AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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BATCH #14

1. SUBJECT CLASSIFICATION

A. PRIMARY
Agriculture — AA00-0000-G704

B. SECONDARY
General--Korea Rep.

2. TITLE AND SUBTITLE
Preliminary user's guide to the recursive linear programming resource allocation component of the Korean Agricultural Sector Model

3. AUTHOR(S)
De Haen,Hartwig

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1973	79p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Mich.State

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*
(In KASS working paper 73-2)

9. ABSTRACT

10. CONTROL NUMBER
PN-RAA- 747

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Computer programs
Korea Rep.
Simulation

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-2975 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

OAU

wd 2975

Agr. 17 //

PRELIMINARY USER'S GUIDE

to the

RECURSIVE LINEAR PROGRAMMING RESOURCE ALLOCATION COMPONENT

of the

KOREAN AGRICULTURAL SECTOR MODEL

Hartwig de Haen

KASS Working Paper 73-2

Korean Agricultural Sector Study
Agricultural Economics Research Institute
Ministry of Agriculture and Fisheries
Seoul, Korea

May, 1973

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1/ This working paper replaces Appendices A and B of KASS Working Paper 72-1, October, 1972.

2/ This appendix does generally not include data and assumptions already contained in the current version of the KASS-Model.

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The model is composed of two major components, the one periodic Linear Programming component and the dynamic Feedback and Linkage between different planning periods.

1. <u>The Linear Programming Component</u> (LP)

The LP component for each year is block diagonal with one block for each of the three regions. In addition there is an overlapping band of equations to account for constraints which hold for all regions simultaneously. Table 1 contains a schematic representation of this multiregional LP matrix. The objective function $\pi(t) = \langle \bar{z}(t), \bar{x}(t) \rangle$ contains farmers' profit expectations, i.e. those expected gross revenues minus variable costs which are not endogenously priced within the model and hence do not appear in the input-output matrix. It is assumed that farmers try to maximize this function subject to the constraints stated in the model. As a result of the maximizing process the model yields a vector of levels of activities $\bar{x}^r(t)$ (primal solution) and a vector of shadow prices for each constraint $\bar{r}^r(t)$ (dual solution).[1/]

The structure of the regional input-output matrix is the same for each of the three regions. Differences in the regional production functions and in the production or investment opportunities are taken into account by varying the coefficients or by blocking single activities. It is therefore enough to describe only one of the three matrices including the corresponding national constraints in detail.

Table 2 contains definitions of variables used in the linear programming component.

1/ The following terms, used in either this paper or in the corresponding computer programs, are equivalent: (x,ACT), (z,OBJ), (u,RHS), (r,PI).

Table 1

Structure of the Multiregional LP Model for a Given Period t 1/

$\bar{z}^1(t)\cdot\bar{x}^1(t) + \bar{z}^2(t)\cdot\bar{x}^2(t) + \bar{z}^3(t)\cdot\bar{x}^3(t)$	$=$	$\pi^*(t) = \max!$
$\underline{A}_1^1(t)\cdot\bar{x}^1(t)$	$\vdots$	$\bar{y}^1(t)$
$\underline{A}_2^2(t)\cdot\bar{x}^2(t)$	$\leq$	$\bar{y}^2(t)$
$\underline{A}_3^3(t)\cdot\bar{x}^3(t)$	$\geq$	$\bar{y}^3(t)$
$\underline{A}_4^1(t)\cdot\bar{x}^1(t) + \underline{A}_4^2(t)\cdot\bar{x}^2(t) + \underline{A}_4^3(t)\cdot\bar{x}^3(t)$	$\vdots$	$\bar{y}^4(t)$

1/ $\bar{z}^r(t)$ vector of objective function coefficients

$\bar{x}^r(t)$ vector of activity levels

$\bar{y}^r(t)$ vector of constraints

$\underline{A}_p^r(t)$ matrix of input output coefficients (activities of region r and equations of region p)

r,p = 1, 2, 3 stands for regions 1, 2, 3

$p = 4$ stands for the whole country

t stands for time periods (years)

$$\bar{z}^r(t) = \left\{ z_1^r(t), \ldots\ldots\ldots\ldots, z_{k_r}^r(t) \right\}$$

$$\bar{x}^r(t) = \left\{ x_1^r(t), \ldots\ldots\ldots\ldots, x_{k_r}^r(t) \right\}$$

$$\bar{y}^r(t) = \left\{ y_1^r(t), \ldots\ldots\ldots\ldots, y_{m_r}^r(t) \right\}$$

$$\underline{A}_p^r(t) = \begin{bmatrix} a_{p1}^{r1}(t), \ldots\ldots\ldots\ldots & a_{p1}^{rk_r}(t) \\ \vdots & \vdots \\ a_{pm_r}^{r1}(t) \ldots\ldots\ldots\ldots & a_{pm_r}^{rk_r}(t) \end{bmatrix}$$

For simplicity the regional submatrices are defined for the same set of rows and columns, i.e. $k_1=k_2=k_3$ and $m_1=m_2=m_3$

Table 2

Definition of Variables in the Recursive Programming Model

L P Problem

Constraint Vector r = 1, 2, 3(regions)

y_1^r (t)	Paddy Land Capacity (1,000 ha)
y_2^r (t)	Upland Capacity for Annual Crops (1,000 ha)
y_3^r (t)	Area Available for Double Cropping (Winter upland) (1,000 ha)
y_4^r (t)	Oxen Labor Balance in Season 1 (June) (1,000 hrs)
y_5^r (t)	Labor Capacity in Season 1 (June) (Mill. hrs)
y_6^r (t)	Labor Capacity in Season 2 (October) (Mill. hrs)
$y_7^{r'}$ (t)	Oxen Labor Balance in Season 2 (October) (1,000 hrs)
y_8^r (t)	Tiller Capacity in Season 1 (June) (1,000hrs)
y_9^r (t)	Tiller Capacity in Season 2 (October) (1,000 hrs)
y_{10}^r (t)	Rice Transplanter Capacity in June (1,000 hrs)
y_{11}^r (t)	Balance Equation for Barley (1,000 MT)
y_{12}^r (t)	Balance Equation for Potatoes (1,000 MT)
y_{13}^r (t)	Balance Equation for Feed Concentrates (1,000 MT TDN)
y_{14}^r (t)	Balance Equation for Roughage (1,000 MT TDN)
y_{15}^r (t)	Area of Potential Pasture Land (1,000 ha)
y_{16}^r (t)	Maximum Feasible Size of Current Dairy Herd (1,000 Dairy Cattle Aggregates)
y_{17}^r (t)	Maximum Feasible Size of Current Korean Cattle Herd (1,000 Cattle Aggregates)
y_{18}^r (t)	Maximum Feasible Size of Current Sow Herd (1,000 Hog Aggregates)
y_{19}^r (t)	Acreage of Orchards in Production (1,000 ha)
y_{20}^r (t)	Acreage of Mulberry Fields in Production (1,000 ha)

continued ...

Table 2 (continued)

y^r_{21} (t)	Flexibility Constraint for Wheat Production (Lower Bound) (1,000 ha)
y^r_{22} (t)	Flexibility Constraint for Barley Production (Lower Bound) (1,000 ha)
y^r_{23} (t)	Flexibility Constraint for Vegetable Production (Upper Bound) (1,000 ha)
y^r_{24} (t)	Flexibility Constraint for Hog Production (Lower Bound) (1,000 Hog Aggregates)
y^r_{25} (t)	Flexibility Constraint for Planting of New Orchards (Upper Bound) (1,000 ha)
y^r_{26} (t)	Flexibility Constraint for the Expansion of the Dairy Herd (Lower Bound) (1,000 Dairy Cattle Aggregates)
y^r_{27} (t)	Investment Constraint for Investment in Tillers (1,000 machines)
y^r_{28} (t) *	Constraint (Upper Bound) for Egg Production (Mill. hens/yr)
y^r_{29} (t) *	Constraint (Upper Bound) for Broiler Production (Mill. broilers/yr)
y^r_{30} (t) *	Flexibility Constraint for Summer Grain (Upper Bound) (1,000 ha)
y^r_{31} (t) *	Flexibility Constraint for Summer Grain (Lower Bound) (1,000 ha)
y^r_{32} (t) *	Flexibility Constraint for Industrial Crops (Upper Bound) (1,000 ha)
y^r_{33} (t) *	Flexibility Constraint for Industrial Crops (Lower Bound) (1,000 ha)
y^r_{34} (t) *	Flexibility Constraint for Potatoes (Upper Bound) (1,000 ha)
y^r_{35} (t) *	Flexibility Constraint for Potatoes (Lower Bound) (1,000 ha)
y^r_{36} (t) *	Flexibility Constraint for Tobacco (Lower Bound) (1,000 ha)

continued ...

* The actual row index of this constraint in the program is different. See note on next page.

National Overall Constraints:

y_1^4 (t) National Constraint for Planting of New Mulberry Fields (Upper Bound) (1,000 ha)

y_2^4 (t) National Constraint for Tobacco Production (Upper Bound) (1,000 ha)

y_3^4 (t) Restriction for Feed Grain imports (1,000 MT TDN)

Note:

As of May, 1973,) the constraints listed as y_{28}^r ..... y_{36}^r have different indices in the computer program. They will be rearranged as soon as a more general matrix generation routine for block diagonal LP problems has been developed.

Region r / Row y	1	2	3
	Index in the computer program		
28	85	87	89
29	86	88	90
30	91	98	105
31	92	99	106
32	93	100	107
33	94	101	108
34	95	102	109
35	96	103	110
36	97	104	111

continued ...

Table 2 (continued)

<u>Activity Vector</u> r = 1, 2, 3(regions)[1/]

$x_1^r(t)$	Production of Rice (with Traditional Technology) (1,000 ha)
$x_2^r(t)$	Production of Rice (with Power Tiller,[2/] Planting by Hand) (1,000 ha)
$x_3^r(t)$	Production of Rice (Planting with Transplanter, Cultivation with Traditional Technology) (1,000 ha)
$x_4^r(t)$	Production of Rice (with Power Tiller and Transplanter) (1,000 ha)
$x_5^r(t)$	Production of Wheat (with Traditional Technology) (1,000 ha)
$x_6^r(t)$	Production of Wheat (with Power Tiller) (1,000 ha)
$x_7^r(t)$	Production of Barley (with Traditional Technology) (1,000 ha)
$x_8^r(t)$	Production of Barley (with Power Tiller) (1,000 ha)
$x_9^r(t)$	Production of Summer Grains (with Traditional Technology) (1,000 ha)
$x_{10}^r(t)$	Production of Summer Grains (with Power Tiller) (1,000 ha)
$x_{11}^r(t)$	Production of Industrial Crops (with Traditional Technology) (1,000 ha)
$x_{12}^r(t)$	Production of Industrial Crops (with Power Tiller) (1,000 ha)
$x_{13}^r(t)$	Production of Vegetables (with Traditional Technology) (1,000 ha)
$x_{14}^r(t)$	Production of Vegetables (with Power Tiller) (1,000 ha)
$x_{15}^r(t)$	Production of Potatoes (with Traditional Technology) (1,000 ha)
$x_{16}^r(t)$	Production of Potatoes (with Power Tiller) (1,000 ha)
$x_{17}^r(t)$	Production of Tobacco (with Traditional Technology) (1,000 ha)

continued ...

1/ All variables refer to yearly time intervals.
2/ Power tiller and attachment, including a binder.

Table 2 (continued)

$x_{18}^{r}(t)$	Production of Tobacco (with Power Tiller) (1,000 ha)
$x_{19}^{r}(t)$	Production of Forage (with Traditional Technology) (1,000 ha)
$x_{20}^{r}(t)$	Production of Forage (with Power Tiller) (1,000 ha)
$x_{21}^{r}(t)$	Feeding of Barley to Livestock (1,000 MT)
$x_{22}^{r}(t)$	Feeding of Potatoes to Livestock (1,000 MT)
$x_{23}^{r}(t)$	Human Consumption of Barley (1,000 MT)
$x_{24}^{r}(t)$	Human Consumption of Potatoes (1,000 MT)
$x_{25}^{r}(t)$	Grass Production, Extensive (No Fertilizer) (1,000 ha)
$x_{26}^{r}(t)$	Grass Production, Intensive (1,000 ha)
$x_{27}^{r}(t)$	Production of Milk and Dairy Beef (Unit: 1,000 Dairy Cattle aggregates)
$x_{28}^{r}(t)$	Keeping of Korean Cattle as Draft Animals (Unit: 1,000 Korean Cattle Aggregates)
$x_{29}^{r}(t)$	Production of Hog (Unit: 1,000 Hog Aggregates)
$x_{30}^{r}(t)$	Production of Eggs (Unit: Mill. Hens)
$x_{31}^{r}(t)$	Production of Broiler Meat (Unit: Mill. Chickens)
$x_{32}^{r}(t)$	Production of Fruits from Existing Orchards (1,000 ha)
$x_{33}^{r}(t)$	Planting of New Orchards (1,000 ha)
$x_{34}^{r}(t)$	Production of Silk from Existing Mulberry Fields (1,000 ha)
$x_{35}^{r}(t)$	Planting of New Mulberry Fields (1,000 ha)
$x_{36}^{r}(t)$	Gross Investment in Power Tillers, Incl. Attachment (1,000 tillers)
$x_{37}^{r}(t)$	Gross Investment in Rice-Transplanters (1,000 Transplanters)
$x_{38}^{r}(t)$	Keeping of Cattle for Beef Production (1,000 Cattle Aggregates)
$x_{39}^{r}(t)$	Feed Grain Imports (1,000 MT)

continued ...

Table 2 (continued)

For variables of the rest of the simulation model (SIM), subscripted by crop, the subscripts are:

1. Rice
2. Barley
3. Wheat
4. Other Grain
5. Fruit
6. Pulses
7. Vegetables
8. Potatoes
9. Tobacco
10. Forage Crops
11. Mulberries
12. Industrial Crops
13. Beef
14. Milk
15. Pork
16. Chicken
17. Eggs

Table 6 1/ contains a general description of the matrix for a given region r and period t. Positive non zero coefficients in the matrix are characterized as X and negative non zero coefficients -X. Some of the input-output coefficients are constant over the whole projection period, others vary through time and are exogenously changed for each year.

Constant over time are:

1. Composition of crop activities of summer and winter crops.
2. Labor requirements of crop and livestock activities
3. Draft animal and machinery hours required by crop activities.
4. Acquisition prices for investment goods.
5. Various unit coefficients.

Varying over time are:

1. Yields from crop activities and from livestock activities.
2. Feed inputs for livestock activities.

All of the objective function coefficients and all the elements of the constraint vector are time variant, the change rate being affected in the dynamic feedback operator by the results of previous solutions of the LP problems and of other components of the simulation model. The following chapter will describe the structure of the dynamic feedback as well as the computation of the exogenous variables.

2. Dynamic Feedback and Exogenous Variables

Following is a description of the dynamic linkage mechanism which relates the values of the objective function coefficients, of the constraints and of the input-output coefficients to preceeding LP solutions, to data being computed in other parts of the simulation model and to exogenous data projections.

1/ See page 50.

Three components[1/] will be described : 2.1 Objective Function Generation

2.2 Right Hand Side Generation

2.3 Input Output Matrix Generation

2.1 Objective Function Generation

2.1.1 Crop activities ($z_1^r(t)$,....., $z_{20}^r(t)$)

Three different groups are distinguished: in the first group (a) the yields are directly priced in the objective function, hence the z coefficient is the difference between (yield times price) and variable costs lagged by one period. As a first approach, one year discrete lags are assumed as expectation models. Only by-products like bran are not included but contained in the A-matrix. In the second group (b) the yields are listed in the A-matrix and priced with opportunity costs, hence the z coefficient is negative and contains just the variable costs. The third group (c) represents those activities which are composed of more than one crop of the rest of the simulation model. The z coefficient is therefore a weighted average of the respective crops.[2/]

Corresponding indices:

Group a:

Activity in LP	i	1	2	3	4	5	6	11	12	13	14	17	18
Crop in SIM 3/	j	1	1	1	1	3	3	12	12	7	7	9	9

$$z_i^r(t+1) = \underline{YLD}_j^r(t)\ \underline{PAVG}_j^r(t)\ \left[1 + TEFF_i\right]$$
$$- \Big[\underline{PFRT}_j(t)\ \underline{FRTPHA}_j^r(t) + \underline{PPEST}^r(t)\ \underline{PSTPHA}_j^r(t)$$
$$+ POI_j(t)\ \underline{OIPHA}_j^r(t) + \underline{PSD}_j(t)\ \underline{SDPHA}_j^r(t)$$
$$+ PCAP^r(t)\ CAPPHA_j^r(t) + MC_i(t)\Big]\ (1+0.5\ RINT(t))$$ [4/]

1/ The actual programs contain scaling in accordance with the scales listed in the variable definitions in section 1.1 and 1.2

2/ The underlined variables are provided by other components of the simulation model. The index r stands for regions. For subscripts see page 1. 3/ SIM stands for the rest of the Simulation Model.

4/ Depending on the run alternative, the yields for modern production technologies (tiller) are increased by a rate TEFF. TEFF is zero for traditional technologies.

where: TEFF — Net yield increase from using tillers for cultivation (proportion)

YLD	Yield polished and hulled	(MT/ha)
PAVG	Average yearly producer price	(W/MT)
PFRT	Price for fertilizer	(W/MT)
FRTPHA	Fertilizer input	(MT/ha)
PPEST	Price for pesticides	(W/MT)
PSTPHA	Pesticide input	(MT/ha)
POI	Price for other input	(W/MT)
OIPHA	Other input	(MT/ha)
PSD	Price for seed	(W/MT)
SDPHA	Seed input	(MT/ha)
MC	Variable machinery costs	(W/ha)
RINT	Interest rate	(proportion)
PCAP	Price index for capital foods	
CAPPHA	Capital input per ha (except tiller and transplanter)	(W/ha)

Group b: Corresponding indices

Activity in LP	i	7	8	15	16	19	20
Crop in SIM	j	2	2	8	8	10	10

$$z_k^r(t+1) = -\Big[\underline{PFRT}_j(t)\ \underline{FRTPHA}_j^r(t) + \underline{PPEST}^r(t)\ \underline{PSTPHA}_j^r(t) + \underline{POI}_j(t)\ \underline{OIPHA}_j^r(t) + \underline{PSD}_j(t)\ \underline{SDPHA}_j^r(t) + PCAP^r(t)\ CAPPHA_j^r(t) + MC_i(t)\Big](1 + 0.5\ RINT\ (t))$$

Group c: Corresponding indices

Activity in LP	i	9	10
Crops in SIM	k	6	6
	j	4	4

$$\begin{aligned} z_i^r(t+1) = {} & PROP^r\ \underline{YLD}_j^r(t)\ \underline{PAVG}_j^r(t)\big[1 + TEFF_i\big] \\ & + (1 - PROP^r)\ \underline{YLD}_k^r(t)\ \underline{PAVG}_k^r(t)\ \big[1 + TEFF_i\big] \\ & - \Big[PROP^r\ (\underline{PFRT}_j(t)\ \underline{FRTPHA}_j^r(t) + \underline{PPEST}^r(t)\ \underline{PSTPHA}_j^r(t) \\ & + \underline{POI}_j(t)\ \underline{OIPHA}_j^r(t) + \underline{PSD}_j(t)\ \underline{SDPHA}_j^r(t) \\ & + PCAP^r(t)\ CAPPHA_j^r(t)) + (1-PROP^r)\ (\underline{PFRT}_k(t)\ \underline{FRTPHA}_k^r(t) \\ & + \underline{PPEST}^r(t)\ \underline{PSTPHA}_k^r(t) + \underline{POI}_k(t)\ \underline{OIPHA}_k^r(t) \\ & + \underline{PSD}_k(t)\ \underline{SDPHA}_k^r(t) + PCAP^r(t)\ CAPPHA_k^r(t) \\ & + MC_i(t)\Big]\ (1. + 0.5\ RINT(t)) \end{aligned}$$

where: $PROP^r$ Proportion of crop j in activity i

2.1.2 Conversion of Barley and Potatoes into Feed and Human Consumption

$z_i^r(t) = 0 \qquad i = 21, 22$ (Feed)

$z_i^r(t+1) = \underline{PAVG}_j^r(t) \qquad$ if $i = 23 \longrightarrow j = 2$ (human
if $i = 24 \longrightarrow j = 8$ consumption)

2.1.3 Pasture land management

$z_{25}^r(t) = 0$

$z_{26}^r(t+1) = -\ VCPASI(t)$

where: VCPASI Variable costs for intensive use of pasture land (Won/ha)

2.1.4 Livestock Production[1/]

Dairy Production ($z_{27}^r(t)$)[2/]

$$z_{27}^r(t+1) = \Big[YLDM1(t)\ \underline{PAVG}_{14}^r(t) + 0.5\ BRTEM(t)\ YLDHE(t)\ \underline{PAVG}_{13}^r(t) + 0.5\ BRTEM(t)\ YLDBE(t)\ \underline{PAVG}_{13}^r(t)\Big](1.-0.5\ RINT(t)) - FDTM1(t)\ PRPU\ PAVFE(t) - MEDM(t)\Big[1. + .66\ BRTEM(t)\Big] - EQUIPM(t) - BRFEE(t)\Big[1 + SARTEM(t)\Big]$$

where:
- YLDM1 Milk yield per year (MT/cow)
- BRTEM Birth rate of dairy cattle (proportion)
- YLDHE Yield of edible meat per replaced cow or female young animal of dairy cattle (MT/head)
- YLDBE Yield of edible meat per fattened male animal of dairy cattle (MT/head)
- FDPUM Concentrate feed input per dairy cow (MT/cow)
- SARTEM National salvage rate of old dairy cows (proportion)
- FDTM1 Feed concentrate input per dairy unit in TDN (MT/cattle aggregate). FDTM1 is computed in the matrix generation component

1/ Livestock production activities are defined for livestock aggregates. One aggregate includes one mature female breeding animal and-in a fixed proportion- all related young animals raised for various purposes. The sex proportion is assumed to be 0.5

2/ The average age of mature heifers and dairy beef cattle is assumed to be 2.5 years. Consequently an average number of 2.5 head will be on the farm during the year per mature heifer or beef cattle.

PRPU	Proportion of value of concentrate in dairy or beef production which has to be purchased (proportion)
PAVFE	Average price for feed concentrates (Won/MT)
MEDM	Veterinary costs per dairy cow (W/cow)
EQUIPM	Equipment costs per unit of dairy activity (W/aggregate)
BRFEE	Breeding fee per cow (W/cow)

all referring to one year

Korean Cattle for Draft and for Beef Production ($z^r_{28}(t)$)

$$z^r_{28}(t+1) = \Big[\mathrm{SARTEK}(t)\ \mathrm{YLDKC}(t)\ \underline{\mathrm{PAVG}}^r_{13}(t) + (\mathrm{BRTEK}(t) - \mathrm{SARTEK}(t))\ \mathrm{YLDKB}(t)\ \mathrm{PAVG}^r_{13}(t)\Big] \cdot (1 - 0.5\ \mathrm{RINT}(t)) - \mathrm{PRPU}\ \mathrm{FDTKC}^r(t)\ \mathrm{PAVFE}(t) - \mathrm{MEDK}(t)\ \Big[1. + .66\ \mathrm{BRTEK}(t)\Big] - \mathrm{EQUIPK}(t)\ \Big[1. + .66\ \mathrm{BRTEK}(t)\Big] - \mathrm{BRFEE}(t)\ \Big[1. + \mathrm{SARTEK}(t)\Big]$$

where:

SARTEK	Natural salvage rate of old Korean cattle cows
YLDKC	Yield of edible meat per replaced cow or female young animal of Korean Cattle(MT/head)
BRTEK	Birth rate of Korean Cattle
YLDKB	Yield of edible meat per male animal of Korean cattle (MT/head)
FDTKC	Feed concentrate input in TDN per Korean cattle unit (MT/cattle aggregate) FDTKC is computed in the matrix generation component
MEDK	Veterinary costs per Korean Cattle cow(W/head)
EQUIPK	Equipment costs per unit of Korean cattle activity (W/head)

Hog Production ($z^r_{29}(t)$)

$$z^r_{29}(t+1) = \Big[(\mathrm{BRTEP}(t) - \mathrm{SARTES}(t))\ \mathrm{YLDP}(t) + \mathrm{SARTES}(t)\ \mathrm{YLDS}(t)\Big]\ \underline{\mathrm{PAVG}}^r_{15}(t)\ (1. - 0.5\ \mathrm{RINT}(t)) - \mathrm{FDTH}^r(t)\ \mathrm{PRPUP}(t)\ \mathrm{PAVFEP}(t) - \mathrm{MEDS}(t)\ (1. + \mathrm{BRTEP}(t)) - \mathrm{EQUIPS}(t)\ (1. + \mathrm{BRTEP}(t)) - \mathrm{BRFES}(t)\ (1.8 + \mathrm{SARTES}(t))$$

where:

BRTEP	Birth rate of sows (piglets/sow/yr)
SARTES	Natural salvage rate of old sows(proportion)
YLDP	Yield of edible meat per hog (MT/head)
YLDS	Yield of edible meat per sow (MT/head)

FDTH	Feed concentrate input in TDN per Hog unit (MT/hog aggregate) FDTH is calculated in the matrix generation component.
PRPUP	Proportion of value of feed concentrate input in hog production that has to be purchased (proportion)
PAVFEP	Average price for concentrate in hog production (W/MT)
MEDS	Veterinary costs per head in hog production (W/head)
EQUIPS	Equipment costs per head in hog production (W/head)
BRFES	Breeding fee per sow (W/sow)

Egg Production ($z^r_{30}(t)$)

$$z^r_{30}(t+1) = \left[YLDEG(t)\ \underline{PAVG}^r_{17}(t) + SARTEL(t)\ YLDL(t)\ \underline{PAVG}^r_{16}(t)\right]$$
$$(1 - 0.5\ (RINT(t) + MORL(t)))$$
$$- FDTEG^r(t)\ PAVFEL(t)\ PRPUEG(t) - MEDL(t) - EQUIPL(t)$$

where:	YLDEG	Yield of eggs per hen (MT/hen)
	SARTEL	Natural salvage rate of old hens
	YLDL	Yield of edible meat per old hen (MT/hen)
	MORL	Loss rate of hens in egg production
	FDTEG	Concentrate feed input per hen in TDN(MT/hen) FDTEG is calculated in the matrix generating component
	MEDL	Veterinary costs per hen (W/hen)
	EQUIPL	Equipment costs per hen (W/hen)
	PAVFEL	Average price for concentrates in egg production (W/MT)
	PRPUEG	Proportion of value of concentrates in poultry production which has to be purchased (proportion)

Broiler Production ($z^r_{31}(t)$)

$$z^r_{31}(t+1) = \left[YLDBR(t)\ \underline{PAVG}^r_{16}(t)\right](1. - 0.5\ (MORBR(t) + 0.167\ RINT(t)))$$
$$- FDTBR(t)\ PAVFEB(t)\ PRPUEG(t)$$
$$- MEDB(t) - EQUIPB(t)$$

where:	YLDBR	Yield of edible meat per broiler (MT/head)
	MORBR	Loss rate of broilers (proportion)
	FDTBR	Concentrate feed input in TDN per broiler (MT/head) FDTBR is calculated in the matrix generation component

PAVFEB Average price for concentrate in broiler production (W/MT)
MEDB Veterinary costs per broiler (W/head)
EQUIPB Equipment costs and acquisition costs for chicken (W/head)

2.1.5 Fruit Production

Production on existing orchards ($z^r_{32}(t)$)

$$z^r_{32}(t+1) = \underline{YLD}^r_5(t)\ \underline{PAVG}^r_5(t) - \Big[\underline{PFRT}_5(t)\ \underline{FRTPHA}^r_5(t) + \underline{PPEST}^r(t)\ \underline{PSTPHA}^r_5(t) + \underline{POI}_5(t)\ \underline{OIPHA}^r_5(t) + \underline{PCAP}^r(t)\ \underline{CAPPHA}^r_5(t) + MC_{32}(t)\Big] (1. + 0.5\ RINT(t))$$

Planting of new Orchards ($z^r_{33}(t)$)

$$z^r_{33}(t+1) = r^r_{19}(t)^* \ (1. - 5/40)$$

where: $r^r_{19}(t)^*$ dual value (shadow price) of the orchard capacity constraint.

2.1.6 Raw Silk Production

Production on existing mulberry fields ($z^r_{34}(t)$)

$$z^r_{34}(t+1) = \underline{YLD}^r_{11}(t)\ \underline{PAVG}^r_{11}(t) - \Big[\underline{PFRT}_{11}(t)\ \underline{FRTPHA}^r_{11}(t) + \underline{PPEST}^r(t)\ \underline{PSTPHA}^r_{11}(t) + \underline{POI}_{11}(t)\ \underline{OIPHA}^r_{11}(t) + \underline{PCAP}^r(t)\ \underline{CAPPHA}^r_{11}(t) + MC_{34}(t)\Big] (1. + 0.5\ RINT(t))$$

Planting of new mulberry fields ($z^r_{35}(t)$)

$$z^r_{35}(t+1) = r^r_{20}(t)^* \ (1. - 3/20)$$

where: $r^r_{20}(t)^*$ dual value (shadow price) of the mulberry field constraint

2.1.7 Machinery Investment

The investment costs of farm machinery are composed of depreciation and interest costs on capital. So long as there are draft animals available which can be replaced by tillers, the costs for tiller investment can be reduced by additional profits which result from more efficient fattening (shorter life time with same final weight) of Korean Cattle. These profits are computed endogenously by substituting the beef fattening activity 38 (see 2.1.8) for the draft animal activity 28.

Tiller with attachment including binder ($z^r_{36}(t)$)

$$z^r_{36}(t+1) = -\ 0.9\ PAVTI(t)\ (0.5\ RINT(t) + 1/7)$$

where: PAVTI Acquisition price for tiller plus attachment (W/aggregate)

Rice Transplanter ($z^r_{37}(t)$)

$$z^r_{37}(t+1) = -\ 0.9\ PAVTR(t)\ (0.5\ RINT(t) + 1/7)$$

where: PAVTR Acquisition price for a rice transplanter (W/machine)

The average value of the machinery to which interest costs are related is assumed to be 1/2 of the total depreciation (life time 7 years[1/]). The salvage value of machinery is assumed to be 10 percent of the acquisition price.[2/] The average proportion of the acquisition price to which interest costs have to be related, is therefore (1. - 0.1) 0.5 = 0.45

1/ EXOTECH Report 1972
2/ EXOTECH Report 1972

2.1.8 Korean Cattle or Other Breeds for Beef Production ($z^r_{38}(t)$)

It is assumed that cattle which is not used for draft purposes will yield 80 percent higher outputs using only 20 percent more inputs than draft cattle.

$$
\begin{aligned}
z^r_{38}(t+1) = z^r_{28}(t+1) & \\
& + 0.8 \Big[\text{SARTEK}(t)\ \text{YLDKC}(t)\ \underline{\text{PAVG}}^r_{13}(t) \\
& + (\text{BRTEK}(t) - \text{SARTEK}(t))\ \text{YLDKB}(t)\ \underline{\text{PAVG}}^r_{13}(t) \Big] \\
& \quad (1 - 0.5\ \text{RINT}\ (t)) \\
& - 0.2\ \text{PRPU}\ \text{FDTKC}(t)\ \text{PAVFE}(t)
\end{aligned}
$$

2.1.9 Feed Grain Purchasing ($z^r_{39}(t)$)

$$z^r_{39}(t+1) = -\text{PAVFIM}(t)$$

where: PAVFIM Average import price of feed grain (W/MT)

2.2 Right Hand Side Generation

The following equations describe the computation of the element of the constraint vector. y's denote right hand sides, x's denote optimal values of activities, and B's denote coefficients, which are time variant, if they are written with a dimension t. B coefficients without the regional subscript r appear in overall national constraints. Definitions of the B's are found in Table 3 (page 23).

2.2.1 Paddy Land

$$y^r_1(t) = y^r_1(t-1) + B^r_1(t)$$

2.2.2 Upland for Annual Crops

$$y_2^r(t) = y_2^r(t-1) - x_{33}^r(t-1) - x_{35}^r(t-1) + B_2^r(t) + RLOUT_4^r(t)$$ [1/]

2.2.3 Winter Upland (Area available for double cropping)

Winter Upland is equal to the previous potential double cropping ratio (DCR) times the current total land area available for annual paddy and upland crops.

$$DCR^r(t) = y_2^r(t-1) / \left[y_1^r(t-1) + y_2^r(t-1) \right]$$

$$y_3^r(t) = DCR^r(t) \left[y_1^r(t) + y_2^r(t) \right]$$

2.2.4 Oxen Labor Balance in Season 1

Since the number of draft animals is an endogenous variable of the model, the limitation is set to zero for draft animal balances.

$$y_4^r(t) = 0$$

2.2.5 Labor Capacity, in Season 1

$$y_5^r(t) = \underline{AGMP}_r(t)\, B_7^r - B_8^r\left(\sum_{s=1}^{4} x_{33}^r(t-s) + \sum_{s=1}^{2} x_{35}^r(t-s)\right)$$

2.2.6 Labor Capacity, in Season 2

$$y_6^r(t) = \underline{AGMP}_r(t)\, B_9^r - B_{10}^r\left(\sum_{s=1}^{4} x_{33}^r(t-s) + \sum_{s=1}^{2} x_{35}^r(t-s)\right)$$

where: AGMP Projected active agricultural labor force in man-equivalent-units (from the population component)

B_7^r and B_9^r are hours per man-equivalent unit in seasons 1 and 2 repectively. As the size of the farm population starts to decline and mechanization takes place, these coefficients are increased towards an upper bound of α times the basic number $[B_i^{r'}]$ to account for learning and increased efficiency in field work.
$B_i^r = B_i^{r'} + 0.5\alpha B_i^{r'} \left[1+\sin(t-t_o)\, \pi/(t_e-t_o) + 1.5\pi\right]$ (t_e= year in which the upper bound is reached; t_o= year in which the learning process starts)

1/ RLOUT is the destruction rate of orchards

2.2.7 Oxen Labor Balance in Season 2

$$y_7^r(t) = 0$$

2.2.8 Tiller Capacity in Season 1

$$y_8^r(t) = B_{11}^r \left[B_{12}^r \sum_{s=1}^{3} x_{36}^r(t-s) + B_{13}^r \sum_{s=4}^{6} x_{36}^r(t-s) + B_{14}^r \, x_{36}^r(t-7) \right]$$

2.2.9 Tiller Capacity in Season 2

$$y_9^r(t) = B_{16}^r \, y_8^r(t)$$

2.2.10 Rice Transplanter Capacity, June

$$y_{10}^r(t) = B_{17}^r \left[B_{18}^r \sum_{s=1}^{3} x_{37}^r(t-s) + B_{19}^r \sum_{s=4}^{6} x_{37}^r(t-s) + B_{20}^r \, x_{37}^r(t-7) \right]$$

2.2.11 Balance Equation for Barley

$$y_{11}^r(t) = B_{21}^r(t) \left(\sum_{s=1}^{4} x_{33}^r(t-s) + \sum_{s=1}^{2} x_{35}^r(t-s) \right)$$

2.2.12 Balance Equation for Potatoes

$$y_{12}^r(t) = B_{22}^r(t) \left(\sum_{s=1}^{4} x_{33}^r(t-s) + \sum_{s=1}^{2} x_{35}^r(t-s) \right)$$

2.2.13 Balance Equation for Feed Concentrates

$$y_{13}^r(t) = B_{23}^r(t) \left(\sum_{s=1}^{4} x_{33}^r(t-s) + \sum_{s=1}^{2} x_{35}^r(t-s) \right)$$

2.1.14 Balance Equation for Roughage

$$y_{14}^r(t) = B_{24}^r(t) \left(\sum_{s=1}^{4} x_{33}^r(t-s) + \sum_{s=1}^{2} x_{35}^r(t-s) \right)$$

2.1.15 Capacity of Pasture Land

$$y_{15}^r(t) = B_{25}^r(t)$$

2.1.16 Feasible Size of Dairy Herd

$$y^r_{16}(t) = x^r_{27}(t-1) + B^r_{26}(t)\ x^r_{27}(t-3) + B^r_{27}(t)$$

2.1.17 Feasible Size of Korean Cow Herd

$$y^r_{17}(t) = x^r_{28}(t-1) + B^r_{28}(t)\ x^r_{28}(t-3) + B^r_{29}(t)$$

2.1.18 Feasible Size of Sow Herd

$$y^r_{18}(t) = x^r_{29}(t-1)\ (1. + B^r_{30}(t))$$

2.1.19 Capacity of Orchards in Production

$$y^r_{19}(t) = \sum_{j=2}^{4} \underline{LPER}_j\ (t)$$

where: $\underline{LPER}_j$ Hectares of Orchards in age cohort j

2.2.20 Capacity of Mulberry Fields in Production

If $(t > B^r_{31})$, then $y^r_{20}(0) = 0$.

$$y^r_{20}(t) = y^r_{20}(t-1) + x^r_{35}(t-3) - (1./B^r_{31})y^r_{20}(0) - x^r_{35}(t-B^r_{31})$$

Flexibility Constraints

Following is a set of upper and/or lower bounds for the year to year changes in production patterns $(y^r_{21}(t),\ldots\ldots,y^r_{36}(t))$. In the case of field crops an adjustment of these bounds is made to account for changes in the total available land areas. For crop activities requiring both summer and winter upland, the adjustment is made proportionally. The year to year changes in total land areas are:

$XLAND^r_1(t) = y^r_1(t)\ /\ y^r_1(t-1)$ for paddy land

$XLAND^r_2(t) = y^r_2(t)\ /\ y^r_2(t-1)$ for summer upland

$XLAND^r_3(t) = y^r_3(t)\ /\ y^r_3(t-1)$ for winter land

2.2.21 Flexibility Constraint for Wheat (Lower Bound)

$$y^r_{21}(t) = B^r_{32}\ (x^r_5(t-1) + x^r_6(t-1))\ XLAND^r_3(t)$$

2.2.22 Flexibility Constraint for Barley (Lower Bound)

$$y^r_{22}(t) = B^r_{33}(x^r_7(t-1) + x^r_8(t-1))\ \ XLAND^r_3(t)$$

2.2.23 Flexibility Constraint for Vegetables (Upper Bound)

$$y^r_{23}(t) = B^r_{34}(x^r_{13}(t-1) + x^r_{14}(t-1) \cdot \left[A^r_{2,13}(t)\ XLAND^r_2(t) + A^r_{3,13}(t)\ XLAND^r_3(t)\right]$$ 2/

2.2.24 Flexibility Constraint for Hog Production (Lower Bound)

$$y^r_{24}(t) = B^r_{35}\ x^r_{29}(t-1)$$

2.2.25 Flexibility Constraint for Planting of Orchards (Upper Bound)

$$y^r_{25}(t) = B^r_{36}\ x^r_{32}(t-1)\ XLAND^r_2(t)$$

2.2.26 Flexibility Constraint for Dairy Production (Upper Bound)

$$y^r_{26}(t) = B^r_{37}\ x^r_{27}(t-1)$$

2.2.27 Constraint for Investment in Tillers (Behavioral Constraint)

$$y^r_{27}(t) = B^r_{38}\ y^r_8/B^r_{11}$$

2.2.28 Constraint (Upper Bound) for Egg Production 1/

$$y^r_{28}(t) = B^r_{41}\ y^r_{28}(t-1)$$

2.2.29 Constraint (Upper Bound) for Broiler Production 1/

$$y^r_{29}(t) = B^r_{42}\ y^r_{29}(t-1)$$

1/ Currently (May 73) the indexing of this row is different. See last page of this appendix.

2/ $A^r_{i,j}(t)$ is the input-output coefficient of activity j in row i of region r.

2.2.30 Flexibility Constraint for Summer Grain (Upper Bound)[1/].

$$y^r_{30}(t) = B^r_{43}(x^r_9(t-1) + x^r_{10}(t-1))XLAND^r_2(t)$$

2.2.31 Flexibility Constraint for Summer Grain (Lower Bound)[1/]

$$y^r_{31}(t) = B^r_{44}\ y^r_{30}(t)\ /\ B^r_{43}$$

2.2.32 Flexibility Constraint for Industrial Crops (Upper Bound)[1/]

$$y^r_{32}(t) = B^r_{45}(x^r_{11}(t-1) + x^r_{12}(t-1)) \cdot \left[A^r_{2,11}(t)\ XLAND^r_2(t) + A^r_{3,11}(t)\ XLAND^r_3(t)\right]$$

2.2.33 Flexibility Constraint for Industrial Crops (Lower Bound)[1/]

$$y^r_{33}(t) = B^r_{46}\ \ y^r_{32}\ (t)\ /\ B^r_{45}$$

2.2.34 Flexibility Constraint for Potatoes (Upper Bound)[1/]

$$y^r_{34}(t) = B^r_{47}(x^r_{15}(t-1) + x^r_{16}(t-1)) \cdot \left[A^r_{2,15}(t)\ XLAND^r_2(t) + A^r_{3,15}(t)\ XLAND^r_3(t)\right]$$

2.2.35 Flexibility Constraint for Potatoes (Lower Bound)[1/]

$$y^r_{35}(t) = B^r_{48}\ \ y^r_{34}(t)\ /\ B^r_{47}$$

2.2.36 Flexibility Constraint for Tobacco (Lower Bound)

$$y^r_{36}(t) = B^r_{49}(x^r_{17}(t-1) + x^r_{18}(t-1))XLAND^r_2(t)$$

2.2.37 National Upper Bound for Raw Silk Production

$$y^4_1(t) = B_{39} \sum_{r=1}^{3} x^r_{34}(t-1)$$

1/ Currently (May 73) the indexing of this row is different. See last page of this appendix.

2.2.38 National Upper Bound for Tobacco Production

$$y_2^4(t) = B_{40} \sum_{r=1}^{3} (x_{17}^r(t-1) + x_{18}^r(t-1))$$

2.2.39 National Restriction for Feed Grain Imports

$$y_3^4(t) = BIMP$$

Table 3

Definition of the B coefficients

B_1^r (t)	Yearly increase (+) or decrease (-) in paddy land (1,000 ha)
B_2^r (t)	Yearly increase (+) or decrease (-) in summer upland (1,000 ha)
B_3^r (t)	
B_4^r (t)	
B_5^r (t)	
B_6^r (t)	
B_7^r	Effective working hours per man-equivalent-unit in season 1 (hours)
B_8^r	Labor requirements for intercropping on orchards or mulberry fields in season 1 (hours/ha)
B_9^r	Effective working hours per man-equivalent-unit in season 2 (hours)
B_{10}^r	Labor requirements for intercropping on orchards or mulberry fields in season 2 (hours/ha)
B_{11}^r	Working capacity per tiller in season 1 (hours/tiller)
B_{12}^r	One minus rate of depreciation over the first three years of tiller life time (proportion)
B_{13}^r	One minus rate of depreciation over the fourth to sixth year of tiller life time (proportion)
B_{14}^r	One minus rate of depreciation in the seventh year of tiller life time (proportion)
B_{15}^r	
B_{16}^r	Ratio between working capacity of a tiller in season 2 and capacity in season 1

continued ...

Table 3 (continued)

B^r_{17}	Working capacity per transplanter in season 1 (hours/transplanter)
B^r_{18}	One minus rate of depreciation during the first three years of rice transplanter life time (proportion)
B^r_{19}	One minus rate of depreciation during the fourth to sixth year of rice transplanter life time (proportion)
B^r_{20}	One minus rate of depreciation during the seventh year of rice transplanter life time (proportion)
$B^r_{21}(t)$	Average barley yields from intercropping on orchards and mulberry fields beginning with the second year of intercropping (MT/ha perennial land)
$B^r_{22}(t)$	Average potato yields from intercropping on orchards and mulberry fields beginning with the second year of intercropping (MT/ha perennial land)
$B^r_{23}(t)$	Average bran yields (in TDN) from intercropping on orchards and mulberry fields beginning with the second year of intercropping (MT/ha perennial land)
$B^r_{24}(t)$	Average roughage yields (in TDN) from intercropping on orchards and mulberry fields beginning with the second year of intercropping (MT/ha perennial land)
$B^r_{25}(t)$	Projected capacity of pasture land (ha)
$B^r_{26}(t)$	Maximum natural expansion rate of domestic dairy herd
$B^r_{27}(t)$	Projected number of imported dairy cows (cows/yr)
$B^r_{28}(t)$	Maximum natural expansion rate of domestic draft cattle herd
$B^r_{29}(t)$	Projected number of imported beef cows (cows/year)
$B^r_{30}(t)$	Maximum natural expansion rate of sowherd (0.5 litter rate minus replacement rate) or, if smaller, upper flexibility coefficient for hog production.
B^r_{31}	Average life time of mulberry trees (years)
B^r_{32}	Flexibility coefficient for wheat (lower bound)
B^r_{33}	Flexibility coefficient for barley (lower bound)

continued ...

Table 3 (continued)

B^r_{34}	Flexibility coefficient for vegetables (upper bound)
B^r_{35}	Flexibility coefficient for hog production (lower bound)
B^r_{36}	Flexibility coefficient for fruit production (upper bound)
B^r_{37}	Flexibility coefficient for dairy production (lower bound)
B^r_{38}	Adoption rate of tiller investment
B^r_{39}	Flexibility coefficient for raw silk production (upper bound)
B^r_{40}	Flexibility coefficient for tobacco production (upper bound)
B^r_{41}	Maximum yearly growth rate of numbers of layers
B^r_{42}	Maximum yearly growth rate of numbers of broilers
B^r_{43}	Flexibility coefficient for summer grain (upper bound)
B^r_{44}	Flexibility coefficient for summer grain (lower bound)
B^r_{45}	Flexibility coefficient for industrial crops (upper bound)
B^r_{46}	Flexibility coefficient for industrial crops (lower bound)
B^r_{47}	Flexibility coefficient for potatoes (upper bound)
B^r_{48}	Flexibility coefficient for potatoes (lower bound)
B^r_{49}	Flexibility coefficient for tobacco (lower bound)
BIMP	Maximal quantity of national feed grain imports per year (1,000 MT)

2.3 Input Output Matrix Generation

Following is a listing of those matrix coefficients, $a^r_{i,j}(t)$, which are changed in time[1/]:

$$a^r_{11,7}(t) = -\underline{YLD}^r_2(t)$$

<u>YLD</u> Yield of KASS commodity i in region r (MT/ha)

$$a^r_{11,8}(t) = -\underline{YLD}^r_2(t)\left[1 + TEFF_8\right]$$

$$a^r_{11,33}(t) = -(\underline{YLD}^r_2(t)\ YLDRB)$$

YLDRB Average proportion of intercropping area on orchards and mulberry fields used for barley production (beginning with the second year)

$$a^r_{11,35}(t) = -(\underline{YLD}^r_2(t)\ YLDRB)$$

$$a^r_{12,15}(t) = -\underline{YLD}^r_8(t)$$

$$a^r_{12,16}(t) = -\underline{YLD}^r_8(t)\left[1 + TEFF_{16}\right]$$

$$a^r_{13,1}(t) = -(\underline{YLD}^r_1(t)\ BRANR)$$

BRANR Proportion of bran in rice (related to polished rice)

$$a^r_{13,2}(t) = -(\underline{YLD}^r_1(t)\ BRANR)$$

$$a^r_{13,3}(t) = -(\underline{YLD}^r_1(t)\ BRANR)$$

$$a^r_{13,4}(t) = -(\underline{YLD}^r_1(t)\ BRANR)$$

$$a^r_{13,5}(t) = -(\underline{YLD}^r_3(t)\ BRANW)$$

BRANW Proportion of bran in wheat (related to milled wheat)

$$a^r_{13,6}(t) = -(\underline{YLD}^r_3(t)\ BRANW)$$

$$a^r_{13,7}(t) = -(\underline{YLD}^r_2(t)\ BRANB)$$

BRANB Proportion of bran in barley (related to milled barley)

$$a^r_{13,8}(t) = -(\underline{YLD}^r_2(t)\ BRANB)$$

1/ Compared to figure A1 the nomenclature is slightly changed for convenience. The coefficient indicating to which region the respective equation belongs, is left out.

$$a^r_{13,9}(t) = - PROP^r \; \underline{YLD}^r_4(t) \; BRANS$$

BRANS Proportion of bran in summer grains (related to milled grain)

$$a^r_{13,10}(t) = - PROP^r \; \underline{YLD}^r_4(t) \; BRANS$$

The following coefficients $\left[a^r_{13,27}, \ldots\ldots\ldots\ldots\ldots, a^r_{13,31}\right]$ contain those proportions of feed concentrate inputs for livestock which can either be farm produced or purchased and which therefore have to appear in the coefficient matrix. The remaining proportions must be purchased (or imported) and appear therefore in the objective function. For dairy production and broiler production it is assumed that exclusively commercial feeding exists. For Korean cattle, hog and egg production by-product feeding is possible within the limit of by-product supply from farm-households. The total feed concentrate inputs are computed as follows:[1/]

<u>Dairy feed concentrates</u>

$$\begin{aligned} FDTM1(t) = {} & FDPUM(t) \\ & + 2.5 \left[BRTEM(t) - SARTEM(t)\right] FDPUBE(t) \\ & + 2.5 \; SARTEM(t) \; FDPUHR(t) \end{aligned}$$

<u>Broiler feed concentrates</u>

$$FDTBR(t) = FDPUBR(t) \; YLDBR(t)$$

where FDTM1 Feed concentrates input per dairy unit in TDN (MT/cattle aggregate)
FDPUM Yearly concentrate feed input per dairy cow in TDN (MT/cow)
FDPUBE Average yearly concentrate input per head of dairy cattle during the fattening process in TDN (MT/head)

1/ Differences in the conceptional approach to compute feed inputs for different kinds of livestock result from differences in the kind of supplied data.

FDPUHR	Average yearly concentrate input per head of dairy cattle being raised for replacement in TDN (MT/head)
FDTBR	Feed concentrate input per broiler in TDN (MT/broiler)
FDPUBR	Feed concentrate input in TDN per MT edible meat in broiler production (MT/MT)

The feed concentrate requirements for Korean cattle, hogs and layers are computed recursively in the following way: Let $CPLT_i^r$ be the 1971 herd size of livestock i (i=1 for cattle, i=2 for hogs, i=3 for layers) in region r. And let $x_i^r(t)$ be the endogenously computed herd size of livestock i in period t. The feed input $a_i^r(t)$ is then computed as follows:

$$a_i^r(t) \begin{cases} = ATR_i \quad , \text{ if } x_i^r(t-1) \leq CPLT_i^r \\ = \Big[ATR_i \; CPLT_i^r \\ \quad + AMO_i(t) \; (x_i^r(t-1) - CPLT_i^r)\Big] / x_i^r(t-1), \text{ otherwise} \end{cases}$$

where ATR_i is the average feed input in 1971, composed of modern and traditional feeding patterns. The ATR_i coefficients are computed in such a way that supply and demand of feed are equated for the initial year 1971. ATR is assumed to be equal for all regions.

AMO_i is the feed input in modern feeding consisting exclusively of commercial feed. AMO is changing with time as a function of biological progress, changes in yield per animal, etc. It is assumed to be

$a_i^r(t)$ Feed r livestock activity i
(MT/ following variable names
are ons.
FDTK t)=$a_2^r(t)$, $FDTEG^r(t)=a_3^r(t)$

This formulation is based on the assumption that the supply of household garbage will not be growing any further and that the current amount is a limitation to traditional feeding patterns.

Livestock production can only be increased at the costs of a growing proportion of commercial feed in the average feed mix AMO_i is computed in the following way:

Korean cattle

$$AMO_1(t) = FDPUKC(t) + \left[BRTEK(t) - SARTEK(t)\right] FDPUKB(t) + SARTEK(t)\ FDPUKH(t)$$

Hog

$$AMO_2(t) = FDPUS(t) + BRTEP(t)\ FDPUP(t)$$

Layers

$$AMO_3(t) = FEDPUE(t) \left[1. + SARTEL(t)\right]$$

where FDPUKC Yearly concentrate feed input per Korean cattle cow in TDN (MT/cow)

FDPUKB Total concentrate feed input required to raise and maintain one Korean cattle animal in TDN (MT/head)

FDPUKH Total concentrate feed input required to raise one Korean cattle heifer for replacement of a breeding cow in TDN (MT/head)

FDPUS Yearly concentrate feed input per sow in TDN (MT/sow)

FDPUP Total concentrate input in TDN required to fatten one hog (MT/hog)

FEDPUE Yearly concentrate input in TDN per layer (MT/hen)

The matrix coefficients for feed inputs are now defined as follows:

$$a^r_{13,27}(t) = (1 - PRPU)\ FDTM1(t)$$

$$a^r_{13,28}(t) = (1 - PRPU)\ FDTKC^r(t)$$

$$a^r_{13,29}(t) = (1 - PRPUP)\ FDTH^r(t)$$

$$a^r_{13,30}(t) = (1 - PRPUEG)\ FDTEG^r(t)$$

$a^r_{13,31}(t) = (1 - PRPUEG)\ FDTBR(t)$

$a^r_{13,38}(t) = 1.1\ a^r_{13,28}(t)$ (Beef fattening)

Following are other time varying matrix coefficients:

$a^r_{13,33}(t) = a^r_{11,33}\ BRANB$

$a^r_{13,35}(t) = a^r_{11,35}\ BRANB$

$a^r_{14,13}(t) = -(\underline{YLD}^r_7(t)\ HEYV)$

HEYV Roughage TDN proportion in vegetable by-products

$a^r_{14,14}(t) = -(\underline{YLD}^r_7(t)\ HEYV)$

$a^r_{14,15}(t) = -(\underline{YLD}^r_8(t)\ HEYP)$

HEYP Roughage TDN proportion in leaves of sweet potatoes

$a^r_{14,16}(t) = -(\underline{YLD}^r_8(t)\ HEYP)$

$a^r_{14,19}(t) = -YLDFR^r(t)$

YLDFR Yield (in TDN) of forage production (MT/ha)

$a^r_{14,20}(t) = -YLDFR^r(t)$

$a^r_{14,25}(t) = -YLDPAE^r(t)$

YLDPAE Yield (in TDN) of grass production without fertilizer input (MT/ha)

$a^r_{14,26}(t) = -YLDPAI^r(t)$

YLDPAI Yield (in TDN) of grass production with fertilizer input (MT/ha)

$a^r_{14,27}(t) = HEYMI^r(t)$

HEYMI Roughage requirement (in TDN) per unit of dairy activity (MT)

$a^r_{14,28}(t) = HEYBE^r(t)$

HEYBE Roughage requirement (in TDN) per unit of beef activity (MT)

$a^r_{14,29}(t) = HEYHO^r(t)$

HEYHO Roughage requirement (in TDN) per unit of hog activity (MT)

$a^r_{14,33}(t) = -(YLDFR^r(t)\ FOROR^r)$

FOROR Average proportion of intercropping area on orchards and mulberry fields used for forage production

$a^r_{14,35}(t) = -(YLDFR^r(t)\ FOROR^r)$

$a^r_{14,38}(t) = 1.1\ a^r_{14,28}(t)$

3. Dynamic Linkages to Other KASS Model Components

3.1 Market Feedback

As generally described in the main paper, the RLP Model is designed to be a component of the KASS Model. Production and allocation decisions are ceteris paribus a function of previously realized prices which determine the current price expectations. Currently realized prices in turn depend on previous production and allocation decisions which determine to a great extent the current market supply.

This dynamic relationship between supply and market component is established by replaceing the exogenous production figures with endogenous variables from the RLP Model in the following way: 1/

3.1.1 Field Crop Acreages

The acreage $A_j^r(t)$ of a KASS-commodity j in region r is computed as the sum over all technologies of the corresponding activity levels $x_i^r(t)$ of the RLP solution for the same year. 2/

Rice $$A_1^r(t) = 1000 \sum_{j=1}^{4} x_j^r(t)$$

Barley $$A_2^r(t) = 1000 \sum_{j=7}^{8} x_j^r(t)$$

Wheat $$A_3^r(t) = 1000 \sum^{6} x_j^r(t)$$

Other grain $$A_4^r(t) = 1000\ PROP^r \sum_{j=9}^{10} x_j^r(t)$$

1/ The equations listed here replace the A-variables in subroutine INPUTS

2/ The RLP-output variables are expressed in 1000 units and have therefore to be rescaled.

where $PROP^r$ is the proportion of "other grains" in the RLP activity "summer grain"

Fruits $A_5^r(t) = \sum_{l=1}^{4} LPER_l^r(t)$

where $LPER_l^r$ is the numbers of hectaresin age cohort l of orchards.

Pulses $A_6^r(t) = 1000\ (1 - PROP^r) \sum_{j=9}^{10} x_j^r(t)$

Vegetables $A_7^r(t) = 1000 \sum_{j=13}^{14} x_j^r(t)$

Potatoes $A_8^r(t) = 1000 \sum_{j=15}^{16} x_j^r(t)$

Tobacco $A_9^r(t) = 1000 \sum_{j=17}^{18} x_j^r(t)$

Forage $A_{10}^r(t) = 1000 \sum_{j=19}^{20} x_j^r(t)$

Mulberry $A_{11}^r(t) = 1000 \sum_{j=34}^{35} x_j^r(t)$

Industrial crops $A_{12}^r(t) = 1000 \sum_{j=11}^{12} x_j^r(t)$

3.1.2 Livestock Production 1/

Other then the existing component, the RLP Model computes livestock production by regions. It is therefore necessary to define new, regionally different livestock production variables, $OUTLVl_j^r(t)$ 2/

Beef

$$OUTLVl_1^r(t) = 1000x_{27}^r(t) \left[0.5\ BRTEM(t)\ YLDHE(t) + 0.5\ BRTEM(t)\ YLDBE(t)\right] + \left[1000\ x_{28}^r(t) + 1150\ x_{38}^r(t)\right] \left[SARTEK(t)\ YLDKC(t) + (BRTEK(t) - SARTEK(t))\ YLDKB(t)\right]$$

1/ The equations listed here replace the corresponding variables in subroutine PRODLV

2/ The following variables are already explained in section 2.3

Poultry Meat $OUTLVl_4^r(t) = 10^6\ x_{30}^r(t)\ SARTEL(t)\ (1 - MORL)YLDL(t)$
$+10^6\ x_{31}^r(t)\ (1\text{-}MORBR)\ YLDBR$

Eggs $OUTLVl_5^r(t) = 10^6\ x_{30}^r(t)\ (1\text{-}MORL)\ YLDEG(t)$

Producer prices for agricultural commodities are computed endogenously by either supply-demand interaction or by application of governmental grain management policies. These prices ($PAVG_i^r(t)$) are fed back to the production and allocation component to close the feed back loop between supply and demand for agricultural commodities.

3.2 Other Linkages

A variety of other forward linkages between the RLP component and the KAS^S-Model are possible. Currently only one linkage is implemented: The planting rate of new orchards is computed endogenously in the allocation model and is fed into the perennial model as input rate RLIN to the first cohort of orchards:

$$RLIN^r(t) = x_{33}^r(t)$$

4. Output Routines

Three different kinds of output routines are available to analyze the performance of the model:

4.1 A complete yearly output

4.2 Additional performance criterion

4.3 Time series tables and plots

4.1 A Complete Yearly Output

A complete output of both the primal (Table 4) and the dual solution (Table 5) can be printed for every year. In addition it contains the current objective function and the constraint vector of the programming model. Sample outputs are attached below. The variables are defined as fo

Table 4) YEAR : Simulation period (for t=1 → year=1971)

OBJ FUNCTION : Total value of objective function $\left[\pi(t)\right]$

REG : Index for regions 1, - -

COL : Index of activity in

ACTIVITY : Name of activity

SOL. VECTOR : Activity level in units specified in the table (T = thousand, M = million, HA=hectares, MT = metric tons)

OBJ. VALUE : Current value of objective function coefficient $\left[z_j^r(t)\right]$

REDUCED COST: Marginal costs of changing the level of the respective activity by one unit $\left[\partial\pi^{(t)}/\partial x_j^r(t)\right]$

TABLE 4

SAMPLE OUTPUT OF PRIMAL SOLUTION: ACTIVITY LEVELS, OBJECTIVE FUNCTION COEFFICIENTS, AND REDUCED COST COEFFICIENTS
YEAR = 1971

OBJ FUNCTION = .626738+09

REG	COL	ACTIVITY	SOLUTION VECTOR		OBJECTIVE VALUE	REDUCED COST
1	1	RICE TRAD.	365.24500	T• HA	224213.33984	-.00000 # / HA
1	2	RICE TILL.	.00000	T• HA	219890.83789	8547.73535 # / HA
1	3	RICE TRANSPL	.00000	T• HA	223683.33789	1535.82108 # / HA
1	4	RICE ALL MOD	.00000	T• HA	219560.83594	10083.55640 # / HA
1	5	WHEAT TRADIT	23.40000	T• HA	41194.67969	-.00000 # / HA
1	6	WHEAT MODERN	.00000	T• HA	27638.67920	21470.47070 # / HA
1	7	BARLY TRADIT	98.38000	T• HA	-15384.83960	.00000 # / HA
1	8	BARLY MODERN	.00000	T• HA	-33234.83936	26299.11670 # / HA
1	9	S.GRAIN TRAD	96.39000	T• HA	26619.92529	-.00000 # / HA
1	10	S.GRAIN MOD.	.00000	T• HA	21494.76489	6548.89490 # / HA
1	11	IND.CRP TRAD	10.43975	T• HA	122401.10742	-.00000 # / HA
1	12	IND.CRP MOD.	.21525	T• HA	122336.60645	-.00000 # / HA
1	13	VEGET. TRAD	.00000	T• HA	473134.82031	11848.70068 # / HA
1	14	VEGET. MOD.	95.22577	T• HA	486939.81641	-.00000 # / HA
1	15	POTATO TRAD	18.57250	T• HA	-17750.75952	-.00000 # / HA
1	16	POTATO MOD.	.00000	T• HA	-29650.75952	15551.21130 # / HA
1	17	TOBACCO TRAD	.00000	T• HA	240517.62500	7403.49475 # / HA
1	18	TOBACCO MOD.	11.45073	T• HA	243902.62305	.00000 # / HA
1	19	FORAGE TRAD	.00000	T• HA	-11119.39966	461679.23047 # / HA
1	20	FORAGE MOD.	.00000	T• HA	-52633.39941	512320.58203 # / HA
1	21	BARLEY FEED	.00000	T• MT	.00000	16000.00000 # / MT
1	22	POTATO FEED	.00000	T• MT	.00000	20043.47778 # / MT
1	23	BARLEY SALE	197.25500	T• MT	47000.00000	.00000 # / MT
1	24	POTATO SALE	75.40435	T• MT	53000.00000	.00000 # / MT
1	25	GRAS EXT.	18.87551	T• HA	.00000	-.00000 # / HA
1	26	GRA INT.	32.72649	T• HA	-4163.99994	.00000 # / HA
1	27	DAI COWS	11.32400	T•COWS	145192.32422	-.00000 # /COW
1	28	KOR.CAT.COWS	91.67767	T•COWS	21923.05249	.00000 # /COW
1	29	HOG PROD.	49.79900	T•SOWS	118821.90527	.00000 # /SOW
1	30	EGG PROD.	5.69000	M•HENS	1076695.00000	-.00000 # /HEN
1	31	BROILER PROD	7.50000	M•CHIK	173090.40039	.00000 #/CHIK
1	32	ORCHARD PROD	13.74400	T• HA	334328.96875	.00000 # / HA
1	33	ORCHARD PLTG	.00000	T• HA	175522.70703	317898.60547 # / HA
1	34	MULBERY PROD	11.63700	T• HA	20423.22168	-.00000 # / HA
1	35	MULBERY PLTG	.00000	T• HA	10415.84314	483331.35156 # / HA
1	36	TILLER INVES	1.67400	T•MACH	-69618.19824	-.00000 #/MACH
1	37	TRANSP INVES	.00000	T•MACH	-10048.49976	.00000 #/MACH
1	38	BEEF CATTLE	8.65733	T•COW	45365.62744	.00000 SW/UNI
1	39	FEED GR.IMP.	132.45617	T• MT	-31000.00000	.00000 # / MT
2	40	RICE TRAD.	724.63411	T• HA	209963.33789	.00000 # / HA
2	41	RICE TILL.	49.88889	T• HA	209928.33789	.00000 # / HA
2	42	RICE TRANSPL	.00000	T• HA	209633.33984	1535.81810 # / HA
2	43	RICE ALL MOD	.00000	T• HA	209598.33594	1535.82108 # / HA
2	44	WHEAT TRADIT	113.91139	T• HA	41194.67969	-.00000 # / HA
2	45	WHEAT MODERN	.00000	T• HA	27638.67920	17607.13062 # / HA
2	46	BARLY TRADIT	646.95999	T• HA	-15384.83960	.00000 # / HA
2	47	BARLY MODERN	.00000	T• HA	-33234.83936	22652.09814 # / HA
2	48	S.GRAIN TRAD	202.05000	T• HA	31553.70898	-.00000 # / HA
2	49	S.GRAIN MOD.	.00000	T• HA	26675.92871	11119.88037 # / HA
2	50	IND.CRP TRAD	47.59371	T• HA	122401.10742	-.00000 # / HA
2	51	IND.CRP MOD.	.00000	T• HA	122336.60645	5680.09387 # / HA
2	52	VEGET. TRAD	.00000	T• HA	473134.82031	5727.00421 # / HA

Table 4 (continued)

2	53	VEGET. MOD.	131.80000	T. HA	486939.81641	-.00000	W / HA
2	54	POTATO TRAD	127.75800	T. HA	-17750.75952	-.00000	W / HA
2	55	POTATO MOD.	.00000	T. HA	-29650.75952	21251.66406	W / HA
2	56	TOBACCO TRAD	20.83300	T. HA	240017.62500	.00000	W / HA
2	57	TOBACCO MOD.	.00000	T. HA	243902.62305	1719.10852	W / HA
2	58	FORAGE TRAD	.00000	T. HA	-11119.39966	156562.39648	W / HA
2	59	FORAGE MOD.	.00000	T. HA	-52633.39941	201570.22461	W / HA
2	60	BARLEY FEED	.00000	T. MT	.00000	16000.00000	W / MT
2	61	POTATO FEED	.00000	T. MT	.00000	21739.13013	W / MT
2	62	BARLEY SALE	1419.77100	T. MT	47000.00000	.00000	W / MT
2	63	POTATO SALE	518.69748	T. MT	53000.00000	.00000	W / MT
2	64	GRASS EXT.	66.95607	T. HA	.00000	.00000	W / HA
2	65	GRASS INT.	.00000	T. HA	-4163.99994	6097.22247	W / HA
2	66	DAIRY COWS	3.15700	T.COWS	145192.32422	-.00000	W /COW
2	67	KOR.CAT.COWS	344.01151	T.COWS	21923.05249	-.00000	W /COW
2	68	HOG PROD.	168.33600	T.SOWS	118821.90527	.00000	W /SOW
2	69	EGG PROD.	8.47000	M.HENS	1076695.00000	-.00000	W /HEN
2	70	BROILER PROD	13.50000	M.CHIK	173090.40039	.00000	W/CHIK
2	71	ORCHARD PROD	30.22000	T. HA	331231.99609	.00000	W / HA
2	72	ORCHARD PLTG	.00000	T. HA	173896.79687	38094.01611	W / HA
2	73	MULBERY PROD	51.61800	T. HA	20423.22168	-.00000	W / HA
2	74	MULBERY PLTG	.03000	T. HA	10415.84314	198818.33594	W / HA
2	75	TILLER INVES	3.55200	T.MACH	-69618.19824	.00000	W/MACH
2	76	TRANSP INVES	.00000	T.MACH	-10048.49976	.00000	W/MACH
2	77	BEEF CATTLE	16.58249	T.COW	45365.62744	-.00000	SW/UNI
2	78	FEED GR.IMP.	35.55852	T. MT	-31000.00000	.00000	W / MT
3	79	RICE TRAD.	135.60800	T. HA	173963.34180	.00000	W / HA
3	80	RICE TILL.	.00000	T. HA	167128.33984	29036.46509	W / HA
3	81	RICE TRANSPL	.00000	T. HA	173633.34180	329.99962	W / HA
3	82	RICE ALL MOD	.00000	T. HA	166798.33984	29366.46484	W / HA
3	83	WHEAT TRADIT	20.00000	T. HA	41194.67969	.00000	W / HA
3	84	WHEAT MODERN	.00000	T. HA	27638.67920	41090.45898	W / HA
3	85	BARLY TRADIT	73.37488	T. HA	-15384.83960	-.00000	W / HA
3	86	BARLY MODERN	.00000	T. HA	-33234.83936	47827.14697	W / HA
3	87	S.GRAIN TRAD	126.20686	T. HA	38639.36836	.00000	W / HA
3	88	S.GRAIN MOD.	.00000	T. HA	34116.54785	11119.82971	W / HA
3	89	IND.CRP TRAD	23.79300	T. HA	122401.10742	-.00000	W / HA
3	90	IND.CRP MOD.	.00000	T. HA	122336.60645	5792.75494	W / HA
3	91	VEGET. TRAD	.00000	T. HA	473134.82031	2388.18555	W / HA
3	92	VEGET. MOD.	36.80000	T. HA	486939.81641	-.00000	W / HA
3	93	POTATO TRAD	40.53100	T. HA	-17750.75952	.00000	W / HA
3	94	POTATO MOD.	.00000	T. HA	-29650.75952	28281.15405	W / HA
3	95	TOBACCO TRAD	1.13960	T. HA	240017.62500	.00000	W / HA
3	96	TOBACCO MOD.	15.36667	T. HA	243902.62305	-.00000	W / HA
3	97	FORAGE TRAD	.00000	T. HA	-11119.39966	68427.80078	W / HA
3	98	FORAGE MOD.	.00000	T. HA	-52633.39941	143718.00586	W / HA
3	99	BARLEY FEED	.00000	T. MT	.00000	16000.00000	W / MT
3	100	POTATO FEED	.00000	T. MT	.00000	18565.21680	W / MT
3	101	BARLEY SALE	133.40398	T. MT	47000.00000	.00000	W / MT
3	102	POTATO SALE	164.55586	T. MT	53000.00000	.00000	W / MT
3	103	GRASS EXT.	18.24872	T. HA	.00000	.00000	W / HA
3	104	GRASS INT.	.00000	T. HA	-4163.99994	5974.53174	W / HA
3	105	DAIRY COWS	1.00100	T.COWS	145192.32422	-.00000	W /COW
3	106	KOR.CAT.COWS	54.84127	T.COWS	21923.05249	.00000	W /COW
3	107	HOG PROD.	28.06600	T.SOWS	118821.90527	.00000	W /SOW
3	108	EGG PROD.	1.43000	M.HENS	1076695.00000	-.00000	W /HEN
3	109	BROILER PROD	2.00000	M.CHIK	173090.40039	.00000	W/CHIK

Table 4 (continued)

3	110	ORCHARD PROD	11.36200	T. HA	331609.25781	.00000 $ / HA
3	111	ORCHARD PLTG	1.35000	T. HA	174094.85937	.00000 $ / HA
3	112	MULBERY PROD	18.09900	T. HA	20423.22168	-.00000 $ / HA
3	113	MULBERY PLTG	.00000	T. HA	10415.84314	34045.83057 $ / HA
3	114	TILLER INVES	.77000	T.MACH	-69618.19824	.00000 $/MACH
3	115	TRANSP INVES	.00000	T.MACH	-10048.49976	10048.49976 $/MACH
3	116	BEEF CATTLE	74.13173	T.COW	45365.62744	.00000 S$/UNI
3	117	FEED GR.IMP.	10.53209	T. MT	-31000.00000	.00000 $ / MT

Table 5) REG : Index for regional (1,2,3) and national constraints(4)

ROW : Row index in the multiregional model

CONSTRAINT : Name of row

Type : For each row a type is specified; (+) refers to $\leq$, (-) to $\geq$ and ( ) to = signs in the model constraints, with the limitations written on the right hand side of the input-output model.

RHS : Current value of constraint element $y_i^r(t)$ in units specified in the table.

SLACK: Amount of RHS not utilized in this period (units are the same as for RHS)

PI : Marginal value product of constraints $\left[\partial \pi(t)/\partial y_i^r(t)\right]$ in unit specified in the table.

4.2 Additional Performance Criteria

In addition to the direct output from the programming component, some specific regional and national accounting is done to compute indicators for mechanization, resource use, capital requirements etc. These additional performance criteria are defined as follows:[1/]

AMOD Proportion of total area cultivated with modern technology

TITN Total number of available tillers plus attachment

TRTN Total number of available rice transplanters

TIRP Number of tillers invested for replacement

TRRP Number of transplanters invested for replacement

TINI Number of tillers net invested

TRNI Number of transplanters net invested

1/ The variables are printed for each region as well as for the whole nation.

TABLE 5

~~SAMPLE OUTPUT OF DUAL SOLUTION:~~ CONSTRAINT VECTOR, SLACKS, AND SHADOW PRICES

(YEAR = 1971)

REG	ROW	CONSTRAINT	RHS		SLACK	PI	
1	1	PADDYLAND	365.24500	T. HA	.00000	235685.13607	$ / HA
1	2	SU.UPLAND	170.02000	T. HA	.00000	57221.44520	$ / HA
1	3	WI.UPLAND	183.97400	T. HA	.00000	931842.14949	$ / HA
1	4	OX WORK JUNE	.00000	T. HRS	.00000	65176.09708	$/T.HS
1	5	LABOR JUNE	229.52000	M. HRS	18.80181	.00000	$/T.HS
1	6	LABOR OCTOB.	229.50000	M. HRS	3.43544	.00000	$/T.HS
1	7	OX WORK OCT.	.00000	T. HRS	2.47161	.00000	$/T.HS
1	8	TILLER JUNE	1183.80000	T. HRS	58.32992	.00000	$/HOUR
1	9	TILLER OCT.	1183.80000	T. HRS	.00000	286.84332	$/HOUR
1	10	TRANSPL.JUNE	.00000	T. HRS	.00000	40.19400	$/HOUR
1	11	BALAN.BARLEY	2.62100	T. MT	.00000	47000.00025	$ / MT
1	12	BALAN.POTATO	.00000	T. MT	.00000	53000.00012	$ / MT
1	13	BALAN.CONCT.	.07110	T. MT	.00000	43478.26123	$ / MT
1	14	BALAN.ROUGH.	6.17190	T. MT	.00000	9897.07312	$ / MT
1	15	PASTURE LAND	51.60200	T. HA	.00000	11586.80483	$ / HA
1	16	DAIRY HERD	13.47300	T.COWS	2.14900	.00000	$ /COW
1	17	KOR.CAT.HERD	100.33500	T.COWS	.00000	32354.99804	$ /COW
1	18	SOW HERD	49.79900	T.SOWS	.00000	32888.72287	$ /SOW
1	19	ORCHARD LAND	13.74400	T. HA	.00000	333677.20934	$ / HA
1	20	MULBER. LAND	11.63700	T. HA	.00000	19119.69983	$ / HA
1	21	MIN.WHEAT LD	23.40000	T. HA	.00000	-866481.63255	$ / HA
1	22	MIN.BARLY LD	98.30000	T. HA	.00000	-843953.11905	$ / HA
1	23	MAX.VEGET LD	97.50000	T. HA	2.27423	.00000	$ / HA
1	24	MIN.SOW HERD	41.30000	T.SOWS	8.49900	.00000	$ /SOW
1	25	MAX.NEW ORCH	2.30000	T. HA	2.30000	.00000	$ / HA
1	26	MIN.DAIRY HD	11.32400	T.COWS	.00000	-33505.44854	$ /COW
1	27	MAX.TILL.INV	1.67400	T.MACH	.00000	2092.38165	$/MACH
2	28	PADDYLAND	774.52300	T. HA	.00000	147835.50274	$ / HA
2	29	SU.UPLAND	421.94400	T. HA	.00000	179002.71476	$ / HA
2	30	WI.UPLAND	872.85500	T. HA	3.88291	.00000	$ / HA
2	31	OX WORK JUNE	.00000	T. HRS	9.80932	.00000	$/T.HS
2	32	LABOR JUNE	656.60000	M. HRS	43.15541	.00000	$/T.HS
2	33	LABOR OCTOB.	656.60000	M. HRS	.00000	212407.35186	$/T.HS
2	34	OX WORK OCT.	.00000	T. HRS	.00000	125301.46008	$/T.HS
2	35	TILLER JUNE	2436.00000	T. HRS	848.11111	.00000	$/HOUR
2	36	TILLER OCT.	2436.00000	T. HRS	.00000	1174.32620	$/HOUR
2	37	TRANSPL.JUNE	.00000	T. HRS	.00000	40.19400	$/HOUR
2	38	BALAN.BARLEY	9.31100	T. MT	.00000	47000.00025	$ / MT
2	39	BALAN.POTATO	.00000	T. MT	.00000	53000.00012	$ / MT
2	40	BALAN.CONCT.	1.83320	T. MT	.00000	43478.26123	$ / MT
2	41	BALAN.ROUGH.	15.48100	T. MT	.00000	2148.02503	$ / MT
2	42	PASTURE LAND	76.87300	T. HA	9.91693	.00000	$ / HA
2	43	DAIRY HERD	3.60500	T.COWS	.44800	.00000	$ /COW
2	44	KOR.CAT.HERD	360.59400	T.COWS	.00000	32151.06157	$ /COW
2	45	SOW HERD	168.33600	T.SOWS	.00000	24365.99856	$ /SOW
2	46	ORCHARD LAND	30.22000	T. HA	.00000	271674.10777	$ / HA
2	47	MULBER. LAND	51.61800	T. HA	.00000	-4096.78082	$ / HA
2	48	MIN.WHEAT LD	96.80000	T. HA	17.11139	.00000	$ / HA
2	49	MIN.BARLY LD	647.00000	T. HA	.00000	26399.45466	$ / HA
2	50	MAX.VEGET LD	131.80000	T. HA	.00000	338772.54634	$ / HA
2	51	MIN.SOW HERD	153.90000	T.SOWS	14.43600	.00000	$ /SOW
2	52	MAX.NEW ORCH	4.75000	T. HA	4.75000	.00000	$ / HA
2	53	MIN.DAIRY HD	3.15700	T.COWS	.00000	-24624.85155	$ /COW
2	54	MAX.TILL.INV	3.55700	T.MACH	.00000	223963.35196	$/MACH

continued . . .

Table 5 (continued)

3	55	PADDYLAND	(+)	135.60800	T. HA	.00000	162860.77964	# / HA
3	56	SW.UPLAND	(+)	190.72600	T. HA	.00000	47500.10373	# / HA
3	57	NT.UPLAND	(+)	148.23200	T. HA	.00000	76821.15083	# / HA
3	58	CX FORK JUNE	(+)	.00000	T. HRS	.00000	72421.27326	#/T.HS
3	59	LABOR JUNE	(+)	155.91000	M. HRS	25.46954	.00000	#/T.HS
3	60	LABOR OCTOB.	(+)	155.91000	M. HRS	5.61634	.00000	#/T.HS
3	61	CX WORK OCT.	(+)	.00000	T. HRS	.37581	.00000	#/T.HS
3	62	TILLER JUNE	(+)	590.00000	T. HRS	76.83333	.00000	#/HOUR
3	63	TILLER OCT.	(+)	590.00000	T. HRS	.00000	934.93175	#/HOUR
3	64	TRANSPL.JUNE	(+)	.07000	T. HRS	.00000	.00000	#/HOUR
3	65	BALAN.BARLEY	(+)	2.25130	T. MT	.00000	47000.00025	# / MT
3	66	BALAN.POTATO	(+)	.00000	T. MT	.00000	53000.00012	# / MT
3	67	BALAN.CONCT.	(+)	.02140	T. MT	.00000	43478.26123	# / MT
3	68	BALAN.ROUGH.	(+)	2.61500	T. MT	.00000	1810.53182	# / MT
3	69	PASTURE LAND	(+)	55.56100	T. HA	37.33228	.00000	# / HA
3	70	DAIRY HERD	(+)	1.29500	T.COWS	.29400	.00000	# /COW
3	71	NON.CAT.HERD	(+)	128.97300	T.COWS	.00000	40691.29359	# /COW
3	72	SOW HERD	(+)	28.08600	T.SOWS	.00000	33062.79986	# /SOW
3	73	ORCHARD LAND	( )	11.36200	T. HA	.00000	330885.04532	# / HA
3	74	BUILDER. LAND	( )	18.09900	T. HA	.00000	19336.90267	# / HA
3	75	MIN.WHEAT LD	(-)	20.00000	T. HA	.00000	-11931.41790	# / HA
3	76	MIN.BARLY LD	(-)	7.00000	T. HA	3.37488	.00000	# / HA
3	77	MAX.VEGET LD	(+)	36.80000	T. HA	.00000	411642.84037	# / HA
3	78	MIN.SOW HERD	(-)	23.90000	T.SOWS	4.18600	.00000	# /SOW
3	79	MAX.NEW ORCH	(+)	1.35000	T. HA	.00000	129778.02876	# / HA
3	80	MIN.DAIRY HD	(-)	1.00100	T.COWS	.00000	-13620.64357	# /COW
3	81	MAX.TILL.INV	(+)	.77000	T.MACH	.00000	164114.73946	#/MACH
4	82	MX.NEW FUL.H	(+)	16.48500	TSD.HA	16.48500	.00000	# / HA
4	83	MX.TOBACCO H	(+)	48.76800	TSD.HA	.00000	182378.54366	# / HA
4	84	MX.FD.GRAINP	(+)	9999.00000	TSD.MT	9820.45312	.00000	# / MT
1	85	BLG.CAP.MENS	(+)	5.69000	T.PL.	.00000	33216.73153	#/PL.
1	86	BLG.CAP.BFOI	(+)	7.50000	T.PL.	.00000	71786.05205	#/PL.
2	87	BLG.CAP.MENS	(+)	8.47000	T.PL.	.00000	6665.81255	#/PL.
2	88	BLG.CAP.BFOI	(+)	13.50000	T.PL.	.00000	65137.70195	#/PL.
3	89	BLG.CAP.MENS	(+)	1.43000	T.PL.	.00000	33216.73153	#/PL.
3	90	BLG.CAP.BFOI	(+)	2.00000	T.PL.	.00000	76133.87921	#/PL.
1	91	MAX.S.GRAIN	(+)	112.54300	T. HA	16.15300	.00000	# / HA
1	92	MIN.S.GRAIN	(-)	96.39000	T. HA	.00000	-15069.51573	# / HA
1	93	MAX.I.CROPS	(+)	14.63900	T. HA	4.18400	.00000	# / HA
1	94	MIN.I.CROPS	(-)	10.65500	T. HA	.00000	-674183.89489	# / HA
1	95	MAX.POTATOES	(+)	22.14650	T. HA	3.57400	.00000	# / HA
1	96	MIN.POTSTOES	(-)	18.57250	T. HA	.00000	-166023.07910	# / HA
1	97	MIN.TOBACCO	(-)	4.87600	T. HA	6.57473	.00000	# / HA
2	98	MAX.S.GRAIN	(+)	235.91000	T. HA	33.86000	.00000	# / HA
2	99	MIN.S.GRAIN	(-)	202.05000	T. HA	.00000	-188133.55189	# / HA
2	100	MAX.I.CROPS	(+)	59.01100	T. HA	11.41729	.00000	# / HA
2	101	MIN.I.CROPS	(-)	42.37100	T. HA	5.22271	.00000	# / HA
2	102	MAX.POTATOES	(+)	127.75800	T. HA	.00000	2237.51582	# / HA
2	103	MIN.POTATOES	(-)	107.14000	T. HA	20.61800	.00000	# / HA
2	104	MIN.TOBACCO	(-)	23.80300	T. HA	.00000	-273775.67848	# / HA
3	105	MAX.S.GRAIN	(+)	144.85200	T. HA	18.64514	.00000	# / HA
3	106	MIN.S.GRAIN	(-)	124.06100	T. HA	2.14586	.00000	# / HA
3	107	MAX.I.CROPS	(+)	23.72300	T. HA	.00000	51224.34424	# / HA
3	108	MIN.I.CROPS	(-)	17.01900	T. HA	6.68400	.00000	# / HA
3	109	MAX.POTATOES	(+)	40.53100	T. HA	.00000	132896.20739	# / HA
3	110	MIN.POTATOES	(-)	33.99100	T. HA	6.54000	.00000	# / HA
3	111	MIN.TOBACCO	(-)	11.33700	T. HA	5.17627	.00000	# / HA

TIRPM Capital requirements for replacement of tillers

TRRPM Capital requirements for replacement of transplanters

TINIM Capital requirements for net investment in tillers

TRNIM Capital requirement for net investment in transplanters

FUELN Total fuel requirements

RPN Total repair costs for farm machinery

FEIN Total feed concentrate input in barley equivalents

FEIM Total import requirements for feed concentrates

4.3 Time Series Tables and Plots

Any of the variables listed under 4.1 and 4.2 as well as any input variable can be printed as a time series for the whole simulation run. It (

5. A Brief Description of the Computer Program

Initial (t=0) data is read for the Y and A matrices. Time varying parameters are read for the A matrix and the Z and Y coefficients. The simulation model is run for one year and its outputs become inputs to the RLP. The Z vector is computed from the simulation model data and the time varying parameters. If it is the initial year, the RLP is then solved (initial data is already in the Y vector and A matrix, so they don't have to be computed.). If it is not the initial year, the Y vector and A matrix are updated and the RLP is then solved.

This is the basic structure of the RLP simulation model combination. The next section describes each of the RLP subroutines in detail.

Main Program

A list of the main executive program for the RLP Model version 1 follows. Version 1 uses KASS-model variables as exogenous data (stored in unit 23 for all 15 years) and does not contain a feedback from RLP to the KASS model.

```
      T = 0.0
C           CALLS TO INITIALIZE RLP DATA SYSTEM
      CALL LPSTRT
      CALL BSET
      CALL ODATA
      CALL AINTAL
C           SIMULATION RUNS
      YEAR = 1970.
      IYR  = 1970.
      DO 400 I = 1,15
      IYR  = IYR + 1
      YEAR = YEAR + 1.
      T = T + 1.
      CALL OREDY
      IF (IYR.EQ.1971) CALL LPRUN
      IF (IYR.EQ.1971) GO TO 400
      CALL ASET
      CALL YINTL
      CALL LPRUN
  400 CONTINUE
      STOP
      END
```

Subroutine LPSTRT

This routine is called once at the beginning of a simulation run to initialize controls and constant coefficients of the yearly LP model. It calls the subroutines INIT, SETVAL and LPDMP

Subroutine INIT

This routine reads the array IFIX (controls for subroutine DULPDX) and five tolerances for the LP.

Subroutine SETVAL

This routine reads the initial input-output matrix A(I,J) and the constraint vector RHS(I), including specifications for the type of constraints. It also includes a switch IFIX(5). If IFIX(5) is equal to 1, it reads an old basis for the next LP solution.

Subroutine LPDMP

This routine prints the initial input-output matrix and the constraint vector.

Subroutine LPRUN

This routine is called yearly to execute the optimization process. First, it calls the LP-subroutine DULPDX. Second, it calls the subroutine PRTCHK to print out those results from the current LP, which are not printed by DULPDX.

DULPDX - LP package

DULPDX refers to a package of 21 subroutines performing the linear programming solution in the double precision version. This package was developed by the University of Wisconsin Computer Center UWCC in Madison.

Subroutine BSET

This routine reads data cards and builds a time varying parameter matrix used to compute the yearly constraint vector Y. Actually 15 matrices are calculated, one for each year 1971-1985. The data cards must be in a specific order. First, the cards for region specific and time specific variables (4 time points). Second, the cards for region specific and time period specific variables (3 time points).

Third, the cards for region specific and time constant variables. And fourth, BIMP, which is a constant national variable.

The data cards are always punched with three regions on one (3F15.7) and are arranged from smallest to largest (B1, B20...) within each of the four sub-groups.

The TABLIE[1/] function is used to interpolate between the data points for a particular year.

After each year is calculated the data is written out on logical unit 22 which is rewound at the end of the subroutine. Unit 22 contains all of the time varying parameter matrices.

Subroutine ODATA

This subroutine reads data cards and sets up time varying coefficients used in calculating the vector of objective function coefficients Z. The order of the data cards must agree with the order of the variable names in the READ(21) statement in subroutine OREDY.

Each data card contains 4 values. These are the values of the variable at 4 points in time (1970, 75, 80 and 85). The TABLIE function is used to interpolate between these data points for intermediate years.

As in BSET, all 15 years are calculated at one time. The data is written on logical unit 21 which is rewound at the end of the subroutine.

Subroutine AINTAL

This subrutine reads data and calculates time varying parameters used to compute new coefficients in the yearly input-output-matrix.

1/ See Fordyn: An Industrial Dynamics Simulator. Robert W. Llewellyn, North Carolina State University

The data order is the same as the one in which these data are read from unit 24 in ASET. The coefficients are calculated for each of the fifteen years and written out on logical unit 24.

Subroutine OREDY

This subroutine calculates the objective function (z vector) from the simulation model values (read from unit 23) and from the objective function parameters (read from unit 21). The order of variables in these read statements must agree with the order in the corresponding write statements (see Unit Directory). Also, some intermediate objective function values are written on logical unit 29 for use in subroutine ASET.

Subroutine ASET

This subroutine reinitializes the A matrix and computes the time varying levels of the A coefficients. The A matrix is saved in subroutine LPRUN and is reinitialized after every solution.

The constant A coefficients are read the first time the subroutine is entered. These are then used in succeeding calculations. Parameters used to compute time varying A coefficients are read from units 24 and 29.

Subroutine YINTL

This subroutine calculates the time varying constraint vector Y. In the first CALL which prepares the constraint vector for year 2, data cards are read to initialize the lagged Y coefficient values. The Y(t-1) values are read from unit 26 and the time varying parameters B from unit 22.

The new Y values are then calculated and also saved on unit 24 to become Y(t-1) values for the next run. The time varying lagged Y coefficient values are then updated.

Subroutine APRT

This subroutine prints the current coefficient matrix.

Unit Directory

Unit No.	Written on	Read from	Use
23	PRCROP	OREDY	transfers data from the simulation model to the RLP
22	BSET	YINTL	time varying parameters for constraint vector
21	ODATA	OREDY	time varying parameters to compute objective function coefficients.
24	AINTAL	ASET	time varying parameters to compute coefficients of the input-output-matrix A
29	OREDY	ASET	time varying parameters, derived from the objective function to compute coefficients of the input-output matrix.A.
27	LPRUN	ASET	initializa A matrix
26	YINTL	YINTL	contains lagged value of constraint vector elements RHS.

Table 6: Structure of the Input Output Matrix for a given Region r and Period t

	Rice				Wheat		Barley		Summer Grains	
	Plant. Hand Cult. Tradit.	Plant. Hand Cult. Tiller	Plant. Mach. Cult. Tradit.	Plant. Mach. Cult. Tiller	Tradit.	Tiller	Tradit.	Til		ler
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	>		x_{10}
	z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	z_9	z_{10}
1	1	1	1	1						
2									1	1
3					1	1	1	1		
4	X		X		X		X		X	
5	X	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X	X	X
7	X		X		X		X		X	
8		X		X		X		X		X
9		X		X		X		X		X
10			X	X						
11							-X	-X		
12										
13	-X	-X	-X	-X	-X	-X	-X	-X	-X	-X
14										
15										
16										
17										
18										
19										
20										
21					1	1				
22							1	1		
23										
24										
25										
26										
27										
28										
29										
30									1	1
31									1	1
32										
33										
34										
35										
36										
1										
2										
3										

Note: Fold out page 54.

continued ...

Table 6 (continued)

	Industrial crops		Vegetables		Potatoes		Tobacco		Forage		Conversion into TDN		Human Consumption	
	Tradit.	Tiller	Tradit.	Tiller	Tradit.	Tiller.	Tradit.	Tiller	Tradit.	Tiller	Barley	Potatoes	Barley	Pot.
	x_{11}		x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	x_{20}	x_{21}	x_{22}	x_{23}	x_{24}
	z_{11}	z_{12}	z_{13}	z_{14}	z_{15}	z_{16}	z_{17}	z_{18}	z_{19}	z_{20}	z_{21}	z_{22}	z_{23}	z_{24}
1														
2	X	X	X	X	X	X	X	X	X	X				
3	X	X	X	X	X	X	X	X	X	X				
4	X		X		X		X		X					
5	X	X	X	X	X	X	X	X	X	X				
6	X	X	X	X	X	X	X	X	X	X				
7	X		X		X		X		X					
8		X		X		X		X		X				
9		X		X		X		X		X				
10														
11											1		1	
12					-X	-X						1		1
13											-X	-X		
14			-X	-X	-X	-X			-X	-X				
15														
16														
17														
18														
19														
20														
21														
22														
23			1	1										
24														
25														
26														
27														
28														
29														
30														
31														
32	1	1												
33	1	1												
34					1	1								
35					1	1								
36							1	1						
1														
2							1	1						
3														

continued ...

Table 8 (continued)

	Grass		Livestock Production					Fruits	
	No. Fertilizer	With Fertilizer	Dairy (Milk, Beef)	Korean Cattle (Draft)	Hog (Sow plus Piglet)	Laying Hen(Eggs)	Broiler	Production	New Planting
	x_{25}	x_{26}	x_{27}	x_{28}	x_{29}	x_{30}	x_{31}	x_{32}	x_{33}
	z_{25}	z_{26}	z_{27}	z_{28}	z_{29}	z_{30}	z_{31}	z_{32}	z_{33}
1									
2									1
3									X
4	X	X		-X				X	X
5	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X	X
7	X	X						X	X
8									
9									
10									
11									-X
12									
13			X	X	X	X	X		-X
14	-X	-X	x	x	X				-X
15	1	1							
16			1						
17				1					
18					1				
19								1	
20									
21									
22									
23									
24					1				
25									1
26			1						
27									
28						1			
29							1		
30									
31									
32									
33									
34									
35									
36									
1									
2									
3									

continued ...

Table 6 (continued)

	Silk		Investment in Machinery			
		Planting	Tiller plus Attachment	Trans-planter	Fattening of Cattle	Feed Grain Purchase
	x_{34}	x_{35}	x_{36}	x_{37}	x_{38}	x_{39}
	z_{34}	z_{35}	z_{36}	z_{37}	z_{38}	z_{39}
1						
2		1				
3		X				
4	X	X				
5	X	X			X	
6	X	X			X	
7	X	X				
8			-X			
9			-X			
10				-X		
11		-X				
12						
13		-X			X	-X
14		-X			X	
15						
16						
17					1	
18						
19						
20	1					
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						
1		1				
2						
3						1

continued ...

Table 6 (continued)

	Constraint Vector r=1, 2, 3(regions) r=4(nation)	
	$\pi(t)$	Objective Function
$\leq$	$y_1^r(t)$	Paddy Land Capacity (ha)
$\leq$	$y_2^r(t)$	Summer Upland Capacity (ha)
$\leq$	$y_3^r(t)$	Winter Upland Capacity (ha)
$\leq$	$y_4^r(t)$	Oxen Labor Balance in Season 1 (hrs)
$\leq$	$y_5^r(t)$	Labor Capacity in Season 1 (hrs)
$\leq$	$y_6^r(t)$	Labor Capacity in Season 2 (hrs)
$\leq$	$y_7^r(t)$	Oxen Labor Balance in Season 2 (hrs)
$\leq$	$y_8^r(t)$	Tiller Capacity in Season 1 (hrs)
$\leq$	$y_9^r(t)$	Tiller Capacity in Season 2 (hrs)
$\leq$	$y_{10}^r(t)$	Rice Transplanter Capacity in June (hrs)
$\leq$	$y_{11}^r(t)$	Balance Equation for Barley (MT)
$\leq$	$y_{12}^r(t)$	Balance Equation for Potatoes (MT)
$\leq$	$y_{13}^r(t)$	Balance Equation for Feed Concentrates (MT TDN)
$\leq$	$y_{14}^r(t)$	Balance Equation for Roughage (MT TDN)
$\leq$	$y_{15}^r(t)$	Capacity of Pasture Land (ha)
$\leq$	$y_{16}^r(t)$	Current Size of Dairy Herd, Including Heifers (Head)
$\leq$	$y_{17}^r(t)$	Current Size of Korean Cattle Herd, Including Heifers (Head)
$\leq$	$y_{18}^r(t)$	Current Size of Sow Herd (Head)
$=$	$y_{19}^r(t)$	Capacity of Orchards in Production (ha)
$=$	$y_{20}^r(t)$	Capacity of Mulberry Fields in Production (ha)
$\geq$	$y_{21}^r(t)$	Flexibility Constraint for Wheat Production (Lower Bound) (ha)
$\geq$	$y_{22}^r(t)$	Flexibility Constraint for Barley Production (Lower Bound) (ha)
$\leq$	$y_{23}^r(t)$	Flexibility Constraint for Vegetable Production (Upper Bound) (ha)
$\geq$	$y_{24}^r(t)$	Flexibility Constraint for Hog Production (Lower Bound) (Head)
$\leq$	$y_{25}^r(t)$	Flexibility Constraint for Planting of New Orahards (Upper Bound) (ha)
$\geq$	$y_{26}^r(t)$	Flexibility Constraint for the Expansion of the Dairy Herd (Lower Bound) (Head)
$\leq$	$y_{27}^r(t)$	Adoption Constraint for Investment in Tillers
$\leq$	$y_{28}^r(t)$	Constraint for Egg Production (Hens)
$\leq$	$y_{29}^r(t)$	Constraint for Broiler Production (Broilers)
$\leq$	$y_{30}^r(t)$	Flexibility Constraint for Summer Grains (Upper Bound) (ha)
$\geq$	$y_{31}^r(t)$	Flexibility Constraint for Summer Grains (Lower Bound) (ha)
$\leq$	$y_{32}^r(t)$	Flexibility Constraint for Industrial Crops (Upper Bound) (ha)
$\geq$	$y_{33}^r(t)$	Flexibility Constraint for Industrial Crops (Lower Bound) (ha)
$\leq$	$y_{34}^r(t)$	Flexibility Constraint for Potatoes (Upper Bound) (ha)
$\geq$	$y_{35}^r(t)$	Flexibility Constraint for Potatoes (Lower Bound) (ha)
$\geq$	$y_{36}^r(t)$	Flexibility Constraint for Tobacco (Lower Bound) (ha)
$\leq$	$y_1^4(t)$	National Constraint for Planting of New Mulberry Fields (Upper Bound) (ha)
$\leq$	$y_2^4(t)$	National Constraint for Tobacco Production (Upper Bound) (ha)
$\leq$	$y_3^4(t)$	Restriction for Feed Grain Imports (MT TDN)

APPENDIX A

Data and Assumptions

Used in the Resource Allocation Model

1. Land Resources and Land Utilization

Table 1.1 : Land Resources in 1971

Category \ Region	1	2	3	Total
Paddy land	365.245	774.523	135.608	1,275.376
Summer Upland 1/ w/o Perennials	170.020	421.944	190.726	782.690
Land Used for Double Cropping 1/ (winter upland)	183.975	872.855	148.232	1,205.062
Orchards	13.744	30.220	11.362	55.326
Mulberry Fields	11.637	51.619	18.099	81.355
Total Utilized Area	721.099	2,106.049	497.648	3,324.796

Source: Yearbook of Agriculture and Forestry Statistics, 1972

1/ The composition of crops among summer and winter crops was calculated using the composition coefficients of table 1.2. The resulting double cropping ratio is maintained as constraint for all years.

Table 1.2 : Composition of Field Crops Among Summer and Winter Crops

	Region 1	Region 2	Region 3
1. Industrial Crop (average, '68-'70)			
Summer	0.158	0.398	0.316
Winter	0.842	0.602	0.684
2. Potatoes (S. Potatoes = Summer Crop, W. Potatoes = Winter Crop, Average, '68-'70)			
Summer	0.627	0.788	0.488
Winter	0.373	0.212	0.512
3. Vegetables (1970)			
Summer	0.513	0.603	0.527
Winter	0.487	0.397	0.473
4. Forage Crops (Assumed)			
Summer	0.5	0.5	0.5
Winter	0.5	0.5	0.5
5. Summer Grain (Pulses and Other Grains) (1970)			
Other grain	0.906	0.773	0.582
Pulses	0.094	0.227	0.418

Source: Yearbook of Agriculture and Forestry Statistics, 1968-1971

Table 1.3 : Projected Crop Land Development and Land Withdrawel by Regions (1000 ha's/year) 1/

Time Period \ Region	1	2	3
	..... Paddy Land		
1971 - 1975	-2.508	-5.350	- .942
1976 - 1980	-2.850	-6.080	-1.070
1981 - 1985	-2.850	-6.080	-1.070
	..... Upland		
1971 - 1975	+2.094	+4.470	+2.235
1976 - 1980	+2.380	+5.080	+2.540
1981 - 1985	+2.380	+5.080	+2.540

Source: Projections by KIM, Young Sik and Karl T. Wright, AERI and MSU.

1/ (-) stands for decrease, (+) stand for increase

Table 1.4 Acreage of Various Crops by Region in Korea, 1965 - 1971

Unit: 1,000 hectares

	1965	1966	1967	1968	1969	1970	1971
				Region I			
Total Rice	351.226	354.457	353.625	350.267	349.900	344.976	341.723
Wheat	31.386	33.634	33.062	31.008	29.998	29.378	23.414
Barley	180.492	168.220	152.854	144.862	134.999	123.233	93.431
S. Grain	151.048	138.526	143.799	134.649	129.173	119.408	98.680
Ind. Crops	13.225	14.739	15.092	13.092	12.696	14.880	12.830
Vegetables	51.745	48.716	59.996	60.962	71.289	97.730	100.576
Potatoes	33.927	31.752	28.797	25.797	24.851	22.509	19.697
Tobacco	5.518	6.140	6.536	6.321	5.684	5.886	5.367
Fruit	13.471	14.596	15.505	15.728	16.902	17.699	13.744
Mulberry	8.463	9.811	10.056	18.361	15.143	12.363	11.637
				Region II			
Rice	757.296	755.655	759.017	679.314	747.682	738.477	729.413
Wheat	92.986	88.224	90.818	99.307	97.525	104.883	98.625
Barley	732.014	685.306	717.508	737.296	719.281	701.386	670.851
S. Grain	287.545	249.924	251.402	307.649	255.350	239.535	218.701
Ind. Crops	35.002	39.446	43.643	44.104	58.156	52.394	55.672
Vegetables	76.854	75.929	86.175	97.924	121.962	120.711	117.336
Potatoes	130.666	130.662	126.084	128.711	125.269	120.318	109.822
Tobacco	17.347	18.628	19.118	20.575	21.565	24.027	23.792
Fruit	24.890	25.275	26.785	28.811	30.708	32.530	30.220
Mulberry	30.633	38.544	43.504	65.258	61.080	53.459	51.619
				Region III			
Rice	129.834	131.478	132.909	130.903	132.104	129.900	129.228
Wheat	28.489	32.365	29.022	38.426	26.660	24.868	21.418
Barley	118.997	115.835	108.446	103.590	95.175	87.270	75.118
S. Grain	172.684	152.212	166.491	158.018	154.410	147.078	134.059
Ind. Crops	12.669	13.990	15.488	14.928	17.918	21.938	22.079
Vegetables	22.075	29.509	31.095	33.705	33.082	35.915	39.338
Potatoes	49.796	47.641	41.598	43.618	42.948	39.078	35.132
Tobacco	11.559	11.958	11.929	11.799	11.832	13.086	11.815
Fruit	4.503	5.319	5.857	6.665	8.089	9.955	11.362
Mulberry	11.381	13.337	14.956	10.825	23.041	19.155	18.100

Sources: Yearbook of Agriculture and Forestry Statistics.

Table 1.5 : Historical Development of Total Utilized Area by Regions 1965 - 1971

Unit: 1000 ha's

Year \ Region	1	2	3	Total
1965	840.500	2,185.232	561.986	3,587.719
1966	820.591	2,107.592	553.643	3,481.826
1967	819.323	2,164.054	557.791	3,541.168
1968	801.046	2,208.948	542.476	3,552.471
1969	790.635	2,238.578	545.258	3,574,472
1970	788.064	2,187.721	528.243	3,504.026
1971	721.099	2,106.049	497.648	3,324.797

Source: Yearbook of Agriculture and Forestry Statistics, 1966-1972

2. Labor Input and Mechanization

2.1 Human Labor

Table 2.1.1 Definitions of Labor - Peak Seasons

Duration \ Season	1	2
Average dates	June 11 - July 13	October 11 - Nov. 9
Calendar days	32	30
Holidays	2	2
Raining days	5	3
Effective Working days	25	25
Hours per day	8.5	8.5
Total Hours per Man Equiv. unit (1970) 1/	225	225

1/ This number is gradually increased in time to account for increasing labor efficiency. It reaches 120 % of the initial value by 1985.

Table 2.1.2 Projected Agricultural Laborforce in Man Equivalent Units by Regions 1970-1985

Year \ Region	1	2	3	Total
1970	1.07	3.05	0.73	4.85
1975	1.13	3.23	0.78	5.13
1980	1.04	2.98	0.71	4.73
1985	0.74	2.10	0.50	3.34

Source: Population Projections by KASS

Table 2.1.3 Labor Requirements for Crop Production by Technology (hrs/ha)

Technology / Crop	traditional (using draft animals)		modern (using a power tiller)		modern (using a rice transplanter)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Rice	311	346	291	186	141	346
Wheat	276	284	131	160	-	-
Barley	307	320	147	180	-	-
S. Grains	98	258	88	238	-	-
Ind. Crops	287	232	277	212	-	-
Vegetables	242	202	146	107	-	-
Potatoes	144	231	104	191	-	-
Tobacco	654	691	628	661	-	-
Forage	218	293	106	106	-	-
Pasture	-	-	10	-	-	-
Orchard	650	245	568	166	-	-
Mulberry	164	106	144	86	-	-

Sources: 1. EXOTECH Systems, Inc.: Farm Mechanization Program for Korea. AID Project, Seoul 1972
2. AERI: Basic Data on Regional Planning, Seoul, 1965
3. K. Wright and Kim, Young Sik: Working Paper on Crop Production
4. Kim, Sung Ho: AERI Report, 1972

Table 2.1.4 Labor Requirements per Unit of Livestock Activity (hrs/head) 1/

Livestock Activity / Season	1	2
Dairy	47.90	47.90
Korean Cattle	40.59	40.59
Hogs	41.00	41.00
1000 Hens	125.	125.
1000 Broilers	31.3	3.13

Source: Based on Yook Chong Yoong: Outline on Animal HusbandFy, AERI, Seoul 1960

1/ These labor requirements refer to animal aggregates, defined i appendix A.

2.2 Draft Cattle

Table 2.2.1 Herd Size of Draft Cattle and Animal Labor Supply by Regions, 1971

Region / Category	1	2	3	Total
	..... 1,000 Animals			
Korean Cattle over 2 years, Ox units(1.0)	136.432	458.226	168.306	762.964
Korean Cattle under 2 years (animals)	102.176	278.262	103.660	484.098
Ox Units (0.25)	25.544	69.565	25.915	121.024
Total Draft Animals (Ox units)	161.976	527.791	194.221	883.988
	..... 1,000 Hours			
Hours per Draft Animal Unit				
Season 1	.200	.200	.200	
Season 2	.125	.125	.125	
Total Draft Animal Hours1/				
Season 1	32,300.	105,500.	38,800.	176.600
Season 2	20,200.	65,900.	24,300.	110.400

1/ These numbers correspond to the number of cows over 2 years (i.e. the numbers of cattle aggregates) multiplied by .342 and .202 for region 1, by .294 and .184 for region 2 and by .304 and .190 for region 3.

Table 2.2.2 Draft Cattle Requirements of Production Activities Using Traditional Technology (hours/ha)

Region	1		2		3	
Production Activity	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Rice	54	15	70	22	42	14
Wheat	15	42	27	48	20	38
Barley	20	43	25	43	25	35
S. Grain	38	10	38	10	38	10
Ind. Crops	45	15	45	15	50	15
Vegetables	36	10	36	10	36	10
Potatoes	32	45	32	45	32	45
Tobacco	120	50	130	45	140	40
Pasture, ext.	50	30	50	30	50	30
Pasture, int.	100	60	100	60	100	60
Forage	50	30	50	30	50	30
Fruit	10	50	12	60	10	50
Mulberry	20	16	20	16	15	10

Source: Informations from the Farm Management Section at AERI, Seoul

2.3 Mechanization

Table 2.3.1 Variable Costs of Machinery Utilization in Crop Production (Won/ha) 1/

Modern Activity	total machine hours/year/ ha	repair and fuel costs (Won/hrs) 2/	Variable costs per ha (Won/ha)
Rice w. Tiller	70	238	16 660
Rice w. Transpl.	30	11	330
Rice, all modern			
Tiller	70	238	16 990
Transpl.	30	11	16 990
Wheat	68	238	16 184
Barley	75	318	17 850
S. Grain	30	238	7 140
Ind. Crops	30	238	7 140
Vegetables	50	238	11 900
Potatoes	50	238	11 900
Tobacco	50	238	11 900
Forage	187	222	41 514
Fruit	127	217	27 559
Mulberry	60	217	13 020

1/ Source: EXOTECH - Consulting Group: Report an Farm Mechanization in Korea, AID Project, August 1970

2/ Assumptions

a. acquisition prices; tiller plus attachment - 381,052 Won. rice transplanter - 55,000 Won. Salvage price = 10% of acquisition price. Average life time: 7 years

b. repair costs per hour in of tiller use { crop production - 63 Won/hour; forage 47 "; fruit and mulberry 42 "}

transplanter use 11 "

c. fuel and oil costs for tillers

consumption per hour: 5.3 l/hour - fuel; 0.1 l/hour - oil

prices: 30Won/l fuel; 160Won/l oil

costs per hour : 175 Won/hour

Table 2.3.2 Machinery Hours during Peak Seasons in Modern Crop Production (hours/ha)

	Power Tiller		Rice Transpl.
	Season 1	Season 2	Season 1
Rice	10	27	30
Wheat	18	31	--
Barley	20	34	--
S. Grains	5	10	--
Ind. Crops	5	10	--
Vegetables	15	15	--
Potatoes	20	20	--
Tobacco	10	15	--
Forage	12	40	--
Pasture	--	--	--
Orchard	21	3	--
Mulberry	10	10	--

Sources: 1. EXOTECH Consulting Group: Report on Farm Mechanization in Korea AID Project, August, 1972
2. Kim, Sung Ho. Labor and Machinery Utilization, 1972, AERI

Table 2.3.3 Total Number of Power Tillers in Agriculture by Regions

Year	Total	Region1	Region2	Region3
1964	601	152	340	109
1965	1,111	324	641	146
1966	1,555	472	823	260
1967	3,819	1,193	2,075	551
1968	6,225	1,719	3,618	888
1969	8,832	2,684	5,001	1,147
1970	11,884	3,348	6,995	1,541
1971	16,842	4,735	9,744	2,363

3. Livestock Production and Feeding

Table 3.1 Variable Costs, other than Feed for Livestock Production in 1971

Activity / Cost Item	Dairy Cattle	Korean Cattle	Hogs	Layers	Broilers
	Won/cow	Won/cow	Won/hog	Won/hen	Won/broil.
Building and Equipment Costs	8614	3630	1448	33.3	2.8
Veter. Costs	4552	363	201	24.3	1.8
Breeding Costs	1500	1500	500	-	44.3
Other Costs	7893	1365	543	18.1	1.8

Source: NACF Reports 1969, 1970

Table 3.2 Feed Requirements for Livestock Production (in TDN) in the Initial Year (1970)

Feed / Livestock category	Unit	Commercial Feed Concentrate (TDN)	Roughage (TDN)
Basic production			
Dairy cow	MT/cow/year	2.4	
Korean cattle	MT/cow/year	0.36	
Sow	MT/sow/year	0.84	
Layer	MT/hen/year	0.0215	
Hog fattening	MT/hog/prod. period	0.241	
Broiler fattening	MT/kg/prod. period	0.0022	
Dairy beef fattening	MT/head/year	0.8	
Korean cattle fatten.	MT/head/prod. period	0.566	
Raising of dairy cattle	MT/head/year	0.87	
Raising of Korean cattle	MT/head/prod. period	0.486	
Aggregated activities dairy	MT/year	3.55	2459
Korean cattle modern	MT/year	0.7447	541 1/
trad.	MT/year	0.083	541 1/
Hog, modern	MT/year	3.294	.024
traditional	MT/year	2.19	.024
Layers, modern	MT/year	28.00	-
(1000) traditional	MT/year	26.67	-
Broilers (1000)	MT/year	2.23	-
Beef cattle	MT/year	.819	595

Sources: AERI - Livestock Report, 1968
Hong Jae Hee : Working Paper for KASS 1972.
Informations from Farm Management Section, AERI

1/ Actually, the roughage consumption of Korean Cattle is assumed to be different in the three regions.

Table 3.3 Selected Data on Livestock - Production for 1970 and Projections for 1975, 1980, 1985

Category \ Year	1970	1975	1980	1985
Milk yield(MT/cow)	4.3	5.0	6.0	7.0
Birth rate, dairy (%)	70.8	83.3	69.0	70.0
Edible meat per dairy beef (MT/head)	.144	.170	.210	.230
Birth rate, Korean Cattle (%)	56.6	66.6	71.2	73.8
Edible meat per Korean Cattle Ox (MT/head)	.130	.130	.130	.130
Piglets per sow per year	10.26	10.8	11.7	12.9
Edible meat per hog (MT/head)	.055	.055	.055	.055
Eggs per layer per year (MT/hen)	.0093	.0096	.011	.0116
Edible meat per broiler (MT/head)	.0007	.0007	.0007	.0007

Source: Hong, Jae Hee : Working Paper on Livestock Production KASS, Seoul, 1972

Table 3.4 Development of Herd Sizes of Selected Livestock Enterprises (Unit 1,000 female animals), 1968, 1969, 1971

	Age	1968	1969	1971
		Region I		
Dairy	over 2 years	5.971	9.175	13.473
Korean Cattle	over 2 years	90.096	90.541	99.793
Beef Cattle	over 2 years	39	.142	28
Sows	over 6 months	139.083	138.536	126.375
Sows	over 10 months	50.285	47.038	49.799
Hens	over 6 months	5,597.660	4,949.000	5,692.967
		Region II		
Dairy	over 2 years	2.150	2.709	3.605
Korean Cattle	over 2 years	362.034	372.717	359.801
Beef Cattle	over 2 years	.147	.399	.184
Sows	over 6 months	513.911	463.809	389.292
Sows	over 10 months	229.336	192.666	168.336
Hens	over 6 months	11,875.978	8,819.000	8,468.508
		Region III		
Dairy	over 2 years	485	708	1.295
Korean Cattle	over 2 years	102.935	120.050	127.443
Beef Cattle	over 2 years	.347	.340	.471
Sows	over 6 months	91.101	89.053	68.362
Sows	over 10 months	35.360	28.048	28.086
Hens	over 6 months	1,752.271	1,285.000	1,428.856

Source: Yearbook of Agriculture and Forestry Statistics.

Table 3.5 TDN - Content of Various Crop By-Products (% TDN)

Main Product	By-Product	% of Main Product	TDN % in By-Product	TDN % in Main Product
Rice	Bran	13.2	79.4	10.48
Barley	Bran	26.3	50.9	13.38
Wheat	Bran	38.9	67.9	26.41
S. Grain	Bran	49.7	37.0	18.39
Vegetables	Roughage	5.0	10.0	0.50
Sweet Potatoes	Roughage	33.0	6.0	1.98
All Potatoes	Roughage	16.1	6.0	0.98

4. Forage Production and Pasture Management

Table 4.1 Assumed Yields of Cultivated Forage Crops on Upland (Average 1970 - 1985)

	Low yield crops	High yield crops	Average
Crop Yield (MT/ha)	30.0	50.0	40.0
Loss Rate (%)	10.0	10.0	10.0
Net Yield (MT/ha)	27.0	45.0	36.0
TDN Content (%)	12-18	12-18	13.0
Net Yield in TDN (MT/ha)	3.2-4.8	5.4-8.1	4.68

Table 4.2 Assumed Roughage Yields from Wild Grass Land by Management Intensity and by Region

	1		2		3	
	No Fertil.	With Fertil.	No Fertil.	With Fertil.	No Fertil.	With Fert.
Grass yield (MT/ha)	6.0	9.0	7.0	10.5	8.0	12.0
Proportion used for feeding (%)	50	50	50	50	50	50
TDN content (%)	50	50	50	50	50	50
Net yield in TDN (MT/ha)	1.5	2.25	1.75	2.63	2.0	3.0

Source: Institute of Agricultural Economics, ORD: Feed Supply and Use for Livestock Production in Korea, Seoul, 1968 pp. 425 - 435

Table 4.3 Variable Costs for Pasture Improvement

	Quantity kg/ha	Price Won/kg	Variable costs Won/ha
Seed			1500.
Lime	3000	.7	2100.
Fertilizer N	9.	15.1	136.
P_2O_5	17.	19.3	328.
K_2O	10.	10.0	100.
Total Costs			4.164.

Table 4.4 Projected Pasture Land Capacity by Regions
(1000 ha)

Region / Land Category	1	2	3
Uncultivated Land (1970)			
9 - 20° slope	44,571	42,621	32,245
20 - 24 slope	7,031	34,252	23,336
Total	51,602	76,873	55,581

Source: VINCENT, W.H. and Kim B. D: Upland Development in Korea. KASS-Working Paper, East Lansing (Seoul 1972)

5. Intercropping

Table 5.1 Composition of Crops Intercropped on Newly Planted Orchards or Mulberry Fields (Assumption) 1/

	Summer Crops	Winter Crops
Total	1.0	1.0
Grain 2/	0.7	0.7
Forage	0.3	0.3

1/ The assumptions for yields, variable costs, labor requirements, etc. are based on the regional double cropping ratio.
2/ Wintergrain is barley.

Table 5.2 Proportion of Area Used for Intercropping on Newly Planted Orchards or Mulberry Fields (Assumption)

	Years after planting				
	1	2	3	4	5
Proportion	.9	.8	.5	.2	.1

6. Flexibility and Adoption Constraints

Table 6 Flexibility Coefficients 1/

	Upper	Lower
Rice	0.0350	0.0380
Wheat Barley	0.062	0.039
Summer Grains	0.0590	0.0930
Industrial Crops	0.1880	0.1470
Vegetables	0.1590	0.1040
Potatoes	0.2130	0.0490
Tobacco	0.1340	0.0690
Forage		
Dairy	0.3883	-
Beef	0.0310	0.0346
Hogs	0.0770	0.1470
Hens	-	-
Chickens	0.3060	0.1320
Mulberry	0.1940	0.1430
Orchard	0.1460	-

1/ Calculated from maximal year to year changes in acreages and livestock herd sizes between 1965 and 1970