SYMPOSIUM ON MEASUREMENT OF AGRICULTURAL PRODUCTIVITY*

MEASUREMENT OF AGRICULTURAL PRODUCTIVITY—CONCEPTS, DEFINITIONS, ETC.

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ONE of the ultimate aims of agricultural development is the improvement of productivity. Often an underdeveloped economy is characterized by a low level of productivity in agriculture. In the context of India's attempt at achieving a break-through in agriculture, it is but natural that attention should be devoted to improvements in productivity. In order to enable formulation of effective policies for this purpose, it would be necessary to determine the current levels of productivity, past trends and future prospects. However, the measurement of productivity in agriculture is more difficult than in industry and poses many problems of concepts, definitions, etc.

MEASUREMENT OF OUTPUT

Broadly, agricultural productivity can be considered in relation to land, labour and capital. It can also be considered in terms of the overall resources employed in agriculture. The output could be expressed in terms of gross or net output. The gross output can be measured in quantitative terms if only one individual commodity is under consideration, but when the output for agriculture as a whole is to be measured, there is the problem of aggregation of different products. While food-grains can be added ton to ton, other heterogeneous commodities like food-grains, fruits and vegetables, sugarcane, fibres and oilseeds cannot be so added. In the case of edible grains and crops, calories may be one possible common unit for expressing the output, but for the agricultural sector as a whole, the only common unit is value which involves pricing of the different products. Different types of prices can be adopted for evaluation, *viz.*, harvest price, wholesale price, etc., each having a definite significance and relevance.

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* Symposium held on 5th January 1964 during the 17th Annual Conference of the Indian Society of Agricultural Statistics at Jaipur under the Chairmanship of Shri Mathura Das Mathur, Minister of Planning and Statistics, Government of Rajasthan.

Further, the output can also be measured either in the form in which it leaves the field or in some processed form. It may relate exclusively to the main product from the field or include by-products also. Similarly, the net output can be defined as output after allowing for seed and feeds, to avoid double counting, particularly if livestock products are also taken into account; or it may be taken as the value added by labour and other factors in agricultural sector, *i.e.*, the value of fertilizers, pesticides and other inputs from outside the agricultural sector is subtracted from the value of output in order to determine the net contribution of the agricultural sector to the national income. Some of the problems of valuation of net output are common to those arising in the estimation of national income from the agricultural sector.

Measurement of Area

With regard to area, a broad distinction is necessary between net sown area and gross area sown and planted area and harvested area. Some of the comparison of yield per acre in India and other foreign counteries are not strictly valid, for, while in India the yield per acre relates to area sown, in other countries it is related to harvested area. Similarly, while comparing the yield per acre, the intensity of cropping is also to be taken into account. Yield per acre on double cropped lands expressed in terms of gross area will be different from that on single cropped area. In some types of studies, the duration of the crop growth is also relevant in comparing the productivity. Further, a distinction between irrigated and unirrigated lands will also be necessary while comparing productivity. The yield per acre also depends on the natural soil fertility. Soil classification adopted for land revenue purposes and that based on Storie's index provide some basis for comparison of different areas. It is, however, necessary to evolve the concept of a standard acre which takes into account these various factors.

Productivity of Labour

The measurement of productivity of labour is also somewhat complex. It is expressed as the ratio of output to labour input needed to produce that output. According to the purpose of study and the data available, the labour input may be expressed as the total number in labour force or, in order to take into account the intensity of labour, as the number of man-hours worked in agriculture. Estimates of output per man-hour are of value in giving some indication of the extent of unemployment and also in drawing up programmes of farm planning. In comparing the productivity of labour under two situations the extent of mechanisation of farming operations has also to be taken into account.

Productivity of Capital

In measuring productivity of capital, it is necessary to evolve some acceptable concept of capital. So far as fixed capital is concerned, annual input due to compensation for the use of capital stock, *i.e.*, interest and its consumption, *i.e.*, depreciation, is of relatively minor importance compared with the other major input groups, *viz.*, land, labour and working capital. Thus, when agriculture is practised on traditional lines, the important aspect of capital to be taken into account in determining productivity is the working capital.

Productivity of Inputs

Agricultural productivity might also be measured with respect to all the resources used in agriculture. In that case, all inputs including labour, land, buildings, machinery, fertilizers, etc., are aggregated and compared with the gross output of the whole sector. Productivity can also be worked out for different types of individual inputs and partial productivity ratios developed. Productive efficiency may also be computed taking into account only a portion of cost, *viz.*, the paid-out cost, total cost including imputed value of labour and of inputs produced on the farm, or various other permutations and combinations thereof.

Average and Marginal Productivity

For detailed planning, it will also be necessary to work out average and marginal productivity. Appropriate production functions could be developed on the basis of farm management and other data. These studies could be undertaken at the micro or macro levels.

Comparisons over Time, Space and Crops

Productivity studies are most useful when they are made over a period of time. The main difficulty, particularly in countries like India in such studies is the non-availability of comparable data. Where comparable series are available, different techniques of time-series analysis can be employed. Some studies of this type have been undertaken by the Institute of Agricultural Research Statistics, Comparison of productivity might also be made over different regions or for different crops. Each of these raises difficult problems of measurement and involves some assumptions.

Measurement of Effects of Technological and Institutional Changes

In long-term planning, it will also be necessary to consider the effects of technological changes on productivity. Further, effects of institutional changes and Government policies like land reforms, supply of credit, taxation, subsidies, price policy, marketing, organization of extension services, also need to be studied.

Index Numbers of Productivity

For working out agricultural productivity, the Directorate of Economics and Statistics has prepared a series of index numbers of area, production and yield per acre, using comparable figures over time. This series is available since 1949–50. The productivity indices, however, relate more to yield per acre than productivity in the true sense of the term, because the influence of season is reflected in this series. The real indices of productivity should be independent of the character of season. The problem of isolating the effect of season on aggregate output from the effect of various input factors in terms of production potential is also very important. Adequate attention has not been paid to this problem in India. Appropriate methodology is yet to be developed, for this purpose. Some work is, however, being done regarding the assessment of effects of uncertain factors like attack by pests and diseases by the Institute of Agricultural Research Statistics.

Growth rates based on index numbers of area, production and productivity at all-India level and on index of production at the State level have also been recently studied in the Directorate of Economics and Statistics. Thus, index numbers have a definite role to play in studies of productivity as through this device, it is possible to secure comparability in otherwise non-comparable figures over a series of years.

Land Use and Crop Planning

Analysis of productivity plays an important role in studies of land use and crop planning, based on maximum long-run productivity. Here, the problem is of working out coefficients taking into account both the relative importance of the crop in an area and also its yield per acre. Useful work on dividing the country into different regions and also studying the cropping patterns and yield per acre of different crops in each region, has been done in the Directorate of Economics and Statistics.

Productivity studies can also be related to size of holding, mode of tenure and type of farming. Some work in this connection is being done in the Institute of Economic Growth.

There is an urgent need to bring together all available literature in this field, study the deficiencies in the existing approaches and data and organise systematic and co-ordinated studies on agricultural productivity in all its aspects.

MEASUREMENT OF THE ACTUALLY REAELISED AGRICULTURAL PRODUCTIVITIES PER ACRE AND PER WORKER IN THE DIFFEERENT CROP REGIONS OF INDIA

BY J. G. ANAND

THEORETICALLY speaking, the mechanism of the production functions or input-output relationships affords the best possible way of measuring either the composite productivity of all the resources employed in an economic activity or the productivity of a single factor of production. The development of production functions for a very large category of soil-types, enterprises and systems of management, however, presents a problem in practical work which cannot be easily solved. In the absence of detailed data on productivity coefficients, it is impossible to utilise this mechanism for the determination of relative agricultural productivities of the different regions or areas. It is therefore necessary to consider what can be achieved with the relatively comprehensive data on cropping and yield patterns which is available for all parts of the country. In this paper an attempt has been made to evolve a practical method for the measurement of average productivities per acre and per worker with the help of these data, and the method evolved has been utilised to work out the indices of these productivities for about 100 homogeneous crop regions into which the country has been divided.

The method of formation of homogeneous crop regions may be explained briefly first. The percentages of areas sown to 20 crops, *viz.*, Rice, Jowar, Bajra, Maize, Ragi, Wheat, Barley, Gram, Tur, Sugarcane, Cotton, Jute, Groundnut, Sesamum, Rapeseed and Mustard, Linseed, Castor Seed, Chillies, Potatoes and Tobacco, which account for about 80 per cent. of the gross cropped area in the country and for which separate figures are available on the gross sown area in each district of the country for the triennium ending 1958–59, have been worked out. The set of the percentages mentioned above in respect of any district is taken to represent the cropping pattern of that district. With these data, contiguous districts having similar cropping patterns have been grouped into homogeneous crop-regions.

A brief mention may be made here of some of the data utilised and the notation used may be explained next. For a region R, the 20 crops are indicated as crops $c_1, c_2 \cdots c_{20}$. The percentages of areas sown to these crops of the gross sown area of the same region R are denoted by $p_1, p_2, \cdots p_{20}$. The percentages of the average yields of these crops in any Region R on the corresponding all-India average yields will be indicated by $y_1, y_2, y_3, \cdots, y_{20}$.

The index of gross agricultural output per acre is conceived as a composite index built out of three component indices which, for reasons explained later, have been termed as:—

(i) the yield index;

(ii) the pattern index; and

(iii) the land use-intensity index.

The yield index gives a composite index of the yield relatives of each region without differentiating between one crop and another. For calculating the yield index of a region R, its yield relatives $y_1, y_2, \cdots, y_{20}$ have been combined into a single index using the proportions $p_1, p_2 \cdots, p_{20}$ as weights. Thus the

$$\text{Yield index } (y_i) = \frac{\sum_{r=1}^{20} p_r y_r}{\sum_{r=1}^{20} p_r}.$$

Each crop here is given the same weight as it enjoys in the cropping pattern of the region R. This index can be taken to represent the general level of physical yields in the region R.

But this index of physical yields cannot be taken as an index of the gross agricultural output per acre since, for the latter differences in cropping patterns have to be taken into account. To serve this purpose, the pattern index which is the second component of the composite index of the productivity per acre, has been developed. For relative evaluation of the cropping patterns of the different regions, we have obviously to assign value relatives to the different crops. These relatives have been assigned here on the basis of the average contribution per acre of each of the crops to the gross national income during the three years ending 1958–59. These contributions have then been adjusted through multiplication by a constant factor to yield the value relatives $w_1, w_2, \ldots, w_{20}$ for the twenty crops such that if $q_1, q_2, \cdots, q_{20}$ form the set of percentages representing the All-India Cropping pattern, then

$$\frac{q_1 w_1 + q_2 w_2 + \cdots + q_{20} w_{20}}{q_1 + q_2 + \cdots + q_{20}} = 100,$$

where $w_1, w_2, \cdots w_{20}$ are proportional to the average contribution per acre of each crop to the national income during the triennium ending 1958–59 and these proportions have been so selected as to ensure that if the All-India Cropping pattern is evaluated using these relatives, that evaluation comes out to be 100.

It is now quite easy to explain that the pattern index of the region R would be given by the formula:

$$\text{Pattern Index} = \frac{p_1 w_1 + p_2 w_2 + \cdots + p_{20} w_{20}}{p_1 + p_2 + \cdots + p_{20}}.$$

This index obviously gives a relative measure of the average value of the gross agricultural produce per cropped acre of the various regions on the assumption that the value of the produce per acre of any crop is the same throughout India and equals the average contribution per acre of that crop to the national income. The regional differences in yields and prices have not been taken into account here. The regional variations in yields were not intended to be taken into account here, for these variations are accounted for in the yield index but if the regional variations in prices could be taken into account that would have improved the quality of this index. The all-India value relative for each crop should have been adjusted for use in the different regions in the ratio borne by the average regional price to the all-India average price of that crop.

In order to work out the index of the gross agricultural output per physical acre of cropped area, we have to allow for differences in intensity of cropping. For this, we compute the third component of the index (of gross agricultural produce per acre), *viz.*, land use-intensity index. Suppose t is the percentage of the average gross cropped area on the net cropped area in India for the triennium ending 1958–59 and k is the corresponding figure for the region R, the land use-intensity index for this region would be $k/t \times 100$.

The three indices developed so far, *viz.*, (i) the yield index (Y.I.), (ii) the Pattern Index (P.I.), and (iii) the land-use intensity (L.U.I.) can now be compounded into a single index of gross agricultural output per acre of net cropped area by multiplying the three and dividing the result by 100×100.

Next, an attempt has been made to work out the index numbers of gross agricultural production per agricultural worker. The number of agricultural workers per acre of net area sown in the region R is x and that for India (regarded as a region) y, the index of agricultural workers per acre for the region R has been computed as $x/y \times 100$. The index of agricultural production per acre divided by the index of agricultural workers per acre gives the index of agricultural production per agricultural worker.

Interpretation of the Indices

Generally, a high yield index is associated with a high pattern index because the level of availability of water happens to affect both these indices in the same direction. The high value crops like tobacco, sugarcane, potatoes, rice, etc., are mostly grown on lands which have the advantage of assured rainfall or of controlled irrigation or both and the quality of agricultural husbandry practised on such lands is far superior to that practised on lands not so favourably placed in regard to water suplies. Therefore, normally high yield index might go with high pattern index. We might have a look at the simple table given below which shows the division of all the States into four categories on the basis of their yield and pattern indices:

		Yield index	
		Above 100	Below 100
Pattern index ..	Above 100	Andhra Pradesh Assam Jammu and Kashmir Madras Orissa U.P. West Bengal	Bihar Kerala
	Below 100	Punjab	Rajasthan Gujarat Madhya Pradesh Maharashtra Mysore

This table seems to indicate a sort of polarisation at the two ends of (i) above average yield and above average pattern indices and (ii) below average yield and below average pattern indices. The States of Andhra Pradesh, Assam, Jammu and Kashmir, Madras, Orissa, U.P. and West Bengal most of which have the advantage of the availability of adequate water-supplies over large parts of their territories come in the first group while the States of Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Mysore which have very small percentages of their areas under irrigation fall into the second group. Bihar is a well-known case of an area where a number of high-value crops like rice, sugarcane, etc., are grown but the yields are generally low. Punjab's position in the table is explained by the fact that while its own yields of wheat, gram and cotton are quite high, at the all-India level, these crops do not belong to the high-value-relative group.

In the land-use intensity index again, the indices of the relatively dry States of Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Mysore are below 100 and here they are, strangely enough, joined by a State like Orissa. Andhra Pradesh also has large tracts of dry areas in Rayalseema and Telengana areas and its land use-intensity index is also below average.

In the composite index of gross agricultural output per acre, Madras (176·2) comes at the top and owes that position mainly to a high yield index (157·7) though its other two component indices are also above 100. In this composite index, Madras is closely followed by Assam (174·0) and West Bengal (168·1) but both these States owe their position near the top to their high pattern indices—152·0 and 148·1 respectively—their yield indices being 110·9 and 112·1 only. In the matter of yield index, Punjab follows Madras though Punjab's yield index (131·7) is very much lower than that of Madras. In the composite index of agricultural produce per acre, after Madras, Assam and West Bengal, come the four States of Kerala, Orissa, Punjab and Uttar Pradesh with their indices lying between 125 and 135. Of these States, Punjab owes its position to fairly good yield and land use-intensity indices while its pattern index is below 100. Kerala and Orissa obtain their positions in this group through relatively high pattern indices—136·0 and 136·1 respectively. Otherwise, Kerala's yield index is only 87·7 and the land use-intensity index 105·2 while Orissa's yield index is 103·0 and the land use-intensity index 94·6. Next in order come the States of Bihar (119·5), Andhra Pradesh (118·9) and Jammu and Kashmir (116·1). There is nothing very peculiar about these States except that in the case of Bihar which has the queer combination of a very low yield index (77·5), and fairly good pattern and land use-intensity indices (131·5 and 117·3 respectively). In the case of Andhra Pradesh, the component index is pulled down a bit by a poor land use-intensity index. The composite indices of Rajasthan (51·7), Gujarat (64·6), Madhya Pradesh (80·6), Maharashtra (65·1) and Mysore (64·9) are all below 100. One peculiar thing about these States is that in each one of them, each of three component indices, *viz.*, the yield index, the pattern index and the land use-intensity index is also below 100. As stated earlier, this shows in a general way the all-pervasive influence of the level of availability of water in the determination of land use efficiency as well as the standards of agricultural husbandry. In this group of States, the variations in the yield index (from 83·6 in Mysore to 93·4 in Madhya Pradesh) are relatively small but the pattern index has a wider range of variation from 61·0 in Rajasthan to 88·1 in Madhya Pradesh. The land use-intensity index also has a relatively small range of variation from 90·6 in Mysore to 98·0 in Madhya Pradesh.

The index of agricultural workers per acre indicates the variations in the presssure of population on land in the different States. The high pressure States are Bihar (190·2), Jammu and Kashmir (175·6), Madras (158·5) and Assam (156·1). Next in order come the States of U.P. (126·8), Kerala (114·6) and Andhra Pradesh (114·6). In

Orissa, this figure comes out to be 100·0 itself and the States of low pressure of population are Madhya Pradesh (85·4), Maharashtra and Mysore (both 73·2), Gujarat (61·0), Punjab (61·0) and Rajasthan (58·4).

The most interesting results come out when the index of agricultural output per acre is studied in conjunction with the index of agricultural output per worker. The most striking cases are those of Punjab, Madras, Bihar and Gujarat. Punjab has the fourth rank in the index of production per acre but with almost the lowest pressure of population, it comes at the top in the index of production per worker, that index being as high as 216·0—the highest index in the entire table giving six indices for each of the fifteen States. Madras with the highest index of production per acre gets pushed down to the fifth rank in the index of production per worker because of a heavy pressure of population. Bihar with its index of production per acre at 119·5 gets pushed to the lowest position in the order for the index of production per worker (62·8) because Bihar has the heaviest pressure of population on land. Jammu and Kashmir is in almost the same position as Bihar. In all the five States of Rajasthan, Gujarat, Madhya Pradesh, Mysore and Maharashtra, the index of agricultural workers per acre is substantially below 100 and their indices of production per worker are therefore substantially higher than their indices of production per acre. The case of Gujarat with its index of production per acre at 64·6 and the index of production per worker at 105·9 is almost as striking as that of Punjab. This State is fourteenth (second from the bottom) in the order for index of production per acre and seventh in the order for index of production per worker. The cases of Andhra Pradesh, Kerala, U.P. and West Bengal are in one category in that in each case the pressure of population on land is substantially higher than the all-India average pressure and their indices of production per worker are lower than their indices of production per acre. This is especially so in the case of U.P. in which the two indices come out to be 101·1 and 128·3 respectively. As stated earlier, the pressure of population in Orissa is the same as the all-India average pressure and its indices of production per acre and production per worker both stand at 132·7.

While the results indicated by the Statewise indices are themselves quite interesting, these indices do conceal a lot of differentiation from region to region in almost all the States. The regional indices having been worked out for homogeneous crop regions bring into sharp focus the real nature and magnitude of the variations within the country.

We may illustrate this with reference to the State of Rajasthan which has been divided into eight regions on the basis of the cropping patterns of the various districts.

In the matter of its soil and natural climate, Region I (Ganganagar) has an affinity with Region II comprising of Bikaner, Jaisalmer, Jodhpur, Sikar, Nagaur, Churu, Jhunjhunu, Barmer and Jalore but has had to be separated from that region because of the very much higher intensity of irrigation and consequent differences in cropping patterns. The crops mainly grown here are wheat, gram, bajra and cotton. The yield index of this region is 107·4 against 88·8 of Rajasthan. But the pattern and the land use-intensity indices being below 100, the index of agricultural production per acre is only 70·5. In this region, however, the pressure of population on land is still very low, the index of agricultural workers per acre being 26·8 only. In the result, the index of production per worker (262·96) comes out to be very high. Region II is Rajasthan's as also the country's least productive region. It grows mainly bajra and miscellaneous pulses. The index of production per acre is only 22·35 (lowest in India) but the pressure of population is quite low and the index of production per worker works out to be 61·1. One of the striking things for the regions of this State as in most other regions of India is that except for Ganganagar, the pressure of population appears to be directly co-related to the agricultural productivity per acre. This is a characteristic which would be naturally expected in a country where subsistence type of farming predominates. Region V of Rajasthan consisting of Udaipur, Chittorgarh and Bhilwara which appears almost at the top in the matter of agricultural production per acre has the highest pressure of population in Rajasthan with the result that its index of production per worker gets pulled down to the low figure of 62·1 which is very nearly equal to the corresponding index for the Bikaner region. Region VI (Bundi and Kotah), on the other hand, shows the highest index of production per worker (113·6) in Rajasthan with the index of agricultural production at 60·7 only. Region VIII (Banswara and Dungarpur) resembles Region V in the relative position of indices. This is also the only region of Rajasthan where a fair percentage of cropped area is devoted to rice and that is why its pattern index comes out to be the highest in Rajasthan.

PRODUCTION FUNCTION APPROCH TO MEASUREMENT OF PRODUCTIVITY IN AGRICULTURE

BY RAM SARAN

AT the present stage of agricultural development in the country, when there is a scarcity pressure on most of the production resources, measurement of agricultural productivity is not of mere academic interest. It has to serve as the basis for planning the allocation of resources in order that production efficiency is improved and output is increased at the minimum possible cost. The production function approach provides a useful tool for measurement of productivity which can be of extreme use for purposes of policy formulation in regard to resource use.

Often productivity from a factor of production is estimated by dividing total output by the units of the factor employed in producing that amount of output. This is known as average productivity of that factor. It should be remembered that the average figure so derived represents the product returns of all factors and not merely of the single factor in question.

The average productivity of a resource provides an indicator of the technical efficiency of its use. But by itself it is not adequate for economic analysis and decision-making in regard to resource use. For example, variations in average productivity due to land, between regions may possibly be due either to differences in quality of land or to differences in the amounts of labour and capital resources employed or to both these factors. In the absence of the information on the factors responsible for variations in productivity between regions, it is difficult to make suggestions on resource use in order that total output in regions and in the country as a whole may be increased. Some idea of the malallocation of resources, obtaining if any, in different regions can be had by simultaneously comparing their average productivities for land as well as for labour and capital. However, even this information will not indicate exactly the manner in which and the extent to which the resources should be organised to achieve the maximum output of product. To facilitate such decision-making, resort should be had to the measure of marginal productivity, which means the addition to product resulting from the addition of one unit of the relevant input, the levels of other inputs remaining the same. This is a highly useful concept which enables us to measure the degree of economic efficiency in the allocation of resources not only between different regions but also between different uses on a farm, different farms, different industries and over time. From the standpoint of society, resources have to be allocated in such a way that, with proper consideration of transfer costs, marginal productivities of their resources should be equal between different technical units within a farm and between farms, regions and industries and over time.

The measure of marginal productivity can be provided by using the concept of production function which represents relationship between variable inputs and output. A production function might be expressed in the form of a statistical table or ilustrated graphically or expressed in algebraic equations. If the input/output relationship were linear, average productivity would remain the same whatever be the quantity of an input used. But in agriculture these relationships have generally been found to be non-linear. There prevails what we call the 'law of variable proportions'. This law states that if the quantity of one input is increased by equal amounts with the quantities of other inputs held constant (in other words, if the proportions in which different inputs combine to produce the product are changed), the increment to total product may increase at first but decrease after a certain point. Agricultural production being subject to this law, average as well as marginal productivity from an input will change with different levels of the input employed.

Production function approach gives us information on resource productivity in physical terms. But in economic context this is not a sufficient index of preductivity. As we know patterns of crop (or farm) production adopted by different farms or different regions may not always be the same; as a result the comparison of average and marginal productivities would be rendered difficult unless a common index of agricultural output is employed. The best thing will be to express the output in terms of money values. By adopting this procedure, production function can be converted into a value production function or revenue function. While production function for a certain production process will be only one, there will be as many revenue functions and for that matter, as many values of average and marginal productivities, as would be the levels of prices for the product or products. From the standpoint of economic efficiency, returns will be maximised when value of marginal productivity is just equal to the prevailing market price or the opportunity cost of the input.

Still another measure of input-output relationship, relevant in production function analysis, is that of coefficient of production elasticity. This indicates the percentage increase in output (y) resulting from a percentage increase in input (x).

This may be computed as marginal productivity divided by average productivity. If output increases by a greater percentage than input, the ratio is greater than unity; if output increases by the same rate as input, it is unity; and if the percentage increase in output is less than in input, it is less than unity.

While production function is essentially a physical concept, representing a specific production process, it may also be considered from the point of the short run and long run analysis. The short run production function is subject to two main restricitions, *viz.*, the period of time is sufficiently short so that (i) the levels of fixed inputs cannot be altered and (ii) the shape of production function is not changed through technological improvements. In the case of long-term production function the period of time is long enough to allow relaxation of both these conditions. The main difference between a short run and long run analysis is that while in the case of the former at least one input is fixed, in the case of the latter, all inputs are variable.

Numerous algebraic equations can be used in deriving production functions. They may express the relationship between one variable input and one product, several inputs and one product, one input and several products or several inputs and several products. Selection of any specific type of equation automatically imposes certain restrictions in respect of the relationship involved. However, some relationships are more flexible than others. The more important types of production functions which are generally used in agriculture for describing input-output relationship between one or more inputs and one product are (i) Cobb-Douglas function, (ii) Spillman function, (iii) Quadratic function.

Considering one variable input (x) and one product (y) the above functions will take the following forms:

1. Cobb-Douglas function

$$Y = ax^b,$$

2. Spillman function

$$Y = M - AR^x,$$

3. Quadratic function

$$Y = a + bx - cx^2.$$

The Cobb-Douglas function allows diminishing marginal productivity but holds production elasticity constant.

The Spillman function assumes declining production elasticity but constant ratios of change in the sense that increment from each level of input represents a given percentage of marginal productivity from the previous level of input. In this case the value of R must be less than unity if diminishing productivities are to hold true, with an infinitely large x the term R approaches zero and hence $M - R^x = M$, the maximum yield.

The quadratic function with a minus sign before c denotes diminishing marginal productivity. It allows both declining and negative marginal productivity, but not both increasing or decreasing marginal productivity. The production elasticity is not constant as in the Cobb-Douglas function but declines as input increases. The marginal productivities do not bear a fixed ratio to each other as in the case of Spillman function. Instead of having a second degree function, we can have a third degree function which may take the form of $Y = a + bx + cx^2 - dx^3$. This allows both increasing and decreasing productivities.

The function, commonly used for expressing input/output relationship in agriculture, is that of Cobb-Douglas. When the relationship between several inputs and one output is to be expressed, the function takes the following form

$$Y = aX_1^b X_2^c X_3^d X_4^e,$$

where X_1, X_2, X_3 and X_4 may stand for various inputs, *e.g.*, land, labour, capital assets and working expenses. The values of b, c, d and e represent elasticities of the respective inputs. Where all the relevant input factors are treated as variables and are used in the function, the sum total of the coefficients of all the elasticities of production can broadly indicate whether constant, increasing or decreasing returns to scale operate. The returns to scale will be constant if the sum total of the coefficients is unity, increasing if it is above unity and decreasing if it is below unity.

The marginal productivity of any input can be measured by differentiating the function with respect to that input while keeping the level of all the other inputs fixed. In the case of Cobb-Douglas function, the most accurate estimates are obtained when all the inputs are held at their geometric mean level.

For developing agricultural production functions, it may be necessary to collect either time series data or cross-sectional data. The difficulty about time series data is that natural factors like weather cause large fluctuations in output from year to year. Further there is often a change in technology over the period; as a result what we may obtain from these data may not be one production function but a number of production functions. In order to use time series data, either they will have to be adjusted to allow for changes in technology, or a 'mongrel' production function may have to be fitted to the observations.* Further, time series data over a sufficiently long time may not be available. The cross-sectional data too may not be suitable for the purpose if the period to which the observations relate happens to be abnormal from the point of view of climate, rainfall, etc. For obtaining time series or cross-sectional data, either special trials and experiments may have to be carried out or a resort may be had to certain non-experimental material already available. In the case of specially conducted experiments it is possible to investigate, to a large extent the performance of the required variable factors under controlled conditions, though in many cases these may not represent real world conditions. The non-experimental data, having been collected independently, may not approximate to controlled conditions leaving thereby some unidentifiable variable, and also not permit the study of the response to desired levels of variable factors. But obviously the cost involved in collecting non-experimental data is small compared to that in conducting the special experiments. In actual practice, in view of the limitation of funds available for research, resort may be had to both the available non-experimental data, and such other data as may be obtained from special experiments.

In India not much work has been done to develop production functions on the basis of either experimental or non-experimental data. Under the 'Soil Fertility and Fertilizer Use Project' launched as a result of an Indo-American Technical Co-operation Agreement, agronomic trials were conducted on rice and wheat in cultivators' fields during 1953-56 for determination of fertilizer responses. The experiments, related to types and levels of nitrogen, phosphate and potash, used either individually or in combination with one another and also

* For a discussion of the way in which such a functfon might be fitted, see *Agricultural Production Functions* (Chapter 7), by E. O. Heady and J. L. Dillon,

to other agronomic factors such as, irrigation, varieties, basal dressing of bulky manures and time and method of application of fertilizers. Although generally not more than two levels of a particular fertilizer were attempted, the experiments have provided useful data on input/output relationships. Quadratic surface equations were also fitted for mean responses to the use of nitrogen (n) and phosphate (p) on both rice and wheat. These equations are as follows:

Rice:

$$Y = 21\cdot46 + 0\cdot2675n - 0\cdot0026n^2 + 0\cdot2054p - 0\cdot0016p^2 - 0\cdot0039np$$

Wheat:

$$Y = 15\cdot2099 + 0\cdot1578n - 0\cdot00104n^2 + 0\cdot12076p - 0\cdot00086p^2 - 0\cdot00125np.$$

With the help of the above equations as well as other statistical data provided by the Project, it is possible to formulate suitable fertiliser use policies for the varying fertilisers/product price relationships.

Production functions have also been fitted to the input/output data collected in the course of farm management studies conducted in recent years in different regions of the country. All factors of production including land, labour, and capital have been treated as variable. Generally Cobb-Douglas equations have been fitted for describing the functional relationships. The available estimated functions and their related statistics are presented region by region in Annexure I. The broad conclusions that emerge from the statement are given in Annexure II.

Apart from region-to-region analysis given in Annexure I, it is also possible to make a comparative study of productivities as between different regions. Since land and even human and bullock labour are more or less immobile and cannot be easily transferred from one region to another, a comparison would be valid mainly in respect of capital and that too particularly for capital services. The comparative position in regard to the mean value of capital services applied, their marginal productivities and the ratios of marginal productivity to opportunity cost are given below;

	Mean value of input	Marginal productivity	Marginal productivity to opportunity cost ratio
	Rs.	Rs.	
U.P. (Working expenses) ..	17·82	1·86	1·55
Andhra Pradesh (Working expenses) ..	189·17	1·76	1·47
Madras Cotton:			
Seed ..	4·93	8·81	7·34
Manures ..	3·20	2·35	2·00
Madras Paddy:			
Seed ..	10·67	10·39	8·66
Manures ..	32·88	0·15	0·12

It would be seen that in all three States, expenditure on the use of manures, fertilizers, improved seeds, etc., could increase profitability from farming. The only exception is paddy crop in Madras where lesser use of manures seems to be called for.

The above approach of estimating resources productivity, aimed at facilitating the rational allocation of resources, has certain obvious limitations. Production functions cannot reflect fully the production processes under consideration. In particular the functions cannot express supplementarity and complementarity between enterprises. Further, the above method of analysis has suggested directions for reorganising resources only in terms of particular categories of resources and not in terms of particular techniques of production.

In spite of the limitations listed above, the production function approach provides the most fruitful measure of estimating the coefficients of productivities of all the inputs used. These coefficients can be of considerable use for the formulation of policies regarding the allocation of various resources particularly scarce resources over regions, industries and enterprises and also in guiding individual farmers in regard to proper use of resources on the farms. The experiments conducted in cultivators' fields like those of fertilizer trials and other investigations on farm management can provide useful information on the economic aspects of adopting improved technology in production. Such studies need to be extended to new techniques of production.

ANNEXURE I

TABLE I

Production elasticities, marginal products and opportunity cost of resources, marginal return to opportunity cost ratios and related statistics for selected production function studies

Item	Production function for Uttar Pradesh 1955–56		
	Whole farm	Sugarcane planted	Irrigated wheat
NUMBER OF FARMS ..	63	63	60
Production elasticities:			
Land ..	0·22*	0·37*	0.50*
Labour ..	0·29*	0·69*	—0·26
Working expenses ..	0·25*	0·30*	0·53*
Capital assets ..	0·21	—0·27	0·17
Sum of elasticities ..	0·97	1·09	0·93
R^2 ..	0·86	0·57	0·81
Sample means† :			
Output (Rs.) ..	1818·00	432·80	284·68
Land (acres) ..	11·57	1·20	1·62
Labour (Rs.) ..	1027·00	181·30	187·92
Working expenses (Rs.) ..	242·70	122·70	18·40
Capital assets (Rs.) ..	84·57	13·20	17·82
Average products† :			
Land (Rs. per acre) ..	157·05	364·72	175·72
Labour (Rs. per Re.) ..	1·79	2·44	1·51
Working expenses (Rs. per Re.) ..	7·44	3·60	15·47
Capital assets (Rs. per Re.) ..	21·10	33·01	15·97
Marginal products† :			
Land (Rs. per acre) ..	34·55	134·96	87·86
Labour (Rs. per Re.) ..	0·52	1·67	—0·39
Working expenses (Rs. per Re.) ..	1·86	1·08	8·29
Capital assets (Rs. per Re.) ..	4·43	—8·91	2·71

TABLE (*contd.*)

Item	Production function for Uttar Pradesh 1955–56		
	Whole farm	Sugarcane planted	Irrigated wheat
Opportunity costs: ..			
Land (Rs. per acre) ..	39·50	39·50	39·50
Labour (Rs. per Re.) ..	1·00	1·00	1·00
Working expenses (Rs. per Re.) ..	1·20	1·20	1·20
Capital assets (Rs. per Re.) ..	0·33	0·33	0·33
Marginal return to opportunity cost ratios† :			
Land ..	0·87	3·41	2·22
Labour ..	0·52	1·67	−0·39
Working expenses ..	1·55	0·91	6·91
Capital assets ..	13·42	−0·27	8·21

* Significantly different from zero at a probability ≤ 5%.
† Estimated at the geometric mean input levels.

TABLE II

Item	Production function for Andhra Pradesh 1958–59		
	Paddy Zone	Tobacco Zone	Zones combined
NUMBER OF FARMS ..	70	37	107
Production elasticities:			
Land ..	0·31*	0·16	0·28*
Human labour ..	0·14	0·36	0·16
Bullock labour ..	0·06	0·09	0·11
Working expenses ..	0·44	0·34*	0·40*
Capital assets ..	0·03	0·01	0·02
Sum of elasticities ..	0·98	0·96	0·96
R^2 ..	0·66	0·83	0·72

TABLE II (*contd.*)

Item	Production function for Andhra Pradesh 1958-59		
	Paddy Zone	Tobacco Zone	Zones combined
Sample mean† :			
Output (Rs.) ..	1067·00	1328·00	1120·00
Land (acres) ..	3·20	3·47	3·17
Human labour (days) ..	231·44	413·55	282·79
Bullock labour (days) ..	35·11	31·83	33·94
Working expenses (Rs.) ..	157·02	269·15	189·17
Capital assets (Rs.) ..	221·02	379·94	266·64
Average products† :			
Land (Rs. per acre) ..	351·21	382·81	353·46
Human labour (Rs. per day) ..	4·43	3·08	4·00
Bullock labour (Rs. per day) ..	30·37	41·79	34·09
Working expenses (Rs. per Re.)	6·61	4·82	6·13
Capital assets (Rs. per Re.) ..	4·33	4·00	4·00
Marginal products† :			
Land (Rs. per acre) ..	108·90	61·25	98·97
Human labour (Rs. per day) ..	0·62	1·11	0·64
Bullock labour (Rs. per day) ..	1·81	3·76	3·75
Working expenses (Rs. per Re.)	2·91	1·64	1·76
Capital assets (Rs. per Re.) ..	0·13	0·04	0·08
Opportunity cost:			
Land (Rs. per acre) ..	153·00	244·00	201·00
Human labour (Rs. per day) ..	1·25	1·25	1·25
Bullock labour (Rs. per day) ..	2·09	2·09	2·09
Working expenses (Rs. per Re.)	1·20	1·20	1·20
Capital assets (Rs. per Re.) ...	0·33	0·33	0·33
Marginal cost to opportunity cost ratios† :			
Land ..	0·71	0·25	0·49
Human labour ..	0·50	0·88	0·51
Bullock labour ..	0·87	1·80	1·80
Working expenses ..	2·42	1·37	1·47
Capital assets ...	0·39	0·01	0·03

* Significantly different from zero at a probability $\leqslant 5\%$.

† Estimated at the geometric mean input levels.

TABLE III

Item	Production function for Madras and Orissa			
	Madras 1956–57			Orissa 1958–59
	Cotton	Paddy	Cholam	Aman paddy
NUMBER OF FARMS ..	84	71	34	100
Production elasticities:				
Land ..	0·10	0·63*	0·81*	0·56*
Human labour ..	0·56*	0·23	0·21	0·11
Bullock labour ..	0·05	0·001	−0·11	0·25*
Working expenses (seed)	0·29	0·31	0·02	..
Manure (N_2) ..	0·05	0·01	−0·004	..
Sum of elasticities ..	1·05	1·18	0·94	0·92
R^2 ..	0·74	0·62	0·82	0·85
Sample means† :				
Output (Rs.) ..	151·70	363·00	136·60	651·66
Land (acres) ..	0·98	0·97	0·57	4·96
Human labour (days) ..	67·45	70·77	29·29	128·90
Bullock labour (days) ..	26·49	49·78	18·83	83·02
Working expenses (Rs.)	4·93	10·67	2·77	..
Manure (Rs.) ..	3·20	32·88	1·65	..
Average products† :				
Land (Rs. per acre) ..	153·00	374·35	240·74	131·16
Human labour (Rs. per day) ..	2·27	5·09	4·67	5·09
Bullock labour (Rs. per day) ..	5·40	7·33	7·26	7·03
Working expenses (Rs. per Re.) ..	30·38	33·52	4·94	..
Manure (Rs. per Re.) ..	46·92	11·02	82·42	..
Marginal products† :				
Land (Rs. per acre) ..	15·30	235·84	195·00	69·28
Human labour (Rs. per day) ..	1·27	1·17	1·00	0·56
Bullock labour (Rs. per day) ..	0·27	0·01	−0·79	1·76
Working expenses (Rs. per Re.) ..	8·81	10·39	1·21	..
Manure (Rs. per Re.) ..	2·35	0·15	−0·35	..

TABLE III (*contd.*)

Item	Production function for Madras and Orissa			
	Madras 1956–57		Orissa 1958–59	
	Cotton	Paddy	Cholam	Aman paddy
Opportunity cost:				
Land (Rs. per acre) ..	55·60	55·60	55·60	26·53
Human labour (Rs. per day) ..	1·02	1·02	1·02	0·89
Bullock labour (Rs. per day) ..	1·04	1·04	1·04	1·04
Working expenses (Rs. per Re.)	1·20	1·20	1·20	..
Manure (Rs. per Re) ..	1·20	1·20	1·20	..
Marginal return to opportunity cost ratios† :				
Land ..	0·27	4·27	3·50	2·56
Human labour ..	1·24	1·15	0·98	0·65
Bullock labour ..	0·26	0·01	−0·76	1·66
Working expenses ..	7·34	8·66	1·00	..
Manure ..	2·00	0·12	−0·30	..

* Significantly different from zero at a probability $\leqslant$ 5%.

† Estimated at the geometric mean input levels.

ANNEXURE II

Interpretation of Results of Production Function Studies

U.P.

(i) The sum total of elasticities of production being around unity for irrigated wheat, sugarcane planted as well as for farm business as a whole, constant returns to scale may be believed to prevail. The negative production elasticities for labour in irrigated wheat and for capital assets in sugarcane planted tend to imply that in relations to the levels of other inputs used, excessive quantities of these inputs are being applied.

(ii) The marginal return to opportunity cost ratios indicate that too little of capital assets and too much of labour were used on the farm as a whole. On individual crop basis it seems that too much labour and too little capital are used in irrigated wheat while too little labour and too much capital are used in sugarcane planted. Further, since land use is satisfactory on a whole farm basis with too little land being used for wheat and planted sugarcane, it may be assumed that too much land is being devoted to the other crops notably the ratoon sugarcane crop.

Andhra Pradesh:

(i) From the sum total of elasticities of production, it seems that constant returns to scale prevail in paddy zones, tobacco zone and in both the zones combined. The elasticities of production for human labour, bullock labour and capital assets being generally low, it seems that these inputs are being used in large quantities.

(ii) The marginal return to opportunty cost ratios indicate that generally too much land, human labour and capital assets are used; on the other hand use of more working capital mainly in the form of manures and fertilizers could increase profitability.

Madras:

(i) From the sum total of elasticities of production, it seems that in this State too constant returns to scale prevail for almost all the crops grown except paddy, where increasing returns to scale seem to be in evidence. In the case of cholam the production elasticity is negative for bullock labour indicating that excessive quantities of this input are being used.

(ii) The use of too much of bullock labour on cholam is also indicated by the marginal return to opportunity cost ratio. Bullock labour is used excessively also on cotton and paddy possibly because the quoted opportunity cost is unreal and there is no use for this input except on owned farms. Even though only a small quantity of nitrogenous manure is used on cholam, it seems that this crop does not need any nitrogen. As between different crops, cotton, paddy and cholam, it seems that the returns will increase if some land is diverted from cotton to paddy and cholam.

Orissa:

(i) From the sum total of elasticities of production it seems that in this State too constant returns to scale prevail.

(ii) Marginal returns to opportunity cost ratios seem to indicate that in relation to the supply of inputs the size of holding in Orissa is too small to be economic. Labour is being used rather excessively to possibly make up for the smallness of holding. The cultivators could increase the use of bullock labour to their advantage.

MEASUREMENT OF PRODUCTIVITY AT MACRO AND MICRO LEVEL

By A. M. Khusro

The emergence of Farm Management data during the late 1950's for two or three contiguous years in seven States of India permits some generalizations about the relations between farm efficiency and farm size. These generalizations are based upon the recurrence of some phenomena almost everywhere among the States studied, despite very substantial dissimilarities in cropping patterns, resource availabilities and socio-cultural conditions.

I

Farm size can be defined either in terms of a single input, *acreage*, or in terms of *output*; and farm efficiency either in terms of *output per unit of a single input, acreage,* or as *output per unit of cost* of all inputs. There are serious limitations in both sets of definitions while there are substantial merits too in either set.

Output, no doubt, is a more general measure of size than acreage. But part of the output is retained by farmers for self-consumption and almost every mode of imputation of value to retained output under or over-estimates value and does so in different proportions for large and small farms. As the ratio of retained output to sold output changes with the size of farm uni-directionally, incomparability between farms increases. Moreover, intertemporal comparisons of output are difficult owing to year-to-year price changes, a difficulty which gets enlarged out of all proportion when farmers of different sizes grow a different variety of crops. If, to avoid this, output is measured in weight or volume there arises a problem of high income-yielding and low income-yielding crops and varieties of crops being clubbed together and no account taken of their differential value. And finally, output can be concealed and evaded.

Acreage, on the other hand, is relatively free from annual fluctuations and changes in composition. But it requires standardization. In any case, acreage is a single input and often not even the preponderant input. There is thus no single satisfactory measure of farm size and the present study uses both measures in turn.

Yield per acre as a measure of efficiency suffers from very similar disadvantages as it has output in its numerator—and that, as shown earlier, is open to some objections. Moreover, yield per acre is a crude return only to a single input, land. And finally, there is no reason why farmers should be interested in maximizing gross output per acre.

An alternative measure of efficiency is cost per unit of output C/O, which farmers are supposed to minimize. But some costs—of family labour, of owned land and of farm-produced capital—are imputed costs and there is some doubt about the correct price for imputation as that depends upon the opportunity costs of these inputs. In any case, farmers are not interested in minimizing these imputed costs, hereafter called retained cost, C_r. They are interested only in minimizing costs which they pay-out, hereafter called paid-out cost, C_p. It is therefore not C/O that farmers will minimize but C_p/O and this latter could be a measure of efficiency. But C_p/O has in its denominator the same output which yield per acre O/A has in its numerator and output is subject, in any case, to the difficulty of measurement. Farmers will maximize not gross output per acre but that output from which paid-out costs have been deducted, that is, they will maximize $(O - C_p)/A = Y/A$, or farm business income per acre. But, in order to arrive at Y/A, if C_p has to be estimated with all the accompanying difficulties, one might as well use C_p/O or average paid-out cost per unit of output as a measure of farm efficiency. The present work, however, uses both definitions of efficiency: returns per acre and average paid-out cost per unit of output.

II

Our scheme of costs and returns is as follows:

(1) Total cost (C) = Paid-out cost (C_p) — Retained cost (C_r).

(2) Gross output (O) — Paid-out cost (C_p) (inclusive of depreciation)* = Net farm business income (Y).

(3) Net farm business income (Y) — Retained cost (C_r) = Net profit (P).

Three yearly averages of returns and cost per farm and per acre have been obtained for each of the seven States. The behaviour of the three types of returns: (i) gross output per acre O/A; (ii) farm business income per acre (Y/A); and (iii) net profit per acre (P/A) has been studied. It appears that in seven cases out of seven O/A decreases with size of farm; in six cases out of seven Y/A decreases by size of farm; and in seven cases out of seven P/A increases by size of farm. A crude "all-India" behaviour of the interpolated values of these variables also shows the same results.

The first and the third tendencies have been noted and explained by some scholars earlier. The present work attempts to show the almost universal occurrence of these tendencies. But it underlines the behaviour of farm business income per acre too which is probably a crucial variable since farmers may be expected to maximize neither O/A nor P/A but Y/A.

Prof. A. K. Sen's explanations of the decrease of O/A and the increase of P/A with an increase in farm size is perhaps the most satisfactory one as it is at once an explanation of both phenomena. This explanation runs in terms of small family-based farms pushing the use of labour, because of its low opportunity costs, to a point beyond the large farms, that is to say, to a point where the marginal product of labour applied to a single acre of land is below the imputed wage-rate and hence profits are less than maximum. Output of small farm is then larger than it would be if labour use were pushed only to the point where marginal product equals wage-rate, as is the case with large farmers. This explanation can be supplemented by one or two others.

(1) It is possible that family labour is qualitatively different in terms of its intensity from hired labour so that the average product curve for labour is higher for family farms (small farms) than for the wage-based farms (large farms). (2) With an expansion of farm size as land leased-in increases as a percentage of total land, returns per acre might decline as farmers may apply themselves and other inputs qualitatively better on owned lands than on lands leased-in.

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* Paid-out cost includes raw material purchased (and farm-produced) interest on borrowed capital (fixed and working), depreciation on fixed capital (purchased and farm-produced) including bullocks, hire of fixed capital (including bullocks), hire of labour, and taxes and irrigation charges and rent on land and farm buildings leased-in.

But Professor Sen's argument, while it explains the difference in output per acre and profit per acre between, say, a 3-acre family-farm and a 15-acre wage-based farm, does not explain the difference between the 15-acre and the 50-acre farm both of which depend heavily on hired labour and on both of which family labour spreads thinly. We thus need some other explanation for the decline in output per acre in the larger ranges of farm size.

III

It is noted that acreage in Farm Management Studies is simple unstandardized acreage with no correction for good or bad lands, wet and dry lands, etc. Per acre land revenue data show a decline in nearly all States as farm size expands and supports the hypothesis that the proportion of poor land increases by farm size. Acreage data are thus corrected and converted into standard acreage by multiplying mean acreage in each size-group with an index of efficiency which is land revenue per acre itself. The new set of data of returns per corrected acre show the following tendencies.

Above the 10 or 15 (corrected) acre size in most States gross output per acre, O/A_0, continues to decline somewhat by size of farm (A_0); Y/A_0 or farm business income per corrected acre is now seen in almost all States to increase slightly by size of farm; while net profits per acre (P/A_0) are negative in some cases, increase quite steeply by size of farm. It would appear that in Indian farming generally as size expands farmers bring about an adjustment in paid-out cost (the difference between O/A_0 and Y/A_0) in relation to gross output in such a way that they end up with increasing farm business income per acre. So long as this happens it is not a matter of any consequence to them if gross output per acre declines somewhat. Judged by their income per acre their efficiency does *not* decline by farm size.

Yet another serious deficiency may be noted here. Almost all methods of valuing retained and sold output in vogue wrongly estimate retained or sold output and the share of farms of different size in the total. In particular, the most commonly used method of valuing all output at farm harvest price grossly underestimates the output of large farmers who have the storage and holding capacity and often sell at high off-season prices. Their share in total output is thus seriously underestimated. No wonder the curve of gross output per acre slopes downwards as farm size expands. If this underestimation were eliminated output per corrected acre may easily be seen to increase by size of farm. Efficiency, then, whether judged by gross output or by income per corrected acre, will not appear to decrease by size.

IV

An alternative study of size and efficiency in which size is represented by output and efficiency by paid-out cost per unit of output is undertaken. This reveals that C_p/O remains, by and large, constant with size of output. The slopes of the regression lines, though generally having a negative sign, have values near zero so that a strong evidence of constant returns to scale in every State emerges, the size of output having no bearing on the level of C_p/O.

It seems almost astonishing that while the levels of O/A (or (O/A_c) and of Y/A (or Y/A_c) are so radically different in different States, the level of paid-out cost, C_p, in relation to output works out everywhere to be the same. It would seem that if farmeres do bring about any adjustments it is this adjustment of C_p in relation to O that they do bring about. A frequency distribution of all observations of C_p/O shows 72% of all values to cluster between 0·5; and 92% of all values lie within a

Paid-out cost/output	Frequency
0·350–0·399	2
0·400–0·449	8
0·450–0·499	14
0·500–0·549	8
0·550–0·599	6
0·600–0·649	3
0·650–0·699	5
0·700–0·749	4
	50

range twice the standard deviation. This great uniformity in the level of C_p/O in different States for all sizes of output warrants the treatment of all observations as part of a single family, and, therefore, a single regression equation for all states taken together. This regression equation for all the 50 observations of C_p/O in relation to O works out to be: $C_p/O = 0\cdot521 - (0\cdot000041)\,O$, the correlation coefficient of 0·33 being significant at 5% level of probability.

This study, like the previous one, confirms that in the Indian farming of the 1950 *s*, if the Farm Management Studies are any indication of the generality of behaviour, there is no evidence of declining efficiency by size of farm and that, in fact, the hypothesis of constant returns to scale is the most plausible one. It also shows that despite great divergencies in regional conditions, the levels of average cost per unit of output are markedly similar among the different States.

EFFECTS OF LAND REFORMS ON PROBLEMS IN MEASUREMENT OF AGRICULTURAL PRODUCTIVITY

BY V. M. JAKHADE

LAND REFORM, in the traditional and accepted sense of the term, means the redistribution of property in land for the benefit of small farmers and agricultural workers. In wider sense 'land reform' is understood to mean any improvement in agricultural economic institutions, implying thereby that governments which undertake reform measures should also undertake regulation of conditions of farm workers, improvement of farm credit system, methods of land taxation, agricultural education, etc. For the purpose of the present paper, the attention may be confined to programmes for establishment of direct relationship between the tiller and the State by abolition of intermediaries, tenancy reforms, *i.e.*, regulation of rent, security of tenure for tenants and conferment of ownership on them and ceiling on land-holdings. The programmes for agrarian reorganisation including consolidation of holdings and prevention of subdivision and fragmentation, co-operative farming and resettlement have been left out as the basic problems in measurement of production under such programmes would not differ from those in respect of other programmes.

'Agricultural productivity' is in practice an elusive term and its measurement is a difficult job. It may be measured in two ways, *viz.*, output per acre and output per person engaged in agriculture. The latter may be more relevant in economically advanced countries where labour is a scarce and costly resource and where increased returns to labour are sought. On the other hand, in less developed countries like India, where labour is relatively abundant, while capital and land are scarce, the concept of productivity in the sense of output per acre becomes more meaningful. It is this concept which has been adopted in this paper.

Agricultural Productivity—A Function of Number of Factors:

Agricultural output is a function of a number of factors. It is known that the Indian agriculture is dependent on the vagaries of monsoons. By the beginning of the Third Plan the irrigated area formed hardly one-fifth of the total cultivated area. Thus the agricultural output varies from year to year—depending on the rainfall and weather conditions. Again the output is influenced by the material inputs like improved seeds, fertilizers and manures, irrigation, as also by farm practices and technical knowledge and various other incentives offered to the farmers through prices, subsidies, etc. In such a situation, for an assessment of the impact of any one measure on agricultural productivity, it would be necessary to isolate the impact of all other factors operating on the farm economy. This task is extremely difficult unless special case studies aimed at such isolation are undertaken specifically for the purpose. In India the programme of land reforms forms a part of an overall plan of agricultural development, which includes a whole range of measures relating to the establishment or strengthening of governmental or co-operative agencies for credit, supply of farm requisites, extension and research, etc. The point that needs to be underlined is that the assessment of the changes in agricultural productivity or yield per acre over a period of time may be rather simple enough; but attributing changes in productivity to any particular measure such as land reforms is by no means easy. Changes in the agricultural techniques and crop patterns, etc., cannot be isolated and apportioned with any semblance of accuracy. The present paper, therefore, tries to disentangle the various facets of the land reform measures that impinge on the agricultural productivity and in the process offers a few suggestions for consideration which may help in assessment of the direction of impact of land reforms on agricultural productivity.

Assumptions Underlying Land Reforms

At this stage we may refer to the theoretical assumptions underlying land reform measures. Firstly, it is assumed that the land reform measures heighten interest and give incentive to the cultivator to work harder and to carry out land improvements, conserve the soil and its fertility, and improve production methods. Secondly, the regulation of rent and the enhanced security of tenure increase both the ability and the incentive of tenants to invest in production. These measures are therefore expected to accelerate the accumulation of capital on land. Either by regulation of rent and stoppage of illegal levies and exactions or by reduction of rent, the savings effected could be invested on farm for increasing agricultural productivity. With the acquisition of right of ownership or security or permanency of tenure the farmers would be more inclined to adopt better technique and to undertake long-term improvements on land in view of the fact that the fruits of their labour would accrue to them. The growth of institutional credit facilities enables them to put through their plans as their credit-worthiness increases. On the whole, land reforms are expected to pave the way for increased efficiency of cultivation through larger investment and better farm management.

It may be pointed out, however, that land reforms break the traditional relationship between the landlord and the tenant. Thus, it may happen that the credit and supplies received by the tenant from the landlord before land reforms may be cut off and the agricultural operations may suffer, unless a co-ordinated programme for development of credit and supply institutions is simultaneously undertaken. Further, if the additional share in farm production, accruing to the tenants through regulation of rent, is used for consumption rather than for production, the impact of agricultural productivity envisaged may not materialise.

The intensive application of labour and capital, adoption of better techniques of cultivation, better farm management, land improvements, etc., result in increasing output and therefore raising agricultural productivity. But as stated earlier, much depends on rainfall and weather conditions. Moreover, the above-mentioned changes follow the land reforms and therefore the impact is combined and cumulative. Under these conditions it may, therefore, be useful to direct attention on studying the trends before and after land reforms in respect of (i) inputs on farms like improved seeds, fertilizers and measures, use of pesticides, etc., (ii) changes in land use and techniques of cultivation, (iii) changes in crop pattern from inferior to superior foodgrains or from foodgrains to cash crops, (iv) capital expenditure on land. Studies on these lines will enable us to assess the direction of change in agricultural productivity, the combined and cumulative result of all factors mentioned above.

TRANSITIONAL AND SUBSEQUENT EVALUATIONS

Because of the variations in the tenurial conditions in different parts of the country, the effects of the introduction of different land reforms may not follow a uniform pattern. One way of assessing the impact on the total situation would be to take one aspect of land reform and try to study separately its effect on productivity in a particular region. By using a methodology appropriate to a particular reform, a regional assessment will have to be first undertaken. It is only by an aggregation of such regional assessments that a total picture could be finally sketched out.

Under the auspices of the Research Programmes Committees some studies have been undertaken. Though they were valuable, the geographical coverage of these studies was rather inadequate to generalise for the whole country. Secondly, the studies generally cover a period beginning some time before the First Plan and ending towards the middle of the First Plan. Since it may take some time before the actual effects of the land reforms begin to manifest themselves on production, perhaps an assessment at a somewhat longer interval could have been more fruitful. In other words, the studies conducted so far may be said to deal with the 'transitional' evaluation, whereas the issues relating to more remote effects have yet to be subjected to what can be called 'subsequent evaluation'.

The beneficial effects of land reforms hinges upon the successful implementation of these measures. In actuality there seems to be a large gap between legislation on the one hand and its implementation on the other. Thus, in judging the impact of land reform measures on productivity, one has to take into account the actual position as obtaining in the States rather than the legislation enacted.

A study concerning the working of the Bombay Tenancy Act of 1948* conducted by the Gokhale Institute of Politics and Economics covering a period of five years, 1948–53, showed that as a result of extensive resumption and changes of tenants that took place even after the enforcement of the Act, the protection given to the tenants could not be effective in practice. Secondly, a more or less normal market in land showed that the provisions for promoting the transfer of land into the hands of the tillers were not quite effective. Thirdly, there was an almost complete absence of any signs of lowering the share and cash rents or of any changes in the tenancy practices.

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* *Working of Bombay Tenancy Act*, 1948, *Report of Investigation.* V. M. Dandekar and G. J. Khudanpur, Poona, 1957, p. 187.

More or less, similar results were brought out by investigations relating to other parts of the country.†

More recently, a team of experts from the Ford Foundation examined the tenurial conditions in five districts covered under the Package Programme: Aligarh, Ludhiana, Shahabad, Tanjore and West Godavari. Except Aligarh in the other four districts the tenurial situation was found to be not satisfactory, perhaps because no serious attempt was made to enforce the legislation enacted. "Ejection of tenants has taken place in the past, and the landlords still continue to change tenants from plot to plot to defeat the tenancy laws. The few tenants who were allowed to continue over a fairly long period also feel insecure. Thus, a large number of cultivators hold no title to the leased lands, pay extortionate rents, and are never certain of their status. They are left with little to subsist on and much less to invest."‡

The picture that emerges is one of a very inadequate implementation of the tenancy legislation. In the context of this failure to implement effectively the legislation enacted, a study of the effects of this reform on the assumption of its being implemented becomes rather of doubtful validity. However, the main findings of some studies which have sought to assess the effects of the legislation are summarised below:

THE MADRAS STUDY

A study made in Madras State, for instance, has indicated that largely as a result of tenancy and other land reform measures, the following effects have been observed: (*a*) increased use of modern equipment like oil engines, electric pumps, etc., (*b*) a marked increase in fertiliser consumption, (*c*) a general tendency for production to go up especially in the case of dry crops and cotton. This larger increase in the dry crop production may be attributed to the operation of the tenancy laws, which prescribed considerably lower proportions of

† 1. *Report of an Enquiry into the Working of Bombay Tenancy and Agricultural Lands Act*, 1948 (as amended upto 1953) in Gujarat (excluding Baroda District), M. B. Desai, Bombay, 1958, pp. 94–95.

2. *An Enquiry into the Effects of the Working of Tenancy Legislation in the Baroda District of Bombay State*, by V. Y. Kolhatkar and S. B. Mahabal, Baroda, 1958, pp. 50–51.

3. *Economic and Social Effects of Jagirdari Abolition and Land Reforms in Hyderabad*, by A. M. Khusro, Hyderabad, 1958, p. 169.

‡ *Tenurial Conditions and the Package Programme* (mimeographed).

the gross produce payable to the land-owner in respect of these crops. In the case of dry crops the proportion was one-fifth as compared to two-fifths or even three-fifths on irrigated land.

Obviously, all the increase in production recorded or improvements in equipments, etc., noticed, cannot be attributed to land reforms. From such studies, therefore, all that one can say is that land reforms have provided a more favourable base for agricultural production, and that they have rendered more effective the other complementary measures of agricultural development like extension, credit, etc.

The Baroda Study

The conclusion of the Baroda study was that "By and large the results are not at all encouraging. Some slight progress is made in respect of seeds, manures, bunding and levelling but it may also be the result of the ordinary course of general economic development.... The Tenancy Act may not take any special credit for this slight improvement. Increased investment in implements, repairs and digging of wells and other irrigation projects would certainly have indicated a greater measure of confidence of the tenants in their tenure. But we find little progress in these directions".§

The Bombay Study

The Bombay Study referred to above seems to provide an interesting methodology for the assessment of the effects of the tenancy legislation in a scientific manner. One of the objects of the tenancy legislation was to promote full and efficient use of agricultural lands which was expected to result from the security of tenure provided and the consequent incentive to the tenants to take better care of land.

SOIL CLASSIFICATION (SETTLEMENT CLASSIFICATION)—A MEASURE OF AGRICULTURAL PRODUCTIVITY

By D. S. Ranga Rao

The relationship between agricultural productivity and the soil value (expressed in annas) with reference to the present system of

§ *An Enquiry into the Effects of the Working of the Tenancy Legislation in Baroda District of Bombay State*, by V. Y. Kolhatkar and S. B. Mahabal, 1958, Baroda, p. 42.

classification of soils in Maharashtra State is explained in this paper. A few suggestions for taking up further investigations in future are also offered.

SETTLEMENT CLASSIFICATION OF SOILS

The soil classification is based mostly on depth, colour and texture of soils and the lime content and is designed to reflect inherent fertility. The soils have been grouped into ten classes. The details of procedure followed for classification have been given in the *Bombay Survey and Settlement Manual*, Volume II, by R. G. Gordon, I.C.S. The scale of classification ranges from 16 annas to 1 anna and is in brief as follows:

Tenth class (corresponding to one anna) consists of soils which are so poor that they cannot be cultivated every year and even when cultivated are only capable of producing fodder crops.

The soil of fine uniform texture varying in colour from deep black to dark brown and having a depth of three feet or more is classified as of '16 annas', while the soil of '2 anna' classification consists of coarse gravel and is of loose friable texture, the colour varying from light brown to grey with depth of six inches or less. The other classes vary between these two extremes. Apart from being based on the above physical characteristics, the soil anna value of any particular field is decreased or increased depending on whether the soil is associated with certain deteriorating factors called 'faults' or certain beneficiary influences called 'chad'. Eight deteriorating factors and five beneficial ones are recognised for this purpose. For instance, a few of the deteriorating factors are (*a*) presence of minute fragments of lime nodules, (*b*) high percentage of large-sized particles of sand, and (*c*) slopy surface. Similarly, the beneficial factors are (i) deposit of silt, (ii) favourable situation of the field ensuring drainage from higher ground, (iii) closeness of a field to a nala or stream, or (iv) nearness of field to a village site. For each 'fault' the value of the soil is reduced by two annas. Sometimes depending on the degree of the deteriorating influence, the value is reduced by half a 'fault' or one anna. For beneficial factor, the value added depends on the extent of benefit derived from that factor. For instance, depending on the quality and evenness of the silt deposit the value of the soil is enhanced from two to six annas. Apparently it is seen that this subtraction or addition of anna values for 'faults' and 'chads' respectively is more or less subjective. One basic assumption in this system of classification is that the yield rate of crops varies directly with the soil classification value and based on that assumption the rate of assessment of fields is fixed. This rate of assessment holds good not for any one particular crop grown in the field, but for all the crops commonly grown in a particular soil group. It would be pertinent to point out that no detailed scientific investigations have been carried out nor any systematic data collected to establish truth of the above assumption.

Only very recently a study was undertaken to assess relationship between the yield rate of a crop and its soil 'anna' value. The study consisted in recording soil anna value of the individual unirrigated fields selected for crop cutting experiments and arranging the yields obtained from these fields in four broad soil groups, namely, 0–4, 4–8, 8–12 annas and above 12 annas and working out the average yield for each group. The study covered paddy, bajri, kharif, jowar, cotton, rabi jowar and wheat each in a different major crop-growing district.

Although in these studies there were at least 20 fields in each group, which were presumed to even out the differences in yield due to differing cultivation practices, it was still thought that the differences between yields of different groups might be partly due to different manurial varietal and other cultivation practices, in the fields of different group and partly due to environmental factors. In order to see whether by removing broadly the effects due to these factors (except environmental) the yield from group to group would show any consistent trend, studies were undertaken on cotton in Dhulia District and on kharif jowar in Satara District. In case of both the crops, the fields chosen in the different soil groups grew the same variety under unirrigated conditions and none of the fields were manured which, in effect, meant there was no influence of these factors on the yield of the crop in different soil groups.

Results of Studies on Relationship between the Yield Rate of a Crop and Its Soil 'Anna' Value

In case of rabi jowar in Ahmednagar District correlation coefficients were worked out between soil anna value and the yield for each of the 10 years from 1951–52 to 1960–61. The coefficients obtained were small for all the ten years, the largest value being 0·4. This apparently showed that the relationship between the soil anna value and the yield of a crop was not close enough to make it a basis for predictive purposes. In respect of other crops the results were as follows;

In case of rice in Kolhapur District a five-year study (*i.e.*, 1957–58 to 1961–62) showed that in one year the yield of rice was of the same order, *viz.*, 1,275 lbs. per acre in both the lowest and highest soil anna groups and in another year the yield in the lowest group (1,200 lbs.) was higher by about 20% than that in the highest group (990 lbs.). In the remaining three years also, there was no consistent increase in yield from the lowest to the highest group.

In case of bajri in Poona District similar conclusions were obtained. For instance, in two out of five years, the lowest group yielded 260 lbs. and 320 lbs. per acre as against the corresponding yields of 275 lbs. and 335 lbs. in the highest group. Here again there was no consistent increase in yield from the lowest to the highest group in any of the five years. In two years however, the group with soil anna value more than 12, yielded the highest.

The study of cotton data in Akola District extending over a period of six years from 1957–58 to 1962–63, showed that cotton is predominantly grown in fields with soil classification exceeding 4 annas. Here also, in one year out of six, it was seen that in the group 4–8 annas, the yield of kapas was 190 lbs. as against 175 lbs. in the group exceeding 12 annas, while in other years, the yield in the group 4–8 annas was less than that in the next two higher groups. However, there was no difference in yield between the next two higher groups in any of the six years under study.

A study of the data of kharif jowar in Satara District carried over a period of 10 years (1952–53 to 1961–62) showed that in 9 out of 10 years, the highest group, *viz.*, annas 12 and above yielded higher than other groups. On an average of 9 years it was 835 lb. as against 445 lb. of the lowest group. Except for the highest soil anna group, there was no consistent increase in yield from the lowest to the next two groups. In some years, the next two higher groups yielded more than the lowest group while in other years the yield in the lowest group was either of the same order or even higher than that in the other two groups.

As regards the position of rabi jowar in Sholapur District, a study carried over a period of 10 years from 1951–52 to 1960–61 showed that the yields in the soil group exceeding 12 annas were higher than in lower groups in 9 out of 10 years. It was further seen that the yields in fields exceeding 8 annas were mostly larger than those in fields less than that value. There was, however, no difference at all in yields between the soil groups 0–4 and 4–8 annas.

The study in respect of wheat carried out in Ahmednagar District from 1951–52 to 1960–61 showed that as in the case of cotton, this crop is also grown in fields exceeding soil anna value 4. Even here there was no difference in yield between the two soil groups, *viz.*, 4–8 and 8–12 annas, while the yield was higher in the group exceeding 12 annas than in the other two groups.

With regard to the results in the study in Dhulia District, the yields obtained in different soil groups in case of cotton in Dhulia District are shown in the table below:

Range of soil value (annas)	Average yield per acre ('Kapas')		
	1959–60	1960–61	1961–62
0·0–6·0 ..	286	510	347
6·1–12·0 ..	426	502	582
12·1 and above ..	254	701	388

A comparison of the figures in the table leads to the conclusion that there was no consistent increasing trend from group to group in any of the three years. In two years, the yields in the highest group, *viz.*, 12 annas and above were lower than in the groups, 6–12 annas, while in one year it was even lower than that in the group 0–6 annas.

For kharif jowar the data are as follows:

Range of soil value (annas)	Average yield (lb. per acre)		
	1959–60	1960–61	1961–62
0·0– 6·0 ..	441	379	331
6·1–12·0 ..	549	527	407
12·1 and above ..	751	1,445	482

The figures show that only in this single case there was consistent increase in yield in all the three years from the lowest to the highest group, although the increase was not linear and the magnitude of the differences between the yields in the different groups vaired from year to year.

Summarising the results, it is seen that (*a*) in case of every crop studied the assumption of linearity of increase in yield from the lowest to the highest soil group has not held good; (*b*) even in those cases where there was a broad indication of a trend of increase in yield from any one soil group to the next higher one, it was not consistent from year to year; (*c*) there was a clear indication of the influence of season and type of crop grown affecting relative position of yields in different soil groups.

Suggestions for Future Studies

The discussion clearly points to the conclusion that to a very large extent the present soil classification does not reflect the true fertility of the soil. It is easy to see that this is so as the very basis of classification is defective inasmuch as it merely took into consideration the physical and topographical characteristics of the soil and omitted altogether its chemical and biological aspects and particularly the nutritional aspects involving the availability of N, P, and K and the PH value. Further, there is accumulating evidence to show that the yield in a particular soil is more likely to be determined by the action and interaction of the three major factors which together influence the yield of a crop, *viz.*, physico-chemical status of the soil, the environmental conditions and type of the crop grown. Besides, the various factors considered in the existing soil classification are assumed to act additively while there is some data to show that the effect of different factors of growth on yield is multiplicative in character.

The present soil classification which is thus not only imperfect but also to some extent subjective in the sense of its assigning values for 'faults' and 'chads' is, to say the least, not at all satisfactory and hence cannot form a sound basis for predicting agricultural productivity. The above considerations lead us to devise more useful, objective and practical criteria for classifiying the soils. The criteria should be such as to afford a quantitative measure for assessing the soil fertility. It is, therefore, worthwhile to define precisely what soil fertility means.

Definition of Soil Fertility

A recent definition of soil fertility is as follows:

"By fertility is meant the quantities and proportions of factors of growth present in the soil: The yield of a crop grown is the result of joint and simultaneous presence and action of all necessary growth factors." "The production capacity of a soil is essentially depending upon its profile but only reaches its maximum when the reserves in nutritive substances are correctly adjusted to the requirements of the plant being cultivated and to the properties of the soil."

In order to study how each of the three factors, *viz.*, physico-chemical status of the soil, the environmental conditions and the type of crop grown affect the soil fertility which forms the basis for predicting agricultural productivity, the following study is proposed. In different well-defined rainfall zones (both in regard to total amount and distribution) a minimum number of fields should be selected in each of different soil groups of the region. Care should be taken to ensure that in these fields same variety of the crop common in the region is grown without irrigation and without any manure being applied. The other cultivation practices such as seed rate, method of sowing, interculturing, etc., would also be kept uniform in all the selected fields. These would remove the effects on yield of the factors of manuring, irrigation, different cultivation practices, etc. The resulting yield data when analysed according to different soil groups based not only on more physical characteristics but also on analysis of its chemical and biological status is expected to lead to a quantitative expression of inherent soil fertility in relation to the crop grown under the environmental conditions obtaining in the region.

It is also suggested that the data obtained from the present fertilizer and varietal trials in cultivators' fields could be appropriately analysed by classifying them according to different soil groups and environmental conditions, with a view to explore the possibility of offering a stable and quantitative definition of soil fertility which may hold good over a large area, say that of a district which can then be used as a measure of agricultural productivity.

In the following years it may even be necessary to increase the number of these trials considerably and also alter the present design suitably to involve pedalogical studies so as to make the definition applicable even to smaller units of area such as that of a development block. It is needless to point out the task would be a gigantic one bristling with technical and statistical complexities, but the only hope is that it would still be a worthwhile attempt and is likely to lead to conclusions of immense practical utility. The task is to be approached as a team-work consisting of Agronomists, Soil Scientists and Statisticians—the Statisticians naturally playing a dominant role in the design of trials and analysis and interpretation of the data obtained therefrom.

SOIL CLASSIFICATION AS A MEASURE OF PRODUCTIVITY WITH PARTICULAR REFERENCE TO STORIE INDEX

BY S. P. RAYCHAUDHURI

PRODUCTIVITY is a function of the following factors: Soil, Climate, Seed and Management. Classification of soil, therefore, goes a long way in calculating productivity ratings. Soils vary widely in their productive capacities and so there is need for comparing the relative productive capacities of different soils, specially in places where a large number of widely divergent soil conditions such as texture, structure, profile characteristics, plant nutrient status, soil reaction and salinity exist. A soil rating would be very useful in land classification and land evaluation.

2. In ancient times in India (2500 B.C. to 600 A.D.) soils were divided into two classes, *Urvara* (fertile) and *Anurvara* or *Ushard* (sterile). *Urvara* soil was subdivided into different kinds with respect to crops; for example, *Java* (barley), *Tila* (sesamum), *Urinhi* (rice), etc. *Anurvara* soil was subdivided into *Usara* (salt land) and *Maru* (desert).

3. The land assessment classification in the sixteenth century in India was based on the suitability of soils for crops and took into consideration such factors as texture and colour of the soil, availability of water, slope of land, and yield of crops. On the basis of the information thus collected and of considerations of marketing facilities, fair estimates of land values were arrived at. Land that is dependent solely on rainfall is called *Barani*; that watered by wells is *Chahi*; land irrigated by canal is *Nahri*; land moistened by river percolation is *Sailabi*. Apart from the above general classifications, local names of soils which conform closely to the soil classes were developed. Thus, for example, for revenue purposes the soils of Raipur District (Madhya Pradesh), which is a part of the Chattisgarh areas in Madhya Pradesh, have been grouped into the following classes:

Matasi.—These are soils of the upland or level land, which are yellow, loam to clay loam and loamy clay in texture, yielding good paddy.

Dorsa.—Soils of the slopes, somewhat darker, with texture same as above. These are also good paddy lands.

Kanhar.—Lowland soils, dark and slightly more heavy than above. Paddy is the main crop, but wheat is also grown.

Bhata.—These are barren waste lands with gravelly sandy soils, reddish-yellow, situated usually on uplands.

Red soils occur in part of the Jhansi District of Uttar Pradesh. There are two types locally known as *Parwa* and *Rakar*. *Parwa* is a brownish-grey soil varying from good loam to sandy or clay loam. *Rakar* is the true red soil which is generally not useful for cultivation.

4. In the Telangana division of Andhra Pradesh where the principal geological formation is a granite-gneiss complex, both red and black soils are widespread. The red soils or "Chalkas" are sandy loams located at higher levels. Such soils are utilised for cultivation of *kharif* crops.

5. In Andhra Pradesh there is another type of soil known locally as "Dubba Soil". It is a loamy sand or very coarse sandy loam which is generally pale brown to brown with reddish-brown patches here and there. The clay content is quite low (less than 10%) and fertility is very low. The soil is invariably neutral in reaction and low in soluble salt content. Organic matter content is little to negligible. The soil is severely eroded and very often covered with multi-sized gravels and cobbles, clearance of which is a prerequisite for conversion into paddy lands. These soils are classes as sub-marginal lands and are more suited for pasture and forage crops than for rice growing, but because canal irrigation is available in this soil region, the whole area has been conditionally declared suitable for paddy cultivation under the Nagarjunasagar project.

6. Similarly in Orissa the soils are classified as *At*, *Mal*, *Berna*, and *Bahal* according to their situations. The revenue system of soil classification and the local name provide an index of fertility. Accurate and reliable yield data are frequently not available and this limitation makes the land revenue classification of restricted value; but if the system is based on fundamental scientific knowledge and reliable data, it will help considerably in correct utilisation and soil classification of this type of land.

7. A number of attempts have been made in more recent years to determine the productive ratirigs of soils by different workers, *e.g.*, Brown and Allison (1916), Russell (1927), Storie (1933), Clarke (1950), Berger (1952), Morgan (1939), Power *et al.* (1948), Basu (1956), Stirk (1953), Mehta *et al.* (1958), Hoon (1952), Raychaudhuri and Murthy (1959), Shome and Raychaudhuri (1960).

8. Storie (1950) has used the following factors in the Storie Index for rating soils based on a study and evaluation of four general characteristics: Factor A relates to soil profile, *viz.*, (i) Depth and (ii) Permeability; Factor B refers to texture of surface soil; Factor C relates to slope; and Factor X represents the factors that can be modified by management, *e.g.*, (i) drainage, (ii) alkali, (iii) nutrient level, (iv) acidity, (v) erosion, and (vi) micro-relief. In order to give a rating for soils, Storie (1933) has given the following soil rating formula:

$$\frac{\text{Factor A} \times \text{Factor B} \times \text{Factor C} \times \text{Factor } x}{100 \times 100 \times 100 \times 100}$$

The grades adopted by Storie in respect of California soils are given in Annexure I.

9. Each of the factors used in the Storie Index for rating soils is evaluated on the basis of 100% for the most favourable conditions. Such rating, however, cannot be final and infallible and may be changed as experience with the use of the soil index indicates. Certain suggestions for assigning weightage of the ratings are given in Annexure II.

10. It may be mentioned that the soil rating data suffer from the serious defect that knowledge of soils in India is very limited. However, it can be urged that the soil index ratings are average approximations for areas which have different kinds of soil and if accuratly calculated the soil index rating may be considered to be a permanent feature of the soil.

11. It has been possible to classify the soils according to soil ratings as follows:

	Soil rating
Excellent	.. 80–100
Good	.. 60– 79
Fair	.. 40– 59
Poor	.. 40

12. The fertility status of a soil depends on its physio-chemical characteristics including soil reaction, texture, depth of the soil,

internal drainage, and content of salt and major and minor nutrients. Determination of the fertility indices of the lowest categories of the soil class is not easy. However, this has to be done so that soil classification may be of practical use. It is at this stage that soil testing and manurial experiments give useful information. Once the results of manurial schedules are available for one particular soil type at one place, the same results can be used for similar soil-climatic conditions at other places where such trials have not been conducted.

ANNEXURE I

Grades Adopted by Storie (1933) *in Respect of California Soils*

Grade 1 (*excellent*).—Soils that rate between 80 and 100% and which are suitable for a wide range of crops, including alfalfa, orchard, truck and field crops.

Grade 2 (*good*).—Soils that rate between 60 and 79% and which are suitable for most crops. Yields are generally good to excellent.

Grade 3 (*fair*).—Soils that rate between 40 and 59% and which are generally of fair quality, with less wide range of suitability than grades 1 and 2. Soils in this grade may give good results with certain specialised crops.

Grade 4 (*poor*).—Soils that rate between 20 and 39% and which have a narrow range in their agricuitural possibilities. For example, a few soils in this grade may be good for rice, but not good for many other uses.

Grade 5 (*very poor*).—Soils that rate between 10 and 19% are of very limited use except for pasture, because of adverse conditions such as shallowness, roughness and alkali content.

Grade 6 (*non-agricultural*).—Soils that rate less than 10% include, for example, tidelands, riverwash, soils of high alkali content and steep broken land.

ANNEXURE II

Suggestions for Assigning Weightage of the Ratings

Factor A

Soil Profile	Ratings %
(i) Unweathered or slightly weathered secondary soils	95–100
(ii) Moderately weathered secondary soils	80– 95
(iii) Thoroughly weathered secondary soils with dense clay subsoils developed on unconsolidated parent material	40–80

Factor B

Surface Texture

1. Loam	100
2. Sandy loam	95
3. Sandy clay loam	90
4. Clay loam	85
5. Sandy clay loam to clay loam	85
6. Sand	60

Factor C

Slope

1. Nearly level (0–1%)	100
2. Gently undulating (1–3%)	100
3. Gently sloping (3–8%)	95–100

Factor X

Drainage

1. Well drained	100
2. Fairly well drained	90

pH

1. Medium acid (5·6–6·0)	90
2. Slightly acid (6·0–6·5)	95
3. Neutral (6·5–7·3)	100

Nutrient Status

(*a*) *Total Nitrogen %*

1. Rich (Above 0·10)	100
2. Good (0·06–0·10)	95

3.	Fair (0·03–0·06) ..	80
4.	Poor (Below 0·03) ..	60

(*b*) *Organic Carbon %*

1.	High (Above 0·75) ..	100
2.	Medium (0·50–0·75) ..	80
3.	Low (Below 0·50) ..	60

(*c*) *Available* P_2O_5 in *lbs./acre*

1.	Very low (below 10 lbs.) ..	70
2.	Low (10–20 lbs.) ..	80
3.	Medium (20–50 lbs.) ..	95
4.	High (50–100 lbs.) ..	100

(*d*) *Available* K_2O *in lbs./acre*

1.	Very low (below 60 lbs.) ..	70
2.	Low (50–100 lbs.) ..	80
3.	Medium (100–250 lbs.) ..	95
4.	High (250–500 lbs.) ..	100

ISOLATION OF EFFECTS OF WEATHER ON PRODUCTIVITY INCLUDING OTHER RISKS SUCH AS DAMAGES BY PESTS AND DISEASES

By T. P. Abraham

Weather exerts a pronounced influence on agricultural production, more so in a country like India which depends heavily on monsoon for timely agricultural operations and for proper growth of crops. Some of the reverses recently experienced in our agricultural production have been attributed in no small measure to vagaries of weather, Under these circumstances, it is of great importance to isolate the effects of weather on agricultural productivity, so that it may be possible to have a more objective assessment of the progress achieved by planned efforts. Weather may influence production either directly through affecting the growth and structural characteristics of the crop such as stand, number or tillers, leaf area, etc., or indirectly through its effects on the incidence of pests and diseases. There have been numerous statistical studies made of the influence of particular weather variables on crop yields, usually in a particular locality based on annual changes in the variables involved. Of the various factors affecting the weather balance of the crop, those affecting moisture supply and moisture requirements are probably the most important especially in regions where water is the principal limiting factor. Fisher developed an elegant approach for dealing with weather yield problem in his study of "The Influence of Rainfall on the Yield of Wheat at Rothamstead". In developing this method, Fisher was guided by the consideration that the influence of a weather factor, such as rainfall on crop yield, has to take into account not only the total amount of rainfall during the season, but also its distribution. He, therefore, suggested dividing the year into short periods such as week or 5-day periods and studying the effect of an additional inch of rainfall on the yield in each of these time periods. The method briefly consists of summarising the rainfall distribution by fitting an appropriate polynomial in time. A multiple regression of yield on the rainfall constants was then worked out. With the help of these partial regression coefficients of yield on the rainfall constants, it is possible to evaluate the effect of an additional inch of rainfall on yield in successive time periods. This method has been tried by a number of workers with varying success. Some of the limitations of the method are that it does not take into account non-linear effects of weather factors, lack of consideration of the joint effects between precipitation in successive periods and the use of calendar periods instead of periods of equal development of the plant. Some of these limitations can be overcome by suitable variations in the form of regression function and by transformation of variables.

The method developed by Fisher can be readily adopted to take account of joint relationship between different weather factors such as rainfall and temperature. This can be done by introducing besides the regression coefficients on rainfall, corresponding coefficients for regression on temperature, and a third set of regression coefficients for the joint effect of rainfall multiplied by temperature. Fisher's method was tried at the Institute of Agricultural Research Statistics to study the effects of rainfall on rice yields for a period of 21 years from 1916–17 to 1936–37 at Coimbatore Research Station. However, the method failed to show association of rainfall with yield. Instead of using Fisher's technique the simpler approach of choosing some of the variables which are known *a priori* as likely to have pronounced effect on yield and correlating these with the observed yield was attempted. The variables chosen were amount of rainfall for a fortnight preceding the flowering period and the rainfall for two weeks, after flowering. These two variables together accounted for about 60% of the annual variation observed in yield. The increased rainfall in the pre-flowering period was beneficial to the crop, while higher rainfall in the post-flowering phase was detrimental to the crop indicating the pronounced effect of moisture supply conditions in critical phases of plant growth. If the objective is to make productivity comparison between regions, it will be necessary to aggregate the measures of the weather effects obtained in individual localities. This can be done by taking a weighted average of the individual estimates by the areas represented by each.

In order to make allowance for weather variations in the comparison of agricultural productivity changes between regions or years, it is not necessary to estimate the effect of individual weather factors. Only the combined effect of all the weather factors occurring in a particular season over a specified area needs to be assessed. In such cases it may be possible to construct an overall weather index for each year provided yields on the same piece of land in different years under uniform conditions of management and practices are available. The yield of plots maintained under the Crop Weather Scheme by the Agricultural Meteorological Department at different research stations provide one such series. The data obtained in permanent trials such as manurial trials with fixed treatments also provide data which can be utilised for the same purpose after suitable adjustments. To each series, a trend line to remove the influence of non-weather variables may be fitted. The residuals from this trend line can be considered largely due to the influence of weather. Indices from different series can be combined for a particular locality by suitably averaging and linking the individual series. A weighted average of such indices over a region can then be constructed, the weights being proportional to the relative quantities produced of the crops in the areas where the stations are located. A beginning on these lines is being made at the Institute of Agricultural Research Statistics with data collected under the National Index of Field Experiments Scheme. Although fluctuations in yields obtained at research stations under uniform conditions in different years may not be entirely representative of variations due to weather factors in the tract, weather indexes constructed from such data supplemented by measurements on other variables may provide a satisfactory means of removing the weather effects from productivity comparisons. The possibility, on the one hand, of the failure of trend lines to remove the predominant part of non-weather influences and, on the other hand, of actually removing a significant part of weather influences should be, however, kept in view.

Another approach to study the effect of weather on crop production on a global basis will be to estimate the possible effects of the various inputs, such as, fertilizers, irrigation, extension of area, etc., on production, using input-output coefficients and to assign the residual as due to weather. In practice, however, reliable estimates of input-output coefficient for different input factors in agriculture are not available and also the estimates of amounts of such inputs which have actually gone for production in any particular year will not be available easily. Besides, the interaction between different inputs is also not taken into account usually in such estimates. However, it may be possible to estimate the cumulative effect of such man-made changes. It will be reasonable to assume that the changes introduced by planned efforts such as introduction of fertilizers will show a smooth trend over the years, while the influence of weather will be distributed, more or less, randomly. Under this assumption it is possible to fit an appropriate trend curve to the acre yields. Generally the progress of productivity is characterised by an average annual growth percentage. Therefore, an exponential trend curve appears to give an accurate picture of the situation. This approach was made on the acre yields of rice and wheat in some of the States in India during the first two plans. The indices of weather calculated from the deviations from the fitted trends are given in Table I. The coefficients of variation of the deviations can be taken as estimates of overall effects of weather on acre yield fluctuations during the plan periods. These are given in Table II. Fluctuations due to weather on productivity show a very large variation from State to State. It will be observed that the variation is least in Andhra Pradesh, Madras and Assam. In Assam, there is an abundant rainfall and there appears to be very little variation in the crop yield from year to year. The small variation in Andhra Pradesh and Madras should be ascribed to the fact that rice is grown under irrigated conditions on most of the area in these States. Bihar, Madhya Pradesh and Uttar Pradesh with relatively small area under irrigation and lower rainfall of about 100 to 130 cm. annually show a very large influence of weather. In the case of wheat crop also, the influence of weather is lower in Punjab with very high percentage of area under irrigated conditions. Bihar again has indicated the largest influence of weather. These figures indicate the need for taking necessary steps for reducing the uncertainties due to weather fluctuations in some of the States like Bihar.

The importance of varying degrees of infestation by insects and diseases in the determination of crop yields has already been mentioned. These factors may be taken into account in two ways. Their dependence on specific weather conditions may be studied and the most

TABLE I

Weather Indices—1950–51 *to* 1960–61

States	1950–51	1951–52	1952–53	1953–54	1954–55	1955–56	1956–57	1957–58	1958–59	1959–60	1960–61
					Rice						
A.P.	99·8	94·1	94·7	107·9	110·3	97·3	100·0	99·1	102·7	101·0	94·7
Assam ..	99·0	97·4	103·0	101·6	104·0	96·5	101·5	97·2	96·0	102·8	101·3
Bihar ..	82·4	96·9	116·8	133·5	87·8	105·2	111·7	66·9	113·9	98·4	103·9
Kerala ..	93·8	103·2	99·5	95·9	105·3	101·5	109·2	105·0	95·2	98·3	94·5
M.P. ..	79·3	116·3	107·8	105·6	95·8	108·8	117·6	72·4	107·8	98·1	101·4
Madras ..	107·6	95·9	93·7	95·7	104·0	99·8	105·8	103·0	96·5	100·0	98·5
Mysore ..	118·7	99·0	92·3	97·7	99·9	81·5	97·2	103·1	109·8	106·7	99·0
U.P. ..	108·0	82·8	96·9	113·2	103·1	116·1	96·6	92·4	111·0	84·9	104·2
W. Bengal	100·9	92·0	96·6	123·0	94·2	100·0	105·3	96·0	92·8	91·4	112·4
					Wheat						
Bihar ..	89·8	87·8	123·1	123·3	125·5	113·3	44·0	101·8	124·4	92·7	113·5
Gujarat ..	88·3	101·2	101·3	100·2	108·0	102·8	84·7	78·6	119·3	92·3	115·4
Madhya Praesh	116·1	83·9	95·3	102·2	114·3	102·8	104·0	70·3	111·9	115·3	96·0
Punjab ..	101·6	94·2	107·8	103·4	105·6	90·0	98·1	95·2	100·7	95·2	110·3
Rajasthan	105·5	74·8	123·6	97·7	107·8	103·2	111·0	88·0	98·3	94·3	104·3
U.P. ..	103·5	95·4	105·7	104·1	108·9	92·6	94·2	87·1	94·3	100·3	117·8
W. Bengal	130·9	122·1	126·5	110·0	119·8	104·3	46·0	83·0	98·4	92·7	103·4

important of these factors may be included in the regression equation or the degree of infestation may be determined each year by inspection of the growing crop and the effect of the incidence directly on yield may be estimated. The I.A.R.S. has started some pilot studies to estimate the incidence of pests and diseases and consequent crop losses in selected districts on rice and wheat. The studies so far conducted show the possibility of getting objective estimates of incidence, but establishing a relationship between yield and the particular pests and diseases appears to be difficult under field conditions. The survey has now been modified to include suitable check plots where all effective control measures will be adopted for control of pests and diseases.

TABLE II

Relative variation due to weather of hectare yields from 1950–51 to 1960–61

State	Average % area irrigated	Normal rainfall in cm.	Mean yield in kg./ha.	Coefficient of variation of deviations from trend
		Crop: Wheat		
Bihar ..	29·4	128·8	559·2	22·6
Gujarat ..	19·3	73·0	686·4	13·3
Madhya Pradesh ..	12·3	122·4	645·5	13·4
Punjab ..	72·2	62·5	1045·3	6·0
Rajasthan ..	12·4	50·8	891·0	11·8
Uttar Pradesh ..	11·1	98·6	825·6	8·5
West Bengal ..	25·5	143·5	695·9	22·1
		Crop: Rice		
Andhra Pradesh ..	94·7	87·1	1,173·5	5·8
Assam ..	33·3	251·6	989·8	2·8
Bihar ..	29·4	128·8	685·6	16·7
Kerala ..	41·9	299·6	1,127·9	5·0
Madhya Pradesh ..	12·3	122·4	751·7	13·1
Madras ..	91·8	100·8	1,307·9	4·1
Mysore ..	55·0	172·8	1197·1	8·7
Uttar Pradesh ..	11·1	98·6	577·9	10·4
West Bengal ..	25·5	143·5	1,028·0	9·3

Comparison of these check plots with other plots suitably chosen can be expected to give a fairly good idea of the avoidable losses due to the cumulative action of all pests and diseases. Work is in progress on these lines.

The study of the influence of weather is needed not merely to assess the progress achieved by our planned efforts, but also to throw light on how such variation can be prevented or reduced by suitable measures. For instance, in some cases, this may lead to evolving varieties which can withstand short periods of drought or excess rainfall in specified periods. It is, therefore, suggested that research on the weather-crop relation may be intensified by examining critically past data available and by setting up permanent plots at a large number of representative areas to collect uniform series of yields over years. The work initiated by the Agricultural Meteorological Department in this direction should be enlarged and intensified.