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IMPACT OF IRRIGATION AND LABOR AVAILABILITY ON MULTIPLE CROPPING: A CASE STUDY OF INDIA

Dharm Narain
Shyamal Roy

November 1980

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v

CONTENTS

Foreword

1. Summary 7

2. Introduction 9

3. Factors Affecting Multiple Cropping 11

4. Sources of Irrigation and Cropping Intensity 22

5. Conclusions 26

Appendix 27

Bibliography 33

TABLES

1. Growth rates of area, cropping intensity, and productivity 10
2. Results of statistical analysis of variations in multiple cropping between states, 1973/74 14
3. Statistical analysis of variations in multiple cropping in southern states 17
4. Statistical analysis of variations in multiple cropping in northern states 18
5. Statistical analysis of variations in multiple cropping in western states 20
6. Statistical analysis of variations in multiple cropping in eastern states 20
7. Interstate analysis of sources of irrigation and cropping intensity 22
8. Important sources of irrigation for selected states 23
9. Correlation matrices for variables used in intrastate analysis 24
10. Pooled analyses of sources of irrigation and cropping intensity 25
11. Interstate data, 1973/74 27
12. Intrastate cropping intensity and irrigation data by farm size and state, 1970/71 28

FOREWORD

Research at the International Food Policy Research Institute has documented in Research Report 3 the immensity of the food problem facing the world in the next decades and the great difficulty of achieving the growth rates required to meet the projected needs. The declining pace at which new land is being brought into agricultural use in Africa as well as elsewhere in the world and the declining productivity of new lands as cultivation is pushed further into marginal areas place much of the burden of increasing production on increased irrigation and other methods of intensified land use.

In IFPRI Research Report 10, it is estimated that even assuming optimistic yield increases in rainfed agriculture, roughly half of the needed production increase during the next 15 years must come from the expansion of irrigated areas, at a cost of some $50 billion (in 1975 dollars). Research Report 10 also indicated that a major portion of the increase in irrigated area and agricultural production was needed in India. The fact that they have occurred adds significantly to the somewhat improved prospects of the global food scene as compared to the previous decade.

The Indian experience provides a unique opportunity to examine the role of key variables in irrigation. The wealth of data and ancillary analyses as well as the wide variation in experience provide a basis for improved hypotheses for the examination of policies in other countries.

In this report Dharm Narain explores the expansion of cropped area through multiple cropping. He examines the importance of multiple cropping to increasing overall production and how multiple cropping relates to the quantity and type of irrigation used.

The problem is meticulously defined and the policy conclusions are clear. Anyone who has worked with Dharm Narain would expect no less. This research report answers important, broad questions of agricultural development policy and sheds light on more difficult, narrower issues. Perhaps, most importantly, from the careful scholarship of this research a great deal can be learned about the relationship among variables, about how to interpret those relationships, and about the scholarly use of data.

This was the last piece of research completed by Dharm Narain. His untimely death left uncompleted an important work on the trends and issues of rural poverty. In a future research report, IFPRI will present the basic elements of that research and an accompanying set of essays dealing with various aspects of the concepts presented. Dharm Narain's careful attention to detail, the detailed and perceptive specification of the empirical investigation, and the precise statement of conclusions evidenced in this research report demonstrate our great loss and suggest the contribution he was able to make to the work of his now bereaved colleagues.

John W. Mellor

Washington, D.C.
November 1980

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1

SUMMARY

Since the early 1960s India's five-year plans have aimed at a growth rate in agricultural output of 4 percent per year or more but have failed to achieve it. Now that the expansion in net sown area has largely petered out, a much faster expansion of multiple cropping is needed if output goals are to be attained. To acquire a better understanding of this source of crop output growth, this report examines the considerable differences in cropping intensity from state to state and within selected states.

Multiple cropping (or cropping intensity) is the planting of successive crops on the same land throughout the year. The analysis shows that three factors alone account for about 80 percent of the interstate variations in cropping intensity. They are availability of labor per unit of sown area and extent and quality of irrigation. With the exception of 5 out of the 17 selected states, the same factors explain 80 percent of the variations in cropping intensity between 12 groups classed according to size of farm holdings within individual states. The results imply that land reforms designed to rectify the existing imbalance between the availability of land and labor can exert a significantly favorable effect on cropping intensity because smaller farms tend to use irrigation and labor more intensively.

Where agroclimatic conditions are such that more than one crop can be grown on a piece of land in a year without the help of irrigation, the pressure of population on land necessitates an increase in cropping intensity while an increase in labor supply makes it possible. But in areas of insufficient rainfall or soil with poor moisture retention, irrigation is essential if a second crop is to be grown in the dry season. The quality of irrigation is crucial because, for example, irrigation canals that are full only during the monsoon season are of little value in raising additional crops during the dry season. Hypothetically other factors such as the development of seeds requiring shorter growing periods and mechanization of farms to speed operations also contribute to multiple cropping, but in reality their contributions are still inconsequential in most states in India. Adjustment is made, however, for areas where the crops are of such long duration that a second crop cannot possibly be planted on the same land within the year.

Because only 8 percent of the variation in multiple cropping among states can be attributed to the extent of irrigation, whereas 43 percent can be explained by the quality of irrigation, an attempt was made to determine how much each of the sources of irrigation affects multiple cropping. However, a high degree of multicolinearity among the independent variables frustrated the effort. To overcome this problem, the observations for the states in which the analysis was able to account for the bulk of intrastate variations were pooled together. With the help of farm size as a variable in place of labor availability (for which data was not available at this level) and the percentages of the net sown area served by each source of irrigation, 77 percent of the variance was explained. Among the different irrigation sources, the results show that tubewell irrigation has the most positive effect on multiple cropping—double that of well and canal irrigation. The impact of tank irrigation could not be determined.

A comparison of the actual change in cropping intensity over a period of time with the changes estimated to arise from the irrigation variable alone suggests that the estimated coefficients arrived at in this report are realistic. Therefore, they may be used to obtain an approximate idea of what the expansion of irrigation can be expected to contribute to an increase in cropping intensity in the coming years.

Using the mean coefficient, it appears that the amount of irrigation expansion called for in the Sixth Five-Year Plan might yield an increase of 5.0 to 6.0 percentage points in the index of cropping intensity or an increase of 1.0 percent per year in the gross cropped area. Thus, even if the growth rate of productivity does not improve but continues at its present rate, agricultural output could increase by 3.5 percent per annum. And if irrigation expansion also

brings about an additional increase in productivity, then reaching the targeted annual growth rate of 4 percent in agricultural output will be possible. This, however, depends on successful implementation of plans for irrigation expansion and the extent that this potential is used for multiple cropping.

2

INTRODUCTION

In India expansion of cultivated area, which made an important contribution to the growth of agricultural output in the 1950s, has declined over the years. Table 1 shows that the growth of net sown area slowed from more than 1.0 percent per annum (compound) in the 1950s to 0.4 percent in the 1960s and to only 0.12 percent in the five-year period ending in 1975/76. The progress of cropping intensity via the spread of multiple cropping[1] proceeded at a slow pace. The index of multiple cropping or cropping intensity is defined as gross cropped area as a percentage of net sown area.[2] It grew by a meager 0.26 percent per annum between 1950/51 and 1975/76. The annual increase was about the same in the 1950s and the 1970s (0.36 and 0.38 percent respectively), while it was significantly lower in the 1960s (0.22 percent). Without improvement in the growth rate of cropping intensity, the rate of expansion of gross cropped area, now mostly reflecting the spread of multiple cropping, dropped to 0.5 percent per annum in the 1970s from a level of 1.5 percent per annum in the 1950s. The growth of productivity per unit of gross cropped area did improve, especially after the introduction of the high-yield varieties of seeds, but the degree of improvement was not sizable enough to accelerate the growth of agricultural output by more than enough to make up for the slowdown in the expansion of area.

It is against this background that one must view the failure of the successive five-year plans since the beginning of the 1960s to achieve a targeted agricultural output growth of 4 to 5 percent per annum. If the expansion of gross cropped area continues at the present rate of only 0.5 percent per annum, meeting the growth rate of 4.0 percent in agricultural production would imply a step-up in the growth rate of productivity per unit of gross cropped area to about 3.5 percent per annum. The best performance of productivity since the introduction of the high-yield varieties of seeds has not yielded an annual growth of more than 2.3 percent between 1964/65 and 1975/76. Thus the difficulties involved in achieving an increase of this magnitude in the growth rate of productivity in a country of India's size are apparent. Because growth in net sown area has almost petered out, an important part of the burden of achieving an annual increase of 4.0 percent in agricultural production falls on multiple cropping.

The index of cropping intensity for India, which stood at 120 in 1975/76, compares unfavorably with those for Bangladesh, the Philippines, and Korea, which ranged between 134 and 147[3], and for Taiwan, which was about 180.[4] More significantly, there are large differences in cropping intensity among the different states in India: the index ranged all the way from 106.7 for Karnataka to 168.6 for Himachal Pradesh. It is therefore

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[1] Multiple cropping in this study connotes the practice of raising more than one crop, one followed by the other, on the same land in an agricultural year, as distinct from growing a combination of two or more crops on the same land at the same time (intercropping). This study is concerned with multiple cropping as a vehicle for raising cropping intensity.

[2] Gross cropped area is made up of net sown area plus area sown more than once where net sown area refers to the physical area sown in which each hectare is reckoned as one irrespective of the number of times it is sown, and area sown more than once represents each net sown hectare times the number of additional crops raised on it during a year. In this report the area sown more than once will also be referred to as the multiple cropped area.

Even though the index of multiple cropping is a crude measure of cropping intensity if the latter is defined in terms of the length of the period for which land is occupied by some crop or another during an agricultural year, multiple cropping and cropping intensity will be used as interchangeable expressions in this paper.

[3] Asian Development Bank, *Asian Agricultural Survey, 1976* (Manila: Asian Development Bank, 1977), p. 411.

[4] Republic of China, Executive Yuan, Council for Economic Planning and Development, *Taiwan Statistical Data Book, 1975* (Taipei: Council for Economic Planning and Development, 1975), p. 48.

Table 1—Growth rates of area, cropping intensity, and productivity

Period	Net Sown Area	Gross Cropped Area	Index of Cropping Intensity[a]	Index of Productivity[b]
1950/51 – 1960/61	1.16	1.52	0.36	
1960/61 – 1970/71	0.40	0.62	0.22	
1970/71 – 1975/76	0.12	0.50	0.38	
1950/51 – 1975/76			0.26	
1950/51 – 1964/65				1.64
1964/65 – 1975/76				2.33

Source: For data and indexes of agricultural production and gross cropped area, see India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Estimates of Area and Production of Principal Crops in India, 1977-78* (Delhi: Controller of Publications, 1979).

Note: Growth rates are obtained by fitting the standard form $y = ab^t$.

[a] Index of Cropping Intensity = $\frac{\text{Gross Cropped Area}}{\text{Net Sown Area}} \times 100.$

[b] Index of Productivity = $\frac{\text{Index of Agricultural Production}}{\text{Index of Gross Cropped Area}} \times 100.$

important to inquire into the reasons for such large differences in order to better understand this source of crop output growth.[5]

[5] The study of the income-employment implications of multiple cropping, although of great importance in efforts to expand opportunities for the agricultural work force, lies outside the scope of this paper.

For a brief review of the existing work on the income-employment aspects of multiple cropping in South Asia, see Inderjit Singh, *Small Farmers and the Landless in South Asia*, Background Paper No. 4 (Washington, D.C.: International Bank for Reconstruction and Development, 1979), pp. 46-51.

See also C. H. H. Rao, *Technological Change and Distribution of Gains in Indian Agriculture* (Delhi: Macmillan Co. of India, Ltd., 1975), and S. Mehra, "Some Aspects of Labour Use in Indian Agriculture," *Indian Journal of Agricultural Economics* 31 (October–December 1976): 95-121.

3

FACTORS AFFECTING MULTIPLE CROPPING

Hypothesis and Specification of Variables

Referring to the general notion that irrigation facilities are necessary for multiple cropping, Dr. V. K. R. V. Rao observed: "Contrary to popular impression, it is not only irrigated area that is capable of having more than one crop. India has a large area under double cropping that is not irrigated but only rainfed, and this is, in fact, substantially larger than the irrigated area under double cropping."[6]

But in arriving at the extent of unirrigated multiple cropping, Dr. Rao erred in equating the difference between area sown more than once (multiple cropped area) and area irrigated more than once (multiple cropped irrigated area) with the multiple cropped area that is entirely rainfed. Before going into why the two are not the same thing, it is useful to define the terms used in Indian statistics on irrigated area. Net irrigated area refers to the physical area irrigated during an agricultural year, each hectare of which is counted only once even if two or more crops are irrigated in different seasons on the same land. Gross irrigated area, on the other hand, represents the net irrigated area times the number of irrigated crops raised on it, one followed by the other, during a year. The area irrigated more than once is the difference between the gross irrigated area and the net irrigated area; it can be easily identified as the irrigated component of the total multiple cropped area. The remainder, however, cannot be assumed to be entirely rainfed as shown by this example. Consider an area on which two crops are grown in a year, an unirrigated crop in the monsoon season and an irrigated crop in the dry season. Because one of the crops is irrigated, this area would figure in the category of net irrigated area, but because the other crop is unirrigated, the double cropping on this land would not be reflected in the gross irrigated area. Hence it will be included in the total of multiple cropped area but not in area irrigated more than once. Considering that double cropping on this land is made possible by irrigation and, at any rate, one of the two crops is irrigated, it is clearly erroneous to equate the difference between the total multiple cropped area and area irrigated more than once with the entirely unirrigated multiple cropped area. The difference includes both entirely unirrigated multiple cropping and that in which an additional crop is raised with the help of irrigation.[7] Thus, given the way the statistics are recorded, it does not seem possible to derive from them the extent of entirely rainfed multiple cropped area. The question of the dependence of multiple cropping on irrigation or, rather, the bearing of irrigation on cropping intensity, needs to be pursued in a different way.

It can indeed be hypothesized that where agroclimatic conditions—the amount and time of rainfall and the moisture-retaining capacity of the soil—make it possible to raise more than one crop in a year, the growing pressure of population on cultivated land[8] would contribute to an increase in multiple cropped area even without irrigation. The need to feed more mouths provides the incentive for increasing production through

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[6] V. K. R. V. Rao, "New Challenges Before Indian Agriculture," Dr. Panse Memorial Lecture at the 27th Annual Conference of the Indian Society of Agricultural Statistics, New Delhi, 1974, p. 13.

[7] See J. S. Sarma, "Concepts of Irrigation and Problems of Measurement," *Role of Irrigation in the Development of India's Agriculture* (Bombay: The Institute for Social and Economic Change, 1976), pp. 3-9; and T. N. Srinivasan and A. Vaidyanathan, "Agricultural Statistics," in *Data Base of Indian Economy: Review and Reappraisal* vol. 2, ed. C. R. Rao (Calcutta: Statistical Publishing Society, 1972), p. 38.

[8] This arises out of lack of employment opportunities elsewhere.

multiple cropping, whereas an increase in the supply of labor makes it possible to do so. But where the rainfall is too little and the moisture-retaining capacity of the soil is too low to raise a second crop in the dry season, multiple cropping would obviously be contingent on the availability of irrigational facilities. Irrigation, however, has not only a quantitative but also a qualitative dimension. Unless the source of irrigation is capable of ensuring water supply in the postmonsoon period, it would be of little help in raising a dry-season crop.

Another obvious factor bearing on the extent of multiple cropping is the relative weight of the long-duration crops in the cultivators' choice of a cropping pattern. A crop like sugarcane, which occupies the ground for most of the year or longer, precludes multiple cropping from areas on which it is grown. Since farmers' choice of crops is taken as given in this study, the index of multiple cropping is adjusted to take this into account, as will be explained later. Additional factors are improvements in technology such as the development of shorter-duration varieties of crops or varieties whose sowing and harvesting times can be dovetailed in a time sequence within the crop calendar of an agricultural year. Alternatively, when available labor proves inadequate to complete the harvesting of a crop in time for the sowing of another, mechanization of certain operations can enable the cultivators to "buy time" which may be crucial for raising cropping intensity.

Although a simple listing of such factors is easy enough, how importantly they bear on cropping intensity in concrete situations needs to be investigated empirically. With the exception of a very few states—principally Punjab, Haryana, and Uttar Pradesh—the mechanization of farm operations other than irrigation would hardly seem to be a factor of much consequence at present. Thus cropping intensity is hypothesized as a function of the availability of labor and irrigation facilities. Although favorable agroclimatic conditions enter the picture, they are best visualized as passive factors that permit, or provide the potential for, an expansion in cropping intensity even without irrigation; the demographic factor is the active force that helps to realize it. Therefore, much of the variation in entirely unirrigated multiple cropping could be expected to reflect the play of the labor availability variable.

Given the labor market dualism, the availability of family labor is more pertinent for our purpose. Because a breakdown of the total number of agricultural workers into cultivators and agricultural laborers is readily available from the 1971 population census, we define the labor availability variable as the number of cultivators per hectare of net sown area. Given the concepts and procedures of the 1971 population census, a doubt could be entertained whether the data on the number of cultivators obtained from this census would constitute a good indication of family labor availability. First, unlike the 1961 census, the 1971 census data on workers pertains to those whose "main activity" was work, thus excluding housewives and students from the labor force even though they may have been working on the family farm as a part-time activity. Second, only those workers were classified as cultivators whose main activity was cultivation (on their own account) thus excluding from this class those small farmers whose time spent cultivating on their own account was not their main activity. These differences between the 1961 and 1971 censuses are believed to be an important reason for the observed decline in the proportion of cultivators and an increase in the proportion of agricultural laborers in the total number of workers during 1961-71.[9] For our purposes the relative variations among states in availability of family labor are what is pertinent. Therefore, we correlated the number of cultivators by states from the 1961 census with those of the 1971 census, expressing each as cultivators per hectare of sown area. The coefficient of correlation was found to be 0.98 and that of rank correlation, 0.93. This suggests that the use of the 1971 census data on the number of cultivators may be satisfactory.

Although the extent of irrigation is easily defined as net irrigated area as a percentage of net sown area, the qualitative aspect of

[9] See Pravin Visaria, "Employment—A Trend Report," in *A Survey of Research in Economics*, vol. 2, ed. D.T. Lakadawala (Delhi: Allied Publishers, 1976), pp. 200-201; and Pravin Visaria and Andrudh K. Jain, *Country Profiles: India* (New York: Population Council, 1976), pp. 17-18.

irrigation is more awkward to handle adequately. In principle, the difficulty does not arise from differences in the quality of irrigation provided by different sources. The area served by each source can be treated as a separate variable by expressing it as a percentage of net sown area. Thus when cropping intensity is regressed on different irrigation sources, the coefficient of each would be expected to capture the impact of its quality[10] on cropping intensity. In practice, however, according a separate treatment to each source can pose a problem by increasing the number of explanatory variables when the number of available observations is not large. From the standpoint of the quality of irrigation, the problem is compounded when the areas served by the same source do not constitute a homogeneous category. One canal may be seasonal and another perennial, but the areas served by both would figure in the same category of canal-irrigated area. And the greater the differences in the quality of irrigation provided by a given source, the more they would tend to obscure the relationship between cropping intensity and the irrigation factor. The more limited the number of available observations, the greater is the need for a separate indicator of quality which in conjunction with the extent of irrigation may serve to bring out the importance of irrigation in accounting for the differences in cropping intensity. Since more than one irrigated crop is raised on some irrigated lands, these areas must be served by nonseasonal[11] sources. Thus the quality of irrigation is defined as the multiple cropped irrigated area as a percentage of the net irrigated area.

The indicator is convenient but it suffers from a deficiency. Whereas the irrigated areas on which more than one irrigated crop is raised can be identified as those served by nonseasonal sources, the converse is not necessarily true. A source of irrigation may well be nonseasonal, but because of the costs of irrigation its water may be used for raising an irrigated crop only in the dry season, after raising an unirrigated crop with the help of free monsoon rains. The mere absence of irrigated multiple cropping in this case would not warrant the inference that this source of irrigation is seasonal. This point is inconsequential in judging the quality of irrigation from the standpoint of multiple cropping, for it is the availability of irrigation water in the dry season that enables the raising of an additional crop, not the use of this irrigation facility in the monsoon period. Thus, our indicator of the quality of irrigation would seem to be alright as far as it goes, but it may not go far enough.

The variations in the extent of multiple cropping caused by the differences in the relative weight of long-duration crops in the cropping pattern are taken into account, albeit partially, by adjusting the indexes of multiple cropping by excluding the areas devoted to sugarcane, fruits, and plantation crops from the gross cropped as well as the net sown area. These crops are of such long duration that the area under them can obviously not be multiple cropped.[12]

Interstate Variations in Cropping Intensity

To examine the influence of labor and irrigation on cropping intensity, the functional relationship was specified as follows:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 ,$$

where Y is the adjusted index of multiple cropping for each state, X_1 refers to the number of cultivators per hectare of net sown area, X_2 is multiple cropped irrigated area as a percentage of net irrigated area in each state, and X_3 is the net irrigated area expressed as a percentage of net sown area.

The results of the regression analysis summarized in Table 2 show that about 80 percent of the variation in multiple crop-

[10] Although quality of irrigation has many dimensions to it, we are here concerned with only one of these—the capacity of a source of irrigation to enable the raising of more than one crop in a year.

[11] The terms seasonal and nonseasonal here refer respectively to sources which ensure water supply only during the monsoon seasons and those which do so even in the postmonsoon period.

[12] From the standpoint of cropping intensity defined as the length of the period for which the land is occupied by some crop or another during a year, the appropriate procedure would be to work out the indexes of cropping intensity by assigning higher weights to the areas under long-duration crops in the gross cropped area. This was attempted but the difference was found to be inconsequential. See footnote 13.

Table 2—Results of statistical analysis of variations in multiple cropping between states, 1973/74

Correlation Coefficients

Variable	Y	X_1	X_2
X_1	0.58		
X_2	0.80	0.28	
X_3	0.53	0.08	0.43

Regression Equation

Variable	Regression Coefficient	"t" Values	Beta Weight
Constant	93.19	19.17	...
X_1	18.10	3.40	0.40
X_2	0.57	4.50	0.59
X_3	0.24	1.99	0.25

Notes: Y is the adjusted index of multiple cropping for each state; X_1 is the number of cultivators per hectare of net sown area; X_2 is multiple cropped irrigated area as a percentage of net irrigated area in each state; and X_3 is net irrigated area expressed as a percentage of net sown area. For the regressions $\bar{R}^2$ is 0.81 and F is 21.85.

ping between states in India is accounted for by the explanatory variables. All the explanatory variables are statistically significant, X_1 and X_2 at 0.05 and X_3 at 0.10 probability levels.[13]

Because the units of the explanatory variables are different, we cannot infer from the sizes of the regression coefficients the relative influence exerted on cropping intensity by the three factors. However, the squares of their respective B weights (also called B coefficients) divided by R^2 indicate the proportions of the total explained variance that can be directly attributed to each of the independent variables. The rest cannot be directly attributed to either of them. Whereas about one fifth of the explained variance may be directly attributed to labor availability per unit of sown area, about one half stem from the irrigation variables. This points up the great importance of irrigation as an underlying factor in cropping intensity. To say this does not imply that multiple cropping is not practiced in unirrigated areas where agroclimatic conditions make it possible to do so.

However, if the variations in unirrigated multiple cropping are suspected to be large, then their independence from the irrigation variables could raise doubts about the veracity of our results that account for the bulk of the interstate variations in cropping intensity unless it can be shown that a good part of the explanation of the variations in unirrigated multiple cropping does in fact lie in labor availability, as hypothesized above.

Although we cannot disentangle the entirely unirrigated multiple cropped area from that that is sometimes irrigated, it is possible to consider separately multiple cropping in high rainfall areas where its dependence on irrigation would be expected to be much less than in low rainfall areas. That this indeed is the case becomes clear when we examine separately the association between the variations in the extent of irrigation and cropping intensity in the high, medium, and low rainfall areas among states. The coefficient of correlation declines as we move from the low to the medium and thence to the high rainfall category.[14]

[13] This exercise was also carried out by defining Y as the index of cropping intensity in which the areas under such long-duration crops as sugarcane, fruits, and plantation crops were counted twice in the gross cropped area on the grounds that these crops occupied the land in both of the major seasons of an agricultural year. However, the results turned out to be substantially similar. Whereas the coefficient of X_2 remained unchanged, the coefficients of X_1 and X_3 differed only marginally from those reported in Table 2, and the differences were not statistically significant.

Another point of interest pertains to the distinction between family and hired labor. When in addition to the labor availability variable used here (number of cultivators per hectare of net sown area), we incorporated the number of agricultural laborers per hectare of net sown area as an explanatory variable in the regression equation, the latter turned out to be statistically nonsignificant, whereas the former continued to be highly significant.

[14] The coefficients of correlation between extent of irrigation and cropping intensity across states are as follows: low rainfall areas, 0.71; medium rainfall areas, 0.44; and high rainfall areas, 0.22.

It is also obvious that the extent of irrigation by itself tells us very little about the variations in cropping intensity within the high rainfall category. Unfortunately, separate data on labor availability for the high rainfall areas is not readily available. However, if we assume that the pattern of labor availability in the high rainfall areas of the different states would not be far different from what it is among the states and use the state figures to incorporate this variable in the regression equation along with that for extent of irrigation, we find that about two thirds of the variations in cropping intensity are explained. Without data on the quality of irrigation specific to the high rainfall areas, it is not possible to infer the actual role of irrigation in the variations in cropping intensity in these areas. But the sharp increase in the explained variance when we incorporate the labor variable strongly suggests that labor availability does account for a large part of the variations in cropping intensity in the high rainfall areas, where among the three rainfall categories the relative weight of unirrigated multiple cropping may be expected to be the highest.

The above discussion about the role labor availability plays in unirrigated multiple cropping reinforces confidence in the importance of the irrigation variables. Considering the existence of unirrigated multiple cropping and the importance of the quality of irrigation as shown below, there is nothing surprising in the lack of a simple association in specific cases between the extent of irrigation and cropping intensity.[15] However, as our results underscore, one should not be misled by this lack of association into discounting the importance for the country as a whole of irrigation for raising cropping intensity. The conclusion that irrigation is important would be of small practical significance if the country's irrigation potential was mostly exhausted, but this is far from the case. Approximately one half of the estimated 117 million hectares that have irrigation potential remains to be exploited.[16]

However, because only 8 percent of the variance can be explained by the extent of irrigation whereas 43 percent can be explained by the quality of irrigation, the effect of irrigation on multiple cropping crucially depends on what kind of irrigation it is. Thus it is important to inquire into what specific irrigation sources are required to increase multiple cropping. But before pursuing this question, we need to ascertain how much labor availability and extent and quality of irrigation affect the variations in cropping intensity within each state.

Intrastate Variations in Cropping Intensity

For convenience states have been formed into groups: southern states, comprising Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu; northern states comprising Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Punjab, Rajasthan, and Uttar Pradesh; western states comprising Gujarat and Maharashtra; and eastern states comprising Assam, Bihar, Orissa, and West Bengal. Data on the relevant variables were obtained from the 1971 agricultural census which reports on various aspects of land utilization in each state for groups classed according to the size of holdings.[17] The variables Y, the index of cropping intensity; X_2, quality of irrigation; and X_3, extent of irrigation are defined in the same way as before. However, since data on family labor availability per unit of land (X_1) corresponding to the different size groups were not readily available, the average size of holding was used as a proxy.[18] This is because of the negative relationship with the number of

[15] See, for example, Biplab Dasgapta, *Agrarian Change and the New Technology in India* (Geneva: United Nations Research Institute for Social Development, 1977), p. 90.

[16] Ibid, p. 89.

[17] India, Ministry of Agriculture and Irrigation, *All-India Report on Agricultural Census 1970-71* (New Delhi: Controller of Publications, 1975).

[18] With the exception of West Bengal, Kerala, and Karnataka, the data for the variables used in the regression analysis for each state are for each of the 12 farm-size groups. Figures for the three exceptions clearly suffer from errors and therefore have not been used.

family members per unit of land.[19] Thus we expect an inverse relationship between cropping intensity and farm size.

Southern States

Results of statistical analysis relating to southern states are summarized in Table 3. Section A of the table shows that more than 90 percent of the variation in cropping intensity between farm-size groups in Andhra Pradesh, Karnataka, and Tamil Nadu is explained by the selected variables. The results for Kerala, however, where the coefficient of quality of irrigation emerges with a negative sign and is yet statistically significant, are suspect. Quality of irrigation as defined here cannot possibly exert a negative effect on cropping intensity. With the exception of this case, the signs of the explanatory variables in all the four states are consistent with expectations. Furthermore, while the coefficients of the extent of irrigation are statistically highly significant for all states, the coefficient of the quality of irrigation is not significant in two of them and that of farm size is not significant in the other two states. This lack of statistical significance partly reflects reality and partly the problem of multicolinearity among the independent variables. As the correlation matrix presented in Section B of Table 3 shows, the quality of irrigation does not seem to have much bearing on variations in cropping intensity in Andhra Pradesh and Kerala. In Karnataka, however, the existence of high multicolinearity between farm size and quality of irrigation is distorting their coefficients. The same is true of Tamil Nadu, where a high multicolinearity exists between the extent and quality of irrigation, on the one hand, and quality of irrigation and farm size, on the other. Thus if we drop the variable of quality from the equation for Tamil Nadu in view of the high correlation between extent and quality of irrigation, the coefficient of extent would capture the effect of quality too. The coefficient of farm size becomes statistically significant, as seen in Section C, Table 3. These two variables of farm size and extent of irrigation continue to account for 97 percent of variation in cropping intensity between farm-size groups.

For Kerala we find that all three independent variables are mutually correlated. In this situation omitting the quality-of-irrigation variable from the equation did not help. The variance in cropping intensity explained by the two variables decreased to 55 percent. But because the influence of the extent of irrigation on cropping intensity is stronger than that of farm size, the multicolinearity existing between the two variables reversed the sign of the coefficient of farm size, as well as leaving it statistically nonsignificant. Since the variance in cropping intensity explained by the extent of irrigation alone remains unchanged at about 54 percent, this factor emerges as the only significant influence on the variations of multiple cropping in the state (Section C, Table 3). The reason for the relatively poor explanation of the variance in cropping intensity in Kerala is to be found, at least in part, in the rainfall pattern. Even before the introduction of irrigation, heavy rainfall from the southwest monsoon enabled farmers to raise one, two, or, in low-lying areas that accumulate water, even three paddy crops in a year, thus reducing the dependence of multiple cropping on irrigation in this state.[20]

In view of the distortions caused by multicolinearity, the coefficients of the different variables cannot always be accepted at their face value. But even after the exclusion of some of the variables from the

[19] Various farm management studies carried out in India show that as the average size of holding increases, average family size also increases but not in the same proportion. As a result, land per capita goes up on large holdings and this establishes a negative relationship between average holding size and family labor availability per unit of land. Data on average area operated by household and average household size by class size of household operational holding are also available for the country as a whole for 1970/71 from the National Sample Survey Organization in India. The data, presented on the basis of 14 size classes of operational holding, show a perfect inverse rank correlation (rank correlation coefficients equals −1) between average area operated by household and average household size per unit of operated area. For the data see India, Department of Statistics, National Sample Survey Organization, *The National Sample Survey: Tables on Land Holdings, Regional State, and All India*, Twenty-sixth Round, July 1971–June 1972, No. 215 (Delhi: Controller of Publications, 1976), p. 15.

[20] India, Ministry of Irrigation and Power, *Report of the Irrigation Commission 1972*, vol. 2 (Delhi: Controller of Publications, 1972), p. 171.

Table 3—Statistical analysis of variations in multiple cropping in southern states

A. Regression Equations

State	Constant	X_1	X_2	X_3	$\bar{R}^2$
Andhra Pradesh	102.98	−0.019	0.003	0.269	0.99
		(2.21)	(0.071)	(21.29)	
Karnataka	101.80	−0.102	0.028	0.180	0.89
		(2.51)	(1.06)	(3.95)	
Kerala	115.55	−0.187	−0.267	0.859	0.84
		(1.48)	(4.25)	(3.99)	
Tamil Nadu	91.61	−0.004	0.275	0.423	0.99
		(1.19)	(8.00)	(19.23)	

B. Correlation Coefficients

Variable	Andhra Pradesh			Karnataka		
	Y	X_1	X_2	Y	X_1	X_2
X_1	−0.66			−0.83		
X_2	−0.07	0.48		−0.59	0.87	
X_3	0.99	−0.60	−0.05	0.87	−0.56	−0.31

Variable	Kerala			Tamil Nadu		
	Y	X_1	X_2	Y	X_1	X_3
X_1	−0.67			−0.63		
X_2	0.19	−0.69		0.94	−0.72	
X_3	0.74	−0.84	0.74	0.98	−0.53	0.86

C. Regression Equations

State	Constant	X_1	X_2	X_3	$\bar{R}^2$
Tamil Nadu	95.41	−0.021	...	0.565	0.97
		(2.62)		(15.26)	
Kerala	107.02	...	...	0.591	0.54
				(3.28)	

Notes: Y is the adjusted index of multiple cropping for each state; X_1 is the number of cultivators per hectare of net sown area; X_2 is multiple cropped irrigated area as a percentage of net irrigated area in each state; and X_3 is net irrigated area expressed as a percentage of net sown area. The figures in parentheses denote "t" values.

equations, the hypothesized variables continue to account for an overwhelming proportion of the variations in cropping intensity in three of the four southern states.

Northern States

The results for the northern states are presented in Table 4. From Section A of the table it can be seen that in five out of seven states more than 84 percent of the variance in cropping intensity is explained by the selected variables. In Jammu and Kashmir, however, the selected variables explain only 58 percent of the variation, and in Himachal Pradesh they explain nothing. Two factors seem to explain the poor relationship in Himachal Pradesh: existence of considerable multiple cropping in unirrigated areas and high pressure of population or availability of family labor per unit of sown area.

Although, as discussed earlier, the precise extent of purely unirrigated multiple cropped area is hard to determine, it is possible to arrive at that component of total multiple cropped area that must necessarily be unirrigated. Because the gross irrigated area figure is arrived at by multiplying the irrigated area by the number of irrigated crops raised on it, the irrigated multiple crop figure cannot exceed the gross irrigated crop figure. Thus where the total multiple cropped area exceeds the gross irrigated area, the excess must necessarily be unirrigated. Since this excess constitutes over 62 percent of the total multiple cropped area in Himachal Pradesh, it shows the existence of widespread multiple cropping on entirely unirrigated areas in this state. It is not surprising, therefore, that the irrigation variables do not show a relationship with the variations of cropping intensity.

As for labor availability, it should be noted that among the different states in India, Himachal Pradesh has the largest number of cultivators per hectare of net sown area.[21] Together with the fact that only a small proportion of the total area of the larger holdings is under cultivation, this suggests that the availability of family labor

[21] See the Appendix, Table 11.

Table 4—Statistical analysis of variations in multiple cropping in northern states

A. Regression Equations

State	Constant	X_1	X_2	X_3	$\bar{R}^2$
Madhya Pradesh	100.35	−0.009	−0.237	1.626	0.97
		(0.40)	(0.43)	(13.30)	
Punjab	47.34	0.295	1.675	0.184	0.99
		(8.90)	(22.01)	(1.30)	
Rajasthan	83.69	0.174	0.176	1.511	0.84
		(0.39)	(0.26)	(1.41)	
Uttar Pradesh	100.30	0.166	−1.273	1.347	0.97
		(5.79)	(6.02)	(14.11)	
Haryana	8.90	−0.139	3.013	0.558	0.94
		(1.93)	(4.63)	(1.47)	
Himachal Pradesh	176.54	0.172	0.233	−1.016	0.07
		(0.51)	(0.23)	(0.37)	
Jammu and Kashmir	112.65	−0.029	0.510	0.156	0.58
		(0.64)	(3.51)	(0.47)	

B. Correlation Coefficients

Variable	Haryana			Himachal Pradesh			Jammu and Kashmir		
	Y	X_1	X_2	Y	X_1	X_2	Y	X_1	X_2
X_1	−0.91			0.23			−0.29		
X_2	0.94	−0.82		−0.20	−0.84		0.78	−0.15	
X_3	0.71	−0.72	0.55	0.05	0.57	−0.19	−0.11	−0.29	−0.33

Variable	Madhya Pradesh			Punjab			Rajasthan		
	Y	X_1	X_2	Y	X_1	X_2	Y	X_1	X_2
X_1	−0.58			−0.67			−0.39		
X_2	−0.07	−0.41		0.95	−0.87		0.39	0.63	
X_3	0.99	−0.58	−0.05	0.41	−0.60	0.50	0.88	−0.79	−0.04

Variable	Uttar Pradesh		
	Y	X_1	X_2
X_1	−0.65		
X_2	0.07	0.16	
X_3	0.93	−0.79	0.24

C. Regression Equations

State	Constant	X_1	X_2	X_3	$\bar{R}^2$
Madhya Pradesh	99.47	−0.003	...	1.646	0.97
		(0.21)		(15.33)	
Punjab	96.56	...	1.069	...	0.90
			(9.38)		
Rajasthan	90.61	...	0.438	1.095	0.86
			(3.51)	(7.02)	
Uttar Pradesh	101.60	...	...	0.829	0.86
				(7.98)	
Haryana	129.83	−0.384	...	0.409	0.82
		(4.27)		(0.60)	

Notes: Y is the adjusted index of multiple cropping for each state; X_1 is the number of cultivators per hectare of net sown area; X_2 is multiple cropped irrigated area as a percentage of net irrigated area in each state; and X_3 is net irrigated area expressed as a percentage of net sown area. The figures in parentheses denote "t" values.

per unit of sown area is comfortable enough for all sizes of farms to extensively practice multiple cropping. As a result farm size also does not show a relationship with the variations of cropping intensity in this state. The situation appears to be somewhat similar in Jammu and Kashmir. In Jammu, where the average cropping intensity is higher than in Kashmir Valley and has increased considerably over time, the pressure of population is cited as the major cause for this increase.[22]

The northern states present a more complex picture than the southern states. Contrary to expectations, the coefficient of farm size bears a positive sign in Punjab, Rajasthan, and Uttar Pradesh and that of quality of irrigation a negative sign in Madhya Pradesh and Uttar Pradesh. Because of the statistical nonsignificance of the coefficients of the size variable in Rajasthan and quality of irrigation variable in Madhya Pradesh, their unexpected signs are of little significance, but the positive sign of the coefficient of farm size in Punjab and Uttar Pradesh and the negative sign of the coefficient of irrigation quality in Uttar Pradesh need to be explained. The high multicolinearity between the variables of size and quality of irrigation in Punjab and between the variables of size and extent of irrigation in Uttar Pradesh, considering that quality of irrigation in Punjab and extent of irrigation in Uttar Pradesh bear a much stronger association with cropping intensity than size does, brings about this distortion in the sign of size.[23] The correlation matrix in Table 4, Section B, makes this clear.

The negative sign of the coefficient of quality of irrigation in Uttar Pradesh is quite puzzling, and the correlation matrix offers no explanation for it. However, since the quality of irrigation by definition cannot exert a negative effect on cropping intensity, this result is spurious and requires the omission of this variable from the equation. Similarly, the problem of multicolinearity requires the omission of the variable of size from the equations of Punjab, Rajasthan, and Uttar Pradesh. But even after these exclusions, the hypothesized variables among themselves explain 82 to 97 percent of the variation in cropping intensity in five out of the seven northern states (see Section C, Table 4).

Western States

The results for the western states are presented in Table 5. Section A of the Table shows that 88 percent of the variation in cropping intensity in Gujarat and almost the whole of it in Maharashtra are accounted for by the explanatory variables. The signs of the independent variables, with the exception of the sign of the quality of irrigation in Maharashtra, are as expected. From the correlation matrix it is clear that a high positive association between the extent and quality of irrigation in Maharashtra, where extent of irrigation bears a stronger association with cropping intensity than in Gujarat, has rendered the coefficient of the quality of irrigation negative and statistically nonsignificant. Because the extent of irrigation in this case captures the effect of its quality as well, we drop the variable of quality from the equation. As seen in Section C, Table 5, farm size and extent of irrigation continue to explain 99 percent of the variation of cropping intensity in this state.

Eastern States

The eastern states present a complex picture. The signs of the coefficients of farm size are positive in Bihar and Orissa, but in Bihar the coefficient of the quality of irrigation is negative. In Assam and West Bengal, on the other hand, the coefficients of the extent of irrigation bear a negative sign (Table 6, Section A).

We therefore turn to the correlation matrices to unravel the phenomena (Table 6, Section B). In Assam and West Bengal, farm size bears a high negative association with the extent of irrigation. Because it is more strongly associated with cropping intensity, it distorts the sign for the extent of irrigation. That farm size also captures the

[22] India, Ministry of Irrigation and Power, *Report of Irrigation Commission 1972*, p. 163.

[23] The multicolinearity between the variables of size and quality of irrigation is high in Haryana too, but because the association between size and cropping intensity is much stronger than between size and quality here, the existence of multicolinearity between size and quality is not able to reverse the sign of size.

Table 5—Statistical analysis of variations in multiple cropping in western states

A. Regression Equations

State	Constant	X_1	X_2	X_3	$\bar{R}^2$
Gujarat	94.00	−0.010	1.073	0.583	0.88
		(0.92)	(5.78)	(5.76)	
Maharashtra	102.27	−0.022	−0.056	0.710	0.99
		(11.20)	(1.28)	(25.10)	

B. Correlation Coefficients

Variable	Gujarat			Maharashtra		
	Y	X_1	X_2	Y	X_1	X_2
X_1	−0.19			−0.71		
X_2	0.44	0.58		0.80	−0.49	
X_3	0.36	−0.62	−0.31	0.98	−0.55	0.83

C. Regression Equations

State	Constant	X_1	X_2	X_3	$\bar{R}^2$
Maharashtra	101.75	−0.022	...	0.682	0.99
		(10.77)		(36.39)	

Notes: Y is the adjusted index of multiple cropping for each state; X_1 is multiple cropped irrigated area as a percentage of net irrigated area in each state; and X_3 is net irrigated area expressed as a percentage of net sown area. The figures in parentheses denote "t" values.

effect of the extent of irrigation is clear: when we drop the latter variable from the equation, the extent of the explained variance in cropping intensity remains almost unchanged at around 85 percent in Assam and 96 percent in West Bengal (Table 6, Section C). In Bihar and Orissa the picture is different. Farm size and quality of irrigation are positively correlated, though much more strongly in Bihar than in Orissa, and this is apparently reflected in the positive sign of the coefficient of farm size.

Table 6—Statistical analysis of variations in multiple cropping in eastern states

A. Regression Equations

State	Constant	X_1	X_2	X_3	R^2
Assam	112.34	−0.029	0.271	−0.252	0.84
		(3.73)	(4.71)	(0.63)	
Bihar	116.74	0.364	−0.646	0.984	0.50
		(2.25)	(1.34)	(2.26)	
Orissa	53.60	0.539	0.2 8	4.239	0.55
		(1.48)	(1.22)	(3.04)	
West Bengal	121.67	−0.040	0.392	−0.312	0.97
		(5.94)	(4.60)	(2.40)	

B. Correlation Coefficients

Variable	Assam			Bihar		
	Y	X_1	X_2	Y	X_1	X_2
X_1	−0.62			0.56		
X_2	0.63	0.10		0.50	0.95	
X_3	0.25	−0.78	−0.33	0.02	−0.58	−0.46

Variable	Orissa			West Bengal		
	Y	X_1	X_2	Y	X_1	X_2
X_1	0.27			−0.90		
X_2	0.45	0.54		0.88	−0.65	
X_3	0.51	−0.44	−0.12	0.55	−0.82	0.28

C. Regression Equations

State	Constant	X_1	X_2	X_3	R^2
Assam	109.88	−0.025	0.286	...	0.85
		(5.54)	(5.66)		
West Bengal	112.10	−0.026	0.509	...	0.96
		(6.24)	(5.80)		

Notes: Y is the adjusted index of multiple cropping for each state; X_1 is the number of cultivators per hectare of net sown area; X_2 is multiple cropped irrigated area as a percentage of net irrigated area in each state; and X_3 is net irrigated area expressed as a percentage of net sown area. The figures in parentheses denote "t" values.

To summarize, out of the 17 selected states an overwhelming proportion of the variation in cropping intensity among farm-size groups—ranging from 82 to 99 percent—is explained by the selected variables. Especially considering that 2 of these 12 states fall in the high rainfall zone and there are high rainfall regions in several others where unirrigated multiple cropping could be significant, it is important to clarify that in principle the farm-size variable relates to unirrigated multiple cropping in the same way as the labor availability variable relates to unirrigated multiple cropping in the interstate analysis. In practice, however, a problem arises because farm size is often negatively associated with extent of irrigation. Where the latter is closely associated with cropping intensity, the variable for extent of irrigation could well have picked up the effect of farm size, too. Insofar as the variations in farm size underlie the variations in unirrigated multiple cropping in such situations, the coefficient of the irrigation variable could present an exaggerated picture of the effect of irrigation on cropping intensity. In view of the problem of multicolinearity, the results of the intrastate analysis should be read with caution. One should not only guard against taking the coefficients of the explanatory variables at their face value but also against attributing to an individual variable the status of a sole causal force, even if its association with the dependent variable is found to be nearly perfect, as for example, in the case of cropping intensity and extent of irrigation in Madhya Pradesh. But even though high multicolinearity between two or more of the explanatory variables makes it impossible to measure the separate influence of the individual variables, the analysis nevertheless shows that the hypothesized variables among themselves generally explain the bulk of the intrastate variations in cropping intensity, as they did for interstate differences in multiple cropping.

The negative association between farm size and cropping intensity is similar to that between farm size and the gross value of output per hectare observed in India's farm management studies. Multiple cropping is an important vehicle through which smaller farms seek to expand their output per unit of net sown area by intensifying family labor. Considering the importance of irrigation for multiple cropping, it is not surprising that small farmers tend to irrigate more in relation to their sown area than larger farmers do. The negative association between farm size and the extent of irrigation is observed in 16 out of 17 states (as shown by the correlation matrices). Thus, in view of the higher cost of labor on larger farms, which have a greater dependence on hired labor,[24] and the managerial and supervisory diseconomics of scale,[25] the expansion of multiple cropping through the traditional labor-intensive methods, including irrigation, is likely to be constrained by the existing size distribution of holdings. If the larger farms could be split into smaller family farms, it would encourage the growth of multiple cropping. Alternatively, the expansion of multiple cropping is likely to accompany the spread of seed, fertilizer, and mechanical technology, which would reduce labor input per unit of output, reduce managerial and supervisory diseconomics of scale, and induce the expansion of irrigation. This was observed at the height of the "green revolution" in India.[26]

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[24] A. K. Sen, "An Aspect of Indian Agriculture," *The Economic Weekly* 14 (February 1962): 243.

[25] C. H. H. Rao, "Alternative Explanation of the Inverse Relationship between Farm Size and Output Per Acre," *Indian Economic Review* 1 (October 1966): 1-12.

[26] See C. H. H. Rao, *Technological Change Gains*, pp. 48-50 and 231-232. Rao's study of Punjab, Tamil Nadu, and Andhra Pradesh shows that the superiority of tractor farms over bullock farms for multiple cropping tends to widen with an increase in the size of the farm. Further, in Andhra Pradesh, an increase in the extent of irrigation is found to increase cropping intensity more on tractor farms than on bullock farms.

4

SOURCES OF IRRIGATION AND CROPPING INTENSITY

Although the handling of the irrigation factor was successful in establishing the preponderant influence of labor availability and the extent and quality of irrigation in accounting for the differences in multiple cropping both within and between states in India, it does not enable us to quantify the impact of irrigation on cropping intensity. Such a measurement is necessary to shed light on how much we might expect irrigation expansion to increase cropping intensity.

Interstate Analysis

The results of regressing cropping intensity on different sources of irrigation and on labor availability are shown in Table 7. Area under each source is expressed as a percentage of net sown area. True to the apprehensions mentioned earlier, the proportion of the variation explained by these variables decreased compared to that explained by the variables used in the preceding chapter. Even worse, the coefficients of all the irrigation sources except tubewells were statistically nonsignificant. Two of these, canal and well irrigation, even bore negative signs.

Intrastate Analysis

An intrastate analysis may be expected to improve the situation in two ways. First, it is hoped that differences in the quality of the same source of irrigation might be less within than between the states. And second, it should be possible to regress cropping intensity on only the more important sources in each state identified in Table 8 so as not to lose too many degrees of freedom and yet obtain a sample of coefficients for each source, especially since many of the states have a sufficient variety of the more important sources. However, as we saw earlier, multicolinearity among independent variables at the state level can be a real problem. As a starting point, therefore, it may be useful to examine the simple correlation that exists between the explanatory variables. Table 9 gives the correlation matrices.

In half the states—Andhra Pradesh, Karnataka, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, and West Bengal—the important sources are highly correlated with each other. Hence it is not possible to estimate the impact of any individual source on multiple cropping. In Punjab, Haryana, and Rajasthan the important sources are nega-

Table 7—Interstate analysis of sources of irrigation and cropping intensity

Correlation Coefficients

Variable	Y	X_1	X_{15}	X_{16}	X_{17}
X_1	0.58				
X_{15}	0.38	0.14			
X_{16}	−0.23	−0.12	−0.06		
X_{17}	0.46	−0.18	0.52	−0.26	
X_{18}	−0.27	−0.33	−0.13	0.49	0.19

Regression Figures

Variable	Regression Coefficients	"t" Statistics
Constant	106.33	14.22
X_1	29.90	3.88
X_{15}	−0.20	−0.68
X_{16}	0.88	0.99
X_{17}	1.38	3.40
X_{18}	−1.29	−1.52

Notes: Y is the adjusted index of multiple cropping for each state; X_1 is the number of cultivators per hectare of net sown area: X_{15} is the area irrigated by canals; X_{16} is the area irrigated by tanks; X_{17} is the area irrigated by tubewells; and X_{18} is the area irrigated by wells. X_{15}, X_{16}, X_{17}, and X_{18} are expressed as percentages of net sown area. For the regression figures, $\bar{R}^2$ is 0.65 and F is 6.07.

tively correlated with each other, and one of these (canal) also bears a negative association with cropping intensity. Although this may be true in particular circumstances (for example, it is plausible that with the arrival of canals, farmers in some regions may find it more profitable to grow one long-duration crop with a higher yield than the two low-yield crops requiring less moisture that they grew before), the coefficients derived on the basis of such relationships are unlikely to have wide applicability. In Gujarat, Maharashtra, and Assam, where the intercorrelation between important sources is not very large, the problem is created by the high correlation between farm size and one or more of the sources. Considering the limited number of observations, the presence of high correlation among independent variables erodes our hope for success in deriving meaningful coefficients of the impact of the individual sources of irrigation on cropping intensity for each state.

Table 8—Important sources of irrigation for selected states

State	Canals	Tanks	Tubewells	Wells
Andhra Pradesh	x	x		
Karnataka	x	x		x
Tamil Nadu	x	x		x
Haryana	x		x	
Madhya Pradesh	x			x
Punjab	x		x	
Rajasthan	x			x
Uttar Pradesh	x		x	x
Gujarat	x			x
Maharashtra	x			x
Assam	x			
West Bengal	x	x		

Analysis of Pooled Data

To overcome these problems, a final step is taken. We pool together the observations for the 12 states in which earlier efforts succeeded in accounting for the bulk of the intrastate variations in cropping intensity. The pooled data have several advantages. First, since the number of observations increases to 142, we have 136 degrees of freedom against which to test the significance of each coefficient. Second, even if the quality of the same source varies between states, an average coefficient derived from 142 observations is likely to reflect reality better than that derived from 17 observations as in the interstate analysis. Finally, the pooled data are likely to ease considerably the problem of multicolinearity that arises when each state is considered separately.

The results of regressing cropping intensity on farm size and individual sources of irrigation are presented in Table 10. As expected, all the coefficients except for tanks prove to be statistically significant. The reason for the nonsignificance of tanks is not hard to see. In the states with the highest concentration of tubewell irrigation, tank irrigation is nonexistent or negligible. This is reflected in the negative association between the two sources of irrigation in the correlation matrix of the pooled data. This fact combined with another—the high positive association between tubewell irrigation and cropping intensity—underlies the negative sign and the statistical nonsignificance of the coefficient of tank irrigation.

The prime influence of tubewells on cropping intensity clearly emerges from Table 10. A 1.0 percentage point increase in area irrigated by tubewells (X_{17}) raises cropping intensity by 0.9 percentage points. The same increase for canals and wells raises it only half as much.

The coefficients of the different variables reflect the average impact each variable exerts on cropping intensity taking the 12 states together. Pending further evidence to serve as a countercheck on the reliability of these estimates, it would be risky to place too much faith in the precise magnitudes of the coefficients. They should, therefore, be

Table 9—Correlation matrices for variables used in intrastate analysis

Variable	Andhra Pradesh					Karnataka					Tamil Nadu					Haryana				
	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}
X_1	−0.66					−0.83					−0.63					−0.91				
X_{15}	0.99	−0.64				0.91	−0.62				0.96	−0.70				−0.63	0.50			
X_{16}	0.96	−0.53	0.96			0.85	−0.54	0.99			0.95	−0.59	0.94			0.00	0.00	0.00		
X_{17}	0.93	−0.45	0.94	0.88		0.81	−0.62	0.84	0.87		0.06	−0.68	0.21	0.11		0.94	−0.94	−0.55	0.00	
X_{18}	0.50	−0.31	0.46	0.59	0.44	0.69	−0.35	0.91	0.96	0.78	0.29	−0.91	0.36	−0.24	0.71	0.99	−0.84	−0.67	0.00	0.89

Variable	Madhya Pradesh					Punjab					Rajasthan					Uttar Pradesh				
	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}
X_1	−0.58					−0.67					−0.39					−0.65				
X_{15}	0.99	−0.52				−0.97	0.60				−0.13	0.00				0.50	−0.83			
X_{16}	0.86	−0.22	0.91			0.00	0.00	0.00			0.91	−0.68	−0.28			0.94	−0.67	0.39		
X_{17}	0.81	−0.42	0.87	0.85		0.48	−0.47	−0.57	0.00		0.52	−0.84	0.25	0.68		0.74	−0.41	0.65	0.50	
X_{18}	0.82	−0.93	0.79	0.56	0.66	0.93	−0.63	−0.85	0.00	0.13	0.84	−0.80	−0.12	0.97	0.83	0.97	−0.81	0.64	0.94	0.69

Variable	Gujarat					Maharashtra					Assam					West Bengal				
	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}	Y	X_1	X_{15}	X_{16}	X_{17}
X_1	−0.19					−0.71					−0.62					−0.90				
X_{15}	0.84	−0.41				0.38	0.32				0.32	−0.78				0.60	−0.84			
X_{16}	0.65	−0.43	0.91			0.96	−0.53	0.51			−0.22	−0.21	0.09			0.29	−0.61	0.80		
X_{17}	0.67	0.03	0.74	0.45		0.00	0.00	0.00	0.00		0.24	−0.47	0.69	−0.14		0.09	−0.09	−0.31	−0.12	
X_{18}	0.31	−0.78	0.54	0.38	0.44	0.97	−0.71	0.37	0.88	0.00	0.36	−0.34	0.32	−0.17	0.51	0.72	−0.48	0.33	−0.08	−0.41

Notes: Y is the adjusted index of multiple cropping for each state; X_1 is the number of cultivators per hectare of net sown area; X_{15} is the area irrigated by canals; X_{16} is the area irrigated by tanks; X_{17} is the area irrigated by tubewells; and X_{18} is the area irrigated by wells. X_{15}, X_{16}, X_{17}, X_{18} are expressed as percentages of net sown area.

Table 10—Pooled analyses of sources of irrigation and cropping intensity

Correlation Coefficients

Variable	Y	X_1	X_{15}	X_{16}	X_{17}
X_1	−0.20				
X_{15}	0.80	−0.14			
X_{16}	−0.12	−0.14	0.07		
X_{17}	0.85	−0.07	0.83	−0.28	
X_{18}	0.19	−0.23	0.01	0.27	0.08

Regression Figures

Variable	Regression Coefficients	"t" Statistics
Constant	107.80	78.95
X_1	−0.022	−2.13
X_{15}	0.453	3.36
X_{16}	−0.114	−0.62
X_{17}	0.902	5.38
X_{18}	0.456	2.66

Notes: Y is the adjusted index of multiple cropping for each state; X_1 is the number of cultivators per hectare of net sown area; X_{15} is the area irrigated by canals; X_{16} is the area irrigated by tanks; X_{17} is the area irrigated by tubewells; and X_{18} is the area irrigated by wells. X_{15}, X_{16}, X_{17}, and X_{18} are expressed as percentages of net sown area. For the regression figures, $\bar{R}^2$ is 0.77 and F is 96.28.

taken as only suggestive of the broad magnitude of change in cropping intensity that a unit change in a given variable may be expected to produce. Even so, we felt it necessary to ascertain whether the coefficients fall in the realistic range by comparing the actual change in cropping intensity over time with the change estimated on the basis of these coefficients. In this connection it is important to distinguish between farm size and the irrigation variables. Because farm size is a proxy for labor availability or the pressure of population on land, the impact of this factor would be expected to vary over time: it would be greater in that phase in which the potential for extending multiple cropping in areas with favorable agroclimatic conditions is large but would diminish as that potential is exhausted. This seems to be why cropping intensity increased more in the 1950s, despite a limited increase in irrigation, than during the 1960s when irrigation expansion occurred at a faster rate. We therefore estimate the increase in cropping intensity using the irrigation variables alone for the 1960s and the few years of the 1970s for which data are available.

The results of the exercise show that about 90 percent of the actual change in cropping intensity in the 1970s is accounted for by the irrigation variables. This seems to suggest that the coefficients of the irrigation variables estimated above are in the realistic range.

5

CONCLUSIONS

The Sixth Five-Year Plan has targeted an increase of 15 million hectares in the total gross irrigated area of India from 1978 to 1983. According to the ratio of the net to gross irrigated area, about 0.8 in recent years, this would imply an increase of about 12 million hectares in the net irrigated area or, alternatively put, an increase of 8 to 9 percentage points in the net irrigated area as a percentage of net sown area. Its actual impact on multiple cropping would obviously depend on the relative weights of the different sources of irrigation used as well as on their distribution among the states.[27] Sufficient information on these aspects of irrigation expansion is not readily available, but even if it were, it would fall short of the requirements, for we have not been able to quantify the impact of the specific irrigation sources in the different states. But since the purpose of this exercise is to illustrate the possibilities rather than to project—much less to predict—future developments, we have chosen to use the mean of the range of the coefficients for the different irrigation sources. The mean coefficient implies an increase of 0.67 percentage points in the index of cropping intensity as a result of a 1.0 percentage-point increase in the percentage of net irrigated area in the net sown area. This suggests that the expansion of irrigation contemplated in the Sixth Plan might yield an increase of 5.0 to 6.0 percentage points in cropping intensity or an addition of around 1.0 percent per annum to the gross cropped area. If the irrigation mix serving the newly irrigated area includes more tubewell irrigation than is implied by the overall coefficient adopted above, the rate of expansion in the gross cropped area would probably be larger. Thus, even if the growth rate of productivity since the mid-1960s does not register any significant improvement but is only maintained, agricultural output could grow at about 3.5 percent per annum. But, considering that the program of irrigation expansion in the Sixth Plan is much larger than that contemplated in any of the previous plans, its successful execution would also help to raise the growth rate of productivity, particularly if the interacting effects from the conjoint use of high-yield seed varieties and fertilizer on the irrigated areas are fully garnered. Thus the targeted annual growth of 4.0 percent in agricultural output is within India's reach. But whether it will in fact be achieved depends upon how successfully the irrigation plan is executed and especially on how fully its potential for raising cropping intensity as well as crop yields is realized.

[27] Strictly speaking, its impact on multiple cropping would also depend on what part of irrigation expansion accrues to long-duration crops which we have excluded, albeit partially, from our index of cropping intensity. However, the proportion of long-duration crops in the total cropped area is so small that, unless it undergoes a considerable change, this factor can be ignored, especially in view of the highly approximate character of this exercise.

APPENDIX

SUPPLEMENTARY TABLES

Table 11—Interstate data, 1973/74

State	Y_1[a]	Y	X_1	X_2	X_3	X_{15}	X_{16}	X_{17}	X_{18}
Andhra Pradesh	113.77	114.24	0.50	26.60	28.20	12.80	8,83	0.96	4.58
Assam	125.14	128.24	1.08	22.00	23.27	14.70	0.00	0.00	0.00
Bihar	128.58	129.55	0.90	20.60	27.70	10.70	0.98	6.69	1.87
Gujarat	107.34	107.56	0.38	13.40	14.16	2.04	0.38	1.34	10.20
Haryana	144.42	146.51	0.37	48.80	48.68	28.38	0.00	17.50	2.66
Himachal Pradesh	163.13	165.85	1.64	65.90	16.91	0.00	0.00	0.18	0.18
Jammu and Kashmir	132.51	133.48	1.24	19.90	43.83	42.09	0.14	0.29	0.00
Karnataka	106.48	106.67	0.40	18.40	11.74	4.43	3.58	0.01	2.67
Kerala	136.19	143.17	0.51	39.60	20.75	10.54	3.45	0.00	0.23
Madhya Pradesh	114.29	114.38	0.44	5.30	8.86	3.84	0.64	0.10	3.54
Maharashtra	106.34	106.45	0.35	19.80	8.03	1.63	1.21	0.00	4.58
Orissa	122.47	123.03	0.55	35.30	14.70	9.34	3.10	0.43	1.82
Punjab	146.27	147.83	0.41	55.20	72.35	31.34	0.00	34.48	6.37
Rajasthan	112.02	112.06	0.40	12.60	14.89	5.29	1.46	0.26	7.65
Tamil Nadu	128.85	125.56	0.76	30.50	45.60	14.96	15.04	0.42	14.65
Uttar Pradesh	134.00	137.43	0.90	17.30	42.18	14.21	1.87	15.09	9.31
West Bengal	120.65	121.18	0.71	3.50	24.07	15.52	4.90	0.00	0.27

Sources: Data on the number of cultivators is from the Indian census of 1971. The area of plantations was estimated from data in India, Ministry of Agriculture and Irrigation, *Report of the National Commission on Agriculture*, vol. 6 (Delhi: Controller of Publications, 1971). It was assumed that their area as a proportion of the total was the same in 1973/74. All other data is from India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Indian Agriculture in Brief* (Delhi: Controller of Publications, 1977).

Notes: Y_1 is gross cropped area as a percentage of net sown area. Y is also gross cropped area as a percentage of net sown area, but it does not include the area of plantations or the area planted with sugarcane and fruits. X_1 is the number of cultivators per hectare of net sown area. X_2 is multiple cropped irrigated area (or area irrigated more than once) as a percentage of net irrigated area. X_3 is net irrigated area as a percentage of net sown area. X_{15} is the area irrigated by canals as a percentage of net sown area. X_{16} is the area irrigated by tanks as a percentage of net sown area. X_{17} is the area irrigated by tubewells as a percentage of net sown area. X_{18} is the area irrigated by wells as a percentage of net sown area.

[a] Unadjusted cropping intensity.

Table 12—Intrastate cropping intensity and irrigation data by farm size and state, 1970/71

Farm Size	Y	X_1	X_2	X_3	X_{15}	X_{16}	X_{17}	X_{18}
(hectares)				**Andhra Pradesh**				
Below 0.5	119.62	0.25	20.74	63.94	31.47	26.24	0.53	3.98
0.5 – 1.0	116.95	0.73	19.51	50.99	26.59	18.79	0.53	4.04
1.0 – 2.0	114.12	1.44	19.89	38.68	20.18	13.62	0.48	3.81
2.0 – 3.0	111.46	2.40	19.96	30.13	15.20	10.03	0.44	3.54
3.0 – 4.0	110.91	3.46	20.08	28.18	14.24	9.46	0.44	3.69
4.0 – 5.0	109.76	4.44	19.98	25.18	12.27	8.06	0.44	3.39
5.0 – 10.0	108.83	6.91	20.64	21.82	10.16	7.35	0.40	3.51
10.0 – 20.0	107.19	13.49	20.25	17.86	6.86	6.63	0.36	3.56
20.0 – 30.0	106.17	23.94	19.73	16.04	4.81	6.41	0.37	3.77
30.0 – 40.0	106.32	34.17	18.81	15.95	4.33	6.88	0.36	3.77
40.0 – 50.0	106.48	44.24	19.46	16.67	4.62	6.46	0.41	3.99
50.0 and above	106.14	74.11	23.11	15.10	6.25	5.31	0.42	3.24
				Karnataka				
Below 0.5	107.49	0.26	25.51	32.02	12.45	14.49	0.00	4.19
0.5 – 1.0	106.88	0.74	20.79	20.98	9.48	8.17	0.00	2.60
1.0 – 2.0	106.29	1.45	23.67	14.43	6.44	5.35	0.00	2.10
2.0 – 3.0	105.05	2.41	25.65	12.34	5.53	4.34	0.00	2.02
3.0 – 4.0	103.90	3.43	25.85	10.75	4.92	3.63	0.00	1.91
4.0 – 5.0	103.29	4.42	27.19	9.91	4.57	3.26	0.00	1.83
5.0 – 10.0	102.37	6.89	23.21	8.33	3.88	2.47	0.00	1.79
10.0 – 20.0	101.63	13.34	19.90	6.58	3.17	1.57	0.00	1.75
20.0 – 30.0	101.27	23.58	25.97	6.08	2.94	1.20	0.00	1.82
30.0 – 40.0	101.22	33.84	42.27	6.21	3.05	1.20	0.00	1.90
40.0 – 50.0	100.74	43.70	86.00	5.81	2.68	1.25	0.00	1.75
50.0 and above	98.86	72.09	314.78	5.49	2.13	1.23	0.00	1.84
				Kerala				
Below 0.5	118.03	0.18	25.63	11.54	2.84	3.28	0.09	2.32
0.5 – 1.0	119.23	0.70	44.05	15.40	6.08	2.71	0.19	2.19
1.0 – 2.0	119.94	1.36	46.46	16.84	7.00	2.13	0.25	2.16
2.0 – 3.0	118.88	2.36	49.96	19.54	8.36	1.94	0.18	2.24
3.0 – 4.0	120.67	3.44	49.18	22.94	10.63	1.68	0.27	2.04
4.0 – 5.0	119.53	4.42	47.80	20.22	7.58	2.31	0.40	2.25
5.0 – 10.0	119.28	6.50	52.03	20.37	8.11	2.01	0.11	2.56
10.0 – 20.0	116.17	12.98	53.29	16.09	4.38	1.12	0.25	1.60
20.0 – 30.0	110.13	23.34	46.48	12.82	2.13	0.35	0.00	1.12
30.0 – 40.0	109.11	34.72	70.39	15.38	3.00	0.29	0.00	0.18
40.0 – 50.0	108.43	44.20	−28.57	7.19	2.47	0.00	0.00	0.00
50.0 and above	107.78	323.08	9.49	0.66	0.10	0.03	0.00	0.28
				Tamil Nadu				
Below 0.5	127.89	0.25	41.35	58.31	20.90	26.24	0.76	10.16
0.5 – 1.0	123.05	0.72	38.98	49.07	18.08	18.30	0.73	11.95
1.0 – 2.0	119.99	1.42	37.36	42.86	15.72	14.07	0.70	12.61
2.0 – 3.0	118.17	2.42	35.86	39.81	14.48	12.16	0.77	12.87
3.0 – 4.0	117.31	3.44	35.83	37.56	12.39	11.72	0.78	13.32
4.0 – 5.0	116.42	4.44	34.85	36.06	11.76	11.01	0.87	13.13
5.0 – 10.0	115.45	6.71	33.26	34.72	11.41	10.29	0.90	13.27
10.0 – 20.0	113.70	13.14	30.49	32.05	9.44	9.14	0.91	13.19
20.0 – 30.0	111.84	23.79	25.73	30.52	8.38	9.00	0.71	12.81
30.0 – 40.0	111.01	34.25	23.43	32.55	9.76	10.34	0.84	12.03
40.0 – 50.0	110.31	42.65	21.87	29.41	10.29	7.42	0.96	9.64
50.0 and above	108.96	145.27	21.97	28.16	1.60	4.14	0.38	3.51

Table 12—Continued

Farm Size (hectares)	Y	X_1	X_2	X_3	X_{15}	X_{16}	X_{17}	X_{18}
				Haryana				
Below 0.5	152.60	0.27	40.68	43.57	21.93	0.00	17.10	4.70
0.5 – 1.0	152.37	0.72	38.21	44.11	23.43	0.00	16.60	4.49
1.0 – 2.0	151.34	1.44	37.55	46.09	25.37	0.00	16.87	4.43
2.0 – 3.0	149.91	2.44	37.76	47.29	26.17	0.00	17.52	4.22
3.0 – 4.0	148.83	3.45	37.86	48.51	27.22	0.00	17.95	3.92
4.0 – 5.0	147.20	4.44	37.18	48.56	28.15	0.00	17.47	3.69
5.0 – 10.0	143.98	6.96	36.62	48.13	29.57	0.00	16.24	3.07
10.0 – 20.0	138.14	13.30	35.72	45.91	30.34	0.00	14.11	2.15
20.0 – 30.0	132.33	23.67	34.76	42.82	29.51	0.00	12.22	1.49
30.0 – 40.0	129.28	34.08	34.32	41.53	28.54	0.00	11.86	1.33
40.0 – 50.0	126.86	44.06	33.53	39.85	26.00	0.00	12.48	0.92
50.0 and above	125.35	72.94	33.89	41.73	30.59	0.00	8.53	1.29
				Madhya Pradesh				
Below 0.5	126.99	0.23	2.29	15.52	10.07	1.21	0.10	3.81
0.5 – 1.0	123.53	0.72	2.36	14.63	9.42	1.11	0.14	3.78
1.0 – 2.0	118.08	1.48	2.81	12.31	7.33	1.16	0.13	3.54
2.0 – 3.0	115.57	2.48	2.44	10.38	5.86	0.90	0.08	3.42
3.0 – 4.0	114.47	3.48	2.68	9.41	5.18	0.78	0.08	3.28
4.0 – 5.0	113.35	4.47	2.62	8.54	4.53	0.66	0.07	3.19
5.0 – 10.0	111.86	7.09	4.32	7.62	3.49	0.73	0.05	3.24
10.0 – 20.0	109.69	13.56	3.01	5.93	2.45	0.54	0.04	2.87
20.0 – 30.0	108.90	23.70	3.11	5.30	2.09	0.54	0.05	2.58
30.0 – 40.0	108.92	33.85	1.69	5.41	2.23	0.62	0.03	2.38
40.0 – 50.0	109.37	44.34	1.66	6.02	2.72	0.69	0.08	2.30
50.0 and above	110.04	78.87	2.16	6.92	3.81	0.95	0.06	1.82
				Punjab				
Below 0.5	164.10	0.25	61.46	71.41	33.76	0.00	24.96	11.86
0.5 – 1.0	161.61	0.71	60.02	74.04	35.33	0.00	27.92	10.24
1.0 – 2.0	159.55	1.43	58.52	75.79	35.14	0.00	31.35	8.91
2.0 – 3.0	158.22	2.43	57.42	77.43	34.67	0.00	35.16	7.31
3.0 – 4.0	157.02	3.44	56.50	78.71	35.28	0.00	36.80	6.36
4.0 – 5.0	155.52	4.44	55.28	79.44	35.57	0.00	37.99	5.59
5.0 – 10.0	151.24	6.89	51.91	80.26	38.28	0.00	37.53	4.20
10.0 – 20.0	143.39	13.17	45.82	77.94	41.18	0.00	33.56	2.91
20.0 – 30.0	135.67	23.69	39.64	72.76	43.18	0.00	26.99	2.14
30.0 – 40.0	132.15	33.92	36.71	71.89	45.16	0.00	24.36	1.67
40.0 – 50.0	131.71	44.31	36.40	71.62	48.26	0.00	21.93	1.58
50.0 and above	142.32	86.76	33.07	70.81	39.82	0.00	27.82	2.89
				Rajasthan				
Below 0.5	132.46	0.26	14.79	28.21	3.01	4.59	0.37	19.99
0.5 – 1.0	126.66	0.73	12.31	23.85	3.49	3.77	0.40	15.97
1.0 – 2.0	121.97	1.45	11.19	21.86	3.92	3.02	0.41	14.31
2.0 – 3.0	117.80	2.48	10.40	20.63	4.41	2.39	0.44	13.28
3.0 – 4.0	114.98	3.48	9.50	21.48	6.56	1.94	0.51	12.39
4.0 – 5.0	113.09	4.48	9.23	20.02	5.58	1.76	0.55	12.03
5.0 – 10.0	108.01	6.96	8.46	19.74	8.90	1.10	0.41	9.34
10.0 – 20.0	106.65	13.18	6.59	13.76	7.37	0.50	0.23	5.72
20.0 – 30.0	103.80	22.24	1.73	8.14	4.38	0.23	0.09	3.49
30.0 – 40.0	100.17	36.63	6.45	5.44	2.94	0.11	0.06	2.34
40.0 – 50.0	100.24	45.61	7.68	4.36	2.39	0.10	0.07	1.78
50.0 and above	117.27	81.12	41.46	8.42	6.71	0.22	0.02	1.48

Table 12—Continued

Farm Size	Y	X_1	X_2	X_3	X_{15}	X_{16}	X_{17}	X_{18}
(hectares)								
				Uttar Pradesh				
Below 0.5	142.76	0.21	12.95	44.48	12.82	2.65	14.82	12.47
0.5 – 1.0	140.43	0.72	14.18	42.58	13.81	2.34	14.17	10.93
1.0 – 2.0	137.66	1.40	15.68	41.98	14.63	2.04	14.34	10.37
2.0 – 3.0	136.44	2.42	17.01	42.36	15.49	1.72	15.17	10.01
3.0 – 4.0	136.37	3.43	18.29	43.14	16.48	1.46	16.40	9.39
4.0 – 5.0	135.55	4.44	18.93	42.92	16.50	1.32	17.04	8.76
5.0 – 10.0	130.55	6.66	18.43	40.13	16.48	1.01	16.33	7.32
10.0 – 20.0	126.46	12.99	17.29	33.97	15.49	0.82	13.59	4.72
20.0 – 30.0	121.23	23.68	14.09	27.62	13.49	0.74	10.12	2.76
30.0 – 40.0	121.12	33.81	13.72	24.25	11.70	0.61	8.84	2.12
40.0 – 50.0	122.42	44.17	12.97	21.80	8.74	0.51	9.20	1.68
50.0 and above	124.78	98.37	19.48	24.68	8 27	0.48	14.05	0.74
				Himachal Pradesh				
Below 0.5	183.62	0.21	92.09	23.09	22.80	0.07	0.20	0.08
0.5 – 1.0	179.10	0.73	88.21	19.24	19.06	0.04	0.17	0.02
1.0 – 2.0	173.95	1.43	80.35	16.58	16.43	0.03	0.14	0.04
2.0 – 3.0	169.28	2.43	74.16	13.65	13.52	0.02	0.12	0.05
3.0 – 4.0	171.69	3.44	71.63	12.61	12.52	0.02	0.10	0.07
4.0 – 5.0	170.19	4.46	67.38	11.77	11.70	0.01	0.10	0.09
5.0 – 10.0	166.59	6.70	63.57	11.47	11.31	0.02	0.13	0.18
10.0 – 20.0	177.90	13.00	76.80	12.63	13.07	0.00	0.26	0.23
20.0 – 30.0	179.51	23.21	76.46	12.71	14.46	0.00	0.35	0.16
30.0 – 40.0	174.76	34.62	46.94	15.54	16.13	0.00	0.11	1.56
40.0 – 50.0	249.11	44.42	59.22	13.07	15.38	0.00	0.10	0.21
50.0 and above	187.37	235.11	22.83	24.69	27.17	0.00	2.99	0.00
				Jammu and Kashmir				
Below 0.5	127.65	0.25	15.63	53.50	50.63	0.27	0.34	0.35
0.5 – 1.0	122.21	0.75	14.92	48.20	46.69	0.24	0.09	0.36
1.0 – 2.0	124.74	1.46	17.27	39.24	37.90	0.16	0.07	0.24
2.0 – 3.0	129.68	2.47	20.91	34.69	33.88	0.22	0.09	0.24
3.0 – 4.0	128.41	3.50	27.31	33.77	33.27	0.07	0.09	0.11
4.0 – 5.0	140.30	4.50	26.00	27.61	26.92	0.11	0.06	0.27
5.0 – 10.0	118.77	6.93	16.92	25.86	25.29	0.11	0.11	0.09
10.0 – 20.0	138.35	13.08	53.49	30.50	29.81	0.00	0.09	0.27
20.0 – 30.0	138.82	23.13	5.57	44.01	42.60	0.00	0.00	0.00
30.0 – 40.0	156.89	35.21	68.85	36.53	43.23	0.00	0.00	0.00
40.0 – 50.0	112.16	44.11	0.00	45.88	45.88	0.00	0.00	0.00
50.0 and above	115.91	219.21	11.84	27.95	29.67	0.00	0.00	0.00
				Gujarat				
Below 0.5	110.26	0.28	7.98	14.26	4.72	1.03	0.92	7.39
0.5 – 1.0	109.17	0.75	6.96	13.17	3.41	0.47	1.08	8.15
1.0 – 2.0	108.22	1.47	6.14	12.25	2.90	0.31	1.00	8.18
2.0 – 3.0	107.77	2.47	6.08	11.85	2.55	0.25	0.93	8.35
3.0 – 4.0	107.34	3.46	5.19	11.84	2.41	0.23	0.88	8.56
4.0 – 5.0	107.04	4.47	5.28	11.54	2.29	0.22	0.76	8.58
5.0 – 10.0	106.31	7.04	6.73	11.09	1.90	0.20	0.53	8.75
10.0 – 20.0	104.52	13.46	5.70	8.71	1.15	0.15	0.25	7.28
20.0 – 30.0	103.35	23.51	5.99	6.55	0.77	0.12	0.17	5.50
30.0 – 40.0	103.31	33.52	5.74	5.93	0.88	0.09	0.18	4.83
40.0 – 50.0	108.60	44.33	10.41	5.31	1.28	0.05	0.18	3.91
50.0 and above	106.88	117.69	9.05	7.57	1.77	0.08	1.16	4.30

Table 12—Continued

Farm Size (hectares)	Y	X_1	X_2	X_3	X_{15}	X_{16}	X_{17}	X_{18}
				Maharashtra				
Below 0.5	110.09	0.24	16.56	12.61	3.56	2.89	0.00	6.44
0.5 – 1.0	109.58	0.74	13.40	11.15	3.34	3.12	0.00	5.35
1.0 – 2.0	107.86	1.46	12.53	8.85	2.51	2.39	0.00	4.85
2.0 – 3.0	106.85	2.45	12.26	7.55	1.95	1.87	0.00	4.70
3.0 – 4.0	106.36	3.46	13.03	6.68	1.61	1.46	0.00	4.60
4.0 – 5.0	105.75	4.46	12.85	6.05	1.39	1.23	0.00	4.40
5.0 – 10.0	105.16	7.02	12.69	5.37	1.11	0.93	0.00	4.29
10.0 – 20.0	104.51	13.47	12.31	4.59	0.72	0.67	0.00	4.04
20.0 – 30.0	104.09	23.70	11.11	4.11	0.54	0.67	0.00	3.62
30.0 – 40.0	103.81	33.96	10.15	3.99	0.50	0.71	0.00	3.47
40.0 – 50.0	103.32	44.15	9.40	3.96	0.53	0.93	0.00	3.15
50.0 and above	103.09	89.03	12.11	4.77	5.36	0.85	0.00	3.31
				Assam				
Below 0.5	118.80	0.26	37.70	5.27	4.60	0.03	0.01	0.00
0.5 – 1.0	119.61	0.72	22.11	7.28	6.25	0.04	0.02	0.00
1.0 – 2.0	117.81	1.42	22.20	8.68	7.63	0.03	0.02	0.01
2.0 – 3.0	114.63	2.43	22.33	9.16	8.38	0.02	0.01	0.00
3.0 – 4.0	116.64	3.43	21.62	9.24	8.66	0.04	0.02	0.00
4.0 – 5.0	116.08	4.43	23.72	9.57	8.88	0.03	0.01	0.00
5.0 – 10.0	115.23	6.49	20.62	9.65	8.97	0.05	0.03	0.00
10.0 – 20.0	112.96	12.78	21.41	8.78	8.58	0.04	0.02	0.00
20.0 – 30.0	112.18	23.69	12.23	10.34	5.89	0.19	0.00	0.00
30.0 – 40.0	111.56	34.40	6.06	5.79	5.40	0.02	0.00	0.00
40.0 – 50.0	124.35	44.28	50.00	6.16	5.43	0.00	0.00	0.00
50.0 and above	106.45	443.92	26.84	1.41	0.99	0.01	0.00	0.00
				Bihar				
Below 0.5	134.39	0.24	17.18	26.45	9.15	0.99	3.33	3.61
0.5 – 1.0	134.81	0.73	17.34	28.48	10.24	1.03	3.28	3.44
1.0 – 2.0	131.58	1.41	18.65	28.77	11.01	1.05	3.37	3.06
2.0 – 3.0	131.40	2.40	17.23	27.85	10.59	1.25	3.45	2.95
3.0 – 4.0	132.17	3.40	20.54	27.16	10.48	1.34	3.49	2.55
4.0 – 5.0	133.97	4.42	21.90	26.30	10.49	1.27	3.59	2.38
5.0 – 10.0	124.39	6.83	20.60	23.97	10.75	1.37	3.02	1.74
10.0 – 20.0	126.62	13.21	23.93	20.52	9.79	1.25	2.78	1.33
20.0 – 30.0	128.99	23.42	20.58	20.67	9.80	1.32	2.57	1.26
30.0 – 40.0	134.40	33.70	24.19	20.46	10.48	1.35	2.72	0.90
40.0 – 50.0	140.95	44.29	28.05	21.50	11.45	1.07	2.72	0.87
50.0 and above	139.21	87.35	46.34	22.81	10.39	0.99	5.42	1.19
				Orissa				
Below 0.5	199.43	0.30	130.80	24.63	18.49	3.94	0.30	0.29
0.5 – 1.0	141.86	0.74	44.47	19.60	14.19	3.59	0.21	0.31
1.0 – 2.0	113.31	1.53	60.15	13.98	10.95	1.53	0.23	0.45
2.0 – 3.0	119.23	2.60	114.47	13.80	9.98	3.31	0.09	0.11
3.0 – 4.0	111.28	3.46	60.07	12.16	8.30	2.55	0.19	0.20
4.0 – 5.0	138.34	4.40	121.38	11.23	8.52	1.97	0.18	0.24
5.0 – 10.0	106.43	6.74	46.10	10.23	6.67	2.85	0.21	0.07
10.0 – 20.0	122.54	13.12	143.78	6.88	3.41	2.77	0.23	0.07
20.0 – 30.0	123.50	23.03	60.33	7.38	1.07	5.40	0.25	0.05
30.0 – 40.0	185.07	33.40	106.77	10.69	1.32	7.69	0.94	0.01
40.0 – 50.0	133.83	43.15	150.37	9.16	5.02	4.05	0.02	0.00
50.0 and above	157.55	75.29	154.59	10.38	4.60	5.40	0.04	0.00

Table 12—Continued

Farm Size	Y	X_1	X_2	X_3	X_{15}	X_{16}	X_{17}	X_{18}
(hectares)				West Bengal				
Below 0.5	128.95	0.24	30.90	18.97	10.13	6.06	0.47	0.29
0.5 – 1.0	127.77	0.73	29.61	17.68	9.77	5.09	0.60	0.37
1.0 – 2.0	127.02	1.38	27.21	18.63	10.82	5.05	0.78	0.35
2.0 – 3.0	126.16	2.35	23.69	19.66	11.94	5.07	0.87	0.31
3.0 – 4.0	124.64	3.41	22.48	21.35	13.09	5.51	0.93	0.21
4.0 – 5.0	124.70	4.35	26.04	19.63	11.99	5.14	1.16	0.18
5.0 – 10.0	122.07	6.32	21.18	19.30	11.91	5.04	1.01	0.14
10.0 – 20.0	119.61	11.38	17.01	21.73	11.56	6.66	1.85	0.14
20.0 – 30.0	116.39	22.78	11.13	30.65	15.17	12.41	0.18	0.00
30.0 – 40.0	123.63	34.62	31.16	24.48	6.09	4.70	10.10	0.00
50.0 and above	101.33	560.34	7.11	1.83	0.16	0.19	0.46	0.00

Source: India, Ministry of Agriculture and Irrigation, *All India Report on Agricultural Census 1970/71* (New Delhi: Controller of Publications, 1975).

Notes: Y is gross cropped area as a percentage of net sown area. It does not include the area of plantations or the area planted with sugarcane and fruits. X_1 is average farm size in hectares for each farm size class. X_2 is multiple cropped irrigated area or area irrigated more than once as a percentage of net irrigated area. X_3 is net irrigated area as a percentage of net sown area. X_{15} is the area irrigated by canals as a percentage of net sown area. X_{16} is the area irrigated by tanks as a percentage of net sown area. X_{17} is the area irrigated by tubewells as a percentage of net sown area. X_{18} is the area irrigated by wells as a percentage of net sown area.

BIBLIOGRAPHY

Asian Development Bank. *Asian Agricultural Survey, 1976.* Manila: ADB, 1977.

———. *Rural Asia: Challenge and Opportunity.* New York: Praeger Press, 1977.

China, Republic of, Executive Yuan, Council for Economic Planning and Development. *Taiwan Statistical Data Book, 1975.* Taipei: Council for Economic Planning and Development, 1975.

Dasgapta, Biplab. *Agrarian Change and the New Technology in India.* Geneva: United Nations Research Institute for Social Development, 1977.

India, Department of Statistics, National Sample Survey Organization. *The National Sample Survey: Tables on Land Holdings, Regional, State, and All India.* Twenty-sixth Round, July 1971 – June 1972, No. 215. Delhi: Controller of Publications, 1976.

India, Ministry of Agriculture and Irrigation. *All-India Report on Agricultural Census 1970-71.* New Delhi: Controller of Publications, 1975.

———. *Report of the National Commission on Agriculture,* vol. 6. Delhi: Controller of Publications, 1971.

India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics. *Estimates of Area and Production of Principal Crops in India, 1977-78.* Delhi: Controller of Publications, 1979.

———. *Indian Agriculture in Brief.* Delhi: Controller of Publications, 1977.

India, Ministry of Irrigation and Power. *Report of the Irrigation Commission 1972,* vol. 2. Delhi: Controller of Publications, 1972.

Mehra, S. "Some Aspects of Labour Use in Indian Agriculture." *Indian Journal of Agricultural Economics* 31 (October–December 1976): 95-121.

Naidu, I. J. *All India Report on Agricultural Census, 1970-71.* Delhi: India, Department of Agriculture, 1975.

Rao, C. H. H. "Alternative Explanations of the Inverse Relationship Between Farm Size and Output Per Acre." *Indian Economic Review* 1 (October 1966): 1-12.

———. *Technological Change and Distribution of Gains in Indian Agriculture.* Delhi: Macmillan Co. of India, Ltd., 1975.

Rao, V. K. R. V. "New Challenges Before Indian Agriculture." Dr. Panse Memorial Lecture at the 27th Annual Conference of the Indian Society of Agricultural Statistics, New Delhi, 1974.

Sarma, J. S. "Concepts of Irrigation and Problems of Measurement." In *Role of Irrigation in the Development of India's Agriculture*, pp. 3-9. Bombay: Institute for Social and Economic Change, 1976.

Sen, A. K. "An Aspect of Indian Agriculture." *The Economic Weekly* 14 (February 1962): 243.

Singh, Inderjit. *Small Farmers and the Landless in South Asia*. Background Paper No. 4. Washington, D.C.: International Bank for Reconstruction and Development, 1979.

Srinivasan, T. N., and Vaidyanathan, A. "Agricultural Statistics." In *Data Base of Indian Economy: Review and Reappraisal*, pp.33-68. Edited by C. R. Rao. Calcutta: Statistical Publishing Society, 1972.

Visaria, Pravin. "Employment—A Trend Report." In *A Survey of Research in Economics*, vol. 2, pp. 125-246. Edited by D. T. Lakadawala. Delhi: Allied Publishers, 1976.

Visaria, Pravin, and Jain, Anrudh K. *Country Profiles: India*. New York: Population Council, 1976.

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37

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