productivity of various intermediate goods taken singly e.g. machinery, fertilizer or in a group. Here the total output or specific products are related to individual inputs (or groups of inputs) separately.

---

7. J.W. Kendrick Output and Productivity Measurement NBER 1961 Princeton Introduction p 4 also S. Fabricant Basic Facts on Productivity Change NBER 1959 Princeton

8. E.O. Saxon "Special Concepts of Productivity" Productivity Vol VI Nos 2&3 National Productivity Council 1965 Delhi p 226-235. Also see French note in Measurement of Productivity OEEC 1955 Paris and Productivity Measurement Vol 1 : Concepts

Within certain narrow limitations[9] these partial ratios provide useful tools for analysis. The partial productivity concept is also known as the specific or single or unifactor measure. The reasons why this concept was ever adopted are simple: information on all resources is not readily accessible, problems of statistical and computational techniques thereby limiting the analysis, and finally the belief that

---

9. Dr. Laszlo Rostas "Alternative Productivity Concepts" who suggests that the partial measure ignores interdependence in the economy. Rostas regards "productivity of labour as a measurement of general efficiency in the use of labour and not of the effort of labour.... productivity of labour is influenced by the combined effect of a large number of separate though interrelated factors such as the amount and quality of equipment employed, technical improvements, managerial efficiency, the flow of materials and components, the relative contributions of units at different levels of efficiency as well as the skill and effort of workers." Some of these factors are measurable, others not yet. The weight of the argument is to show that the ceteris paribus argument begs the question and attempts to separate/isolate a given input artificially - with inaccurate results. Productivity Measurement Vol 1 : Concepts OEEC/EPA 1955 Paris p 31-42
S. Fabricant in Basic Facts on Productivity Change NBER 1959 New York suggests "....an adequate index of productivity for a single resource requires not only eliminating the effect of changes in other resources, but also somehow taking into account the relative importance of the resource." (p. 6) Only when the resources are of small importance or moved in the same direction (in identical proportion) would an index of productivity based on a single resource provide a reasonably accurate measure. See E.O. Saxon "Special Concepts of Productivity" Productivity Vol VI and J.W. Kendrick Output Input and Productivity Measurement NBER Princeton 1961 also Concepts of Productivity Measurement in Agriculture on a National Scale Documentation in Food and Agriculture No. 57 OECD 1962 Paris

all inputs could be converted to a single homogenous unit. This discussion is extraneous to the subject at hand. My view is that all partial measures depend mostly upon these reasons.

In total productivity measures, output is related to a combination of inputs, either excluding or including intermediate products. The concept is alternately known as aggregate or general or comprehensive or multifactor productivity. These measures have evolved partly in an attempt to resolve the question of bias originating from the partial measures and partly because the concept of specific factor productivity has presented difficulties in measurements.

Even though specific productivity measures were.... "conceived with reference to any or all input factors, practical choice is limited to the significantly measurable ones. Measurability is hampered by the extreme heterogenity of a definable input class, either within a given period or over time."[10] The paucity of data/information on other resources, the view that labour was both a factor of production and the ultimate consumer, and possibly some vestigial variant of the labour theory of value expected to yield a "per capita" measure led to the adoption of the productivity of labour concept.

---

10. Irving H. Siegel <u>Productivity Measurement Vol 1: Concepts</u> OEEC/EPA 1955 Paris p 44. Siegel supports this view with instances (i) essence of entrepreneurship cannot be measured in manhours; (ii) volume of capital inhibits routine deflation; (iii) longterm price of land does not reckon with intangibles - air, sunshine, rain, etc.

The productivity of labour measure was selected mainly on the grounds of expediency - practical measurability - and based on a crude summation in manhours of diverse skills, background and experience but ignoring sex distribution and age distribution. The simple productivity measure relating physical output to labour input per manhour suffers from an upward bias,[11] not only from the omission of capital and other inputs but also from the neglect of changes in composition and/or quality of labour - more particularly so if it is used as a measure of efficiency. Apart from the obvious exclusion of other factors, the conversion into manhours views proprietors, supervisory, clerical and wage-earner categories as homogenous; besides neglecting "intangibles" such as different skills, levels of education and lengths of experience.

The index of output per weighted manhour includes some intangibles "....forms of human capital that aid in production and contribute to wage salary differentials..." but continues to treat labour as homogenous. The general or broad level of education is not taken into account, nor indeed are the components of the imperfectly measured differentials in wages and salaries viz cost of living, uncompleted adjustments to changes in demand and supply, trade unions and several noneconomic factors. The index

11. S. Fabricant Basic Facts on Productivity Change NBER 1959 Princeton p 6-9

consequently, indicates only direction, but not the degree of bias arising from the neglect of changes in quality of labour.

The situation with respect to capital - tangible capital - seems to be only slightly better. The problems in relation to the treatment of depreciation, allowance for changes in price, and the proper valuation of land, among others, make the index of output per weighted unit of tangible capital[12] a very imperfect measure of productivity. As mentioned earlier, there is as yet no satisfactory formulation for entrepreneurship. Nor indeed, do land and natural resources generally lend themselves to treatment in such a measure.

It is generally agreed that "....much of the significance of such measurements [productivity of labour] consists in relating production to that factor in production which is least likely to change but which is probably most sensitive to any alteration in any other factor. Experience shows that most improvements are due, not to greater effort

---

12. Additional attributes that are seen to complicate measurement with respect to capital are the longevity, impermanence, technological change, source of future income, and limited second hand market considerations cf. Evsey Domar Output, Input & Productivity Measurement NBER 1961 Princeton p 61
This, however, constitutes an actual problem and not a conceptual one. The problem of measurement remains complex due to the fact that capital input or flow of services, on account of the processing of the production factors (not the actual consumption), is a minor input factor; yet alteration in net factor productivity may be due largely to substitution of labour inputs by other inputs. In any case, this measure is not used very much in agriculture.

on the part of the workman, but to an efficient use of this effort and to other factors in production. Human effort is always limited in itself, but the influence of the organisation of work, the quality of materials, the type of product manufactured, the capital invested, management efficiency, etc., is a deciding factor in the level of productivity."[13]

Whereas it may be admitted that labour productivity, by and large measures not merely labour productivity, and has a tendency to take in intermediate production[14] it is still not, especially in the shortrun".... a good proxy for all factor productivity." The time element is stressed as yet another significant factor, complicating the construction and use of partial measures.[15]

Attempts have been made to combine indices of input; and while they have proved superior to the specific measures, they too are subject to problems faced when constructing separate indices, and the additional one of converting/reducing the inputs to comparable units. The efforts to

---

13. Measurement of Productivity OEEC 1952 Paris p 16-17 It should be noted that scale of operations would form part of this.

14. Irving H. Siegel Productivity Measurement Vol 1: Concepts OEEC/EPA 1955 Paris includes in intermediate production - (a) Creation of institutions (b) knowledge (c) nonhuman energy (d) processed material (e) capital instruments, etc. p 45

15. Output, Input and Productivity Measurement NBER 1961 Princeton cf articles by I.H. Siegel "On the Design of Consistent Output and Input Indexes for Productivity Measurement: with comment by Carl F. Christ p 23-46 and George J. Stigler "Economic Problems in Measuring Changes in Productivity: with comments by R.M. Solow, M.A. Copeland, R.L. Richman and R. Eisner p 46-78

convert all inputs into manhours were found impracticable and difficult of interpretation.[16] The suggestion that inputs be converted into money terms is complicated by including factors which determine prices and yields a better measure of profitability than productivity.[17]

It has been suggested[18] that the development of productivity analysis was delayed on account of the lack of clarity in respect of the aim, purpose or objective of productivity measurement. Nowadays, a certain amount of caution is excercised in preparing indices for specific purposes; and it is considered advisable to disabuse innocents regarding any general purpose productivity index.[19] Indeed, there is a desire to confine indices to measurement of technological change by segregating effects of changing scale, rates of utilisation of capacity and changing inherent quality of inputs.[20]

The productivity of labour measure must "not be interpreted causally. It reflects, at best, the average productivity - not the marginal productivity - of labour in a

---

16. Productivity Measurement Vol 1: Concepts OEEC/EPA 1955 Paris cf summary of findings sections 5-13 p 12-14

17. Dr. Laszlo Rostas "Alternative Productivity Concepts" Productivity Measurement Vol 1: Concepts p 32

18. ibid p 31-32

19. Output, Input and Productivity Measurement NBER 1961 Princeton. Comment by J.W.Kendrick in Introduction to article by Irving H. Siegel "On the Design of Consistent Output and Input Indexes for Productivity Measurement" p 7

20. Output Input and Productivity Measurement. Comment by J.W.Kendrick in Introduction to article by George S.Stigler "Economic Problems in Measuring Changes in Productivity" p 8

sequence of static equilibrium situations".[23] The concept of marginal productivity refers to the change in output associated with a small change in one input, given that all other inputs are constant. It is also possible to calculate the marginal productivity of all inputs, taken together, assuming that these are applied in constant proportions. "Comparisons of change in total output, with changes in one or more associated inputs between two points of time, preserve something of the concept of marginal productivity in that the average productivity of some increment or decrement in inputs may be examined. Such comparisons are often more meaningful than average ratios calculated from total output and input data, although it is usually not possible to separate increases in production due and higher productivity from these, due to changes in scale of operations which result from increased inputs."[24]

The widespread use of productivity analysis has gradually brought home the realization that."....one should never look at average products, only at marginal products."[25]

---

23. Irving H. Siegel "Aspects of Productivity Measurement & Meaning" Productivity Measurement Vol 1: Concepts European Productivity Agency OEEC 1955 Paris

24. E.O. Saxon "Special Concepts of Productivity" Productivity Vol VI No2&3 National Productivity Council 1965 New Delhi

25. G.S. Stigler "Economic Problems in Measuring Changes in Productivity" Output, Input and Productivity Measurement NBER 1961 Princeton p 47

Further, that the "...equality of marginal products in all uses is a necessary condition for efficient use of a resource, and hence for maximum output. The marginal productivities are basic elements of the demands for productive factors. The dependence of marginal products on the quantities of and proportions among productive factors is the essence of the theory of production. These are illustrative statements of the fundamental role of marginal products in economic analysis. So far as I know, not a single theoretical statement of any importance can be made about the average products of factors."[26]

The discussion of productivity relating output to units of input seems charged with responsibility regarding the definition of output and input, in accordance with the production process, whose productivity it is intended to measure. There are "....two focuses of the conceptual problem of productivity measurement....[one]...is the weighting of output and input items, this problem being created by the need to sum physically dissimilar components of the output on the one hand and of the input on the other in a manner which is meaningful for the purpose....The other focus is the problem of choosing that relationship between output and input which is most suitable for the greatest number

26. G.S. Stigler "Economic Problems in Measuring Changes in Productivity" (Ibid) p 47-48

of purposes or a particular purpose."[27]

Now, the different purposes envisaged by the measurement, together with the availability of data and the relative ease or difficulty of measurement create divergences in the meaning of both output and input concepts. Three classifications have been suggested;[28] the first two relate to the "length" and "breadth", the dimensions or extent of the production process, the third to total and partial measure.

With the development or extension of appropriate statistical and computational techniques, there have been attempts at application of the theory of production. Production functions, such as the Cobb-Douglas function permit estimations of mathematical functions of production and inputs, facilitating the approximation of marginal productivity. The usual productivity measures are different from measures derived from econometric equations involving production and one or more elements of input in that they refer to average rather than marginal productivity in each period.[29]

---

27. Concepts of Productivity Measurement in Agriculture on a Natural Scale OECD 1962 Paris p 11
Also S. Fabricant Basic Facts on Productivity Change NBER 1959 Princeton "The technical choices, often not specified, of how output and inputs are defined; how weights of components are determined, and how data are selected/estimated and from what source; are extremely important in productivity analysis.
28. Concepts of Productivity Measurement in Agriculture on a National Scale OECD 1962 Paris p 11-13
29. Irving H. Siegel "Aspects of Productivity Measurement & Meaning" Productivity Measurement Vol I: Concepts OEEC 1955 Paris p 46. And cf. K.E.Boulding Output, Input and Productivity Measurement NBER 1961 Princeton "Some Difficulties in the Concept of Economic Input" with comment by M. Kemp p 331-345. Also E.H. Phelps-Brown "The Meaning of the Fitted Cobb-Douglas Function" QJE 71:1957 p 546-560

Average products have been used as measures of efficiency in the absence of marginal productivity data but they have no strict validity as indicators of resource-use efficiency. After all the average product of each resource is merely the mean output divided by the mean input of the resource - this average includes the product returns of all inputs, not merely the product attributable to the single resource. On the other hand the marginal product indicates the expected increase in output attributable to the use of an additional unit of the single resource, other inputs remaining unchanged. The marginal productivity of any input depends in general terms upon (i) the quantity already in use and (ii) the quantities of other inputs with which it is combined.

The calculation of marginal productivity requires the establishment of appropriate production functions; this in turn depends on comprehensive and reliable input data.[30] Heady suggest that "Formal estimation of production functions allows derivation of marginal products, physical maxima or minima....(of possible factor substitution)....isoquants, isoclines, marginal rates of substitution, and other quantities which cannot be computed from experiments which imply

30. Zvi Griliches "The Sources of Measured Productivity Growth; US Agriculture 1949-60" JPE 1963 p 331-346 cf especially p 333-335 and "Estimates of the Aggregate Agricultural Production Function from Cross-Sectional Data" JPE 45:II 1963 p 419-421. Also W.E.G. Salter Productivity and Technical Change CUP 1960 Cambridge p 13-26

discrete data and which are designed only to provide point estimates. From this standpoint, production function analysis has scientific as well as practical importance.... [whilst]....not a substitute for budgeting, programming or planning procedures....it does have some uses in assessing resource productivity in agriculture...."[31]

Consequently, literature on the estimation of production functions, dwells at length on the importance of the specification and selections of procedures.[32]

The appropriateness of the function fitted depends on a large number of considerations and includes the use or purpose of the estimation, whether the function fitted has any similarity with the real or objective production function and any special reasons for including variables in the research design. These classifications enable the (threeway) distinction of the output[34] with reference to agriculture as: (a) total or gross output; (b) net factor output and

---

31. E.O.Heady and J.L.Dillon Agricultural Production Functions Iowa State 1961 Ames p 5-6
32. E.O.Heady and J.L. Dillon op.cit. p 102-107 and p 195-217 also see E.O.Heady "Technical Considerations in Estimating Production Functions" Resource Productivity Returns to Scale and Farm Size Iowa State 1956 Ames p 3-15
33. M. Ezekiel and K.A.Fox Methods of Correlation and Regression Analysis John Wiley 1959 New York
34. J.W.Kendrick Productivity Trends in the US NBER 1961 Princeton see comments on real input and output p 6-8 and p 20-56. Also see J.W.Kendrick Productivity Trends: Capital and Labour Occasional Paper 53 NBER Princeton p 4-6

(c) net output or output of domestic agricultural resources. Corresponding to the distinctions of output we have in inputs (a) total input of farm factors and intermediate products and (b) net factor input.

The problem of identification[35] is important in the context of the Cobb-Douglas function employed. For example, if the amount of capital used by an industry and the amount of labour employed influence the prices of these inputs, then the simple least-squares estimates will not yield unbiased estimates of the parameters. The issue of identification thus extends to various assumptions about input markets, output markets and the use of alternative measures of inputs and outputs. Clearly ones ability to estimate the production function would depend on the specification of the nature of the system.

Thus, the rank and order conditions of identification will be satisfied if the subsystem selected conforms to certain conditions and specifications of the overall system. Some decision is necessary to delimit the implicit assumptions to conform to the overall system; even though no subsystem can be truly satisfactory.

A subsystem which includes the product market and supply functions of the inputs in addition to the production functions may require various assumptions to permit estimation.

---

35. Franklin M. Fisher The Identification Problem in Economics McGraw Hill 1966 New York
Also see Marc Nerlove Estimation and Identification of Cobb-Douglas Production Functions North Holland 1965 Amsterdam

For example, the assumption of perfect competition in factor markets making factor demand by the industry ineffectual in regard to price, enables the use of a single equation, which is considered adequate for identification. Since inputs are defined broadly as labour and capital, an assumption of perfect competition is consequently not too unrealistic.

Some of the most widely known and used comprehensive measures are given below. It may be found convenient to use certain symbols corresponding with already established concepts. An O.E.C.D. study Concepts of Productivity Measurement in Agriculture on a National Scale[36] has done this, and uses the following symbols.

(a) INPUT CATEGORIES	L	Labour	original factors of production
	C	Capital (interest only)	
	S	Land	
	M	Intermediate Products, including Capital consumption or depreciation	
	D	Capital depreciations	
(b) OUTPUT	O_c	Total output of final agricultural products	
	O_{fn}	Net factor output of the agricultural sector	
(c) AGRICULTURAL AND NON AGRICULTURAL SECTOR	F_a	Total net factor input	Subscript (a) used for agricultural sector
	$F_a = L_a + C_a + S_a$		

36. Concepts of Productivity Measurement in Agriculture on a National Scale Documentation in Food & Agriculture #57 OECD 1961 Paris p 30

F_b	= Sum of inputs of non agricultural sector	Subscript (b) is used for non agricultural sector
F_b	= $L_b+C_b+S_b$; the Output is M	

In addition, the numerical subscripts are used to indicate time periods 1 and 2.

Thus we have, "three concepts of Comprehensive productivity measure....defined with the help of symbols:

A. Relating to the agricultural sector only:

(i) Total Productivity (P_t)[37]

(ii) Net factor productivity (P_{fn})

---

37. Not to be confused with Kendrick's gross total factor productivity. It would appear that Kendrick uses a concept of gross factor productivity in a special sense. Whilst his definitions of gross and net output are identical, and that of net input (including capital depreciation) is similar in principle; when it comes to total or gross input he deviates from the accepted usage. Output is not made to correspond with inputs. Kendrick relates both total and net output to net factor input to obtain a formula expressed in symbols:

$$\frac{O_{t2}}{F_{a2}+D_2} : \frac{O_{t1}}{F_{a1}+D_1}$$ [INPUT <u>INCLUDING</u> CAPITAL CONSUMPTION]

$$\frac{O_{t2}}{F_{\hat{a}2}} : \frac{O_{t1}}{\bar{F}_{\hat{a}1}}$$ [INPUT EXCLUDING CAPITAL CONSUMPTION]

see <u>Concepts of Productivity Measurement in Agriculture on a National Scale</u> OECD 1961 Paris p 35-36

B. Relating to all the consolidated production stages including the agricultural sector

(iii) Consolidated total productivity (CP_t)

By using the....symbols we can define our three productivity measures as follows:

(i) $$P_t = \frac{O_{t2}}{F_{a2} + M_2} : \frac{O_{t1}}{F_{a2} + M_1}$$

(ii) $$P_{fn} = \frac{O_{t2} - M_2}{F_{a2}} : \frac{O_{t1} - M_1}{F_{a1}} = \frac{O_{fn2}}{F_{a2}} : \frac{O_{fn1}}{F_{a1}}$$

(iii) $$CP_t = \frac{O_{t2}}{F_{a2} + F_{b2}} : \frac{O_{t1}}{F_{a1} + F_{b1}} = \frac{O_{fn2} + M_2}{F_{a2} + F_{b2}} : \frac{O_{fn1} + M_1}{F_a}$$

An advantage of such measures of productivity is that they permit the comparison of different situations, "....(a) for practically identical products or groups of products:

(i) over time (at least two periods)

(ii) geographically (at least two regions or countries)

(b) for nonidentical products or groups of products."[39]

With careful definitions of the concept of productivity, it is possible to limit the margin of uncertainty quite markedly; also by clearly understanding the purpose

38. Ibid p 31

39. Concepts of Measurement of Productivity in Agriculture on a National Scale OECD 1961 Paris p 42

for which the measure is intended, it is possible to eliminate certain bias which might otherwise distort the results.[40]

Yet another extremely important/significant element is the choice of weights and the set of prices selected for the weighting.[41] [Not merely the choice of representative base years, but also the shift in relative price relationships of input items are of extreme significance to the results.]

The purpose of weighting is to aggregate the various input and output items, particularly where nonidentical goods or groups of products are involved. The widely different price structure over the two periods and/or possibly in two different locations has to be kept in mind.

Generally speaking, the economic significance of the components of both output and input are most adequately measured by their price per unit - strictly speaking this is true only under conditions of perfect competition in both product and factor markets. Prices of agricultural products are influenced to varying degree by public policy and may therefore, at least on a national scale, be selected as weights for aggregating output and input items. However, the prices selected can only be factor prices rather than

---

40. ibid. p 41-42 and p 48

41. ibid. p 49-50 and L.A.Vincent "The Main Formulae for Productivity Measurement in a National Economy or Sector" _Productivity Measurement Review_ OEEC May 1961 No 25

market prices. Since the object of productivity measurement is to determine difference (in relationships) between two countries/regions or two time periods, the influence of changes in the price component is eliminated in the comparison. The common practice is to use constant prices for measuring the output and input items i.e. the aggregation due to differences in quality.

In principle, the weighting problem is the same whether differences are measured over time or between different regions. Obviously the critical factor is the degree of difference between two sets of relative prices and the composites of inputs and output items.[42]

The particular technique chosen to measure productivity is that developed by Barzel.[43] In so/as much that it relates output per unit of input as a measure of productivity, it is similar to that used by Fabricant, Abramowitz, Solow, Schultz, Kendrick, etc. Barzel's argument in support of the procedure adopted suggests:

(i) Inadequate knowledge of the production process

---

42. Concepts of Measurement of Productivity in Agriculture on a National Scale OECD 1961 Paris p 50. Also see Output Input and Productivity Measurement NBER 1961 Princeton p 263 and D.Paige and G.Bombach A Comparison of National Output and Productivity OEEC 1959 Paris p 43

43. Yoram Barzel "Productivity in the Electric Power Industry 1929-1955" Unpublished PhD Dissertation Department of Economics University of Chicago 1961 Chicago

leaves us with the uncomfortable knowledge that we do not know the functional form relating inputs to outputs. Consequently any functional form we adopt can only be an approximation, leaving the burden of proof of appropriateness of the function used as an additional problem. The ideal method of studying and measuring changes in productivity would be to follow shifts in the production function which is fully specified in form - implicitly taking into account economies of scale, and in conventional inputs - labour, capital, raw materials, management, etc.

(ii) Uncertainty as regards the "neutrality" of shifts in the production function.[44] The uncertainty relates/refers to the possibility of excess capacity.

(iii) Barzel categorises any attempt to measure productivity and simultaneously derive the production function from the same data as misleading; consequently his technique is valuable in that it eliminates any estimation of the production function as part of the calculation of a productivity measure. Barzel assumes that the production function is fitted without allowing for technical change in fitting the production function. Lave sharply criticizes Barzel

---

44. E. O. Heady Economics of Agricultural Production and Resource Use Prentice Hall 1952 Englewood Cliffs p 453-455. Heady also draws attention to this aspect but includes it under discussion of the several types of uncertainty facing the agricultural producer.

for this and suggests that there is an implicit production function.[45]

(iv) Whereas the conditions/assumptions of this technique are heroic - i.e. (a) of no economies of scale; (b) of pure competition; and (c) of no changes in marginal productivity of the inputs between the two years compare. The "....restrictions imposed by the main alternative - the production function approach - are much more serious."[46]

If O = output quantity

I_i = input quantities

P_i = input prices

MP_i = input marginal productivities

Q_{12} = productivity index defined as productivity in year 2 relative to productivity in year 1 (subscripts 1, 2 refer to years 1 and 2 respectively.)

Then assuming (i) a production function, homogenous of first degree i.e. no economics or diseconomics of scale, the relation $O = \sum I_i MP_i$ holds . . . . (1)

(ii) competitive operation, i.e. the factors are paid the value of their marginal product, we can replace relation (1) with the relation

$$\underset{\text{(physical units)}}{O} \propto \underset{\text{(money units)}}{\sum I_i P_i} \quad \ldots\ldots\ldots \quad (2)$$

($\propto$ denoting proportionality)

45. Lester B. Lave Technological Change: its Concepts and Measurement Prentice Hall 1966 Englewood Cliffs p 48-63
46. Barzel (p 4) "The production function approach....requires the specification of the production function, and of the pattern of shifts in the function over time. This is clearly much more restrictive and much more difficult to handle than the output per unit of input approach."

Linear homogenity is sufficient but <u>not</u> really necessary. The lowest point on the average cost curve is adequate if considering the individual firm but when considering the whole industry both the absence of externalities <u>and</u> a competitive product market are necessary.

Stating relation (2) with specific reference to year 1 we have:

$$O_1 \propto \sum I_{1i} P_{1i} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (2')$$

Suppose, that inputs in year 2 are assigned marginal productivities proportional to their prices in period 1, then we have the relation

$$O_2^* \propto \sum I_{2i} P_{1i} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (3)$$

O^*_2 is the output that would have been produced in year 2 ahd the production and factor marginal productivities remained constant. O^*_2 would have been the production in year 2 if input quantities are those actually used in year 2, but under "technical" conditions of year 1. O_2 is the output actually produced in period 2 under technical conditions different from those of year 1. O_2 is produced with the same inputs but under the technical conditions of year 2. Hence, the ratio of the changed production from year 1 to year 2. We thus have:

$$Q_{12} = \frac{O_2}{O_2^*} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (4)$$

When relation (3) is divided by (2') we obtain an equality, instead of a proportionality.

$$\frac{O_2^*}{O_1} = \frac{\sum I_{2i} P_{1i}}{\sum I_{1i} P_{1i}} \quad . \; . \; . \; (5)$$

Transfering O_1 we have

$$O_2^* = O_1 \frac{\sum I_{2i} P_{1i}}{\sum I_{1i} P_{1i}} \quad . \; . \; . \; . \; . \; . \; . \; (5')$$

Restating relation (4) and substituting (5') into it, we obtain:

$$Q_{12} = \frac{O_2}{O_1} \frac{\sum I_{1i} P_{1i}}{\sum I_{2i} P_{1i}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

It is interesting to note that all equations to the right of the sign of equality are observable; enabling the productivity measure Q_{12} to be computed.

For relation (6) to hold, the assumptions: (a) no economies of scale, (b) of competitive conditions, and (c) no changes in the marginal productivity of inputs between the two years compared, must be strictly adhered to. Alternately, the effect of any violation of these conditions must be determined.

This avoidance of the necessity of any specification of the production function and of the pattern of shifts in the function over time is valuable for purposes of arriving at a productivity measure. The only assumption made, if input weights (prices) are changed frequently, is that of no economies of scale. As mentioned earlier, Lave suggests that, while there is no explicit production function, there is an implicit one.

However, the understanding of what components contribute towards the level of productivity, and whether the resources being used are used efficiently can only come from some other system. For this reason we use a separate technique, devised by Wolfson[47] that enables us to develop a production function which permits: (i) measurement of area differentials in marginal productivities of the factor inputs, and (ii) estimation of the effect of weather or a agricultural output. The former will assist in studying resource allocation, the latter in estimation of the quantitative effects of an extremely important variable, namely rainfall.

Wolfson's technique is based upon the following assumptions: (i) Payments to factors are related to the marginal value products of those factors. Under conditions of pure competition in the product market "....the marginal value product of a factor of production is equivalent to the product of output price and the first partial derivative of the production function with respect to that factor of production."[48] (ii) This necessarily requires a knowledge

---

47. R.J. Wolfson "An Econometric Investigation of Regional Differentials in American Agricultural Wages: Econometrica Vol 26 1958 p 225-257. The objective of that study was primarily to account for variations in farm wage rates. The form of the production function chosen, however, incidentally permitted an estimation of the effect of weather on agricultural outputs. The type of cross section data available to, and used by Wolfson suggested a possibility of application to our purposes.

48. R.I. Wolfson (Ibid) later cites Schultz, Boulding and Ducoff in support of the contention "....that agriculture is an industry verging on pure or perfect competition." p 237

of both the production function and the input and output prices.[49] (iii) Farmers are price-takers in factor markets. (iv) The function chosen is a technical production function, which seeks to relate physical inputs to physical output; is of the Cobb-Douglas type in which the sum of the exponents are not restricted. The exponents of the production function are equal to the factor cost shares. (v) Except for local conditions within the different regions being considered, common technologies are being employed.[50]

For: X_o = physical amount of output

X_i = physical amount of i^{th} input ($i = 1,2,3,...n$)

a_i = production elasticity of the i^{th} input

A = constant

P_i = prices of the i^{th} input

---

49. R.J. Wolfson (Ibid) "....the producer's planned output and planned use of inputs....[is]....based upon the following considerations: a. his knowledge of his production function; b. his belief that costs of inputs will not change much from last year (if they do, he will be in a fairly flexible position with respect to many of them anyway); c. his belief that the price of hsi output may change radically, but that he is in no position to estimate which way it will change, or to what degree, and therefore will assume at the outset that it will be the same as for the crop year just ended." p 239

50. R.J. Wolfson (Ibid) There exists"....within a group of producers, technical homogenities (that is, certain common practices and beliefs about production technique which we might designate as common technology) ...." p 240

$\overline{P_o}$ = price of output

$\overline{P_o}$ = last year's output price

W_j = Factors unknown and of a random nature

S = numbers of types of climatic conditions entering regression

R_{jl} = actual weather observations (j = 1,2,3,...m)

[subscript j indicates individual observations]

log U_j = a random variate normally distributed with a mean of zero and a variance of

and is the final residual.

Then: $X_o = A X_1^{a_1} X_2^{a_2} X_3^{a_3} \ldots\ldots X_n^{a_n} = A \prod_{i=1}^{n} X_i^{a_i}$ .... [1]

$$a_i = \frac{p_i X_i}{p_o X_o}$$ THE EXPONENTS OF THE PRODUCTION FUNCTION WILL BE EQUAL TO THE FACTOR SHARES [2]

$$a_{ij} = \frac{p_i X_{ij}}{\overline{p_o} X_{oj}}$$ THE SUBSCRIPT j DESIGNATES INDIVIDUAL OBSERVATIONS E.G. PRODUCERS OR REGIONS [3]

The p_i are relatively stable, changing little from year to year. The p_o are comparatively volatile, being exogenous and outside of the producer's control. The producer attempts to predict p_o on the basis of many factors - on the demand and supply side of crop production. These include weather, foreign demand and other factors including last year's price as the expected value of this year's price.

And $X_{oj} = A_j \prod_{i=1}^{n} X_{ij}^{a_{ij}}$ . . . . [3']

SUBSTITUTING FOR a_{ij}, WE HAVE $X_{oj} = A_j \prod_{i=1}^{n} X_{ij}^{\frac{p_i X_{ij}}{p_o X_{oj}}}$ . . . . . [4]

$\hat{a}_i = \left[\prod_{j=1}^{m} a_{ij}\right]^{1/m}$ GEOMETRIC MEAN OF OBSERVED a_{ij}'s MAXIMUM LIKELIHOOD ESTIMATE . . . [5]

Relations (3) and (3') give the producers planned output and planned use of input based upon: (a) knowledge of producer's production function; (b) producer's belief that input costs do not change much from the previous period; and (c) producer's assumption that output price will continue unchanged.

$$\hat{X}_{oj} = A \prod_{i=1}^{n} X_{ij}^{\hat{a}_i} \quad \left[\text{PRODUCTION PLANNING FUNCTION FOR EACH INDIVIDUAL FIRM}\right] \quad . . . . . \quad [6]$$

and

$$X_{oj} = \hat{X}_{oj} \cdot w_j = A \left[\prod_{i=1}^{n} X_{ij}^{\hat{a}_i}\right] \cdot w_j \quad . . . . . . \quad [7]$$

IT IS POSSIBLE TO SPLIT w_j INTO WEATHER AND RESIDUAL FACTORS[51] — PROVIDING A REGRESSION $\log A w_j$ AGAINST RELEVANT WEATHER VARIABLES

Then, converting the relation into logarithmic form we have:

$$\text{estimated } \log A\, W_j = K + \sum_{\ell=1}^{s} b_\ell R_{j\ell} \quad \left[\text{INCLUDING ONLY THE RELEVANT WEATHER VARIABLES}\right] \quad . . \quad [8]$$

Where s = number of types of climatic conditions which enter the regression, and R_{jl} are the actual weather observations.

$$\log A\, w_j = k + \sum_{\ell=1}^{s} b_\ell R_{j\ell} + \log u_j \quad . . . . . \quad [9]$$

$$X^*_{oj} = \left[\prod_{i=1}^{n} X_{ij}^{\hat{a}_i}\right] \cdot 10^{k} + \sum_{\ell=1}^{s} b_\ell R_{j\ell} \quad . . . . . \quad [10]$$

[FINAL ESTIMATE OF OUTPUT]

$$X_{oj} = X^*_{oj} \cdot u_j \quad \left[\text{ACTUAL OUTPUT}\right] \quad . . . . . . \quad [11]$$

---

51. based on a number of agronomic studies, some of which are mentioned elsewhere.

In our objectives, we stated our interest lay in investigating the effect of some independent variables in addition to rainfall, namely size of holdings or scale, irrigated and unirrigated land, size of family, etc. In effect this requires the study of the subclasses (subgroups) or class-differences and involves the use of dummy variables[52] or zero-one[53] variables as they are sometimes called.

Dummy variables are frequently used with variables the influence of which is normally known, but of which some estimate or measurement is desired. Their use in econometric research is indicated when:[54] ".... 1. The original observations can be divided with logic into mutually exclusive classes or groups..." The use of dummy variables allows

---

52. Daniel B. Suits "Use of Dummy Variables in Regression Equations" Journal of American Statistical Association 1957 Vol 52 p 548-551. Also M. Davies "Multiple Regression Analysis withAdjustment for Class Differences" Journal of American Statistical Association Sept 1961 p 729-735
For description of use in regression analysis and econometric research see John Johnston Econometric Methods McGraw Hill 1963 New York p 221-228 and Arthur S. Goldberger Econometric Theory Wiley 1964 New York p 218-231

53. W.G. Tomek "Using Zero-One Variables withTime-Series Data in Regression Equations" Journal of Farm Economics Nov 1963 Vol 45:4 p 814-822. Technically speaking zero-one variables are only one form of dummy variables; the teem "characteristic variable" would be consistent with the division of data into mutually exclusive classes.

54. W.G. Tomek op.cit. p 814

for class effects and perhaps more significantly the specific analyses of class effects, and ".... 2. The effect of the class difference is to change the level (intercept) of the regression equation without changing the slope coefficient." The analysis may require a comparison of the class (e.g. seasonal) intercept with the average (e.g. annual) intercept.

The use of dummy variables involves additional constraints on the parameters of regression equations. When dealing with a single class or system of classes it is advisable either to set the constant term in the equation to zero or to omit one of the dummy variables from the equation. When dealing with several systems of classes it is advisable to delete one dummy variable from each system.

Studies indicate that the element of distortion or bias due to faulty specification introduced through the use of dummy variables can be checked: (a) by varying the base, (b) by eliminating use of dummy variables(and comparing results with undifferentiated classes or groups), and (c) by verifying that effect of any one of the dummies is not greater than that of the whole[55] independent variable.

---

55. Whole to signify "unbroken, undivided, undifferentiated, aggregated" (i.e. not disaggregated). In this connection see Zvi Griliches "Specification Bias in Estimates of Production Function" JFE 1957 p 8-18 and Yair Mundlak "Empirical Production Function Free of Management Bias" JPE 1961 p 44-56

Part of the bias is on account of two factors - interaction and additivity. In any production function "....like the dependent variable the choice of independent variable is usually a compromise between what we would like and what we can afford."[56] Interaction is due to the fact that the effect of one independent variable depends on the value of another. Additivity occurs when independent variables do not interact, thus one independent variable can be added to the effect of the other to get the total effect of the two combined.[57]

Now, adopting Wolfson's equation expressing the relationship between output and inputs we have:

$$X_o = \left[\Pi_{i=1}^{n} X_{ij}^{\hat{a}_i}\right] A.W$$

$$\propto$$

$$X_o^* = \left[\Pi_{i=1}^{n} X_i^{\hat{a}_i}\right] 10^{K + \Sigma_{l=1}^{s} b_l \ell_{jl}} \qquad \text{where } X_o = X_o^* . U_j$$

Since we have differences in:

(1) Labour a. male b. own: family
female hired: rented
child

(2) Capital a. Could assume that Rs 100 worth of capital is same all over country i.e. homogenity of capital

b. size of capital investment:

---

56. Daniel B. Suits <u>Statistics: An Introduction to Quantitative Economic Research</u> Rand-McNally 1963 Chicago p 108 also "Use of Dummy Variables in Regression Equations" (op.cit.) p 548-551
57. Daniel B. Suits (op.cit.) on Interraction and Additivity (p 83) and on Hidden Interaction and Hidden Correlation (p 111-115)

(i) excluding land (Rs)

0-1000 1000-2000 ; 2000-3000 3000-4000 ;
(0-2000) (2000-4000)

4000-5000 5000-6000 ;
(4000-6000)

6000-7000 7000-8000 ;
(6000-8000)

8000-9000 9000-10,000 ;
(8000-10,000)

10,000-11,000 11,000-12,000 ;
(10,000-12,000)

12,000-13,000 13,000-14,000 ;
(12,000-14,000)

over 14,000

(3) Land -Irrigated
-Unirrigated

(4) Size or Scale of Holdings: 0-5; 5-10; 10-15; 15-20; 20-25; over 25

The problem here is to use dummy variables to obtain solutions for the subclassifications in each input component.

When introducing dummy variables, one alternative is to add the component $\sum \lambda_i d_i$ to the regression equation. The Wolfson equation would then read:

$$X_0^* = \left[\prod_{i=1}^{n} X_i^{\hat{a}_i}\right] 10^{K + \sum_{l=1}^{s} b_l R_{jl}} \left[\lambda_i d_i\right]$$

The insert [$\lambda_i d_i$] would solve as follows for K_1 Mutually exclusive classes in a single classification:

$$[\lambda_i][d_i]_{j=1}^{j=k_i} = \lambda_1 d_1 , \lambda_2 d_2 , \lambda_3 d_3 , \ldots\ldots \lambda_{k_i} d_{k_i} \quad (j = 1, 2 \ldots . k_i)$$

and would be represented

$$\sum_{j=1}^{j=k_i} \lambda_j d_j$$

For t systems of classification, of which the i^{th} contains K_i mutually exclusive classes, we have:

$$[\lambda_i][d_i]_{i=1}^{i=t} = \begin{array}{lllll} \lambda_{11} d_{11} & \lambda_{12} d_{12} & \lambda_{13} d_{13} & \ldots\ldots & \lambda_{1k_i} d_{1k_i} \\ \lambda_{21} d_{21} & \lambda_{22} d_{22} & \lambda_{23} d_{23} & \ldots\ldots & \lambda_{2k_i} d_{2k_i} \\ \cdot & & & & \\ \cdot & & & & \\ \cdot & & & & \\ \cdot & & & & \\ \lambda_{t1} d_{t1} & \lambda_{t2} d_{t2} & \lambda_{t3} d_{t3} & \ldots\ldots & \lambda_{tK_i} d_{tK_i} \end{array}$$

and would be represented:

$$\sum_{i=1}^{i=t} \sum_{j=1}^{j=k_i} \lambda_i d_i$$

The regression equation would then read:

$$X_o^* = \left[\prod_{i=1}^{n} X_i^{\hat{a}_i}\right] 10^{k} + \sum_{\ell=1}^{s} b_\ell \ell_{j\ell} \left[\sum_{i=1}^{i=t} \sum_{j=1}^{j=k_i} \lambda_{ij} d_{ij}\right]$$

The solution of the regression equation containing the dummy variables mentioned in the first alternative requires the setting up of a zero-one matrix. The two types of matrices possible are indicated below.

Thus d_{ij} =

$$\begin{array}{cccccccc} 1 & 0 & 0 & 0 & 0 & \ldots\ldots & 0 \\ 0 & 1 & 0 & 0 & 0 & \ldots\ldots & 0 \\ 0 & 0 & 1 & 0 & 0 & \ldots\ldots & 0 \\ 0 & 0 & 0 & 1 & 0 & \ldots\ldots & 0 \\ 0 & 0 & 0 & 0 & 1 & \ldots\ldots & 0 \\ \cdot & & & & & & \cdot \\ \cdot & & & & & & \cdot \\ \cdot & & & & & & \cdot \\ 0 & 0 & 0 & 0 & 0 & \ldots\ldots & 1 \end{array} \quad \text{or} \quad \begin{array}{cccccccc} 0 & 0 & 0 & 0 & 0 & \ldots\ldots & 0 \\ 1 & 0 & 0 & 0 & 0 & \ldots\ldots & 0 \\ 0 & 1 & 0 & 0 & 0 & \ldots\ldots & 0 \\ 0 & 0 & 1 & 0 & 0 & \ldots\ldots & 0 \\ 0 & 0 & 0 & 1 & 0 & \ldots\ldots & 0 \\ 0 & 0 & 0 & 0 & 1 & \ldots\ldots & 0 \\ \cdot & & & & & & \cdot \\ \cdot & & & & & & \cdot \\ 0 & 0 & 0 & 0 & 0 & \ldots\ldots & 1 \end{array}$$

(Zero-One <u>diagonal unity</u> matrix) (standard Zero-One matrix)

Using the example of the diagonal unity matrix, because $\lambda_{ij} d_{ij}$ are mostly multiplicants of zero, and only d_{11}, d_{22}, $d_{33}, \ldots . d_t d_{ki}$ respectively are equal to unity, only $\lambda_{11}, \lambda_{22}, \lambda_{33}, \ldots \ldots \lambda_t \lambda_{ki}$ are included.

One immediate disadvantage of this procedure is that it requires the setting up of a very large matrix. On the other hand, it does permit the consideration of additivity - more than one set of dummies permit additive interaction only.

The second alternative is to follow a relatively simple tabular procedure and allocate dummies d_i ($i = 1,2,3,\ldots t$) to the mutually exclusive classes within several classifications as if they were part of a single classification. Regression equation would then read:

$$X_o^* = \left[\prod_{i=1}^{n=1} X_i^{\hat{a}_i}\right] 10^{K + \sum_{e=1}^{s} b_e \ell_{je} \left[\sum_{i=1}^{i=t} \lambda_i d_i\right]}$$

Finally a brief statement in defense of the techniques selected. The use of specific productivity measures was rejected in favor of the total or aggregate measures, as being more suited to the measurement of productivity in agriculture and perhaps because of this, expecially applicable to the problems of underdeveloped regions.

The first, identified as the Barzel method, permits the measurement of interregional differentials in aggregate or total productivity (a ratio of output per unit of inputs) based on a single money valuation of inputs for a chosen base period. The calculations are simple arithmetic procedures, and the method permits the inclusion of subclasses of inputs in the analysis of results. Barzel's technique eliminates any explicit estimation (specification) of the production function and consequently does not require any proof of appropriateness of the function used. Further, the method avoids the specification of shifts in the function over time. Barzel also avoids the restrictive assumptions made by Kendrick. The method yields readily available results in the form of a productivity ratio which is simple to analyse and to compare with the base period.

The second method adopted contains a production function and equations of marginal productivity (with measurement of area differentials in marginal productivities to account for variations) for each of the factor inputs. "The share of the i^{th} factor payments in the value of the output is set equal to the production elasticity coefficient except for random deviation v_{ij}." Wolfson estimates production elasticities from marginal productivity equations, then substitutes these estimated values into the production function - using them to estimate residual factors (mainly climatic and weather). Contrast this with Solow who estimated a series on technological change from marginal productivity equations and then used these values to estimate output elasticities from the production function.

The method chosen, identified as the Wolfson method, was selected because it facilitates understanding of what contributes towards the level of productivity and whether the resources being used can only come from some other system. This method employs a single equation which is based on the Cobb-Douglas production function and yields results which are relatively simple to analyse. In addition it permits the inclusion of several variables and subclasses of variables, including weather, rainfall and climatic factors explicitly, separating them from "random error". Though an incidental part of the original model, this latter element was included to test the marginal productivity equations and technical equations in combination.

Further it permits the inclusion of time as a variable without conflict. This is particularly important in the estimation of year to year change.[58] Consequently, Wolfson

58. It has been suggested that for estimating year-to-year technical change, two methods may be used. The first is the arithmetic calculation of annual changes in the residual changes of productivity - in the form of a ratio series of output per unit of input. The absolute quantities of inputs are weighted by given arithmetic weights (as suggested by Kendrick, Solow et al) usually derived from market shares. Alternately, weighting the logarithms of input quantities by given weights (as suggested by Griliches) derived from fitted production functions. The second method is to employ regression methods wherein time-periods are used as additional variables to fit a trend to technical change. Alternately to compute annual indices of productivity from the fitted production function itself. This is done through the covariance matrix method in which cross-section data is combined with time-series data. In this connection see: Irving Hoch "Estimation of Production Function Parameters Combining Time-Series and Cross Section Data" Econometrica XXX (Jan 1961) p 34-53

succeeds in obtaining a more than nebulous measure of technical progress. Contrast this with Solow who succeeded essentially in deriving a mechanical trend varying in some fixed manner. The Wolfson method is probably more consistent in terms of the probability implications of the model.

Sources and Adjustment of Data

In this section, data[59] relating to the production of wheat in selected regions of India is discussed and arranged, in accordance with the procedures suggested earlier (and discussed at length in Chapter II). An attempt will be made to treat the variables separately; justifying their consideration, indicating their sources, any changes introduced and various problems and considerations involved in selecting and arranging the data. Finally, any assumptions made in respect of the data will be stated.

The bulk of the information is drawn from _Studies in the Economics of Farm Management_[60] dealing with the regional economy of selected states. _The Studies in the Economics of Farm Management_ were initiated by the federal government of India. The individual studies, conducted in six typical[61] regions of the country--Bombay, Madhya Pradesh, Madras, Punjab, Uttar Pradesh and West Bengal--extended over the period 1954-55 to 1956-57, except for Madhya Pradesh which was limited to 1955-56 and 1956-57.

---

59. For details relating to sources and adjustments to data please see Appendix 1.

60. India (Republic) Directorate of Economics and Statistics _Studies in the Economics of Farm Management_ Ministry of Food and Agriculture Government of India 1963 Delhi

61. These six typical regions were selected on the basis of their "....distinctive soil, climate and soil complexes." Later a seventh region, Orissa, was added to the _Studies_

The studies were "....initiated and coordinated by the Directorate of Economics and Statistics, Ministry of Food and Agriculture...(and)...sponsored and financed by a grant from the Research Programmes Committee of the Planning Commission." Reports were published on the basis of each year's investigation, followed by a consolidated or combined report at the end of the research period.

The regions, selected for their representative character, were further divided into two more or less homogenous zones, from which random selection of a certain number of villages was made for detailed study.

It would seem that the Studies were initiated, more to establish an analytical picture of conditions as they existed at the time of the Studies, rather than to follow the trend of economic change in agriculture. Because of the unique character of the Studies--being a single shot affair, there is no time series, properly speaking. The Studies make available some significant cross-section data for a limited period.

CHAPTER 3 : MEASURED DIFFERENTIALS IN INTERREGIONAL PRODUCTIVITY

The results of this study are based on two separate procedures. The first relates to the calculation of productivity ratios by simple statistical (arithmetic) procedures. The technique employed, attempts to provide a measure of total or aggregate productivity, irrespective of its sources, in terms of output per unit of input(s). The second relates to estimation of area differentials in marginal productivities of factors, with a view to studying resource allocation, and the quantitative effects of particular independent variables or classes of variables. The technique employed is relatively complicated, involving methods of correltation and regression analysis.

1. Productivity Ratios

The technique employed required the selection of a base period--the region Punjab during 1954-55 was selected for period 1. Thus we have three constant values, starting with the calculated value of physical output (output <u>times</u> price of output) and extending over the base period input quantities and corresponding input prices.

Calculations insert the values of physical output and input quantities for subsequent observations--unirrigated and irrigated regions, different size groups, periods and regions. In all cases the input quantities are weighted by input prices of the base period.

Two sets of productivity ratios were obtained. The first dealing with all sizes, the second dealing with the overall size of holding.

In the case of the former (see Table 1) productivity ratios - the selected base region and year (Punjab 1954-55) for the size group 0-5 acres does not indicate any special productivity features. The table indicates a sharp increase in overall productivity with the increase in size group of holdings. Other states, notably Madhya Pradesh indicate extremely high productivity, this is more likely than not due to the fact that traditional or conventional inputs are likely more important than those which are employed (and'money-value' quantified) in the other regions where market economies are both more firmly and widely established.

Punjab

Productivity ratios for the Punjab are not nearly as high as one would expect. The expectation is that the relative prosperity of Punjab is based on a more efficient agriculture and at that with specific reference to the major staple cereal. Generally speaking, the irrigated tract productivity ratios are twice those of the unirrigated tracts. In some cases the ratio is higher, due most probably to extraneous factors. In the Punjab the pattern of productivity ratios rising with increases in scale of holding, emerges very clearly for irrigated land. There also seems to be a tendency for the ratio to increase with the seale for unirrigated land. In both categories of land there is a gradual increase in productivity ratios through the first three sizegroups, followed by a consistently large increase for the 20 & above acres. This in part is almost certainly due to the use of improved, manufactured inputs and in several cases commercial management provided by entrepreneurs moving into the rural sector.

Uttar Pradesh

The results for Uttar Pradesh are much more consistent. The productivity ratios for the irrigated tracts are between one and one-half and twice those of the unirrigated tracts. There are two exceptions; the first in 1954-55 when the ratio for the unirrigated tract sizegroup 20 & Above acres was almost twice that of the irrigated tract in the same sizegroup. The second was during 1956-57 when the productivity ratio for the sizegroup 0-5 acres was almost the same for both unirrigated and irrigated tracts. The region displays a spectacular upward jump in the 10-20 acres sizegroup for irrigated tracts. In 1954-55 this was followed by a sharp decline and in 1956-57 was followed by a very small increase for the next sizegroup. On the other hand, the spectacular increase takes place in the 20 & Above acres sizegroup in the unirrigated tracts during the first two years and less noticeably during 1956-57.

<u>Gujarat</u>

The table of productivity ratios for Gujarat also indicates that the irrigated tracts are between one and one half to twice as "productive" as unirrigated tracts. For two of the three year study period the sizegroup 0-5 acres indicates that no effort was made to grow wheat. In 1956-57 there is an instance of productivity ratios for unirrigated tracts being higher than those of the irrigated tracts in the 10-20 acres sizegroup, this was most probably due to an unique combination of favorable weather and climatic conditions. Two other instances of breaks from the general pattern occur during 1955-56 in the 0-5 and 5-10 acres sizegroups when the productivity ratio for irrigated tracts show themselves to be approximately 10 times and 5 times higher than unirrigated productivity ratios. During 1954-55 productivity ratios for irrigated tracts show a rapid increase up to 5-10 acres, decline for 10-20 acres and increase again for 20 & Above acres. The ratio for unirrigated tracts indicates a rapid decline after the 5-10 acres sizegroup. In 1955-56 the productivity for irrigated tracts ratio was high for 0-5 acres, showed a slight decline for the 5-10 and 10-20 acres sizegroups and a large increase for the 20 & Above sizegroup. In 1956-57 the ratio displays an even but substantial increase with the increase in sizegroups. For unirrigated tracts there is a substantial increase up to 10-20 acres sizegroup followed by a levelling off.

Maharashtra

Productivity ratios in Maharashtra for irrigated tracts are generally twice those of unirrigated tracts. During 1954-55 the 0-5 and 20 & Above acres sizegroups irrigated tract ratio was approximately three times that of the unirrigated tract. In 1955-56 the ratio for the irrigated 0-5 acre tract was lower than for the unirrigated holdings. During the same year the ratios for the two categories of land were close in the 20 & Above sizegroups. The irrigated tract ratio for the 0-5 acres sizegroup in 1956-57 was almost seven times that of the unirrigated holdings. During 1954-55 the productivity ratios rose with the increase in sizegroup in the irrigated category. In the same land category the productivity ratios during 1955-56 and 1956-57 increased with sizegroup up to 10-20 acres but subsequently declined slightly. In the case of unirrigated holdings the ratio indicates even substantial increases up to 10-20 acres sizegroup after which there was a levelling off.

Madhya Pradesh

The last region in the study presents some problems in as much that it has no irrigated land holdings for comparison. In addition there is no data for 1954-55, as that year was not included in the Studies. The productivity ratios (figures) obtained are comparatively very high i.e. relative to the base region, period and scale. It can only be concluded that the inputs of this region are in the category of "traditional or conventional" which are as yet not monetised and part of the market economy structure.

TABLE 1: PRODUCTIVITY RATIOS FOR DIFFERENT SIZES OF HOLDINGS

YEAR	SIZEGROUP	PUNJAB		UTTAR PRADESH		GUJARAT		MAHARASHTRA		MADHYA PRADESH	
		IRRIG	UNIRRI	IRRIG	UNIRRI	IRRIG	UNIRRI	IRRIG	UNIRRI	IRRIG	UNIRRI
1954-55		(*)					(**)				
	0-5	1.00000	1.89342	2.12462	1.18415	0.63206	0.00000	1.40045	0.40212	--	--
	5-10	2.22102	1.18317	2.55382	1.40930	5.98100	3.05380	1.99781	0.90547	--	--
	10-20	2.61467	1.44785	3.16802	1.81043	3.41792	2.58505	2.90498	1.07911	--	--
	20 & Above	3.49195	2.02911	1.46710	2.92482	4.94759	1.92986	4.09869	1.07835	--	--
1955-56											
	0-5	1.50086	0.78470	2.21284	0.94195	3.71874	0.36063	0.66996	1.61008	--	5.26918
	5-10	1.63824	0.87653	2.59941	1.10167	3.13098	0.68497	1.54759	1.09399	--	3.33630
	10-20	2.58704	1.41878	2.42390	1.30809	3.55193	2.08108	3.13110	2.09548	--	3.88802
	20 & Above	3.69649	2.14339	2.64464	1.94264	5.38866	2.04621	2.87653	2.17533	--	3.41924
1956-57							(**)				
	0-5	1.99205	0.36063	2.61180	1.66347	1.19066	0.00000	2.23754	0.31216	--	5.92022
	5-10	2.41972	1.33581	2.48897	2.00923	2.15666	1.09446	1.84484	1.14461	--	7.12201
	10-20	2.89743	1.62518	3.46204	2.22665	3.46788	4.18832	3.81323	1.82039	--	9.62067
	20 & Above	4.30690	2.54129	3.78465	2.42351	4.10494	2.43640	3.74799	1.86718	--	6.7305

(*) Base Year, Size and Category (**) No Unirrigated wheat for Sizegroup

The calculation of productivity ratios for the overall size of holdings was done on the same basis as that for the different sizes. The base selected was again Punjab during 1954-55. The results (see Table 2) indicate that Punjab of all the regions appears to have the highest productivity ratios in the irrigated categories, followed by Uttar Pradesh, Gujarat and Maharashtra. In the case of the unirrigated categories Madhya Pradesh indicated the highest productivity ratios, then Gujarat followed by Punjab which is very close to Maharashtra. Uttar Pradesh comes a poor low and last. Generally speaking, except for Gujarat where the productivity ratios for irrigated and unirrigated categories of holdings are very close, the productivity ratios for irrigated tracts are between one and one half times to twice those of unirrigated holdings.

TABLE 2: PRODUCTIVITY RATIOS FOR OVERALL SIZE OF HOLDING

REGION	YEAR	IRRIGATED	UNIRRIGATED
PUNJAB	1954-55	1.00000*	0.36729
	1955-56	0.88107	0.55741
	1956-57	1.01419	0.50071
UTTAR PRADESH	1954-55	0.80398	0.42287
	1955-56	0.76913	0.38483
	1956-57	0.87984	0.57145
GUJARAT	1954-55	0.71674	0.70465
(AHMEDABAD DISTRICT)	1955-56	0.75115	0.70831
	1956-57	0.85443	0.27320
MAHARASHTRA	1954-55	0.73538	0.54077
(NASIK DISTRICT)	1955-56	0.57095	0.59454
	1956-57	0.41282	0.10664
MADHYA PRADESH	1954-55	--	--
	1955-56	--	2.45421
	1956-57	--	1.21885

(*) BASE PERIOD AND CATEGORY

The chances are that a "truer" picture of productivity ratios for both the different sizes of holdings and the overall size of holding would be found in the results for irrigated categories of land. Certain factors - notably rainfall, climatic and weather conditions that affect the growth cycle, the development of the plant and its career as a standing crop, and finally the harvesting and recovery procedures - affect the yield, and are included only very indirectly in the calculation of productivity ratios. The wheat crop on irrigated holdings is not dependent on rainfall either for its planting or its growth. However, it still registers, via the yield, the depredations of frost, hail, snow, storm, insects, pests, rodents, plant diseases and excess precipitation causing waterlogging, flooding, etc. Of course in exceptional circumstances the consistent failure of rains might cause drought and water famine conditions in which the sources of irrigation may also dry up.

Unirrigated holdings are of course totally dependent on rainfall. Not merely the amount of precipitation but also the timing of rain are important for appropriate soil conditions for sowing and growing. Consequently the unirrigated tracts are subject to both deficiency and excess of rainfall and resultant soil moisture. They are subject to <u>all</u> the rainfall, climatic and weather factors <u>plus</u> all the other attendant risks and dangers affecting the wheat crop yield and size of the harvest.

It may be remembered that the calculation of productivity ratios has been made on the basis of the assumption that for our purposes all land is homogenous. That only those inputs considered in the calculations are significant. In reality, of course, the different regions are not strictly comparable, belonging as they do to unequal rainfall and different soil distribution regions. Until a method of measuring the effect of these additional factors can be employed, such assumptions will continue to be necessary.

2. Efficiency of Resource Use and Effects of Particular Variables

The technique employed is a form of regression analysis. This statistical technique is increasingly being used by economists engaged in empirical investigations partly on account of simplicity of procedures and the fact that it lends itself to further mathematical and statistical treatment.

In multiple regression analyses, the regression equation describes the path of the mean of the dependent variable (y) for all combinations of x_i ($i = 1,\ldots,n$) i.e. for every combination of fixed x's there is a distribution of y's. Each such distribution has a mean $\mu_{y \cdot x_1,x_2,x_3,\ldots x_n}$ and a standard deviation $\sigma_{y \cdot x_1,x_2,x_3,\ldots x_n}$

The term "multiple" regression signifies that y (dependent variable) is being explained in terms of several (two or more) independent variables. The solution of the regression equation yields a multiple correlation coefficient which is a measure of the "goodness of fit" of the least squares surface to the data and seeks to explain a number of independent variables taken together. The solution also yields a number of constants, (the α and β in the general form of the linear equation $Y = \alpha + \beta x$) which gives values for the pure constant B(O) and the coefficients of the x_i variables. These coefficients of the x_i variables are known as net regression coefficients i.e. they show the relation of the dependent variable to the x_1, x_2, $x_3 \ldots$, x_n respectively. Net regression coefficients are sometimes called partial regression coefficients.

The solution also provides a measure of the reliability of each of these partial coefficients, and enables an inference regarding the parameters of the population from which the sample of observations was taken. There is, however, the danger that the net regression coefficient will ascribe or attribute to any independent variable not merely the variation in the dependent variable which is directly due to that independent variable but also the variation which is due to such indpendent variables correlated with it as have not been separately treated in the study or analysis. The partial correlation coefficient is a measure of the amount of variation explained by one independent variable after the others have explained all they could.

Another item of information provided by the regression solution is a series of Beta weights, these indicated how

<u>much</u> <u>change</u> is produced by a standardised change in one of the independent variables when the others are controlled. The greatest advantage of the stepwise procedure is that intermediate results are obtained, which give valuable statistical information at each step in the calculation. Thus a number of intermediate regression equations are obtained. These intermediate regression equations are obtained by adding one variable at a time.[1]

The variable included or added is adjudged making the "best fit." The coefficients in turn represent the best values obtained when the individual specific variables are added to the regression equation. An interesting and important feature of the stepwise regression procedure is that the variable found significant early in the calculation and included in the equation may later be found to be less significant or insignificant, and be removed. This is done before an additional variable is added. Consequently, at least theoretically, only significant variables are included in the final regression equation.

---

1. Following the general form: $y = a + b_i x_i$ the intermediate regression equations read:

$$\left.\begin{array}{ll} y = a + b_1 x_1 & \ldots(i) \\ y = a' + b_2 x_2 & \ldots(2) \\ y = a'' + b_3 x_3 & \ldots(3) \\ \vdots & \quad\vdots \\ y = a^{n-1} + b_n x_n & \ldots(n) \end{array}\right\}$$

Where y is the dependent variable x_i is the independent variable, $(i = 1,..,n)$
a is a constant
b_i are the coefficients of the variables $x_i (i = 1,...,n)$

The use of dummy variables or more properly zero-one variables has been discussed in a previous chapter. Dummy variables are used where nonquantifiable economic relationships are known to exist. Qualitative comparisons and structural changes in the economic system are not quantifiable. Consequently, this is one of the areas where zero-one variables are employed, to represent changes in nonquantifiable variables. It may be mentioned here, however, that the protagonists[2] of dummy variables warn that if the changes are gradual, the use of dummy variables may not yield significant results.

In this study dummy variables have been employed to represent the nonquantifiable elements of interregional differences (five regions) over a period of three years for two categories of land (unirrigated and irrigated). In the case of one set of observations, scale of holdings (four classes of size group) have been assigned dummy variables.

Earlier, it has been mentioned that dummy variables have been employed in the regression equation for the different regions, over the three years that data is

---

2. Daniel B. Suits "Use of Dummy Variables in Regression Equations" Journal of American Statistical Association 1957 Vol 52 p 548-551. Also see W.G. Tomek "Using Zero-One Variables with Time-Series Data in Regression Equations" Journal of Farm Economics Nov 1963 Vol 45 p 814-822 and M. Davies "Multiple Regression Analysis with Adjustment for Class Differences" Journal of American Statistical Association Sept 1961 p 729-735

available. The three years data is represented by the base period and two dummy periods for year 1 and year 2. These estimate technical change in effect.

In the estimation of year to year technical change, it is possible to follow changes in the arithmetic productivity ratio, with either arithmetically weighted[3] inputs or to assign the logarithms of input quantities given weights.[4] These weights are derived from market shares and fitted production functions respectively. The second method of estimating technical change is to employ the time period or number of years as a variable to fit a trend to technical change in a regression equation. The regression method employs "the covariance matrix method with time series data, often using a series of dummy variables."[5]

So long as capital values are employed as measures of available capital rather than utilized capital, it is possible to have some confusion about measurement of

---

3. R. Solow "Technical Change and Aggregate Production Function" RES XXXIX Aug 1957 p 312-320 and J.W. Kendrick Productivity Trends in United States NBER 1961 Princeton

4. Zvi Griliches "The Sources of Measured Productivity Growth: US Agriculture 1940-1960" Journal of Political Economy LXXI Aug 1961 p 311-346

5. C. John Kurien "Technical Change in U.S. Manufacturing Industries 1947-64" Unpublished Ph.D Dissertation Vanderbilt University 1967 Nashville

technical change. Utilisation of capacity alters between consecutive time periods, affecting the relationship between the available capital and utilized capital. This is reflected in the measured coefficients of technical progress. In order to make more accurate estimates, it would therefore be necessary to adjust capital stock values for variations in utilization of capacity. But this generates its own problems, and cannot be discussed here. Any assumption of full utilization of capacity would be misleading and unwarranted anyway.

Kurien[6] assumes efficiency in resource allocation for the industry as a whole--thus the industry behaves as if it were a single unit of production. Two factors are sufficient for satisfying the assumptions--industry behaves as if a single firm and factors are paid their marginal product.

Under the assumption of Hicksian[7] neutrality of technical progress, technical change takes place by an upward shift in the whole production surface, while the general shape of the production surface itself remains the same. However, this assumption has come to be regarded as restrictive and as the subject matter for examination.

---

6. loc cit p 39

7. J. Johnston Econometric Methods, McGraw Hill 1960 New York p 106-142. Assumption of the simple model referred to as general linear model.

Technical change refers to changes in the production function, theoretically speaking a production function is specified by the description of individual output and the corresponding input combinations. Unless some a priori restrictions are stipulated upon its shape, the specification of the production function may require an infinity of parameters. Thus any shift in the function would affect all those parameters. Only a very large (infinite) number of observations could provide estimates of all these parameters and all the changes/shifts in these parameters.

The assumption of perfect competition in the factor markets--demand for factors of production by the industry does not affect their price--permits the use of single equation for identification. Consequently, single equations are used to estimate the production factor.

A word of explanation about the "selection" or inclusion of independent variables. Under the mormal stepwise procedure, intermediate results can be obtained (but are not normally recorded) from intermediate regression equations. These intermediate regression equations are obtained by adding one independent variable at a time. An interesting and important feature of the stepwise regression analysis procedure is that the variable found significant early in the calculation and included in the equation may later be found to be less significant - even insignificant and be removed. This is normally done before an additional variable is included. Consequently, at least theoretically, only significant variables are included in the final regression equation.

The problem, however, is that there is no *a priori* measure for the significance of the individual variables. The only real alternative is to recombine independent variables, suppressing one or another and/or suppressing subclasses (subgroups) or class differences in the specific independent variables. The selected sets of computations are intended to test the significance of the individual variables and/or subclasses of independent variables.

Different combinations of the different independent variables have been attempted and included as separate alternatives. Consequently, there are nine sets (see Chart following) of computations yielding results for the multiple regression equations involving first the different sizes of holdings, (see Table 3) and second the overall size of holding (see Table 4).

Separate Alternatives Attempted

	Description	Given Name	All Sizes No.of var	Overall Size No.of var.
1.	Containing all variables	All Variables	16(104)	13(26)
2.	Suppressed unirrigated-irrigated dummy	Irrigation	15(52)	12(14)
3.	Suppressed all capital retaining all labour variables	Labour	13(104)	11(26)
4.	Suppressed all labour retaining all capital variables	Capital	13(104)	11(26)
5.	Suppressed hired labour	Family Labour	15(104)	12(26)
6.	Suppressed hired labour & working capital	Family Labour & Fixed Capital	14(104)	11(26)
7.	Suppressed hired labour & fixed capital	Family Labour & Working Capital	14(104)	11(26)
8.	Suppressed region dummys i.e. combined data for all regions	Periods	12(104)	9*(6)
9.	Suppressed period dummys i.e. combined data for all periods	Regions	14(104)	11*(9)

(*) The relatively small number of observations made necessary the further reduction of number of variables. The removal of irrigation-unirrigated dummy and region dummys was effected. This was effective only in the case of Regions; there was no solution possible for the alternative Periods -- in the set relating to the Overall Size of Holding.

N.B. Number of observations are indicated in parenthesis.

TABLE 3: RESULTS OF MULTIPLE REGRESSION COMPUTATIONS: ALL SIZES OF HOLDINGS

	MULTIPLE REGRESSION EQUATION	MULTIPLE CORRELATION COEFFICIENT	F TEST FOR MULTIPLE CORRELATION WITH DEGREES OF FREEDOM	FRACTION OF VARIABLILITY ACCOUNTED FOR	STANDARD ERROR OF ESTIMATE	PURE CONSTANT
1.	ALL VARIABLES	0.99022	295.62817 with 15. and 88. degrees of freedom	0.98054	0.1985	0.3557 Sec 0.255 T Test C 1.394
2.	IRRIGATION	0.98034	72.27786 14. & 41	0.96106	0.1208	0.5749 Sec 0.528 T Test C 1.089
3.	LABOUR	0.99507	696.50439 13. & 90.	0.99016	0.1400	0.6718 Sec 0.074 T TestC 9.018
4.	CAPITAL	0.93817	50.84764 13. & 90.	0.88016	0.4886	0.3410 Sec 0.591 T Test C 0.577
5.	FAMILY LABOUR	0.99519	655.79272 14. & 89.	0.99040	0.1383	0.4085 Sec 0.183 T Test C 2.233
6.	FAMILY LABOUR FIXED CAPITAL	0.99517	711.27100 13.& 90.	0.99036	0.1386	0.4177 Sec 0.182 T Test C 2.290
7.	FAMILY LABOUR WORKING CAPITAL	0.99512	904.86719 13. & 90.	0.99027	0.1392	0.6381 Sec 0.078 T Test C 8.206
8.	PERIODS	0.99149	63.30954 11. & 12.	0.98306	0.0663	1.4023 Sec 0.916 T Test C 1.531
9.	REGIONS	0.99768	363.27393 13. & 22.	0.99536	0.1122	0.4950 Sec 0.290 T Test C 1.705

TABLE 3 (cont'd)

	COEFFICIENTS OF VARIABLES				
	LAND	FAMILY LABOUR	HIRED LABOUR	FIXED CAPITAL	WORKING CAPITAL
1.	-010457	0.9680	0.0082	0.0697	0.0731
2.	-0.2584	0.9506	0.1660	0.0279	0.0085
3.	0.0274	1.0696	0.0114	--	--
4.	0.2551	--	--	0.1097	0.5889
5.	-0.0771	1.0432	--	0.0807	0.027
6.	-0.0821	1.0722	--	0.0851	--
7.	-0.0286	1.0439	--	--	0.0289
8.	0.4097	0.5055	-0.0246	-0.5245	0.6125
9.	0.0494	0.8419	-0.0447	-0.0015	0.2556

TABLE 3: (cont'd)

	COEFFICIENTS OF DUMMYS									
	REGIONS				PERIOD		SCALE			Unirr/ Irrig
	1	2	3	4	1	2	5-10	10-20	20&Above	
1.	0.0124 .9876	-0.1606 T .8394	-0.2399 T .7601	0.5225 .4775	0.0915 .9085	0.1219 .8781	0.1623 .8377	0.1154 .8846	0.1576 .8424	-0.0574 T .9426
2.	-0.0438 0.9562	-0.3318 0.6682	-0.3725 .6275	-0.0762 .9238	0.0702 .9298	0.1281 .8719	0.0669 .9331	0.1430 .8570	0.2163 .7837	-- --
3.	-0.3266 T .6734	-2.2556	-3.5506	1.3970 .6030	0.3732 .6268	0.6647 .3353	0.5043 .4957	0.6636 .3364	1.0370 .9630	0.0643 .9357
4.	-0.7566 T .2434	-2.1832	-1.1911	7.4139	-0.2961 T .7039	0.8533 .1467	4.5540	3.7497	4.0399	-3.0934
5.	-0.3463 T .6537	-2.2743	-3.5245	2.2044	0.4592 .5408	0.7766 .2234	0.8855 0.1145	1.1709	1.7061	0.0134 0.9866
6.	-0.3251 T .6749	-2.3555	-3.5832	2.0132	0.5092 .4908	0.7690 .2310	0.8257 .1743	1.1800	1.7281	0.0352 .9648
7.	-0.3207 T .6749	-2.2648	-0.0354 .9646	--	1.7268	0.3524 .6476	0.6530 .3470	0.7666 .2334	1.1848	0.0132 .9868
8.	--	--	--	--	-0.0620 T .9380	-0.2725 T .7275	0.3877 .6123	0.1387 .8613	0.7729 .2271	-1.2135
9.	0.1736 .8264	-1.4006	-3.2963	1.8403	--	--	0.3595 .6405	0.9481 .0519	1.0236	-0.0163 T .9837

TABLE 4: RESULTS OF MULTIPLE REGRESSION COMPUTATIONS: OVERALL SIZE

	MULTIPLE REGRESSION EQUATION	MULTIPLE REGRESSION COEFFICIENT	F TEST FOR MULT. COR. DEGREES OF FREEDOM	FRACTION OF VARIABILITY ACCOUNTED FOR	STANDARD ERROR OF ESTIMATE	PURE CONSTANT
1.	All Variables	0.99601	135.08583 12. to 13.	0.99204	0.0594	1.0148 Sec 0.948 T Test C 1.070
2.	Irrigation	0.99010	9.04352 11. to 2.	0.98029	0.0650	0.91381 Sec 1.945 T Test C 0.470
3.	Labour	0.00616	194.31097 10. to 15.	0.99234	0.0583	1.6993 Sec 0.153 T Test C 11.136
4.	Capital	0.99538	161.25180 10. to 15.	0.99078	0.0639	0.9043 Sec 0.988 T Test C 0.915
5.	Family Labour	0.99629	170.49937 11. to 14.	0.99259	0.0573	1.0595 Sec 0.886 T Test C 1.196
6.	Family Labour Fixed Capital	0.99620	196.12389 10. to 15.	0.99241	0.0580	1.3885 Sec 0.844 T Test C 1.643
7.	Family Labour Working Capital	0.99653	214.82759 10. to 15.	0.99307	0.0554	1.2084 Sec 0.416 T Test C 2.903
8.	Periods	--	--	--	--	--
9.	Regions	0.97227	10.36876 5. to 3.	0.94530	0.1519	0.9077 Sec 1.093 T Test C 0.830

TABLE 4 (cont'd)

	COEFFICIENTS OF VARIABLES				
	LAND	FAMILY LABOUR	HIRED LABOUR	FIXED CAPITAL	WORKING CAPITAL
1.	0.4123	0.2809	-0.0235	0.0738	0.2952
2.	0.2622	0.2319	-0.1257	-0.2039	0.7209
3.	0.6503	0.3736	0.0032	--	--
4.	0.4543	--	--	-0.0249	0.6134
5.	0.4182	0.2771	--	0.0667	0.2767
6.	0.5219	0.3759	--	0.1290	--
7.	0.4813	0.2741	--	--	0.2838
8.	--	--	--	--	--
9.	0.5704	-0.2892	0.0867	-0.3311	1.0160

TABLE 4: (cont'd)

	COEFFICIENTS OF DUMMYS						
	REGIONS				PERIODS		
	II	III	IV	V	2	3	Unirrig/ Irrig
1.	-0.0912 T .9188	-0.0610 T .9390	-0.2805 T .7195	0.3889 .6111	0.0241 .9759	0.0400 .9600	-0.1398 T .8602
2.	-0.0806 T .9194	-0.0802 T .9198	-0.2971 T .7029	0.1988 .8012	0.0073 .9927	-0.0133 T .9867	--
3.	-0.8641 T .1359	-1.7338	-3.6509	3.0229	0.2712 .7288	0.5543 .4457	-1.9142 T .0858
4.	-0.9292 T .0708	0.1750 .8250	-2.0811	2.8851	0.0298 .9702	0.1351 .8649	-1.4319
5.	-0.9419 T .0581	-0.6909 T .3091	-2.8482	3.6568	0.2309 .7691	0.4172 .5828	01.4144
6.	-0.8040 T .1960	-1.2673	-3.2609	3.9978	0.3478 .6522	0.6080 .3920	-1.9134
7.	-0.9733 T .0267	-0.9112 T .0888	-3.0356	3.1639	0.1904 .8096	0.3842 .6158	-1.4033
8.	--	--	--	--	--	--	--
9.	--	--	--	--	--	--	--

TABLE 5: STANDARD ERROR OF COEFFICIENTS: ALL SIZES OF HOLDINGS

EQUATION → VARIABLE ↓	ALL VAR.	IRRIG.	LABOUR	CAPITAL	FAMILY LABOUR	FAMILY LABOUR & FIXED CAPITAL	FAMILY LABOUR & WORKING CAPITAL	PERIOD	REGIONS
Land	0.1107	0.2291	0.0274	0.2551	0.0766	0.0766	0.0271	0.3889	0.1277
Fam. Labour	0.0471	0.1589	0.0226	--	0.0324	0.0209	0.0326	0.2412	0.2332
Hired Labour	0.0224	0.0614	0.0158	--	--	--	--	0.1176	0.0277
Fixed Capital	0.0788	0.1391	--	0.1097	0.0547	0.0547	--	0.3529	0.0911
Work. Capital	0.0326	0.0209	--	0.5889	0.0228	--	0.0229	0.2325	0.2149
Region 1	0.0577	0.0590	0.4094	-0.7566	0.4031	0.4035	0.4053	--	0.5925
Region 2	0.0656	0.1174	0.4622	-2.1832	0.4423	0.4377	0.4451	--	0.9858
Region 3	0.0584	0.0858	0.4234	-1.9106	0.4139	0.4116	0.4163	--	0.8076
Region 4	0.0993	0.1781	0.6091	7.4039	0.6968	0.6786	0.6210	--	0.9421
Period 1	0.0484	0.0438	0.3341	-0.2961	0.3379	0.3358	0.3322	0.7444	--
Period 2	0.0469	0.0422	0.3287	0.8533	0.3293	0.3299	0.3264	0.5203	--
Scale 5-10	0.0668	0.0694	0.4368	4.5540	0.4537	0.4517	0.4282	0.777	0.6529
Scale 10-20	0.0764	0.0897	0.4554	3.7497	0.5126	0.5186	0.4361	1.3556	0.7567
Scale 20 & Above	0.0898	0.1182	0.5118	4.0399	0.5861	0.5869	0.4706	1.7352	0.8557
Irrigated/ Unirrigated	0.0447	--	0.3202	-3.0934	0.3146	0.3147	0.3167	0.6685	0.4638
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

TABLE 6: STANDARD ERROR OF COEFFICIENTS: OVERALL SIZE OF HOLDING

EQUATION → VARIABLE ↓	(1) ALL VARIABLES	(2) IRRIGATION	(3) LABOUR	(4) CAPITAL	(5) FAMILY LABOUR	(6) FAMILY LABOUR & FIXED CAPITAL	(7) FAMILY LABOUR & WORKING CAPITAL	(8) PERIODS	(9) REGIONS
Land	0.3822	0.7331	0.1109	0.4097	0.3677	0.3612	0.1631	--	1.0681
Family Labour	0.1345	0.3868	0.1058	--	0.1284	0.0977	0.1233	--	0.4649
Hired Labour	0.1219	0.2113	0.0967	--	--	--	--	--	1.0302
Fixed Capital	0.3594	0.9153	--	0.3820	0.3452	0.3451	--	--	0.9485
Working Capital	0.2636	0.4989	--	0.1986	0.2367	--	0.2263	--	1.3639
Region 1	0.0439	0.0739	0.3846	0.4434	0.3976	0.3843	0.3509	--	(*)
Region 2	0.1487	0.2766	0.3804	1.4659	1.3773	1.3016	0.7479	--	(*)
Region 3	0.1223	0.2567	0.3957	1.2319	1.1603	1.1187	0.6168	--	(*)
Region 4	0.2954	0.5798	0.7034	2.8765	2.6038	2.6187	0.5046	--	(*)
Period 1	0.0376	0.0739	0.2972	0.3879	0.3601	0.3501	0.2832	--	--
Period 2	0.0383	0.0767	0.2955	0.3732	0.3593	0.3239	0.3058	--	--
Irrigation-Unirrigation	0.0650	--	0.4668	0.6937	0.6220	0.4579	0.5992	--	(*)

AN AND STANDARD DEVIATION: ALL SIZES OF HOLDINGS

ALL VARIABLES		IRRIGATION		LABOUR		CAPITAL		FAMILY LABOUR		FAMILY LABOUR & FIXED CAPITAL		FAMILY LABOUR & WORKING CAPITAL		PERIODS		REGIONS	
-0.6546	0.8906	-0.1613	0.5170	-0.6546	0.8906	-0.6546	0.8906	-0.6546	0.8906	-0.6546	0.8906	-0.6546	0.8906	0.3016	0.4087	-0.6219	0.9841
0.4938	1.2427	1.0589	0.5049	0.4938	1.2427			0.4938	1.2427	0.4938	1.2427	0.4938	1.2427	1.5187	0.4200	0.4519	1.4376
-0.2720	1.5649	0.4610	0.7605	-0.2720	1.5649									1.0358	0.5227	-0.2329	1.6180
1.5517	1.1464	2.0517	0.6164			1.5517	1.5383	1.5517	1.1464	1.5517	1.1464			2.6449	0.3376	1.5299	1.2852
1.1723	1.5383	1.7255	1.1013			1.1723	1.5383	1.1723	1.5383			1.1723	1.5383	2.3695	0.4565	1.1964	1.1653
0.2308	0.4234	0.2143	0.4140	0.0321	0.0423	0.0231	0.0423	0.0231	0.0423	0.0231	0.0423	0.0231	0.0423			0.0222	0.0422
0.2308	0.4234	0.2143	0.4140	0.0321	0.0423	0.0231	0.0423	0.0231	0.0423	0.0231	0.0423	0.0231	0.0423			0.0222	0.0422
0.2404	0.4294	0.2143	0.4140	0.0231	0.0423	0.0231	0.0423	0.0321	0.0423	0.0231	0.0423	0.0231	0.0423			0.0222	0.0422
0.0769	0.2677	0.1428	0.3531	0.0077	0.0268	0.0077	0.0268	0.0077	0.0268	0.0077	.0.268	0.0077	0.0268			0.0111	0.0319
0.3461	0.4780	0.3571	0.4835	0.0346	0.0478	0.0346	0.0478	0.0346	0.0478	0.0346	0.0478	0.0346	0.0478	0.0333	0.0481		
0.3750	0.4865	0.3750	0.4885	0.0365	0.0484	0.0365	0.0484	0.0365	0.0484	0.0365	0.0484	0.0365	0.0484	0.0417	0.0504		
0.2596	0.4405	0.2500	0.4369	0.0259	0.0441	0.0259	0.0441	0.0259	0.0441	0.0259	0.0441	0.0259	0.0441	0.0249	0.0442	0.0249	0.0439
0.2500	0.4351	0.2500	0.4369	0.0249	0.0435	0.0249	0.0435	0.0249	0.0435	0.0249	0.0435	0.0249	0.0435	0.0249	0.0442	0.0249	0.0439
0.2308	0.4234	0.2321	0.4260	0.0231	0.0423	0.0231	0.0434	0.0231	0.0424	0.0231	0.0424	0.0231	0.0424	0.0167	0.0381	0.0249	0.0439
0.5192	0.5020			0.0529	0.0576	0.0529	0.0502	0.0529	0.0502	0.0529	0.0502	0.0529	0.0502	0.0499	0.0511	0.0555	0.0504
1.1585	1.4231	1.7766	0.6122	1.1424	1.4114	1.1424	1.4114	1.1424	1.4114	1.1424	1.4114	1.1424	1.4114	2.2841	0.5096	1.1359	1.6477

TABLE 7: MEAN AND STANDARD DEVIATION: ALL SIZES OF HOLDINGS

EQUATION VARIABLE	ALL VARIABLES		IRRIGATION		LABOUR		CAPITAL		FAMILY LABOUR		FAMILY LABOUR & FIXED CAPITAL		FAMILY LABOUR & WORKING CAPITAL		PERIODS		RE
Land	-0.6546	0.8906	-0.1613	0.5170	-0.6546	0.8906	-0.6546	0.8906	-0.6546	0.8906	-0.6546	0.8906	-0.6546	0.8906	0.3016	0.4087	-0.621
Family Labour	0.4938	1.2427	1.0589	0.5049	0.4938	1.2427			0.4938	1.2427	0.4938	1.2427	0.4938	1.2427	1.5187	0.4200	0.451
Hired Labour	-0.2720	1.5649	0.4610	0.7605	-0.2720	1.5649									1.0358	0.5227	-0.232
Fixed Capital	1.5517	1.1464	2.0517	0.6164			1.5517	1.5383	1.5517	1.1464	1.5517	1.1464			2.6449	0.3376	1.529
Working Capital	1.1723	1.5383	1.7255	1.1013			1.1723	1.5383	1.1723	1.5383			1.1723	1.5383	2.3695	0.4565	1.196
Region 1	0.2308	0.4234	0.2143	0.4140	0.0321	0.0423	0.0231	0.0423	0.0231	0.0423	0.0231	0.0423	0.0231	0.0423			0.022
Region 2	0.2308	0.4234	0.2143	0.4140	0.0321	0.0423	0.0231	0.0423	0.0231	0.0423	0.0231	0.0423	0.0231	0.0423			0.022
Region 3	0.2404	0.4294	0.2143	0.4140	0.0231	0.0423	0.0231	0.0423	0.0321	0.0423	0.0231	0.0423	0.0231	0.0423			0.022
Region 4	0.0769	0.2677	0.1428	0.3531	0.0077	0.0268	0.0077	0.0268	0.0077	0.0268	0.0077	0.268	0.0077	0.0268			0.011
Period 1	0.3461	0.4780	0.3571	0.4835	0.0346	0.0478	0.0346	0.0478	0.0346	0.0478	0.0346	0.0478	0.0346	0.0478	0.0333	0.0481	
Period 2	0.3750	0.4865	0.3750	0.4885	0.0365	0.0484	0.0365	0.0484	0.0365	0.0484	0.0365	0.0484	0.0365	0.0484	0.0417	0.0504	
Scale (5-10)	0.2596	0.4405	0.2500	0.4369	0.0259	0.0441	0.0259	0.0441	0.0259	0.0441	0.0259	0.0441	0.0259	0.0441	0.0249	0.0442	0.024
Scale (10-20)	0.2500	0.4351	0.2500	0.4369	0.0249	0.0435	0.0249	0.0435	0.0249	0.0435	0.0249	0.0435	0.0249	0.0435	0.0249	0.0442	0.024
Scale (20&Above)	0.2308	0.4234	0.2321	0.4260	0.0231	0.0423	0.0231	0.0434	0.0231	0.0424	0.0231	0.0424	0.0231	0.0424	0.0167	0.0381	0.024
Irrigation Unirrigation	0.5192	0.5020			0.0529	0.0576	0.0529	0.0502	0.0529	0.0502	0.0529	0.0502	0.0529	0.0502	0.0499	0.0511	0.055
Output	1.1585	1.4231	1.7766	0.6122	1.1424	1.4114	1.1424	1.4114	1.1424	1.4114	1.1424	1.4114	1.1424	1.4114	2.2841	0.5096	1.135

MEAN AND STANDARD DEVIATION: OVERALL SIZE OF HOLDING

	ALL VARIABLES		IRRIGATION		LABOUR		CAPITAL		FAMILY LABOUR		FAMILY LABOUR & FIXED CAPITAL		FAMILY LABOUR & WORKING CAPITAL		PERIODS		REGIONS	
	-0.5158	0.5886	-0.0275	0.3938	-0.5158	0.5886	-0.5158	0.5886	-0.5158	0.5886	-0.5158	0.5886	-0.5158	0.5886	0.4315	0.1315	-0.0075	0.5719
	0.6979	0.6276	1.1675	0.5304	0.6979	0.6276			0.6979	0.6276	0.9679	0.6276	0.6979	0.6276	1.6869	0.2617	1.2169	0.5928
	0.2670	0.6299	1.0911	0.1341	0.2489	0.6393									1.2166	0.3137	0.8160	0.6167
	1.6314	0.6620	2.0814	0.5850			1.6314	0.6620	1.6314	0.6620	1.6314	0.6620			2.6276	0.2124	2.1227	0.6351
	1.4922	0.6434	1.9729	0.5321			1.4922	0.6434	1.4922	0.6434			1.4922	0.6434	2.4728	0.3014	2.0040	0.6179
	0.2308	0.4297	0.2143	0.4258	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429			(*)	(*)
	0.2308	0.4297	0.2143	0.4258	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429			(*)	(*)
	0.2308	0.4297	0.2143	0.4258	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429			(*)	(*)
	0.0769	0.2717	0.1428	0.3631	0.0077	0.0272	0.0077	0.0272	0.0077	0.0272	0.0077	0.0272	0.0077	0.0272			(*)	(*)
	0.3461	0.4851	0.3571	0.4972	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	(*)	(*)		
	0.3461	0.4851	0.3571	0.4972	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	(*)	(*)		
n ion	0.5385	0.5084			0.0538	0.0508	0.0538	0.0508	0.0538	0.0508	0.0538	0.0508	0.0538	0.0508	(*)	(*)	(*)	(*)
	1.4299	0.6658	1.9661	0.4632	1.4299	0.6658	1.4299	0.6658	1.4299	0.6658	1.4299	0.6658	1.4299	0.6658	2.4016	0.3559	1.9566	0.6498

TABLE 8: MEAN AND STANDARD DEVIATION: OVERALL SIZE OF HOLDING

EQUATION ▶ VARIABLE ▼	ALL VARIABLES		IRRIGATION		LABOUR		CAPITAL		FAMILY LABOUR		FAMILY LABOUR & FIXED CAPITAL		FAMILY LABOUR & WORKING CAPITAL		PERIODS		REGIONS
Land	-0.5158	0.5886	-0.0275	0.3938	-0.5158	0.5886	-0.5158	0.5886	-0.5158	0.5886	-0.5158	0.5886	-0.5158	0.5886	0.4315	0.1315	-0.0075
Family Labour	0.6979	0.6276	1.1675	0.5304	0.6979	0.6276			0.6979	0.6276	0.9679	0.6276	0.6979	0.6276	1.6869	0.2617	1.2169
Hired Labour	0.2670	0.6299	1.0911	0.1341	0.2489	0.6393									1.2166	0.3137	0.8160
Fixed Capital	1.6314	0.6620	2.0814	0.5850			1.6314	0.6620	1.6314	0.6620	1.6314	0.6620			2.6276	0.2124	2.1227
Working Capital	1.4922	0.6434	1.9729	0.5321			1.4922	0.6434	1.4922	0.6434			1.4922	0.6434	2.4728	0.3014	2.0040
Region 1	0.2308	0.4297	0.2143	0.4258	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429			(*)
Region 2	0.2308	0.4297	0.2143	0.4258	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429			(*)
Region 3	0.2308	0.4297	0.2143	0.4258	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429	0.0231	0.0429			(*)
Region 4	0.0769	0.2717	0.1428	0.3631	0.0077	0.0272	0.0077	0.0272	0.0077	0.0272	0.0077	0.0272	0.0077	0.0272			(*)
Period 1	0.3461	0.4851	0.3571	0.4972	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	(*)	(*)	
Period 2	0.3461	0.4851	0.3571	0.4972	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	0.0346	0.0485	(*)	(*)	
Irrigation Unirrigation	0.5385	0.5084			0.0538	0.0508	0.0538	0.0508	0.0538	0.0508	0.0538	0.0508	0.0538	0.0508	(*)	(*)	(*)
Output	1.4299	0.6658	1.9661	0.4632	1.4299	0.6658	1.4299	0.6658	1.4299	0.6658	1.4299	0.6658	1.4299	0.6658	2.4016	0.3559	1.9566

CHAPTER 4 : SUMMARY AND CHAPTERS

This study has attempted to measure and compare productivity ratios over five wheat producing regions in India for the three year period between 1954-55 to 1956-57. The first method sought to establish an arithmetic productivity ratio with land, labour (two kinds - family and hired) and capital (also two kinds - fixed and working) as the inputs at constant prices, and the output seen as value added at constant prices. The second method sought to fit several variables to compute annual indices of productivity from the fitted production function itself. This was done through the covariance matrix method whereby cross-section data was combined with time-series data.

Chapter II attempted to discuss the conceptual problems relating to productivity and productivity measurement and some associated technical problems. A brief review of the development of the specific productivity measures and some reasons for their rejection in favor of aggregate or total productivity measures follows. A survey of the problems involved in the employment of input-output procedures follows. The special problems relating to the measurement of agricultural productivity are outlined. This is followed by a description of some procedures suggested for adoption in agriculture on a national scale. The specific methods of estimation chosen are outlined and some special reasons for their choice are stated.

Chapter III presents the results of the computations made according to the two methods selected, along with some explanation of those results and some indication of their shortcomings. Of special interest are the measurement of year-to-year technical changes, the effect of irrigation, the effect of size or scale of holdings and the several alternatives attempted through different combinations of groups of independent variables.

Initially this study was intended to include weather, climatic and rainfall factors among the independent variables. In fact, the choice of Wolfson's method for the second part of the computations was made specifically because of its attempt at estimating the so-called "residual" factors - mainly climatic and weather, including rainfall. A number of difficulties arose, making necessary the abandonment of this aspect.

Among these was the problem of different rainfall zones even within the regions selected. Then there was the very large number of class intervals or sizegroups, both negative and positive, indicating deviations from "normal" rainfall, and the problem of attaching weights to the benefit or damage accruing from the many possible conditions of excess, "normal" and deficient precipitation. It would have been possible to include at least rainfall provided one was prepared to use a sufficient number of dummy variables. But such a study would perhaps be useful if aimed specifically at measuring the effect of rainfall and not encumbered with comparing interregional differentials.

A very detailed "agricultural diary", compiled from reports by patwaris was faced with the same dilemma. These reports give account of damage by storm, wind, frost, snow, hail, flood, excess rainfall, insufficient soil moisture, drought, plant diseases, insects and pests and several other categories of essential farm information. There was, however, no satisfactory method of attaching weights to favorable and/or unfavorable conditions.

Prior to excluding this aspect from the study, several items were collected from State records and sources. These included monthly precipitation or rainfall data and the deviations from normal - an average ranging in duration from nine to twelve years. This monthly data was arranged so that the early, regular and late wheat sowings could be correlated with the growth cycle and the known strategic. periods in that cycle. Here again, though the "agricultural diary" yielded information there were some notable gaps. Because of the problem of weighting, mentioned earlier it was not thought desirable to pursue this line of inquiry.

In the early stages, another interesting area of fruitful inquiry was seen to be that of Management. Studies relating to agricultural production in countries like India, tend to ignore the management input. This is done partly to avoid problems of quantification in a difficult area, and partly because there is an underlying belief that, because of the underdevelopedness of the economy and the prevalence of a traditional agriculture, the management component can be ignored or taken as given. After all, the argument proceeds, in a traditional agriculture management decisions are "traditional" and no special initiative exists.

In my opinion this is a mistaken view. There are diversities in agricultural techniques followed, in the spreading of risk and effort; attempts at staggered maturation of crops; balancing of production for personal consumption and marketing; and the systems of land tenure with the considerable differences in incentives and motivation due to ownership and permanency of tenure. Even the incentive of hired labour categories varies depending upon the manner in which the wages are paid; when the payment in kind is fixed amounts of agricultural produce the incentive is seen to be considerably different from when the wage is a percentage of the final output. With respect to underdeveloped regions, where investment of human effort into land is particularly important, economic studies cannot afford to ignore the separate entrepreneurial, security and accounting function elements comprising management. The inclusion of management in future studies of Indian agricultural economy could provide significant insights into agricultural investment, accumulation of capital and the question of real alternatives facing the farmer.

In the course of the study, whilst calculating the arithmetic productivity ratio, the problem of valuation of family labour arose. The wage rate for casual labour, whilst suitable for valuation of the hired labour input was adjudged too low for the family labour input, consequently the casual wage rate was increased by a small fixed percentage of the regional rate.

The somewhat arbitrary limitations of a thesis subject preclude the investigation of intimately related areas of study e.g. substitution among factors and crops, optimum size, technological change, bias on account of specification and management, etc. These fall under the category of investigation into the nature of the structure of agriculture and factors involving growth.

An interesting feature that emerges from this study of wheat productivity is that cereal production, with the possible exception of rice is always conducted in combination with other crops. The proportion of the two crops varies from region and farmer and in some measure at least signifies choice. In the Studies data was often presented for wheat and wheat combinations, and it was the former that was selected. It may not be always possible to determine easily which is the dominant crop. Production techniques are often directed towards increasing the output of cash crops, rather than those that are intended for personal consumption.

APPENDIX 1 : SOURCES AND ADJUSTMENTS TO DATA

Two methods[1] were followed in the Studies in the Economics of Farm Management, i.e. Cost Accounting and Survey. Both methods used village proformas for collecting information; data was collected by investigators from farmers. Under the Survey Method the sample was generally larger, the information was collected over frequent visits. For the Cost Accounting Method the sample information, though relating to a smaller number of farmers, was collected by field investigators who actually stayed in the villages. Otherwise, the villages and farms were selected under the same sampling technique. The investigators were trained diploma-holders from agricultural schools, supervised by trained agricultural economists with postgraduate degrees.

The reports generally conclude that the Cost Accounting Method has certain advantages over the Survey Method. Whilst considerably more expensive and time consuming, the Cost Accounting Method yields results more accurate and reliable. The reports further conclude that it would be possible, in the interests of expediency, speed and

---

1. For a detailed description of the Method followed, and an evaluation of their comparative value see the Combined Report in each of the Studies. (Punjab p 197-200) (Uttar Pradesh p 154-177) (Bombay p 295-314). No similar information was given in the Combined Report for Madhya Pradesh, and it can only be assumed that similar or comparable procedures were followed with comparable results in the evaluating of methods utilised.

economy to use the Survey Method in a slightly modified form. Yet, in the majority of cases, the results obtained from the two methods are close. When selecting data for this study, an effort was made to select data collected by the Cost Accounting Method for all areas. For our purposes, the selection was purely arbitrary.

Some important theoretical aspects dealing with inputs have been dealt with below.[2] This section attempts to deal with the categories of inputs. The various inputs will be dealt with briefly, indicating where the information was obtained; what steps were taken to process the data; any extrapolations made; the difficulties encountered; the assumptions made and the discrepancies, if any, in the sources.

It is certain that some degree of substitution exists within the regional or traditional pattern of resource use. However, the extent to which resources are substituted and can be substituted for one another are both severely limited by the local technology and traditional patterns of a region. The unique factor mix of one region may differ substantially from another. We are forced to assume away any intraregional differences; and assume that differences exist only in the amounts of the interregional aggregate units of inputs.

---

2. cf: Chapter 2: The Measurement of Agricultural Productivity.

The data is representative of the wheatgrowing regions. It is necessary to assume that techniques of production are constant and that the quality of inputs remains constant. Further that the price valuation of inputs reflects all/ most variations in the quality of both inputs and outputs. There is the danger of inaccuracy here, on account of the fact that a large proportion of the payments for inputs are made in kind, rather than in cash. This cautionary note, however, has reference perhaps only for the method adopted by Barzel. Particularly in respect of agricultural wages and family income, a large proportion of earnings are in kind and not in cash. The assumption is that price valuation of output eliminates and/or otherwise takes care of nonhomogenities in output. Whether or not this is a safe assumption is respect of inputs is a moot point.

A great deal of nonhomogeneity exists among the individual inputs. India is a large country and the socio-economic differences between the groups and communities that constitute the rural population of the different states are quite remarkable. The more obvious cultural differences express themselves in clothing, food, language, family organisation, techniques and practices, and the distribution of wealth in the agrarian economy. The unit of cultivation varies quite considerably. There are historical and sociological reasons to explain this as well as the ownership of land and the extent of landless agricultural labourers. Skills and experience have combined with natural conditions of soil and climate to effect vast differences in livestock, tools, equipment, and technology. The consideration of inputs, therefore, requires some caution,

Data has been collected for (i) Punjab; (ii) Uttar Pradesh; (iii) Ahmednagar District[3]; (iv) Nasik District[4] and (v) Madhya Pradesh. Basic data was presented for different size groups and for the average or overall size of holding. Because of the disparity and lack of uniformity in the sizes of operational holdings the former sets of data had to be rearranged in similar/comparable sets. The procedure involved was to sum the products of the data and the frequency distribution under the relevant size groups, dividing by the sum of the frequencies. Four sets of size groups were selected as practical(0-5, 5-10, 10-20, and 20 & Above acres). Data for the five selected regions was processed to give weighted averages for all the categories of input data.

---

3. Taken to be representative of Gujarat State, the data was published under Bombay State which has since been divided into two separate states, on a linguistic basis.

4. Taken to be representative of Maharashtra State. The data was published under Bombay State which has since been divided into two separate states on a linguistic basis.

Two sets of raw input data are thus available:

1. The first set refers to the different size groups. Data relating to land gives the actual average size of land holding in each size group, the percentage under irrigated wheat, followed by the percentage of the area which is irrigated. Data relating to labour inputs gives the number of mandays per acre spent on irrigated wheat for family labour and hired labour respectively.

Data relating to capital inputs gives the amount of fixed capital per acre and working capital per acre for irrigated wheat.

Data relating to wage rates is presented as the wage per manday (1 day = 8 hours) and output as physical yield per acre of irrigated wheat.

Data relating to price is the village price per maund of wheat (as opposed to market price), which we will assume is what the agricultural producer obtains for his output.

The last two columns of data contain the rent and rental value (imputed in the Studies) and interest on fixed capital respectively, for irrigated wheat.

The second row of data presents comparable information under the same size group for unirrigated wheat which varies considerably except for the categories of land, fixed capital, wages, and price which are unaffected by the distinction between irrigated and unirrigated wheat production.

Since data is available for three consecutive years, with the exception of Madhya Pradesh, we have four sets of data for three years and one with only two years. Counting the two separate subsets for irrigated and unirrigated wheat makes eight subsets of data for each year - 24 for each region except for Madhya Pradesh which has only 16.

2. The second set refers to the overall size of holding. Data is available on much the same format as for the first set. Each year yields two subsets of data, six for three years for each region except for Madhya Pradesh which yields only two subsets for each of two years.

With the first set of data, ten dummy variables are used. The first four relate to the five regions, the next two to the three periods, the following three to the four size groups and the last to the two categories of irrigated and unirrigated land. Following the second set of data, there are seven dummy variables. The first four relate to the five regions, the next two to the three periods, and the last to the two categories of irrigated and unirrigated land.

The Studies do not give any estimates of physical output of wheat for the different size groups under the irrigated and unirrigated categories of land. Consequently, the raw data was processed to derive such estimates of output. The processed data, yields the actual acreage under wheat, the actual number of mandays worked by family labour, and hired labour respectively; the actual amount of fixed capital and working capital respectively, followed by the appropriate set of dummy variables. Lastly the value of the physical output from that size group. The first row being processed data for irrigated land in any size group. The second row being processed data for unirrigated land in that size group.

In all instances, during the processing of raw data, where the amount/quantity of any independent variable was negligible, and values tended to be zero, these were corrected to indicate a small value. This was particularly necessary on account of the fact that some computations require transformation into logarithm values. The alternative was to throw out any observation or part of an observation where values of any independent variable were equal to zero. This is not expected to appreciably alter the result of any caluclations of regression and/or productivity. In fact, in so far as these are small values, one should not think of them as sources of error.

The processed data consisted of eight real input variables followed by the dummy variables and another column containing the calculated output. The first five being input quantities: land, family labour, hired labour, fixed capital and working capital. The next three columns contain input prices: wages, based on the daily rate for casual hired labour, rent and rental value per acre and interest on fixed capital per acre. The dummy variables are ten in number for the data set relating to the different size-groups and seven for the overall size of holdings. Finally, the column indicating the value of physical output. Two input prices are missing: one, the wage rate for family labour; and two, the interest on working capital. In order to be able to calculate productivity ratios, both these input prices are necessary.

There were two alternatives seen in each case:

a. (i) Assume the wage rate for family and hired labour to be the same.

(ii) Assume the wage rate for family labour to be casual wage rate x (1+x), i.e. impute a value consistent with the role played by family labour.

b. (i) Assume the imputed interest rate on working capital to be the same as for fixed capital, namely 6% per annum. It is not certain whether this sum should be charged for the whole year or merely for 5-1/2 months required for wheat production.

(ii) Assume that the interest rate in working capital will be the approximate commercial going-rate for loans and borrowed moneys. There are difficulties involved in so doing. There is no indication of how many farmers borrow moneys towards working capital; also the commercial rate varies a great deal and part of the transaction involves sale of product to the person or agency lending the money. We are reluctantly, therefore, going to eliminate this alternative.

The Studies yielded breakdown of irrigated and unirrigated land under wheat, the amount of mandays worked by family labour and hired labour separately per acre of irrigated and unirrigated wheat. Data was also available on the per acre investment in fixed capital and working capital corresponding to the irrigated and unirrigated categories of wheat. Consequently, one of the subclasses or categories selected for inclusion in the study was the effect of irrigation or lack of irrigation.

Further, the same information was collected for four selected size groups indicated earlier, permitting scale of holdings to be included in this study. Naturally, when considering the overall size, consideration of scale of holdings is omitted, there being the one average regional size.

The Studies in the Economics of Farm Management for the separate regions were not available for each of the years of the study period. The Combined Report compiled at the end of the study period, in most cases provided the relevant information in the format in which it has been used in this study. However, in some cases the Combined Reports contented themselves with presentation of averages for the two and three year periods respectively.

Also for several areas of information where the regional data did not register changes the Combined Reports did nto contain certain information and suggested that reference be made to the separate Annual Reports.

For reasons unknown, the policy of libraries where the Studies could be traced has been to secure the Combined Reports and certain of the Annual Reports, but in no case all of them. The collection of data consequently involved some correspondence and frequent periods of waiting for interlibrary loans to be secured. Only recently has the McGill University Library been able to secure copies of the Annual Reports, which interestingly enough, are not available in most other places for interlibrary loan.

As mentioned earlier the data for the overall size of holdings was secured from the Combined Reports. The only adjustment was the calculation of actual family labour and hired labour data from value of family and hired labour. This was necessary in the case of Uttar Pradesh and was done by simply dividing the value of the two categories of labour by the wage rate.

The data for the different sized of holdings was secured from the Combined Reports and various Annual Reports as they became available. This group of data also required several changes and adjustments which are indicated in the footnotes to the following tables of sources.

SOURCES OF DATA Table 1: Punjab

ITEM	ALL SIZES OF HOLDING			OVERALL SIZE OF HOLDINGS		
Land size & frequency	CR	Table 3.1	p 8	CR	Table 3.1	p 8
		Table 3.3	p 9		Table 3.3.a	p 9
Percentage area under wheat	(b)	Table 3.13	p 18	CR	Table 5.1	p 73
		Table 3.14	p 20 (1)			
		Table 3.15	p 22			
	(c)	Table 3.13	p 19			
		Table 3.14	p 20			
		Table 3.15	p 21			
		Table 3.16	p 23			
Percentage area irrigated & unirrigated	CR	Table 3.5	p 13	CR	Table 3.5	p 13
Labour Family	CR	Table 5.8	p 83	CR	Table 5.8	p 83
Hired (irrigated)	CR	Table 5.8	p 83	CR	Table 5.8	p 83
Labour Family Hired (unirrigated)			(2)	CR	Table 5.18	p 91
Capital Fixed	CR	Table 3.23b	p 24	CR	Table 3.23.b	p 24
Capital Working irrigated	CR	Table 5.2	p 74	CR	Table 5.12	p 87
unirrigated		(3)				
Wages	CR	Table 2.2	p 7	CR	Table 2.2	p 7
Yield Irrigated	CR	Table 5.5	p 79	CR	Table 5.5	p 79
Unirrigated		(4)		CR	Table 5.15	p 88
Price	CR	Table 2.1	p 5			
	(c)	Table 2.1	p 5	(c)	Table 2.1	p 5
Rent & Rental Value Irrigated				CR	Table 4.21	p 58
Unirrigated				CR	Table 4.21	p 58
Interest		(5)				
Irrigated				CR	Table 4.20	p 57
Unirrigated				CR	Table 4.20	p 57

CR = Combined Report

(a) = 1954-55 Annual Report (b) = 1955-56 Annual Report (c)=1956-57 Annual Report

Table 1 : Punjab (cont'd)

(1) There was no data available for the first year of the Studies. However, the statement that there was "no appreciable alteration in data for the last two years in cropped area and its distribution....", appears in the 1955-56 Annual Report. The data used in consequence is the same as for 1955-56.

(2) The Annual Report for 1954-55 probably contained valuable information relating to the unirrigated holdings, unfortunately it was not available. In subsequent years the policy of the authors and editors was to eliminate data on unirrigated holdings relating to wheat unless it was of more than unusual interest. In the case of labour data, both family and hired, relating to unirrigated holdings, the assumption that values are one half of the irrigated values was made on the strength of the statement that "....physical input of labour is about half of that spent on irrigated wheat..." (p 91 CR) This is amply borne out by the data for Overall Size of Holding. It was not necessary to attempt to scale the assumed data by the data for Overall Size.

(3) The "....detailed description of...." inputs per unirrigated acre of wheat..." has been excluded from the Combined Report on account of their small number and relative unimportance. The data used is taken from general inputs (CR Table 4.14 p 51) appropriately scaled by Overall Size data relating specifically to unirrigated wheat.

Table 1 : Punjab (cont'd)

(4) Breakdown of yields for unirrigated wheat was not available. The irrigated wheat yields have been scaled down by the Overall Size data. The Combined Report (p 90) states that "....these yields are roughly half of those for wheat grown on irrigated areas...." and the results obtained by scaling procedure adopted substantiate this.

(5) Breakdown of Rent & Rental Value and Interest on Fixed Capital by sizegroup for wheat was not available. The relevant values in the general inputs (irrigated-cum-unirrigated food crops) by sizegroup was consequently used (CR Table 4.19 p 55). The figures for irrigated and un-irrigated wheat were obtained by scaling the general input data by the Overall Size data available in the Combined Report. (CR Table 5.7 p 81 & Table 5.18 p 90)

SOURCES OF DATA Table 2: Uttar Pradesh

Item	All Sizes of Holding	Overall Sizes of Holding
Land size & frequency	CR Table 3.3 p24 Table 3.5 p26	CR Table 3.3 p24 Table 3.5 p26
Percentage area under wheat	CR Appendix Table 15 p213 (1) (c) Table 3 p122	CR Appendix Table 15 p213 (c) Table 3 p122
Percentage area irrigated & unirrigated	CR Table 3.10 p29	CR Table 3.10 p29
Labor Family Hired (irrigated)	CR Table 3.39 p47 (2) Appendix Table 17 p214 (b) Appendix Table 24A p159-60 Table 2.23 p18	CR Table 3.39 p47 Appendix Table 17 p214 (b) Appendix Table 24A p159-60
Labor Family Hired (unirrigated)	(c) Appendix Tables 24 & 25 p141-42	(c) Appendix Tables 24 & 25 p 141-42
Fixed Capital	CR Table 3.26 p39 (3)	CR Table 3.26 p39
Working Capital irrigated	CR Table 5.37 p117 (4) Table 2.9 p10 Table 2.11 p11 (b) Table 2.12 p12	CR Table 5.37 p117 (b) Tables 2.9,2.11 & 2.12 p 10-12
unirrigated	(c) Table 4.27 p63-64	(c) Table 4.27 p63-64
Wages	CR Section 2.17 p19-20	CR Section 2.17 p19-20
Yield irrigated	CR Table 5.49 p123 (5) Table 5.50 p124	CR Table 5.49 p123
unirrigated	(b) Table 4.40 p84 (c) Table 4.36 p69	(b) Table 4.40 p84 (c) Table 4.36 p69
Price	CR Table 2.8 p20	CR Table 2.8 p20
Rent & Rental Value irrigated	(6) (b) Appendix 24A p159-60	(b) Appendix 24A p159-60
unirrigated	(c) Appendix 24&25 p141-42	(c) Appendix 24&25 p141-42
Interest irrigated		
unirrigated		

(a)=1954-55 Annual Report;(b)=1955-56 Annual Report;(c)=1956-57 Annual Report and CR=Combined Report

Table 2 : Uttar Pradesh (cont'd)

(1) Starting with percentage area under wheat the Combined Report gave annual totals for (combined) irrigated and unirrigated land, but no breakdown. The percentage distribution of area under irrigated wheat - average for three years found in 1956-57 Annual Report was used to derive the breakdown into percentage irrigated and unirrigated wheat.

(2) Percentage share of total labour utilisation combined with a breakdown into family and hired categories of labour (CR Table 3.39 p 47 & Table 4.31 p 66). Results were combined with human labour days per acre for wheat, irrigated and unirrigated separately, to derive annual data for the three years of the Studies. (CR Appendix Table 17 p 214; Annual Report 1955-56 Appendix Table 24A p 159-160; Annual Report 1956-57 Appendix Tables 24 & 25 p 142-143). The value of labour inputs divided by the wage rate to derive mandays, and this combined with the classification into family and hired labour respectively. (Annual Report 1955-56 Table 2.23 p 18 and Appendix Table 24A p 159-160)

(3) Data for 1954-55 derived from the Combined Report average for three years and the separate data for 1955-56 and 1956-57, from the Annual Reports of those years.

(4) Data for 1954-55 derived from the Combined Report average for three years and Annual Report for 1955-56 (Table 4.40 p 84) and 1956-57 (Table 4.36 p 69). In addition

Table 2 : Uttar Pradesh (cont'd)

the statement that the yield of unirrigated wheat is two-thirds that of irrigated wheat occurs in the 1956-57 Annual Report (p 124).

(6) Data for 1954-55 derived from the Combined Report average for three years and the Annual Reports for 1955-56 and 1956-57.

Item	All Sizes of Holding	Overall Sizes of Holding
Land size & frequency	CR Table 3.3 p36	CR Table 3.3 p36
Percentage area under wheat	(1)	CR Table 64 p300
Percentage area irrigated & unirrigated	CR Appendix Table 3.7 p348-351 (2)	CR Appendix Table 3.7 p348-351
Labor Family Hired (irrigated)	CR-A Table 5.40 CR-N Table 5.61 p200	CR-A Table 5.40 CR-N Table 5.61 p200
Labor Family Hired (unirrigated)	CR-A Table 5.29 p160 CR-N Table 5.50 p187	CR-A Table 5.29 p160 CR-N Table 5.50 p187
Capital	CR Appendix Table 3.9 p356-7	CR Appendix Table 3.9 p356-7
Working Capital		
irrigated	CR-A Table 5.38 p170 CR-N Table 5.59 p197	CR-A Table 5.38 p170 CR-N Table 5.59 p197
unirrigated	CR-A Table 5.27 p157 CR-N Table 5.48 p185	CR-A Table 5.27 p157 CR-N Table 5.48 p185
Wages	CR Table 2.20 p36	CR Table 2.20 p32
Yield irrigated	CR Table 5.35 p166 Table 5.67 p207	CR Table 5.35 p166 Table 5.45A p181
unirrigated	Table 5.45A p181 Table 5.56 p192	Table 5.56 p192 Table 5.67 p207
Price	CR Table 2.19 p31	CR Table 2.19 p31
Rent & Rental Value		
irrigated	(b) Appendix 5.5 p376-7 (3) Appendix 5.7 p380-1	CR Table 5.28 p158 Table 5.39 p171
unirrigated	(c) Appendix 5.9 p384-5 Appendix 5.11 p388-9	CR Table 5.49 p186 Table 5.60 p198
Interest		
irrigated		
Unirrigated		

(a)= 1954-55 Annual Report; (b)=1955-56 Annual Report; (c)-1956-57 Annual Report and CR = Combined Report
A represent Ahmednajar District(Gumarat) & N represent Nasik District (Maharashtra)

<u>Table 3 : Gujarat & Maharashtra (cont'd)</u>

(1) Percentage area under wheat was calculated from the distribution of area under different crops per holding by sizegroups (CR Appendix Table 3.6 p 342-347) and distribution of area under different irrigated crops per holding by sizegroup (CR Appendix Table 3.7 p 348-351). The total cropped area minus the irrigated area yielded percentage values for the area under wheat by sizegroup. These values were scaled to correspond to those provided by the Overall Size (CR Table 6.4 p 300).

(2) Data for 1954-55 obtained from the Combined Report average for three years and the Annual Reports for 1955-56 and 1956-57.

(3) Data for Rent & Rental Value and Interest on Fixed Capital with sizegroup breakdown was available only for the year 1956-57 in the Annual Report for that year. The Combined Report provided the Overall Size data for each of the three years of the <u>Studies</u>. This data was used to provide scaled estimates of the sizegroup breakdown for the two years where such breakdowns were not available.

SOURCES OF DATA Table 4: Madhya Pradesh

Item	All Sizes of Holding	Overall Sizes of Holding
Land size & frequency	CR Table 3.2.1 p7 Table 3.4.1 p9	CR Table 3.2.1 p7 Table 3.4.1 p9
Percentage area under wheat	(1)	CR Table 5.1.1 p49
Percentage area irrigated & unirrigated	(2)	CR Table 2.15.1 p10 (b) Table 2.16.1 p10
Labor Family Hired (irrigated)	-	-
Labor Family Hired (unirrigated)	CR Table 4.5.1 p38	CR Table 4.5.1 p38
Fixed Capital	CR Table 3.10.1 p13	CR Table 3.10.1 p13
Working Capital irrigated	CR Table 4.5.1 p38	CR Table 5.3.1 p52
unirrigated		
Wages	CR Table 2.8.2 p6 (3)	CR Table 2.8.2 p6 (4)
Yield irrigated	(4)	(3)
unirrigated		
Price	CR Table 2.8.1 p5	CR Table 2.8.1 p5
Rent & Rental Balue irrigated		
unirrigated		
	CR Table 4.5.1 p38	CR Table 5.3.1 p52
		(b) Table 5.4.1 p57
Interest irrigated		
unirrigated		

(a) =1954-55 Annual Report, (b) = 1955-56 Annual Report; (c) =1956-57 Annual Report and CR = Combined Report

Table 4 : Madhya Pradesh (cont'd)

(1) The region is mainly unirrigated with less than 0.4 per cent in 1955-56 and 0.5 per cent in 1956-57 irrigated. "All crops grown are fed by rain water only. Even rabi crops depend on pre-rabi rains for their sustenance....(only) ....some vegetables and orchards are irrigated by the well water..." (p 11)

(2) Determination of percentage under wheat by sizegroup was done by scaling the data available for wheat and wheat combinations (Annual Report 1955-56 Table 5.1 p 49) combined with data provided by the Combined Report (Table A.4.1. p 62; Table A.4.2 p 63; Table 5.1.1 p 49) which provide actual percentages of pure wheat and wheat combinations to the total cropped area. The 1955-56 data was first scaled to correspond to the Combined Report estimates for 1955-56 and then the 1056-57 breakdown for sizegroups estimated by rescaling. This operation was based on the statement "....The crop pattern was almost the same for all size-groups of holdings....no change in cropping pattern in the two years...." of the Studies was reported or observed. (CR p 57).

(3) Wage per manday was obtained by multiplying the average hourly (CR Table 2.8.2 p 6) wage rate by eight (1 adult male manday = 8 hours).

(4) Yield per acre was obtained by dividing the value of wheat output (CR Table 5.4.1 p 53) by the corresponding price per maund.

APPENDIX 2 : <u>BACKGROUND</u>

Land utilisation statistics in India indicate that some 53.4 per cent of the land is agriculturally productive, another 18 per cent is under forests, and some 29 per cent is totally unproductive from the point of view of agriculture and silviculture. There has been some increase in the net area sown, the area sown more than once and consequently in the total cropped area. (See Table 1 below).

TABLE 1: <u>Land Utilisation</u> (million acres)

	1948-9	1950-51	1955-56	1960-1	1961-2
Total geographical area:					
By Surveyor General:	810.8	810.8	806.3	806.3	806.3
By village papers:	588.3	702.6	719.6	738.9	738.4
Classification of reporting area:					
Forests	86.7	100.0	125.6	137.7	137.8
Are not available for cultivation	101.9	117.4	118.4	120.1	120.8
Other uncultivated land (excluding fallow lands)	93.2	122.3	97.0	96.0	93.2
Total fallow lands	63.3	69.5	60.4	57.0	52.0
Net area sown	243.2	293.4	318.2	328.0	334.0
Area sown more than once	33.4	32.5	44.3	48.2	50.6
Total Cropped area	276.6	325.9	362.5	376.2	384.6

(Source: Pocketbook of Economic Information Dept. of Economic Affairs, Ministry of Finance Goi 1965)

The extension of various irrigation projects under central and state government sponsorship has led to an increase in the irrigated acreage. It appears that, on average, two out of every five acres of irrigated land is watered by canals, one acre from tanks and the last two acres from wells and other sources. The following table (see Table 2) gives an indication of the extent of the irrigated area by sources and the distribution of the irrigated area by crops. The absorption of irrigated area by major foodgrains has been quite spectacular.

TABLE 2 : Irrigated Area: By source and absorption by crops (million acres)

Sources/Crops	1948-49	1950-51	1955-56	1960-61	1961-62
Canals:					
Government	15.9	17.9	19.8	22.9	23.1
Private	4.5	2.8	3.4	3.0	2.8
Tanks	7.7	8.8	10.9	11.1	11.3
Wells	12.6	14.7	16.6	18.0	18.0
Other Sources	6.2	7.3	5.5	6.0	6.0
Total Net Area Irrigated	46.9	51.5	56.2	61.0	61.2
Area irrigated more than once	3.1	4.3	7.3	8.2	8.9
Total Gross area Irrigated	50.0	55.8	63.5	69.2	70.1

Table 2 (cont'd)

	1948-49	1950-51	1955-56	1960-61	1961-62
Rice	21.3	24.3	27.3	30.8	na.
Wheat	7.4	8.4	10.3	10.5	na.
Other Cereals	12.3	7.8	8.4	8.4	na.
Pulses		4.8	4.9	4.9	na.
Foodgrains	41.0	45.3	50.9	54.4	na.
Sugarcane	2.6	2.9	0.7	4.1	na.
Oilseeds	..	..	3.1	1.0	na.
Cotton	0.7	1.1	2.1	2.1	na.
Total Gross Area Irrigated (including other crops)	50.0	55.8	63.5	69.2	70.1

(Source: Pocketbook of Economic Information: Department of Economic Affairs, Ministry of Finance G.O.I. 1965)

N.B. Absorption by crops for 1961-62 not available.

Needless to say in the event of a bad year for rainfall the amount of irrigated land decreases sharply as the precipitation declines. Rivers not wholly dependent on melting snows depend in the main upon rainfall. Wells and tanks and ponds also draw largely on the surface precipitation and subterranean flows. When rivers run low, so do canals.

Approximately three-fourths of the total cultivated land in India is under food crops, yet the total value of food crops is equal to that of the cash crops.[1] The main

1. Of the total value of crops (Rs. 60,870 million at constant prices) 55 per cent represented foodgrains in 1963-64.

food crops are rice and wheat which take up 22 per cent and 9 per cent respectively of the cropped area. The major cash crops are oilseeds, cotton, sugarcane and jute. It is significant that less than 20 per cent of the area is under food crops, rice alone accounts for 45 per cent. This leaves only 20 per cent of the irrigated area for "other crops"; consequently it may be observed "other crops" are almost entirely dry farming crops. Further the major crops are really quite dependent on irrigated land: the variations in annual production being the result of the dependence on rain. (See Table 3)

TABLE 3 : Agricultural Production and Acreage

	million tons		(million acres in parenthesis)			
Crop	1949-50	1950-51	1955-56	1960-61	1963-64	1964-65
Rice	23.54 (74.5)	20.58 (76.1)	27.56 (77.9)	34.20 (82.9)	36.89 (87.7)	38.70 (n.a.)
Wheat	6.39 (24.1)	6.46 (24.1)	8.76 (30.6)	10.99 (32.0)	9.71 (32.9)	12.10 (n.a.)
Other Cereals	16.83 (96.0)	15.38 (93.1)	19.49 (107.3)	23.13 (107.6)	23.36 107.0)	n.a. (n.a.)
Pulses	8.16 (49.8)	8.41 (47.2)	11.04 (57.4)	12.65 (57.3)	9.87 (58.7)	n.a. (n.a.)
Total Foodgrains	54.92 (345.3)	50.83 (240.5)	66.85 (273.2)	80.97 (279.8)	79.43 (286.3)	88.40 (n.a.)
Sugarcane (gur yield)	5.02 (3.6)	5.71 (4.2)	6.08 (4.6)	10.62 (5.8)	10.26 (5.5)	11.60 (n.a.)
Oilseeds	5.23 (24.9)	5.16 (26.5)	5.73 (29.9)	6.62 (33.4)	7.10 (36.0)	8.40 (n.a.)
Cotton	2.60 (12.2)	2.88 (14.5)	3.95 (20.0)	5.32 (18.9)	5.43 (19.6)	5.30 (n.a.)
Jute	3.11 (1.2)	3.31 (1.4)	4.23 (1.7)	4.01 (1.5)	6.18 (2.1)	6.08 (n.a.)

Source for Table 3: Pocketbook of Economic Information Department of Economic Affairs; Ministry of Finance G.O.I. 1965.

The annual data for 1960-61 in the preceding table provides the partially revised estimates for that crop year. The figures for 1963-64 are the final extimates, and those for 1964-65 are provisional estimates with acreage breakdowns not yet available. The sugarcane figures (for all years) are expressed in million tons of gur (raw unrefined sugar). Cotton and jute are expressed in million bales of 180 kilograms each.

This is quite understandable in the light of the distribution of rainfall according to the total area. (See Table 4)

TABLE 4 : Annual Distribution of Rainfall According to the Total Area

Average Annual Rainfall	Percentage to the Total Area
Above 75 inches	11%
Between 50-75	21%
Between 30-50	37%
Between 15-30	24%
Below 15 inches	7%

Source: Indian Agriculture in Brief Table 5.2 p 22)

The wheat "industry", if it may be so called, is a relatively large segment of the agricultural foodgrain product/ sector. In international terms India produces some 4.3 per cent of the world's[2] wheat; in domestic terms this adds up to approximately 12 million tons produced on 33 million acres. The Indian wheat crop occupies some 10 per cent of the total cultivated area, of which one-third is irrigated. In recent years, wheat has grown in importance as a major cereal on account of the fact that its consumption is regarded as being superior to that of the minor cereals -- ragi, bajra, jowar and maize -- coarser grains and millets.

Wheat is basically a crop belonging to the moderate temperate climates, but generally also grows within the tropics -- Mexico, Egypt, Central Africa, Phillipines, and India. In Europe wheat is found up to latitudes 65° North, in North America to latitude 50° North and in both Australia and South America up to latitude 45° South. The distribution of wheat is affected by range of temperature ".... the soil temperature at seeding time is very important in the production of winter wheat. When sown too early while the ground is warm, plants may start well but will soon decay and be attacked by white ants (termites). It is considered safe to seed when the temperature of the soil has fallen to about 25°C (77°F) but not when it is as high as about 30°C (86°F)." The distribution of wheat is also affected by moisture..." most of the important wheat growing

2. India (Republic) Statistical Handbook, Central Statistical Organisation 1964 G.O.I. Wheat 1963-64: India 4.3%; USSR 26.9%; USA 12.4%; Canada 7.9%; France 4.1%; Turkey 4.o%; Australia 3.6%; Italy 3.2%.

regions in the world have an annual precipitation of 30 inches. Successful growth of wheat is not limited by heavy rains, but other crops are found to be more profitable with heavier rainfall; also rusts and fungus diseases develop with warm and moist spring weather."...."It has been found in India that good soil aeration, by means of which the soil organisms and the roots of the wheat plant can obtain abundant oxygen, is quite as important as the water supply. It seems that any interference with aeration at ripening time prevents maturing and tends to increase rust attacks."[3]

Wheat in India is normally a winter crop, grown predominantly in the north. The crop is generally grown after a summer fallow and except in irrigated tracts, depends largely on conservation of soil moisture from the previous monsoon. The crop is generally harvested during the period February-April, and threshing, winnowing, etc., go on till the end of May when the grain reaches the markets. The loss annually due to rust -- black, red and yellow -- and fungus diseases is put at 5 per cent.[4]

An important factor in the agricultural life of India is the meteorological phenomena known as the monsoons. This accompanies the alternation of the seasons -- Southwest monsoon, Post-monsoon, Winter or Northeast monsoon and Pre-monsoon --- corresponding with or accompanying summer, fall

---

3. J. Warren Smith Agricultural <u>Meteorology</u> Macmillan 1920 New York p 183-5

4. India

or autumn, winter and spring respectively. (See Table 5)

TABLE 5 : Distribution of Rainfall According to Different Seasons

Rainfall Season	Duration	Percentage of the Annual Rainfall
Southwest monsoon	June–September	75%
Post–monsoon	October–November	13%
Winter or Northeast monsoon	December–February	2%
Pre–monsoon	March–May	10%
		100%

Source: Indian Agriculture in Brief Table 5.1 p 22

The southwest monsoon is a continuation of the south-east trade wind; a wind of oceanic origin advances over India between June and September in two currents; one deposits rainfall on the peninsular plateau in South India, the other comes up the Bay of Bengal and is deflected into East India whence it continues westward. Both depleted currents meet in the interior of North India and retreat during September. Rain is intermittent, not continuous; and this fact is of great importance to the agriculturist. The Northeast monsoon is found between mid-January and the end of May; is of land origin and gets very hot and dry with the passing of spring.

The bulk of precipitation occurs during the South-east monsoon with some exceptions. The exceptional areas are: (1) The south-eastern coastal regions of Madras, which not only are affected by the easterly branch of the south-west monsoon, but also receive rain in October and November, and sometimes also in December, from the so-called north-east monsoon. The trade wind after summer months is laden with moisture from the heatedBay of Bengal; (2) the north-west of India, which in January, February and March is subject to a succession of shallow storms, bringing rain, insignificant in absolute quantity, but important from the point of view of the wheat and other grain crops of the area; and (3) the Ganges plains, which receive slight winter and considerable spring rain."[5] An interesting and significant feature of these exceptions is that those regions are also the major wheat growing centres.

Economists and geographers have found it convenient to divide India into zones of certain and uncertain rainfall. The zones of uncertain rainfall comprise the areas with an average precipitation of 15 to 40 inches, including U.P., Western, Central and North Rajasthan, a large portion of Gujarat and Maharashtra. In these areas occasional droughts occur, and are disastrous particularly because of their unexpectedness. Surprisingly enough, the zones of "certain" rainfall are areas with average precipitation below 15 inches (desert or dependent on irrigation) and above 40 to 50 inches.[6] It also happens that the wheat growing regions lie in the zone of uncertain rainfall.

---

5. Vera Anstey The Economic Development of India Longmans 1931 London Second Edition p 15-16
6. Vera Anstey Ibid. Also p 76

Whereas incessant or continuous rainfall would cause growing crops to deteriorate and rot, insufficient rainfall or variations in the direction of the rainbearing winds convert narmally productive areas into deserts. Heavy rainfall causes erosion and damage due to loss of fertile soil; waterlogging and/or damage by floods is yet another problem. At the same time there is considerable loss of moisture due to too rapid flow onto shallow top soil, water fails to sink into the sub soil and replenish the reserve of water.

Yet another factor influencing the cultivation of crops is the precipitation of moisture in the form of dew and the range of humidity and temperatures during the growing season.

Cultivation depends in great measure upon the character of the soil. The question of soil and soil qualities is an important factor which is inadequatley discussed in relation to Indian agriculture. The traditional scheme involves a statement of the principal kinds of soil and register four main types:

(a) The alluvial soils which are in the Indo Gangetic plains, cover at least 300,000 sq. miles and are agriculturally the most important: accounting for 19% of the total area and 42% of the population. If the people of the river delta regions of the west centre and the far south are added, this brings the total to 50% of the country's population. The soils grade from the coarse material of the piedmont bhabar to the fine silts of the Ganges delta, internally the most striking distinction is between the older bhangar and the long fingers of the recent khadar in the main flood-plains, in many places annually refreshed by new silt. Apart from this, variations in fertility are due mainly to factors of water-table, and the presence or absence of cal-careon concretions in the subsoil. In general, lime is about adequate, the nitrogenous and organic content are low. Potash and phosphoric acid slats, though not exactly super-abundant are less deficient than in other Indian soils. In the drier areas, strong alkaline soils and even salt deposits occur.

(b) Regur - typically found on the Deccan plateau, some is redeposited in the river valleys by streams flowing from the Deccan Lavas. Regur of varying qualitites is found in gneisses and other rocks in the South India regions, (Madras Deccan, extreme Southeast, in the alluvian of Gujarat and along the Coromandel coastal strip.) The regur is moisture retentive and this region is mostly used for cotton growing. The soil is black, not with the presence of humus but with (probably) finely divided iron particles. A high proportion of calcium and magnesium carbonate is to be found in regur. At some places the soil is deep but on higher ground it is thinner and grades into reddish-brown and red soils. On Archaens it is often underlain by a Kanker horizon. The black soil is in general adequate in potash and lime but deficient in nitrogen, organic matter and phosphoric acid.

The moisture retentive qualities of regur and its aeration by deep hot weather cracking are characteristic; it swells when wet and this alternation insures thorough mixing of soil particles. Unless tilled after the onset of rains, it is extremely sticky and difficult to work.[7]

(c) Red soils - may be brown, grey black and include most of the soils developed on the Archaen crystallines. There is considerable variation with parent rock, climate and local terrain. Very poor indeed in uplands where they may be almost loose gravels, they include in depressions (soil wash traps) some good loams, which respond well to irrigation. Mineral deficiencies are similar to those of regur.

(d) Laterite soils - very poor soil, scrubland for source of fuel. Building settlements with nursed land use -- houses, gardens, and orchards, rough grazing, coarse scrubland.

One thing that seems pretty obvious from the detailed regional geological reports is that even though we have these four broad categories of soil, this does not imply that these four categories are isolated and continuous. These categories exist side by side in such a way that they inhibit the spread of uniform agricultural practices, techniques and, of course, the cultivation of crops. It is not uncommon, thus, to find areas in the Gangetic plain which are completely sandy and consequently unfit for cultivation.

---

7. inhibits use of equipment and machinery

This is not immediately obvious from the broad outlined description of categories of land.

In the review of soils it may be mentioned in passing that the topsoil depth varies from several feet to a depth of only a few inches. Even in comparatively fortunate areas where the soil is rich and where the rainfall is adequate and perhaps where even irrigation facilities are available, it will be found that the depth of topsoil serves as a severely limiting factor in the use of equipment and machinery, whether devised for clearance and reclamation, weed elimination or ploughing and harrowing to pulverise the soil preparatory to sowing.

The relation of weather and climatic factors to the output of agricultural products was observed a long time ago. The authors associated with these enquiries and their studies provide an impressive list. Interest in the relationship was generated by the desire to predict economic conditions at harvest time, to forecast yields and possible to avert possible losses. Indeed some part of the interest in this field can be attributed to the growing desire to examine the employment of economic resources in agriculture.

Early attempts were made to relate the "law of the changing supply of raw material....with a law of changing weather"; and to discover the law and cause of cycles in economic phenomena.[8] Other attempts were more specific

---

8. Henry L. Moore <u>Economic Cycles: Their Law and Cause</u> Macmillan 1914 <u>London & New York p 2</u>

and sought directly to relate output with rainfall and other climatic factors. Studies singled out the amount and time of incidence of rainfall during crop year to final output of crop.[9] Other studies suggested that weather itself was an important component in a series of associated major factors ".?.(i) Inherent capacity of the plant itself to bear; (ii) fertility of the soil; (iii) weather and length of the growing season; and (iv) cultural methods applied to the crop during its growth; that is, the influence which the grower can exert to accentuate favourable, and minimize unfavourable, natural conditions."[10]

Enquiries began to be based upon the information provided by agronomists and meteorologists; estimates of probability to enable safeguarding against the consequences of unseasonable frosts; hail storms, wind, rain, and flood damage; prolonged droughts and insect and pest damage. The collection of data nad improvement in processing and analysis of agricultural statistics underwent a great change in the inter-war period. Improvements in crop estimating were made by: (a) increasing the size of the same i.e. increasing the number of crop reports; (b) securing better crop reporters, through better geographic distribution or

---

9. R.A.Fisher "The Influence of Rainfall Upon the Yield of Wheat at Rothamsted" Phil. TransSeries B Vol 213 CCXIII 1924 0 89-142 Fisher cites A.Walters' study of effects of weather on sugar crops in Mauritius.

10. B.B.Smith "The Adjustment of Agricultural Production to Demand" Journal of Farm Economics Vol VIII No 2 April 1926 p 145-165

through representative farm holdings or farm operators; (c) partial elimination of bias; and (d) partly through re-checking by alternative methods.

Careful cooperation of economists and agricultural meteorologists served to highlight the components of weather -- light, heat and moisture.[11] Photo-synthesis was dependent on plant leaf area and thickness, on chlorophyll content etc. The intensity and character of light under ordinary conditions of cultivation, indicated a significant/directly determining factor in yields. The relationship between sunshine and temperature indicate a high correlation i.e. when sunny the temperature is usually warm, warmth having important effects upon growth of plants. Not all plants, however, require similar light and warmth. Plants were also observed to be responsive to latitude; hours of sunshine per day of the growing season increase with latitude. At higher latitudes the growing season is shortened, spring coming later and autumn sooner; but the hours of sunshine are not proportionately higher because the days are longer in summer.

Thus, among the factors considered important among the weather and climate group were: (a) rainfall - amount, distribution, reliability and effectiveness; (b) evaporation; (c) temperatures - maximum, minimum, and average;

---

11. C.L. Arlsberg and L.P. Griffing "Forecasting Wheat Yields from the Weather" Wheat Studies Food Research Institute Vol 5 No 1 1928 Stanford University Palo Alto

(d) length of drought periods; (e) length of growing season - stages of plant growth, critical or special periods when certain weather factors or combinations produce large yields; (f) amount of sunlight and soil moisture; and (g) etc.

In this type of treatment[12] the superiority of procedure treating with separate elements cannot be overemphasized. For example attempting to relate the stages of plant growth with other factors is obviously more meaningful than would be, say, an annual or even monthly division of data. It must, however, be pointed out that there are no dates for these stages, and, like what one would expect they vary from year to year and place to place.

Studies in plant growth led to the attempt to identify the main stages in wheat growth.[13] These were identified as germination, tillering, jointing, heading, blossoming, and ripening; after which the crop could be harvested, threshed winnowed, etc.

The period of germination up to the formation of the first leaf and the period of flowering are regarded as critical.[14] However, since the period of flowering is very

---

12. Norah E. Zink "The Relation of Weather Factors to Wheat Yields on Levan Ridge, Utah" Monthly Weather Review Vol 68 March 1940 p 66-71 US Dept. of Agriculture Weather Bureau Washington
13. J. Warren Smith Agricultural Meteorology Macmillan 1920 New York and Girolamo Azzi "Problems of Agriculture Ecology" Monthly Weather Review 50:193 April 1922 Weather Bureau US Department of Agriculture Washington
14. C.L. Arlsberg and L.P. Griffing "Forecasting Wheat Yields from the Weather" Wheat Studies Food Research Institute Vol 5 No 1 1928 Stanford University Palo Alto

brief, there is some difference of opinion as to whether the critical period is just before, during, or just after flowering. Perhaps the most critical stage consists of three to four weeks before the plant heads; consequently the date of heading is very important and more reliable than the date of ripening. From the heading date the most critical period in the growth of wheat (which occurs shortly before heading) is established. A study by Azzi[15] of winter wheat in Italy indicates that the 20-day period just preceding heading was very important in the region studied - the soil had to be kept moist or the crop reduced. Another study by Smith[16] suggests another critical period at the time of planting when both temperature and moisture requirements are exacting. Winter wheat yields demonstrated great response to temperatures of a single month or of a season.

The preceding discussion serves to delineate the general problem namely, to determine which, if any, of the weather factors considered and available are in terms of probability, significant to the resulting yields, and to what degree.[17]

---

15. Girolamo Azzi (ibid)
16. J. Warren Smith Agricultural Meteorology Macmillan 1920 New York p 191-199 Smith also cites the example of Utah State particularly April temperatures and April, May and June precipitation.

17. Norah E. Zink "The Relation of Weather Factors to Wheat Yields in Levan Ridge, Utah" Monthly Weather Review Vol 68 March 1940 Weather Bureau US Department of Agriculture Washington

In India, as most everywhere else, efforts are being made to introduce and extend the use of fertilizers; water and soil conservation schemes; extend methods of irrigation; and introduce improved implements, improved seed varieties and measures against insects and plant diseases. In some limited measure these efforts are proving successful. Despite a adaption in crop plants and different forms of tillage and the use of manures and fertilizers to compensate for soil conditions, agricultural production remains both variable and hazardous mainly on account of fluctuations in weather.

The choice of major wheat growing regions in India was facilitated by the index provided in the percentage distribution of area under wheat to the area under all cereals and millets. (See Table 6)

TABLE 6 : STATEWISE AVERAGE AREA UNDER WHEAT FOR TRIENNIAL ENDING 1960-61

State	Wheat (000 hectares)	Total Cereals & Millets (000 hectares)	Percentage distribution of area under wheat
Andrha Pradesh	18	7964	0.28
Assam	3	1710	0.17
Bihar	632	7342	8.38
Gujarat & Maharashtra	1332	14176	9.39
Madhya Pradesh	2904	11141	26.07
Madras	2	4423	0.05
Mysore	301	5875	5.12
Orissa	6	4027	0.15
Punjab	2129	4499	47.32
Rajasthan	1449	7704	14.90
Uttar Pradesh	3890	13722	28.35
West Bengal	39	4597	0.85

Source: Agricultural Situation in India August 1961 p 628-631 and C.S.O. Statistical Abstract of the Indian Union no 16 p 43-44

The area under wheat as a percentage of total cropped area is yet another means of highlighting the major wheat growing regions;[18] and confirms the choice made by the previous method. In alphabetical order these are: (i) Bihar; (ii) Gujarat and Maharashtra; (iii) Himachal Pradesh; (iv) Madhya Pradesh; (v) Punjab; (vi) Rajasthan and (vii) Uttar Pradesh. However, for the kind of analysis attempted, data availability restricts the study to Punjab, Uttar Pradesh, Gujarat and Maharashtra (Bombay) and Madhya Pradesh.

One of the most important sources of data have been the Studies in the Economics of Farm Management conducted in six typical regions in the country (Bombay, Madras, Punjab, U.P., West Bengal) between 1954-57 and in Madhya Pradesh between 1955-56 and 1956-57. The studies were initiated and conducted by the Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India.

---

18. Area as percentage of total cropped area

Punjab 20.7	India 7.6	Madhya Pradesh 3.0	India 22.6
Rajasthan 9.8	India 9.1	Maharashtra 4.4	India 8.2
Himachal Pradesh 31.3	India 10.3	West Bengal negligible	India
Gujarat 4.7	India 8.2	Orissa 0.1	India negligible

The area under wheat in each state is indicated as a percentage of the total cropped area. In addition, the position of the state is indicated as a percentage of the all-India total cropped area.

These studies were one-shot affairs and comparable or similar data is unlikely to be collected for the other regions, not included in the study. The four regions selected for this study vary quite considerably. The following table gives some general information about them. (See Table 7)

TABLE 7: Area, Population, Rural Population and Density of Population

State	Area 000 sq. km.	Population million	Percentage of rural population	Density of Population persons / sq. km.
Punjab	122.3	20.3	79.9	166
Uttar Pradesh	87.6	34.9	87.2	251
Bombay [19]				
Maharashtra	307.5	39.6	71.8	128
Gujarat	187.1	20.6	74.2	110
Madhya Pradesh	443.3	32.4	85.7	73

Source: India 1965 p 14

19. Bombay State has been divided into two linquistic regions - which have had additional territories from adjoining regions to form Maharashtra and Gujarat States.

BIBLIOGRAPHY

Articles

Alsberg, Carl L. and Griffing, L.P. "Forecasting Wheat Yields from the Weather: Elements of an Unsolved Problem " Wheat Studies Food Research Institute Vol V No 1 November 1928 Stanford University Palo Alto

Azzi, Giro "Problems of Agriculture Ecology" Monthly Weather Review 50-193 April 1922 Weather Bureau US Department of Agriculture Washington

Black, J.D. Allen, R.H. and Negaard, O.A. "The Scale of Operations in Agriculture" Quarterly Journal of Economics Vol LIV 329 1939

Bracken and Stewart "A Quarter Century of Dry Farm Experiment" Bulletin of Utah Agricultural College Experimental Station No 222 1916

Chamberlain, E.H. "Proportionality, Divisibility and Economics of Scale" Quarterly Journal of Economics Vol LXII 1948

Davies, M. "Multiple Regression Analysis with Adjustment for Class Differences" Journal of American Statistical Association September 1961

Davis, Floyd E. and Pallesen, J.E. "Effect of the Amount and Distribution of Rainfall and Evaporation during the Growing Season on Yields of Corn and Spring Wheat" Journal of Agricultural Research Vol VI No 1 January 1940

Domar, E.D. et al "Labour Productivity" Review of Economics and Statistics 1963

Domar, E.D. "On the Measurement of Technological Change" Economic Journal December 1961

Domar, E.D. "On Total Productivity and All That" Journal of Political Economy December 1962

Domar, E.D., Eddie, M.E. et al "Economic Growth and Productivity in United States, Canada, United Kingdom, Germany and Japan" Review of Economics and Statistics 1964

Fisher, R.A. "The Influence of Rainfall upon the Yield of Wheat at Rothamsted" Philosophical Transactions Series B Vol CCXIII 1924

Griliches, Zvi "Comment on Capital Theory" The American Economic Review May 1961

Griliches, Zvi, "The Sources of Measured Productivity Growth in U.S. Agriculture, 1940-60" Journal of Political Economy August 1961

Griliches, Zvi "Estimates of the Aggregate Agricultural Production Function from Cross-sectional Data" (and discussion by) Journal of Farm Economics Vol XLV No 2 May 1963

Heady, E.O. "Use and Estimation of Input-Output Relationships or Productivity Coefficients" Journal of Farm Economics Vol XXXIV 1952

Henry A.J., Kincer, J.B., et al "Weather and Agriculture," U.S. Department of Agriculture Separata from Yearbook 1924 No 918

Hoch, Irving "Estimation of Production Function Parameters Combining Time-Series and Cross-Section Data Econometrica XXX January 1961

Hoffman, R.A. and Heady, E.O. "Production, Income and Resource Changes from Farm Consolidation" Iowa Research Bulletin No 502 February 1962

Johnston, Bruce F. "The Choice of Measures for Increasing Agricultural Productivity" Tropical Agriculture Vol XLI No 2 April 1964

Kendrick, J.W. "Productivity Trends in Agriculture and Industry" Journal of Farm Economics Vol XL December 1958

Linney, Charles E, "Climate as it affects Crops and Ranges in New Mexico" Bulletin of Agricultural Experimental Station No 182 March 1930

Misner, E.G. "Farm Management Problems in North Eastern Dairy Belt" Journal of Farm Economics Vol VII April 1925

Mundlak, Yair "Empirical Production Function Free of Management Bias" JPE 1961

Nelson, Michael "The Use of the Production Function" Land Economics Vol XXXIII August 1957

Nelson, R.R. "Aggregate Production Functions and Medium Range Growth" American Economic Review September 1964

Pasinetti, L.L. "On Concepts and Measures of Changes in Productivity" (followed by R.M. Solow's Comment and Pasinetti's Reply) Review of Economics and Statistics, Vol XLI August 1959

Patton, Palmer "The Relationship of Weather to Crops in the Plains Region of Montana," Agricultural Experimental Station University of Montana Bulletin No 206 August 1927

Phelps Brown, E.H. "The Meaning of the Fitted Cobb-Douglas Function" Quarterly Journal of Economics Vol LXXI 1957

Read, L.M. "A New Approach to the Measurement of Total Factor Productivity" mimeographed paper of Carelton University Ottawa (undated)

Rymes, T.K. "Proffessor Read and the Measurement of Total Factor Productivity" Carleton University Ottawa (undated)

Schmookler, Jacob "The Changing Efficiency of the American Economy" RES XXIV August 1952

Schultz, T.W. "Investment in Human Capital" AER LI March 1961

Smith, Bradford B. "Relationship between Weather Conditions and Yield of Cotton in Louisiana" Journal of Agricultural Research Vol XXX no 11 June 1925

Smith, Bradford B. "The Adjustment of Agricultural Production to Demand" Journal of Farm Economics Vol VIII No 2 April 1926

Solow, R.M. "The Production Function and the Theory of Capital" Quarterly Journal of Economics Vol LXX November 1956

Solow, R.M. "Technical Change and the Aggregate Production Function" Review of Economics and StatisticsVol XXLIX August 1957

Solow, R.M. "Reply" Review of Economics and Statistics Vol XL November 1958

Solow, R.M. "Concepts and Measures of Changes in Productivity" Review of Economics and Statistics Vol XLI August 1959

Solow, R.M. "Investment and Technical Change" Mathematical Methods in Social Sciences (Arrow et al) Stanford University 1959 Stanford

Suits, Daniel B. "Use of Dummy Variables in Regression Equations" Journal of American Statistical Association 1957 Vol 52

Suryanarayana, K.S. "Resource Productivity and Size of Farms" The Asian Economic Review Vol VIII No 1 November 1965

Tomek, William G. "Using Zero-One Variables with Time-Series Data in Regression Equations" Journal of Farm Economics November 1963 Vol 45:4

Walters, A.A. "Survey of Cost and Production Function" Econometrica 1963

Westfield, Fred M. "Technical Change and Returns to Scale" RES XLVIII November 1966

Wolfson, R.J. "An Econometric Investigation of Regional Differentials in American Agricultural Wages" Econometrica Vol XXVI 1958

Waugh, Frederick V., Stevens, Chester D. and Burmeister, Gustave "Methods of Forecasting New England Potato Yields" U.S. Department of Agriculture Bureau of Agricultural Economics, (Mimeographed Report) Feb 1929

Zink, Norah E. "The Relation of Weather Factors to Wheat Yields on Levan Ridge Utah" Monthly Weather Review Vol LXVIII March 1940 Weather Bureau US Department of Agriculture Washington

Books

Anstey, Vera The Economic Development of India Longmans 1931 London

Basu, S.K. (ed.) Studies in Economic Problems Asia Publishing House 1965 London

Bushaw, D.W. and Clower, R.W. Introduction to Mathematical Economics Irwin 1957 Homewood

Chenery, Hollis B. and Clark Inter-Industry Economics

Clark, Colin The Conditions of Economic Progress 2nd Edition Macmillan 1951 London

Das, Nabagopal Spotlight on Indian Economic Problems A. Mukheiji 1961 Calcutta

Datta, Bhabatash 3rd revised edition The World Press 1960 Calcutta

Davies, C. Colin An Historical Atlas of the Indian Peninsula 4th impression 1956 Oxford University Press 1949 London

Datta, Kalikinkar Survey of India's Social Life and Economic Condition in the Eighteenth Century, 1707-1813 Firma K.L. Mukhopadhyay, 1961 Calcutta

Dudley,Stamp, L. Our Developing World Faber & Faber 1960 London

Ezekiel, Mordecai and Fox, Karl A. Methods of Correlation and Regression Analysis 3rd edition John Wiley & Sons 1959 New York

Fabricant, S. Basic Facts on Productivity Change Occasional Paper 63 National Bureau of Economic Research New York & Princeton 1959

Fisher, Franklin M. The Identification Problem in Economics McGraw Hill 1966 New York

Goldberger, Arthur S. Econometric Theory Wiley 1964 New York

Heady, Earl O. and Dillon, J.L. Agricultural Production Functions Iowa State 1961 Ames

Heady, Earl O. Economics of Agricultural Production and Resource Use Prentice Hall 1952 New York

Heady, Earl O., Johnson, G.L. and Hardin, L.S. Resource Productivity, Returns to Scale and Farm Size Iowa State College 1956 Ames

Jathar, G.B. and Beri, S.G. Indian Economics 9th edition Oxford University Press 1949 London

Johnston, John Econometric Methods McGraw Hill 1963 New York

Kendrick, J.W. Output, Input and Productivity Measurement NBER 1961 Princeton

Kendrick, J.W. Productivity Trends in the U.S.A. Princeton University Press, 1961 Princeton

Klein, Lawrence R. (ed.) Contributions of Survey Methods to Economics Columbia University Press, 1954 New York

Klein, Lawrence R. A Textbook of Econometrics Row Peterson & Co., 1953 Evanston Illinois

Klein, Lawrence R. An Introduction to Econometrics Prentice Hall 1962 Englewood Cliffs

Lave, Lester B. Technological Change: Its Concept and Measurement Prentice Hall 1966 Englewood Cliffs

Lok, S.H. An Inquiry into the Relationships between Changes in Overall Productivity and Real Net Return Per Farm, and between Changes in Total Output and Real Gross Return Canadian Agriculture, 1926-57 1961 Ottawa

Lokanathan, P.S. Industrial Organization in India George Allen & Unwin 1935 London

Miernyk, William H. the Elements of Input-Output Analysis Random House 1965 New York

Misner, E.G. Weather: Its Relation to the Production and Price of Farm Products Cornell University Press 1929 Ithaca

Misner, E.G. Studies of the Relation of Weather to the Production and Price of Farm Products I Corn; 1928; II Cotton 1932 Cornell University mimeographed publication 1928 and 1932 Ithaca

Moore, Henry L. Economic Cycles: Their Law and Cause Macmillan 1914 London

Nerlove, Marc Estimation and Identification of Cobb-Douglas Production Functions North Holland 1965 Amsterdam

Orcutt, Guy H. Greenberger, Martin et al Microanalysis of Socioeconomic Systems: A Simulation Study Harper & Row 1961 New York

Paige, Deborah and Bombach, Gottfreid A Comparison of National Output and Productivity OEEC 1959 Paris

Phillips, John The Development of Agriculture and Forestry in the Tropics Faber & Faber 1961 London

Salter, W.E.G. Productivity and Technical Change Cambridge University Press 1960 Cambridge

Sanderson, Fred H. Methods of Crop Forecasting Harvard University Press 1954 Cambridge

Sangha, Kehai Productivity and Economic Growth Asia Publishing House 1964 London

Sen S.R. The Strategy for Agricultural Development and other Essays Asia Publishing House 1962 London

Smith, J. Warren Agricultural Meteorology: The Effects of Weather on Crops Macmillan 1920 New York

Sreenivasan, K. Productivity and Social Environment Asia Publishing House 1964 London

Suits, Daniel B. Statistics: An Introduction to Quantitative Economic Research Rand McNally 1963 Chicago

Trewartha, Glenn T. The Earth's Problem Climates University of Wisconsin Press 1961 Madison

Vakil, C.N. Poverty and Planning Allied 1963 Bombay

Vitkevich, V.L. Agricultural Meteorology (Translation from Russian) Israel Program for Scientific Publication 1963 Jerusalem

Documents

India (Republic) Directorate of Economics and Statistics, Ministry of Food and Agriculture Studies in the Economics of Farm Management New Delhi
(i) Bombay State
(ii) Madhya Pradesh State
(iii) Uttar Pradesh State
(iv) West Bengal State
(v) Punjab State
(vi) Madras State

India (Republic) Directorate of Economics and Statistics Ministry of Food and Agriculture Economic Survey of Indian Agriculture (Annual Reports) New Delhi
(i) 1954-55
(ii) 1955-56
(iii) 1956-57
(iv) 1957-58
(v) 1958-59
(vi) 1959-60

India (Republic) Economic and Statistical Advisor to G.O.I. Ministry of Food and Agriculture Area, Production and Average Yield per acre of Principal Crops in India
(i) 1951/52 to 1954.55 (statistical supplement to 'Agricultural Situation in India' March 1956)
(ii) 1949-50 to 1957-58 (statistical supplement to 'Agricultural Situation in India' September 1958)

India (Republic) Directorate of Economics and Statistics Ministry of Food and Agriculture Agricultural Situation in India New Delhi

India (Republic) National Productivity Council Productivity (Special Supplement on Agricultural Productivity) Vol 2 & 3 1965 New Delhi

India (Republic) Statistical Handbook Central Statistical Organisation G.O.I. 1964 New Delhi

O.E.C.D. Concepts of Productivity Measurement in Agriculture on a National Scale Series: Documentation in Food and Agriculture No 57 1962 Paris

O.E.E.C. Measurement of Productivity OEEC 1952 Paris

O.E.C.D. Cost-Return Relationships in Agriculture (ed. J. Horring) series: Documentation in Food and Agriculture No 1 1959 Paris

O.E.E.C. Productivity Measurement Review (ed. L.A. Vincent) The Main Formulae for Productivity Measurement in a National Economy or Sector No 25 May 1961 Paris

O.E.E.C. Productivity, Prices and Wages (ed. J. Fourastiè) 1957 Paris

O.E.E.C./E.P.A. Productivity Measurements (Vol I - Concepts Vol II - Plant Level Measurement) 1955 Paris

United Kingdom Commonwealth Economic Committee Grain Crops 1954-61 London

United Kingdom Economic Trends, Ministry of Agriculture, Fisheries and Food Productivity Measurement in Agriculture London

United States Department of Agriculture, Senate Hearings Commercial Policy for Agriculture Washington

United States Department of Agriculture, Agricultural Hand - book #146 Foote, Richard J. Analytical Tests for Studying Demand and Price Structures August 1958 Washington

United States Department of Agriculture, Technical Bulletin No 1238 Loomis, R.A. and Barton, G.T.: Productivity of Agriculture in the United States, 1870-1958 Washington

United States National Bureau of Economic Research Productivity Trends: Capital and Labour Occasional Paper No 53 Princeton

United States National Bureau of Economic Research Basic Facts on Productivity Change Occasional Paper No 63 Princeton

United States National Bureau of Economic Research Output, Input and Productivity Measurement Studies in Income and Wealth Vol 25 Princeton

United States Department of Agriculture Technical Bulletin 1238 USDA Washington

Theses

Barzel, Yoram "Productivity in the Electric Power Industry, 1929-1955" Unpublished Ph.D dissertaion University of Chicago 1961 Illinois

Berglas, Eitan "Stimulating Investment, Technological Change and Growth" Unpublished Ph.D. Dissertation, University of Chicago 1963 Illinois

Kurien, John C. "Technical Change in U.S. Manufacturing" Unpublished Ph.D. dissertation Vanderbilt University 1967 Nashvelle

Maddala, G.S. "Technological Change in the Bituminous Coal Industry, 1919-1954" Unpublished Ph.D. dissertation University of Chicago 1963 Illinois

Sahota, Gian S. "An Analysis of the Causes of the Secular Decline in the Relative Price of Fertilizer" Unpublished Ph.D. dissertation Department of Economics, University of Chicago 1965 Chicago