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ECOSYSTEM SIMULATION SUB-MODELS FLORA AND FAUNA

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ABSTRACT

The present report forms a part of a series of reports which when combined together will result to description of development of a comprehensive watershed resources development model which is based on studies done in Arizona, USA. A brief description of floral and faunal resources of the country is included in the report besides including a brief description about inventory techniques and detailed description of simulation sub-models for development of these resources. The report also discusses briefly the overall watershed resources development model along with the various kinds of land management practices.

The Flora sub-model consists of simulation components for predicting the growth, yield and diversity of forest overstories, the production and composition of herbaceous understories and the development and accumulation of organic material on the forest floor. In order to estimate growth and yield of forests stand, inputs like listing of trees per hectare, associated diameter growth rates and volume expressions are required. The herbage production could be related to forest overstorey parameters, precipitation amount, and the time since implementation of silvicultural practices. The organic matter accumulation may be related with estimates of tree leaves and needles on a forest floor at a point in time. All these aspects combined together will yield effects of various land management activities on floral resources of a watershed.

The Fauna sub-model consists of components developed to describe habitat quality for a variety of animal species and the animal supporting capacity of an area. The habitat quality predictions are based on changes in food, cover and diversity resulting from the implementation of a land management practice. The animal supporting capacity of an area is based on production of herbage from an area and requirement of forage per animal per unit of time. Based on the management practice adopted the forage production may be altered which will affect animal supporting capacity of the area.

In the end, data requirement and limitations of the study are described in the report. In fact, for successful use of such an integrated model, an inter-disciplinary approach is required while planning development of watershed resources.

1.0 INTRODUCTION

The problem relating to water resources development and management have been receiving critical attention in recent years in our country. As per 1981 census our population was 684 million and it is estimated to reach 1000 million by 2000 AD. It has been estimated that the food production required for feeding such a large population is around 230 million tonnes which is nearly twice the present level of production. The total culturable area of the country is around 189 million ha. and since almost the entire area is under cultivation there is possibility of marginal increase in area under agriculture production.

Our country is blessed with large amount of water resources but these are not evenly spread in time and space causing thereby problems of floods and drought. An area of about 117 m.ha in 99 districts in 13 states is drought prone. On the other side, 40 million ha. area of the country is flood prone as the annual flood affected area varies from 8 m.ha. to 18.6 m.ha. During the last three decades of planned development highest priority has been accorded to water and power resources development. Around 2000 large dams, either completed or in advanced stage of construction and thousands of kms. of lines and unlined irrigation canals and water carriage system have been constructed.

Over years due to increased demand of food and fibre attempts have been made to exploit the natural resources and in the process unscientific manipulation of land use has resulted in some cases probably because of possibility of quick economic gain. Also, environmental concerns have not received adequate attention while planning development activities. In nature there exists some sort of interrelationship among natural resources as one is developed, another gets affected in some way. Therefore, concept of integrated development of resources has significant importance in view of heavy burdon on natural resources. In this context, an idea of developing integrated watershed resources management model was described in one earlier report of this series wherein it was indicated that such a model may have three main sub-models dealing with water, flora and fauna. Each sub-model consists of number of components describing how changes in land use have affected various aspects of a particular resources. The present report describes the sub-models of flora and fauna alongwith their components

2.0 WATERSHED RESOURCES DEVELOPMENT MODEL

With the rapid increase in developmental activities owing to increased demand of food, fibre & fuel in various sectors attempts are being made to exploit the natural resources in possible matters. However, at times due to unscientific manipulation of the natural resources adverse effects are being realised on one resource while the other is being developed. In nature, a definite relationship exists among the natural resources and with the development of one the other gets affected in a positive or negative sense. These relationships are of three types, viz. complementary, supplementary and competitive. These relationships are easy to define on a management unit and a watershed can be chosen as the convenient unit of management. A land management policy implemented to meet the increasing demand of one or the other resource must ensure the various kinds of relationships existing among the resources before the practices are implemented.

Land, water, flora and fauna constitute an important part of the natural resources of a watershed. As said earlier development of one resource may affect the other depending upon the type of relationship existing among these resources. In many instances and situations, use of only one or two watershed resource products may lead to some sort of environmental imbalances. It is, therefore, an efficient and integrated development of the resources is essential to ensure their sustained yields to avoid conditions of imbalance.

Based on the available information or by conducting experiments and studies, relationships could be developed between growth and yield of resources as affected by various kinds of land management practices. Basically these relationships could be used to define the impact of changed land management practices on resources like water, flora and fauna. The effects of development on various aspects of these resources could be modelled in the form of components of a sub-model which will indicate the effects on a particular resource as a result of a mànagement policy. These sub-models when combined together will form an integrated resources management model indicating the effects on various resources with various kinds of management practices. Broadly, there can be three main sub-models which can be represented in a resources development model which are as below:

i) a sub-model which will include computation of water yield, suspended sediment and chemical quality of streamflow under given and changed land management conditions.

ii) a sub-model that will evaluate growth and yields of forests alongwith other related aspects such as amount of organic matter on forest floor

iii) a sub-model to assess the animal habitat, and carrying capacities under existing or changed land management conditions.

A schematic diagram of watershed resources development model is shown in fig. 1. A sub-model may consist of a number of components depending upon the type of watershed resource it has been developed for. For example, the sub-model describing water will include components to assess effects of land management practices on water yield, sedimentation and water quality. These model components can be so designed such that these are simple to operate and the predicted effects of land management practices is evaluated based on measured responses from field data. The input requirement can be kept to be minimum. Based on comparison of predicted and field observations, the components of all sub-models can be developed.

The sub-models could be developed for land areas ranging from a fraction of hactare to thousand hectare which mainly depends on the data availability and their spatial variability. The various parameters to be used for simulation may represent the average conditions of the area under consideration. For larger areas, the models may be operated several times on subareas of the larger areas, where each operation of the model uses data values characteristic of the sub-area. Addition of sub-area responses yields these for the entire area.

The users may require default data for using various sub-models in case a particular data element is not available. These default data could be "average" or "typical" values for the specific parameter in the particular ecosystem being simulated. The default data could

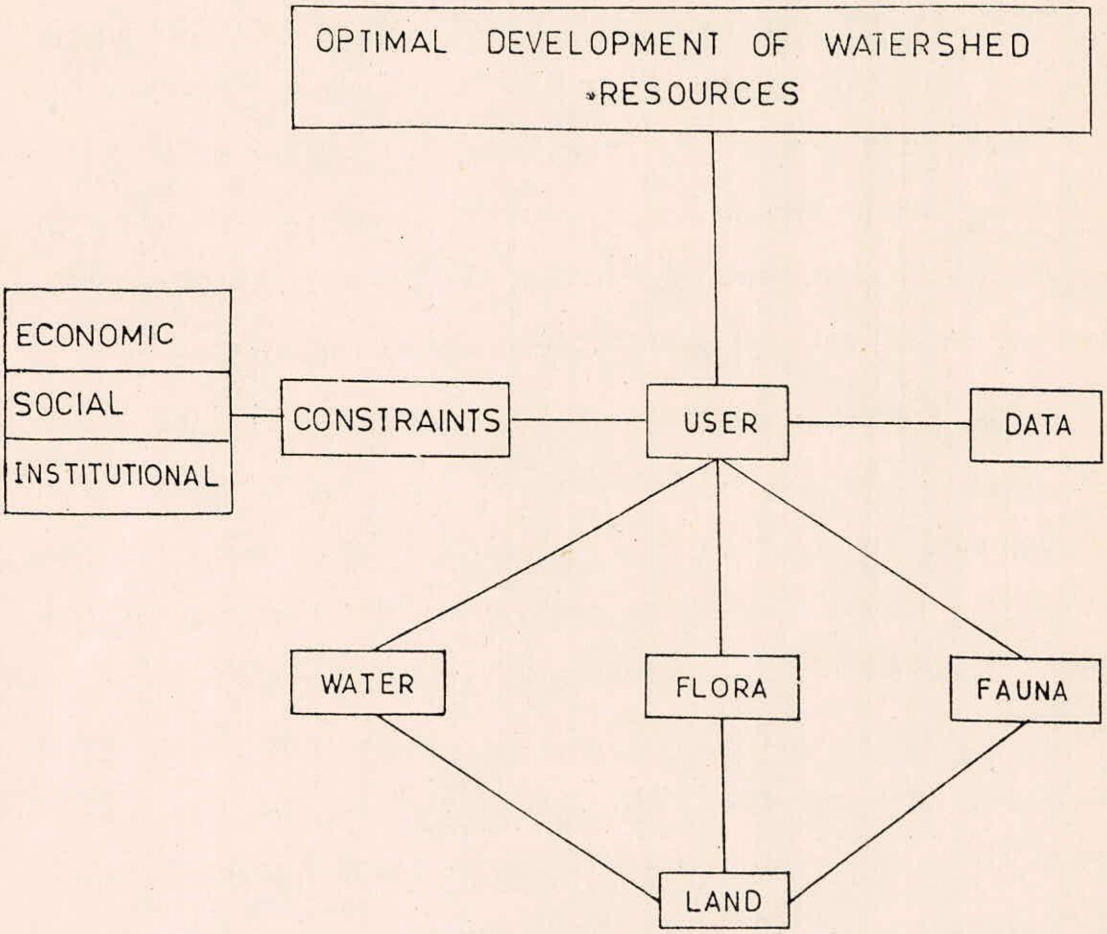

FIG.1 WATERSHED RESOURCES DEVELOPMENT MODEL

be generated by review of literature, research and field data. In many cases, the default data are ecosystem specific i.e., the default values change with the ecosystem being simulated.

The sub-models including the various components may have three phases of operation, viz., initialisation, time cycling and summary. In the initialisation phase, all needed input data could be fed to the model. These could be in the form of data comming directly from the user,default data, or data generated from the operation of another simulator. In the second phase the frequency of operation of model is set in depending on the nature of the model. For example, in the simulation of water yield, there are daily reiterations, while for forest growth and yield, they are yearly. For some modular components, the cycling time could be only twice, i.e.,before and after the implementation of land management practice. The third phase of model operation could be summary phase when all totalling and processing of the data at the end of simulation can be done. These summaries will show the state of a particular component of the watershed resources at the start of the simulation, and the change in it due to various land management activities or passage of time. The effects of changed management activities become apparant in output summaries based on which the best practice for overall management of watershed resources for their sustained and optimal yields could be decided.

2.1 Land Management Practices

In order to understand various effects of land management practices, it may be necessary to describe the various such practices which could be adopted in forested watershed. In this reference silviculture needs to be defined. Silviculture has been defined as the cultivation and care of trees in a forest ecosystem or in simple words it is an art and science of cultivating forest crops. A silviculture system involves the removal of a forest crop, replacing it with new crop of desired form and tending it till next final harvest. It is a technique based on the experience and knowledge of silviculture, including ecology, and applied to a given forest after considering the requirements of the forest management and objectives to be fulfilled. Based on origin of the forest, the silvicultural systems are divided into two broad groups, namely, high forest systems and coppice systems. High forest is a forest which originated from seed either naturally or artificially. Coppice forests have origin from the coppice shoots from the stump of a cut tree and from root suckers. Depending upon the mode of regeneration, production of even-aged or unevenaged crop and removal of mature crop etc. various classification of silvicultural systems both under high forest systems and coppice systems have been done. Under high forest systems the various practices include clear felling system. shelterwood system and selection system. In the clear felling the oldest trees are cut each year, and next oldest trees are to be removed in the next year. The coppice systems are the oldest systems of forest management in the world. In this system regeneration depends on vegetative form of reproduction e.g. stool coppice, root collar shoots, pollard shoots and seeding coppice. For production of better and strong coppice it is necessary to cut the tree as close to the ground as possible and the stumps are dressed to have sloping surface all round with highest point being the centre of the stumps. A number of coppice shoots may emerge from the stump out of which only the healthy ones are retained after one or two years. The coppice system is not a permanent system, as the coppicing can not be achieved for a number of rotations. The important reason is death of large number of stumps due to various climatic and biotic factors. Example, in case of Eucalyptus globulus it becomes necessary to replant the area with nursery raised seedings after the fourth rotation of coppice crop. Depending upon the local demands, slivicultural and economic factors, the silvicultural systems are chosen. The silvicultural factors include conditions of regeneration, rate of growth, soil characteristics and topography. The economic factors are development of infrastructure, availability of labour, nature of produce required, subject of rights and concession to the local propulation and other economic considerations(Dwivedi,1980).

3.0 ECOSYSTEM SIMULATION MODELS FOR FLORA AND FAUNA

In the earlier section a brief description of overall watershed resources development model was given. As described earlier, each sub-model of the overall model consists of various components each describing effects of management practices on different aspects of the resource. In the following sections a brief description of floral and faunal resource of the country, inventory techniques and description of various components of the flora and fauna sub-models have been given:

3.1 Floral and Faunal Resources

India with its wide range of climatic conditions from the torrid to the arctic has a rich and varied vegetation, which few other countries of comparable size possess. The main floristic division of the country are western Himalayas, Eastern Himalayas, Assam, Indus plain, Gangetic plain, Deccan, Malabar and Andamans. There are about 15000 flowering and 35,000 non-flowering plants in the country (India, 1984).

Forests are an essential part of a country's geography. There are a number of demands that are met by forests. There has been growing concern in past due to reduction in forest resources of the country as a result of various developmental activities. According to the Natural Forest Policy (1952), about 33% of the geographical area (i.e. 110 m.ha.) of the country should be under forests. Against this only 23% of the geographical area or about 75 m.ha. under forest cover has been reported as per the statistics of State Forest Departments. A different picture of forest coverage in the country is painted by National Remote Sensing Agency which has found that forest cover had reduced from 55 m.ha. to 40 m.ha. during the period 1972-1982 (Anon, 1986). If these findings are assumed to be correct, the rate at which the forest coverage is being lost works out to be about 1.5 m.ha. per year which indicates the gravity of problem. It was in this background a Forest Conservation Act, 1980 was enacted with the objectives of checking the diversion of forest land for non-forestry purposes.

The depletion of the country's forest wealth can be attributed to a number of reasons. The increasing pressure of human and cattle populations on the land naturally led to excessive falling and grazing in adjacent forest areas as well as to encroachments on forest lands and their conversion to agricultural use.

A recent report by the World Resources Institute has compared the position of forest cover in developed and developing countries. In former case, the forest cover area has been reported to be more or less stabilised as it increased from 2.0 billion ha. to 2.1 billion ha. from 1900 to 1985. The reason for this could be economic development and employment opportunities in non-agricultural activities. The migration of rural population to urban areas is associated with greater employment opportunities in cities of developed countries. On contrary, a reduction is noted for developing countries. A large number of marginal farmers and landless labours migrate to cities in developing countries because of a break down in the balance between the human population and natural resources of the village (Swaminathan, 1985).

India which has diverse physical and climatic conditions possess a tremendous varieties of fauna. As per the estimates of Ministry of Information and Broadcasting, Govt. of India, there are about 350 species, of mammals and 1200 species of birds in the country. More than 30,000 different species of insects, apart from a great variety of fishes and reptiles are also found (India, 1984). The economic justification for retaining natural resources of wildlife and their unspoiled environment is being increasingly recognised.

The wild fauna is an integral part of the renewable natural resources of each country. For long ages man has lived in general balance with his environment, both as a hunter harvesting game for food and as a cultivator using alluvial lands for food crops or shifting his farms plot to plot of burned over forest. Today, with the human population explosion and massive technological innovation, this balance has been destroyed and the natural resources are at hazard. A large number of original flora and fauna have become extinct or come in the endangered list.

3.2 Inventory of Floral and Faunal Resources

3.2.1 Flora

An accurate assessment of various natural resources both in quantity and quality is very much essential for watershed resources management. The inventory techniques of floral and faunal resources are briefly descirbed as below:

The rate at which a tree or a crop increases is known as increment. The term is often applied to the actual increase itself within a certain period and may refer to any factor which increases with age - such as girth, diameter, basal area, height, volume, quality, price or value. The increase in diameter or girth of a tree would depend on the quality of locality, crown size, age, origin and the treatment given. Similarly the height increment will depend upon quality of locality, species, age, origin and treatment. For the unit area of forest to produce maximum increment, the growing space must be so fully occupied as to allow the individual stems to have the optimum space for optimum growth. In forest, the measurement of yields may be concerned with forest density, growth rate, volume of timber etc. It is basically measurements of a tree like basal area, height etc. which are used for working out volume and density of trees. The measurement of tree stem diameter at about 1.3 m above ground surface is the most common measurement used for calculating basal area. The height measurement of a tree could be of two types;

viz., total height (the height between ground and tip of the tree) and merchantable height being a measure of usable portion of a tree. With known height and diameter, the volume of trees can be worked out with the help of tables.

The growth rate of a tree is defined as its volume divided by its age. Generally the age of a tree is determined by either general appearance aided by judgement or by counting annual rings or branch whorls.

Generally, density of forest stand is used to indicate inventory of forests. Density could be expressed by various ways including number of trees, basal area and volume. These indicators of forest density are worked out based on sample surveys. Another indicator of density of forest could be growth rates of individual trees and forest trees. In order to project forest growth rates for future, the analysis of past growth rates is done. The evaluation of the site or the environmental conditions affecting the growth and survial of a forest or other plant community is required to categorise the quality of various forest growing sites. The measurement of site quality could be done by integrating all factors influencing the productivity of forest stands. Of all measures of site quality, tree height in relation to age has been found the most practical, consistent and useful. Height growth is sensitive to differences in site quality,little affected by density of forest stand and is strongly correlated with volume. Therefore, a site index could be defined in terms of total height of dominant or co-dominant trees in well-stocked, even aged stand at specified age.

The forage production of a watershed can also be indexed in terms of number of animal it can feed per unit of time. The forage produced in sample plots can be weighed and yield of forage in kg/ha. can be found out. The forage production of a watershed can be characterised as its capacity to feed a unit animal per month per unit of land and can be referred to as carrying capacity. In other words, the carrying capacity can be defined as the ratio of usable forage actual produced in the watershed and requirement of forage per unit animal per unit land. With the known value of carrying capacity one can estimate animal supporting capacity of a unit of watershed land per unit of time.

3.2.2 Fauna

The inventory techniques of wild life may include estimation of number of animals, determination of animal productivity and evaluation of wild life habitat.

The number of animals in a watershed can be found out by three main methods including direct census, indexing method and ratio method to assess population change. If the vegetative over-stories are minimal, direct census of animals can be done by aerial counting. Indirect methods of indexing population numbers are based on counts of somethings other than animal themselves. The ratio method are based on two techniques, one based on banding or marking of animals and second based on kill data from legal hunting.

The productivity of animals is based on census and composition. Generally, the smaller the animal, the fast their production, normal population loss and regeneration each year.

Measurement of habitat quality is a third classic wild life inventory and can be broken down into elements of habitat required by most wild life species. The most important elements to describe habitat quality could be water, food, cover and distribution of these with respect to space. Most of the wild life animals will need these elements in their daily range of movement and if all these are amply available, the habitat quality can be described as highly productive for wild life populations.

3.3 Components of Flora and Fauna Sub-Models

In the present report methodologies have been described based studies done abroad to develop ecosystem simulation models for describing changes in floral and faunal resources as affected by the changes in land management policies. The models being describing in following sections are aimed at providing quantitative answers to the effects of specific activities on the ecosystem. As said earlier, there are three phases in the operation of models. viz. intialisation, cycling in time and summary. During the first phase (initialisation) all needed data are input to the model. The second phase (cycling in time) is dependent upon the type of process being modelled e.g. for simulation of forest growth annual cycles will be operated. In the third phase all totalling and processing of the data at the end of simulation are conducted This phase exhibits the changes in status of resources at the start of the simulation and after the land management practices was implemented. The flora sub-model has been developed to evaluate growth and yields of forests alongwith other related aspects such as amount of organic matter on forest floor The fauna model in the similar way consists of sub-models to assess the animal habitat and carrying capacities under existing and changed climatic conditions. The description of sub-models of flora and fauna is given in following sections:

3.3.1 Flora

The sub-model is consisting of computer simulators that predict growth and yield of forest overstories, herbage production and accumulation and distribution of organic material on a forest floor. This sub-model helps in finding out growth and yield of forests as these are affected by management policies. A brief description of various components of the sub-model is given below:

(a) Stand component:

One of the components of FLORA model is 'STAND' which simulates growth and yield of forest stands as affected by various types of land management practices The component can be developed initially for a specific forest ecosystem (forest types, tree species) and can later be applied to a wide variety of forest types and tree species with suitable modifications Alternatively separate sub-models can be developed to simulate growth and yield of an individual tree, a type of forest stand and an entire forest property as affected by land management practices. A conceptual component to describe growth and yield of a type of forest stand could be as below:

i) Conceptual component: If the entire forest stand can be grouped into various diameter breast height (DBH) classes, (say DBH class of 5, 10, 15 cms) and by finding out the gross change in number of trees in a specific DBH class, it can be worked out that how many trees are growing into and out of that particular class during a particular projection period which will indicate the net increase or decrease in number of trees falling in a particular DBH class. This value of net increase or decrease in number of trees in a particular class multiplied by the average volume of that class will give the net change in growth of trees' volume. In other words:

$$\Delta T_5 = G_{I5} - G_{05} \qquad (1)$$

Where: ΔT_5 = change in number of trees in 5 cm DBH class

G_{I5} = Growth into 5 cm DBH class

G_{05} = Growth out of 5 cm DBH class

Assuming, average volume of 5 cm DBH class = V_5

So,

Net growth of volume in

$$\text{5 cm class } (NG_5) = \Delta T_5 \cdot V_5 \qquad ...(2)$$

Once such values for each DBH class are obtained, gross growth can be obtained as:

$$GG = \sum_{i=1}^{n} \Delta T_i V_i \qquad (3)$$

where n = number of DBH class

In order to take care of natural mortalities, it may be required to know mortality for each DBH class(M_i). Once M_i is known, the net growth in volume of trees including all DBH classes can be found out by:

$$NG = \sum \Delta T_i (V_i) - M_i \qquad (4)$$

The input requirements for above calculations would be:

- a stand table of growing stock by 5 cm diameter classes.
- average annual rate of diameter growth by 5 cm diameter classes.
- individual tree volume for each 5 cm diameterclass

The stand table would represent number of trees per ha. for each DBH class. Individual tree volumes for each 5 cm DBH class can be developed through localisations of standard volume table. The average annual rate of diameter growth by 5 cm diameter classes can be assumed as a function of 5 cm diameter classes which will also depend upon the typical site conditions. The mortality function to describe natural tree mortality in relation to 5 cm diameter classes can be derived from source data collected as a part of forest survey. For example, the mortality function as derived for ponderosa pine stand growing in Arizona, U.S.A. was developed as:

$$M = -0.674 \times 10^{-4}(DIA^3) + 0.00496(DIA^2) - 0.0905(DIA) + 0.815 \quad ...(5)$$

where,

M = mortality, expressed in percent of trees in 5 cm diameter class

DIA = 5 cm diameter class

The sub-model can be developed to simulate growth and yield under current conditions, at some point in future and after implementation of a land management change. A typical flow chart describing flow of activities as performed by the component is given in figure 2.

ii) Application of sub-model: As has been already described that the component can be used to simulate growth and yield of a forest stand under varying conditions of management. As can be followed from figure 2, to use the component, one has to specify the forest type and tree species first. This is followed by specifying the type of option for simulation (whether current or after implementation of land management practices etc.) The stand table is then entered indicating number of trees in each DBH class for the region being simulated. The output in the form of total basal area and volume represents the growth and yield of the forest type. Similar excercise can be repeated by excercising another option of simulation for future or after implementation of a specific land mana-

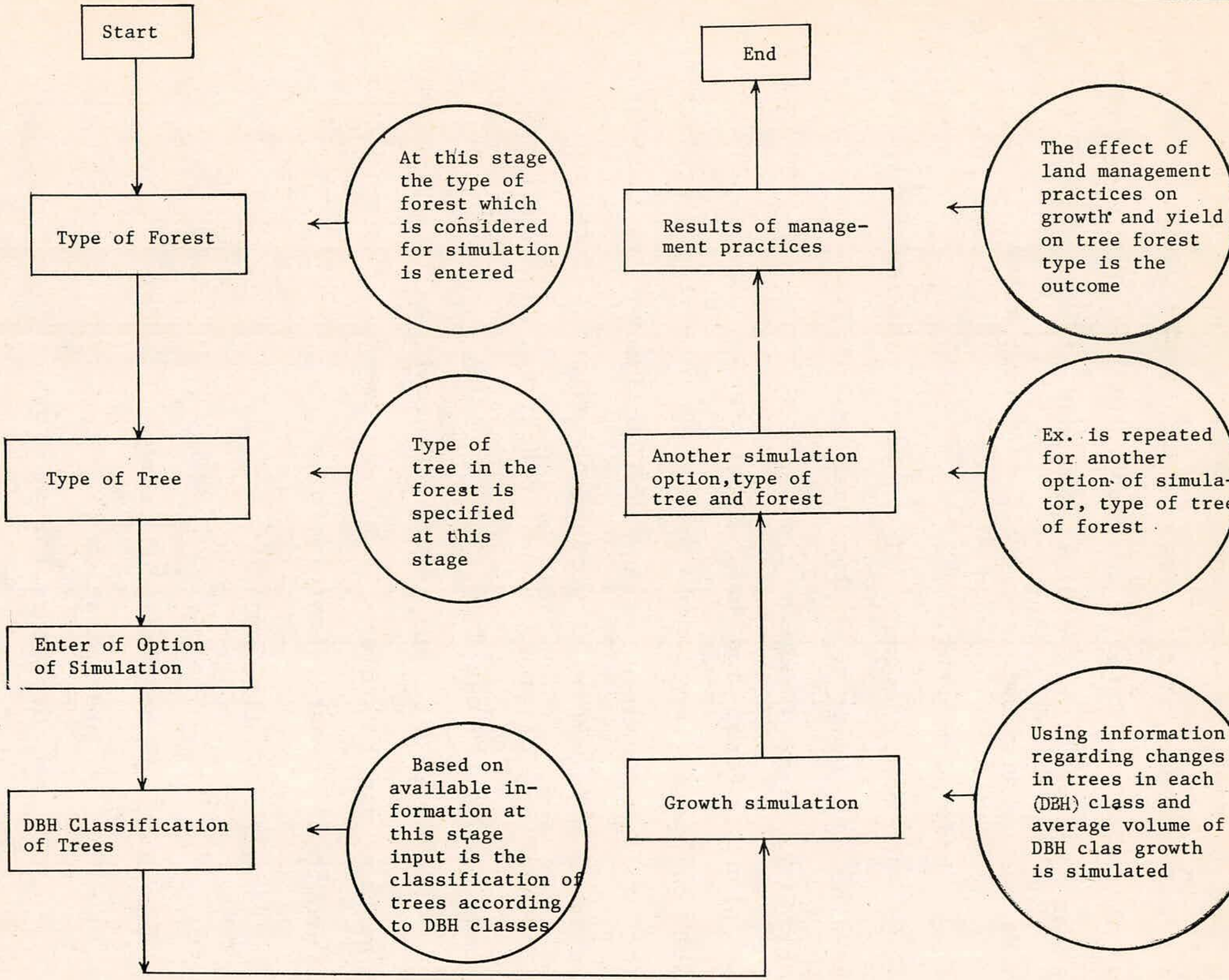

FIG.2 Flow chart of 'STAND' component

gement practice The effects of land management practice is incorporated in the sub-model in the form of reducing the DBH classes by clearing trees beyond a specific DBH class and reducing number trees within a DBH class by thinning operation. Effects of such actions on total basal area and volume of trees give the net effect of land management policy on growth and yield of forest stand.

(b) Under Component:

Another component of t__ra is the one which will determine the impacts of land management practices on production of herbage which includes all grasses and grass like plants, ferbs and half shrubs and shrubs. The sub-model could be developed to evaluate herbage production prior to a management change and following the management practice. By comparing production values before and after implementation of management practices, the effects on herbage production could be found out.

i) Conceptual component: Basically the production of herbage can be related with the amount of precipitation and growth of forest overstory, or.

$$H.P. = f(P, OFG)$$

where,

H.P. = herbage production

P = precipitation

OFG = overstory forest growth

Relationships can be developed by experimentation as has been reported by Ffolliott and Clary (1974) for pine forests in igneous soils in Arizona, USA as given below:

$$HP = 46.8\,(P) - 17.0\,(F) - 188 \qquad \ldots(6)$$

where,

HP = herbage production in pounds/acre/yr.

P = annual precipitation, inches.

F = annual forest overstory growth, cubic-feet/acre.

Once a particular land management practice is imposed, the coefficients in the relationships will get changed. However, the maximum change will be noticed immediately after implementation of land management practice and gradually the relationship will reform to pre-management level. For example, it was reported that after implementation of a particular land management practice, the relationship of herbage production was reported as under for similar conditions of forests in Arizona, USA:

$$HP = 58.8\,(P) - 15.7\,(F) - 188 \qquad \ldots(7)$$

In developing above types of relationship, it may be necesary to define the various components of herbage like grasses, shrubs etc. With the help of such relations it may be easy to workout production of herbage for various computations of annual precipitation and forest overstory growth values. A flow chart of such a component is shown in figure 3.

ii) Application of Component: As has been said the component can be used to estimate the herbage production

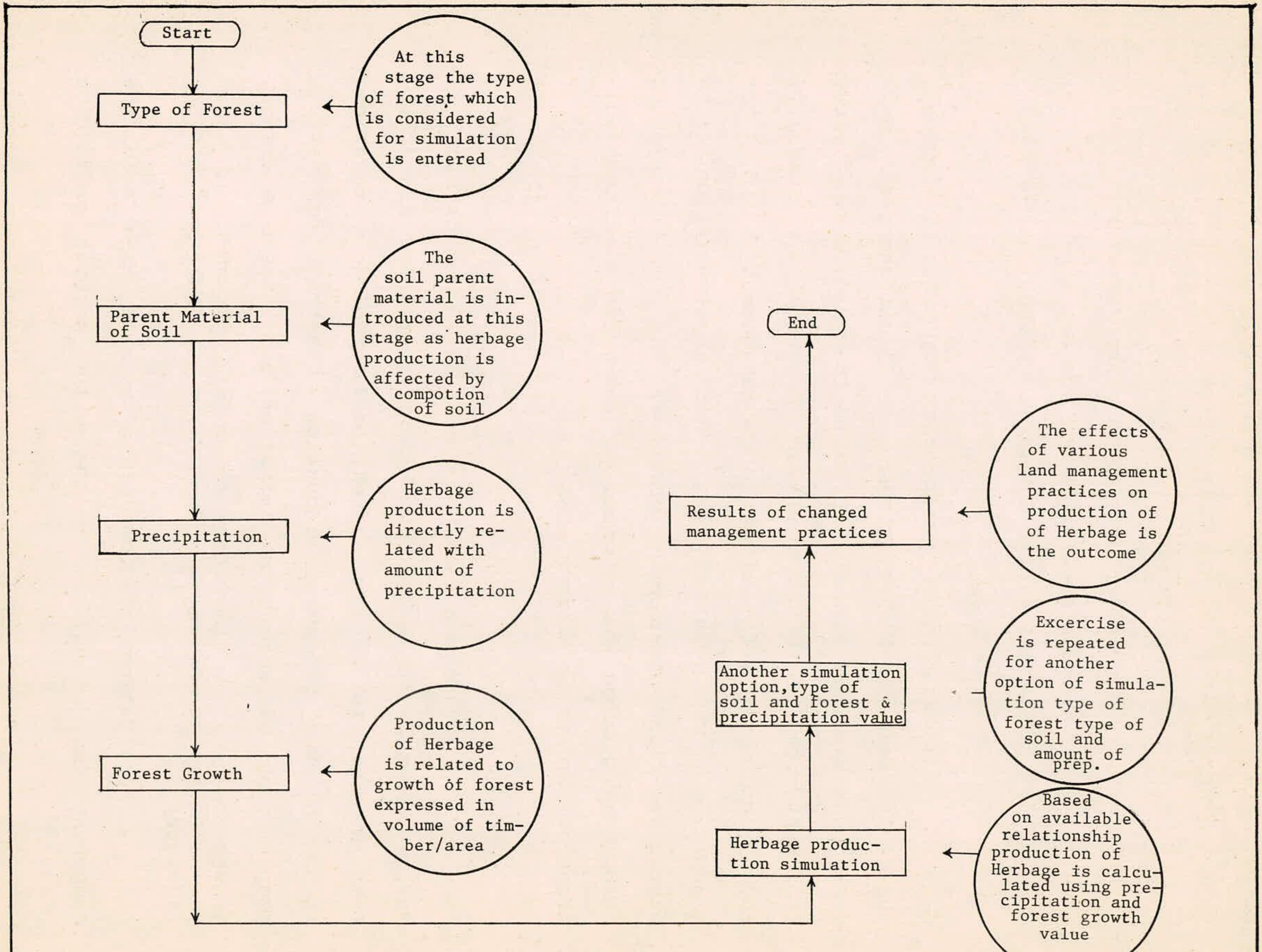

FIG.3 Flow chart of 'UNDER' component

as affected by various types of land management practices. The inputs that may be required for running the component will include type of forests, herbage component that is required to be estimated, amount of rainfall, forest growth rate, and type of soil in the area under simulation. The output will be in the form of production of herbage or its component expressed in suitable units. Based on the requirement of herbage, the management policy can be decided as for various combinations of treatments, the production of herbage can be compared with other potential uses of watershed resources. Initial development of the component can be done for a particular type of forest and then it can be extended to other forest types.

(c) Floor sub-model

One of the components of FLORA sub-model is the one designed to evaluate impacts of land management practices on the development, accumulation and distribution of dead organic material on a forest floor.

i) Conceptual Component:

The Component can be developed using the idea that on a given site, the development, accumulation and distribution of (dead) organic material above soil depends on the characteristics of soil, temperature conditions, age of forest stand, and overhead tree crown closure. This could also be expressed as:

$$OM = f(S, T.A.C.) \qquad \ldots(8)$$

where,

OM = development, accumulation and distribution of organic material.

S = soil characteristics

T = temperature conditions

A = age of forest stand

C = overhead crown

The soil characteristics influence the decomposition rate of organic material by virture of its chemical characteristics. As reported by Lutz and Chandler (1957) the process of decomposition takes place at a faster rate on warm conditions than on cool conditions. Kitteredge (1948) has reported age of forest stand as good indicator of organic material accumulation. In forest stands where ages of trees do not differ by more than 10-20 years, the correlation of age of stand with forest floor accumulations has been found good (Aldon, 1968; Brender et al.,1976; Crosby and Loomis, 1974; Williston, 1965), Kittredge (1948) has also reported that organic material accumulations vary with overhead tree crown closure. The best index to relate overhead tree crown closure has been found as basal area.

The variables considered in the conceptual model are significant to describing accumulations of tree needles or leaves at a point of time, however in general application the temperature variable can be excluded. Since the accummulation of tree needles has been found correlated with basal area then forest density can be used as a good indicator of such assessment. Such correlation established by Aldon (1968) is given as:

$$OM_t = 0.0589 (F_d) + 2.45 \qquad ...(9)$$

where,

OM_t = accumulation of tree needles and leaves at a point in time (ton per acre)

F_d = forest density (sq.ft./acre)

For predicting annual rate of accummulation of organic material, the basal area can again be correlated with the annual tree needle and leaf drop. In other words:

$$RA = f(Fd) \qquad ...(10)$$

where,

RA = annual organic material accumulation (tons/acre)

Fd = forest density (Sq.ft/acre)

Davis et al.(1968) reported one such relationship as:

$$RA = 0.082 (\log Fd)$$

The spatial distribution of organic matter on forest floor could also be related to basal area.

ii) Application of sub-model

The Component can be applied to determine development, accumulation and distribution of the organic material on the forest floor under varying conditions of management. As described already, the main variable used in simulation excercise is basal area and any change in basal area as a result of management policy will affect the organic matter accumulations. The flow chart of the component is shown in

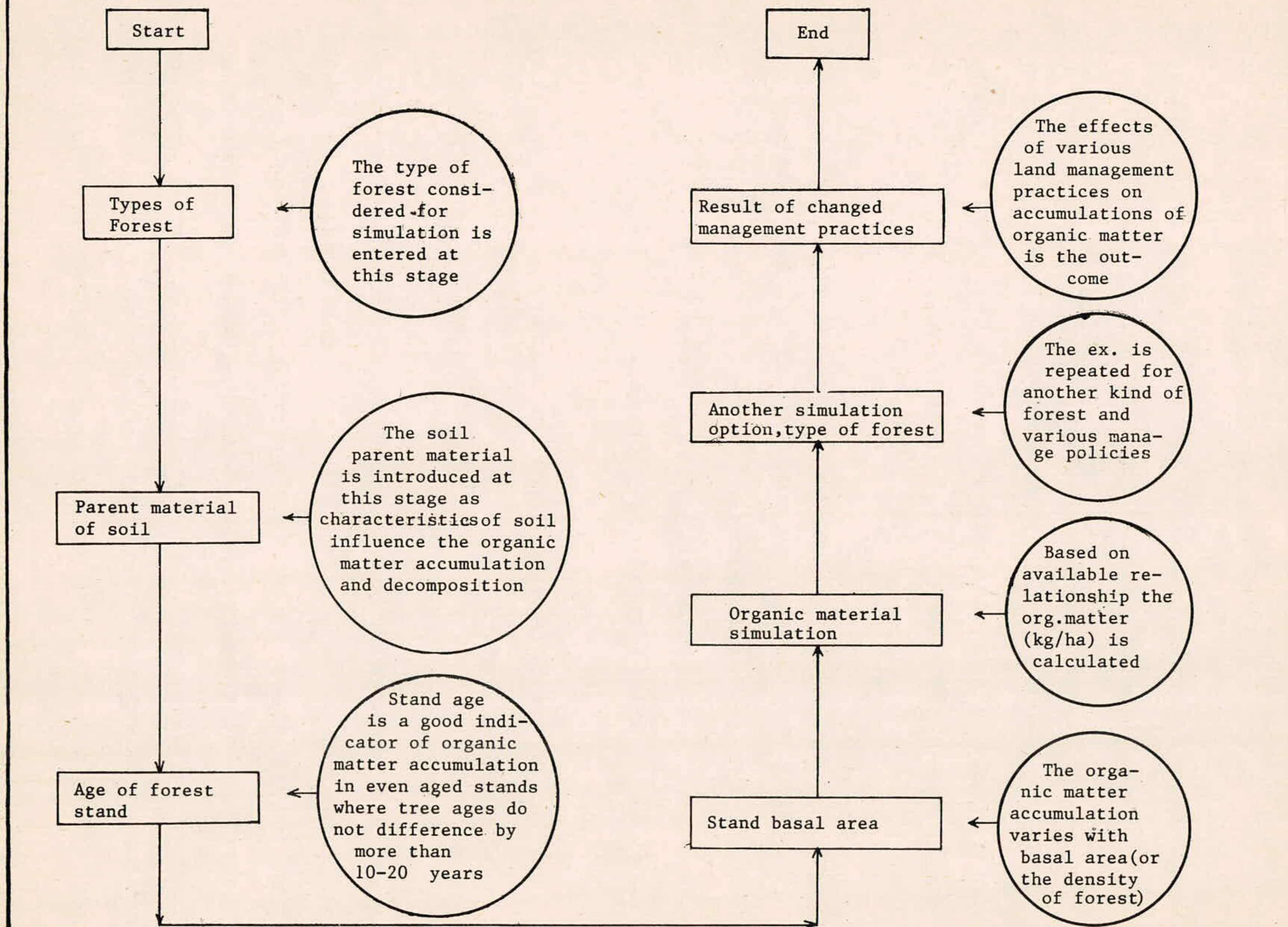

FIG.4 Flow chart of 'FLOOR' component

figure 4.

3.3.2 Fauna

The sub-model consists of computer simulators that describe animal carrying capacities of the watershed/ region being modelled and habitat quality for the various animals in the watershed. With this model it is possible to find out effects of land management practices as it affects the habitat quality and animal supporting capacity of the management unit. A brief description of the components of fauna is given below:

a) Carry component:

One of the important Components of the Flora sub-model is the one that predicts the animal population supporting potential of a particular land unit or watershed under consideration. The effects of a particular land management policy on carrying capacity can be determined by computing the increase/reduction in animal supporting capacities of the land. Such a Component can be first developed for some particular animals for whom the rate of forage utilisation are known. Based on the amount of forage production, the carrying capacity can be computed in terms of potential for supporting cattle units.

(i) Conceptual Component: Based on the information about the common animals in a particular land unit, the information regarding their preferred food can be found from literature. Out of the total herbage production, a portion will be useful for a particular animal which can be said as the forage production for this animal. To express forage requirements of animals, a standard animal's monthly consumption can be assumed as 1.0 and for other animals, this could be expressed as some fraction (like 0.6 of the standard animal) of 1.0. Also, depending upon geographical position, weather factors, year of simulation etc., the duration of forage utilisation is determined. The calculation of carrying capacity of a particular land unit may be done as below:

$$\text{Carrying capacity (CC)} = \frac{(PU)\ (FP)\ (A)}{(FR)\ \ \ (D)} \qquad \ldots(11)$$

where,

PU = proper use factor(fraction)

FP = forage production(kg/ha.)

A = area of land (ha.)

FR = forage requirement(Kg. of forage per month)

D = duration of forage utilisation(months)

The proper use factor is introduced in above equation to meet the specific land management objectives. Like in a land unit which is subjected to prolonged overgrazing pressure, the proper use factor will be less, resulting in less amount of forage available for consumption. The above equation gives unadjusted estimates of carrying capacities assuming single use (by one animal). Also relatively less is known about possible constraints that may affects the distribution of animals on a tract of land.

(ii) Application of Component: The flow chart of carry Component is given in figure 5. It may be noted that first

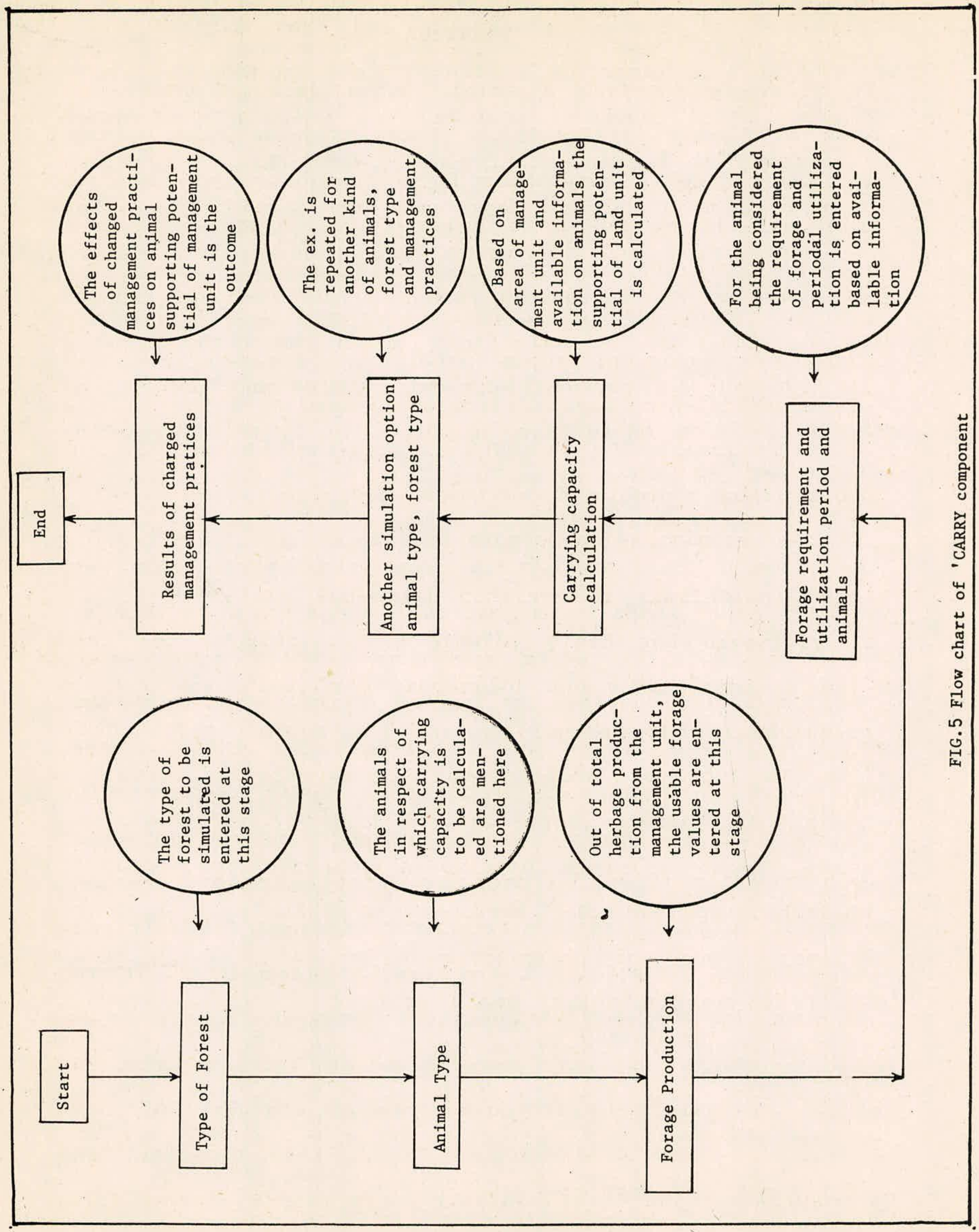

FIG.5 Flow chart of 'CARRY component

the animals of interest and forest type are selected. The values of herbage production are then entered based on available information. Also,information regarding area of land unit, forage requirement of animals and period of utilisation are then entered. With this information carrying capacity of the land unit is calculated. Then the changes in land management practices are introduced and with the new values of forage production the changed carrying capacity is calculated which is then compared with the earlier carrying capacity value and effects of changes in land management practices on animal supporting capacity of the region is evaluated.

b) Habran component:

With the changes in land management practices, the resultant changes on habitat quality are eminent. Therefore, there is needed a Component which can simulate the effects on habitat quality of animals as introduced by changed land management practice. For this purpose, the animal behaviour of the region under consideration will need to be studied. The Component can be developed for a specific animal or for a variety of animal species. The model suggested by researchers in Arizona State University, assigns numerical values ranging from 0 to 10 for characterising the habitat quality. Researchers have attempted to relate habitat preferences of animals with the readily accessible input data through analysis of some mathematical functions(Worley & Gill, 1969; Ffolliott and Pattan,1975; Boyce 1977): Also efforts made by Farmer,1978;

Pettinger et al., 1978; and Williamson, 1978 have demonstrated usefulness of index values in evaluating wild life habitat quality. Once the assessment of habitat quality is done prior and after the implementation of land management practices, the effects as introduced by the land management practices can be evaluated.

i) Conceptual Component: The Component for assessing the impact of land management practices on habitat quality shall make use of some mathematical functions which relate habitat preferences of various animals to readily available data. These mathematical functions would, however, be animal and ecosystem specific. the Component developed in Arizona State Univ., USA has considered mainly two components for describing habitat quality, namely available food and cover. Therefore, consideration has been done of availability of food and cover conditions as related to forest overstories. The availability conditions have been translated into a single function that reflects the changes in habitat components with respect to forest overstories spatial distribution. For modelling spatial distribution of forests basal area per unit area could be taken as the best indicator. The mathematical function as has been used to develop the Component is as given below:

$$H = a \pm b(BA) \pm C(BA)^2 \pm d(BA)^2 \pm \ldots \qquad \ldots(12)$$

where,

H = habitat quality, expressed as index value ranging from 0-10.

BA = basal area, sq.m/ha.

While relating basal area with the habitat quality it has been assumed that water is not a limiting factor, animal movement unconstrained and logging residues created through implementation of land management practices will remain onsite to provide cover.

ii) Application of Component: The flow chart of the Component is given in figure 6. For using the component the type of forests and animals for which habitat quality is to be evaluated are selected. Using the chosen response functions the habitat quality for the selected animal under selected forest types are evaluated. After implementation of land management policy the effects as caused on habitat quality can be evaluated by examining the changes in habitat index which could either improve or deteriorate. Based on data available for various animals the response functions could be developed separately for different forest types. Based on these relations the effects on habitat quality as evaluated can be described and for various animal species a matrix of + and - can be developed indicating improvement (+) detrioration (-) of habitat quality as affected by land management practices.

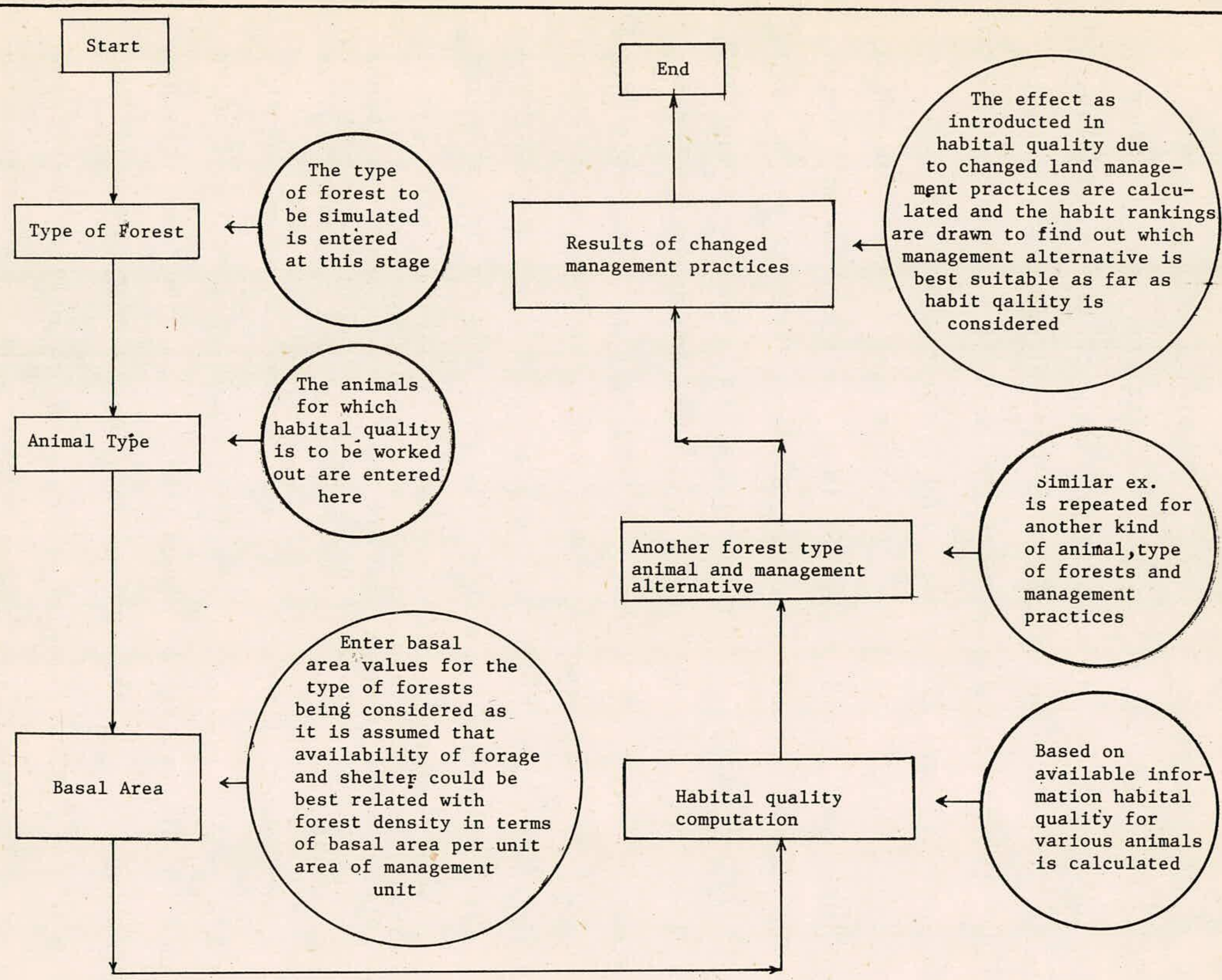

FIG.6 Flow chart of 'HABRAN' component

4.0 DATA REQUIREMENT

The sub-models described in the earlier sections have been developed for some typical conditions in Arizona State of University, U.S.A. However, the relationships could be utilised to similar conditions in the country provided data as required for the models is available. The FLORA sub-model consists of three components namely, STAND, UNDER and FLOOR. As is evident from the flow chart for developing/implementing STAND component, one has to clearly identify the forest type and tree species for which simulation of growth and yield is to be done. Also information regarding variation in diameter breast height(dbh) for the watershed under consideration would be required. In addition, information is required to convert diameter values to volume of timber for tree species under consideration. For implementing UNDER component, which has been developed for working out herbage production as affected by land management practices, besides knowing forest types and tree species, the information regarding soil parent material, annual precipitation and growth rate of trees also required. The FLOOR component which basically is for computing distribution and accumulation of organic matter on the floor requires information whether the forests under consideration are even aged or uneven aged besides other information as required by other components of FLORA.

The FAUNA sub-model consists of mainly two components viz. CARRY and HABRAN which have been designed to simulate effects of land management practices on animal supporting capacities of the management unit and changes in habitat quality. For working out the carrying capacity the forage need and duration of requirement of the typical animals in the management units would be required. Also, the rate of production of forage and fraction of total herbage which can be used by animals for consumption would be needed. The HABRAN component, which simulates the effects of changed land management practice on the habitat quality, requires information regarding basal area expressed as sq. meter per unit management area besides information whether there are restrictions imposed on free movement of animals in the management unit. A detailed list of data required for the FLORA and FAUNA sub-models is as given in Table 1.

TABLE : 1

DATA REQUIREMENT FOR FLORA AND FAUNA SUB-MODELS

Sl. No.	Type of input data required	Name of sub-model	Name of Component	Sl. No.	Type of input data required.	Name of sub-model	Name of component
1.	Forest Type	Flora & Fauna	all	14.	Proportion Usable Forage	Fauna	Carry Habran
2.	Tree species	Flora	Stand	15.	Proper Use factor	Fauna	Carry
3.	No. of trees per sq.m.for a given DBH(Diameter Breast height) class.	Flora	Stand	16.	Area of plots(Sq.M.)	Flora	Stand
4.	No. of individual trees for each DBH Class	Flora	Stand	17.	Basal Area(Sq.M.)	Flora Fauna	Under Carry Habran
5.	Forest growth(Cubic Meter)	Flora	Under	18.	Percentage of area excluding from grazing	Fauna	Carry
6.	Soil Parent Material	Flora	Under & Floor	19.	Type of land management practice imposed	All sub-models	All Components
7.	Name of the animal of which carrying capacity and habitat ranking are to be evaluated	Fauna	Carry Habran	20.	Number of Years since management practice imposed	All sub-models	All Components
8.	Forage requirement of animals per unit time	Fauna	Carry				
9.	Max.& Min. DBH Class	Flora	Stand				
10.	No. of Sampling points	Flora	Stand				
11.	No. of plots	Flora	Stand				
12.	Precipitation(Annual,Monthly, Daily) in meters	Flora	Under				
13.	Production of herbage	Fauna Flora	Carry Under				

5.0 CONCLUSION

The report describes methodologies to model the effects of various land management practices on floral and faunal resources of a management unit. For the sake of convenience a watershed has been suggested as the suitable management unit for which an inventory of resources can be made and based on studies relationships could be developed to indicate effects of changed management practices on various aspects like growth and yield of trees, production of forage, habitat quality, animal supporting capacity of the management unit etc. The components described in the report have been based on studies conducted on southwestern forest ecosystems in Arizona, USA. The relationships can be used for some typical forest ecosystems in the country by suitably introducing appropriate coefficients. The basic purpose of such simulation models is to help the land use planners for making decision while implementing various kinds of management practice.

The availablity of data is the major constraint in testing such modelling techniques. Such data may be generated first on a small area where the inventory of resources could be done easily and any desired management practice can be tested. Once the sub-models are tested on such small units of management, then these could be applied to larger areas. It may be worthwhile to run the sub-models on some average values on various data. Besides scarcity of type of data required, there may also be legal, social and economic concerns which are set by human beings to meet specific demands. The desired policy of development should be based on social, institutional and economic boundaries.

Once the data base as required for the sub-models is established, the user can readily see the effects of various management practices of yield of various resources. After successful implementation of the major components of the sub-model e.g. growth and yield of forest, production of forage and organic matter accumulation on floor of flora sub-model other aspects like simulation of accumulation of tree crowns and non-commercial wood can also be considered for modelling. Once such integrated model is developed, then the land use planner can use it at remote locations and obtain reliable predictions using modest computer terminal equipment. As the programmes are made interactive, one can easily use them for various alternatives of management on readily available data. Minimal data requirements of the models should be one of the considerations in development of models. This can be ascertained by having personal communications with the land managers and other potential users. As the sub-models involve minutes details of resources, the study group need to have experts of various disciplines which cover the resource being modelled.

With the over increasing developmental activities, the utility of such an integrated model is great. This will avoid problems of uni-directional development of one resource adversely affecting others which will in turn maintain the environmental balance among various resources and balanced development of the resources would be the result.

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