AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 31

1. SUBJECT CLASSIFICATION

A. PRIMARY
Agriculture AE10-0000-G635

B. SECONDARY
Agricultural economics--India

2. TITLE AND SUBTITLE
Economic production possibilities of soybeans in northern India,a preliminary study

3. AUTHOR(S)
Dovring,Folke; Jindia,J.R.; Misra,R.S.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1970	69p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Ill.

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In Ill. Univ. Office of Int.Agr. Research ser.1)

9. ABSTRACT

10. CONTROL NUMBER
PN-AAB-809

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Economic factors
India
Product development
Soybean

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-3292 GTS

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

IN 633.34
D-74
CSN-3292, GTS
PN-AAB-810

University of Illinois at Urbana-Champaign
Office of International
Programs and Studies

PUBLICATION SERIES I

Economic Production Possibilities of Soybeans in Northern India: A Preliminary Study

by

FOLKE DOVRING

JASWANT RAI JINDIA

RAMA SHANKER MISRA

University of Illinois at Urbana-Champaign
Office of International
Programs and Studies

PUBLICATION SERIES I

University of Illinois at Urbana-Champaign
Office of International Agriculture
RESEARCH SERIES 1

Economic Production Possibilities of Soybeans in Northern India: A Preliminary Study

by

FOLKE DOVRING
JASWANT RAI JINDIA
RAMA SHANKER MISRA

Contents

Foreword		vii
Acknowledgments		ix
Chapter One	Introduction	1
Chapter Two	Field Survey and Analytical Framework	7
Chapter Three	Assumptions about Prices and Other Variables	14
Chapter Four	Rates of Return to Several Crops and to Major Factors	19
Chapter Five	The Possible Place of Soybeans in North Central India	52
Appendix		57

Foreword

This monograph is the first in a series to be published by the University of Illinois at Urbana-Champaign Office of International Programs and Studies embracing various areas of University study. The first publication is presented by the Office of International Agriculture. Future publications will encompass among other topics: comparative education, agriculture, and the four University geographic area centers — Asia, Africa, Latin America, and Russia and East Europe. Faculty and graduate students at the University of Illinois at Urbana-Champaign and faculty at other locations will contribute manuscripts for consideration in this series.

Acknowledgments

This study was undertaken as part of the Agency for International Development (AID) — University of Illinois at Urbana-Champaign Coordinated Research Project (Soybeans), under the direction of Dr. Earl R. Leng, Professor of Agronomy, University of Illinois at Urbana-Champaign. This phase of the project was led by Folke Dovring. The field work of collecting on-farm data was carried out by R. S. Misra, who received help as needed from University of Illinois at Urbana-Champaign staff and other faculty at the Jawaharlal Nehru Agricultural University at Jabalpur, Madhya Pradesh, India. J. R. Jindia was in charge of statistical processing of the incoming data in Urbana. Several staff members of the University of Illinois at Urbana-Champaign gave help and advice at various stages of the project; among these were Dr. Bruce L. Brooks who assisted in gathering data in India, and Dr. John T. Scott, Jr., who helped develop the linear programming models. The bulk of the content of this bulletin is taken from the Ph.D. theses of Jindia and Misra.

CHAPTER ONE

Introduction

The Soybean

The soybean, native to eastern Asia, has been grown as a food crop in China and Japan for centuries. Introduced into the United States toward the end of the nineteenth century, it is today one of the most important crops in the country. It shows great promise in both tropical and temperate countries.

In India some soybeans have been grown for long periods in the northern hill regions, primarily for local consumption. The crop varieties were late maturing and low yielding. Experimental work conducted during the past few years has shown some U.S.-bred varieties to be very successful in northern India. They are early maturing and have yielded as well as or even better than in the United States. Of the varieties tested thus far, Bragg, a Group 7 maturity rating type widely grown in Mississippi and Arkansas, has been the most consistently high yielding and the best performer.[1] The varieties Hood, Lee, Hardee, Hampton, and Clark 63 also have done well. This work has brought the soybean into the limelight as a new crop of great promise to India.

These findings occurred in the midst of a technological revolution in Indian agriculture, as new varieties of old crops were being introduced. The high-yielding dwarf varieties of wheat and rice, as well as hybrid maize and hybrid jowar (sorghum), have created a breakthrough in agricultural production. So far, the advances have been mainly in the production of cereal grains.

The need is urgent to introduce more variety into the cropping pattern.[2]

---

[1] E. R. Leng, "U. S. Soybeans Perform Well in India," *Illinois Research*, Fall 1969, p. 10. Cf. also *Indian Farming*, Sept. 1969, with several articles on soybeans in India.

[2] L. S. Negi, Vice Chancellor, Jawaharlal Nehru Agricultural University, Jabalpur (Madhya Pradesh), in a welcome address delivered at the Conference on Soybean Production and Marketing, Sept. 1968.

In this regard the soybean offers several advantages. As a leguminous crop, it can add nitrogen to the soil. As a variation on the cropping pattern it can contribute to spreading the labor load over time and to reducing overall risk in farming. The best planting time for the Bragg variety is about July 1, and under northern Indian circumstances it takes about 105 days to mature.[3] The Clark 63 variety matures even earlier; it requires less than 100 days. Thus, such varieties can be grown in the rainy season (as "kharif" crops) and the same land can be available for planting of dry-season ("rabi") crops like wheat which is normally sown in early or mid-November.

Along with other new crop varieties, soybeans can contribute to increasing the incomes of Indian farmers, which United Nations comparative data show to be among the lowest incomes in the world. The special advantage of soybeans lies in the possibility of growing them on land now left fallow in the monsoon season, or otherwise not suitable for the new high-yielding varieties of other crops, many of which require a controlled water supply in a higher degree than is the case with soybeans.

Still more important is the need for a boost in the production of high-energy and protein-rich foodstuffs. The degree of mainutrition in the Indian population is gauged by the average protein availability of 53 grams per day as against the recommended standard of 75 grams per day. The lower income group (over 70 percent of the population) in India cannot afford to purchase high-protein food to balance its diet.[4] Animal sources provide only about 12 percent of the protein supply in India, the balance being based on vegetable sources such as pulses and oilseeds. Soybeans may well come to occupy an important position here. Compared to 20–25 percent protein content of most Indian pulses, soybeans have a protein content of 40–45 percent. Pulses in India yield only 3.5 quintals per acre on the average, while soybeans yield about 7.5 quintals under similar conditions. Thus soybeans can yield 3½ to 4 times as much protein per acre as pulses and twice as much as other oilseeds. Soybean protein is also superior to other vegetable protein sources.[5] The protein efficiency ratio (PER) of soybeans is 2.4 as compared to 1.7 of groundnuts and 1.5 to 1.7 of pulses. The PER of milk is 3.0 and of eggs is 4.0.

India is deficient in fats and oils also. Per-capita availability is only 27 grams, as opposed to 100 grams in the rich countries. The oil content in soybeans is much lower than in groundnuts, but soybean per acre yield

---

[3] Leng, op. cit., pp. 10–11.

[4] "Annual Report of Agricultural Production," Ministry of Food and Agriculture, Government of India, 1969.

[5] Food and Agriculture Organization, Nutrition Division, Nutrition Document R-I Add/2IPAG/Aug. 1966.

Table 1. PER ACRE YIELD FROM SOYBEANS AND GROUNDNUTS

	Yield per acre, quintals	*Oil content, percent*	*Oil yield per acre, quintals*
Soybeans	7.5†	20	1.5‖
Groundnuts (shelled)	2.2‡	47§	1.0‖

† Average yield obtained on cultivators' fields.
‡ Average of two five-year periods, 1952–56 and 1960–64, 3.06 and 3.02 quintals per acre, respectively, of nuts in shell from the Food and Agriculture Organization *Production Yearbooks*, 1963–1968, converted by a shelling ratio of 72.5 percent. See *Handbook of Agriculture*, rev. ed. (New Delhi: Indian Council of Agricultural Research, 1966), p. 222: "The pods yield 70 to 75 percent of kernels by weight." Data for 1965 and 1966 were omitted because of abnormally low yields in those years.
§ *Handbook of Agriculture*, op. cit., p. 219: oil content varies from 44 to 50 percent.
‖ If adjustment is made for sowing seed, these ratios are reduced to 1.43 for soybeans and 0.93 for groundnuts, thus the comparative advantage of soybeans is somewhat increased.

is so much higher that the oil yield per acre comes out substantially higher with soybeans, as shown in table 1.

Soybean oil also has a ready market in India. The vanaspati (vegetable oil) industry already consumes nearly 81,000 tons (average of four years, 1965–68) of soybean oil per year, purchased under the Public Law 480 program. The demand is expected to go even higher (150,000 tons per year) by the end of the fourth five-year plan in 1976.

There is a substantial shortage of livestock and poultry feed in India; one estimate goes as high as 85 million tons per year.[6] The gap can to some extent be narrowed by reducing the very large numbers of ill-fed cattle, but large increases in feed supply also are an obvious need. Soybeans can mean a significant addition here by providing high quality animal feed.

It is thus quite clear that soybeans can play a very important role in the agricultural and food economy of India. The problem needs to be examined from the viewpoint of the Indian farmer, who has to make the practical decisions about whether, where, and to what extent the crop will be grown. The Indian farmer operates under several constraints imposed by the low-income economy within which he lives, such as low capital supply and large on-farm consumption.

Possible Location of Soybean Production in India

For the time being the question of possible location of soybean production in India is being limited to northern India, where the University of Illinois is helping to build two agricultural universities (at Pant Nagar,

[6] R. O. Whyte and M. L. Mathur, "An Analysis of the Feed and Fodder Resources for the Livestock Population of India," *Indian Dairyman* 17, no. 10 (1965): 323–33.

Uttar Pradesh, and Jabalpur, Madhya Pradesh) with facilities for research and extension.

Based upon available knowledge, soybeans seem to grow best in northern and north-central India in the monsoon season. Northeastern India, especially Bengal and Assam, is too wet in this season. On the other hand, in northwestern India, especially Punjab and Rajasthan, the climate is too dry to sustain soybean growth, except under irrigation. While replacing other irrigated crops with soybeans may be feasible, this possibility is not the most convincing initial argument for soybeans as a large element in the land use and production systems of Indian agriculture.

In most of northern and central India, rainfall ranges between 30 and 50 inches, which presents close to ideal conditions for soybean growth without irrigation.

One of the important characteristics of the land use system in this part of the country is the high incidence of cropland lying fallow during the kharif (monsoon) season. In Madhya Pradesh, this is especially striking — nearly 42 percent of the total cropland area is idle during this season of abundant vegetation; but there also are large fallow areas (often 30 percent or more) in most of Uttar Pradesh and in northwestern Bihar. There is a negative correlation between rainfall and the rate of monsoon season cropping. As rainfall declines, the rate of kharif season fallow goes up, apparently to conserve moisture and productivity of the soil for the rabi (dry season) crop. This appears to be a very extensive use of the land. The saving of moisture to meet the requirement of dry-season crops is at best incomplete. The use of nondescript spontaneous vegetation as pasture (particularly in current fallow) is certainly inferior to the use of more highly productive feed crops. This practice only has the advantage of requiring virtually no labor. This monsoon season vegetation renders soil preparation for winter crops more exacting than would be the case if the same fields had borne a monsoon season crop and had been weeded accordingly. Some of this fallow land could be planted with soybeans.

Another major avenue for introducing soybeans on a large scale is in a redirection of the use of marginal rice lands. Rice is the prevalent grain crop throughout all of Bihar and in the eastern one-third of both Uttar Pradesh and Madhya Pradesh. The average yield of rice in these areas is below that of India as a whole. Several districts with about 40 inches of rainfall have rice yields below the average for these states, even in areas where rice is the principal crop, as in eastern Uttar Pradesh. When average rainfall in the district is marginal for rice, then evidently some localities are below the margin. More significantly, on slightly undulating terrain, the water will assemble most readily in low-lying spots, which may then be adequately inundated, while higher ground and sloping areas have more

difficulty becoming covered, even with elaborate bunding. In the main-crop rice areas of eastern Uttar Pradesh and some adjacent areas in Madhya Pradesh and Bihar, considerable acreage now used for rice is so marginal that a shift to soybeans would be an improvement, even without double cropping. The combined yield of an early-maturing monsoon crop plus a subsequent dry-season crop would, in almost all cases, exceed the present yield of rice alone. To what extent soybeans will prove superior to other early-maturing monsoon crops — among which certain other rice varieties are possible only on irrigable areas — is among the topics to explore by field survey work and subsequent analysis.

As already pointed out, some of the present rice areas are so marginally watered that they are unlikely prospects even for improved rice varieties. Soybeans as a rain-fed crop are likely to find such areas well suited for satisfactory yield levels.

In both cases — planting part of the present monsoon-fallow acreage and replacing marginal rice — the relatively early maturing of soybeans under Indian conditions would normally allow a second crop to be planted. The larger amount of work in the monsoon season would be somewhat wider spread over that season, and the tillage required for winter crops would be lighter.

In addition, other monsoon crops than rice may be displaced by soybeans, as will be shown in some detail in the following analysis. But the acreages which are likely to become available from fallow and from marginal rice land are already so large that they alone indicate a large scope for future soybean production. As mentioned above, it is important to show whether soybeans can bring substantial gains in production on rain-fed lands, without drawing on the scarce resources for controlled water supply.

The above reasoning on the possibilities of modifying the cropping systems by bringing in soybeans could be made even more far-reaching if it could be combined with a scheme for reorganizing animal husbandry, particularly the widespread buffalo enterprise. Buffalo in these parts are mainly used for milk and salable offspring, seldom for draft power. However, the cattle kept mainly for draft power also should be reorganized. All of this applies in varying degrees to most of Uttar Pradesh and Madhya Pradesh and most of northwestern Bihar. These areas may someday become a soybean belt in India.

Research Approach and Analytical Framework

To gain some first-hand insights into the possibilities of soybean production in northern India, from the viewpoint of farmers' production alternatives, a field survey of a limited sample of farms was conducted. It

was essential that this inquiry be made in areas where American-type soybeans had already been grown on farmers' fields. It also was desirable at this stage to narrow down the area of investigation by selecting groups of districts where the conditions favoring the introduction of soybeans were most strikingly evident. If the investigation bears out that these areas have a large potential for soybean production, then such a finding is likely to be well established for at least those districts and, by inference, for others similar to them. If investigation of such central districts were to give discouraging results, then even less could be expected from areas with fewer evident preconditions, in the sense discussed above.

The investigation was limited to some districts in northern and western Madhya Pradesh, mainly in districts close to the border of Uttar Pradesh and having similar conditions of climate and soil to adjacent areas of that state.

A sample of 108 farms located in four districts was analyzed by (1) production functions for individual crops and for whole farms, (2) partial budgeting, and (3) linear programming and analysis of variance, as set forth in some detail in the following chapters.

A major limitation of the study is that most of its data came from a single kharif (monsoon) season; thus the effects on rabi (dry) season production of the projected modifications in the cropping patterns have not been studied in any detail.

As shown in summary form in the last chapter, the results appear highly encouraging. Despite its limitations, the study indicates that soybeans can become a highly profitable element in the crop production systems of northern Indian farms.

CHAPTER TWO

Field Survey and Analytical Framework

The state of Madhya Pradesh lies in the center of India approximately between the latitudes of 18° and 27° (see maps in the Appendix). It is a land-locked state bounded by Uttar Pradesh on the north, Bihar and Orissa on the east, Maharashtra and Andhra Pradesh on the south, and the arid tracts of Rajasthan on the west. The state is a watershed for numerous rivers flowing out in all directions. Low mountain ranges break up Madhya Pradesh into natural regions between which communication is difficult. As in most of northern India, the state has a hot, dry season from April through June followed by monsoon rains from July through September. Average rainfall is about 40 inches, decreasing from east to west. The western and northwestern districts receive 30 inches or less. The heaviest rainfall is in the southeastern districts.

Madhya Pradesh has a low population density compared with India as a whole — 152 persons per square mile as opposed to 312 for the country. The density varies considerably within the state. The hilly and forest tracts are thinly populated, while the fertile valley and plain areas have high densities. Pockets of high density around urban areas — Gwalior, Indore, Jabalpur, Bhopal, Ratlam, Ujjain — also are apparent.

Of Madhya Pradesh's population, 88 percent live in rural areas. This is a higher proportion than in India as a whole. Villages generally are smaller than in the country; the average village has about 330 inhabitants. Roughly 44 percent of the state's population live in settlements with less than 500 inhabitants. The villages of Madhya Pradesh are not only small, they also are widely scattered. Lacking transport facilities, the small villages are more isolated and their integration into the wider economy becomes more difficult.

The most striking fact about agriculture in the state is its low productivity. From 38 million acres of cropped area, it produces crops worth

only 2,700 million rupees. This is only about 70 rupees per acre (gross produce) as compared with an all-India average of 152 rupees. Agricultural production per capita also is lower than the all-India average (103 rupees against 134 rupees) despite a larger cultivated area per capita (1.39 acres against 0.82 acres).

Apparently there are two main reasons for this low productivity. The most immediate is that yields per acre are much lower than in the country at large. A second reason is that the farmer in Madhya Pradesh puts a much larger proportion of his land and efforts into low-value crops, mainly the cheaper food grains such as millets. Of the cropped area, only 5.5 percent is under irrigation, as opposed 17 percent for all of India. Forty-five percent of the cropland is left fallow in the kharif (monsoon) season and 40 percent in the rabi (dry) season, not counting areas in year-round fallow. Thus the rate of double cropping is low.

The density of livestock on the cropland in Madhya Pradesh is higher than the average for India (70 head of cattle and buffalo for 100 acres compared with 57 head for 100 acres). If pastures, forests, and wastelands are included, the livestock density in Madhya Pradesh is slightly lower than in India as a whole (28 head of cattle and buffalo compared with 30). The quality of animals is poor. The cattle population is roughly balanced with equal numbers of males and females; but in the adult buffalo population, which is kept mainly for milk, female animals outnumber the males 2 to 1.

Choice of Zones in Madhya Pradesh

In the Indian system of agroclimatic zones, based on cropping patterns, the state of Madhya Pradesh has been divided into eleven zones.[1] These zones do not cut across district boundaries. Four of these zones were singled out for study as presenting the most immediate likelihood that soybean cultivation would be successful. They are: zone 3 (districts Panna, Satna, Rewa, Jabalpur, and Seoni); zone 4 (districts Tikamgarh and Chhatarpur); zone 5 (districts Bhind, Morena, Gwalior, Datia, and Shivpuri); zone 8 (districts Rajgarh, Shajapur, Ujjain, Indore, and Dewas).

This choice of zones within Madhya Pradesh excluded rice districts in the east, but included a part of the cotton belt in the southwest. Grain cropping still included sizable rice areas in zone 3, while the rest had combinations of jowar (sorghum) and maize in the kharif season and wheat and gram (chick pea) in the rabi season. Oil seeds were of small impor-

[1] Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India, "Division of the Country into Homogeneous Crop Zones," *Agricultural Situation in India* (Aug. 1964): 456–71.

Table 2. NAMES OF DISTRICTS AND VILLAGES SELECTED FOR STUDY

Name of district	*Inhabited villages*	*Names of villages selected*
Rewa	2,298	Category 1 Bansa Category 2 Badawar Category 3 Mando
Gwalior	760	Category 1 Rudrapura Category 2 Serol Category 3 Jadaduva
Tikamgarh	872	Category 1 Sheopuri Category 2 Durgapur Category 3 Rajpura
Indore	640	Category 1 Simrol Category 2 Dudhiya Category 3 Hatod

tance generally and particularly during the kharif season. However, groundnuts were included in zone 8 along with some cotton. On the whole, larger areas were in kharif fallow (except in zone 8) than in the zones not included in the study.

Design of the Survey

The sampling design used can be termed a multistage stratified random sample, with districts as the first-stage units, villages as second-stage units, and farms within the village as third-stage units. As already pointed out, the study was conducted in four agroclimatic zones of Madhya Pradesh. One district was randomly selected to represent each zone. Out of each district, three villages were randomly selected as shown in table 2.

All the cultivating households in each selected village were ranked according to the size of land cultivated by them. The households were then divided into three categories (strata), each accounting for roughly the same amount of cultivated area. These categories were: category 1 — up to 7.5 acres; category 2 — from 7.5 to 15 acres; and category 3 — over 15 acres.

Three holdings were selected from each category, making nine holdings from each village. Holdings from each category were selected randomly. In this way, 27 farms were selected from each district, making a total of 108 farms from the four districts.

Collection of Data

The data were collected from the sample farmers through the personal-interview technique on questionnaires drawn up in advance. The following three types of questionnaires were used:

1. Village schedule: cultivated and uncultivated area, area under kharif and rabi fallow, farming and nonfarming population, holding size distribution, storage facilities, crops grown, types of tenure, livestock, irrigation facilities.
2. Farmer schedule: size of farm, family, area cultivated and fallow, tenure, livestock.
3. Record of crop operations: operations performed and cost of each operation, in regard to each crop grown by the farmer.

The data relate to the crop year 1968–69. Details of the cost of production of crops are available only for the kharif season of 1968. The total time spent in field survey work was six months.

Whole Farm Production Function

Production functions were fitted to the data collected from the 108 sample farms to see what kind of input-output relations existed in the farming industry of this area and how output could be increased by a given increase in resources.

As the sample is a stratified one, with 27 farms selected from each of the four crop zones, the production functions were fitted to each of the four subsets of data to find out whether there was any significant variation in the coefficients from one zone to the other.

The sample design also permitted the division of the entire sample into small, medium, and large farms with 36 observations in each category. This enables us to fit a separate function to each size category of farms. These functions will reveal the differences, if any, in the input-output relations by size of farms.

Single equation methods were used in the present study. Linear, Cobb-Douglas, and quadratic equations were fitted to the data, but the Cobb-Douglas function seemed to do the best job. The Cobb-Douglas or the power function is of the form:

$$Y = a\, X_1^{b_1} X_2^{b_2} \ldots X_n^{b_n}$$

where X_i are the variable resources, Y is the output, and a is a constant. The exponents b_i are the elasticities of output with respect to the relevant inputs. The sum of the b_i indicates the nature of the returns to scale. If $\Sigma b_i = 1$, then a given percentage increase in all inputs will result in an equal percentage increase in output. When elasticity sums are more or less than 1, output will increase by a greater or smaller percentage, respectively, than inputs.[2] No output is possible with any factor at zero level.

[2] E. O. Heady and J. L. Dillon, *Agricultural Production Functions* (Ames: Iowa State University Press, 1961), p. 83.

The equation is estimated in logarithmic form, and it allows either constant, increasing, or decreasing marginal productivity.

Individual Crop Production Functions

To study the influence of different input factors on the output of crops, production functions were computed for the two most important crops of the region — paddy (rice) and jowar (sorghum). These two crops, however, are not represented in Indore district. So production functions for cotton and groundnuts, the two most important crops of the Indore district, also were computed. In addition, a production function for soybeans was calculated. As very few sample farms grew soybeans, the sample data were supplemented by the available data from research stations for calculation.

Partial Budgeting

Since the inclusion of soybeans does not have to involve a complete reorganization of the Indian farming pattern in the initial stages, the technique of partial budgeting was used as a tool in analyzing this kind of change.[3]

The elements of the partial budgeting used in this project were:

1. Additional receipts — expected additional returns for products sold and services rendered as a result of the proposed change.
2. Reduced costs — estimate of costs which no longer will be incurred if the changes are made.
3. Additional receipts plus reduced costs (if any) will make total credits.
4. Additional costs that would occur as a result of the change.
5. Reduced receipts — returns that would no longer be received after the changes have been made.
6. Additional costs plus reduced receipts will make total debits.
7. Difference — change in the net income per unit.

These elements will compare the effect on net income of the enterprise being dropped with that of the one being added, and will not show the effect of the latter without dropping an enterprise where feasible. The difference lies in the impact of the proposed changes on farm income and organization.

The proposed changes will not affect the entire farm organization and, in such a situation, some of the costs and receipts will remain constant, but others will change. The analysis was used to identify only those costs

---

[3] I. F. Fellows, "Basic Theory and Assumptions Underlying Use of Budgeting Techniques," Storrs Agricultural Experiment Station, University of Connecticut *Bulletin* 357 (1960): 7–9.

and returns that will be changed. The method was applied to both situations: where soybeans replace a kharif crop or crops, and where soybeans are sown on kharif temporary fallow land.

Linear Programming

Along with the partial budgeting technique, linear programming also was applied to depict the potential impact of soybeans on the whole farm organization. This indicates the optimum organization of resources for farms and suggests desirable farm adjustments to obtain optimum production patterns.

A mathematical statement of a general form of the linear programming model follows. Find $x_1, x_2, \ldots, x_n$ which maximize the linear function $Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$ (objective function), subject to the restrictions:

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n &\leq b_1 \\ a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n &\leq b_2 \\ &\vdots \\ a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n &\leq b_m \end{aligned}$$

and

$$x_1 \geq 0, x_2 \geq 0, \ldots, x_n \geq 0$$

where the a_{ij}, b_i, and c_j $(i = 1, \ldots, m, j = 1, \ldots, n)$ are given constants.[4]

Given n competing activities, the decision variables $x_1, x_2, \ldots, x_n$ represent the levels of these activities which, in the present problem, are the number of acres devoted to each of the various crops or the amount of capital consumed or bullock or human labor used as well as the necessary programming accounting activities.

The overall measure of effectiveness is Z which in this case is the amount of profit. The increase in overall measure of effectiveness (change in profit) is c_j; it will result from each unit increase in x_j.

The number of relevant scarce resources is m. Each of the first m linear inequalities corresponds to restrictions such as the acres of land available during the kharif season (excluding the temporary fallow land), available capital, fodder requirements, and staple food requirements of the family corresponding to the b_i. The amount of resource i consumed by each unit of activity j is a_{ij}.

The nonnegative restrictions $(x_j \geq 0)$ rule out the possibility of any negative activity level.

Four models were formed to represent the four districts corresponding to each of the four zones from which the districts were selected at random.

Each model consists of three submodels representing the three categories of farms by size of land holdings.

---

[4] F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research* (San Francisco: Holden Day, Inc., 1967), pp. 127–28.

Analysis of Variance

Since one of the objectives concerned soybeans planted on kharif fallow land, it was necessary to know the pattern of distribution of fallow land in each category of size of holdings, village, and district and whether the pattern was different from one of these groups to another.[5] A factorial design was selected to evaluate the pattern of distribution of fallow land.

Adequacy of the Sample

The adequacy of the sample for the kind of analysis applied was examined with reference to the most limiting input factor, the cash input. It was found that the sample size was adequate so far as the total soybean region in the state of Madhya Pradesh was concerned. In this case, as already pointed out, the sample was 108 farms. For the individual districts the sample size was inadequate. The estimates for individual districts were subject to unduly large standard errors as the sample size for each district was only 27 farms.

The analysis done for the adequacy of the sample also showed that some improvement in the sampling design for future surveys of this type is possible. This problem is discussed in more detail elsewhere.[6]

---

[5] The statistics regarding the fallow land released by the government do not relate to the land kept fallow during kharif and rabi seasons; instead, they issue statistics of the land kept cultivated more than once during the whole year.

[6] J. R. Jindia, "Estimation of Costs and Returns on Indian Farms: Sampling Problems and Production Function Analysis" (Ph.D. diss., University of Illinois at Urbana-Champaign, 1970), pp. 83 sqq.

CHAPTER THREE

Assumptions about Prices and Other Variables

Rather conservative assumptions were made for the analysis of the data. Some of these assumptions are described below.

Yield of Soybeans

The expected yield level of soybeans on the farmers' fields was assumed to be 758 kg per acre. This figure was based on the yields obtained by some farmers who actually grew the crop in 1968, and also on some demonstration trials conducted on farmers' fields. This was a rather conservative estimate of the expected soybean yield, because at the experiment stations in Madhya Pradesh much higher yield levels have been obtained. Farmers usually obtained a lower yield per acre as compared with the experiment stations because most of them did not follow the recommended set of practices and did not apply the recommended level of inputs. Farmers who do follow them are sometimes able to obtain yields even higher than those at the experiment stations. Table 3 shows the yield levels on some major crops of the area both at the research stations and on farmers' fields. The yields of the research stations were those obtained in an entire experiment and not just from the plots receiving the best set of treatments. As an experiment usually has some control plots and some which receive an overdose of the treatments, the yield per acre from the entire experiment is always lower than that obtainable if the area had been under the best set of treatments.

Price of Soybeans

As soybeans are a new crop for all practical purposes, some kind of price assumption was necessary. This was obtained by comparing soybean oil and meal with groundnut oil and meal, because groundnuts also are a

Table 3. COMPARATIVE YIELDS AT RESEARCH STATIONS AND THE SAMPLE FARMS
(yield in kg per acre)

Crop	*Yield at research stations in Madhya Pradesh*	*Yield at sample farms*	*Farmers' yield as percent of research station yield*
Taichung paddy	1,335†	1,052	79
Local paddy	1,158‡	481	42
Hybrid jowar	944§	1,215	129
Local jowar	564‖	397	70
Cotton	567††	305	54
Soybeans	1,222‡‡	758	62

† A. B. S. Verma et al., "Response of Four Varieties of Paddy to Three Fertility Levels," *Indian Journal of Agronomy* 13, no. 2 (1968). Yield of cross 4-2 at Jabalpur, 1966–67.
‡ Yield of variety Nusahi in the experiment reported in Verma et al.
§ N. G. P. Rao et al., "Further Studies in Breeding Hybrid Sorghums," *Indian Journal of Genetics and Plant Breeding* 26, no. 1 (1966). Yield of hybrid CSH-1 at Gwalior, 1964.
‖ Yield of local jowar in the experiment reported in Rao et al.
†† Chokhey Singh et al., "Effect of Sowing Time, Spacing, and Nitrogen on Irrigated Cotton in Madhya Pradesh," *Indian Journal of Agronomy* 14, no. 2 (1969). Yield at Khandwa, 1966–67.
‡‡ Earl R. Leng, "Soybean Yield as Influenced by Inoculation, Nitrogen Application, and Variety," Summary Report of the Coordinated Research Project, Soybeans, 1969. Yield of the entire experiment at Jabalpur, 1968.

kharif oilseed crop and their oil and meal were the closest substitute for soybean oil and meal.

The Vanaspati Manufacturers Association maintains that, compared to groundnut oil, soybean oil is difficult to process; it must undergo degumming before refining, it needs more hydrogen for hardening than groundnut oil, and consequently, a longer production cycle leading to smaller production per unit of time. Soybean products also have a somewhat shorter shelf life. The industry, therefore, recommended to the State Trading Corporation of India that the imported soybean oil sold to the industry be priced at least 150 rupees per metric ton lower than the market rate of groundnut oil.[1] During 1968 the State Trading Corporation sold imported soybean oil for an average price of 2,500 rupees per metric ton as opposed to the average market price of 2,900 rupees per metric ton of groundnut oil. Considering these factors, the price of soybean oil has been taken to be 300 rupees per metric ton less than groundnut oil.

Soybean meal is superior to groundnut meal is several respects. Unlike groundnut meal it is free from toxic materials and has protein of better quality. It can be more easily converted into protein-rich foods for humans. Because of the present lack of processing facilities in India, the highest-valued consumer products cannot be made out of soybean meal in the immediate future. Soybean meal is, therefore, regarded as a stock feed just

[1] "The Vanaspati Manufacturers Association of India 1967 Annual Report," pp. 6–11.

Table 4. COMPARISON OF GROUNDNUT AND SOYBEAN PRICES†

	Groundnut (100 kg) (70 kg nuts without shells)	*Soybeans (100 kg)*
Oil content (kg)	28 (40%)	20 (20%)
Price of oil per kg (rupees)	2.90	2.60‡
Meal content (kg)	42	80
Price of meal per kg (rupees)	.70	.70
Total value of oil (rupees)	81.20	52.00
Total value of meal (rupees)	29.40	56.00
Processing costs and margin (rupees)	10.60	12.00§
Transportation, procurement, and other marketing costs (rupees)	10.00	10.00
Net worth (rupees)	90.00	86.00

† These prices are average annual prices for 1968. Shelling rate and oil content of groundnuts differ from those in table 1, to make them realistic for Madhya Pradesh.
‡ Prices of soybean oil have been calculated at 300 rupees per metric ton less than those of groundnut oil.
§ The processing cost, which includes margins for the processors also, has been calculated at more than 10 percent.

like groundnut meal and its price also has been assumed to be the same as that of groundnut meal. Table 4 shows calculations based on these assumptions and the price of soybeans that would follow from these.

Thus, if groundnuts in shell sell at 90 rupees per quintal, the price of soybeans should be 86 rupees per quintal. Of course, this price is based strictly on the uses of the oil and cakes made at the time. If new protein foods for human consumption were to be developed to utilize soybean meal, which would raise its price slightly, this would have a proportional effect on the income of the producers, which would be larger than that caused by the same rise in the oil prices. If no uses are developed to increase the demand for soybean meal, the maximum price of soybeans will continue to be governed by the prices processors are able to pay for groundnut oil and meal.

Classification and Measurement of Inputs

The inputs have been classified as human labor, bullock labor, cash input, and land. Human labor includes family and hired labor actually used in the production process. Wage rates prevalent at the time of inquiry in the villages selected were used for converting this input into money value. On most small farms the available family labor is more than the labor actually used in production. Most large farms hire outside labor and most small-farm families have members who work as day laborers on large farms. No account of the number of days worked for wages off the farm is available so no allowance could be made for this. Inclusion of all

available family labor would lead to serious overestimates of the labor used on the small farms.

Bullock labor actually employed in the production process was used in the inquiry. It was converted into value terms by the prevailing rental rates for bullock labor.

Cash input included the cost of seed, fertilizer, plant protection, irrigation charges, maintenance of farm implements, and other miscellaneous crop outlays.

Land was measured in acres. No account could be taken of land quality differences, although effects might be serious. Land quality differences were likely to be systematically related to differences in other inputs, because the better quality land tended to be farmed more intensively.

Farm Output

Farm output consists of the value of all crop produce on the farm, whether sold, consumed, or stocked. Only the value of the crops was included. Income from livestock was not included because data on the value of milk and other livestock products were not available. Farm output figures are for the monsoon season since only such data were available.

Use of Fallow Land

Realistic assumptions were made about the extent to which fallow land can be brought under crops in the kharif season. All the available fallow land cannot be used for soybeans or other kharif crops because of the topography and drainage system of the area and also because the nondescript vegetation growing on the fallow land is utilized for grazing animals.

The available data showed a clearly positive correlation between fallow land and animals kept on the farm. This led the authors to suspect that a reduction in the fallow land may create difficulties for the farmers in maintaining their livestock. The extent to which the animals would be displaced by a reduction of the fallow land was, therefore, examined by fitting a regression equation with fallow land as the independent variable and animal units as the dependent variable.[2] The regression equation is as follows:

$$A = 11.7 + \underset{(0.0922)}{0.7343}L$$

where A is the animal units, L is the acres of fallow land in the kharif season, and the figure in parentheses is the standard error. The average

[2] The animals were aggregated into animal units on the basis of their feed requirements. For details, see Jindia, op. cit., pp. 58–61.

number of animal units per farm at present is 17, and the average number of animal units per farm when fallow land is half of the present is 14.

This analysis shows that a 50 percent reduction in kharif fallow land will displace about 18 percent of the animals. This can be taken care of by a better utilization of the remaining fallow land or by some reorganization of the livestock enterprises, or a combination of both.

Therefore, in the linear programming models, constraints were imposed so as to permit only about 50 percent (on the average) of the fallow land to be converted to cropland. The percentage varies from one region to another.

Cultivation of Traditional, but Less Remunerative Crops

It was further assumed that the crop or crops which might prove less remunerative than soybeans would not be replaced fully because farmers in Madhya Pradesh operate their farms in a traditional semisubsistence pattern. They also prefer to spread the risk by growing a large number of crops rather than concentrating on one crop even when this might be the most remunerative crop. Specialized farming has not yet gained full acceptance.

The farmers also feel economically more secure in giving priority to satisfying their family food and livestock feed requirements from their farming units rather than purchasing them on the market.

Suitable constraints were, therefore, imposed on the model, so that basic consumption requirements of the farm family and the farm livestock were met from the products of the farm itself.

Financial Resources

It was assumed that all farm units have been in operation for some time and no major capital outlay for nonrecurring expenditure is necessary other than those required to conduct normal farm operations in addition to all recurring expenditures in raising crops. Only operational capital in each model was considered. Additional borrowing was not permitted because the objective was to find out the optimum level of inclusion of soybeans (a new activity) in the existing cropping pattern with existing resources which were available to the farmers before the inclusion of the new activity.

CHAPTER FOUR

Rates of Return to Several Crops and to Major Factors

As mentioned in chapter two, the data from the sample farms were analyzed in three principal ways: by production functions, by partial budgeting, and by linear programming. The results of these analyses are summarized in this chapter.

All three analytical approaches aimed to compare the economic advantages of alternative crops, specifically as this concerns the comparison between soybeans and other crops. The production function analysis also intended to show some essential characteristics of the sample farms and of the data, as a background to the kinds of results obtained in regard to specific crops.

Production Function Analysis

Three functions — linear, Cobb-Douglas, and quadratic — were fitted to the data.[1] The Cobb-Douglas function, which was found to be the best for the purpose, is reported here:

$$Y = aX_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}$$

where Y is the farm output in rupees, X_1 is the human labor input in rupees, X_2 is the bullock labor input in rupees, X_3 is the cash input, and X_4 is the land holding in acres.

Production Function for the Whole State. The regression coefficients of the Cobb-Douglas production function for the whole state are given in table 5. The regression is highly significant. R^2 for the function is 0.98 which indicates that 98 percent of the total variation in farm output is explained by the four input factors included in the function. All four input factors are significant.

[1] For details see Jindia, op. cit., pp. 93–96.

Table 5. Coefficients of the Cobb-Douglas Production Function for the Whole State

Input factor	*Regression coefficient*	*T. ratio*
Constant term	0.9588	
X_1	0.4083	6.680**
X_2	0.1466	2.333*
X_3	0.2922	15.059**
X_4	0.1333	2.769**
R^2	0.9815	

* Denotes significance at 5% level.
** Denotes significance at 1% level.

Looking more carefully at the coefficients of the function we find that all the elasticities are smaller than 1. Hence all the input factors show decreasing marginal returns.[2] The sum of the elasticities is 0.9804. This is near enough to 1 that we have constant returns to scale. This conclusion was tested statistically as described in the Appendix. It was found that the hypothesis that there is a linear, homogeneous production function, cannot be rejected. This is an important result, because it means that there are probably no economies or diseconomies of large-scale production.

Production Functions for the Size Categories of Farms. The regression coefficient for the three size categories of farms — small, medium, and large — is given in table 6. It is interesting to note that the coefficient of X_4 (land holding) has become insignificant in each of the categories. The reason for this is apparently an effective reduction in the variation of this factor, within the categories. The farms within size categories are more homogeneous in respect to land acreage, so land is no longer an important explanatory variable for explaining variation in farm output. The effect of land becomes incorporated in the constant term.

The sum of the elasticities for the three size categories of farms is 0.9705, 0.8544, and 0.9884 for the small, medium, and large farms respectively. The hypothesis that each of these sums is equal to 1 was tested according to the procedure described in the Appendix. It was found that F in each case is nonsignificant. This shows that the production function in each size category is linear and homogeneous.

Production Functions for the Four Zones. The coefficients of the Cobb-Douglas function for each of the four zones are given in table 7. Cash input is the only factor that is significant in all the four zones. The other factors

[2] G. Tintner, *Econometrics* (New York: John Wiley and Sons, Inc., 1965), p. 54.

Table 6. Coefficients of the Cobb-Douglas Production Function for Size Categories of Farms

	Input factor	*Regression coefficient*	*T. ratio*
SMALL FARMS			
	Constant term	0.9248	
	X_1	0.4107	4.642**
	X_2	0.1976	2.070
	X_3	0.2668	10.729**
	X_4	0.0954	1.276
	$R^2 = 0.9516$		
MEDIUM FARMS			
	Constant term	1.0249	
	X_1	0.4123	4.278**
	X_2	0.0991	0.919
	X_3	0.3810	12.042**
	X_4	−0.0380	−0.246
	$R^2 = 0.9132$		
LARGE FARMS			
	Constant term	0.8090	
	X_1	0.4622	3.113**
	X_2	0.1695	1.096
	X_3	0.2505	3.831**
	X_4	0.1062	1.442
	$R^2 = 0.8724$		

** Denotes significance at 1% level.

are significant in some zones and insignificant in others. This is because of a high degree of multicollinearity among these variables.

Table 8 gives the correlation coefficients among the input factors (for all four zones combined). Cash input has the least amount of correlation with other input factors. This factor, therefore, could be considered as an independent variable, whereas the others are more like a package. It is not possible to impute the farm output to the various cooperating factors on the basis of the production function coefficients. All the four factors together are very good in explaining the farm output, but it is very difficult to say how much of the output is attributable to one particular factor.

The sum of the elasticities for the districts was 1.0330, 0.9717, 1.0003, and 0.9541 for Rewa, Tikamgarh, Gwalior, and Indore respectively. These also were statistically tested against the hypothesis that the sum of the elasticities is 1. The *F* values in every case were nonsignificant, which means that the hypothesis cannot be rejected. This shows that there were probably constant returns to scale in the farming industry of each of these districts.

Composition of Farm Output. Paddy and jowar (sorghum) account for nearly 50 percent of the total farm output in the kharif season. Paddy is

Table 7. Coefficients of the Cobb-Douglas Production Function for the Zones

	Input factor	*Regression coefficient*	*T. ratio*
REWA DISTRICT			
	Constant term	1.1755	
	X_1	0.0912	0.839
	X_2	0.3808	3.782**
	X_3	0.1979	4.030**
	X_4	0.3631	3.757**
	$R^2 = 0.9886$		
TIKAMGARH DISTRICT			
	Constant term	0.9714	
	X_1	−0.0962	−0.520
	X_2	0.7014	4.426**
	X_3	0.2434	8.018**
	X_4	0.1231	1.351
	$R^2 = 0.9914$		
GWALIOR DISTRICT			
	Constant term	1.2913	
	X_1	0.3623	2.778*
	X_2	−0.0628	−0.370
	X_3	0.3497	7.311**
	X_4	0.3511	2.553*
	$R^2 = 0.9972$		
INDORE DISTRICT			
	Constant term	1.0092	
	X_1	0.5025	3.556**
	X_2	−0.0428	−0.339
	X_3	0.2983	12.057**
	X_4	0.1961	1.960
	$R^2 = 0.9928$		

* Denotes significance at 5% level.
** Denotes significance at 1% level.

the most dominant crop in Rewa, jowar in Tikamgarh, and cotton in Indore. Gwalior has both paddy and jowar as dominant kharif season crops. Indore has more specialized farming with emphasis on cash crops, such as cotton and groundnuts, whereas the other three districts grow mostly food crops. The percentage contribution of each crop to the total farm output is given in table 9.

Contribution of Various Inputs. Of the three input factors — human labor, bullock labor, and cash input — human labor is the predominant factor, accounting for about 40 percent of the total input costs. On small farms, this percentage is 45 whereas on large farms it is 38. This is quite natural considering the fact that most small farms have surplus labor and large farms hire outside labor. For large farms, labor is a variable cost and it will be substituted with other factors wherever possible. Table 10 gives the value of these factors per farm.

Table 8. Correlation Coefficients among Input Factors

	Land	*Cash input*	*Human labor*	*Bullock labor*
Land	1.0000			
Cash input	0.6701	1.0000		
Human labor	0.9192	0.7873	1.0000	
Bullock labor	0.8949	0.7131	0.9145	1.0000

Table 9. Percentage Contribution of Each Crop to the Total Farm Output on Sample Farms

Crop	*Rewa percent*	*Tikamgarh percent*	*Gwalior percent*	*Indore percent*	*All four districts percent*
Paddy	47.65	16.66	33.98	....	26.94
Jowar (sorghum)	4.48	32.30	24.43	25.35	20.08
Groundnuts	....	1.01	1.52	22.68	5.87
Cotton	....	....	....	32.78	7.60
Small millets	12.81	10.32	....	....	5.85
Sesame	....	5.60	1.43	....	1.45
Pulses	4.82	8.15	7.51	7.65	6.84
Others	30.24	25.96	31.13	11.54	25.37

Table 10. Value of the Inputs per Farm in Rupees

	Small farms	*Medium farms*	*Large farms*	*All farms*
Human labor	215.66 (23.60) †	582.24 (32.50)	1770.86 (172.36)	856.25 (79.71)
Bullock labor	119.12 (8.85)	389.49 (20.00)	1302.87 (128.00)	603.82 (58.76)
Cash input	142.63 (30.71)	456.66 (58.57)	1605.57 (198.55)	734.95 (82.38)
Total	477.42	1428.39	4679.30	2195.02

† Figures in parentheses are the standard errors.

Production Functions for Individual Crops. For this analysis, variables were classified as follows.

Output: Y is the output per acre of the crop (in maunds).

Inputs:

1. Human labor (X_1) in terms of days of man labor used per acre of the crop cultivated.

2. Bullock labor (X_2) in terms of bullock-pair days used per acre. This was done because the bullocks in this region are regularly used in pairs.
3. Cash input (X_3) in rupees per acre. This is the value of other inputs and includes cost of seed, fertilizer, irrigation, and insecticides.
4. Size of holding (X_4) in acres of land actually operated. This is the size of an operator's entire holding and not just the land under the crop for which the production function was fitted.

Each input factor was first of all regressed individually on yield per acre. This gave some idea of the relative importance of each factor. Cash input was thus found to be the most important single variable. Then taking cash input as the base, other combinations were tried. It was found that by including the size of holding in the production function, the adjusted R^2 actually decreases, rather than increases.

This shows quite reasonably that this factor was of no importance in explaining variations in yield per acre. A small farmer probably would be working more intensively, thereby trying to increase the yield per acre. At the same time, most small farms had a larger proportion of their area under cultivation, thus extending the cultivation of individual crops to submarginal lands. This factor would tend to lower the yield per acre of any particular crop on small farms. These two factors are likely to neutralize the effect of each other, so that there is hardly any net effect of size of farm on yield per acre. This also confirms the finding reported in the previous chapter, that there are constant returns to scale in each size category of farms.

For the purpose of fitting production functions, the size of holding as a factor was therefore omitted. Production functions were fitted with human labor, bullock labor, and cash input only. The results will be discussed in some detail for one crop (paddy) and more summarily for the other crops included in the analysis.

Coefficients for paddy are shown in table 11. In proper functional form, the results for paddy are shown in table 12.

The relationships obtained were fairly strong, explaining 37 to 91 percent of the total variation in output. The first three equations represent the production function for each district separately and the fourth was an aggregate function of Rewa and Tikamgarh districts. The coefficient of input cost (X_3) was quite consistent in the first three equations, but the other coefficients were very different in the case of Gwalior district.

The reason for this abnormal production function for Gwalior seems to be that paddy is a relatively minor crop in this district. Only eleven farmers grew this crop as compared with twenty-five in Rewa and sixteen in Tikamgarh. A minor crop could sometimes receive resources in a non-optimal manner and this seems to be the case with paddy in Gwalior

Table 11. Cobb-Douglas Production Function Coefficients for Paddy

	Input factor	*Coefficient*	*T. ratio*
REWA DISTRICT (Sample size = 25)			
	Constant term	−0.0684	
	X_1	0.1741	0.731
	X_2	0.1547	1.085
	X_3	0.3900	5.040**
	adjusted R^2 = 0.5115		
TIKAMGARH DISTRICT (Sample size = 16)			
	Constant term	0.0166	
	X_1	0.1946	1.384
	X_2	0.0136	0.089
	X_3	0.4345	7.977**
	adjusted R^2 = 0.9107		
GWALIOR DISTRICT (Sample size = 11)			
	Constant term	0.0121	
	X_1	0.3679	1.988*
	X_2	−0.4033	1.013
	X_3	0.4987	2.251**
	adjusted R^2 = 0.3680		
WHOLE REGION (Sample size = 41)			
	Constant term	0.1753	
	X_1	0.0348	0.413
	X_2	0.1150	1.148
	X_3	0.4296	9.757**
	adjusted R^2 = 0.7307		

* Denotes significance at 5% level
** Denotes significance at 1% level.

Table 12. Cobb-Douglas Production Functions for Paddy

REWA DISTRICT			
	0.1741	0.1547	0.3900
Y = 0.854	X_1	X_2	X_3
TIKAMGARH DISTRICT			
	0.1946	0.0136	0.4345
Y = 1.039	X_1	X_2	X_3
GWALIOR DISTRICT			
	0.3679	−0.4033	0.4987
Y = 1.028	X_1	X_2	X_3
WHOLE REGION			
	0.0348	0.1150	0.4296
Y = 1.497	X_1	X_2	X_3

district. Therefore, to find a production function for paddy for the whole region, only Rewa and Tikamgarh were aggregated.

The cash input (X_3) has become a highly significant factor. This is in agreement with the previous findings in this chapter.

The coefficients of regression here are the elasticities of output with respect to the inputs. *Elasticity* can be defined as percentage change in output divided by percentage change in input, that is:

$$e = \Delta Y/Y \div \Delta X/X = \Delta Y/\Delta X \cdot X/Y$$

By substituting the geometric averages of X and Y we can find:

$$e = \Delta Y/\Delta X \cdot \overline{X}_g/\overline{Y}_g$$

$$\text{or } e = MP \cdot \overline{X}_g/\overline{Y}_g$$

$$MP = e \cdot \overline{Y}_g/\overline{X}_g$$

where MP is the marginal product, e is the elasticity of output with respect to particular input, $\overline{X}_g$ is the geometric mean of input X, and $\overline{Y}_g$ is the geometric mean of output Y.

By using the above formula we can find the marginal productivities of all three factors. This is shown below for the whole region.

$MP\ X_1 = 0.0348 \cdot 13.26/61.60$
$= 0.00749$ (maunds of rice per day of human labor)

$MP\ X_2 = 0.1150 \cdot 13.26/11.90$
$= 0.1281$ (maunds of rice per day of bullock-pair labor)

$MP\ X_3 = 0.4296 \cdot 13.26/59.24$
$= 0.0961$ (maunds of rice per rupee of cash input)

The coefficients of the production function for jowar are given in table 13. As in the case of paddy, cash input is highly significant here also. But it also appears that human labor is significant in Gwalior, and bullock labor in Indore. In Tikamgarh both of these factors are nonsignificant, but in the combined function for the whole region, both are highly significant.

The significance of human labor in Gwalior was observed in the case of paddy also. The reason for this probably lies in the rather abnormal sample from this district. All the three villages selected lie within 11 miles of the town of Gwalior and are situated on main roads. The town of Gwalior is easily accessible from these villages, and so it is possible that the farm workers in these villages have alternative employment opportunities in the city. The same argument cannot be advanced for Indore district even though the town of Indore is larger than Gwalior, because the sample villages of this district lie much farther away from the town of Indore and also are not situated on the main roads. So it would be much more difficult for the farm workers of these villages to go to Indore for employment. The relationships observed here are very strong, explaining

Table 13. Cobb-Douglas Production Function Coefficients for Jowar

	Input factor	*Coefficient*	*T. ratio*
TIKAMGARH DISTRICT (Sample size = 22)			
	Constant term	0.2606	
	X_1	0.1839	0.957
	X_2	0.2593	1.127
	X_3	0.1590	6.357**
	adjusted R^2 = 0.8232		
GWALIOR DISTRICT (Sample size = 10)			
	Constant term	0.1962	
	X_1	0.3488	1.967*
	X_2	0.1384	0.505
	X_3	0.1053	2.650*
	adjusted R^2 = 0.8290		
INDORE DISTRICT (Sample size = 11)			
	Constant term	0.2388	
	X_1	0.1049	0.436
	X_2	0.4256	2.200*
	X_3	0.1592	5.609**
	adjusted R^2 = 0.7852		
WHOLE REGION (Sample size = 43)			
	Constant term	0.2101	
	X_1	0.2294	3.655**
	X_2	0.2585	5.036**
	X_3	0.1473	10.561**
	adjusted R^2 = 0.8479		

* Denotes significance at 5% level.
** Denotes significance at 1% level.

Table 14. Cobb-Douglas Production Functions for Jowar

TIKAMGARH DISTRICT			
	0.1839	0.2593	0.1590
Y = 1.823	X_1	X_2	X_3
GWALIOR DISTRICT			
	0.3488	0.1384	0.1053
Y = 1.571	X_1	X_2	X_3
INDORE DISTRICT			
	0.1049	0.4256	0.1592
Y = 1.733	X_1	X_2	X_3
WHOLE REGION			
	0.2294	0.2585	0.1473
Y = 1.622	X_1	X_2	X_3

Table 15. Cobb-Douglas Production Function Coefficients for Hybrid Jowar, Cotton, Groundnuts, and Soybeans

Input factor	*Coefficient*	*T. ratio*
HYBRID JOWAR — WHOLE REGION (Sample size = 18)		
Constant term	−0.0552	
X_1	0.2596	2.597*
X_2	−0.1027	1.104
X_3	0.5146	6.006**
adjusted R^2 = 0.7901		
COTTON — INDORE (Sample size = 19)		
Constant term	−0.7171	
X_1	0.3669	1.599
X_2	0.1081	0.397
X_3	0.4320	6.513**
adjusted R^2 = 0.8607		
GROUNDNUTS — INDORE (Sample size = 22)		
Constant term	−0.2301	
X_1	0.2785	1.343
X_2	−0.0973	0.469
X_3	0.4545	5.666**
adjusted R^2 = 0.7903		
SOYBEANS — WHOLE REGION (Sample size = 25)		
Constant term	0.7723	
X_1	0.1102	1.408
X_2	0.2247	1.447
X_3	0.6567	47.002**
adjusted R^2 = 0.9967		

* Denotes significance at 5% level.
** Denotes significance at 1% level.

79 to 85 percent of the variation. The above results are shown in functional form in table 14.

The coefficients of the Cobb-Douglas production function for hybrid jowar, cotton, groundnuts, and soybeans are given in table 15 with the functional form in table 16.

Soybeans have the highest elasticity of output with respect to cash input — higher than either paddy or jowar as shown in tables 11 and 13.

The marginal physical productivities for five of the six crops discussed in this section are given in table 17. The outputs and the inputs X_1 and X_2 are in physical terms, X_3 (cash input) in rupees. For soybeans, both output and all inputs were measured in rupees, and therefore this crop does not appear in table 17, but in the next table which shows comparable rates of value product.

Table 16. Cobb-Douglas Production Functions for Hybrid Jowar, Cotton, Groundnuts, and Soybeans

HYBRID JOWAR — WHOLE REGION			
	0.2596	−0.1027	0.5146
Y = 0.8808	X_1	X_2	X_3
COTTON — INDORE			
	0.3669	0.1081	0.4320
Y = 0.1918	X_1	X_2	X_3
GROUNDNUTS — INDORE			
	0.2785	−0.0973	0.4545
Y = 0.5888	X_1	X_2	X_3
SOYBEANS — WHOLE REGION			
	0.1102	0.2247	0.6567
Y = 5.920	X_1	X_2	X_3

Marginal Value Products of the Input Factors in Various Enterprises. So far, the discussion has been in terms of the physical inputs and outputs. The marginal productivities calculated in the previous sections are all in physical terms. This makes the comparison of the marginal productivities very difficult. In order to facilitate comparison, the marginal value products of the various inputs have to be worked out. The factor costs and prices of the outputs used in making these calculations are given below. These are the average prices paid or received by the farmers of the area.

Cost of one human labor day	= Rs 2.00
Cost of one bullock pair day	= Rs 8.00
Price of paddy	= Rs 50.09 per quintal (Rs 18.64 per maund)
Price of jowar (sorghum)	= Rs 53.65 per quintal (Rs 19.96 per maund)
Price of hybrid jowar	= Rs 53.65 per quintal (Rs 19.96 per maund)
Price of cotton	= Rs 152.76 per quintal (Rs 56.84 per maund)
Price of groundnuts (peanuts)	= Rs 90.00 per quintal (Rs 33.49 per maund)
Price of soybeans	= Rs 80.00 per quintal (Rs 29.77 per maund)

The marginal value products obtained by using the above price data are given in table 18. The marginal value product of X_3 (cash input) is very high in all the enterprises. Soybeans give the highest returns on this input. The other two input factors produce much lower returns. Of these

Table 17. MARGINAL PHYSICAL PRODUCTS OF THE INPUT FACTORS IN MAUNDS OF THE CROP

Input factor	*Paddy*	*Jowar*	*Hybrid jowar*	*Cotton*	*Groundnuts*
Human labor (X_1).....	0.0075	0.0685	0.1198	0.0441	0.0627
Bullock labor (X_2).....	0.1281	0.2602	−0.2453	0.0897	−0.1460
Cash input (X_3).....	0.0961	0.0721	0.0830	0.0323	0.0435

Table 18. MARGINAL VALUE PRODUCTS OF THE INPUT FACTORS IN RUPEES

Input factor	*Paddy*	*Jowar*	*Hybrid jowar*	*Cotton*	*Groundnuts*	*Soybeans*
X_1.....	0.07	0.68	1.20	1.25	1.05	0.79
X_2.....	0.30	0.64	−0.61	0.65	−0.61	0.85
X_3.....	1.79	1.44	1.66	1.84	1.46	2.87

two factors, X_1 (human labor) seems to have a little better return than X_2 (bullock labor).

Thus additional investment in cash inputs (which includes seed, fertilizer, plant protection, and irrigation) is very productive. More of these items may be used in order to maximize farm returns, as long as increased production does not lead to lower prices. Human and bullock labor seem to be generally more than the needs of cultivation, and a cutback on these inputs may be desirable wherever such cutback is feasible. It is possible that as the farmers use greater cash input, the utilization of labor may improve, because more labor will be needed to apply more irrigation, fertilizer, insecticides, and the like. As the crop improves, more labor also will be required for harvesting this crop. Thus the marginal returns to labor may increase as a result of greater cash inputs.

Pattern of Fallow Land in Madhya Pradesh. The pattern of fallow land in different sizes of holdings of the selected zones and districts of Madhya Pradesh is summarized below.

The overall district means of the percentage of fallow land during the kharif season were:

Zone 3	Rewa district	42.37%
Zone 4	Tikamgarh district	48.24%
Zone 5	Gwalior district	39.18%
Zone 8	Indore district	39.68%

These figures indicate that those districts which are industrially progressive, such as Gwalior and Indore, also have developed irrigation

resources and a somewhat reduced percentage of fallow land in their villages.

The percentage of the kharif temporary fallow land to the total land under cultivation in each size group of holdings in all the districts combined was:

Category 1 (up to 7.5 acres of land)	37.66%
Category 2 (from 7.5 to 15 acres of land)	42.05%
Category 3 (over 15 acres of land)	48.39%

It appears from these results that as the size of the holdings increases, the intensity of cropping decreases. The overall percentage of temporary fallow land to the land under cultivation in all the zones surveyed was found to be 42.37 percent.

The extent of fallow land which could be brought under soybean cultivation (taking into account economic and agronomic considerations) will be discussed in the next sections.

Cost and Return Analysis through Partial Budgeting

In this part of the study, the term *costs* includes all the cash expenditures incurred in producing the crop and these have been termed *variable costs*.[3] This includes items like costs of seeds (whether produced on the farm or purchased from the market), manures and fertilizers, insecticides and pesticides, interculture operations and irrigation charges, prevalent rate of interest (for half of the total duration of the crop), land taxes (from Government Revenue Department), and any other recurring expenditure that the farmer incurs. Depreciation on either the total inventory or the dead stock has not been included in the variable costs because the study was based on a particular point in time (the kharif season, 1968). The charges for human labor days or bullock labor days (either family or hired, paid either in cash or in kind) also have not been included in the variable costs. They have been accounted for separately, and they have been charged at the local rate prevalent in the area.

The term *gross income* in this part of the study indicates the cash received by the farmers after deducting the marketing and other charges plus the value which the farmers could receive for the by-products of that particular crop at prevalent local rates. For analytical purposes, returns over variable costs and net returns (gross returns minus total costs) have been used throughout the study as indicators of profitability of the different crops.

---

[3] Cf. P. N. Driver and D. K. Desai, "Studies into the Economics of Farm Management in Bombay State," New Delhi, 1958, issued by Directorate of Economics and Statistics, Government of India.

As there was a marked disparity in the costs and returns of the same crop in different regions under survey, these have been presented separately for the crops in each zone. However, the costs and returns data for soybeans have been combined for all four zones because the soybean crop has been introduced very recently and has not yet been fully adopted in the regular cropping system of the farmers.

There are thirteen crops besides soybeans for which costs of production and returns are given in table 35 in the Appendix. Regarding human and bullock labor costs, there are only rather moderate differences in the costs for a particular crop in different regions. Most of the operations carried out for raising a certain crop are more or less the same from region to region but there appear to be wide differences in variable costs. These variable costs are important indicators of efficiency in using the various inputs for different crops.

Another important feature brought out by table 35 is the total amount of money costs the farmers have incurred for hybrids and cash crops. For example, the farmers in Rewa district have spent on an average only 12.5 rupees per acre on local jowar. They have spent nearly twenty times more in variable costs for raising hybrid jowar. These costs may explain the high proportion of land devoted to low-quality crops. But it would appear that once farmers were convinced of the comparative advantage of a particular crop, they did not hesitate to allocate the maximum of whatever resources they had to that enterprise.

The soybean crop has shown a higher net return per acre than any other crop (328.12 rupees). The next highest return crop is Gwalior district's hybrid jowar (318.75 rupees). When a comparison is made of gross returns per rupees of total costs, soybeans have the highest return (2.18 rupees). The next highest are hybrid jowar, hybrid maize, hybrid bajra, and Taichung paddy (which are about 1.59, 1.62, 1.67, and 1.59 rupees, respectively). The corresponding figures for local paddy, local maize, local bajra, and millets are lower (about 1.40 rupees).

When considered in terms of per rupee return over the human labor costs (after deducting the bullock labor charges) soybeans have again given the highest return (5.06 rupees); hybrid jowar, hybrid maize, Taichung paddy, and cotton are the next highest (around 3.50 rupees); and then local paddy, local jowar, local bajra, millets, and pulses (around 2.0 rupees).

Thus from simple comparison soybeans have turned out to be the most profitable crop based on the criteria of per rupee investment, per rupee return over human labor costs, and net profit. But these comparisons have been made from single-value estimates, and therefore they do not give a very clear picture from the point of view of the total farm organization where there are land constraints, cash resources constraints,

and a defined acreage under different crops. To assess the overall possibility of including soybeans in the whole farm organization under real situations, programming models would be useful.

Programming Models

A linear programming model has been used to find out what the optimum production pattern would be under existing conditions if soybeans were included in the cropping pattern.

Four variations of the basic linear programming model representing the corresponding four zones have been developed. Each zonal model has three submodels based on the three different size groups of holdings — less than 7.5 acres, 7.5 acres to 15 acres, and over 15 acres. These submodels have been developed by averaging the corresponding sample data. The properties, characteristics, and corresponding assumptions built into these basic models are as follows:

1. The concept of time is essentially short run. The representative model for each zone is analyzed on the basis of data for the kharif season (120 days approximately) starting in June and ending in September. The survey data were collected in 1968–69. All activities or processes are transacted and terminated within one planning period — a kharif season. It would have been better if the data collection could have been extended to at least one more season — rabi — completing the one-year cycle of the cropping pattern.
2. Since each representative model is programmed for three different farm sizes, there will be three independent optimum solutions in each of the four zonal models. The only link that has been assumed within these three different submodels representing a particular zone is the same input-output coefficients per unit of activity with different levels of constraints.
3. Since each model is designed to represent one zone, the availability of fallow land for crops, the crops grown, the requirements of human and bullock labor days, cash outlays, and crop acreage constraints are different from one model to another.
4. As explained above, it has been further assumed that all the fallow land available during the kharif season could not be used for crops. Only a fixed proportion of the fallow land (which is different in the different regions) has been allowed for conversion into crops.
5. In each model, only family labor available in each period has been considered in determining the selling and hiring activities, except in the case of large-sized holdings. On the large-sized farms, outside labor has been assumed to be available at a given fixed price. Nonfarm employment has not been considered. The constraints for labor avail-

Table 19. CONSTRAINTS AND UTILIZATION OF FALLOW LAND

Size of holdings	*Acres under cultivation*	*Acres under kharif fallow*	*Percent fallow land placed under constraints*	*Percent fallow land utilized under optimum plan*
ZONE 3 REWA				
Category 1	5.49	2.40	58.33	41.67
Category 2	11.55	4.82	58.29	41.71
Category 3	71.23	37.94	60.01	39.99
(Average) †	88.27	45.16	59.74	40.26
ZONE 4 TIKAMGARH				
Category 1	5.16	1.87	38.50	61.50
Category 2	10.50	3.96	50.00	50.00
Category 3	30.30	13.44	44.64	55.40
(Average) †	45.96	19.27	45.14	54.85
ZONE 5 GWALIOR				
Category 1	4.17	1.37	22.62	77.38
Category 2	10.80	4.35	42.52	57.48
Category 3	37.77	19.13	47.72	52.28
(Average) †	52.74	24.85	45.43	54.47
ZONE 8 INDORE				
Category 1	4.11	1.28	49.21	50.79
Category 2	11.52	4.76	57.57	42.43
Category 3	32.90	13.05	54.94	46.06
(Average) †	48.53	19.09	45.88	54.12
AVERAGE FOR ALL †	235.50	108.37	51.42	48.58

† The averages are those of all the holdings and are not weighted averages due to the lack of proper weights.

ability in each period of time have been fixed accordingly. The same assumptions have been considered in the case of availability of bullock labor in two periods of time at a fixed price.

6. Single values of prices, yields, and production functions have been assumed, except in the case of soybeans where different price ranges have been incorporated into the model. Prices of other competing farm products are taken as fixed.

Utilization of Fallow Land. Table 19 shows the possible utilization pattern of kharif fallow land in all the optimum models.

In the zones under survey, the farmers in the smallest holdings have been found to place comparatively small areas under constraints because they want to increase their intensity of cropping to get more returns by minimizing their fallow land in the kharif season, if the fallow land could be replaced with a more remunerative crop. The farmers on larger holdings

have placed comparatively greater percentages of fallow land under constraints.

On an average of the total land holdings under survey, about 50 percent of the total fallow land in kharif season could be released for growing crops even without making allowance for additional resources.

Comparison of Actual Cropping and Optimum Plans. The programming models were used to compare crop production under actual and optimum conditions and to evaluate the potential of incorporating soybeans into the cropping patterns.

First, the actual (observed) cropping system was compared with an optimum programmed solution in which there were no minimum constraints, no change in fallow area, and no soybeans. Thereafter, crop constraints, as discussed earlier, also were used to obtain a realistic plan which could be compared both with the actual, the unconstrained optimum, and the plans with soybeans. These crop constraints were developed on the basis of the family's basic food requirements and the fodder requirements of the livestock kept on the farm. Although these constraints are opposed to the concept of a global maximum, the practical situation makes it impossible to impose the motives of a completely commercialized economy on the farmers who are in a stage of transition from a subsistence economy to a commercialized one. Up to this point, no change was made in the rate of fallowing. These optimum plans without soybeans already show a substantial increase in income. In most cases, these additional returns (over the actual ones) due to planning are only slightly lower in the constrained than in the unconstrained version of the optimum plan.

In a second round of optimum models, soybeans were introduced. The minimum crop constraints are now the same as in the constrained version without soybeans, but the models with soybeans also have a constraint on the use of fallow land. Subsequently, the version with soybeans was varied by allowing increases in cash outlays by 50 percent and by 100 percent above the level observed in actual conditions and maintained in the previous versions of the plan. These variations were introduced to get some idea of the changes that could occur in resource allocation and production as profitability of new and improved crops makes more cash available. The development of these alternative optimum models will be discussed separately for each district.

Rewa District. Table 20 gives the actual and optimum crop plan with and without constraints and without soybeans in Rewa district. It shows that with a reorganization of resources, the farmers could increase their income (returns over variable costs) by 73 percent, 86 percent, and 97 percent. In the optimum plan (without constraints), the Taichung

Table 20. ACTUAL AND OPTIMUM PLAN WITHOUT SOYBEANS IN REWA DISTRICT

Crop	*Acres under actual plan*	*Acres under optimum plan*	*Minimum constraints*	*Acres under optimum plan with constraints*
CATEGORY 1 (farm up to 7.5 acres—average = 5.49 acre area)				
Local paddy	1.11		0.50 or	
Taichung paddy	0.33	1.80	0.27	1.77
Local jowar	0.66	1.29	0.33	0.76
Millets	0.66		0.33	0.33
Pulses	0.33		0.25	0.25
Total cropped area	3.09	3.09		3.09
Total variable costs (rupees)	146.45	146.45		146.45
Total returns over variable costs (rupees)	467.36	810.82		791.29
Percentage of additional returns due to planning		73.48		69.31
CATEGORY 2 (farm from 7.5 acres to 15.00 acres—average = 11.55 acre area)				
Local paddy	3.72		1.50 or	
Taichung paddy	1.72	4.29	0.75	4.26
Local jowar	0.28	2.44		1.89
Millets	0.61		0.33	0.33
Pulses	0.40		0.25	0.25
Total cropped area	6.73	6.73		6.73
Total variable costs (rupees)	435.76	435.76		435.76
Total returns over variable costs (rupees)	956.79	1776.51		1759.01
Percentage of additional returns due to planning		85.67		83.83
CATEGORY 3 (farm over 15.00 acres—average = 71.23 acre area)				
Local paddy	13.66		2.00 or	
Taichung paddy	6.88	26.81	1.00	26.81
Local jowar	4.88		1.00 or	
Hybrid jowar	1.55	3.21	0.50	3.24
Millets	3.44		1.00	1.00
Pulses	2.88	3.27	0.50	2.25
Total cropped area	33.29	33.29		33.29
Total variable costs (rupees)	3385.09	3385.09		3385.09
Total returns over variable costs (rupees)	4240.00	8342.12		8301.07
Percentage of additional returns due to planning		96.76		95.78

variety of paddy (the most remunerative crop) occupies an important place in all the different sizes of holdings. Next in importance is the crop which happens to be the minimum input-cost requiring crop (jowar) except in the large-sized holdings where hybrid jowar (the second most remunerative crop) takes the second place after Taichung paddy followed by pulses which was the crop with the lowest input cost. The

Table 21. RETURNS AFTER INCLUDING SOYBEANS IN THE EXISTING CROP PLAN IN KOWA DISTRICT

Crop	*Acres under actual plan*	*Minimum constraints*	*Acres under optimum plan*	*Acres under 50 percent increase cash resources*	*Acres under 100 percent increase cash resources*
CATEGORY 1 (farm up to 7.5 acres)					
Local paddy	1.11	.50 or			
Taichung paddy	0.33	.25	.25	.25	.25
Local jowar	0.66	0.33	2.42	1.71	1.01
Millets	0.66	0.33	0.33	0.33	0.33
Pulses	0.33	0.25	0.25	0.25	0.25
Soybeans			0.84	1.55	2.25
Total cropped area	3.09		4.09	4.09	4.09
Fallow land	2.40	1.40	1.40	1.40	1.40
Total acreage	5.49		5.49	5.49	5.49
CATEGORY 2 (farm from 7.5 to 15.00 acres)					
Local paddy	3.72	1.50 or			
Taichung paddy	1.72	0.75	0.75	0.75	0.75
Local jowar	0.28		5.45	3.80	2.16
Millets	0.61	0.33	0.33	0.33	0.33
Pulses	0.40	0.25	0.25	0.25	0.25
Soybeans			1.96	3.61	5.25
Total cropped area	6.73		8.74	8.74	8.74
Fallow land	4.82		2.81	2.81	2.81
Total acreage	11.55		11.55	11.55	11.55
CATEGORY 3 (farm over 15.00 acres)					
Local paddy	13.66	2.00 or			
Taichung paddy	6.88	1.00	1.00	1.00	1.00
Local jowar	4.88	1.00 or	25.77	12.96	0.39
Hybrid jowar	1.55	0.50			0.31
Millets	3.44	1.00	1.00	1.00	1.00
Pulses	2.88	0.50	0.50	0.50	0.50
Soybeans			20.19	33.00	45.25
Total cropped area	33.29		48.46	48.46	48.46
Fallow land	37.94		22.97	22.97	22.97
Total acreage	71.23		71.23	71.23	71.23

model with constraints shows some reduction in net returns, proportionately largest in the small-sized holdings.

The optimum plan with soybeans brings even greater changes. Results on crop acreages are given in table 21. This optimum plan shows that soybeans and local jowar are very important crops within the constraints imposed. Soybeans, being the most profitable, could occupy a very prominent position.

With limited cash available to the farmers at present, soybeans have become so profitable that farmers would use a large share of the cash for

the higher inputs required by soybeans and in so doing, they have to increase the production of local jowar (a low cash requirement crop) in order to utilize the available land and labor resources, thus displacing crops of intermediate profitability or those with a lower ratio of profit to cash requirement.

The optimum plan also shows that, as the availability of cash is increased, the acreage under local jowar declines. In the case of farmers belonging to the smallest size of holdings group, the production of local jowar declines from 2.42 to 1.71 acres when cash resources are increased by 50 percent, and finally to 1.01 acres where availability of cash is increased 100 percent. Farms over 15 acres would reduce the acreage under jowar even more.

Another important feature which the optimum model has exhibited is the utilization of additional land taken out of current kharif fallow land after meeting the necessary constraints of fallow land. Additional cash is needed to increase intensity of cropping and if soybeans are to displace other crops and not only fallow.

The model also has compared the increase in returns (over variable costs) in the optimum and actual plans after inclusion of soybeans in the cropping patterns. Table 22 shows the change in the level of returns to optimizing plans in different size holdings groups.

The results in table 22 show the increase in returns in the optimum plan due to the inclusion of soybeans. The increases in returns over variable costs are 105, 125, and 146 percent in the first, second, and third categories of holdings sizes respectively. These increases occur even without an increase in the existing cash resources. Part of these increases in the returns come from more intensive land utilization (reduction of fallow land). The results also reflect the trend in the percentage increase by size of holdings. As the size of the holdings increases, there is a corresponding greater increase in returns over variable costs.

Further, with the increase in the cash resources to the extent of 50 percent, the increase in the net returns comes to 150, 174, and 225 percent in the different sizes of holdings. The same trend is maintained when the cash availability is increased 100 percent, the increases being 194, 223, and 300 percent respectively.

Tikamgarh District. Table 23 compares the optimum plan with existing ones. The farmers without using additional resources can increase their returns by 20, 28, and 33 percent in the first, second, and third categories, respectively, by adopting the optimum plan. In all the cases, Taichung paddy, which happens to be the most remunerative crop under existing conditions, takes an important position in allocating the resources to optimize the income. Next in importance is the crop which is the minimum input-cost

Table 22. INCOME CHANGES IN THE OPTIMIZING MODELS WITH SOYBEANS IN REWA DISTRICT

Size of holdings	*Existing plan*		*Optimum plan*		*With 50 percent increase cash resources*		*With 100 percent increase cash resources*	
	VC†	*NR*†	*VC*	*NR*	*VC*	*NR*	*VC*	*NR*
Category 1	146.45	467.36	146.45	958.26	279.66	1165.83	372.90	1372.18
percentage increase				(105.03)		(149.45)		(193.60)
Category 2	435.76	956.79	435.76	2149.38	653.64	2621.79	871.53	3088.60
percentage increase				(124.64)		(174.01)		(222.81)
Category 3	3385.09	4240.00	3385.09	10451.97	5078.37	13767.72	6770.18	17000.40
percentage increase				(145.50)		(224.71)		(300.00)

† VC = variable costs; NR = net returns; both are expressed in rupees.

Table 23. ACTUAL AND OPTIMUM PLAN WITHOUT SOYBEANS IN TIKAMGARH DISTRICT

Crop	*Acres under actual plan*	*Acres under optimum plan*	*Minimum constraints*	*Acres under optimum plan with constraints*
CATEGORY 1 (farm up to 7.5 acres — average = 5.16 acre area)				
Local paddy	0.60		0.50 or	
Taichung paddy		1.21	0.25	1.20
Local jowar	1.01		1.00 or	
Hybrid jowar	0.22		0.50	0.50
Pulses	0.33	2.08	0.25	1.09
Millets	0.58		0.25	0.25
Sesame	0.55		0.25	0.25
Total cropped area	3.29	3.29		3.29
Total variable costs (rupees)	238.00	238.00		238.00
Total returns over variable costs (rupees)	714.47	859.38		845.30
Percentage of additional returns due to planning		20.28		18.31
CATEGORY 2 (farm 7.5 to 15.00 acres — average = 10.50 acre area)				
Local paddy	0.55		0.50 or	
Taichung paddy	0.33	2.93	0.25	2.93
Local jowar	2.33		1.00 or	1.00
Hybrid jowar	0.95		0.50	
Pulses	0.66	3.61	0.50	2.03
Millets	1.39		0.33	0.33
Sesame	0.33		0.25	0.25
Total cropped area	6.54	6.54		6.54
Total variable costs (rupees)	536.00	536.00		536.00
Total returns over variable cost (rupees)	1371.53	1758.85		1716.91
Percentage of additional returns due to planning		28.29		25.23
CATEGORY 3 (farm over 15.00 acres — average = 30.30 acre area)				
Local paddy	1.33		0.50 or	
Taichung paddy	0.66	9.10	0.25	8.69
Local jowar	5.88			2.00
Hybrid jowar				
Pulses	2.33	7.75	0.50	4.84
Millets	3.00		0.50	0.50
Sesame	3.33		0.50	0.50
Groundnuts	0.33		0.33	0.33
Total cropped area	16.86	16.86		16.86
Total variable costs (rupees)	1567.50	1567.50		1567.50
Total returns over variable costs (rupees)	3242.76	4328.05		4195.15
Percentage of additional returns due to planning		33.48		29.37

requiring crop, pulses. Even under the required minimum constraints, there is a substantial increase in net returns in all sizes of holdings; this increase follows the same trends as the optimum plan without constraints.

The percentage of increase in net returns goes on increasing as the size of the farm increases, which indicates that the farmers on small-sized farms are more efficient farmers than those farmers on large-sized farms in the actual planning. It also reflects the lesser effect of the minimum constraints on the larger farms.

Results of the optimum plan with soybeans are shown in table 24. Soybeans, which is the most remunerative crop, and pulses, which is the lowest input-cost crop, occupy important places in the crop plan. It appears that with the limited resources available (particularly cash), soybeans may use up a large share of the cash, and thereby increase the acreage under pulses in order to utilize the remaining resources of land, labor, and cash.

This fact is further substantiated when the available cash is increased by 50 percent and 100 percent. The area under soybeans then increases from 0.70 to 1.72 and 2.73 acres in the first category of farmers, 2.27 to 4.57 and 6.62 acres in the second category, and from 6.9 to 13.6 and 20.2 acres in the third category. The area under pulses is reduced with the increase in cash in all sizes of holdings.

Another important trend which can be visualized from the above results is the area under hybrid and improved varieties of seeds; when an option is given under the constraints, the local varieties have been fully replaced by hybrids and improved varieties, as these are more profitable although they require higher input costs.

Table 25 shows the changes in the level of returns due to optimizing plans in the different size holdings. The results of the optimum plan indicate that there is an increase of 55, 70, and 81 percent in the net returns of the first, second, and third categories of holdings respectively in the case where soybeans are incorporated into the crop plan. These increases in net returns occur without additional cash resources. Where the available cash resources are increased by 50 percent, there is an increase in net returns to the extent of 92, 113, and 127 percent in the three categories. Similar trends are seen when the cash outlay is increased by 100 percent.

Gwalior District. The results of table 26 show that even without increasing available resources, the farmers can increase their income by 32 percent in the first category, 31 percent in the second category, and 32 percent in the third category simply by reorganizing their cropping plans.

In the optimum plan without constraints, only two crops (hybrid bajra and local jowar) utilize all the available resources; hybrid bajra being a

Table 24. Returns after Including Soybeans in the Existing Crop Plan in Tikamgarh District

Crop	Acres under actual plan	Minimum constraints	Acres under optimum plan	Acres under 50 percent increase cash resources	Acres under 100 percent increase cash resources
CATEGORY 1 (farm up to 7.5 acres)					
Local paddy	0.60	0.50 or			
Taichung paddy		0.25	0.25	0.25	
Local jowar	1.01	1.00 or			
Hybrid jowar	0.22	0.50	0.50	0.50	0.50
Pulses	0.33	0.25	2.49	1.47	0.47
Millets	0.58	0.25	0.25	0.25	0.25
Sesame	0.55	0.25	0.25	0.25	0.25
Soybeans			0.70	1.72	2.73
Total cropped area	3.29		4.44	4.44	4.44
Fallow land	1.87		0.72	0.72	0.72
Total acreage	5.16		5.16	5.16	5.16
CATEGORY 2 (farm from 7.5 to 15.00 acres)					
Local paddy	0.55	0.50 or			
Taichung paddy	0.33	0.25	0.25	0.25	0.25
Local jowar	2.33	1.00 or	1.00	1.00	0.43
Hybrid jowar	0.95	0.50			0.18
Pulses	0.66	0.50	4.42	2.12	0.50
Millets	1.39	0.33	0.33	0.33	0.33
Sesame	0.33	0.25	0.25	0.25	0.25
Soybeans			2.27	4.57	6.62
Total cropped area	6.54		8.52	8.52	8.52
Fallow land	3.96		1.98	1.98	1.98
Total acreage	10.50		10.50	10.50	10.50
CATEGORY 3 (farm over 15.00 acres)					
Local paddy	1.33	0.50 or			
Taichung paddy	0.66	0.25	0.25	0.25	0.25
Local jowar	5.88	2.00	2.00	2.00	1.96
Hybrid jowar					0.02
Pulses	2.33	0.50	13.86	7.16	0.50
Millets	3.00	0.50	0.50	0.50	0.50
Sesame	3.33	0.50	0.50	0.50	0.50
Groundnuts	0.33	0.33	0.33	0.33	0.33
Soybeans			6.86	13.56	20.23
Total cropped area	16.86		24.30	24.30	24.30
Fallow land	13.44		6.00	6.00	6.00
Total acreage	30.30		30.30	30.30	30.30

Table 25. INCOME CHANGES IN THE OPTIMIZING MODELS WITH SOYBEANS IN TIKAMGARH DISTRICT

Size of holdings	*Existing plan*		*Optimum plan*		*With 50 percent increase cash resources*		*With 100 percent increase cash resources*	
	VC†	*NR*†	*VC*	*NR*	*VC*	*NR*	*VC*	*NR*
Category 1	238.00	714.47	238.00	1109.03	357.00	1370.18	476.00	1620.70
percentage increase				(55.22)		(91.77)		(127.95)
Category 2	536.00	1371.53	536.00	2332.20	804.00	2920.53	1072.00	3454.78
percentage increase				(70.04)		(112.93)		(151.89)
Category 3	1567.50	3242.76	1567.50	5862.60	2351.25	7356.47	3135.00	8709.01
percentage increase				(80.79)		(126.85)		(160.56)

† VC = variable costs; NR = net returns; both are expressed in rupees.

Table 26. ACTUAL AND OPTIMUM PLAN WITHOUT SOYBEANS IN GWALIOR DISTRICT

Crop	*Acres under actual plan*	*Acres under optimum plan*	*Minimum constraints*	*Acres under optimum plan with constraints*
CATEGORY 1 (farm up to 7.5 acres — average = 4.17 acre area)				
Local jowar	0.88	1.39	0.50 or	1.14
Hybrid jowar			0.25	
Local paddy	0.33		0.50 or	
Taichung paddy	0.53		0.25	0.25
Maize				
Hybrid maize	0.06			0.06
Pulses	0.75		0.22	0.22
Bajra	0.22		0.11	0.11
Hybrid bajra		1.40		1.00
Total cropped area	2.79	2.79		2.79
Total variable costs (rupees)	293.00	293.00		293.00
Total returns over variable costs (rupees)	701.73	924.69		909.07
Percentage of additional returns due to planning		31.77		29.54
CATEGORY 2 (farm from 7.5 to 15.00 acres — average = 10.80 acre area)				
Local jowar	2.33	3.03	1.00 or	2.61
Hybrid jowar	0.90		0.50	
Local paddy			0.50 or	
Taichung paddy	1.46		0.25	0.25
Bajra	0.55			
Hybrid bajra		3.42		3.01
Groundnuts	0.66		0.33	0.33
Pulses	0.55		0.25	0.25
Total cropped area	6.45	6.45		6.45
Total variable costs (rupees)	824.00	824.00		824.00
Total returns over variable costs (rupees)	1560.15	2050.92		2012.88
Percentage of additional returns due to planning		30.68		28.89
CATEGORY 3 (farm over 15.00 acres — average = 37.77 acre area)				
Local jowar	9.66	8.82	2.00 or	7.81
Hybrid jowar	1.23		1.00	
Local paddy			0.50 or	
Taichung paddy	1.33		0.25	0.25
Local bajra	1.00		0.25 or	
Hybrid bajra	0.55	9.82	0.12	8.92
Groundnuts	1.11		0.66	0.66
Pulses	2.33		0.50	0.50
Sesame	0.88		0.25	0.25
Maize	0.55		0.50 or	
Hybrid maize			0.25	0.25
Total cropped area	18.64	18.64		18.64
Total variable costs (rupees)	2371.00	2371.00		2371.00
Total returns over variable costs (rupees)	4144.08	5472.32		5411.54
Percentage of additional returns due to planning		32.05		30.59

highly remunerative crop and local jowar being the least input-cost requiring crop in the region. After meeting the minimum crop constraints, the remaining resources in this region too are utilized in about the same manner, although the optimum returns are lowered due to these constraints. Another important feature is that the efficiency level of the farmers, no matter which size of holdings they belong to, is the same, unlike the farmers of the previously discussed regions.

With the inclusion of soybeans in the optimum plan (table 27), farms of all sizes show greater returns than the optimum plan without soybeans. The results indicate that even without increasing any resources, soybeans can be considered the most remunerative crop among the existing crops grown by the farmers of the region. Local jowar which is a low input-cost crop again is a major part of the optimum plan. When the available cash resources are increased, the acreage under this particular crop has decreased whereas the acreage under soybeans has increased significantly.

The results given in table 28 show increases of 66, 73, and 74 percent of net returns in comparison to the existing crop plan in the first, second, and third categories of holdings, even without increasing the cash resources of the farmers. However, a large part of this increase is due to the inclusion of a part of the fallow land in the optimum crop plan. The effect of the incorporation of soybeans in the optimum plan can be seen when the cash resources are increased by 50 percent and 100 percent respectively.

Indore District. The results given in table 29 confirm the same trend seen in the previous three regions, except Indore region is highly progressive and has large acreages under cotton (entirely a cash crop).

In the optimum plan without soybeans for this region, cotton is given an important position among the existing nd the rest of the resources go to local jowar, the least input-cost demanding crop. The increase in the net returns by the optimum plan is 41, 28, and 33 percent in the first, second, and third categories respectively. With minimum crop constraints, there is a reduction in the net returns of all the sizes of holdings; again, proportionately most reductions are on farms of the smallest size group where the subsistence-crop constraint is proportionately largest.

The results of the optimum plan with soybeans given in table 30 show that the soybean crop has a better production potential than the other existing crops grown by the farmers in the region, even without increasing cash resources. Soybeans utilize the maximum share of all the resources after meeting the minimum crop constraints. The next position goes to local jowar, a minimum input-cost crop.

When the availability of cash is increased by 50 percent and 100 percent, the area under soybeans would increase, reducing the acreage under the other competing crops. The acreage under soybeans increased from

Table 27. Returns after Including Soybeans in the Existing Crop Plan in Gwalior District

Crop	Acres under actual plan	Minimum constraints	Acres under optimum plan	Acres under 50 percent increase cash resources	Acres under 100 percent increase cash resources
CATEGORY 1 (farm up to 7.5 acres)					
Local jowar	0.88	0.50 or	2.11	0.83	
Hybrid jowar		0.25			0.25
Local paddy	0.33	0.50 or			
Taichung paddy	0.53	0.25	0.25	0.25	0.25
Local maize					
Hybrid maize	0.06	0.06	0.06	0.06	0.06
Pulses	0.75	0.22	0.22	0.22	0.22
Local bajra	0.22	0.11	0.11	0.11	0.11
Hybrid bajra					
Soybeans			1.11	2.39	2.94
Total cropped area	2.79		3.86	3.86	3.86
Fallow land	1.38		0.31	0.31	0.31
Total acreage	4.17		4.17	4.17	4.17
CATEGORY 2 (farm from 7.5 to 15.00 acres)					
Local jowar	2.33	1.00 or	3.72	0.62	
Hybrid jowar	0.90	0.50		0.18	0.50
Local paddy		0.50 or			
Taichung paddy	1.46	0.25	0.25	0.25	0.25
Bajra	0.55				
Hybrid bajra			0.25	0.14	
Groundnuts	0.66	0.33	0.33	0.33	0.33
Pulses	0.55	0.25	0.25	0.25	0.25
Soybeans			4.15	7.17	7.62
Total cropped area	6.45		8.95	8.95	8.95
Fallow land	4.35		1.85	1.85	1.85
Total acreage	10.80		10.80	10.80	10.80
CATEGORY 3 (farm over 15.00 acres)					
Local jowar	9.66	2.00 or	14.80	4.53	
Hybrid jowar	1.23	1.00			4.53
Local paddy		0.50 or			
Taichung paddy	1.33	0.25	0.25	0.25	0.25
Local bajra	1.00	0.25 or			
Hybrid bajra	0.55	0.12	0.25	0.25	0.13
Groundnuts	1.11	0.66	0.66	0.66	0.66
Pulses	2.33	0.50	0.50	0.50	0.50
Sesame	0.88	0.25	0.25	0.25	0.25
Local maize	0.55	0.50 or			
Hybrid maize		0.25	0.25	0.25	0.25
Soybeans			11.70	21.97	22.10
Total cropped area	18.64		28.66	28.66	28.66
Fallow land	19.13		9.11	9.11	9.11
Total acreage	37.77		37.77	37.77	37.77

Table 28. INCOME CHANGES IN THE OPTIMIZING MODELS WITH SOYBEANS IN GWALIOR DISTRICT

Size of holdings	*Existing plan*		*Optimum plan*		*With 50 percent increase cash resources*		*With 100 percent increase cash resources*	
	VC†	*NR*†	*VC*	*NR*	*VC*	*NR*	*VC*	*NR*
Category 1	293.00	701.73	293.00	1162.63	439.50	1475.51	586.00	1721.20
percentage increase				(65.68)		(110.20)		(145.28)
Category 2	824.00	1560.15	824.00	2694.22	1236.00	3507.68	1648.00	3754.18
percentage increase				(72.69)		(124.83)		(140.63)
Category 3	2371.00	4144.08	2371.00	7210.13	3556.50	9445.85	4742.00	10673.72
percentage increase				(73.98)		(127.93)		(157.56)

† VC = variable costs; NR = net returns; both are expressed in rupees.

Table 29. ACTUAL AND OPTIMUM PLAN WITHOUT SOYBEANS IN INDORE DISTRICT

Crop	*Acres under actual plan*	*Acres under optimum plan*	*Minimum constraints*	*Acres under optimum plan with constraints*
CATEGORY 1 (farm up to 7.5 acres — average = 4.11 acre area)				
Local jowar	0.90	0.69		1.30
Hybrid jowar				
Cotton	0.66	2.15	0.33	0.93
Groundnuts	0.73		0.36	0.36
Pulses	0.55		0.25	0.25
Total cropped area	2.84	[illegible].84		2.84
Total variable costs (rupees)	406.00	406.00		406.00
Total returns over variable costs (rupees)	692.37	977.85		925.91
Percentage of additional returns due to planning		41.23		33.58
CATEGORY 2 (farm from 7.5 to 15.00 acres — average = 11.52 acre area)				
Local jowar	2.77	1.56	1.00 or	1.00
Hybrid jowar	0.33		0.50	
Cotton	1.55	5.20	0.77	4.76
Groundnuts	1.00		0.50	0.50
Pulses	1.11		0.50	0.50
Total cropped area	6.76	6.76		6.76
Total variable costs (rupees)	536.00	536.00		536.00
Total returns over variable costs (rupees)	1371.53	1758.85		1716.91
Percentage of additional returns due to planning		28.29		25.23
CATEGORY 3 (farm over 15.00 acres — average = 32.90 acre area)				
Local jowar	7.36	6.25	1.00 or	6.10
Hybrid jowar	1.30		0.50	
Local maize	0.45			
Hybrid maize	0.68			0.28
Cotton	5.95	13.60	3.00	11.29
Groundnuts	2.36		1.18	1.18
Pulses	1.75		1.00	1.00
Total cropped area	19.85	19.85		19.85
Total variable costs (rupees)	1567.50	1567.50		1567.50
Total returns over variable costs (rupees)	3242.76	4328.05		4195.15
Percentage of additional returns due to planning		33.48		29.37

Table 30. Returns after Including Soybeans in the Existing Crop Plan in Indore District

Crop	*Acres under actual plan*	*Minimum constraints*	*Acres under optimum plan*	*Acres under 50 percent increase cash resources*	*Acres under 100 percent increase cash resources*
CATEGORY 1 (farm up to 7.5 acres)					
Local jowar	0.90		0.57		
Hybrid jowar				0.25	0.25
Cotton	0.66	0.33	0.33	0.33	0.33
Groundnuts	0.72	0.36	0.36	0.36	0.36
Pulses	0.55	0.25	0.25	0.25	0.25
Soybeans			1.96	2.29	2.29
Total cropped area	2.83		3.47	3.47	3.47
Fallow land	1.28		0.64	0.64	0.64
Total acreage	4.11		4.11	4.11	4.11
CATEGORY 2 (farm from 7.5 to 15.00 acres)					
Local jowar	2.77	1.00 or	4.58	1.88	
Hybrid jowar	0.33	0.50			0.50
Cotton	1.55	0.77	0.77	0.77	0.77
Groundnuts	1.00	0.50	0.50	0.55	0.55
Pulses	1.11	0.50	0.50	0.50	0.50
Soybeans			2.42	5.07	6.45
Total cropped area	6.76		8.77	8.77	8.77
Fallow land	4.76		2.75	2.75	2.75
Total acreage	11.52		11.52	11.52	11.52
CATEGORY 3 (farm over 15.00 acres)					
Local jowar	7.36	1.00 or	15.30	7.78	0.96
Hybrid jowar	1.30	0.50			0.16
Local maize	0.45		0.55	0.55	
Hybrid maize	0.68				0.28
Cotton	5.95	3.00	3.00	3.00	3.00
Groundnuts	2.36	1.18	1.18	1.18	1.18
Pulses	1.75	1.00	1.00	1.00	1.00
Soybeans			5.76	13.28	20.21
Total cropped area	19.85		26.79	26.79	26.79
Fallow land	13.05		6.11	6.11	6.11
Total acreage	32.90		32.90	32.90	32.90

1.96 acres to 2.29 acres in the first category of holdings, from 2.42 acres to 6.51 acres in the second category, and from 5.76 acres to 20.21 acres in the third category where available cash resources were increased 100 percent.

Table 31. INCOME CHANGES IN THE OPTIMIZING MODELS WITH SOYBEANS IN INDORE DISTRICT

Size of holdings	*Existing plan*		*Optimum plan*		*With 50 percent increase cash resources*		*With 100 percent increase cash resources*	
	VC†	*NR*†	*VC*	*NR*	*VC*	*NR*	*VC*	*NR*
Category 1	406.00	692.37	406.00	1270.76	609.00	1409.00	812.00	1409.10
percentage increase				(83.53)		(103.52)		(103.52)
Category 2	653.00	1299.68	653.00	2375.38	979.50	3120.45	1306.00	3595.59
percentage increase				(82.75)		(140.09)		(176.65)
Category 3	1823.00	3242.76	1823.00	6528.14	2734.50	7509.36	3646.00	9997.13
percentage increase				(101.31)		(131.57)		(205.20)

† VC = variable costs; NR = net returns; both are expressed in rupees.

Table 31 shows the variable costs and net returns (income over variable costs) under the existing and optimum crop plans after incorporating soybeans.

With the inclusion of soybeans in the optimum crop-planning models, there were significant increases in the net returns even without increases in the available cash resources. In this region, the increase is 84, 83, and 101 percent in the first, second, and third categories of holding sizes respectively. Again, the increase in net returns is partly due to the increase in the cropping acreage obtained from the fallow land.

The results further indicate that when the available cash resources are increased by 50 percent and 100 percent, the increases in the net returns are 104 percent for the first category, 140 and 177 percent for the second category, and 132 and 205 percent for the third category of holding sizes. These increases occur through the increase in available cash and not through any increase in acreage over the optimum plan.

CHAPTER FIVE

The Possible Place of Soybeans in North Central India

The agronomic data on the performance of soybeans in north central India, and other technical data on their potential use in the country, is indicative that soybeans may have great possibilities in this part of India. The economic analysis presented in the preceding chapters relating to four farm production zones in northern and western Madhya Pradesh gives strong support to this assumption. A summary of the findings follows.

The *production function analysis* brought out a number of significant relationships in farm production in the areas under investigation. Farm size could be eliminated as a factor affecting productivity and the analysis could therefore be concentrated on three input groups: human labor, bullock labor, and cash inputs. The analysis showed the latter to be the critical factor for expanding farm production. Inputs used in soybean production show higher marginal value productivities than those used for other crops in the area. The difference is largest for cash inputs — the input group in scarce supply.

Costs and returns analysis through *partial budgeting* took account primarily of cash costs; labor costs were accounted for separately. This analysis showed soybeans with a higher net return per acre than any other crop of significance in the area. In terms of gross returns per rupee of total cash costs, the advantage of soybeans over other crops becomes even more striking. In terms of returns to human labor, soybeans again show the highest rate of return.

These findings are further confirmed by the more comprehensive analysis obtained through *linear programming models.* In the optimizing models, soybeans occupy an important place among existing crops in all the regions under survey, irrespective of farm size. A summary of the results (see table 32) shows the position soybeans would take in the

Table 32. ACREAGE UNDER SOYBEANS IN OPTIMUM PLANS

Size of holdings	*Total acres of holdings*	*Cropped acres including part of fallow land*	*Acres under existing plan*	*Soybeans optimum plan*	*Area under soybeans with increase in cash resources*	
					50 percent	*100 percent*
ZONE 3 REWA						
Category 1	5.49	4.09	nil	0.84	1.54	2.25
Category 2	11.55	8.74	nil	1.96	3.61	5.25
Category 3	71.23	48.46	nil	20.19	33.00	45.26
(Total)	88.27	61.29		22.99	38.15	52.76
Percentage of total cropped area				37.51	62.24	86.08
ZONE 4 TIKAMGARH						
Category 1	5.16	4.44	nil	0.70	1.72	2.73
Category 2	10.50	8.52	nil	2.27	4.56	6.62
Category 3	30.30	24.30	nil	6.86	13.56	20.23
(Total)	45.96	37.26		9.85	19.84	29.58
Percentage of total cropped area				26.43	53.24	79.38
ZONE 5 GWALIOR						
Category 1	4.17	3.86	nil	1.11	2.39	2.94
Category 2	10.80	8.95	nil	4.15	7.17	7.82
Category 3	37.77	28.66	nil	11.64	21.97	22.10
(Total)	52.74	41.47		16.90	31.53	32.86
Percentage of total cropped area				40.75	76.03	79.23
ZONE 8 INDORE						
Category 1	4.11	3.48	nil	1.96	2.29	2.29
Category 2	11.52	8.77	nil	2.42	5.12	6.51
Category 3	32.90	26.79	nil	5.76	13.28	20.21
(Total)	48.53	39.04		10.14	20.69	29.01
Percentage of total cropped area				25.97	53.00	74.30

different zones. According to these results, soybeans would occupy 38, 26, 41, and 26 percent, respectively, of the total cropped area in the monsoon season in the four zones, without an increase in cash outlay. The share in cropped area appears large even in Indore district, despite competition with cash crops such as cotton and groundnuts.

As long as cash outlays are not increased, most of the soybean acreage would come from conversion of fallow land. If cash resources are increased by 50 percent, the acreage under soybeans nearly doubles; with a 100 percent increase in cash resources, soybean area increases still further. In both cases, other crops would be displaced, often down to the limit set by the minimum constraints.

With the inclusion of soybeans in the optimum models, there are significant increases in net returns in comparison both with existing conditions and the optimum plan without soybeans. A summary of these increases is given in tables 33 and 34.

These results show that the inclusion of soybeans in the cropping systems of the farmers in these zones would increase the income of the farmers by 88 percent without an increase in resources. About half of this gain could be obtained by optimum planning without soybeans. Up to this point, the income increment from soybeans can be traced mainly to the conversion of fallow land. Where cash resources can be increased by 50 percent, the increase in net returns would be 135 percent over present conditions, and in the case of a 100 percent increase in cash resources, the rise in net income would average 175 percent. Again, some but not all of these gains could be obtained from other crops.

These results are based on static price assumptions and cannot be used to project future changes when the impact of agricultural expansion becomes large. The results indicate however some of the possibilities for expansion that will open when a highly remunerative cash crop such as soybeans begins to increase the farmers' cash resources.

The findings on possible soybean acreages reflect conservative assumptions, because of the restrictions built into the linear programming models. Yet we need not even take them literally to realize that the total potential for this crop in north central India is very large. In northern and western Madhya Pradesh, where the present rate of monsoon (kharif) season fallowing is about 40 percent, this rate could be cut down to half; this alone would free 20 percent of the cropland in these zones in the monsoon season, without yet counting the transfer of low-yielding grain land to soybean production. If this finding is applied to only one-half of Madhya Pradesh, which is again a conservative assumption, a potential four million acres emerges in this state by fallow conversion alone. With at least a similar area in Uttar Pradesh and northwestern Bihar, and with transfer of some low-yielding grain land (especially rice) to soybeans, a round figure of

Table 33. Percentage Increase in Net Returns in Optimum Plans Due to Inclusion of Soybeans

Size of holdings	*Optimum plan without soybeans*	*Optimum plan with soybeans*	*Optimum plan 50 percent increase cash resources*	*Optimum plan 100 percent increase cash resources*
ZONE 3 REWA				
Category 1	69.31	105.03	149.45	193.60
Category 2	83.84	124.64	174.01	222.81
Category 3	95.78	145.50	224.71	300.00
Average†	82.98	125.06	182.72	238.80
ZONE 4 TIKAMGARH				
Category 1	18.31	55.22	91.77	127.95
Category 2	25.23	70.04	112.93	151.89
Category 3	29.37	80.70	126.85	168.56
Average†	24.30	68.65	110.52	149.47
ZONE 5 GWALIOR				
Category 1	29.54	65.58	110.26	145.28
Category 2	28.89	72.69	124.83	140.63
Category 3	30.59	73.98	127.93	157.56
Average†	29.67	70.75	121.01	147.82
ZONE 8 INDORE				
Category 1	33.58	83.53	103.52	103.52
Category 2	25.23	82.76	140.09	176.65
Category 3	29.37	101.31	131.57	205.20
Average†	29.39	89.20	125.06	161.79
Total average†	41.58	88.42	134.83	174.47

† Unweighted averages.

Table 34. Average Percentage Increase in Net Returns in Optimum Plans for Different Sizes of Farms in Regions under Survey

Size of holdings	*Optimum plan without soybeans*	*Optimum plan with soybeans*	*Optimum plan 50 percent increase cash resources*	*Optimum plan 100 percent increase cash resources*
Category 1	37.68	77.34	113.75	142.59
Category 2	40.80	87.53	137.96	173.00
Category 3	46.28	100.37	152.76	207.83
Average†	41.58	88.42	134.83	174.47

† Unweighted averages.

ten million acres in north central India becomes a very low estimate of the soybean potential in this part of India. A maximum estimate, which we have no reason to discuss here, would of course still be much larger.

The analysis shows that soybean plantings on large acreages are equally feasible on small, medium, and large farms.

Not all the effects of soybean production on other lines of farm output were investigated, but the advantage of soybeans over alternative crops was found to be large enough for the above presented minimum estimate to be soundly based.

Appendix

Test for Linear Relations

The test for linear relations involves the following hypothesis: The sum of the regression coefficients (elasticities) is equal to 1. The statistical test of this hypothesis consists in comparing the sum of squares of the deviations from the regression equation fitted by the method of least squares without the restriction that the sum of the coefficients is equal to 1, with the sum of squares of the deviations from another regression equation fitted with this restriction.

In order to test whether, in the fitted production function, the relationships are linear, we fit another production function under the assumption that the sum of the elasticities (regression coefficients) is 1. Then we compare the sum of squares of the residuals for both fits. These are: for the fit without the assumption of a linear homogeneous production function, 0.886244; and for the fit with the assumption indicated above, 0.898080. The difference of the two sums of squares is 0.011836 and can be tested by analysis of variance. The test function as developed by Tintner[1] is as follows:

$$F = (Q_2 - Q_1)\ (N - P)/Q_1$$

where Q_1 is the sum of squares of residuals for the regression equation fitted without the restriction, Q_2 is the sum of squares of residuals for the regression equation fitted with the restriction that the sum of the coefficients is 1, and $N - P$ stands for the degrees of freedom. We find that $F = 1.508$ and is distributed with 1 and 103 degrees of freedom. At 5 percent level of significance the permissible value of F is 3.90. Hence the empirical F is not significant. The hypothesis that there is a linear homogeneous function cannot, therefore, be rejected.

[1] Tintner, op. cit., p. 91.

India

Madhya Pradesh

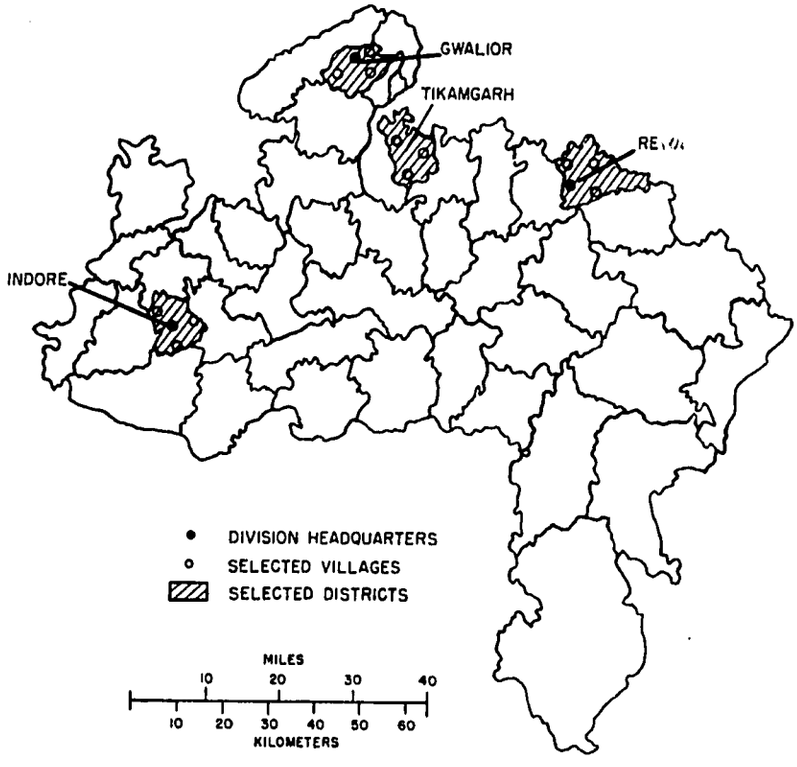

Table 35. FINAL RESULTS OF PARTIAL BUDGETING (WITH SOYBEAN CROP) AND RETURNS

Crop	District and number of observations	Added costs a_1	Reduced income a_2	Subtotal A (a_1+a_2)	Reduced costs b_1	Added income b_2	Returns over per rupees: On variable costs	Returns over per rupees: On human labor	Subtotal B (b_1+b_2)	Change in net income
Local paddy	Rewa (19)	145.16	53.77	198.93	50.63	328.12	1.29	1.66	378.75	179.82
	Tikamgarh (10)	145.16	61.80	206.96	50.30	328.12	1.41	1.84	378.42	171.46
Taichung paddy	Gwalior (11)	145.16	224.46	369.62	179.50	328.12	1.56	2.52	507.62	138.00
	Rewa (6)	145.16	156.33	301.49	94.16	328.12	1.58	2.26	422.28	120.79
	Tikamgarh (6)	145.16	209.16	354.32	148.96	328.12	1.64	3.00	477.08	122.76
Local jowar	Rewa (2)	145.16	57.50	202.66	12.50	328.12	1.41	1.82	340.62	137.96
	Tikamgarh (22)	145.16	64.54	209.70	30.73	328.12	1.40	2.00	358.85	149.15
	Gwalior (10)	145.16	74.68	219.84	30.50	328.12	1.43	2.28	358.62	138.78
	Indore (22)	145.16	57.00	202.16	24.00	328.12	1.39	1.85	352.12	149.96
Hybrid jowar	Rewa (2)	145.16	259.50	404.66	246.00	328.12	1.61	3.20	574.12	167.46
	Tikamgarh (10)	145.16	180.50	325.66	176.60	328.12	1.45	3.07	504.72	179.06
	Gwalior (4)	145.16	318.75	463.91	258.75	328.12	1.68	3.43	586.87	122.96
	Indore (3)	145.16	235.50	380.66	214.50	328.12	1.63	3.37	542.62	161.96
Local maize	Indore (2)	145.16	67.00	212.16	55.00	328.12	1.42	2.28	383.12	170.96
Hybrid maize	Gwalior (2)	145.16	243.00	388.16	174.00	328.12	1.65	2.91	502.12	113.96
	Tikamgarh (1)	145.16	168.00	313.16	151.00	328.12	1.51	2.43	479.12	165.96
	Indore (3)	145.16	258.66	403.82	202.66	328.12	1.69	3.43	530.88	127.06
Local bajra	Gwalior (5)	145.16	66.60	211.76	32.00	328.12	1.42	1.99	360.12	148.36
Hybrid bajra	Gwalior (2)	145.16	285.50	430.66	214.00	328.12	1.67	3.05	542.12	111.46
Groundnuts	Tikamgarh (2)	145.16	154.00	299.16	166.00	328.12	1.45	2.37	494.12	194.96
	Gwalior (3)	145.16	171.35	316.51	143.30	328.12	1.52	2.37	471.42	154.91
	Indore (17)	145.16	176.62	321.78	169.23	328.12	1.54	2.68	497.35	175.57
Cotton	Indore (19)	145.16	171.10	316.26	121.63	328.12	1.63	3.00	449.75	133.49
Millets	Rewa (22)	145.16	42.50	187.66	13.50	328.12	1.43	1.93	341.62	153.96
	Tikamgarh (21)	145.16	43.54	188.70	12.86	328.12	1.58	2.01	340.98	152.28
Sesame (til)	Tikamgarh (12)	145.16	89.34	234.50	45.00	328.12	1.56	2.29	373.12	138.62
	Gwalior (27)	145.16	87.00	232.16	37.00	328.12	1.55	2.12	365.12	132.96
Urd moong (pulses)	Tikamgarh (15)	145.16	79.94	225.10	28.20	328.12	1.50	2.24	356.32	131.22
	Gwalior (5)	145.16	72.00	217.16	32.00	328.12	1.55	2.07	360.12	142.96
Soybeans	(25)						2.18	5.06		

List of Publications

Economic Production Possibilities of Soybeans in Northern India: A Preliminary Study

by F. Dovring, J. R. Jindia, and R. S. Misra

International Programs and Studies I — International Agriculture 1

Additional copies of the above monograph may be obtained from the Office of International Programs and Studies, Room 301, 409 East Chalmers Street, Champaign, Illinois 61820.