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IMPACT OF HOMESTEAD FORESTRY ON DOMESTIC ENERGY SUPPLY - A SYSTEM DYNAMIC APPROACH

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ABSTRACT

A microlevel study on the homestead forest and energy consumption for cooking was conducted covering three villages. A system dynamics model was developed to identify the impacts of present trend of cutting plant, plantation rate and energy consumption for cooking on the homestead forest for the next two decades from 1990. Two policies, enhanced plantation rate and a ban on cutting plant from outside homestead i.e. natural forest, were incorporated in the model. The results show that if the present trend of per capita consumption of energy continues, homestead forest will be declining. But with the adopted policies natural forest depletion could be stopped and homestead forest would be increasing. An increase of 7.6 per cent per capita energy is observed in the year 2010, though a ban exists on collection of fuel wood from natural forest. For national level planning it is proposed that the availability of energy and its use, and the consequences interfering availability and use can very well be modeled by applying the system dynamics methodology.

INTRODUCTION

In Bangladesh biomass fuel is the main source of energy in rural areas. In 1981, 81.7% of the total energy consumption was met by biomass fuels (BEPP, 1981). Among them agricultural residue, wood fuels and animal dung contributed 66.3%, 17.5% and 16.2% respectively (GOB, 1985). The high consumption of agricultural residues and animal dung indicates scarcity of fuel wood and limited distribution of gas supply.

In 1947, 35% of the total land area of Bangladesh was covered by forest and in 1994 it was only 13% of the total area (BBS, 1994). This deforestation is mainly due to rapid population growth which demand more areas for houses and cultivable land; the high energy consumption for cooking, the expansion of the rural industries and the infrastructure.

Self reliant development of the country should not only consider population control measures and increased production policies but also need to take into account integrated use of energy for improving quality of life and self sufficiency in energy. Domestic energy system is a complex combination of social, economic and technological elements containing inherent time-lag characteristics and non-linearity. The system dynamics methodology developed by Forester (1971) is probably the most appropriate technique to study the dynamic behaviour of such a complex system.

A microlevel study on homestead forestry taking three villages of Atpara Upazilla of Netrokona district was conducted as a case study with the following objectives.

(a) to analyse the present status of the homestead forestry,

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(b) to develop a system dynamics model on homestead forestry showing its impact on domestic energy supply.

METHODOLOGY

Three villages named Baniajan, Mallikpur Sunai and Dakkin Sukhari from three different union of Atpara Upazilla (shown in Fig. 1) were selected to conduct a microlevel study on the homestead forestry. Present status of homestead forestry and energy consumption for cooking were surveyed for 300 families, 100 from each of the three villages. Data were collected from households at random.

Biomass fuels used for cooking were divided into three groups, such as

1. Crop residue: straw, rice hulls, jute stick and bagasse etc.
2. Trees: firewood, branches, leaves and twigs etc.
3. Livestock dropping: dry cowdung etc.

Total number of plant cutting and plantation were estimated by using the following formulae :

$$P_c(i) = P_{cf}(i) + P_{ct}(i)$$
$$PT(i) = P_{ex}(i) + P_c(i)$$

Weight of the tree was determined by using the following biomass equation (Overend, 1985).

$$M = a + b\,D^2 H$$

Crop residue used as fuel was found by using the following equation.

$$C_{rf}(i) = Cr_t(i) \times F_{cr}(i)$$

Total energy sypply for cooking was estimated by using the following formulae

$$T_f = \sum_{i=1}^{n} W_f(i) \times H_f(i)$$

Homestead Forestry and Energy Supply - A System Dynamics Model

In system dynamics studies the descriptive statements are conveniently translated into feedback loop structures. The feedback loop is a closed path that connects an action (policy/ decision) to its effect on the surrounding conditions (level) and these resulting conditions (changes in level) in turn come back as information to influence further action. Two distinct categories of feedback loops are used in the system dynamics studies for presenting the information about the system in a definite structured manner - the positive and the negative feedback loops. A positive feedback loop generates growth or decay in a system, while the negative feedback loop seek an equilibrium (i.e. goal seeking). A closed path (loop) should be chosen by following the arrow directions. A positive sign along the arrow direction shows that an increase (or decrease) in the preceding variable (arrow tail) will cause an increase (or decrease) in the next directly related variable (arrow head). On the other hand, negative sign indicates the decrease if the related variable with the increase of the previous one and vice-versa. DYNAMO equations are written after the flow chart has been made.

System Diagram

The system dynamics flow diagram (influence diagram) of the homestead forestry - energy supply /demand system is shown in Fig. 2. The major causal loop of the whole system is summarized in the following paragraphs. One major positive and one major negative loops are controlling the whole system. This influence diagram is the guide to model formulation. The successive sub-system are described as follows:

Major negative loop : An increase of the homestead forest will increase fuel wood supply and therefore total energy supply, percieved energy stock and energy requirement coverage will increase. The increase of energy requirement

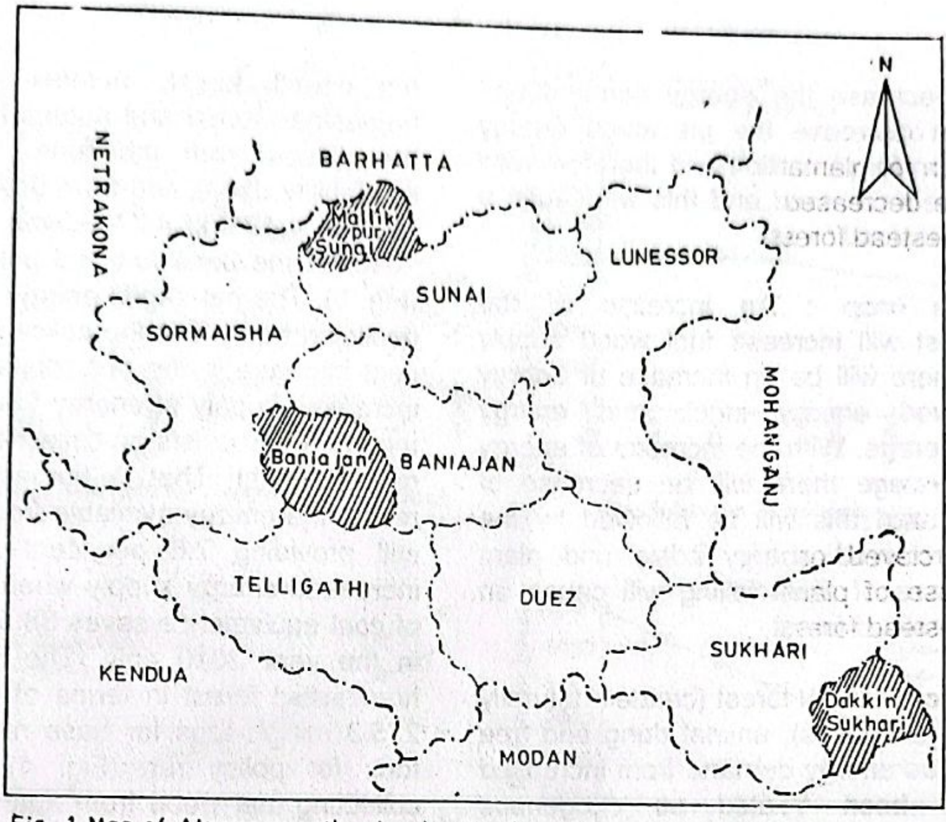

Fig. 1 Map of Atpara upazila showing the location of the study area.

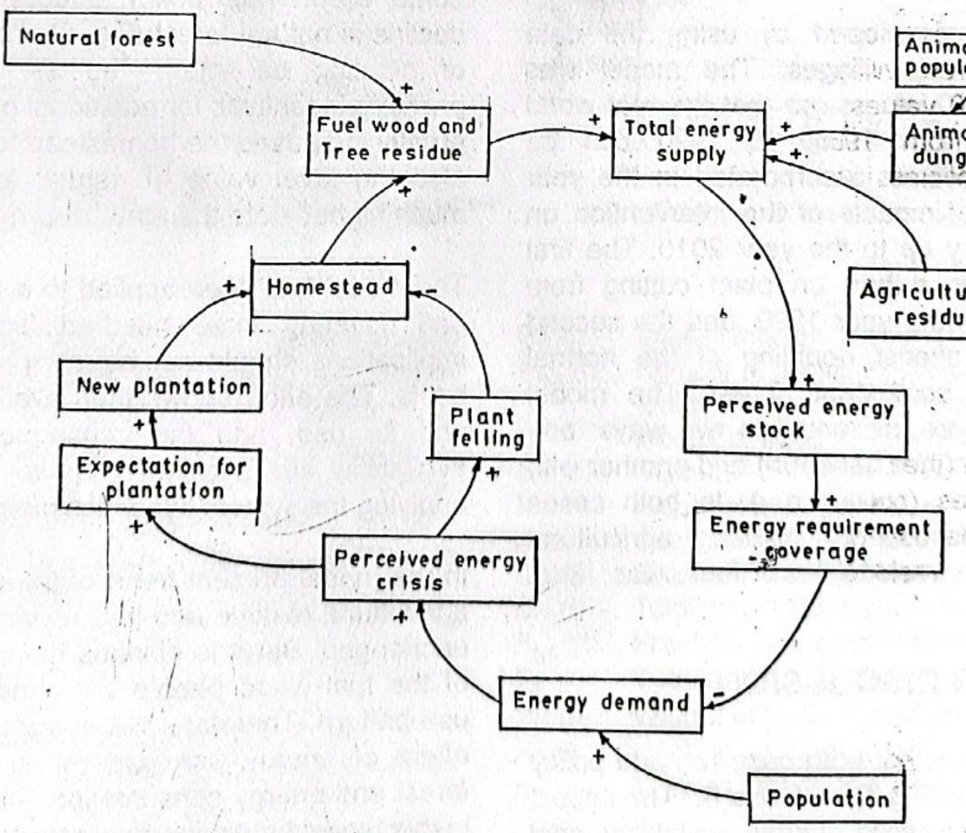

Fig. 2: Influence diagram showing energy supply and demand dynamics.

coverage will decrease the energy demand and this will in turn decrease the percieved energy crisis, expectation for plantation and therefore new plantation will be decreased and this will cause a decrease of homestead forest

Major positive loop : An increase of the homestead forest will increase fuel wood supply and therefore there will be an increase of energy supply, percieved energy stock and energy requirement coverage. With the increase of energy requirement coverage there will be decrease of energy demand and this will be followed by the decrease of percieved energy crisis and plant felling. A decrease of plant felling will cause an increase of homestead forest.

Energy supply from natural forest (created naturally at the back of the houses), animal dung and tree residue, as well as energy demand from increased population has been treated as exogenous influence on the model.

The model was developed by using the data collected from three villages. The model was initialized with 1960 values, so that the real world energy situation from 1960 to 1990 can be visualized. Two policies incorporated in the year 1990 to show the impacts of the intervention on homestead forestry up to the year 2010. The first policy incorporates a ban on plant cutting from natural forest from the year 1990, and the second policy considers almost doubling of the normal planting rate on homestead forest. The model simulated results are presented in two ways: one with no intervention (the base run) and another with incorporated policies (policy run). In both cases present trend of the use of cowdung, agricultural residue and tree residue as fuel was kept unchanged.

RESULTS AND DISCUSSION

The simulated results for both base run and policy run are presented in Fig. 3, 4, 5 and 6. The impact is measured on per capita energy availability, coal equivalence of wood energy supplied from homestead forest, number of plants in the homestead forest and natural forest by comparing the values from the runs. Per capita energy availability decreased from 5.24 GJ/person-year in 1990 to 4.43 and 4.77 GJ/year-person in the year 2010 for the base run and policy run respectively (Fig. 3). The per capita energy availability shows a declining trend. Still the policy run shows a 7.6 per cent increase in the per capita availability, due to increased supply of energy from homestead forest though a ban exists on collection of fuel wood from natural forest. That is homestead forest compliments the energy available from natural forest and still providing 7.6 per cent more energy. This increased energy supply when measured in terms of coal equivalence saves 38.5 million tons of coal in the year 2010 only. The total contribution of homestead forest in terms of coal equivalence is 275.3 million tons for base run and 313.8 million tons for policy run (Fig. 4). The stoppage of collecting fuel wood from natural forest should be interpreted as a ban on cutting wood from outside home area. This policy effectively stopped the decline in natural forest (Fig. 6). The enhanced rate of planting be interpreted as a policy, which provides incentives for additional plants. This policy greatly increased the homestead forest (Fig. 5) and also the level value of natural forest stood at a much higher state than the base run.

The model has been applied to a very limited area and covering three hundred families only. The implications should not be interpreted on national basis. The effort shows that, availability of energy and its use, and the consequences interfering availability and use can very well be modeled by applying the system dynamics methodology.

In the model present trend of the use of cowdung, agricultural residue and tree residue as fuel is kept unchanged. But it is obvious that with the scarcity of the fuel wood people will change their energy use pattern. Therefore it is suggested to study the effect of energy use pattern on the homestead forest and energy consumption. On the other hand in this model human population, animal population,

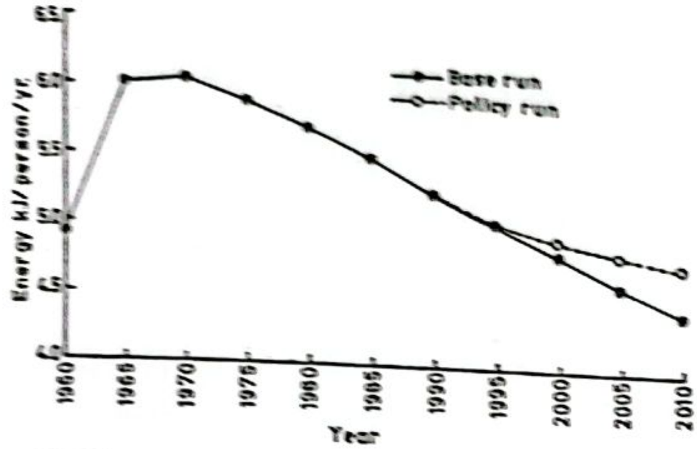

Fig.3 Per capita energy available for cooking with the year

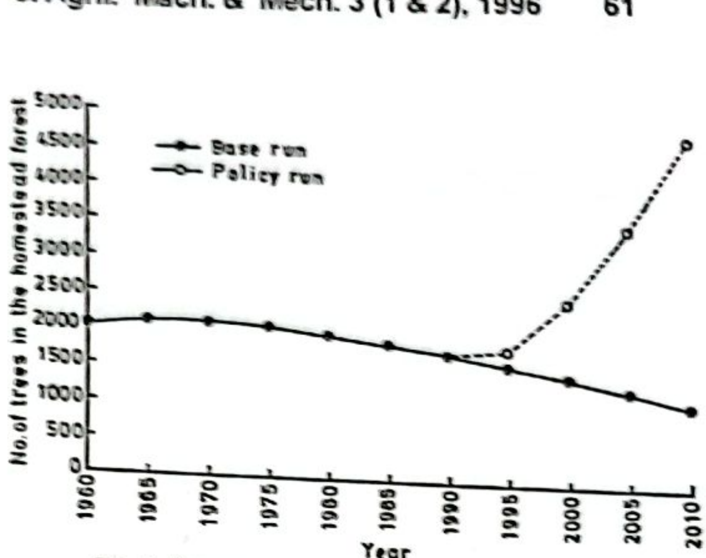

Fig. 5 Status of homestead forest with the year

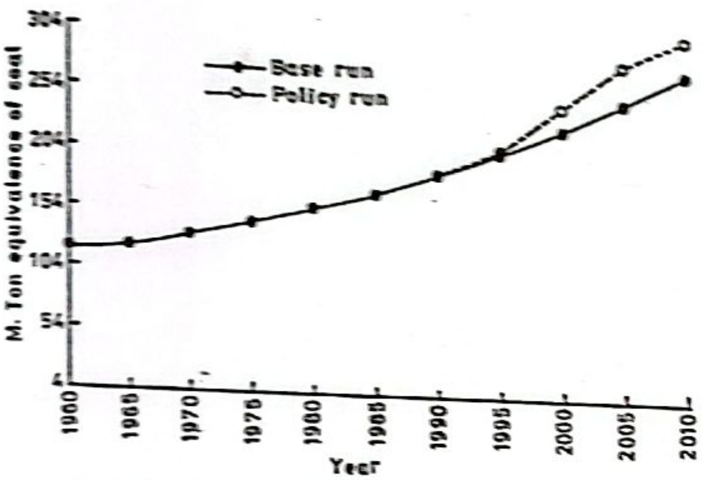

Fig.4 Energy contribution of homestead forest in terms of coal equivalence, M.ton

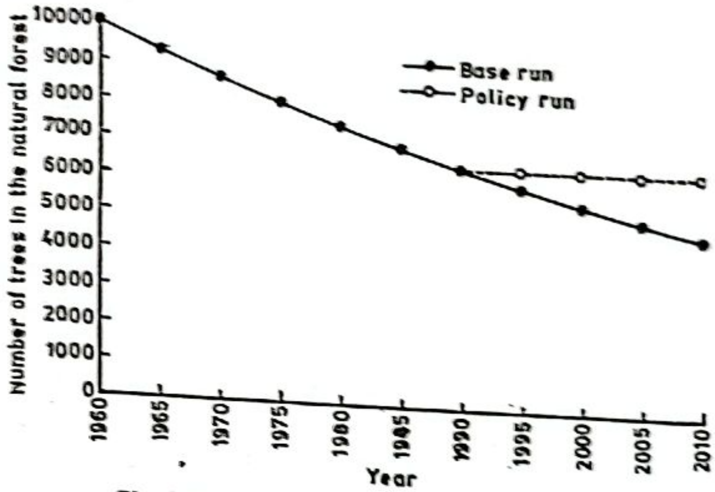

Fig. 6 Status of natural forest with the year

agricultural residue availability and fuel wood from natural forest have been incorporated as exogenous variables. That is, these four factors will influence homestead forest, in turn, homestead forest has no bearing on these four factors. Considering the effect of these factors on the homestead forest, the model may be modified to get more realistic result.

Nomenclature

P_c (i)	Total number of plant cutting in ith year
P_{cf} (i)	Number of plant cutting for firewood in ith year
P_{ct} (i)	Number of plant cutting for timber wood in ith year
PT (i)	Total plantation in ith year
P_{ex} (i)	Number of plants, existing in homestead forest with planting in the year
M	Weight of wood at 10% m.c., kg
D	Diameter of the tree at the breast height, cm
H	Height of the tree, m
a, b	Coefficients which vary with tree varieties
Cr_f (i)	Crop residue of (i) crop used as fuel, kg
Cr_t (i)	Total crop residue production of (i) crop, kg
F_{cr} (i)	Fraction of (i) crop residue used as fuel
T_f	Total energy supply for cooking, kJ
W_f (i)	Weight of (i) fuel used for cooking, kg
H_f (i)	Heating value of (i) fuel, kJ/kg
n	Type of fuel used for cooking

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