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A COMPUTERIZED SYSTEM FOR WILD LAND USE PLANNING AND ENVIRONMENTAL IMPACT ASSESSMENT*

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Scope and purpose—The purpose of this article is to describe a simulation system developed for the evaluation of physical, economic and environmental consequences of wild land use planning decisions. Snohomish River Basin in the Western Washington has been used for system calibration and testing.

Abstract—The paper describes a computerized system useful for examining the physical, economic and environmental consequences of alternative wild land use decisions. The system consists of a set of simulation models linked to a geographic data base by an information storage and retrieval subsystem. The simulation models cover forest production, timber harvesting, recreation, fish-wildlife-insect dynamics, atmospheric, and hydrologic processes. System inputs consist of land-use and management decision alternatives. The consequences of these system inputs can be evaluated at varying scales of spatial and temporal resolutions in terms of goods, services, and environmental impacts. Uses to date suggest that the system is a valuable aid to land-use planners and forest management decision makers.

INTRODUCTION

Increasingly, societies all over the world are confronted with the responsibility of making far-reaching decisions relating to the current and future use of the available resources. The prevailing practice has been to allocate these scarce resources according to economic criteria. However, emphasis now appear to be shifting to other, often intangible, consequences which may follow. The use of wild lands in the U.S.A. provides a case to the point. The overriding concern about the aesthetic and amenity values has resulted in re-evaluation of timber production—the most extensive and economically viable land use—both as the basic land use policy and related management activities such as clear-cutting, burning, etc. The increased public pressure on the diversification of wild land use and concern about the preservation of aesthetic and amenity values has made it mandatory to evaluate public land use planning in its totality including economic feasibility, environmental impact studies, and the anticipated sociopolitical consequences of proposed actions. The need for a device to monitor and evaluate the economic and other consequences following specific land use activities is obvious in rational decision making.

The College of Forest Resources, University of Washington, is currently engaged in a research project which has as its central objective the development of a general methodology for evaluating the physical, economic, and environmental consequences of alternative land-use decisions and resultant manipulations of the forest ecosystem. Because of the scope and complexity of this task, as well as the necessity to assume a holistic rather than an elemental approach, the methodology of systems analysis and operations research has been adopted.

STUDY OBJECTIVE

The primary objective of this study was to develop an integrated computer simulation model to evaluate selected environmental impacts associated with alternative forest land-use decisions and man-induced manipulations. The model components include timber production, timber harvesting, forest residue reduction, wildlife, insect, hydrology, and recreation subsystems. All

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these subsystems have been so designed that these could be used independently or combined with one or more of the above subsystems.

The area selected for calibration and testing of the models developed by the project is the Snohomish River Basin located on the west slope of the Cascade Mountains in Western Washington, U.S.A. This basin of approximately 1.2 million acres drains into Puget Sound at Everett, Washington. With the exception of agricultural activities along the flood plains and the land devoted to urban development in the Seattle-Everett metropolitan area, the basin is covered by forests. These forest lands are used for a multiplicity of purposes including timber production, outdoor reaction, water, fish, wildlife, and the generation of outstanding scenic amenities. Hence, the basin provides an ideal area for evaluating models developed by our project—the Snohomish Valley Environmental Network (SVEN).

MODEL DESCRIPTION

SVEN consists of a system of simulation models which, though capable of independent performance, have been interlinked and hooked to a resource base to generate consequential information on various land-use practices and management intensities. Figure 1 depicts the philosophy underlying the system. The resource base is activated by three driving systems, two of which are natural. The biological processes and climatological input act continuously over the resource base with or without human interventions. Human interventions, as the name implies, create disturbances in the natural scheme of things. These may include cuttings, soil disturbances, regeneration, fertilization, chemical spraying, burning, hunting, fishing and other forms of outdoor recreational activities. The impact generated from the interaction of the driving systems on the resource base includes changes in the biological data and flow of commodities and amenities both in the spatial and temporal context. Undesirable consequences such as suspended particulate matter in the air and water, change in water temperature, level of chemicals and dissolved oxygen are also part of impact generation.

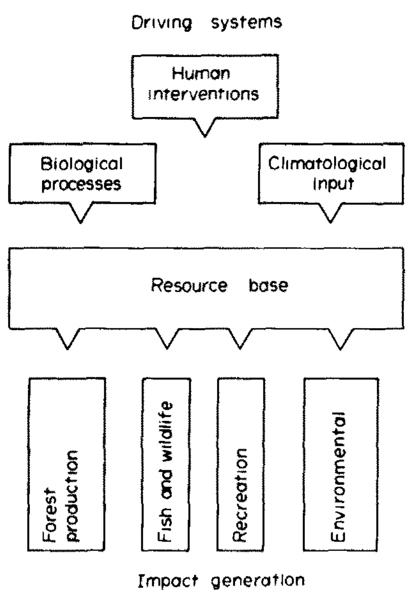

Fig. 1.

The SVEN system is an effort to simulate the natural processes and the human intervention and quantify the consequences. This task is essentially complex and even though the framework has been designed and tested, the impact generation functions would continue to require periodic updating and refinement.

For purposes of description the SVEN system may be divided into the following component subsystems:

I INFORMATION
II FOREST PRODUCTION
III FISH AND WILDLIFE
IV ENVIRONMENTAL
V RECREATION

I. INFORMATION SUBSYSTEM*

This SUBSYSTEM is the "chassis on wheels" on which the driving force is applied. All the resource-related information is processed, stored and updated here. All output is also controlled by this subsystem. The amount of resource-related information, the degree of resolution of this information and whether cell or polygon approach is to be used, would depend on the objectives and the size of the land resource. For the Snohomish River Valley, for example, where the model was validated, a 40-acre cell approach was used to store, retrieve, and display resource information.

Resource data base

The SVEN Resource data base was developed as a variable size cell system. After considerable deliberations a basic cell size of 40 acres was selected. It was desired that these cells be associated with the legal boundaries described by township, range and section. In some cases discrepancies in surveyed land lines led to odd shaped and sized cells; thus, the variable cell size. This has not been a severe problem as cells are located within a section so as to minimize the number of distorted cells.

Four files make up the SVEN Resource Data Base. These include:

Cell file: A set of 47 attributes are used currently to describe each cell (approx. 40 acres). These attributes cover information on: (a) cell identification for data storage, retrieval, updating, mapping and display, (b) physical description including size, land use, ownership, topography, road and stream lengths, (c) soils data, and (d) timber inventory.

Stream file. Operating in conjunction with the cell file is a stream file. This file contains locational and identifying information for each stream in the basin. The stream file provides the capability for routing water flow throughout each major watershed. Streams are located within each 40-acre cell by using an interior set of 12 grid points. Thus streams are located to the nearest 300 feet. For those cells not containing a stream, a pointer to the cell into which the water will flow is stored. Using the stream file, we are able to reconstruct the mini-watershed which surrounds any selected cell. This provides the capability for assessing the impact of non-point sources of pollution on stream quality at any chosen point. The stream file also permits the assignment of attributes to each stream segment contained in the file. Currently, only locational and identification information is contained in this file. Other attributes such as stream flow histories, fisheries potential, stream gradient and stream bed gravel condition may be added as the information becomes available. Presently, these data are not available for the majority of the streams in the basin.

The stream file provides one of the most unique features of this system. This file allows a user to trace water flows both upstream and downstream and to define the watershed for any point within the basin. Interaction between the cell and stream files allows models to determine the factors affecting the hydrology of any point in the basin. For example, if certain fish spawning sites are known, the watersheds for these points can be determined and activities within this area related to effects on the fish. We see this to be a valuable tool for modeling these types of activities. For monitoring stream output at any point, the Snohomish basin has been divided into 11 watersheds and numerous subwatersheds.

Soils file. The soils found in the basin have been aggregated into 42 classes according to depth, texture, structure, gravel content, and permeability. This static file is referenced by using the average soil type contained in the cell file for any particular cell. This information has been

*For detailed description see "Models of the Forested Ecosystem of the Snohomish River Drainage Basin" by the College of Forest Resources, University of Washington, 1974.

useful during model development as well as during the running of the simulation model. Additional soils data reflecting a subjective assessment of sedimentation yield potential, capacity to retain chemicals, and potential for regeneration are also stored on the cell file.

History file. In addition to the above files, several additional items of information are combined and stored on a history file. Briefly, these are: (a) watershed summaries of selected attributes (for example, deer populations), (b) recreation facilities information concerning the location and characteristics associated with recreation facilities, (c) a history of manipulations occurring during the simulation, and (d) economic and demographic trend data.

Information system

Concurrent with the design and implementation of the Resource Data Base a series of programs were developed to provide the capabilities for information retrieval and update of the various files. The continuing demands for data in varying forms led to the development of a flexible large scale resource information system. This system has developed into a general cell-based system which is independent of restrictions such as cell size, number and types of cell attributes and the manner of access to cells for data retrieval. The three major purposes of the SVEN information system are to: (a) provide for efficient storage, retrieval and updating of information during running of the system simulation model, (b) provide information to support model development, and (c) respond to queries requesting information in the form of maps, summaries or listings.

At the most elementary level the information system provides the capacity for retrieval and update of data on a cell-by-cell basis. This is the normal mode of interaction with models which are simulating operations on a specific area. Cell data may be retrieved or updated in either random or sequential fashion. In random access operations the order in which the cells are accessed makes no difference to the system. In sequential access operations the user specifies the area in which he is interested, such as a particular watershed or section, and the cells are returned one at a time when requested. In either case, a specific subset of the attributes describing the contents of a cell or all of the attributes may be retrived.

At a higher level the system responds to user inquiries about certain data over a specified area. The user can request output in the form of summaries, listings or maps. A specific group of attributes can be summarized over a given area. These summaries reveal the total acreage in each area by attribute. For example, acreage in each timber type may be retrieved for a watershed. An English language dump or atlas describing the contents of cells in a specified area may also be obtained.

Three types of displays may be produced using the SVEN Information System. These are line printer plots using different characters to represent the various values of an attribute, shaded line printer plots which utilize overprinting to designate areas of differing attribute values, and CALCOMP plotting of an area in three dimensions. Figures 2(a, b and c) illustrate the display potential of SVEN system. They all show the Middle Fork watershed of the SVEN Basin. Figure 2(a) shows the distribution of forest types in the watershed using letter code display. Figure 2(b) displays a topographic map using shaded line printer, and Fig. 2(c) presents a three-dimensional view of the watershed from an elevated point outside the watershed using CALCOMP plotter.

Approximately 200 computer programs have been written to create, update, edit, retrieve, summarize, list, and map information from the resource data base. Most of these are best viewed as service programs which provide a much needed capability for efficient manipulation during system development and operation. A special control language—SVENESE—has been developed specifically for SVEN simulation model which permits users unfamiliar with data formats and calling sequences to access and utilize the full potential of the SVEN information system and resource data base.

II. FOREST PRODUCTION SUBSYSTEM

The Forest Production Subsystem includes four simulation models. These are:

(a) Timber production model
(b) Timber harvesting model
(c) Forest residue model
(d) Forest protection model

Fig. 2(a). A computer-generated forest type map of the Middle Fork watershed.

Fig. 2(b). A computer-generated topographic map of the Middle Fork watershed.

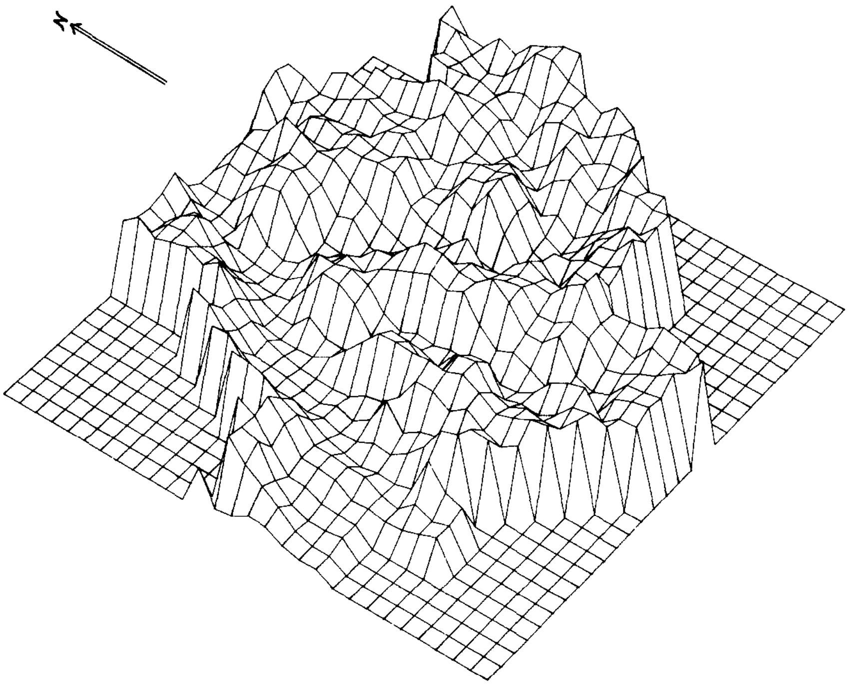

Fig. 2(c). A computer-drawn 3-d perspective of the Middle Fork watershed in the Snohomish River Basin. The two horizontal axes are not to the same scale.

Most of the human interventions mentioned earlier are handled by this subsystem. Each of the component models listed above are capable of being used independently as "stand alone". As part of the subsystem they cover all aspect of forest management activities relating to production and harvest of timber. Each of these models generate output which in turn is used by other models in this and other subsystems.

(a) *Timber production model*

This model updates cell (or stand) attributes over any desired length of time. Besides updating, as a result of growth, the model implements forest management decisions. Two basic assumptions underlying this model are:

(i) that each cell (or stand) is uniform with respect to age, composition, site and stocking
(ii) that the specified treatment is applied to the entire cell (or stand) at one time.

The management interventions handled by the model include:

(i) Final harvest with choice of clearcut of shelterwood cut
(ii) Thinnings from below
(iii) Three options of artificial regeneration besides natural regeneration
(iv) Fertilization with 200 lbs. of N/acre.

The cell (or stand) attributes such as basal area per acre, dominant height of the stand and number of trees per acre are updated over time using growth functions. Using volume equations, cubic volume per acre is computed from basal area per acre and dominant height. The current version of the timber production model incorporates these growth and yield functions for Douglas-fir and Western Hemlock—the two most valuable and predominant species of the Snohomish River basin.

The model also attempts to incorporate the effects on growth of application of 200 lbs. of N/acre. It is assumed that the increased growth rate due to fertilization lasts for the next five years.

The spatial and temporal ordering of different management activities is an input to the model and not determined by it.*

*In some timber simulation models the spatial and temporal ordering of management activities such as harvesting and thinning are not input but determined by them.

The model generates timber production related output periodically (every year or longer). These include:

(i) Area summary by age and site

(ii) Growing stock, growth and removal summary by species

(iii) Undiscounted cash flow summary incorporating management-related costs and stumpage returns

(iv) Listing of cell (or stand) attributes

(v) Summary list of harvested cells (or stands) together with their attributes

(vi) Summary list of thinned cells (or stands) together with their attributes.

(b) *Timber harvesting model*

This model complements the timber production model. The periodically generated list of cells harvested and thinned in the timber production model are used as input by the timber harvesting model. In addition, this model uses the physical cell description and soil information from the Information Subsystem. Five logging options are available for each cell specified for total or partial cut. These are:

(i) High lead

(ii) Tractor

(iii) Skyline

(iv) Running skyline-choker

(v) Running skyline-grapple

The haul road and yarding road pattern for harvesting a 40-acre (20 chain square) cell for different logging options is incorporated in the model. Given a logging method, the model computes the lengths of different roads, the amount of soil disturbance and the area effectively excluded from timber production because of roads, landing and skid trails. The following output is generated by the model:

(i) Acres harvested by different logging methods

(ii) Cubic and board foot volume harvested by log grades and logging methods

(iii) Road mileage (by mainline, secondary and spur) to implement specified logging scheme

(iv) Area occupied by roads, landing and buffer strips (to be excluded from potential timber production area)

(v) Cash flow summary of logging and road construction costs and value of harvested logs

(iv) Identities of cells and the logging method used. This is used as input by the Hydrology Model.

(c) *Forest residue model*

This model estimates the amount of residue ofter logging in a cell as a function of initial cell attributes and the logging method used.

Then it implements two stage specified management decisions on the cell basis as follows:

(i) If salvaged operations have been specified, it computes the salvageable volume and the balance residue.

(ii) It executes the specified residue treatment. The model incorporates four options including doing nothing. Two of the options involve slash disposal by burning.

Associated with each treatment are costs, probability of success in natural regeneration, and release of solid and gaseous pollutants in the atmosphere. Aesthetic aspect involving visual pollution is not considered. The output from the model includes:

(i) An undiscounted cash flow summary of residue treatment and salvage operation costs and dollar returns from salvage operations, if any.

(ii) The amount of solid and gaseous pollutants released to the atmosphere.

(d) *Forest protection model*

Though forest protection encompasses preventive and remedial measures against insect damage, pathological diseases, and forest fires, in the Forest Protection Model only the insect part is operational so far. The insect model has been designed to simulate the Douglas-fir bark beetle management problem. The model, programmed in MIMIC, operates on a daily cycle in view of a short and seasonal life cycle of the bark beetle.

The input to the model can be classified under three headings as under:

(i) The host material. This includes the available infested and not infested blowdown, slash and live timber in the area in question.

(ii) The insect population. This includes the total population size, the sex ratio and the intraspecific competition constants.

(iii) Management policy. This includes the intensity and time lag of insect control management for all types of host material.

Given specific value for different inputs, the model simulates the cyclic development of the insect population. The model output includes the status of host material and insect population size over time by management alternatives. This model is yet to be interfaced with other components of the SVEN system.

III. FISH AND WILDLIFE SUBSYSTEM

The human interventions for manipulating the forest ecosystem as well as the exploitation of both fish and wildlife resources regulate the dynamics of the fish and wildlife population. Timber harvests not only increase forage production; they also cause increased run off and higher stream temperature thus affecting the environment for both fish and wildlife. As there is no significant interaction between fish and wildlife, two models, one for simulating the impact on fish and the other on wildlife, are required. However, due to lack of appropriate documented research, the current constituent of the fish and wildlife subsystem is a single species (i.e., black-tailed deer) model.

Wildlife (black-tailed deer) model

Because of the high mobility of wildlife populations, this single species model operates on an aggregate basis and essentially ignores emigration to, and migration from surrounding areas. Given initial deer population levels, the extent of harvesting activities and stocking levels (both influencing the carrying capacity), the model simulates the development of deer population over time.

The model operates in two steps per year. In the first step changes in population caused by births and death due to natural causes including predation are simulated. In the second step, the hunting impact on the deer population under three different assumptions of hunting regulations is simulated. Though lack of data made absolute validation of this model difficult, the model has been tested for consistency and reasonableness of the output.

IV. ENVIRONMENTAL SUBSYSTEM

This subsystem has been designed to monitor the environmental impact generated by the manipulation of the wild land ecosystem. With the help of this subsystem, resource managers should be able to evaluate the impact on air and water qualities of alternative management strategies. The hydrologic output would be an indispensable input to the development of fisheries model of the SVEN system.

Three simulation models constitute the environment subsystem. These are:

(a) Meteorologic model

(b) Hydrologic model

(c) Atmospheric model

The contribution of these three models to the SVEN system are discussed below:

(a) *Meteorologic model*

As mentioned earlier, this model is part of the driving force on the SVEN system. It provides information on temperature and precipitation (rain and snow) used primarily by the hydrologic model (to be described later). Based on the historical meterological observations from 10 weather stations in the Snohomish River Valley, monthly temperatures and precipitation values are randomly generated under the assumption that these are distributed normally around monthly average values (from historical data). Adjustments to account for changes due to altitudinal changes were made to these randomly generated values to derive values for each specific cell. The form of precipitation, rain or snow, is determined by the threshold temperature of 28°F.

(b) *Hydrologic model*

The main objective of the hydrologic model is to quantitatively simulate responses on the water yield and quality to manipulation of the forest ecosystem by harvesting and fertilization. The focus here is primarily to monitor changes in the hydrological environment even though absolute levels of water quantity and quality are also obtained from this model. The time resolution here is one month as compared to a year for the SVEN system in general. The parameters estimated by the model include:

(i) Water yield as a function of total precipitation, evapotranspiration and interception losses, and changes in the monthly watershed storage

(ii) Suspended sediment as a function of water flow rate and roading activities

(iii) Stream temperature as a function of air temperature, water flow rate and vegetation cover

(iv) Nitrate concentration as a function of area fertilized, rate of fertilization application, water percolation and sub-soil storage

(v) Dissolved oxygen as a function of elevation water flow rate, water temperature and water pollutants concentration.

The output from the model includes tables and graphs depicting monthly water yield, sediment concentration, stream temperature, and nitrate concentrations resulting from harvesting and fertilization activities.

(c) *Atmospheric model*

The objective of the atmospheric model is to provide quantitative estimates of pollutant concentration resulting from emissions within the forest ecosystem. The accumulation of pollutants usually happen under critical meteorological conditions. In the Pacific Northwest these conditions prevail during the summer months. The model, therefore, focuses on prediction of pollutant concentration during summer and early fall.

Using the output from Forest Residue Model (quantity of hydrocarbon, carbon monoxide and suspended particulate matter) and the climatological information from the meteorological model, the atmospheric model simulate the percent number of days when the pollutant level exceeds any specified threshold constant concentration standard (in $\mu g/m^3$). The model thus predicts how air-quality standards would restrict forest management practices during critical period rather than indicating how management activities would influence air quality at a specified time during a year.

V. RECREATION SUBSYSTEM

Recreation activities are part of the total human physical and biological system. Increasing pressures of urban living, availability of leisure time and transportation facilities, and availability of areas and opportunities within short driving distances for diversified outdoor recreation in the Pacific Northwest, has made it a major land use competing with other conventional land uses such as timber production and is generating considerable environmental impact of its own.

The objectives of the recreation subsystem were two-fold. First, to predict the demand (both current and future) for outdoor recreation activities in the Snohomish River Basin for proper planning of recreational facilities; and second, to estimate environmental impact, both direct and indirect, generated by these activities.

Using the basic procedure developed by Cicchetti and others,* a twostep multiple regression model using some 75 independent variables, the total number of user days for each of 11 major outdoor recreational activities in the Snohomish River Basin were generated. The recreation activities included in the study were: camping remote and developed, canoeing, other boating, driving for pleasure, fishing, hiking, hunting, sightseeing, skiing and swimming.

Given the total number of user days of various outdoor recreational activities in the Snohomish River Basin and the amount of solid waste and gaseous pollutants generated per user day by different activities (from historical data), the total amount of pollutants, both solid and gaseous released to the environment can be estimated. The solid waste such as garbage and sewage may be disposed of in a manner without polluting the environment thus causing little

*C. J. Cicchetti, J. J. Seneca and P. Davidson, *The Demand and Supply of Ourdoor Recreation*, Bureau of Economic Research, Rutgers University, New Brunswick, N.J. (1969).

impact on the environment. But the exhausts of motorized equipment and autos could certainly contribute to the air pollution. Because of the problems in simulating the distribution of these air pollutants both spatially and temporally over the basin, no attempt is currently made to monitor concentration levels of gaseous pollutants. The model also does not provide for interaction between recreation and other land use activities.

SYSTEM INTEGRATION AND IMPLEMENTATION

The SVEN system operates in cycles of one year or longer. It essentially operates in four steps, with each step involving activities which are similar. The information system maintains and continuously updates three sets of files; cell file, history file and management file. These files are used by the system models during execution and provide the only linkage between the information and other systems. There is no direct linkage between the model components of the system. The main advantage of this approach is that the system may be enlarged by adding other components or reduced by not using them as the situation may warrant. A summary description of different steps in system implementation for a single cycle follows:

At step one, the system consolidates all the input information. The cell file is updated as a result of biological growth using the timber production model. Weather information is generated using the meteorologic model and stored on the history file. All management decisions are stored on the management file.

At step two, operations included in the harvesting and residue models, and the regeneration component of the timber production model are used to implement management decisions. The effects of the decisions are stored on the management file. The cell file is also updated in the process, because operations such as harvesting or regeneration will materially alter the cell data.

At step three, the impact generation models such as the atmospheric and hydrologic models are used to compute environmental and other impacts. This impact information is stored on the history file.

Though not currently operational, the next step would be the use of the fish and wildlife models to evaluate the influence of management decisions and other interventions on the status of the fish and wildlife populations in any given watershed.

At the last step, the results for a given cycle are reported. The information system achieves this using the updated files and produces summaries, listings and maps of all activities and impacts undertaken during the cycle. Summaries, listings and/or plots showing the status of the entire river basin at the conclusion of the cycle may also be requested. In addition, a time history for any desired output variable from past cycles may be retrieved and displayed.

Upon completion of a cycle, the updated cell and history files are retained for use during the next cycle. The management file is destroyed as new decisions for the next cycle will be read again in step one.

SUMMARY AND CONCLUSION

This paper briefly outlined the breadth and scope of the project SVEN currently under development at the University of Washington, College of Forest Resources. The basic objective of this study is to provide a rational basis for decisions relating to planning of wild land management. The SVEN system attempts to quantify goods and services and associating environmental impact resulting from manipulation of this resource.

The description of the component models has been necessarily brief. However, an attempt was made, in this short paper, to give a complete picture of the system and component capabilities. Detailed monographs of the system components are under preparation and should be available shortly. Included within each monograph are: (a) full description of each model, (b) user guide for the associated computer program and (c) samples of model output. Since total system output is too voluminous for inclusion here, interested readers may consult these monographs for sample output.

The project also brings to light the problems associated with such analytical models. Even gross spatial resolution of 40-acre cell resulted in storage and processing of an incredibly large amount of data with its attendant problems. It also revealed the inadequacy of the *in-situ* data and the absence of suitable relationships for processing of this data by different subsystems. The time and resources available for the project precluded extensive work in this direction. A methodology for efficient collection of data and development of functional relationships for predicting purposes is a promising area of research.

The system of models can be used either as individual or stand alone models or as one giant model by interfacing the component models. In either of these forms the system has several policy uses, some of which have actually taken place while others are in the implementation or exploration stage. The following examples may be illustrative:

1. The recreation model is currently being used by a state agency in charge of allocating funds to purchase new recreational resources and to develop existing ones. The recreation usages projected by the recreation model through the year 2000 and the environmental impacts form the basis for allocating funds to one recreational activity rather than to another one, and to favor certain types of facilities (such as campgrounds with septic tanks) over others. In addition this agency commissioned work to adapt the models, which are currently operative on a regional basis, to a finer spatial resolution of a county. When completed this will form the basis for the allocation of funds to the different counties to meet expected recreational demands. Finally it has expressed an interest to change the spatial resolution to a three-state level with the objective of using it as a tool to harmonize future recreational data collection and facilities development between the states. Thus to serve the needs of policy makers and planners, the spatial resolution was accepted as it is at one level of decision making and will be both refined as well as enlarged to serve other levels.

2. The resource information system in conjunction with some of the outputs of the timber production and recreation models has been used by the U.S. Forest Service in planning the land use and in studying the management alternatives along a major stretch of interstate highway. In view of the very high level of sensitivity and public visibility of lands managed by this agency along the interstate highway, decisions had to be made as to which areas could be harvested and managed for timber production without constraints, which were to be subjected to some form of constraint, and which were to be left essentially untouched.

3. The State of Washington (like many other states) has recently passed a new Forest Practices Act. To implement this act a whole set of rules and regulations is currently being worked out. The system models are an ideal tool to evaluate the trade offs between alternative regulations. For example they were used to determine the amount of land lost to timber production and the resulting impact on timber production under alternative widths of buffer strips left untouched along 5 classes of streams. These buffer strips were to protect streams from debris and siltation, as well as to prevent possible increasing water temperatures associated with increased solar radiation resulting from the removal of the vegetation screen along the streams.

4. It was found that uses of the models or the whole system as is, are rare. More generally a potential user has to adapt the models to serve its specific needs. In view of this National Science Foundation has recently comissioned a state agency to explore the usability and transportability of some of the components developed with a view of its particular needs. This agency is in charge of managing the state forest lands; it is also charged with the implementation of the new Forest Practices Act. This will be another very interesting test case.

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