

A DYNAMIC PROGRAMMING MODEL OF STORAGE, RELEASE AND IMPORT OF FOODGRAINS

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ABSTRACT

A dynamic programming model for storage, release and import of food grains is presented. The model was programmed in BASIC and has been applied to the foodgrain management system in Bangladesh. This model and program are designed to teach dynamic programming with application in grain storage management.

INTRODUCTION

Food deficit in developing countries like Bangladesh is met up by import and food aid. The supply of foodgrain has a profound effect on the movement of price of food grains over time and hence on the consumption benefit. An effective procurement and release can iron out the seasonal variations of price and provide greater consumer welfare. Hence, an analytical tool is of vital importance for foodgrain management systems essentially consisting of procurement, release, storage and import of food grains.

Barlage (1973) developed a dynamic programming model to design food grain import and storage policy in Bangladesh. The model is essentially a multistage one in time period with each period consisting of initial stock, import ordering, production, local procurement and release from the system.

Bala et al (1990) developed a system dynamics model of foodgrain procurement, release and import system in Bangladesh. The model effectively take into account the nonlinearity and inherent time lag of the systems. The model was simulated to analyse the impacts of different production scenario and to explore the policy implications of local procurement and rationing on market price and consumption.

The model developed by Barlage (1973) is essentially a least cost model consisting of storage cost, import cost, holding cost and shortage cost. The model does not consider the consumer welfare. The purpose of this study was to develop a dynamic programming model of foodgrain to provide maximum consumption benefit and minimize storage cost and to program it in BASIC suitable for micro computer for teaching dynamic programming.

MODEL STRUCTURE

The decision process for foodgrain storage, release and import can be considered sequential in the sense that a decision made at this month will affect future decisions. For example, If foodgrain is released in this month, less is stored and available for release in the next month or months. Similarly if foodgrain is imported and stored in this month, more foodgrain can be released in the next month or months. This type of sequential decisions can be best characterised by a dynamic programming model.

The model assumed twelve months period (one year) time horizon. At any time period, i , there are seven distinct actions/decisions that can be taken for foodgrain storage, release and import system. They are : 1. storage only; 2. release of 0.5 million tonnes of foodgrain only; 3. release of 1.0 million tonnes

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foodgrain only; 4. release of 1.5 million tonnes foodgrain only; 5. import of 0.5 million tonnes of foodgrain and storage with the previous carryover stock; 6. import of 1.0 million tonnes of foodgrain and storage with the previous carryover stock and 7. import of 1.5 million tonnes of foodgrain and storage with the previous carryover stock.

Some of these are not feasible for some of the states of a particular stage. For example, if the stock available is 1.5 million tonnes, we will not release any grain or if the storage capacity is full we can not import any grain. The decision process can be pictorially represented as in Fig.1.

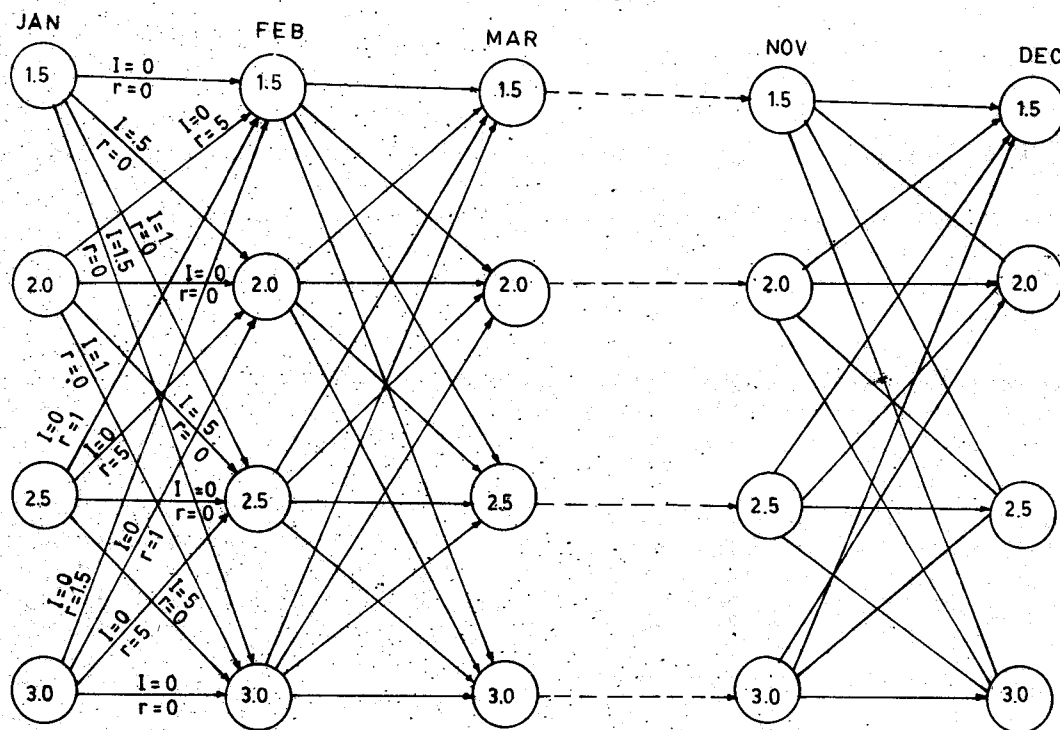


Fig. 1(a) Alternatives of storage, release and import of foodgrains. The numbers in the circles indicate the stock level of foodgrains in millions and the flow of foodgrains from a high level to a low level indicates release while that from a low to a high level indicates importation.

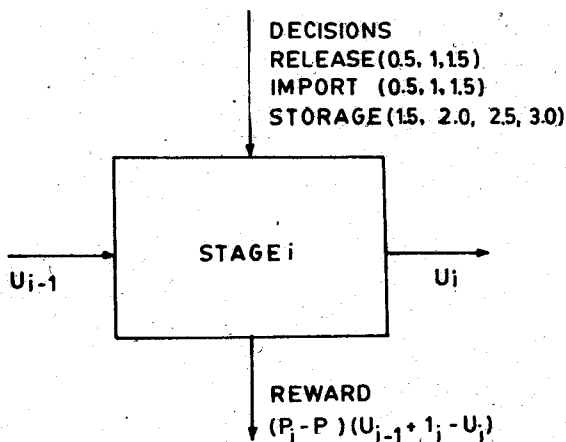


FIG. 1(b) A GENERALISED STAGE OF FOODGRAIN STORAGE, RELEASE AND IMPORT SYSTEM.

At each stage or period the state variable and net benefit are computed. The grain stock available for carryover at the beginning of each period depends on grain stock available for carryover in the previous period and the decisions being made in the last period. The net return in each period depends on the decision being made in that period and can simply be expressed as the consumption benefit minus the cost of storage. We would like to find the best combinations of storage, release and import decisions that will maximize the total returns from 12 month periods.

The price of foodgrains are lowest at the harvest and then gradually increases with storage time until the next harvest. The fluctuations of the price of the foodgrains are shown in Fig.2. The consumption benefit can be maximized by storing the grains during the off peak periods and then releasing foodgrains during the peaks of the price. The optimal decision is to be determined from a series of alternatives of storage, release and import policies for each of the twelve months of the year. Release or import is considered to be a multiple of 0.5 million tonnes of foodgrain. For example, from a stock level of 2 million tonnes in the month of April, we can opt

for one of the following: (i) releasing of 0.5 million tonnes with consumption benefit of 384.5 million taka, (ii) no release or no import with a storage cost of 200 million taka, (iii) importation of 0.5 million tonnes of foodgrain with a storage cost of 250 million taka and (iv) importation of 1 million tonnes of foodgrain with a storage cost of 300 million taka. The optimal policy can be identified based on the Belman's principle of Optimality.

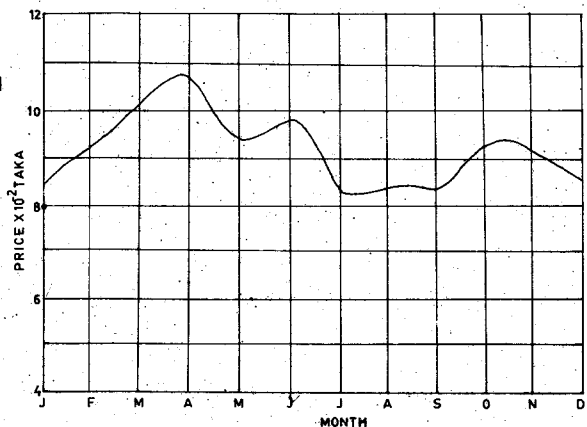


FIG. 2 MONTHLY VARIATIONS OF PRICE OF FOODGRAINS

An optimal policy has the property that whatever the initial state and optimal first decision may be, the remaining decisions constitute an optimal policy with regard to the state resulting from the first decision.

In essence the consumption benefit of the consumers is to be optimized and it is defined here as the product of the price differential between the actual price and the equilibrium price, and quantity of grain released from the public stock. The amount released from the stock is thus

$$r_i = u_{i-1} + I_i - u_i \quad (1)$$

and the stage return is

$$(P_i - P_e)\{r_i\} - s_i u_i$$

This leads to the following dynamic programming formulation

$$V_i\{u_i\} = \text{Max}[(P_i - P_e)(u_i + I_i - u_i) - s_i u_i + V_{i+1}\{u_i\}] \quad (2)$$

$$u_i \quad (i = n, \dots, 1)$$

Subject to

$$u_{\min} \leq u_{i-1} + I_i \leq u_{\max}$$

Consequently the computationally more efficient formulation is

$$V_i\{x_i\} = \text{Max}[(P_i - P_e)\{x_i - u_i\} - s_i u_i + V_{i+1}\{u_i\}] \quad (3)$$

$$u_{\min} \leq u_i \leq u_{\max}$$

with

$$V_{n+1}\{x_{n+1}\} = 0$$

where $x_i = u_{i-1} + I_i$ is referred to as total supply.

SIMULATED RESULTS

Numerical computations were done for storage capacity of three million tonnes. Data on storage and import of foodgrain for simulation of the model are shown in Table 1. The price levels of the foodgrain for the simulated period are those shown in Fig. 2. Stock of foodgrain were allowed to assume four levels starting at 1.5 million tonnes to 3.0 million tonnes. The imports permitted were 0.5, 1.0 and 1.5 million tonnes. The net benefits for different levels of foodgrain storage and import are computed from these data.

Table 1 Data on storage and import management

Maximum storage capacity (million tonnes)	3.0
Minimum security reserve (million tonnes)	1.5
Maximum import in any month (million tonnes)	2.0
Equilibrium price level (taka/tonnes)	9000.0
Storage cost (taka/tonnes/month)	100.0

1 Dollar = Taka 39.40

The details of optimal path is shown in Table 2. The optimal path is same for all initial state. The simulated available foodgrain stock for optimal policy for the simulated period is shown in Fig. 3 and the optimum consumer benefit is 1633.5 million taka. The fluctuating price levels had peaks in the months of April, June and August and an amount of 1.5 million tonnes of foodgrain is to be released in each of these months whereas the price levels had the fluctuating bottom in the month of January, March and September and an amount of 1.5 million tonnes of foodgrain is to be importated in each of these months (Fig. 3).

Table 2 Details of optimal path

Stage No.	State decision		Stage return	Values (Million Taka)
	No.	No.		
1	1	4	-300.0	1633.5
2	4	1	363.0	1933.5
3	1	4	-300.0	1570.5
4	4	1	1453.5	1870.5
5	1	4	-300.0	417.0
6	4	1	1132.5	717.0
7	1	1	-150.0	-415.5
8	1	1	-150.0	-265.5
9	1	4	-300.0	-115.5
10	4	1	484.5	184.5
11	1	1	-150.0	-300.0
12	1	1	-150.0	-150.0
13	1	0	0.0	0.0

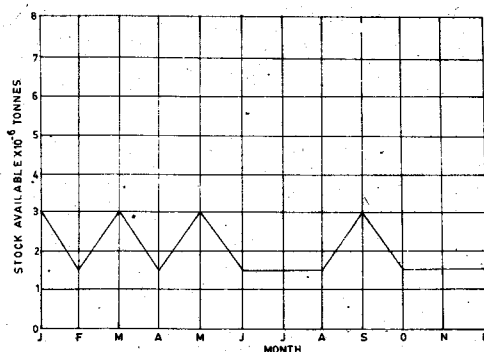


FIG. 3 SIMULATED AVAILABLE FOODGRAIN STOCK FOR OPTIMAL POLICY

The release of foodgrains in the fluctuating peaks of price would provide maximum consumer welfare and importation of the foodgrain in off peaks would minimize storage cost. Thus, the simulated results are logical and consistent with price stabilization policy of agricultural commodities using buffer fund

4. Microcomputers are now widely available and this model has been programmed in BASIC suitable for microcomputer. Thus, this model and the program can be used as a tool for teaching dynamic programming with application in foodgrain storage and import management.

CONCLUSIONS

A dynamic programming model of storage, release and import of foodgrain in Bangladesh is presented. The model has been programmed in BASIC suitable for micro computer. This model and program have been prepared for teaching dynamic programming to the agricultural engineering and industrial engineering students.

NOMENCLATURE

- I_i import of foodgrain at i th month, tonnes/month
- P_i price of foodgrain at i th month, taka/tonne
- P_e equilibrium price of foodgrain, taka/tonne
- r_i release of foodgrain, tonnes/month
- s_i storage cost in the i th month, taka/month/tonne

- u_i stock available for carryover in the i th month, tonnes/month
- $u_{\max}$ maximum stock available for carryover, tonnes/month
- $u_{\min}$ minimum stock available for carryover, tonnes/month
- V_i consumption benefit of the consumers, Taka/month
- X_i total supply of foodgrains, tonnes/month

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