A Model for Estimating the Effects of Credit Pricing on Farm Level Employment and Income Distribution

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This paper describes a method for evaluating the effects of selected policy variables on farm production mix and technology choice, and thence on the employment and incomes of different groups of beneficiaries. The main emphasis is placed on the role of the interest rate charged for farm credit. The problem is formulated as a linear programming model in which the decision-maker maximizes alternative objective functions, while varying cultivation schedules and patterns of labor and equipment use, subject to land, water, machine capacity and work rate constraints, and other agronomic restrictions. It is used to examine the effects on the size, composition and distribution of income under different combinations of four policy instruments: the interest rate, the wage rate, the farm management decision rule (the maximand) and the output price.

The model applies to a 1600 ha. irrigated farm in a village of 350 households, 150 of which do not own land. It exemplifies a method which could be applied more broadly in the design and appraisal of agricultural projects. Section V of the paper discusses the possibilities for expanding the model.

Prepared by:
Tariq Husain, Europe, Middle East and North Africa Projects Department, and
Richard Inman, Development Research Center
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Introduction

1. This paper reports a method for evaluating the effect of the interest rate used for agricultural machinery purchases on the production mix and technology choice at the farm level. The machinery purchases constituted an agricultural lending project, and hence the model was a tool for project design. In this case, the design question involved considerations of equity as well as efficiency. The production mix and technology choice both directly affect the distribution of work between labor and machines, and consequently they affect the distribution of factor incomes between the two, subject to institutional constraints.

2. While the title of the paper has singled out the "interest rate" as a main variable, the model presented is general in that the implications of any other single "price" variable (wage rate) or a combination of variables (wage rate, interest, product prices, current input prices) could be explored.

We have benefitted from comments from Lesmond Ffrench-Duval and we are especially indebted to Roger Norton who not only assisted and advised during concept formulation and problem solution stages, but also labored on our earlier drafts to help us produce a clearer exposition. Mr. Bastian Van Keulen was instrumental in the development of the technology matrix used in this paper. This paper represents the views of the authors and not necessarily those of the World Bank.
with equal ease. The model presented is in the spirit of the Mexican models\(^1\) CHAC and EL BAJIO and was developed jointly by the Europe, Middle East, and North Africa Projects Department and the Development Research Center of the World Bank. The model was used to evaluate a project which was formerly under consideration by the World Bank and the model's solutions directly influenced the Bank's appraisal of it. Although no description of the actual project is presented, the summary data reported here are real and the "problem" for which the model was designed is stated with an adequate perspective.

3. This paper has five sections. The first section defines the problem; the second defines the model briefly; the third describes selected applications of the model; the fourth discusses other ways of utilizing the existing analytical framework of the model; and the final section suggests possibilities for expressing the model.

I. THE PROBLEM IN GENERAL TERMS

4. In the broader context this paper addresses some of the analytic aspects of decision-making on relatively large farms; the focus is on the analytics of decision-making in the organizational framework of a joint stock company. In many developing countries, public or quasi-public farms have an organizational structure similar to the one described here. The model is intended for use in the exploration of the employment and income distribution effects of investment projects on such farms, under alternative national

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policies regarding a few key agricultural sector variables, and under two alternative management decision rules for the farming unit. Estimation of the broader sectoral and/or regional level effects of the investment programs has not been attempted, as that would require inclusion of market demand functions in the model and assumptions about terms of trade between agriculture and industry.

5. Due to the predominance of small farms in developing countries and the need for consolidation (in order to gain from economies of scale in the use of equipment), cooperatives or corporations in the 500 to 2000 hectare size range may be used effectively for transfer of technology to rural areas. The consolidation may take the form of converting former land owners into corporation shareholders or members of cooperatives. After the consolidation, the rural community may be defined to comprise shareholders and non-shareholders, and the income and employment effects of alternative sector policies (interest rates, output prices, ...) may be simulated with reference to these two groups.


3/ This term is used generically and includes all categories of membership in cooperative ventures. Analytically, the main difference among alternative organizational forms is embodied in the "rules" for distributing income and allocating costs. These "rules" may have substantial implications for incentives and consequently on the output response characteristics of the different organizational forms.
6. A consolidation of this type occurred in the case of the investment project in question. The major issues were the following: a) what interest rate should be used to govern the project managers' decisions on machinery purchases; b) are there significant income distributional choices, and how are these affected by the interest rate decisions; c) what should be the pricing policies for other inputs, such as irrigation water; and d) what are the cropping pattern implications of all the foregoing. In reading the results it should be borne in mind that the initial project formulation called for a relatively low interest rate (4%) and consequently a rather intensive capitalization in agricultural machinery. One of the principal issues to which the model was addressed was whether significantly higher rural employment effects, and a significantly more equitable income distribution, could be achieved through use of a higher interest rate for project design.

7. In this paper we ignore the effect that uncertainty about the production function - that tenuous relationship between inputs and outputs and incomes - has on the choices of technology and product mix. Likewise, we ignore uncertainty regarding the availability of important inputs (water, sunshine). Extensions may be made to the model in this area; the underlying theory has been partly developed, with some recent applications to agriculture. This paper also does not directly address the decision-making problems of the small farmer whose problems are more fundamental.

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small physical resource base, lack of education, production for consumption—rather than sales—which are better addressed by evaluating alternative institutional forms.

II. THE STRUCTURE OF THE MODEL

8. The model follows a linear programming formulation in which the manager of the corporation/cooperative makes choices about:

(i) which crops to plant;
(ii) how much area to allocate to each crop;
(iii) which production technologies to use for various crops; and
(iv) how to allocate water among crops.

These choices are made under different combinations of policy parameters: interest rate, wage rate, and output prices. In the model, the policy parameters are specified as exogenous variables, which are then varied in value over successive solutions. The model is structured with substantial disaggregation, with technologies defined as alternative ways of performing agricultural tasks over 24 semi-monthly time periods (one calendar year). The following agricultural tasks are taken into account: ploughing, discing, harrowing, spraying, drilling, precision planting, fertilizer spreading, cultivation, harvesting, baling, and transportation. The alternative ways

6/ In a sector-wide model, some of these parameters (wages, prices) could become endogenous variables.
of performing the above tasks are classified according to the choice of power source: 110 HP tractors; 65 HP tractors; self-propelled machinery units (cereal and forage harvesters, and cotton pickers); 2-oxen teams; and manual labor. There is flexibility for displacement of task execution over time, subject to agronomic constraints. In its most compact form, the model contains 550 constraints and 4000 non-zero coefficients. It is called the SARF model. A complete statement of the equations of the model, plus an LP tableau, is found in the annex. In these paragraphs we attempt to give a verbal overview of key interrelationships in the model.

9. The SARF model essentially depicts alternative input-output flows, or production processes. One set of choices concerns the different land-crop combinations (i.e. "crop X, 100 ha", "crop Y, 300 ha", etc.), which then must be processed by means of the agricultural tasks above to produce outputs of "crop tons". Another set of choices is the technologies ("machine processes") to be used for the various tasks. In both choice sets, there is considerable interdependence: the seasonality of input requirements makes some crop combinations more attractive than others, and also some machines can be used for multiple tasks whereas others cannot.

10. The model structure is general, as the agricultural tasks at different points of time are effectively defined as separate "machine processes"; also the work rate characteristics of alternative "power-implement" combinations could be defined as time dependent. Real life operations on farms have these characteristics. For example, crop yields depend on planting dates, and the work rate for ploughing with oxen depends on temperature on the date of ploughing and whether it has rained the day before (say).
The potential generality of the model is, however, limited by informational \(^7\) as well as computational \(^8\) constraints. In this model, therefore, crop yields have not been varied as a function of planting dates nor have work rates been related to the incidence of natural events. However, "water response functions" for different crops have been used to enable the model to choose water application rates according to economic as well as agronomic criteria.

Production cost in SARF comprise cash outlays for current inputs plus annualized costs for irrigation infrastructure and machinery. The wage rate refers to unskilled labor, which is undifferentiated. The incremental cost of skilled labor (over that of unskilled labor) is included in the operating cost of machinery. Land is not priced explicitly but is bounded. Water is bounded in availability as well as priced at its operating cost per unit volume, which includes the amortization cost of developing the infrastructure for supplying the water expressed as an annuity (and thus it varies with the exogenous interest rate). The capital cost of a unit of machinery is computed by annualizing its purchase cost over the expected life of the machine at the same interest rate.

As mentioned earlier, risk has not been incorporated in the model. The lumpiness of capital cost incurred in the acquisition of capital equipment is

\(^7\) It would be counter-productive to disaggregate beyond the limits of available information. For example, if the "crop yield vs planting date" functional relationship is unknown the model should not be specified in terms of these variables; or unless one could forecast the probability of rain on day x it would be inappropriate to include technology options which relate to rainfall. This is one of the familiar headaches of realistic model specification.

\(^8\) Even when model specification could be more detailed on informational grounds (including the problem of accounting for interactions among variables) the computational cost considerations related to model size and the other model management costs may favor a less complex model.
not fully reflected in this model. An integer programming model would have been more appropriate, but it was felt that the error of approximation involved was not likely to be substantial.

12. To express the choice regarding management decision rules, two alternative objective functions have been used: (i) profit maximization and (ii) profit plus shareholder wage maximization. Both objectives typically are feasible alternatives for the manager of a farm corporation, especially if it is state-owned. Use of the first objective function tends to favor the larger shareholders/members, who hold a disproportionate number of shares. The second objective function represents total corporation income, valuing shareholder wage income on a par with dividend income. A consequence of using this second objective function is that more on-farm employment is created, giving small shareholders a greater possibility of increasing their incomes.

13. The power sources (Para. 8), in combination with various implements, are used to perform agricultural tasks in the model. Table 1 gives the costs, expected lifetimes, fortnightly capacities and operating costs of the available pieces of machinery. Table 2 describes the technologies: the ways in which the different power sources and implements are combined to perform the agricultural tasks. The coefficients in Table 2 implicitly describe the assumptions made about the work rates of different pieces of equipment.
14. Thus Tables 1 and 2 describe the set of technologies available and the degree of flexibility in technological choices in SARF. For example, according to Table 2, the ploughing of land could be performed by using the draft unit and a 1 furrow plough (TD, DA) at the rate of 45 hours per ha; or by using a 110 HP tractor and a 5-6 furrow plough (TL, LA) at the rate of 2 hours per ha; or by using a 3-furrow plough hooked to either a 65 HP or a 110 HP tractor, at a rate of 3 hours per hectare.

15. Given the purchase prices and operating costs of machinery, the average unit cost of performing an agricultural task is a function of the wage rate, the interest rate, and the annual utilization of each machine that is used. However, the cost of an incremental unit of the task, which is the cost concept on which the model bases its decisions, further depends on machine utilization by time period. For example, during a period of under-utilization, the incremental cost of using a machine is only its operating cost because the incremental capital cost is zero in that period. If there is only one period of full utilization, the incremental cost is the operating cost plus the full capital cost of a new unit of capacity. If a machine is used to full capacity in more than one time period, then the capital cost of the last unit is allocated over all those periods, and the incremental cost of machine utilization is lower than it would be were there fewer full-capacity periods.9/ As the relative cost of capital and labor is varied, by exogenous changes in the interest and wage rates and by endogenous changes in the scheduling of machinery utilization, the incremental unit costs of the alternative technologies change, leading to changes in (i) the aggregate machinery-mix, and (ii) the mechanization level of each agricultural task.

<table>
<thead>
<tr>
<th>Item of Machinery</th>
<th>Symbol</th>
<th>Purchase Cost (10^3)</th>
<th>Expected Life (years)</th>
<th>Fortnightly Capacity (hrs.)</th>
<th>Operating Cost (per hour)</th>
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<td><strong>Power Units</strong></td>
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</tr>
<tr>
<td>110 HP tractor</td>
<td>TL</td>
<td>1000</td>
<td>5</td>
<td>140</td>
<td>220</td>
</tr>
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<td>65 HP tractor</td>
<td>TS</td>
<td>540</td>
<td>5</td>
<td>140</td>
<td>113</td>
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<td>Draft unit (2 oxen)</td>
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<td>100</td>
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<td>1500</td>
<td>6</td>
<td>140</td>
<td>770</td>
</tr>
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<td>PF</td>
<td>1500</td>
<td>10</td>
<td>140</td>
<td>1310</td>
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<td>4000</td>
<td>8</td>
<td>80</td>
<td>770</td>
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<td><strong>Implements</strong></td>
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<td></td>
<td></td>
<td></td>
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<td>for 110 HP tractor:</td>
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<td></td>
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<tr>
<td>5-6 furrow plow</td>
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<td>140</td>
<td>5</td>
<td>140</td>
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<td>140</td>
<td>54</td>
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<td>for 65 or 110 HP tractor:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 furrow plow</td>
<td>SA</td>
<td>100</td>
<td>10</td>
<td>140</td>
<td>11</td>
</tr>
<tr>
<td>Spike-tooth harrow</td>
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<td>8</td>
<td>140</td>
<td>5</td>
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<td>140</td>
<td>11</td>
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<td>6</td>
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<td>140</td>
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<td>3</td>
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<td>15</td>
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<td>4</td>
<td>140</td>
<td>12</td>
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<td>SK</td>
<td>280</td>
<td>4</td>
<td>140</td>
<td>70</td>
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<td>4-ton trailer</td>
<td>SL</td>
<td>180</td>
<td>5</td>
<td>140</td>
<td>28</td>
</tr>
<tr>
<td>for draft unit:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Furrow plow</td>
<td>DA</td>
<td>3</td>
<td>3</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Harrow</td>
<td>DB</td>
<td>3</td>
<td>3</td>
<td>100</td>
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<tr>
<td>Sprayer</td>
<td>DC</td>
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<td>3</td>
<td>100</td>
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</tr>
<tr>
<td>Drill</td>
<td>DD</td>
<td>13</td>
<td>3</td>
<td>100</td>
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<tr>
<td>Fertilizer Spreader</td>
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</tr>
<tr>
<td>Cultivator</td>
<td>DG</td>
<td>13</td>
<td>3</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>1/2 ton trailer</td>
<td>DL</td>
<td>25</td>
<td>5</td>
<td>100</td>
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<tr>
<td>for manual use:</td>
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<td></td>
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<td></td>
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<tr>
<td>Knapsack sprayer</td>
<td>MC</td>
<td>11</td>
<td>2</td>
<td>84</td>
<td>0</td>
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Table 2: SARF: ALTERNATIVE TECHNOLOGIES FOR PERFORMING AGRICULTURAL TASKS

<table>
<thead>
<tr>
<th>Agricultural Tasks</th>
<th>TD</th>
<th>TL</th>
<th>TS</th>
<th>TT</th>
<th>TA</th>
<th>IM</th>
<th>Pieces of Equipment</th>
<th>Summary: No. of Techniques Available For Each Task</th>
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<tbody>
<tr>
<td>Ploughing</td>
<td>45.0</td>
<td>2.0</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
<td>DA DA LA SA</td>
<td>3</td>
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<tr>
<td>Discing</td>
<td>5.0</td>
<td>0.6</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td>DB DB LB SB</td>
<td>3</td>
</tr>
<tr>
<td>Harrowing</td>
<td>2.0</td>
<td>1.6</td>
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<td>50.0</td>
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<td></td>
<td>DC DB SC MC</td>
<td>3</td>
</tr>
<tr>
<td>Spraying</td>
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<td>1.0</td>
<td>8.0</td>
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<td>Drilling</td>
<td>8.0</td>
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<td>DD DF SF</td>
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<tr>
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<td>1.0</td>
<td></td>
<td>50.0</td>
<td></td>
<td>SI</td>
<td>1</td>
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<tr>
<td>Beet Lifting</td>
<td>2.5</td>
<td></td>
<td></td>
<td>200.0</td>
<td></td>
<td></td>
<td>SJ</td>
<td>1</td>
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<td>Mowing</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
<td>SK SK</td>
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<td>Windrowing</td>
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<td>Baling</td>
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<td></td>
<td>SK SK</td>
<td>2</td>
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<tr>
<td>Grain Harvesting</td>
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<td></td>
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<td>1.0</td>
<td>PG</td>
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<td>Forage Harvesting</td>
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<td></td>
<td></td>
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<td>1.25</td>
<td>PF</td>
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<tr>
<td>Cotton Harvesting</td>
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<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>PC</td>
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</tr>
<tr>
<td>Transportation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>504.0</td>
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</table>

Notation: TD: draft unit (2 oxen) TT: adaptable mode which permits use of either 65 HP or 110 HP tractor
TL: 110 HP tractor TA: self-propelled equipment
TS: 65 HP tractor TM: most labor-intensive (manual) technology

1/ Equipment symbols defined in Table 1.
16. The agronomic constraints, defined as the time periods (in fortnightly intervals) demarcating the possible beginnings and ends of various agricultural tasks for the crops in the model are specified in Table 3. For example, ploughing a field for alfalfa may be done any time from December 14 (fortnight 23) to March 31 (fortnight 6); discing should follow ploughing and may be done during fortnight 6 or 7; and so on for the other agricultural tasks. The full set of combinations indicated by Table 3 is not included in the model. Rather, several alternative feasible annual cultivation schedules were chosen beforehand from the possible combinations, and the model chooses among this restricted set of combinations.

17. Crop-specific water response functions are included in the model (Figure 1); they express the relation between crop yield and total irrigation water applied. Timing of water applications is not incorporated in these functions. They are non-linear in all cases and they have been expressed by piecewise linear approximations. Downward movement over these functions results in "water saving" with a corresponding reduction in "crop yield" - the water saving and the yield reduction are adjusted through the water supply and commodity balance rows. When water availability is a constraint on production, the model will choose water-to-yield ratios for each crop from the points on the response curves, such that total returns, whether defined as profits or profits plus shareholder wages, are maximized.
Table 3: SARF: PERMISSIBLE AGRICULTURAL TASK SEQUENCES

<table>
<thead>
<tr>
<th>Month</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
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<th>February</th>
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</table>

### ALFALFA
- Ploughing
- Sowing
- Fertilizing
- Spraying herbicide
- Harvesting
- Slashing stalks in the field
- Top dressing fertilizer
- Harvesting
- Baling straw
- Transport

**Alternative 1**

### COTTON
- Ploughing
- Sowing
- Poincting
- Inter-row cultivation (2 times)
- Spraying pesticide (6 times)
- Harvesting
- Transport
- Slashing stalks in the field

### IRRIGATED WHEAT
- Ploughing
- Sowing
- Spraying herbicide
- Harrowing
- Fertilizing
- Harvesting
- Transport

The arrow-line indicates the feasible time period defining the possible beginnings and ends of the specific activity. The activity must be completed within this interval irrespective of when it is started. The precise starting and ending dates would be determined by the cropping pattern, power availability, rates of work with alternative technologies.
Table 3: (Contd.) SARR: PERMISSIBLE AGRICULTURAL TASK SEQUENCES

<table>
<thead>
<tr>
<th>Month</th>
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</tbody>
</table>

**MAIZE FORAGE**
- Discing
- Planting
- Spraying herbicide
- Inter-row cultivation
- Topdressing fertiliser
- Harvesting
- Transport to Silo

**SUGARBEET**
- Ploughing
- Discing
- Spraying herbicide
- Harrow
- Inter-row cultivation
- Fertilising
- Harvesting
- Transporting

**SUGARBEET**
- Ploughing
- Discing
- Spraying herbicide
  - Harrowing (2 times)
  - Topdressing (2 times)
- Spraying Insecticide
  - (6 times)
- Fertilising top dressing
- Beet lifting
- Transporting

---

The arrow-line indicates the feasible time period defining the possible beginnings and ends of the specific activity. The activity must be completed within this interval irrespective of when it is started. The precise starting and ending dates would be determined by the cropping pattern, power availability, rates of work with alternative technologies.
Figure 1: SARF: WATER RESPONSE FUNCTIONS BY CROP

1/ To the agronomic maximum.
18. Consider a village with 350 households of which 200 are land-owning. The total area of the land is 1,600 ha, all of which is potentially irrigable. Water is available through tube wells which give a maximum potential annual water supply of 21.73 million cubic meters.\textsuperscript{10} Wheat, soya, forage maize, alfalfa, sugar beets and cotton may be grown in the area subject to the agronomic constraints given in Table 3. Representative existing wage rates in different regions of the country are 135, 250 and 400 monetary units per man-day (which equals 6 hours); each of these wage rates is used in different model experiments. Also, labor is somewhat mobile interregionally, so further experiments were made regarding the consequences of different degrees of labor mobility.

19. As mentioned earlier, in one respect the objective of the analysis is to search a four-dimensional "policy space" comprising (i) interest rate policy; (ii) wage rate policy; (iii) farm management decision rules; and (iv) an output price policy. Of the above four, the important macro variables are the interest rate and the output pricing structure. It is assumed that wage rates cannot be significantly influenced by policy in the short run. In a way, the farm management policy may also be an important macro variable (regional emphasis, target group emphasis) - but for this analysis it is treated as a micro variable and has implications for the incomes of three groups: corporation members, corporation shareholders, and non-members (outside hired labor). The first two groups are overlapping in composition.

\textsuperscript{10} Additional water could be available at a very high cost, but that possibility is not included in the model.
20. Within a given structure of output prices and a given wage rate, a decrease in the interest rate would affect the choice of technology and thus influence the level and composition of income. Whether the effect on the level of income would be positive or negative would depend on the constraint set of the problem. The composition of income, however, could be expected to change so that the share of "profits" would increase relative to the share of "wages", as machinery is substituted for labor in field tasks. The extent of these effects would differ with the wage level - for instance, at a higher wage rate, where substantial substitution has already taken place, increases in the interest rate may have virtually no effect on technology choice and thus on the composition of income.

21. In this study, the model is used to evaluate empirically the nature and extent of changes in the following variables as a consequence of alternative "policy packages":

- level of income;
- composition of income; and
- distribution of income between the two sub-groups.

At the same time, the model provides detailed information about important intermediate processes: the technology choices, the cropping pattern, and the level and composition of the machinery stock. A change in the relative price of capital and labor, for example, changes the ranking of alternative "machine-process-agricultural task" combinations leading to changes in choice of technology; this, of course, also affects the net profitabilities (due to cost of production change) of alternative crops, resulting in changes in the cropping pattern, and the above two effects influence the level, composition and distribution of income.
In the subsequent paragraphs, model results are presented in the following sequence:

- effects of interest rate and wage rate changes under both objective functions; and
- effects of output price changes.

**Effects of interest rate and wage rate changes**

22. The effect of the interest rate on the level, composition and distribution of income depends on (i) the wage rate and (ii) the objective function of the corporation/cooperative membership. Table 4 summarizes the incremental effects of changing the interest rate from 4% to 12% with profit maximization as the objective function; Table 5 gives more details. The three wage rates reflect regional variations - 135/man-day is likely to prevail in areas of surplus labor, and 400/man-day in the vicinity of a large city or another location where heavy construction activities are in progress. The 250/man-day wage is an intermediate point on the spectrum. The wage rates are reference prices used by the decision maker (for technology choices) after having accounted for seasonal wage rate variation. The interest rate spectrum represents the extreme positions realistically possible. The most striking element of Table 4 is the ineffectiveness of the interest rate as a determinant of employment policy once the wage rate has reached its high level of 400. Given the technology and production set that was incorporated in this application of the model, the increased interest cost only serves to reduce the profit of the corporation; it does not affect the optimal pattern of mechanization.

11/ The model may be used with seasonal prices as well, and the effect of this would be reflected in the usage pattern of labor on the agricultural tasks.
Table 4: SUMMARY OF SARF RESULTS UNDER THE PROFIT MAXIMIZATION OBJECTIVE

<table>
<thead>
<tr>
<th>Wage rate (per/manday)</th>
<th>135</th>
<th>250</th>
<th>400</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Employment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (10^3 mandays)</td>
<td>29.75(44%)</td>
<td>8.31 (16%)</td>
<td>0</td>
</tr>
<tr>
<td>Shareholders</td>
<td>-0.34</td>
<td>0.97</td>
<td>0</td>
</tr>
<tr>
<td>Non shareholders</td>
<td>30.09</td>
<td>7.34</td>
<td>0</td>
</tr>
<tr>
<td><strong>Wage Bill (10^6 units)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.02</td>
<td>2.08</td>
<td>0</td>
</tr>
<tr>
<td>Shareholders</td>
<td>-0.05</td>
<td>0.24</td>
<td>0</td>
</tr>
<tr>
<td>Non shareholders</td>
<td>4.07</td>
<td>1.84</td>
<td>0</td>
</tr>
<tr>
<td><strong>Profit of Corporation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10^6 unit)</td>
<td>11.50</td>
<td>-12.30</td>
<td>-12.6</td>
</tr>
<tr>
<td>Profit - shareholder wage bill (10^6 units)</td>
<td>-11.55</td>
<td>-12.06</td>
<td>-12.6</td>
</tr>
<tr>
<td>Profit - total wage bill</td>
<td>-7.48</td>
<td>-10.22</td>
<td>-12.6</td>
</tr>
<tr>
<td>Gross value of production (10^6 units)</td>
<td>+4.94</td>
<td>+0.83</td>
<td>0</td>
</tr>
</tbody>
</table>

* Numbers in parenthesis give percentage increases over the employment level at 4% interest rate.
23. In the labor surplus situations, however, the interest rate effects on employment, profit and wage bill are significant. At a wage rate of 135 the increase in employment is 44% when the interest rate is moved from 4% to 12%. As Table 5 shows, this mainly comes about by (i) a change in the cropping pattern in favor of labor-intensive crops and (ii) a more efficient use of machinery. While aggregate employment is increased, the entire increment accrues to the non-shareholders. This occurs because (i) under profit maximization the decision maker is unconcerned about the employment and distribution effects of his decisions; and (ii) the seasonal pattern of labor demand is such that non-shareholder labor would be required to meet peak demands. The reduction in profit is essentially due to the increase in interest cost. The employment effect at a wage rate of 250 is less, but still significant. In this case, shareholders and non-shareholders both share in the employment increase, although most of the gain still goes to the non-shareholders.

24. The main conclusions from the above simulation are that increasing the interest rate:

(i) increases employment of non-shareholders;

(ii) the extent of the increase is related to the wage rate, i.e. at the highest wage rate, interest rate variation has no effect on employment or on the composition and distribution of income; and

(iii) total rural income (wage bill + profit) is reduced while income to the lending agency is increased.
Table 5: SARF MODEL: PARAMETRIC VARIATION RESULTS  
(Profit Maximization, Labor Unbounded)

<table>
<thead>
<tr>
<th>Wage Rate</th>
<th>Unit</th>
<th>Interest Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
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</tr>
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<td>4</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>

### Employment
- **A. Total**
  - Thousand
  - 66.90
  - 68.30
  - 96.65
  - 51.49
  - 51.49
  - 59.80
  - 20.50
  - 20.50
  - 20.50
- **B. Non-Shareholders**
  - Man-days
  - 21.22
  - 36.70
  - 61.31
  - 70.78
  - 20.80
  - 28.12
  - 6.87
  - 6.87
  - 6.87

### Wage Bill
- **A. Shareholders**
  - Million units
  - 4.82
  - 4.27
  - 4.77
  - 7.68
  - 7.67
  - 7.92
  - 5.45
  - 5.45
  - 5.45
- **B. Non-Shareholders**
  - Million units
  - 4.21
  - 4.95
  - 8.28
  - 5.19
  - 5.20
  - 7.03
  - 2.75
  - 2.75
  - 2.75

### Profit
- **A. Shareholders**
  - Million units
  - 4.82
  - 4.27
  - 4.77
  - 7.68
  - 7.67
  - 7.92
  - 5.45
  - 5.45
  - 5.45

### Production of:
- **Wheat**
  - Hectares
  - 250
  - 250
  - 250
  - 250
  - 250
  - 250
  - 250
  - 250

### Average annual utilization of:
- 110 HP tractor
  - % 59
  - 67
  - 80
  - 47
  - 47
  - 58
  - 61
  - 61

### Equipment purchased:
- 110 HP tractor
  - Number of 2
  - 2
  - 2
  - 3
  - 3
  - 3
  - 3
  - 4
  - 4
  - 4

- 65 HP tractor
  - Number of 12
  - 11
  - 11
  - 15
  - 15
  - 16
  - 14
  - 14

---

1. 250 man-days = 1 man year.
2. Profit = (Gross income - Production costs inclusive of labor).
3. Of shareholders and non-shareholders.
4. Assuming 200 families outside the FC.
5. Sum of profit and wage per Shareholder.
6. Assuming 150 families outside the FC.
7. Shareholders plus non-shareholders.
That is, under the profit maximization objective, if the "target group" were the shareholder population, increasing the interest rate would not be beneficial to the target group. However, if the non-shareholder population were the target group, the distribution of benefits would be significantly (depending on the wage rate) improved as a result of this policy package.

25. The effect of interest rate variation turns out to be different, however, when the objective of the corporation includes an explicit concern for its own shareholders. A way of accomplishing this is to maximize the sum of profits plus shareholder wages; through this specification the decision maker sees the opportunity cost of shareholder labor as zero, and uses this information in making his allocation decisions. The effect on employment and its sharing between shareholders and non-shareholders is substantial. Table 6 shows the incremental effects of increasing the interest rate from 4% to 12% when shareholders' wages, as well as profits, are to be maximized. (More details are given in Table 7.) In percentage terms total employment rises only one fourth as much as it did under the profit maximization objective (compare 11% in Table 6 with 44% in Table 4). However, the actual level of employment is consistently higher, for all combinations of interest rates and wage rates, with this objective function than with profit maximization alone. This can be seen from Table 8, which compares total employment, shareholder employment, and profit + shareholder wages.
Table 6: SUMMARY OF SARF RESULTS UNDER THE PROFIT PLUS WAGE MAXIMIZATION OBJECTIVE

<table>
<thead>
<tr>
<th>Wage Rate (per/manday)</th>
<th>135</th>
<th>250</th>
<th>400</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incremental Effects When The Interest Rate Is Changed From 4% to 12%</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Employment (10⁻³ manday)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10.11 (11%)*</td>
<td>-0.05 (0%)</td>
<td>-3.47 (-6%)</td>
</tr>
<tr>
<td>Shareholders</td>
<td>1.31</td>
<td>-0.11</td>
<td>-2.68</td>
</tr>
<tr>
<td>Non shareholders</td>
<td>8.80</td>
<td>0.06</td>
<td>-0.79</td>
</tr>
<tr>
<td><strong>Wage Bill</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.36</td>
<td>-0.01</td>
<td>-1.39</td>
</tr>
<tr>
<td>Shareholders</td>
<td>0.18</td>
<td>-0.02</td>
<td>-1.07</td>
</tr>
<tr>
<td>Non shareholders</td>
<td>1.18</td>
<td>0.01</td>
<td>-0.31</td>
</tr>
<tr>
<td><strong>Profit of Corporation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10⁶ units)</td>
<td>-11.68</td>
<td>-12.28</td>
<td>-11.09</td>
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<tr>
<td><strong>Profit + shareholder wage bill</strong></td>
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<td></td>
<td></td>
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<tr>
<td>(10⁶ units)</td>
<td>-11.50</td>
<td>-12.30</td>
<td>-12.16</td>
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<tr>
<td><strong>Profit + total wage bill</strong></td>
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<tr>
<td>(10⁶ units)</td>
<td>-10.32</td>
<td>-12.29</td>
<td>-12.48</td>
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<tr>
<td><strong>Gross value of production</strong></td>
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<tr>
<td>(10⁶ units)</td>
<td>-2.24</td>
<td>-1.72</td>
<td>-1.99</td>
</tr>
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</table>

* The figure in parentheses is the percentage increase (decrease) in employment over level at 4% interest rate.
### Table 7: SARF Model: Wage and Interest Variation Results
(Profit plus wage maximization, labor unbunded)

<table>
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<tr>
<th>Wage Rate</th>
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<th>250</th>
<th>400</th>
<th>400</th>
<th>400</th>
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<td>Unit</td>
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<td>4</td>
<td>8</td>
<td>12</td>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>

#### Employment

- **A. Total**
  - Thousand
    - 90.90
    - 91.01
    - 101.01
    - 69.53
    - 69.47
    - 69.48
    - 60.81
    - 58.08
    - 57.34

- **B. Non-shareholders**
  - Man/days
    - 36.60
    - 36.71
    - 47.60
    - 17.01
    - 17.01
    - 17.13
    - 3.55
    - 3.55
    - 4.76

#### Wage Bill

- **A. Shareholders**
  - Million
    - 7.06
    - 7.06
    - 7.24
    - 13.11
    - 13.10
    - 13.09
    - 22.10
    - 21.01
    - 20.99

- **B. Non-shareholders**
  - Million
    - 5.21
    - 5.23
    - 6.60
    - 4.27
    - 4.28
    - 4.28
    - 2.22
    - 2.22
    - 1.91

#### Profit

- **Profit + shareholder wage**
  - Million
    - 60.44
    - 54.64
    - 48.76
    - 51.39
    - 45.50
    - 52.20
    - 57.10
    - 50.80
    - 96.50

- **Profit + wage per shareholder**
  - Million
    - 107.01
    - 107.02
    - 104.77
    - 102.44
    - 100.72
    - 98.47
    - 98.47
    - 98.47
    - 98.47

- **Profit + wage per non-shareholder**
  - Million
    - 35.00
    - 35.00
    - 63.00
    - 28.00
    - 29.00
    - 15.00
    - 15.00
    - 15.00
    - 15.00

- **Profit + wage per rural family**
  - Million
    - 208.00
    - 197.00
    - 178.00
    - 196.00
    - 180.00
    - 180.00
    - 169.00
    - 151.00

#### Area under:

- **Wheat**
  - Hectares
    - 250
    - 250
    - 250
    - 250
    - 250
    - 250
    - 412
    - 412
    - 456

- **Soybean**
  - Hectares
    - 125
    - 126
    - 92
    - 206
    - 210
    - 208
    - 254
    - 254
    - 212

- **Maize forage**
  - Hectares
    - 260
    - 240
    - 240
    - 240
    - 240
    - 240
    - 240
    - 240
    - 240

- **Alfalfa**
  - Hectares
    - 743
    - 745
    - 822
    - 547
    - 543
    - 543
    - 324
    - 324
    - 324

- **Sugarbeet**
  - Hectares
    - 195
    - 195
    - 229
    - 197
    - 197
    - 197
    - 210
    - 210
    - 208

#### Production of:

- **Wheat**
  - Tons
    - 875
    - 875
    - 875
    - 875
    - 875
    - 875
    - 1,442
    - 1,442
    - 1,597

- **Soybean**
  - Tons
    - 14,400
    - 14,400
    - 14,400
    - 14,400
    - 14,400
    - 14,400
    - 14,400
    - 14,400
    - 14,400

- **Maize forage**
  - Tons
    - 3,604
    - 3,389
    - 2,360
    - 4,560
    - 4,560
    - 4,560
    - 4,560
    - 4,560
    - 4,560

- **Sugarbeet**
  - Tons
    - 24,660
    - 24,506
    - 25,607
    - 17,750
    - 17,597
    - 16,997
    - 10,582
    - 10,582
    - 10,582

- **Cotton**
  - Tons
    - 657
    - 657
    - 770
    - 567
    - 567
    - 567
    - 608
    - 608
    - 608

#### Average annual utilization of:

- **110 HP tractor**
  - %
    - 59
    - 64
    - 72
    - 56
    - 58
    - 58
    - 58
    - 58
    - 57

- **65 HP tractor**
  - %
    - 61
    - 61
    - 69
    - 47
    - 47
    - 47
    - 47
    - 45
    - 53

#### Equipment purchased:

- **110 HP tractor**
  - Number of
    - 2
    - 2
    - 2
    - 3
    - 3
    - 3
    - 4
    - 4
    - 4

- **65 HP tractor**
  - Number of
    - 12
    - 12
    - 10
    - 14
    - 14
    - 14
    - 13
    - 13
    - 13

---

77 250 man-days = 1 man year.
77 Profit = (Gross income - Production costs inclusive of labor).
77 Of shareholders and non-shareholders.
77 Assuming 200 families per FC.

---

TABLE 7: SARF MODEL: WAGE AND INTEREST VARIATION RESULTS
(Profit plus wage maximization, labor unbunded)
under extreme "wage-interest" co-ordinates under the two objective functions. And as one would expect, total corporation members' income is higher with the P & W objective function. It is apparent that if the target group were shareholders, the P & W objective function would be the preferred decision criterion under all interest-wage combinations. As a corollary, the non-shareholders receive only the residual spillover of work and income.

Table 8: COMPARISON OF SARF RESULTS UNDER TWO OBJECTIVE FUNCTIONS

<table>
<thead>
<tr>
<th>Wage Rate</th>
<th>Profit Maximization (P)</th>
<th>Profit + Wage Maximization (P &amp; W)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>135</td>
<td>400</td>
</tr>
<tr>
<td>Interest Rate %</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Total employment (10^3 manday)</td>
<td>66.90</td>
<td>96.65</td>
</tr>
<tr>
<td>Shareholder empl. (10^3 manday)</td>
<td>35.68</td>
<td>35.34</td>
</tr>
<tr>
<td>Profit + shareholder wage (10^6 units)</td>
<td>66.52</td>
<td>54.97</td>
</tr>
</tbody>
</table>

28. This is a rather startling example of the effect of shadow pricing on the allocation of resources and the distribution of income. The income calculations under the P & W objective functions have been made with reference to market wage rates, while the allocation decisions have been made with reference to a shadow wage rate of zero. This result is not surprising; the P & W objective function essentially decreases the relative price of labor which is the obverse of an increase in the price of capital. The driving
force in both cases is the change in relative price and this change works through the technology and production options to create the observed employment and income distribution effects. Table 9 gives a more detailed comparison of the employment, production, income distribution effects of the two alternative objective functions.

29. In summary, the SARF cropping responses are complex inasmuch as they depend not only upon relative prices but also upon seasonal complementarities in the use of land, machinery, and water. However, factor prices do tend to have systematic effects on the cropping patterns, given that factor intensities vary significantly over crops. To see this in numbers, some illustrations are drawn from Table 5 and presented in Table 10.

30. Cotton is one of the most labor-intensive crops and soybeans is the least, so this pair may be selected for illustrative purposes. At the lowest wage rate-interest rate combination (135, 4), ten hectares of cotton and 230 hectares of soybeans are planted. When the interest rate is moved to its highest level to attain the factor price combination (135, 12), labor-intensive modes of production are favored and hence the cotton area increases to 240 hectares while the soybean area drops correspondingly to zero. Note, however, that the movement in this direction is not smooth, owing to the complementarities referred to above: in Table 5, at the intermediate interest rate of 8% (with \( w = 135 \)), there is a slight reversal of the trend for these two crops.

31. The principal tendency is continued as factor prices are further changed from (135, 12) to (250, 12). This increase in the relative labor costs reduces the cotton area to zero and raises the soybean area from zero
Table 9: SARF MODEL: PARAMETRIC VARIATION FOR TWO MAXIMANDS

<table>
<thead>
<tr>
<th>Wage Rate</th>
<th>Interest Rate</th>
<th>Profit &amp; Wages</th>
<th>Profit &amp; Wages</th>
<th>Profit &amp; Wages</th>
<th>Profit &amp; Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>135</td>
<td>4%</td>
<td>4%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>250</td>
<td>4%</td>
<td>4%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Maximize:

<table>
<thead>
<tr>
<th>Employment (thousand man-days)</th>
<th>135</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Total</td>
<td>66.9</td>
<td>69.53</td>
</tr>
<tr>
<td>* Non-shareholders</td>
<td>31.20</td>
<td>59.80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wage bill (Million units)</th>
<th>135</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Shareholders</td>
<td>4.82</td>
<td>7.68</td>
</tr>
<tr>
<td>* Non-shareholders</td>
<td>4.21</td>
<td>7.47</td>
</tr>
<tr>
<td>* Total</td>
<td>9.03</td>
<td>14.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Profit /1</th>
<th>135</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit &amp; shareholder wage bill</td>
<td>66.52</td>
<td>64.50</td>
</tr>
<tr>
<td>Profit &amp; all wage bill</td>
<td>70.73</td>
<td>68.77</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area under (ha)</th>
<th>135</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Wheat</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>* Soybean</td>
<td>230</td>
<td>206</td>
</tr>
<tr>
<td>* Maize Forage</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>* Alfalfa</td>
<td>305</td>
<td>400</td>
</tr>
<tr>
<td>* Sugarbeet</td>
<td>805</td>
<td>710</td>
</tr>
<tr>
<td>* Cotton</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Utilization (%)</th>
<th>135</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>* 110 HP Tractors</td>
<td>59</td>
<td>58</td>
</tr>
<tr>
<td>* 65 Tractors</td>
<td>60</td>
<td>50</td>
</tr>
</tbody>
</table>

/1 Gross revenue - All costs of production including labor
<table>
<thead>
<tr>
<th>Solution No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage Rate (w)</td>
<td>135</td>
<td>135</td>
<td>250</td>
<td>250</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Interest Rate (R)</td>
<td>4</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Ratio (w/R)</td>
<td>33.75</td>
<td>11.25</td>
<td>20.83</td>
<td>62.50</td>
<td>100.00</td>
<td>33.33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hectares planted</th>
<th>Level</th>
<th>Change from Solution 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>Soybeans</td>
<td>230</td>
<td>-230</td>
</tr>
<tr>
<td>Cotton</td>
<td>10</td>
<td>+230</td>
</tr>
<tr>
<td>Sugar beets</td>
<td>805</td>
<td>+99</td>
</tr>
<tr>
<td>Employment</td>
<td>66.90</td>
<td>+29.75</td>
</tr>
<tr>
<td>Tractors purchased</td>
<td>14</td>
<td>-1</td>
</tr>
</tbody>
</table>
to 240 hectares. Taking another step in the same direction, moving from (250, 12) to (250, 4), soybeans are increased still more to a level of 412 hectares. In this case, the additional soybean area is provided at the expense of sugarbeets, which are comparable to cotton in being quite labor-intensive.

32. Continuing still further, the move from (250, 4) to (400, 4), another increase in the relative cost of labor, drops sugarbeets completely out of the cropping pattern and increases both soybeans and wheat (the next least labor-intensive crop). Finally, moving from (400, 4) to (400, 12) has no effect on the cropping pattern. Evidently, when labor costs are as high as with a wage rate of 400, the farm is forced into a mechanization and cropping pattern which remains optimal even under interest rate changes of this magnitude.

Effects of output price changes

33. The analysis under section (a) above essentially operated through changes in the cost of production. It should be interesting to observe the effect of varying relative profitabilities of crops through changes in their prices. Since the focus is on employment and income distribution, the price variation effects are traced through two crops (i) wheat (which is easily mechanized) and (ii) cotton (relatively labor intensive). Table 11 gives the seasonal employment effects of varying the prices of these two crops under (i) labor supply unbounded and (ii) labor supply restricted to the available village labor supply (10,200 mandays per month, equal to twice the available shareholder labor); and Table 12 gives details about the production, income and other effects of the price variations.
### Table 11: SARF MODEL: Employment Effects of Crop Price Variations
Profit and Wage Maximization, (Wage = 250, Interest = 8%)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>145% 200% 250%</td>
<td></td>
<td>118% 135% 159% 145% 200% 250%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labor bound = 10,200</td>
<td></td>
<td>Labor Unbounded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3 1 1 0 0 0 3 1 0 0</td>
<td></td>
<td>67 51 26 19 5 5 67 51 26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>59 53 53</td>
<td></td>
<td>67 51 26 19 5 5 67 51 26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100 100 100</td>
<td></td>
<td>137 114 100 35 19 19 138 114 100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>135 135 143</td>
<td></td>
<td>135 102 50 100 6 6 135 102 50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>98 100 100</td>
<td></td>
<td>94 78 34 67 25 25 100 78 34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>198 200 200</td>
<td></td>
<td>100 100 59 486 553 553 100 82 59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>48 43 41</td>
<td></td>
<td>47 47 35 41 62 62 47 47 35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>128 126 126</td>
<td></td>
<td>78 80 76 163 1,083 1,083 78 100 76</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>100 200 200</td>
<td></td>
<td>100 100 100 232 1,161 1,161 100 100 100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>100 200 200</td>
<td></td>
<td>100 100 100 116 182 182 100 100 100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>131 127 133</td>
<td></td>
<td>122 100 1 100 0 0 122 100 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>50 50 50</td>
<td></td>
<td>51 50 1 50 0 0 51 50 1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual</th>
<th></th>
<th>95.6</th>
<th>111.2</th>
<th>112.2</th>
<th>86.1</th>
<th>76.9</th>
<th>48.4</th>
<th>117.2</th>
<th>257.5</th>
<th>257.5</th>
<th>86.6</th>
<th>77.1</th>
<th>48.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total man-days</td>
<td>64,210</td>
<td>74,712</td>
<td>75,377</td>
<td>57,854</td>
<td>51,688</td>
<td>32,522</td>
<td>78,763</td>
<td>173,050</td>
<td>173,050</td>
<td>58,185</td>
<td>51,787</td>
<td>32,524</td>
<td></td>
</tr>
<tr>
<td>Man Years:</td>
<td>257</td>
<td>299</td>
<td>302</td>
<td>231</td>
<td>207</td>
<td>130</td>
<td>315</td>
<td>692</td>
<td>692</td>
<td>233</td>
<td>207</td>
<td>130</td>
<td></td>
</tr>
</tbody>
</table>

/ Price increases expressed as percentage increase over base-run prices. An employment index value of 100 is equivalent to 5600 mandays per month, which is the shareholder labor supply. The employment bound of 10,200 mandays per month represents the village labor supply.
/2 Base price is US$ 32/lb fibre.
/3 Base price is US$ 148/m. ton.
/4 250 man-days = 1 man year.
Table 12: SARF MODEL: parametric Price Variation
Profit + Wage Maximization
(Wage = 250, Interest = 8%)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>145</td>
<td>290</td>
<td>135</td>
<td>169</td>
<td>250</td>
<td>250</td>
<td>331</td>
</tr>
<tr>
<td>200</td>
<td>290</td>
<td>135</td>
<td>169</td>
<td>250</td>
<td>250</td>
<td>331</td>
</tr>
<tr>
<td>260</td>
<td>240</td>
<td>146</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>320</td>
<td>190</td>
<td>146</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Labor bound = 10,200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor unbounded</td>
<td>295</td>
<td>118</td>
<td>213</td>
<td>932</td>
<td>932</td>
<td>1365</td>
</tr>
</tbody>
</table>

Cropping pattern (ha)

<table>
<thead>
<tr>
<th>Wheat</th>
<th>Soybean</th>
<th>Maize forage</th>
<th>Alfalfa</th>
<th>Sugarbeet</th>
<th>Syngenta</th>
<th>Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>797</td>
<td>308</td>
<td>313</td>
<td>531</td>
<td>922</td>
<td>1345</td>
<td>250</td>
</tr>
<tr>
<td>133</td>
<td>163</td>
<td>173</td>
<td>231</td>
<td>234</td>
<td>226</td>
<td>0</td>
</tr>
<tr>
<td>260</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>400</td>
<td>322</td>
<td>400</td>
<td>146</td>
<td>146</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>326</td>
<td>325</td>
<td>322</td>
<td>190</td>
<td>167</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>454</td>
<td>461</td>
<td>463</td>
<td>115</td>
<td>98</td>
<td>29</td>
<td>1183</td>
</tr>
</tbody>
</table>

Machine purchases

<table>
<thead>
<tr>
<th>Tractor 110 HP</th>
<th>257</th>
<th>299</th>
<th>302</th>
<th>231</th>
<th>207</th>
<th>130</th>
<th>315</th>
<th>692</th>
<th>692</th>
<th>233</th>
<th>207</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 HP</td>
<td>67</td>
<td>64</td>
<td>65</td>
<td>51</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65 HP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average utilisation (%)

<table>
<thead>
<tr>
<th>Tractor 110 HP</th>
<th>50</th>
<th>49</th>
<th>38</th>
<th>52</th>
<th>61</th>
<th>34</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>110 HP</td>
<td>47</td>
<td>47</td>
<td>54</td>
<td>56</td>
<td>51</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65 HP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total employment (man-years)

| Non-shareholders | 642 | 74.7 | 75.4 | 57.9 | 51.7 | 32.5 | 78.8 | 173.1 | 173.1 | 58.2 | 51.8 | 32.5 |
| Shareholders    | 11.9 | 23  | 23.8 | 5.3  | 0.8  | 36.7 | 166.3 | 166.3 | 5.3  | 0.8  |     |     |

Wage bill (10^6 units)

| Non-shareholders | 3.0  | 5.8  | 6.0  | 1.3  | 0.2  | 0.0  | 8.7  | 36.1  | 36.1  | 1.3  | 0.2  | 0.0  |
| Shareholders    | 13.1  | 12.9 | 12.9 | 13.2 | 12.7 | 8.1  | 11.0 | 7.2   | 7.2   | 13.2 | 12.7 | 8.1  |

Value of maximand (10^6 units)

| Non-shareholders | 66.4 | 78.3 | 99.4 | 60.8 | 64.6 | 78.1 | 71.0 | 110.7 | 180.1 | 60.8 | 64.6 | 78.1 |
| Shareholders    |      |     |     |     |     |     |     |       |       |     |     |     |

Profit (10^6 units)

| Non-shareholders | 55.3 | 85.4 | 86.5 | 47.7 | 51.9 | 70.0 | 60.9 | 103.5 | 172.9 | 47.6 | 51.9 | 70.0 |
| Shareholders    | 64.4 | 78.3 | 99.4 | 60.8 | 64.6 | 78.1 | 71.0 | 110.7 | 180.1 | 60.8 | 64.6 | 78.1 |

Profit + shareholder wages (10^6 units)

| Non-shareholders | 69.4 | 84.1 | 105.4 | 62.1 | 64.8 | 78.1 | 79.7 | 168.8 | 216.2 | 62.1 | 64.8 | 78.1 |
| Shareholders    | 65.4 | 66.6 | 66.6 | 66.6 | 41.5 | 55.5 | 36.5 | 36.5 | 66.6 | 41.5 | 66.6 | 41.5 |

Total income per shareholder

| Non-shareholders | 332 | 391 | 497 | 304 | 323 | 391 | 356 | 524 | 901 | 304 | 323 | 391 |
| Shareholders    | 109 | 146 | 146 | 146 | 146 | 146 | 146 | 146 | 146 | 146 | 146 | 146 |

Wage income per rural family

| Non-shareholders | 198 | 240 | 301 | 177 | 185 | 223 | 227 | 419 | 618 | 177 | 165 | 223 |
| Shareholders    | 198 | 240 | 301 | 177 | 185 | 223 | 227 | 419 | 618 | 177 | 165 | 223 |

* Maximand = (Net income + shareholder wage bill) - (Non-shareholder wage bill).

1. 200 shareholders
2. 150 non-shareholders
3. Base price is US$: 32/lb. fibre
4. Base price is US$: 148/m ton
Increasing the price of cotton, with labor unbounded, creates a rapid convergence of the cropping pattern to a stable combination, as may be seen below (details Tables 11, 12).

<table>
<thead>
<tr>
<th>SARF Cropping Pattern with Labor Unbounded</th>
<th>Cotton Price Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 145 200 290</td>
</tr>
<tr>
<td></td>
<td>ha</td>
</tr>
<tr>
<td>Wheat</td>
<td>250 250 250 250</td>
</tr>
<tr>
<td>Soyabean</td>
<td>210 0 0 0</td>
</tr>
<tr>
<td>Maize forage</td>
<td>240 240 240 240</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>400 0 0 0</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>543 167 0 0</td>
</tr>
<tr>
<td>Cotton</td>
<td>197 1,183 1,350 1,350</td>
</tr>
</tbody>
</table>

Profit ($10^6$ units) 45.50 60.00 103.50 172.90
Total employment ($10^3$ manday) 69.47 78.80 173.1 173.10
Non-shareholder employment ($10^3$ manday) 17.06 34.70 144.3 144.3

The presence of wheat and maize in the final cropping pattern is due to externally imposed production and agronomic constraints. With these cropping pattern constraints binding, all price increases get funnelled into profit. The seasonal labor demand pattern (Table 11) further indicates the substantial peaking (10 times shareholder labor supply) which occurs in months 8 and 9. It may not be possible to satisfy such peak demands. The effect of constraining the labor supply may be seen in the parallel case with labor bounded:
Tables 11 and 12 show a more plausible seasonal labor demand pattern and a more realistic cropping pattern when the labor supply is bounded. But the labor bound causes a high price to be paid in terms of profit foregone (86.4 million). In situations like this, there would be strong pressures to import labor from other regions.

35. Under both cases, employment increases are mainly a function of the cropping pattern (increased amounts of cotton relative to other crops) but with some very interesting changes in the machinery mix: elimination of the cotton picker, increased use of the large tractor, and reduced total horsepower through both tractors.
When the wheat price is increased, the peak seasonal demand for labor does not go beyond the available village supply of labor, owing to the lower labor intensity of that crop. In this case, the seasonal labor demand patterns are identical with and without labor constraints (Table 11). However, the wheat price changes do cause substantial variations in the cropping pattern and machinery mix, with the consequence of substantial reduction in total employment and corresponding changes in the composition and distribution of income.

Main conclusions

36. The SARF model was used to simulate the effects of varying interest rate, wage rate, and output prices on employment, level and composition of income under two objective functions in the framework of an interdependent economic system. The main conclusion of the analysis is that the design of policy could be better made with explicit
reference to (i) the target groups, (ii) resource technology constraints, and (iii) alternative possible values of the available policy instruments. In terms of the target groups of this analysis, the non-shareholders benefit most under the profit maximization objective and a high interest rate while the shareholders fare better if P&W maximization is the objective, interest rate is low, and output prices are high. Needless to say, these are empirical results constrained by the scope of the model and the appropriateness of its specification. The point is that a model like this can be used to explore systematically the consequences of policy alternatives, at least in terms of relative magnitudes for a given particular situation.

37. There are a number of other uses of such a model which are discussed next, followed by some suggestions about expanding the scope of the model.

IV. OTHER USES OF THE MODEL

38. The underlying premise of this model is that project design could be improved and project appraisal facilitated if analysts could explore a larger set of alternatives than they are presently able to do. This premise has two parts: (i) the specification of technical and behavioral relationships which is the art and science of the analyst and (ii) given a specified set of relationships, the evaluation of the effect of alternative policy instruments, which is essentially a question of technology (existence of algorithms and easy access to computers). The first part of the premise is the more difficult; it could be aided by theory as well as feedback from selective empirical adventures but it
requires sensitive judgements from analysts. The second part is simpler, and mainly requires development work on algorithms. At this stage, however, the latter (not the former) is the binding constraint on improving project designs/appraisals. Both parts are addressed in this paper; the first through one example of a specification, the second through the development of the computer program which was used in the analysis and can be used by others for a number of other purposes with or without alternative specifications about technical and behavioral variables.

39. As it is presently formulated, the model (computer program) may be easily used for the following specific analyses (all of which are interrelated):

- farm budget analysis
- cropping pattern planning
- machinery stock acquisition planning and machinery stock usage
- water supply planning

Each of these uses are briefly discussed below.

40. Farm budget analysis. The model essentially performs farm budget analysis - which crops, on what acreages, with which technology, and with what income effects. It is able to answer the above questions under a much wider range of assumptions than is at present possible without the aid of a computer. The model permits a far more disaggregated analysis than is possible in a conventional farm budget, as it enables the analyst to get such specific details as (i) how many tractors; (ii) of which horsepower; (iii) used for which
agricultural tasks; (iv) extent of tractor utilization; and (v) costs of inputs, and so on. The model may be operated at various levels of disaggregation depending on the availability of information.

41. **Cropping pattern planning.** This is a subset of farm budgeting but may be singled out as a focus of analysis. The implications of alternative cropping patterns may be traced to find out about the seasonal pattern of machine, labor and input use. This would aid in the selection of a cropping pattern which fits within the existing resource constraints or which would fit future resource availabilities.

42. **Machinery stock acquisition planning.** Another sub-problem which may be singled out for analysis is to trace out substitution of alternative machine systems; to work out their use in the performance of agricultural tasks; to improve utilization of machinery pools; to evaluate the comparative economics of renting vs. buying; and so on.

43. **Water supply planning.** Another subset which may require special attention in case there is considerable overlap of competing demands; to estimate the trade-offs between meeting the full agronomic water requirements of crops vs. starving one crop to feed another crop; and so on.

44. The possibilities are substantial and the major benefit is in enabling the analyst to explore alternatives and options in order to extract the most out of the resources available to a farm.

V. **POSSIBILITIES FOR EXPANDING THE MODEL**

45. The model presented in this paper is like a first draft - it can be improved. This is inevitable and desirable. Without getting
into much detail let us suggest three priority directions in which this model may be expanded:

(i) response to irrigation water as a function of time of application;
(ii) effects on yields of:
    soil type
    planting date
    harvesting technology
(iii) financial variables—effects of incidence of cash costs
    (like fortnightly wage payments vs. annual interest payments) on choice of technology.

46. Irrigation water response. As the model is presently formulated, crop yield per hectare is related to the total water applied. It would be more realistic to divide the growing period into several stages and to have yield respond differently to moisture deprivation in each stage. In many cases, however, this treatment will not be possible because sufficient data will not be available. Nevertheless, time-dependent water response functions would be a significant enrichment of the model and they should be included when the data permit.

47. Effect on yields. In this model, yield effects are confined to (i) water deprivation and (ii) harvesting technology for cotton. The model could be expanded to include yield responses in relation to agronomic practices (simply described by planting date above) and soil type variation.
48. **Financial variables.** This is a major omission of the model. In making choices about technology, the manager is strongly influenced by the time pattern of cash inflows and outflows - i.e. can he meet the wage bill? Can he borrow for working capital? How much can he borrow? What are the rescheduling options for short-term as compared with long-term debt? The choice of a higher capital intensity may often be strongly influenced by the simple fact that working capital (for meeting the more frequent wage bill outflows of cash) is not available, or is costly or is insufficient. In addition, lenders may put financial constraints on his balance sheet requiring him to keep a certain cash position, or a debt-equity position, or a certain composition of assets, etc. In a realistic technology choice simulation these financial constraints must be reflected. If priority were desired, this expansion of the model should be the first that should be made.
1. This annex presents a detailed algebraic statement of the SARF model. The presentation is summarized in Table A, the linear programming tableau.

2. The SARF model has approximately 550 rows, 500 columns, and almost 4000 non-zero coefficients. A commercially available matrix generator language was used to prepare the model for input to the linear programming algorithm. For models containing several thousand non-zero coefficients, computer generation is essential in order to reduce errors and to facilitate parametric variations. Furthermore, the generator program provides precise documentation of the model in terms of its basic data and structure. This is an advantage not only when the size of a model is large, but also when a number of people work together on a model, each contributing his own specialized agricultural, economic, or regional knowledge. The algebraic notation used here corresponds closely to the notation used in the program. Both presentations identify numerical values and specify matrix vectors by reference to meaningful sets of elements.

3. A few comments on the size of the matrix may be in order. The SARF model takes account of 16 agricultural tasks, 29 types of equipment, and 6 technology classifications, each of which must be indexed by 24 time periods. If all possible combinations of these set elements are included, the model would have 384 agricultural service balances, 696 equipment capacity constraints, and 2304 agricultural technology vectors. However, Table 2
in the text specifies that only 35 out of the 96 possible techniques are relevant so that only 840 technology vectors need be included. Furthermore, not all tasks can be performed in all time periods. For example, forage harvesting can occur in only 2 of the 24 time periods, so that 44 rows and 22 more columns can be eliminated. The computer program performs this elimination procedure for all tasks, by analyzing the crop cultivation schedules, and finally generates a model with 130 service balances, 355 equipment capacity constraints and 322 technology vectors.

A. Algebraic Statement of the SARF Model

Set identification

The following subscripts are used to identify coefficients, activities, and equations in the model. Small letter subscripts represent sets of elements; capital letter subscripts represent particular elements of a set.

<table>
<thead>
<tr>
<th>No. of elements</th>
<th>Set subscript</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>c</td>
<td>crops</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WI irrigated wheat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SY soybeans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MF maize forage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AL alfalfa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SB sugar beets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CT cotton</td>
</tr>
<tr>
<td>24</td>
<td>t</td>
<td>fortnightly time periods</td>
</tr>
<tr>
<td>16</td>
<td>g</td>
<td>agricultural tasks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PL ploughing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DS discing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HR harrowing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SP spraying</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PD drilling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PN precision planting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FT fertilizer spreading</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CL cultivating</td>
</tr>
</tbody>
</table>
Classification by power source of the agricultural technology vectors:

- D: draft unit
- L: 110 HP tractor
- S: 65 HP tractor
- T: choice of 65 or 110 HP tractor
- A: self-propelled units
- M: manual operations

The elements of this set are described in Table 1. The set is divided into the set of power units and:

- m: subset m, implements plus self-propelled units. Often this subset is itself subscripted mf,g to indicate that the particular element is a function of the choice of technology f and the task g being performed.

Identification of coefficients:

- z: Cost per m³ of water calculated by amortizing the exogenously estimated capital costs over a thirty year period at an interest rate, r, which is varied in successive runs. The interest rate does not appear explicitly in the tableau or the equations; rather, it is implicit in the values of z and kq.

- Yc,i: Crop yields in metric tons per hectare, and corresponding water requirements along the water response function of each crop.

  The response function is approximated by the piecewise linear function that connects the specified points, indexed by i. Yields and water requirements are maximal when i = 0.

- Pc: Selling price per metric ton of crop c.

- dc,i: Monetary cost per hectare of input i for crop c. These inputs are seed, fertilizer, herbicides, and pesticides.
\[ \delta_{c,j,t} \]
equals 1 if crop \( c \) on schedule \( j \) is under cultivation during time period \( t \); otherwise, equals 0.

\[ b_{c,j,t} \]
man-hrs. of labor required by crop \( c \), schedule \( j \) during time period \( t \).

\[ a_{c,j,g,t} \]
Level of demand for agricultural service \( g \) by crop \( c \), schedule \( j \), during time period \( t \).

\[ h_{f,g} \]
Hours of equipment and labor use required by technology \( f \), to provide one unit of agricultural service \( g \).

\[ V_q \]
Hourly operating cost of equipment \( q \) subscripted \( V_{mf,g} \) to indicate a piece of equipment functionally dependent on the elements of \( f \) and \( g \).

\[ k_q \]
Capital cost of equipment \( q \) amortized at interest rate \( r \) over the expected life of the equipment.

\[ x_q \]
Number of hours that a unit of equipment \( q \) may be operated during each fortnight.

**Identification of Activities**

<table>
<thead>
<tr>
<th>No. of Columns</th>
<th>Name</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>( C_{c,j} )</td>
<td>crop cultivation schedules-number of hectares cultivated under each schedule ( j ) for each crop ( c ).</td>
</tr>
<tr>
<td>17</td>
<td>( WS_{c,i} )</td>
<td>water response function-number of hectares, to which is applied the water use and yield reduction specified by segment endpoint ( i ), for each of ( c ) crop-specific functions.</td>
</tr>
<tr>
<td>1</td>
<td>WSUP</td>
<td>water supply-cubic meters of water consumed per annum</td>
</tr>
<tr>
<td>6</td>
<td>DEM( _c )</td>
<td>crop sales-metric tons of crop ( c ) produced and sold per annum</td>
</tr>
<tr>
<td>322</td>
<td>( T_{f,g,t} )</td>
<td>agricultural technologies - the number of units of agricultural task ( g ) performed during time period ( t ) by each technology classification ( f ). Except for transportation, which is in ton-hours, the units are the number of hectares on which the task is performed.</td>
</tr>
</tbody>
</table>
choice of tractor size - hours of small $S$ and large $L$ tractor utilization in technology classification $T$, by time period $t$.

equipment purchase - number of units purchased for each equipment specification $q$, including all power units, implements, and self-propelled units.

employment - number of man-days of labor employed in each time period $t$.

Identification of Equations

<table>
<thead>
<tr>
<th>No. of Rows</th>
<th>Row Name</th>
<th>Identification and Equation Listing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FOB</td>
<td>Objective function: maximize profit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\sum_c P_c \cdot \text{DEMC}_c$ revenue from sale of crops</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$- \sum_{i,j} d_{c,i} C_{c,j}$ minus cost of seed, fertilizer, herbicides and pesticides</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$- z \cdot \text{WSUP}$ minus cost of water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$- \sum_v [h_{D,v} (v_{TD} + v_{MD,v}) v_{D,v} + h_{L,v} (v_{TL} + v_{ML,v}) v_{L,v} + h_{S,v} (v_{TS} + v_{MS,v}) v_{S,v} + h_{T,v} v_{MT,v} v_{T,v} + h_{A,v} v_{MA,v} v_{A,v} + h_{M,v} v_{MM,v} v_{M,v}]$ minus operating cost of equipment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$- \sum_v v_{TL} v_{TT,L,v} - \sum_v v_{TS} v_{TT,S,v}$ minus amortized cost of purchased equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$- \sum_w LEMP_t$ minus wages paid to labor</td>
</tr>
<tr>
<td>6</td>
<td>CB$_c$</td>
<td>Crop Commodity balance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\sum_{j} y_{c,o} C_{c,j}$ yield generated by cultivation activities</td>
</tr>
</tbody>
</table>
minus yield reduction due to reduced water use

- DEM  

minus crop sales equals 0

1 Water Annual demand for water

\[ \sum_{c} \sum_{j} u_{c,o} \cdot C_{c,j} \]  
water demanded by cultivation activities

\[ \sum_{c} \sum_{i} (u_{c,o} - u_{c,i} ) WS_{c,i} \]  
minus water saved by moving along the water response functions of each crop

WSUP  =  0  
minus total annual water requirement equals zero

6 WLc Convexity constraints for segmented water response functions

\[ \sum_{c} C_{c,j} \]  
hectares planted in each crop

\[ - \sum_{c} WS_{c,i} < 0 \]  
hectares to which the water response function is applied \leq 0

Agronomic constraints

1 ULMF  

\[ \sum_{j} C_{MF,j} \leq 240 \]  
total hectares planted in maize forage \leq 15% of total area

1 ULAL  

\[ \sum_{j} C_{AL,j} \leq 400 \]  
total hectares planted in alfalfa \leq 25% of total area

24 LND  

Land constraints

\[ \sum_{c} \sum_{j} \delta_{c,j,t} \cdot C_{c,j} \leq 1600 \]  
total land area under cultivation at time period \( t \) \leq total land available

24 EKU_t  

Labor requirements

\[ \sum_{c} \sum_{j} b_{c,j,t} \cdot C_{c,j} \]  
hours of labor required by the cropping activities

\[ + \sum_{f} \sum_{g} h_{f,g,t} \cdot T_{f,g,t} \]  
plus hours of labor required by the agricultural technology vectors

\[ - 6 \cdot LEMP_t \leq 0 \]  
minus six hours/day times the number of days of labor employment \leq 0
Agricultural task balances

\[ \sum \sum a_{c,j,g,t} \cdot C_{c,j} \] demand for agricultural service \( g \) in time period \( t \) by the cultivation schedules

\[- \sum \sum T_{f,g,t} \cdot f_{g,t} = 0 \] minus the supply of service \( g \) in time period \( t \) by the set \( f \) of technology vectors equals zero.

Equipment capacity constraints

Draft Units

\[ E_{TD,t} \] hours of demand for draft units in time period \( t \)

\[- x_{TD} \cdot EP_{TD} \leq 0 \] minus hours available in each fortnight \( \leq \) zero

110 HP Tractors

\[ E_{TL,t} \] hours of demand for 110 HP tractors in time period \( t \)

\[- x_{TL} \cdot EP_{TL} \leq 0 \] minus hours available in each fortnight \( \leq \) zero

65 HP Tractors

\[ E_{TS,t} \] hours of demand for 65 HP tractors in time period \( t \)

\[- x_{TS} \cdot EP_{TS} \leq 0 \] minus hours available in each fortnight \( \leq \) zero

Implements and self-propelled units

\[ E_{mf,g,t} \] hours of utilization of implement \( m \) demanded by the technology vectors in time period \( t \)

\[- x_{mf,g} \cdot EP_{mf,g} \leq 0 \] minus hours available in each fortnight \( \leq \) zero
Tractor choice constraint

\[ \sum_{T} g_{T,t} = h_{T,t} \]

hours of demand for tractors by technology classification \( T \) in time period \( t \).

\[ T_{L,t} \]

minus supply met with 110 HP tractors.

\[ T_{S,t} = 0 \]

minus supply met with 65 HP tractors equals zero.

Total equations

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A model for estimating the effects of credit pricing on farm level employment and