



A method for analyzing environmental effects of impacting activities  
by Louis Theodore Egging

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE  
in Industrial and Management Engineering  
Montana State University  
© Copyright by Louis Theodore Egging (1976)

**Abstract:**

The public land manager is directed by law to manage for multiple use and sustained yield of goods and services. This must be accomplished without long term detriment to the environment. He must also analyze the environmental consequences of any proposed management action. These impacts might not only be short term effects, but may be long range as well.

The ecosystem, impacted by the activity, is a complex maze of relationships. An impact directed at one resource will influence not only that resource but others as well. Some effects are immediate, others are not apparent until after a considerable time period. This complexity requires the ecosystem to be analyzed as a whole. It must be perceived as a complete system.

A method is proposed to help the manager analyze the environmental impacts of an activity. Using systems analysis and computer simulation techniques, a two-phased simulation model is presented. This approach models the activity as the micro phase. If desired, this phase can be modeled in detail suitable for productivity optimization, or it can be modeled simply. The macro phase of the approach models the ecosystem. This phase simulates the dynamic response of the ecosystem to the impact.

STATEMENT OF PERMISSION TO COPY

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at Montana State University, I agree that the Library shall make it freely available for inspection. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by my major professor, or, in his absence, by the Director of Libraries. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature

Rouis L. Eggen

Date

10/22/76

A METHOD FOR ANALYZING ENVIRONMENTAL EFFECTS  
OF IMPACTING ACTIVITIES

by

LOUIS THEODORE EGGING

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

MASTER OF SCIENCE

in

Industrial and Management Engineering

Approved:

*David F. Wilson*

Chairman, Examining Committee

*John A. Ritchey*

Head, Major Department

*Henry L. Parsons*

Graduate Dean

MONTANA STATE UNIVERSITY  
Bozeman, Montana

September, 1976

## ACKNOWLEDGMENT

I wish to extend my appreciation to the U.S.D.A. Forest Service for supporting this effort. A special thanks goes to Dr. James E. Lotan, Program Manager and Dr. Richard J. Barney, my immediate supervisor for their continued support, not only financial, but professional and personal as well.

I acknowledge the clerical personnel at the Northern Forest Fire Lab for their efforts in preparing drafts of this thesis. For her typing of this final draft, a special thank you goes to Betty Lackey.

Dr. David F. Gibson, my major professor and advisor is gratefully recognized for his direction and guidance. I thank all those too numerous to mention who offered their support.

To my little wife, Gabriela, and my growing family, I apologize for the many hours I was absent when working on this study. I sincerely say thank you for your understanding and support.

## TABLE OF CONTENTS

	Page
LIST OF TABLES . . . . .	vi
LIST OF FIGURES . . . . .	vii
ABSTRACT . . . . .	x
 Chapter	
1. INTRODUCTION . . . . .	1
Multiple Use Management . . . . .	1
Land Use Planning . . . . .	4
The Problem . . . . .	6
2. SYSTEMS AND SIMULATION: A METHOD . . . . .	9
The Systems Approach . . . . .	9
Systems and Simulation . . . . .	14
Systems Dynamics . . . . .	18
GASP IV . . . . .	25
Approach to the Problem . . . . .	27
3. MODEL DEVELOPMENT . . . . .	30
The Systems Description . . . . .	30
System Objectives . . . . .	31
Environment . . . . .	33
Resources and Components . . . . .	34
System Manager . . . . .	34
Ecosystem - Harvesting Productivity Model . . . . .	36
Combining Model Types . . . . .	39

	Page
4. MACRO-MODEL PHASE . . . . .	42
Area Subsystem . . . . .	43
Moisture-Water Subsystem . . . . .	45
Timber Subsystem . . . . .	48
Forage Subsystem . . . . .	50
Wildlife Subsystem . . . . .	52
Erosion Subsystem . . . . .	54
5. MICRO-DISCRETE PHASE . . . . .	56
Harvesting Subsystem . . . . .	56
Fire Subsystem . . . . .	60
Road Building and Closing Subsystem . . . . .	62
6. SIMULATION RESULTS . . . . .	65
Ecosystem Base Run . . . . .	65
Combined Impacts . . . . .	69
7. SUMMARY AND RECOMMENDATIONS . . . . .	75
LITERATURE CITED . . . . .	77
APPENDICES . . . . .	80
APPENDIX A: Flow Charting Symbols . . . . .	81
APPENDIX B: Ecosystem Model . . . . .	83
APPENDIX C: Model Variables Defined . . . . .	98
APPENDIX D: Model Output . . . . .	112
APPENDIX E: Computer Listing of Selected Routines . . . . .	125

## LIST OF TABLES

Table	Page
1. Harvesting Subsystem Production and Cost Summaries . . . . .	73
2. Area Subsystem Equations . . . . .	85
3. Moisture-Water Subsystem Equations . . . . .	88
4. Timber Subsystem Equations . . . . .	91
5. Forage Subsystem Equations . . . . .	93
6. Wildlife Subsystem Equations . . . . .	95
7. Erosion Subsystem Equations . . . . .	97
8. Area Subsystem Variables Defined . . . . .	99
9. Moisture-Water Subsystem Variables Defined . . . . .	101
10. Timber Subsystem Variables Defined . . . . .	105
11. Forage Subsystem Variables Defined . . . . .	107
12. Wildlife Subsystem Variables Defined . . . . .	108
13. Erosion Subsystem Variables Defined . . . . .	110
14. System Constants Defined . . . . .	111
15. Production and Cost Summaries for Felling Activity . . . . .	117
16. Production and Cost Summaries for Skidding Activity . . . . .	118
17. Production and Cost Summaries for Loading Activity . . . . .	119
18. Production and Cost Summaries for Hauling Activity . . . . .	120

## LIST OF FIGURES

Figure	Page
1. Resources and Resource Uses . . . . .	3
2. The Influence of Timber Harvesting Activity on Resources and Uses . . . . .	7
3. Classification of Simulation Languages . . . . .	17
4. Decisions and Information Feedback . . . . .	19
5. Forrester's Flowcharting Method . . . . .	24
6. Ecosystem Diagram Showing Environment, Resources, and Components . . . . .	35
7. Black Box Diagram of Ecosystem Response to Activity Impacts . . . . .	37
8. Black Box Diagram of Harvesting Productivity Model . . . . .	38
9. Time Scales of Combined Macro - Micro Simulation Model . . . . .	41
10. Area Subsystem Flow Diagram . . . . .	44
11. Moisture-Water Subsystem Flow Diagram . . . . .	47
12. Timber Subsystem Flow Diagram . . . . .	49
13. Forage Subsystem Flow Diagram . . . . .	51
14. Wildlife Subsystem Flow Diagram . . . . .	53
15. Erosion Subsystem Flow Diagram . . . . .	55
16. Harvesting Subsystem Flow Diagram . . . . .	57
17. Fire Subsystem Flow Diagram . . . . .	61
18. Road Building and Closing Subsystem Flow Diagram . . . . .	64



Figure	Page
19. Ecosystem Summary Plot for Base Simulation Run . . . . .	67
20. Ecosystem Summary Plot for Combined Impact Run . . . . .	70
21. Flowcharting Symbols Defined . . . . .	82
22. Systems Diagram of Area Subsystem . . . . .	84
23. Systems Diagram of Moisture-Water Subsystem . . . . .	87
24. Systems Diagram of Timber Subsystem . . . . .	90
25. Systems Diagram of Forage Subsystem . . . . .	92
26. Systems Diagram of Wildlife Subsystem . . . . .	94
27. Area/Erosion Subsystem Plot for Base Run . . . . .	113
28. Moisture-Water Subsystem Plot for Base Run . . . . .	114
29. Timber Subsystem Plot for Base Run . . . . .	115
30. Forage/Wildlife Subsystem Plot for Base Run . . . . .	116
31. Area/Erosion Subsystem Plot for Combined Impacts . . . . .	121
32. Moisture-Water Subsystem Plot for Combined Impacts . . . . .	122
33. Timber Subsystem Plot for Combined Impacts . . . . .	123
34. Forage/Wildlife Subsystem Plot for Combined Impacts . . . . .	124
35. FORTRAN Source of Initializing Routine, INTLC . . . . .	126
36. FORTRAN Source of Ecosystem Routine, STATE . . . . .	139
37. FORTRAN Source of Tree Volume Routine, VOLPT . . . . .	149
38. FORTRAN Source of Time Conversion and Parameter Setting Routine, CTME . . . . .	150
39. FORTRAN Source of Fire Routine, FIRE . . . . .	151
40. FORTRAN Source of Roadbuilding and Closing Routine, ROADBLD . . . . .	153

Figure	Page
41. FORTRAN Source of Harvest Starting Routine, STRTLOG . . . . .	154
42. FORTRAN Source of Harvest Ending Routine, ENDLOG . . . . .	157
43. FORTRAN Source of Output Plotting Routine, GPLOT . . . . .	158

## ABSTRACT

The public land manager is directed by law to manage for multiple use and sustained yield of goods and services. This must be accomplished without long term detriment to the environment. He must also analyze the environmental consequences of any proposed management action. These impacts might not only be short term effects, but may be long range as well.

The ecosystem, impacted by the activity, is a complex maze of relationships. An impact directed at one resource will influence not only that resource but others as well. Some effects are immediate, others are not apparent until after a considerable time period. This complexity requires the ecosystem to be analyzed as a whole. It must be perceived as a complete system.

A method is proposed to help the manager analyze the environmental impacts of an activity. Using systems analysis and computer simulation techniques, a two-phased simulation model is presented. This approach models the activity as the micro phase. If desired, this phase can be modeled in detail suitable for productivity optimization, or it can be modeled simply. The macro phase of the approach models the ecosystem. This phase simulates the dynamic response of the ecosystem to the impact.

## Chapter 1

### INTRODUCTION

#### Multiple Use Management

Society's growing concern for "conservation" and "ecology" has caused the U.S. Forest Service to pursue with renewed vigor, the directive of "multiple use" and "sustained yield" in its public land management. This policy was established by Congress in 1960 when Public Law 86-517 was handed down on June 12. This, the Multiple Use - Sustained Yield Act states in part:

It is the policy of the Congress that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes.

The Secretary of Agriculture is authorized and directed to develop and administer the renewable surface resources of the national forests for multiple use and sustained yield of the several products and services obtained therefrom. (USDA, 1963).

The objective of multiple use management is to manage the resource complex for the most beneficial combination of both present and future uses. This idea of deriving maximum benefit from a given resource base is not new, but it becomes more important and complicated as the competition for limited and interrelated resources increases.

While the basic concept of multiple use is generally accepted, its application is still a difficult process. As outlined by Ridd (1964) the term "multiple use" may be applied to areas of land or to particular resources available on that land. When applied to land areas, it refers

to the production and management of the various resources or resource combinations on that land area. These managed resources may be competitive or complementary to one another. When applied to resources, "multiple use" refers to the various uses of those resources. For example, the water resource can be used for irrigation, municipal and industrial water, esthetics or recreation. Timber can be used for lumber, pulpwood, esthetics or recreation. Figure 1 (Ridd, 1964) provides an overview of possible relationships between resources and resource uses.

Multiple use land management involves both the multiple use of individual resources and the multiple use of the land areas. A demand for a particular resource for a specific use will place demands on a land area where that resource is produced.

When speaking of multiple use, the four resources; water, timber, forage, and wildlife, are generally discussed along with recreation. However, recreation is actually a use to which the resources are put. This recreational use is centered primarily on one resource; however, the "quality" of the recreation is influenced by several resources comprising the environmental complex.

In managing a land area, no resource or use can be isolated. Any management action, even when directed at one resource, is going to have an affect on the other resources and their uses. A logging operation started in any forest will affect not only the timber resource, but also

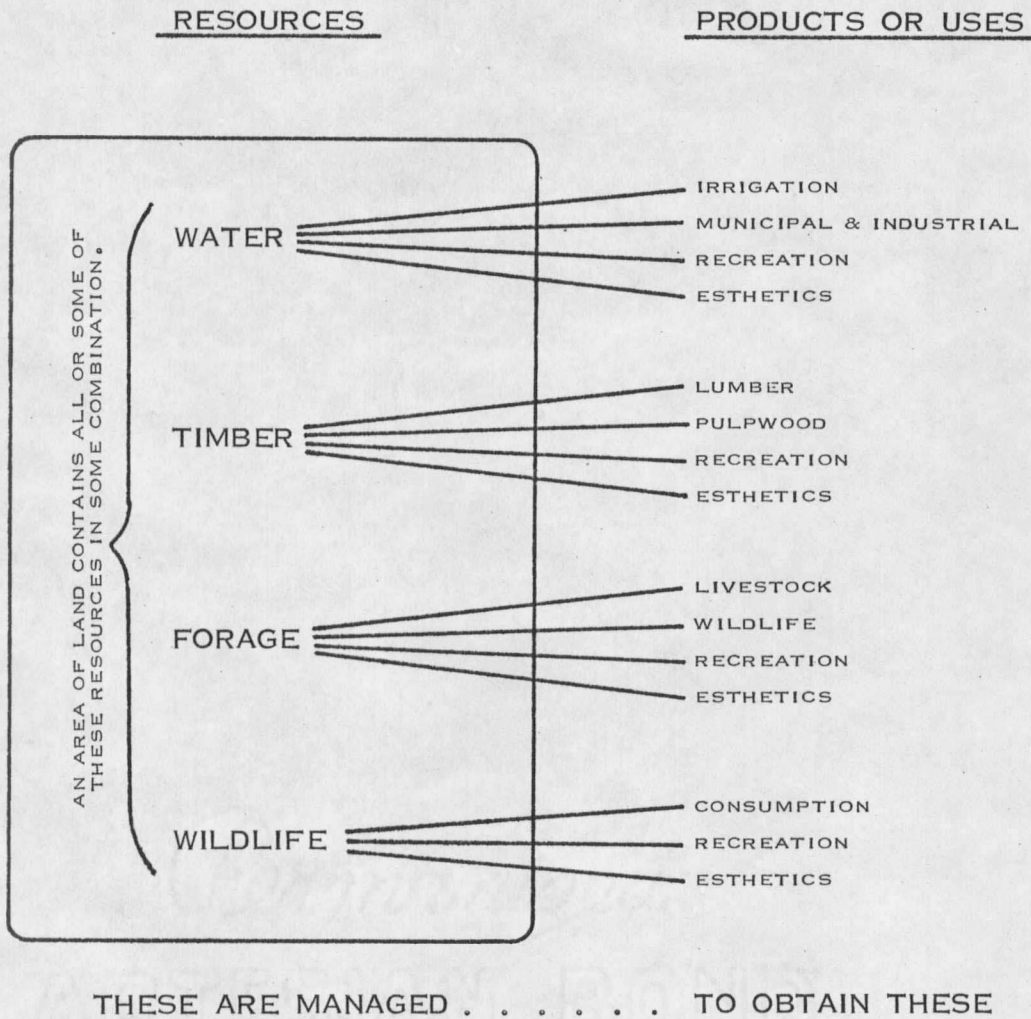


Figure 1. Resources and Resource Uses

the water, forage, and wildlife resources. For this reason, the overall area with all its resources must be viewed as a whole in making any management decisions on a proposed activity.

### Land Use Planning

Over half the land area in the United States is in forest, brush, or rangeland. Of this area, the Forest Service has the responsibility for managing 187 million acres to obtain sustained flows of goods and services under the multiple use management concept. This philosophy requires the balancing of various land uses to minimize conflicts while providing for a sustained yield over an extended time period.

With growing pressures from timber and cattle interests for specific resource uses, the Forest Service became more and more production oriented in its management. This was at times accomplished to the long term detriment of the total environment. Timber and forage production increased to satisfy demand. Irreversible consequences to the ecosystem were not a prime consideration.

In 1968, Congress enacted into law the National Environmental Policy Act. This Act directs the land manager to assess his management activities from an environmental impact standpoint. The Act declared it "a national policy [to] encourage productive and enjoyable harmony between man and his environment; [and] to promote efforts which will prevent or eliminate damage to the environment" (USDA, 1974:243). "This policy is one of balancing the amenities or quality of life against the

continued use of renewable resources" (Leopold, 1975:609). Recognizing that man's activities do impact the interrelationships of the ecosystem components, the manager must prepare a detailed statement of the environmental impacts of any proposed action that might have an effect on the quality of the human environment.

The Forest Service has been preparing "Multiple Use" or "Land Use" Plans to implement these directives. A Land Use Plan is intended to be a planning document directed at a specific area of land. Resource capabilities are identified, demands and resource uses are estimated for the present and future, and management alternatives are identified and presented to the public for scrutiny. These documents are prepared and presented to the public soliciting and encouraging public involvement and participation in determining management direction. Coupled with the Land Use Plan is the Environmental Impact Statement which must be prepared for any proposed management action. This statement is an attempt to identify and quantify the environmental impacts of the activity. These impacts must include not only the short term immediate effects, but also the long range effects of the activity.

The public land manager is directed by law to manage on a multiple use and sustained yield basis. He must analyze and document the environmental consequences of proposed activities. This can be a difficult task as the system being impacted consists of numerous



interacting relationships. The area must be viewed as a whole in making management decisions.

### The Problem

The problem is basically that of identifying the impacts or effects of a given activity upon an area's ecosystem. The impacts cannot be limited only to short term immediate effects, but must also include the long range time dependent effects. The system being impacted is a complex maze of interrelated interacting cause-effect relationships.

As an example of man's activities impacting the ecosystem, we might look at timber harvesting. The interactive influences of timber harvesting on the system might be illustrated as in Figure 2. For measurable impacts, we are primarily interested in the effects on the other resources and resource uses for the area. The harvesting of timber from a given area and the method used in harvesting will have a direct effect upon other resources such as water quality and quantity, timber availability now and in the future, forage quality and quantity, and the amount of type of wildlife present. These can be both short and long range effects.

In addition to these primary effects, the changes brought on by the primary influences in the available resources will also cause secondary changes in the resources and uses of the area. Recreation and esthetics will be influenced secondarily. Changes in the resources will change the recreational appeal of the area. There are also secondary



























































































































































































































































































































































