

Distinguishing the Forest from the Trees: Synthesizing IHRMP Research¹

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Abstract: A conceptual model of hardwood rangelands as multi-output resource system is developed and used to achieve a synthesis of Integrated Hardwood Range Management Program (IHRMP) research. The model requires the definition of **state variables** which characterize the system at any time, processes that move the system to different states, **outputs** (at the site and the landscape level) which are produced by processes as the system changes state and **values** which are derived from outputs or directly from the system's state. Processes can be further categorized as **intensive** (i.e. involving function within the hardwood system) or **extensive** (involving reduction in the extent of the hardwood system). The **incidence** of processes sets the model in motion. Research projects are evaluated by the extent to which they contribute to the measurement of model components and the elucidation of the relationships between them.

All natural resources management employs models of varying degrees of elaboration to predict the natural system's response to management. This paper proposes a "state-transition" model of hardwood rangelands as a framework for integrating IHRMP research results in support of program goals. Integrated Hardwood Range Management Program (IHRMP) goals can be expressed as desired states of the natural resource system. Research projects clarify the dynamics that produced changes, or transitions, in the system's state. This formulation suggests a set of criteria by which to classify, evaluate and integrate the results of research projects.

A STATE-TRANSITION MODEL OF HARDWOOD RANGELANDS

The model proposed for California's hardwood rangeland sees that landscape as a spatial array of cells (figure 1), just as would a geographic information system (GIS). The condition of the resource base (the system's **state**) at any time is characterized by **state variables**. Examples of state variables include

such things as elevation, soil texture, vegetation, ownership, etc. **Processes**, both natural and management, interact with state variables to produce both new values for the state variables and **outputs** from each cell. For instance, a process, such as fire, alters the state variables of vegetation and produces outputs, such as air pollutants. Processes can be classified as causing changes within the system (**intensive**) or reducing the extent of the system (**extensive**) (Doak and others 1988). Outputs can be measured objectively and are tied to individual cells. **Landscape outputs**, such as livestock production and watershed sediment yields, refer not to individual cells but rather to the interaction of numerous cells. State variables, outputs and landscape outputs generate **values** either through the market, for such things as livestock production, or through non-market mechanisms, for such things as biodiversity or visual quality.

This state-transition formulation is not a complete description of reality since it predicts only what would happen if particular processes were applied to particular pieces of land. It does not estimate the probability of particular processes occurring on particular pieces of land. When these probabilities or **incidences** are estimated outside the model or determined within the model as functions of state variables, the model becomes a spatial simulation model.

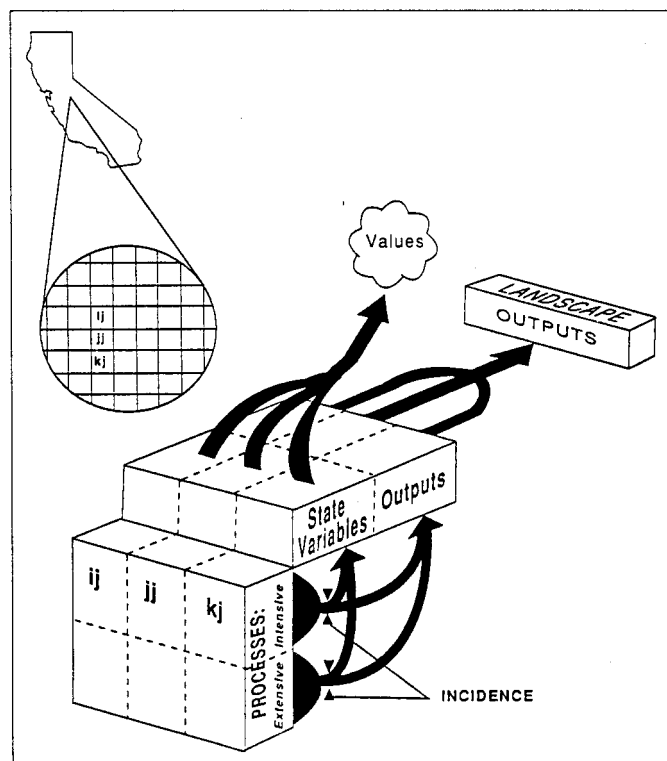


Figure 1—State-Transition Model of Hardwood Rangelands.

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The contribution of individual research projects to the attainment of program goals can be traced through the model structure. For instance the goals of the hardwood program were defined by the State Board of Forestry (1986) as a set of desirable system states involving the state variables relating to hardwood species, soil and water characteristics, and wildlife habitat (table 1). The Board invoked the processes of erosion, grazing, range improvement, and conversion to agriculture or urban use. It specifies outputs and landscape outputs such as income for landowners and water quality. The role of research is to improve our understanding of the operation of the system in both its anthropological and biological dimensions so that the State can deploy its programs with some assurance of moving the system toward the desired state.

How well has IHRMP research improved our understanding of system structure and function? Each research project can be evaluated in terms of the model through a series of questions:

System definition: what are the important state variables?

Current state of the system: how can we affix values to the state variables?

System evolution: how will the system change in the future?

- do we know the important processes?
- can we judge their incidence?
- do we know their effect on state variables?

Outputs and Landscapes: what will changes in the system state mean?

- do we know the important cell and landscape outputs and values?
- can we translate changes in state variables into changes in outputs and values?

System Definition

Table 2 lists state variables, outputs and processes investigated by several typical IHRMP research projects. Since the state-transition model is spatial in nature, every state variable could, in theory, be mapped. Those that have been incorporated into the California Department of Forestry/Forest and Rangeland Resources Assessment Program GIS are noted in the table as being mapped. The table also shows the general direction of causality investigated by each project.

Research projects generally fall into four categories (table 2). Projects in Group 1 investigate the factors determining a subset of state variables pertaining to oak stand structure (e.g., Muick and Bartolome 1986). These factors are both processes and state variables themselves and relate principally to intensive change. They include location, natural processes, traditional management practices and artificial regeneration.

Group 2 attempts to translate state variables into outputs (e.g., Block 1989). Those that have focused on wildlife habitat relationships have used a range of state variables far wider than

Table 1— *Desired State of Hardwood Lands*

"Behind any policy is a vision of the future. ... (T)he following general vision is suggested...."

The hardwood resource, whether on conifer or hardwood- rangelands, generally should be protected and enhanced. This means that **all hardwood species are regenerating, soil and water quality are preserved and sufficient habitat diversity is achieved statewide to protect the viability of critical wildlife species.**

Range and timber stand improvement can continue - but such activities should take account to sensitive environmental areas and serious wildlife damage. Additional sources of income to landowners are available through improved utilization, new markets for products from species that are regenerating well, and programs to compensate landowners for leaving hardwoods.

Land can continue to be converted to intensive agriculture and residential/commercial development - but it should be directed away from environmentally sensitive areas, avoid serious damage to wildlife and not interfere with the ability of landowners to manage their land economically.

Government Involvement In land management decisions of private Individuals should be minimized and in so far as is possible, supportive of their needs. Public agencies, federal through local, should understand and be coordinated with each other and with private landowners in their management goals and practices."

from State Board of Forestry (1986); emphasis the author's.

that investigated by Group 1. Wildlife investigations have included such measures as the diversity of overstory species within a plot while Group 1 projects generally classified hardwoods into single species categories. Other projects within this second group translate oak canopy cover and other state variables into forage production and erosion hazards. In some cases Group 2 projects have attempted to carry the analysis through to the landscape level in terms of wildlife habitat and watershed function. This second class of projects is concerned again with intensive change.

Group 3 attempts to understand the incidence of management processes, particularly those that reduce the extent of the oak woodland system. Group 3 projects have generated a long list of state variables that are a mix of natural and socioeconomic characteristics of ownerships, the larger market and institutional forces. The relationships between these state variables and the incidence of processes is conceptual at best. These projects do not carry through to an assessment of the impact of processes on state variables or landscape outputs.

Group 4 classifies and measures state variables (e.g. Pillsbury 1990) or otherwise improves the methodology of assessment.

This pattern of research merits several comments. First, **the state variables used to characterize the hardwood resource (oak stand structure) are a small subset of the number needed to predict the outputs included in the vision.** Predictions of changes in wildlife, water quality, and sensitive environmental areas will require a more detailed understanding of the structure of hardwood range vegetation in terms of species diversity, presence of shrubs, presence of large individuals, vegetative cover, etc.

Table 2 —Typical IHRMP projects: state variables, outputs and processes

Project	State Variables	Mapped?	Outputs	Processes
Group I Analysis of oak regeneration (Muick and Bartolome 1986)	regeneration index oak species size class density origin (acorn, resprout) elevation fire slope aspect canopy position regional location presence livestock		forage water yield wildlife diversity recreational use	recruitment grazing wildlife use wood cutting
Group II Habitat relationships in oak woodlands (Block 1989)	oak species woody cover shrub cover herbaceous cover tree density special habitat elements regional location		avian spp. abundances herp spp. abundances mammalian spp. abundances	
Group III Legal environment for hardwood land ownerships (Doak and others 1988)	zoning classification registration under -CLCA -CRP -AB580 presence of -VMP -CFIP -RCD			clearcutting conversion to housing conversion to agriculture regulation of use prescribed fire reforestation soil conservation
Group IV Assessment of CA hardwood lands (Pillsbury 1990)	oak species density class			
The arrows indicate the direction of causality, beginning at predictor variables and leading to dependent variables.				

Second, while site classification systems (Group 4) may organize this mass of variables, **it is unlikely that a single landscape classification system will capture all the information required to achieve the vision.** A system keyed on existing vegetation cannot contain all the information necessary to predict water quality. Botanical species composition may be necessary but not sufficient to predict wildlife habitat value. While a coarse grain description of vegetation may be sufficient for explaining wildlife species distribution within the state, it is insufficient to explain fire risks where the influence of vegetative ladders and firebreaks, features indistinguishable at the larger scale, govern the phenomenon.

Third, **there has been little emphasis on methodologies that generate landscape outputs from state variables.** Ideally, the state-transition model would predict a future landscape which would then be evaluated as a whole for its provision of landscape outputs such as wildlife habitat, water quality or fire risk. While difficult to calculate, landscape outputs, such as water quality and fire risk, are more evident and more important than the output of any individual cell.

The designation of "critical sites" is an ad hoc means that condenses landscape analysis into a single state variable. A "critical site" designates certain parts of the landscape as having particularly high value and implies that, regardless of the fate of other portions of the landscape, these areas should be conserved.

Fourth, **extensive change remains poorly understood.** While demographic projections convey the scope of potential conversion at a county level, social scientists are only now beginning spatial analysis of development patterns (T. Bradshaw, pers. comm.) Furthermore, the effects of conversion on state variables and landscape outputs are not clear. While the impact on hardwoods of their conversion to parking lots is obvious, the impact on wildlife and water quality of conversion to low density rural residences is not.

Finally a review of individual projects confirms that **hardwood vegetation is not a homogeneous type, but is comprised of at least five classes with different research and policy requirements.** Although regeneration of valley oak and Engelmann oak may be problematic in intact woodlands, the principal threat to their existence appears to be conversion. Their

current extent is quite restricted and located in areas with high development potential. Blue oak on the other hand is quite extensive. It exists within a pastoral economy and its habitats are less threatened than those of the previous two species. However, its ability to regenerate appears problematic. Oregon white oak appears to be somewhat restricted and may regenerate poorly. It exists within a timber economy and its regeneration difficulties appear linked to fire management. Live oaks in general appear to be regenerating well though their habitats may be locally endangered by conversion. Finally, black oak appears to be regenerating well, is linked closely with conifer lands and the timber economy and appears to present economic opportunities completely different from that of the other species.

System Change and Its Meaning

In this paper I wish only to explain the framework suggested by the model for the evaluation of contributions of research projects to our understanding of system evolution, outputs and landscapes. The evaluation itself is pursued elsewhere (Greenwood 1990).

Table 3 portrays how one might analyze studies of intensive processes. The table lists the processes driving intensive change that projects have investigated to date. These include the growth, reproduction and mortality of the herbaceous, shrub and tree layers, since together they determine the structure of the vegetation. Diseases of hardwoods merit special attention since, in the absence of cutting, they are the major killers of mature hardwoods. Similarly, herbaceous growth establishes a competitive situation which may account for most oak seedling mortality. The invasion (or perhaps re-invasion) of woodlands by shrubs is a significant process particularly for wildlife. Grazing, prescribed fire, thinning and artificial regeneration interact with natural processes to drive the hardwood system in different directions.

The model structure forces one to consider how well we understand the incidence of processes as well as their effects on state variables. Table 3 approaches these questions in the sim-

plest fashion - by reporting the number of IHRMP projects that have investigated these issues. It is clear that incidence of reproduction has received far more attention while that of other processes. Even so, our understanding, at least as reflected in our ability to calibration a state-transition model, remains poor: it remains impossible to draw a definitive map of the regeneration status of blue oak, much less explain the geographic pattern. While many mechanisms pertaining to regeneration have been investigated, no single factor appears overwhelmingly important in determining the fate of hardwood vegetation.

The model structure also forces one to consider the impact of processes on cell and landscape outputs. Table 4 provides an example of how fire might effect six important landscape outputs. This framework raises specific questions (e.g., how does fire influence water quality) which serve as criteria by which to judge project findings. In this instance, table 4 includes some of the mechanisms that might mediate the relationship between process and outputs, procedures that can be used to model these mechanisms, and issues raised by each interaction.

CONCLUSIONS

Why is this model framework useful?

First, it allows one to relate research to the goals of the program. Both the goals of the program and the details of research can be expressed within the common framework defined by processes, state variables, outputs and landscape outputs. Research is useful to the extent that it increases our understanding of model function and the means to arrive at the desired state. Questions suggested by the model but not yet addressed by projects are candidates for future research.

Second, the model framework is extremely flexible, thereby allowing new results to be incorporated easily. New processes, state variables and outputs can be added without redoing the entire model. Furthermore, the "grain" of the model is adjust-

Table 3—Intensive processes: number of projects elucidating process incidence and effects on state variables by species

Process	State Variables					Incidence				
	QULO	QUDO	QUEN	QUAG	QUWI	QULO	QUDO	QUEN	QUAG	QUWI
Tree growth	0	1	0	1	1	0	0	0	0	0
Reproduction	-	-	-	-	-	4	4	5	2	1
Mortality	-	-	-	-	-	1	1	1	1	0
Disease	0	0	0	0	0	1	1	1	1	1
Herbaceous growth	0	2	0	0	0	0	0	0	0	0
Shrub growth	0	1	0	0	0	1	2	1	1	1
Fire: prescribed	0	2	2	1	0	0	1	0	0	0
Grazing	1	5	2	2	0	1	1	1	1	1
Thinning	1	1	1	1	1	1	1	1	1	1
Artificial regen.	-	-	-	-	-	2	2	2	1	1

(abbreviations signify oak species: QULO=valley, QUDO=blue, QUEN=Engelmann, QUAG=coast live, QUWI=interior live)

Table 4—Fire: mechanisms and predictive procedures for outputs and values

Outputs/Values:		
<u>Water Quality</u>	<u>Wildlife Habitat and Use</u>	<u>Livestock and Firewood Production</u>
#loss of cover	#change in habitat type	#maintenance of "grazing complex"
#change in soil surface	#change in habitat stage	#sprouting response
#fire intensity	#loss of habitat elements	#type conversions: chaparral to grass
#rain intensity	#fire frequency	woodland to grass
>erosion hazard rating	>WHR	#elimination of shrub understory
>USLE		
>sediment routing models	?impact of spatial patterns created by fires	>regional mean change in annual forage quantity and quality
?short term impact of fire itself vs long term impact of vegetative change	?value of landscape rather than single habitat islands	?mediation of woodland-chaparral boundary
		?mediation perennial grass persistence
		<u>Productive Potential of Site</u>
<u>Wildfire Risk</u>	<u>Biodiversity</u>	#loss of nutrients
#reduction in fuels	#loss of particular habitats	#loss of soil
#fire intensity		
#change in habitat type	>critical site criteria	>
#change in future rate of spread, ease of attack	#increase in habitat diversity	?
>	>	
?	?scale of shifting mosaic steady state	

(# signifies a mechanism or important factor, > signifies a predictive procedure, ? signifies a question or issue)

able. Generic processes, state variables and outputs can be further subdivided as needed without altering other parts of the model. The specificity of the goals will determine to a large extent the grain appropriate to each part of the model. Lastly, the model does not limit the factors that mediate the relationships between processes, state variables and outputs. The only limitation is that the relationships be consistent over time within a cell.

Third, the model is extremely inclusive. An enormous range of questions can be expressed using model constructs. The

model generates certain obvious questions involving the effect of a given process on a given state variable. The model itself does not always generate interesting new questions, since many of them involve either adding new processes, variables or output to the model structure, or subdividing these entities in novel ways not derivable from the model itself. Nonetheless, the ability of the model to stretch itself over a wide range of phenomena allows potential divergent lines of research to be viewed together.

Finally, the model organizes knowledge in a form analogous to our technology of expert systems and GIS. The construct of the cell shows the link to GIS while the consistent rules that define the relationships between processes, state variable and outputs are the usual components of expert systems.

A fully calibrated, fine grain model of hardwood rangelands may appear to be an unrealistic goal, a sink for research resources that should be avoided in order to address a few pressing hardwood issues. Yet many of the pressing issues point toward "sustainable development" and "landscape management." This holistic imperative requires new paradigms, such as this model, to achieve a landscape synthesis.

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