

**RECREATION RELATED DEGRADATION IN KANSAS
STATE PARKS: APPLYING GIS MODELS**

by

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A THESIS

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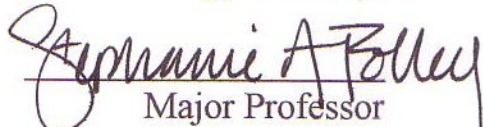
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ABSTRACT

This paper presents a model which identifies areas in state parks most susceptible to recreation related degradation. Factors of soil capability class rankings, slope, native vegetation presence, rangeland productivity, visitation, and revenue are overlaid in a weighted raster model to extract those land parcels within Glen Elder State Park, Kansas, which have the highest susceptibility to environmental degradation and greatest potential to generate high revenue. Park user characteristics stored in an attribute table are related to vulnerable parcels so park managers can develop management or mitigation strategies reflecting the strength of environmental, social, or economic interactions in an area.

TABLE OF CONTENTS

- i. List of Figures (vi)
- ii. List of Tables (vii)
- iii. Acknowledgements (viii)
- I. Introduction (1)
- II. Background (3)
 - A. History of Landscape Suitability Assessment (4)
 - 1. Gestalt (5)
 - 2. SCS Land Capability System (6)
 - 3. Physiographic Unit Method (7)
 - 4. Resource Pattern Method (10)
 - 5. Ian McHarg and the University of Pennsylvania Method (13)
 - B. Methods of Factor Combination (15)
 - 1. Ordinal Combination (16)
 - 2. Linear Combination (17)
 - 3. Non-Linear Combination (18)
 - 4. Factor Combination (23)
 - 5. Rules of Combination (23)
 - C. Landscape Suitability Analysis and Factor Modeling: Case Studies in the Sciences (25)
 - 1. Modeling the Suitability of Potential Wetland Mitigation Sites with a Geographic Information System (26)
 - 2. The Effects of Future Urban Development on Habitat Fragmentation in the Santa Monica Mountains, CA (27)
 - 3. Physical Environmental Modeling, Visualization, and Query for Supporting Landscape Planning Decisions (32)
 - D. Kansas Department of Wildlife and Parks Recreation Surveys
 - 1. Survey Method (33).
- III. Methodology (38)
 - A. Operational Definitions (40)
 - B. Study Site (40)
 - C. Environmental Factor Justifications (41)

D. Raster Model Builder Process for Recreation Related Degradation Model

1. Environmental Vulnerability Model
 - a. Slope (43)
 - b. SCS Soil Classification Rating (44)
 - c. SCS Rangeland Productivity (44)
 - d. Presence of Native Vegetation (45)
 - e. Vegetation Vulnerability (46)
- a. Visitation (46)
- b. Revenue (47)
2. ModelBuilder Process (48)
 - a. Environmental Vulnerability Index (50)
 - b. Recreation Related Degradation Model (RRD) (53)
 - c. Color Coded Environmental, Visitation, and Revenue Overlay (55)

IV. Results (57)

1. Osage (58)
2. Beach (59)
3. Cheyenne (60)
4. Marina Parking (62)
5. Kanza (63)
6. Ramp Parking (64)
7. Sioux (65)
8. Kaw (66)
9. Kiowa / Arickaree (67)
10. Prairie Dog (69)
11. Takota Point (69)

V. Conclusions (71)

1. Applying the RRD Model and Attribute Tables for Park Management (71)

VI. Future Considerations (72)

1. Statistical Validation (72)
2. Geodatabase Development (74)
3. GPS Integration (76)
4. Development of Vector Based Site Scale Analysis (78)
5. Statistics vs. Color Overlay (79)

VII. Bibliography (80)

VIII. Appendix (82)

1. ModelBuilder Steps (82)
2. Operational Definitions (89)
3. Raw Attribute Tables for Day Use Areas
4. Figure 17 Foldout: ModelBuilder Diagram

LIST OF FIGURES

1. Hills Diagram (8)
2. Lewis Cross Section (11)
3. Statistical Combination (20)
4. Zonneveld Earth as Ecosystem Diagram (21)
5. Fabos' METLAND Model (5)
6. McHarg Factor Combination Method (23)
7. Kuiper, 2004 Wetland Modeling Factors (26)
8. Kuiper, 2004 Factor Overlay (27)
9. Franklin and Swensen Santa Monica Urban Growth Factors (29)
10. Franklin and Swensen Santa Monica Area Build-Out Scenario Patches (30)
11. Franklin and Swensen Scattergrams (31)
12. Brian, 2004, List of Modeling Factors and Parameters (32)
13. Brian, 2004, SimilarAreas Analysis (33)
14. Glen Elder Lake Park Locator Map (41)
15. Recreation Related Degradation Factor Maps (42)
16. RRD Model Formula for Revenue (46)
17. RRD ModelBuilder Diagram (49 and Appendix 4)
18. Environmental Vulnerability Raster Model (52)
19. Recreation Related Degradation Raster Model (RRD Model) (54)
20. Environmental Vulnerability, Visitation Rate, Revenue Color Overlay (56)
21. Osage Area Color Overlay Detail Map (58)
22. Beach, Cheyenne, Marina Parking Color Overlay Detail Map (61)
23. Kanza, Ramp Parking, Marina Parking Color Overlay Detail Map (63)
24. Kaw and Sioux Color Overlay Detail Map (65)
25. Prairie Dog and Kiowa / Arickaree Color Overlay Detail Map (68)
26. Takota Point Color Overlay Detail Map (70)
27. Regression Statistic Applied to RRD Model (73)
28. R Square Value and F Value Statistic (74)
29. Conceptual Geodatabase Structure for Kansas Department of Wildlife and Parks (77)

LIST OF TABLES

1. Ordinal combination (17)
2. Linear Combination (18)
3. Non-Linear Combination (19)
4. Lawrence, 2004, User Survey Schedule (36)
5. Slope Value Reclassification Table (43)
6. SCS Capability Class Value Reclassification Table (44)
7. SCS Rangeland Productivity Value Reclassification (45)
8. Vegetation Vulnerability Value Reclassification Table (46)
9. Visitor Value Reclassification Table (47)
10. Revenue Value Reclassification Table (48)
11. Environmental Vulnerability Weighted Overlay (51)

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INTRODUCTION

User, fishery, wildlife, avifaunal, and vegetation surveys are common reporting devices for Glen Elder State Park (GELP); however, these reports are typically two-dimensional spreadsheets that do not address the spatial characteristics of multi-dimensional social, economic, and environmental interactions. By applying ArcInfo to park management, user surveys and park revenue data can be stored in a shape file attribute table of a day use area and related to the natural resources present in the day use area.

Environmental factors of soil capability class, slope, native vegetation presence, and rangeland productivity, are combined in a weighted overlay to identify areas in the state park with the most environmental vulnerability. Visitation rates and revenue generation in each day use area are overlaid upon the environmental vulnerability map to identify the day use areas with the most environmental vulnerability, highest visitation rates, which generate the most revenue. ArcGIS ModelBuilder tool is used to combine environmental vulnerability, visitation rates and revenue generation to create the recreation related degradation model (RRD model), which assigns a numeric value of susceptibility to recreation related environmental degradation for each 30m x 30m raster cell.

The user survey information describing the quantity, age, origin, vehicle type, watercraft type, primary activity, and facility use of park users for each day use area, can be utilized by park managers to develop management strategies reflecting the results of the RRD model for each day use area. The weighted overlay and factor combination techniques applied in the RRD model, are similar to techniques developed by McHarg (McHarg, 1993), Hills, Lewis (*Belknap and Furtado, 1968*), and Steinitz (*Steinitz, 1967*).

The need for such a system park land management became apparent during the summer of 2004 when the author was hired as an intern for Glen Elder State Park to update

the environmental management plan and conduct a user survey. After reviewing previous recreation studies and available environmental management data at Glen Elder State Park, it was discovered that there was no method for linking park user studies, daily revenue data, and natural resources data. The RRD model links recreation survey data, daily revenue data, and natural resources data to determine if a state park is generating profit from environmentally sensitive land.

BACKGROUND

The history of landscape suitability assessment in landscape architecture is not a topic with a wealth of publications which one could draw upon. Most likely, since landscape suitability analysis are used widely in the professional realm, techniques developed for landscape suitability analysis are not published because of time constraints or from a perceived lack of interest by the public from the professional who developed the technique. Several noted authors used in this text have contributed greatly to the coherent historical organization of landscape suitability assessment, and thus are cited generously in the background. These authors are Forester Ndubisi, *Ecological Planning: A Historical and Comparative Synthesis* (2002), Raymond Belknap and John G. Furtado, *Three Approaches to Environmental Resource Analysis* (1967), and Lewis Hopkins, *Methods for Generating Land Suitability Maps: A Comparative Evaluation* (1977). These authors deserve note due to their influence in concisely organizing historical and comparative studies of landscape suitability assessments and factor combination techniques.

Landscape suitability models were first employed as map overlays in the early 20th century to gain insight about a land parcels inherent capability and fitness of uses. Since that time, approaches to landscape suitability modeling has progressively gotten more complex and inclusive both in terms of the quantity and quality of map layers included and in the technology available to build models. This chapter takes a look at the initial history of landscape suitability mapping and then takes an in-depth look at four paradigmatic approaches to suitability modeling which evolved out of the map overlay. These include the landscape suitability assessment approach, the applied human ecology approach, the applied ecosystem approach, and the applied landscape ecology approach. The landscape suitability assessment relies on map overlays, land parcel description, and methods of

ranking and combination to produce suitability, capability, or vulnerability maps. The other three approaches are more involved techniques which rely on factor analysis mapping, written impact assessments, and ecosystem models as a holistic approach to solving planning and land-use challenges.

Before discussing the history of landscape suitability assessments, operational definitions need to be clarified. The focus on the fitness of a given tract of land for a particular use, being chiefly concerned with optimal location for different uses of the landscape is considered a suitability analysis (Ndubisi, 35)." An inverse method to the suitability analysis is the vulnerability analysis developed principally by Ian McHarg in the 1960's as a reaction to the environmental crisis becoming apparent from the maltreatment of the landscape during the industrial and agricultural revolutions. The vulnerability analysis is concerned with identifying vulnerable areas in a landscape which could be negatively impacted from development and should be avoided, protected, or monitored post development. Identifying land units or tracts suitable for development or vulnerable to impacts requires two things "1) a procedure for identifying parcels of land that area homogenous and 2) a procedure for rating these parcels with respect to suitability for each land use (Hopkins, 1977) "

HISTORY OF LANDSCAPE SUITABILITY ASSESSMENT

During the 19th century, the reality of urban blight and the decrease in landscape quality in the United States and Western Europe was becoming a stark reality. Solutions were needed to solve water quality problems in cities, recreation areas were needed for urbanites in industrial areas, and intrinsically valuable landscapes and natural resources, such as the Yosemite Valley and Chesapeake Bay, needed a system of conservation and protection. As

a result, a movement began which changed the perception of landscape value which has resulted in the diverse fields of planning, landscape planning and landscape architecture. (Ndubisi, 2000)

The first influential proponents for landscape preservation were poets and artists such as Ralph Waldo Emerson (1803-1882), George Catlin (1796-1872), and Henry David Thoreau (1817-1862). These poets and artists revered the beauty and elegance of the natural landscape and found spiritual truths in its observation. The works of Emerson and Thoreau influenced Frederick Law Olmsted who drew upon the poets perception of nature as a source of spiritual healing for his restorative designs, which used trees in open space to affect human emotions, and vegetated canal systems to cleanse water in urban areas. As Olmsted grew in popularity and his project base grew his office began to employ new methods for understanding the complex relationships between man and the biotic and abiotic components of landscape. (Ndubisi, 2002)

Gestalt

The gestalt method is an early system of landscape analysis which took into account all the factors of a landscape to derive an understanding of the function, vulnerabilities, and possibilities of a landscape. The American Heritage College dictionary defines gestalt as " a physical, biological, psychological, or symbolic pattern of elements so unified that its properties cannot be derived from the sum of it parts (American Heritage, 1993)." Lewis Hopkins explained gestalt as "a way of understanding and analyzing perceivable patterns in the landscape without considering compositional elements such as slope, soil, vegetation, etc. (Ndubisi, 2002)."

The basic tenant of the gestalt method of landscape suitability analysis is that it relies on experiential knowledge rather than technical knowledge, and has two steps 1) experiential knowledge is derived from observations made from aerial photography, site visits, or site imagery, and information is recorded and homogeneous area or patterns are identified, and 2) the planner makes inferences about the effects of development on the landscape based on his/her observations. Ndubisi (2002) asserts that gestalt judgment is arguably a feature of every landscape suitability model at some time, and Hopkins notes that "once a factor such as cover type is identified one can no longer use the gestalt method because by definition the method does not combine factors (Hopkins, 1977)." (Ndubisi, 2002)

Although the gestalt method is an excellent technique for generally identifying areas suitable for development, a real depth of environmental data, categorized by land units, and presented in a publicly accessible format didn't exist until the Soil Conservation Service developed the Land Capability System.

SCS Land Capability System

The earliest standardized, and perhaps most widely used, method of identifying land units was developed by the Soil Conservation Service (now NRCS) after WWII to help with agricultural development. The SCS created maps at the scale of 7.5 minute 1:24K topo quadrangles delineating soil class boundaries for the entire United States. The soil units are approximate and without exact boundaries between soil classes, yet are a basis for the division of and allow the ranking of soil types for productivity. The classification system is focused on soil limitations rather than potentials, and uses the logic that certain combinations of soil properties pose restrictions to agriculture.

Thee NRCS classifies soil into three Capability Classification levels: 1) class 2) subclass and 3) unit. The capability class, the broadest classification, designates soils with a roman numeral I-VIII indicating progressively greater limitations a soil has for agricultural productivity based on type of geology, erodability, and intensity of management practices. The subclass consists of soil groups within a class and is indicated by the letter e (erosion), w (water), s (stoniness or shallowness), and c (climatic variation). The third level, subunit, consists of soils within a subclass which support similar crops and have similar management and production qualities. Subunits are indicated by and Arabic numeral system such as llw₃. (SCS, 1983)

The information was created in a 1927 series and 1983 series developed by county and available in book form. For use with GIS, the SSURGO soil boundaries with embedded MUSYM soil labels can be downloaded from many geospatial data clearing houses such as the Kansas Data Access Support Center, USGS Seamless Data Access Site, or Geography Network Geospatial Data Clearinghouse.

Physiographic Unit Method

The physiographic unit method was developed in 1961 by Angus Hills for a newly proposed Canadian Land Information System. Hills' basic method divides the landscape into homogeneous physiographic units for planning and analysis, which relates organisms to their biological and physical environment. By classifying landscapes based on the land unit an organism needs to survive ensures that the biological productivity of the land will be maintained and that "any area of land combined with the organism it supports constitutes a biological productivity system (Belknap and Furtado, 1967)."

Hills' five step method for assessing landscape suitability, creates an "inventory which focuses on the physical and biological characteristics of the study area and on existing or projected social and economic conditions (Ndubisi, 2000; 40)." The five steps are 1) identify a study area which characterizes the entire area for which a planning study will be created 2) divide the units into 5 hierarchical levels of site units 3) identify areas in each land unit suitable for agriculture, forestry, development, or conservation 4) combine the suitability, vulnerability, and feasibility studies into one map, and 5) develop management guidelines based upon the composite map. (Belknap and Furtado, 1967)

DIAGRAMMATIC OUTLINE OF ANALYSIS PROCEDURE

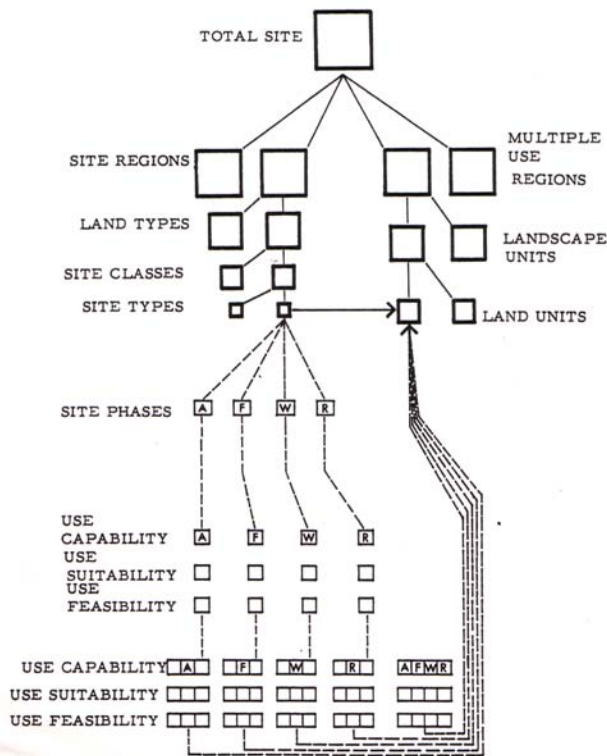


Figure 1. Hills Physiographic Unit Analysis Structure (Belknap and Furtado, 1967)

Hills acknowledged that many planning studies included areas too large and expensive to be mapped in a detailed manner. Therefore, Hills proposed selecting a study area which was large enough to contain the largest land unit (site region) and diverse enough to contain all or most of the smallest units (site units). This philosophy worked well for the vast county of Canada, which is too large to map in depth, but had a sufficiently homogenous landscape to be characterized by only a handful of study sites. (Belknap and Furtado, 1967)

The second step of the physiographic unit method was to divide the study site into five hierarchically homogenous

physiographic units of 1) site regions 2) landscape types 3) site classes 4) site types, and 5) site units. Site regions display constant patterns of vegetation and microclimate, recorded succession of forest types and major landform classes. Landscape types are based on landform, geologic composition, and water regime. The approximate scale of a landscape type is 1 square mile. Site classes are distinguished by variations in soil moisture, depth to bedrock, and local climate, with an average size of 10 acres. Site types are distinguished by various combinations of soil moisture, depth to bedrock, or local climate. An example of a site type is moderately deep soil in a dry local climate. The smallest unit, the site unit, is identified by soil profile, stoniness, slope, or aspect. It should be noted that the site unit or site type are the units most comparable with the SCS land capability system, and that the Hills system presents a holistic unit classification for landscapes spatially more encompassing than the SCS system. (Belknap and Furtado)

The third step in the physiographic unit method is to use locals and experts who know the land in the study site to identify areas in each of the five site levels most suitable for agriculture, forestry, conservation, development, industrialization, urbanization, or other land uses. Land use areas are identified by developing suitability, vulnerability, and feasibility from the expert and local judgment. Feasibility maps "determined the relative advantage of managing a tract of land for specific uses under existing or forecasted conditions (Belknap and Furtado, 1967)." The inclusion of experts and locals helped to encourage interdisciplinary approaches to land use problems which are still valued today.

After developing the suitability, vulnerability, and feasibility maps, the fourth step is to combine the maps into one composite map depicting landscape units that may support multiple uses. The expert panel then makes recommendations to a group of locals who make the final land use decisions. Step five is to apply the land use decisions toward

making meaningful local land management guidelines to ensure the monitoring and implementation of the proposal. (Belknap and Furtado, 1967)

Hill's method is arguably the most ecologically sensitive land unit classification because he recognized that vegetation, wildlife, physiographic, hydrologic, and edaphic, and geologic exist together as an interrelated unit. In Hill's system, site types are ecosystems at edaphic climax, and the smaller site units are the successional stage of a community when surveyed. This unit division methodology fundamentally differs from the SCS methodology of classifying an entire country on soil divisions alone, in that Hill's assumes interconnectivity between landscape factors, and the SCS system basis all systems on the productivity of soil.

Resource Pattern Method

Phil Lewis was primarily concerned with growth in the Midwest which occurred with little regard for the "intrinsic qualities inherent in nature's design (Lewis, design for tomorrow)." Lewis sought to discover, protect, and preserve the declining recreation areas being swallowed by urbanization, and that the environmental corridor was the key important landscape resource unit. The rich riparian corridors of the central lowlands form a network of surface water distribution, wetlands, and topographic features which he believes hydrology plays the key role in forming and managing Midwest landscapes. (Lewis, 1996) (Belknap and Furtado, 1967)

Lewis defined the environmental corridor as the "major" unit in his landscape classification system. Major resource corridors are enhanced by additional resources such as waterfalls, rock outcrops, fish habitats, or picnic areas which are classified as "nodes" in the resource pattern method. By focusing attention away from single resource and towards corridors, Lewis was able to create a land unit classification system which preserved

multiple landscape resources which overlapped in the corridors and nodes, similar to the factor overlay method, and applied explicitly to the major and nodal units related to recreation. By preserving the continuity of corridors and identifying nodes of ecological productivity, visual, and recreation value, the resource method became a principal instigator in the environmental greenway movement (Belknap and Furtado, 1967)

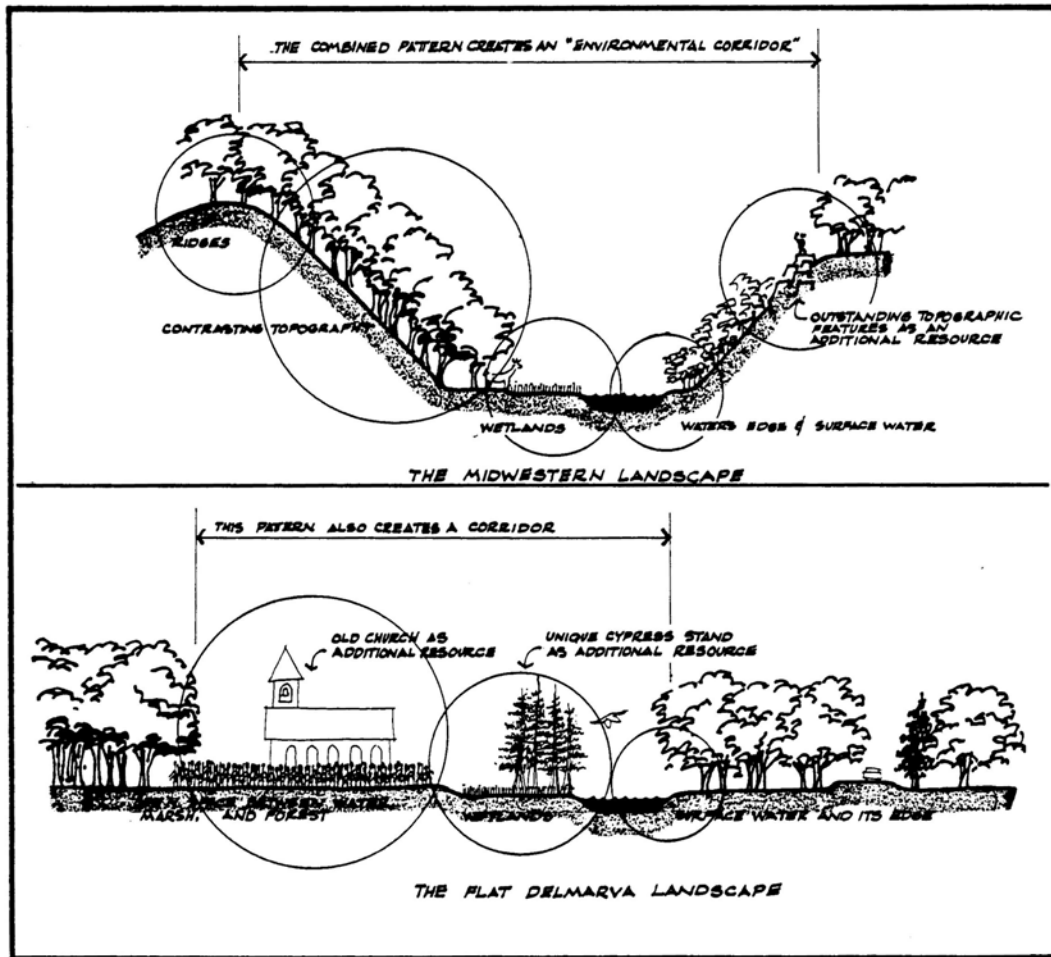


Figure 2. Cross Section of Lewis' Proposed Major Resources and Minor Resource Nodes (Belknap and Furtado, 1967)

The resource pattern method consists of seven procedures, which are 1) identification of pilot area, 2) identification of key recreation uses 3) identify major resources and create a composite major resource map 4) identify minor resources and use local people to rank importance of minor resources 5) correlate major and minor resources on a

composite map 6) extrapolate important findings of pilot area to entire region. (Ndubisi, 2002) (Belknap and Furtado, 1967)

The first step of the resource pattern method, identification of the pilot area, is similar Hills' method, that extensive mapping and analysis is not necessary if large homogenous regions can be categorized by a pilot area. Lewis proposes a pilot area of approximately 100 square miles. (Ndubisi, 2002) (Belknap and Furtado, 1967)

Step two, identification of key recreational uses of major resources in the pilot area, is of prime importance for the establishment of a land use criteria in Lewis' method.

Recreation uses of an area speak about the pattern of that areas resource, and can help investigators identify areas of ecological or physiologic transition where different land use criteria may need to be considered. Key recreation uses of major resources also help identify areas of minor resource value. For example, key hiking, canoeing, fishing, and camping values may be physiographic contrast, visual contrast between landscape types, and landscape diversity. (Ndubisi, 2002)

The third step is to develop separate resource maps for all the factors that combine to make a major resource unit, such as hydrology, topography, elevation, wetlands, aquifer recharge zones, vegetation, geology, existing land use, historic value, and visual quality. These separate maps are then combined into one composite major resource map. (Ndubisi, 2002) (Belknap and Furtado, 1967)

Step four is to identify minor areas, or nodes, within the major areas and create a composite minor resources map. The minor resources area identified by working closely with local state park, wildlife, forestry, officials as well as local inhabitant to verify the best resources area selected. (Belknap and Furtado, 1967)

Step five is to correlate the major and minor resources on a master composite overlay, and the final step is to extrapolate the important natural resources on a regional basis with priority conservation values given to those areas locally identified as the most degraded. (Ndubisi, 2002) (Belknap and Furtado, 1967)

Lewis was commissioned to develop this method for the planning of the state of Wisconsin's recreation areas, and was able to show that wetlands, water bodies, stream/river corridors, and physiography constituted about 90% of the resources which were in environmental corridors and held in high esteem by local inhabitants. (Ndubisi, 2002)

One of Lewis' key factors in developing this model is to assess the health of nodes within recreation areas based on intensity of use and to help park administrators manage user information for making informed decisions for restoration of degraded areas. The raster model developed for this thesis is a good monitoring tool to assess the placement of minor recreation areas and to ensure the continual health and enjoyment of recreation nodes, while predicting areas that could be problematic in the future.

Ian McHarg and the University of Pennsylvania Overlay Method

Arguably one of the most influential environmental thinkers in the last century was Ian McHarg. McHarg developed a paradigm of sustainable developed from the dialectic of nature and the city he experienced as a young boy in Scotland. (McHarg, 1969) McHarg believed that a dialogue between man and nature should exist which is mutually beneficial for both. McHarg wrote that nature had inherent values which had their own right to exist, and that processes such as aquifer recharge zones, wetland networks, and vegetation

associations maintained water quality, and environmental quality so humans could exist.

(Ndubisi, 2002) (McHarg, 1993)

To evaluate these intrinsic values nature possessed, McHarg developed a landscape suitability assessment which had a great impact on the environmental movement of the 60's and 70's, forming a base for much of today's suitability assessments. "In essence the method consists of identifying the area of concern as consisting of certain processes in land, water and air, which represent values. These can be ranked - the most valuable land to the least, the most and least productive agricultural land, the richest wildlife habitats and those of no value, the areas of great or little scenic value, historic buildings and their absence, and so on (McHarg, 1993; 110)." The method McHarg developed has six steps: 1) identify goals of the study 2) develop an ecological inventory 3) create individual maps of landscape factors 4) rank each landscape factor from low suitability to high suitability for land use described in step one 5) create map overlays for each land use category 6) combine land use category maps to create a composite land use index. (Ndubisi, 2002) (McHarg, 1993)

The first step in McHarg's method is the same as Phil Lewis or Angus Hills, in that an objective for the study needs to be determined and land use criteria established. The second step of conducting a biological inventory of the important factors in the study is the process of mapping and documenting, in order of hierarchical geographic and biophysical magnitude. McHarg approached his inventories in order of geologic age to understand the underlying process and mechanics which formed and affect a site, thus beginning with geology, then surface hydrology, then physiography, then soils, and so on. (McHarg, 1993) (Ndubisi, 2002)

Step three is to map each of the separate landscape characteristics mapped in the inventory, displayed as homogenous areas suitable for development, such as soil

productivity, depth to bedrock, vegetation associations, existing wetlands, etc. Step four ranks each factor according to its suitability for the proposed land use, for least to best. The resulting output is a color coded map with the lightest colors being the most suitable and the darkest being the least suitable. Step five is to group ranked land use factors according to their importance in determining land use categories, such as recreation, industrialization, or urbanization, on a transparent overlay to identify areas with overlapping high and low suitability. The final step is to combine the separate land use maps as color coded gradient overlays which identify the intersection of land use considered in the study. (Ndubisi, 2002) (McHarg, 1993)

McHarg employs the ordinal combination method in his factor overlay method, which is a powerful way of combining factors and visually understanding their interactions. The map overlay method is also easily reproducible with GIS. The downfall to this method is that combining factors such as geology, soils, and vegetation, which are measured on different value scales, is an invalid mathematical operation (Ndubisi, 2000; 53). The solution to the invalidity of ordinal combination is to apply a linear combination method for numeric factor evaluation, rather than a color gradient method, which can appropriately weight landscape factors which need more importance than others (floodplain for example would have a high weighing coefficient because the magnitude of disaster in flooding is extremely costly for buildings and people living in flood prone areas).

METHODS OF COMBINATION

Once a system of land unit division is developed, it's possible to rank different factors of land units for higher or lower value, such as rate of water infiltration, slope percent, crop productivity, or soil capability class. Most systems of landscape suitability assessment

discussed in this paper deal with combining factors, therefore an explanation of the method of combinations and their drawback is needed. The basic methods are 1) ordinal combination 2) linear combination 3) non linear combination 4) factor combination and 5) rules of combination. (Hopkins, 1977)

Ordinal Combination

Ordinal combination dates back to Olmsted and Elliot and was employed by McHarg. The basic method for ordinal combination is 1) Map the pertinent landscape characteristic according to a land unit or landscape type 2) Rate the features of each landscape characteristic for each prospective land use according to quality of landscape characteristics within that unit (i.e. High quality soil, low water quality, high slope percent) 3) Prepare a single overlay map for each landscape characteristic (slope, soil, hydrology, elevation, vegetation, etc) with the same scale of ordinal ranking (i.e. 1-5 or 1-10) 4) Combine the single characteristic ranked maps into one composite map overlay resulting in a patchwork of overlaying numeric values and intersecting land units and ecological boundaries with specific numeric values. 5) Present the final overlay map using a color gradient to graphically depict areas with low numeric value and high numeric value. Typically, in a suitability and vulnerability analysis, high rankings are given to land units with high vulnerability to impact, or low suitability for development. And low rankings are given to areas with low vulnerability to impact, or high suitability to development. Suitability maps can also be created for specific uses, such as suitability for development, industrialization, or recreation, as in the Staten Island Study by McHarg (1969), which were ultimately combined as one master suitability map. (Ndubisi, 2000)

According to Hopkins (1977) the ordinal combination method does not function mathematically because each land use suitability map is developed for one land use characteristic and creating a composite map by adding does not take into account the importance of some factors vs. others. The "Ordinal Combination Suitability Assessment Matrix for Potential Development Site X" shown below illustrates this problem:

Ordinal Combination Suitability Assessment Matrix for Potential Development Site "X"

	Slope	Soil Depth	Flood Hazard	Proximity To Water	Total Suitability
Floodplain	2	2	1	2	7
Hilltop	1	1	2	1	5

low suitability = 1
high suitability = 2

Table 1. Sample Ordinal Combination Matrix

This sample suitability matrix presents floodplain as more suitable for development over hilltop because the deep soils, proximity to water source, and level ground are more conducive to development. The hazard of a floodplain is under ranked because the additive combination of slope, soil depth, and proximity to water outrank negative aspect of flooding. In essence, the ordinal combination tries to quantitatively compare the qualitative difference between apples and oranges. One solution to this problem is linear combination.

Linear Combination

Linear combination takes into account the differences in importance between characteristics and uses a multiplier or "weighting" to equalize the relative importance between map factors (Hopkins, 1977). The weighting is chosen based upon the prior experience of the landscape planner, or by consultation of experts. In this method, the planner or landscape architect uses a common scale among categories, like the ordinal

combination method, then uses a multiplier to rank for a second time the different map factors used in an overlay. The table " Linear Combination Suitability Assessment Matrix for Potential Development Site X" shown below illustrates the linear combination method:

Linear Combination Suitability Assessment Matrix for Potential Development Site "X"

Locations	Slope	Soil Depth	Flood Hazard	Proximity To Water	Suitability	Weighted Overlay	Weighted Suitability
Floodplain	2	2	1	2	7	0	0
Hilltop	1	1	2	1	5	1	5

low suitability = 1
high suitability = 2

Table 2. Sample Linear Combination Matrix

The same ranking is used in the linear combination matrix as in the ordinal combination matrix except a weighting of "0" for floodplain and "1" for hilltop sites is applied. In this final weighted suitability the floodplain has an appropriate ranking of zero, which is the product of suitability ranking and weighting, accurately representing the inhibiting hazard of flooding for floodplain development versus hilltop development. Although this matrix is simplistic, when locations and factors become more numerous a system of weighting is important to individually rank and distinguish criteria for suitability and vulnerability. For more complex matrices, individual criteria can be weighted separately from the overall ranking to exaggerate the importance of certain criteria over others as well as applying an overall weighing. This is presented in the matrix below where the importance of slope and soil depth are more heavily weighted heavier than flood hazard and proximity to water, while still retaining a flood hazard index and ecosystem vulnerability rating characterized as "physiographic vulnerability multiplier." The resulting suitability weighting shows the hilltop as the most suitable area, then, hillsides, escarpments, and wetlands. Floodplain is not suitable, and it may be desirable for the planner or landscape architect to

give wetlands a physiographic vulnerability multiplier if working in arid regions where wetlands area scarce, versus the southeast where wetland mitigation may be a possibility.

Linear Combination Suitability Assessment Matrix for Potential Development Site "X"
 With Importance Given to Slope, Soil Depth, and Physiographic Vulnerability

Locations	Slope (w4)		Soil Depth (w3)		Flood Hazard (w1)		Proximity To Water (w2)		Physio Vlnrability Multiplier	Weighted Suitability
	W		W		W		W			
Floodplain	5	4	2	3	1	1	5	2	0	0
Hilltop	4	4	1	3	5	1	1	2	1	16
Hillside	2	4	3	3	3	1	3	2	1	8
Escarpment	3	4	5	3	4	1	2	2	0.5	6
Wetland	5	4	4	3	2	1	4	2	0.25	5

low suitability = 1
 high suitability = 5

low suitability = 0
 high suitability = 16

Table 3. Sample Weighted Non-Linear Combination Matrix

Often, a model needs to be evaluated several times with different weightings to develop a weighing scheme which accurately models the vulnerability and suitability (opportunities and constraints) of a site.

Non Linear Combination

Non-linear combination is the combination of factors in a formulaic manner. An extension of the linear technique, the non-linear technique supplements simple multiplicative weightings for formulas to derive or characterize a relationship between two variables. This method is most regularly applied with statistical analysis (Murgante and Las Casas, 2004), (Liu and Zhu, 2004), (Kuiper et al, 2004 -shown below), and (Baja et al, 2002) most commonly applied by geographers, soil scientists, and landscape ecologists as described below and discussed in the Quantitative land use modeling section of the background.

$$\text{Suitability} = \left(\prod_{i=1}^n \text{SI}_i^{w_i} \right)^{1/\sum_{i=1}^n w_i}$$

where SI_i is the suitability index score for variable i and w_i is the weight given to variable i .

For our model,

$$\text{Suitability} = \text{SI}_{\text{hydrology}}^2 \text{SI}_{\text{soils}}^3 \text{SI}_{\text{historic}}^2 \text{SI}_{\text{adjacent vegetation}}^2 \text{SI}_{\text{vegetation cover}} \text{SI}_{\text{land use}}^{1/18}$$

Figure 3. Weighted statistical combination (Kuiper et al, 2004)

Using formulas based upon a body of statistical testing and verification, complicated relationships can be estimated between many variables which would get jumbled in an overlay map. In ArcHydro hydraulic modeling and flood prediction software, where complicated relationships need to exist between channel dimensions, flow volume, velocity, and vegetation conditions to determine sediment quality and flood height, statistical formulas are necessary for comparable quantitative results, which non statistical studies could not produce.

In terms of modeling human behavior, however, formulas have a difficult time capturing the complex social, biophysical, and economic relationships in our world with accuracy. This author believes that developing model to predict human and environmental behaviors will be of key importance in the application of geographic database modeling in the future. One of the purposes of this thesis is to present a simple example of geographic database modeling, which has the capacity to quantify environmental factors in linear or non-linear raster modeling and relate that data to qualitative (observed) data in a queryable databases. This simple study serves as a building block for the computerization of such complex models as "Landscape as (Eco)System" (Zonneveld and Foreman, 1990) and Dr. Fabos' METLAND project (Fabos and Caswell, 1977) . Non-linear combination also treats

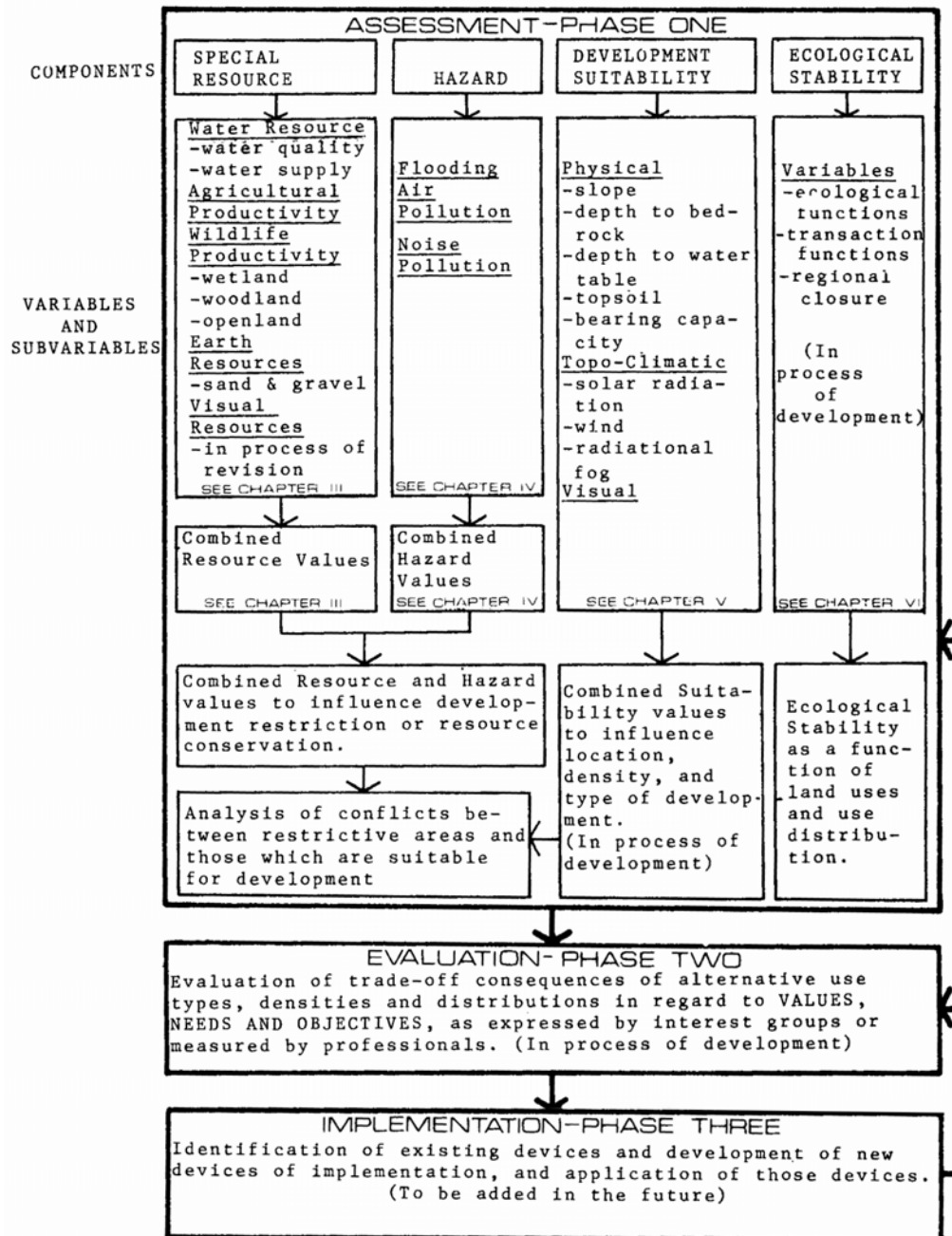


FIGURE 2.- Conceptual Framework of the METLAND Model Process.

Figure 5. Conceptual Framework for METLAND Project (Fabos and Caswell, 1977)

Factor Combination

One method of overcoming the problem of linear and non-linear combination treating the landscape as separately interacting units is to apply a factor overlay method. This method, not to be confused with weighted overlay, combines observed landscape characteristics

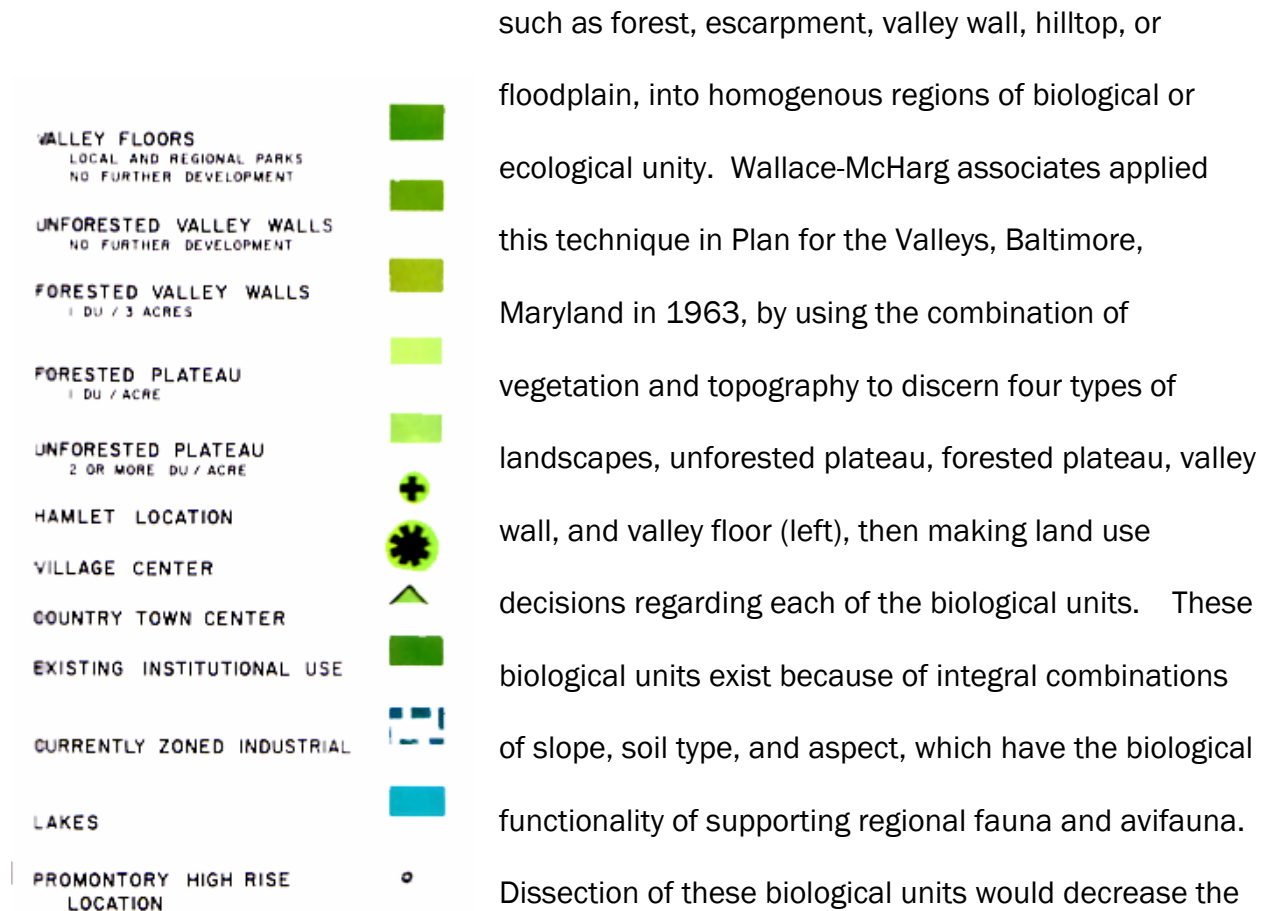


Figure 6. McHarg's Factor Combination from "Plan for the Valleys." (McHarg, 1993)

such as forest, escarpment, valley wall, hilltop, or floodplain, into homogenous regions of biological or ecological unity. Wallace-McHarg associates applied this technique in Plan for the Valleys, Baltimore, Maryland in 1963, by using the combination of vegetation and topography to discern four types of landscapes, unforested plateau, forested plateau, valley wall, and valley floor (left), then making land use decisions regarding each of the biological units. These biological units exist because of integral combinations of slope, soil type, and aspect, which have the biological functionality of supporting regional fauna and avifauna. Dissection of these biological units would decrease the functionality of the landscape and ultimate result in degradation. (McHarg, 1993)

Rules of Combination

Rules of combination are similar to the factor overlay method in that a compound set of factors are overlaid to extract a suitability or vulnerability index. Rules of combination differs from factor combination in that rules of combination use linear or non linear methods

to combine land units, which in turn identify areas of suitability or vulnerability. Factors of combination do not use numeric rankings or land unit divisions such as soils or Hills' biological units. The technique has a three step process in which 1) land unit suitability maps area created for individual characteristics, 2) factor maps are ranked based upon expert consultation or prior experience, and 3) explicit rules are used to combine only certain ranges or values from each factor map to identify areas suitable for or vulnerable to a proposed land use. (Ndubisi, 2000)

An example of a simple formula using the rules of combination for a development would be "to exclude areas that are prone to flooding, possess slopes of 25% or greater, contain lowland hardwoods, and are located more than a quarter mile from public sewer and water mains. The logic governing this rule is that certain types of landscapes may be degraded and development costs may increase if infrastructure is placed on steep slopes, located in flood prone areas, far from existing utilities.

The rules of combination method has particular merit in regards to GIS. The operations of linear combination and factor aggregation are based on layer classification and union commands, while proximity and exclusion operations are handled by raster reclassification and buffer commands. These commands are some of the most basic tools capable of geographic information systems and are done in the computer the same as would be done in map overlay. The predictive degradation model developed for this thesis applies a rule of combination hypothesizing that areas with high slopes, native vegetation, low soil capability classifications, and high visitation are the most sensitive lands in Glen Elder State Park.

Carl Steinitz applied McHarg's method on the computer, using the GRID program developed in an interdisciplinary studio at Harvard in the spring of 1968 (Steinitz, 1968).

Dr. Julius Fabos utilized the COMLUP mapping system in his METLAND planning model which is "able to estimate or simulate the cause-effect relationship of proposed alternative environmental land use patterns and decisions" (Fabos, 1977; 19). These two landscape planners applying computers represents the beginning of programs able to apply the overlay techniques by handling vector, raster, and attribute table data necessary to create computerized map overlays.

Environmental Systems Research, founded by Jack Dangermond who worked with Steinitz at Harvard, released ARC/INFO Geographic Information System in 1982, a graphic display and data management modeling tool designed to run on microcomputers. In 1992 a PC based version was released, and in 2001 ArcGIS 8.1 was released, capable of relational database management, raster modeling, cartographic display, internet interface, and many other cartographic analysis tools. The version used in this paper is ArcGIS 9.0. Geographers have widely applied GIS and modeling to solve spatial problems, yet, this author's research showed few GIS model applications by landscape architects.

LANDSCAPE SUITABILITY ANALYSIS AND FACTOR MODELING: CASE STUDIES IN THE SCIENCES

Geographers and other scientists were quick to apply GIS in the early 1980's when ESRI first released ArcGIS. Geographers specifically have developed a specialty in computer modeling which allows the profession access to many environmental modeling and analysis grants and jobs. This section examines some of the applications geographers, soil scientists and environmental planners have recently developed using GIS, which differs in the statistical analysis and quantitative importance from the more qualitative and visual

landscape suitability assessment methods developed by landscape planners. Landscape architects who prefer to think on geographic or planning scales and understand the applications of GIS and basic statistics, are poised to compete with geographers for planning and environmental modeling applications, while at the same time, adding some statistical analysis to help validate design decisions and direct land management and programming in a way most designers shy away from. Many of these papers site McHarg, Lewis, or Hills as an influence, but GIS modeling has developed its own eclectic yet statistically valid methodologies adapted to the capabilities of the tool. A similar thread to most of the scientific papers is the use of a known statistic, such as regression analysis, correlation, or Pearson's r, in justifying factor selection and for mathematical factor combination. A few annotated bibliographies are presented below to give the reader an understanding of the factors and methods involved in these studies.

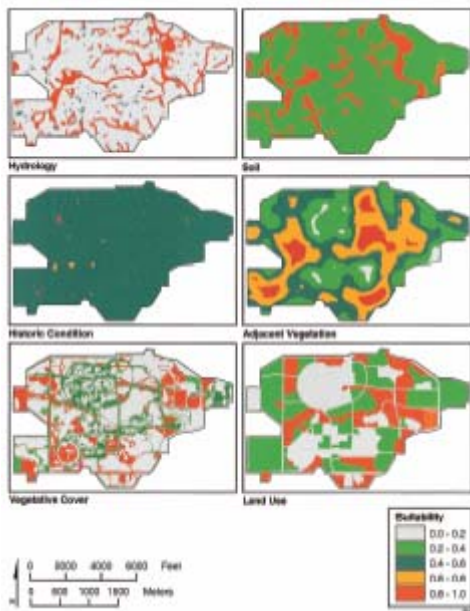


Figure 7. Wetland Mitigation Factors (Kuiper, et al., 2004)

Modeling the Suitability of Potential Wetland Mitigation Sites with a Geographic Information System.

Wetland suitability mapping is used by private and public agencies to determine areas where wetland banking is possible. This paper presents a weighted overlay method using 2-D GIS maps to determine areas with wetland potential in Argonne, Illinois, USA. The team used the factors of hydrology, Soil, Historic Condition, Adjacent Vegetation, Vegetative Cover, and

Land Use combined with the statistic in *Figure 3*. The team used the grid extensions in ArcInfo 7.1.2 to calculate the overall suitability based on individual raster cells. The resultant final overlay map was presented as a 2-D image in this paper, showing that the greatest suitability for wetland restoration are areas near remnant wetland vegetation and riparian zones, with hydric soils or standing water, in dedicated easements, without historic importance. The addition of a statistic to calculate overlay was a good addition lending credibility to the project. A 3D perspective rendering showing topographic lowlands with a soil, vegetation, and infrastructure would have helped illustrate the result. (Kuiper, 2004)

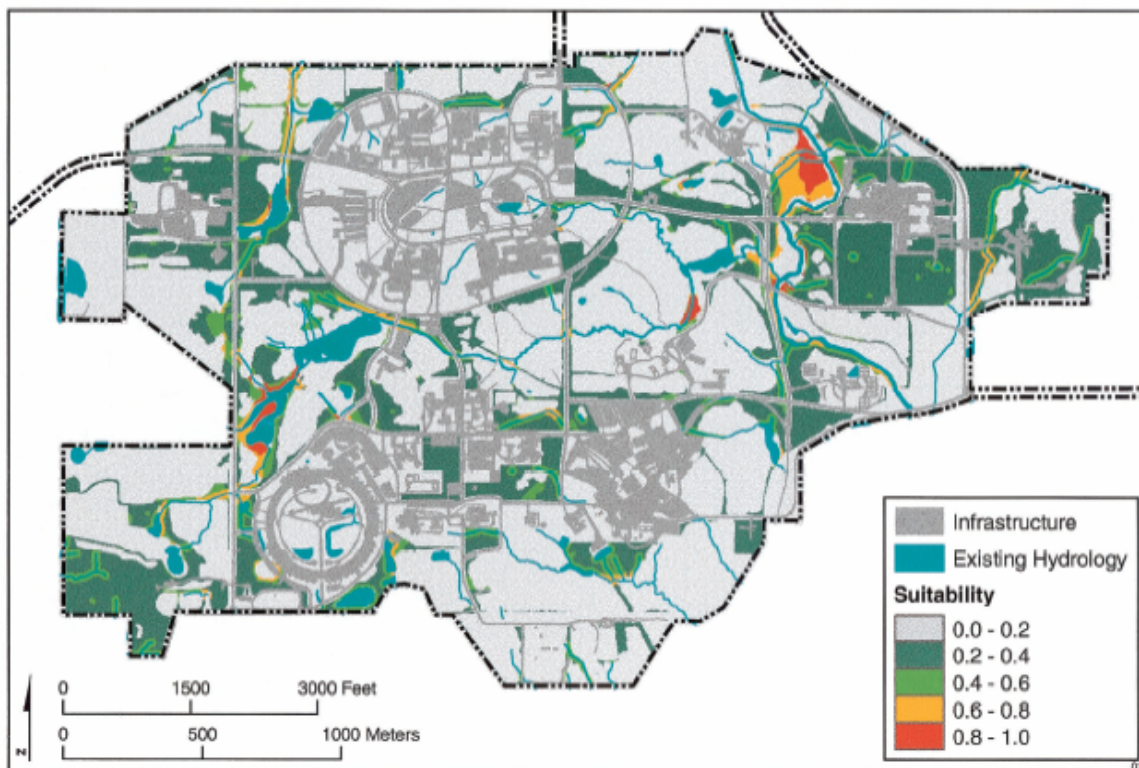


Figure 8. Wetland Suitability in Argonne, Illinois Based on Factors Presented in Figure 7 (Kuiper et. al., 2004)

The Effects of Future Urban Development on Habitat Fragmentation in the Santa Monica Mountains.

In 2000, The National Parks Service was trying to obtain lands in the Santa Monica Mountains National Recreation Area in Southern California. A team of researchers from Oregon State University, Corvallis, developed a landscape simulation model with the factors of vegetation, elevation, hydrology, roadways, current land ownership, and proposed development plans, to identify areas available to the National Park Service for purchase. The simulation model used four different buffer widths around existing development, and three different widths around roadways, resulting in twelve different "build out" scenarios.

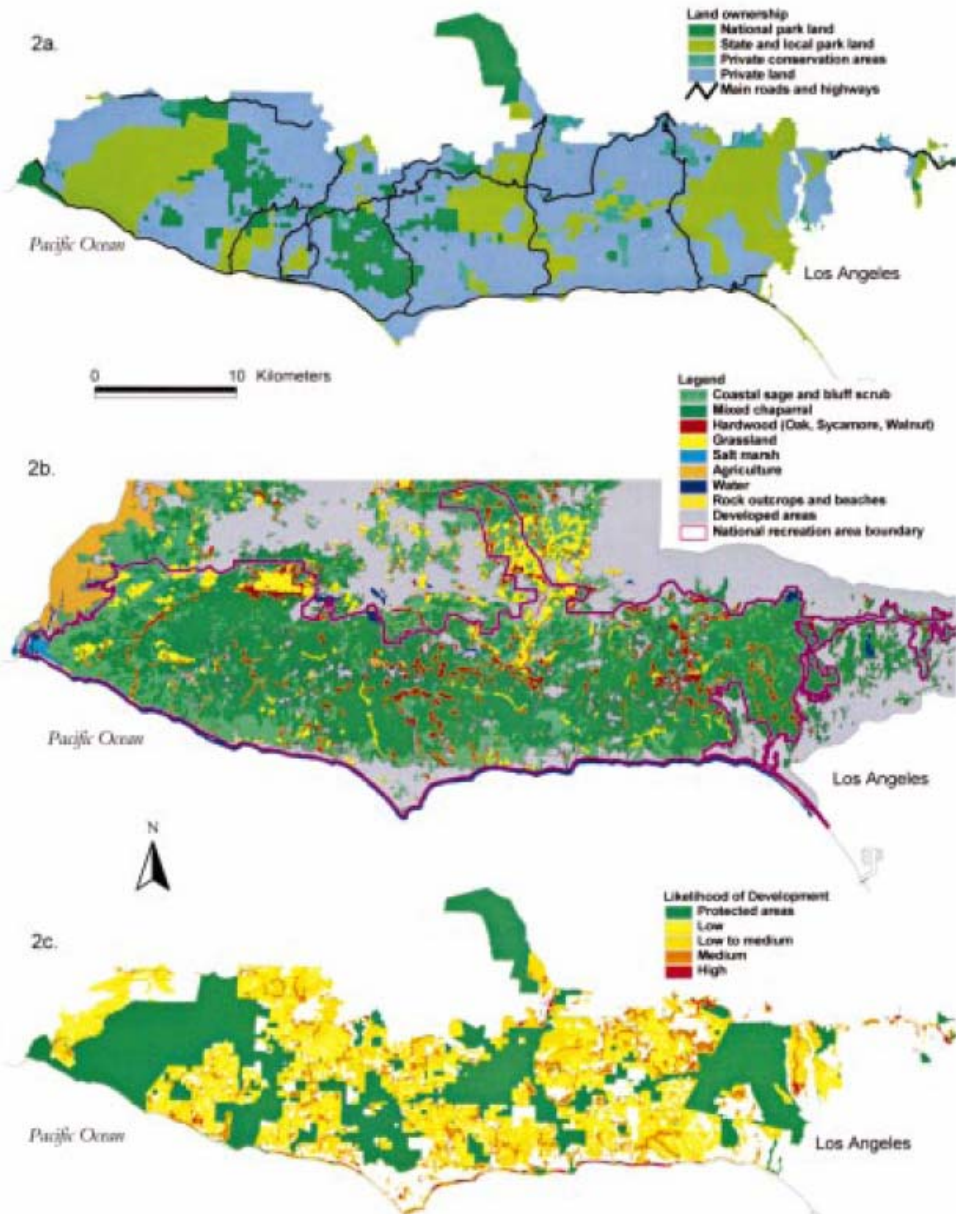


Figure 9. Santa Monica Urban Growth Factors (Franklin and Swensen, 2000)

The Objective of the build out simulations was to identify ranked sizes of vegetation patches which would exist after each of the twelve scenarios. The vegetation patches which

would remain in all the twelve scenarios area the patches most appropriate for purchase by the NPS.

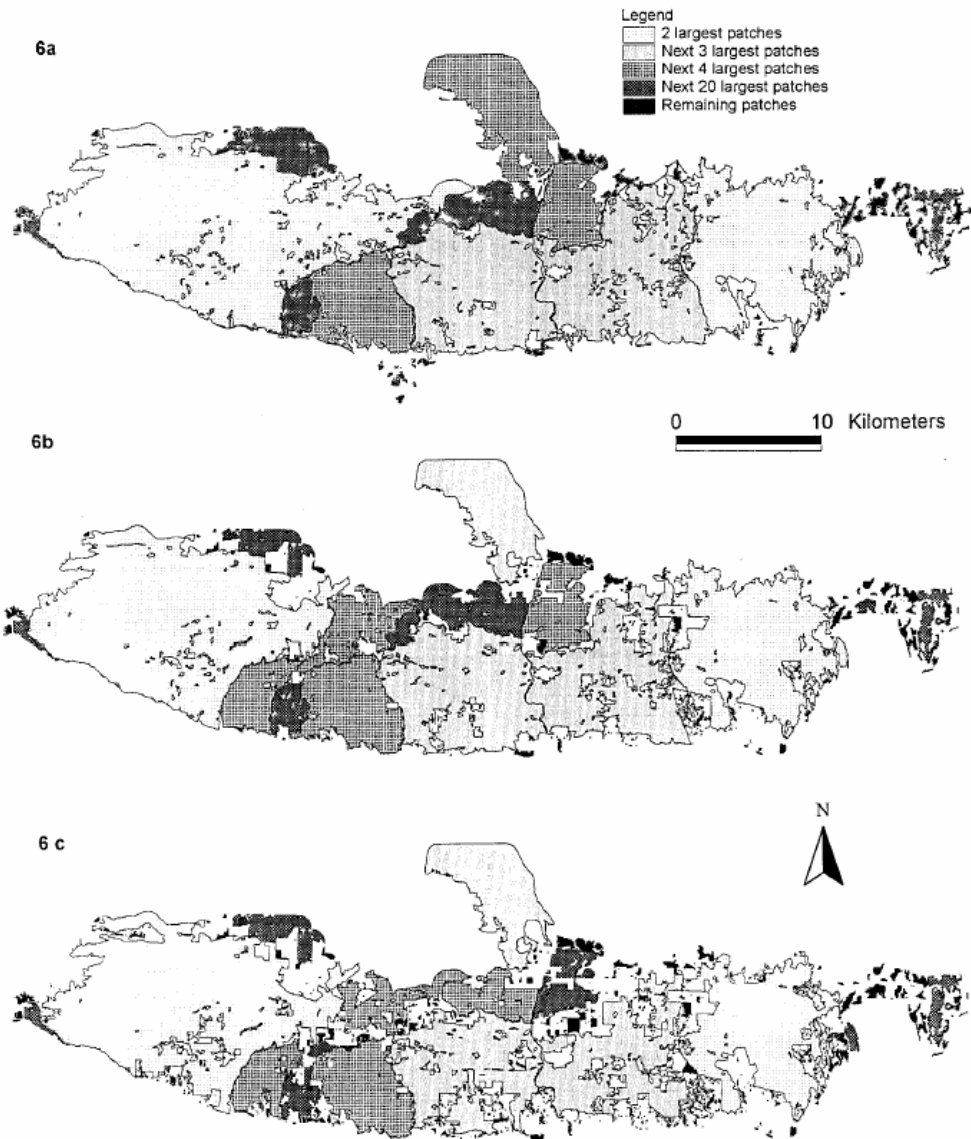


Figure 10. Santa Monica Build-Out Scenarios (Franklin and Swense, 2000n)

The result for this simulation was an overlay diagram showing the methodology of factor overlay analysis and 2-D maps of the simulation results. Scattergrams were used to show the relationships between % Vegetation x % Core Area, Vegetation Removed x Edge, %

Vegetation Removed x # of Patches, and % Vegetation Removed x Landscape Shape Index, showing high existing core habitat, high edge removed by build out scenarios, low patches removed by model, and high effect on shape of patch by build out model.

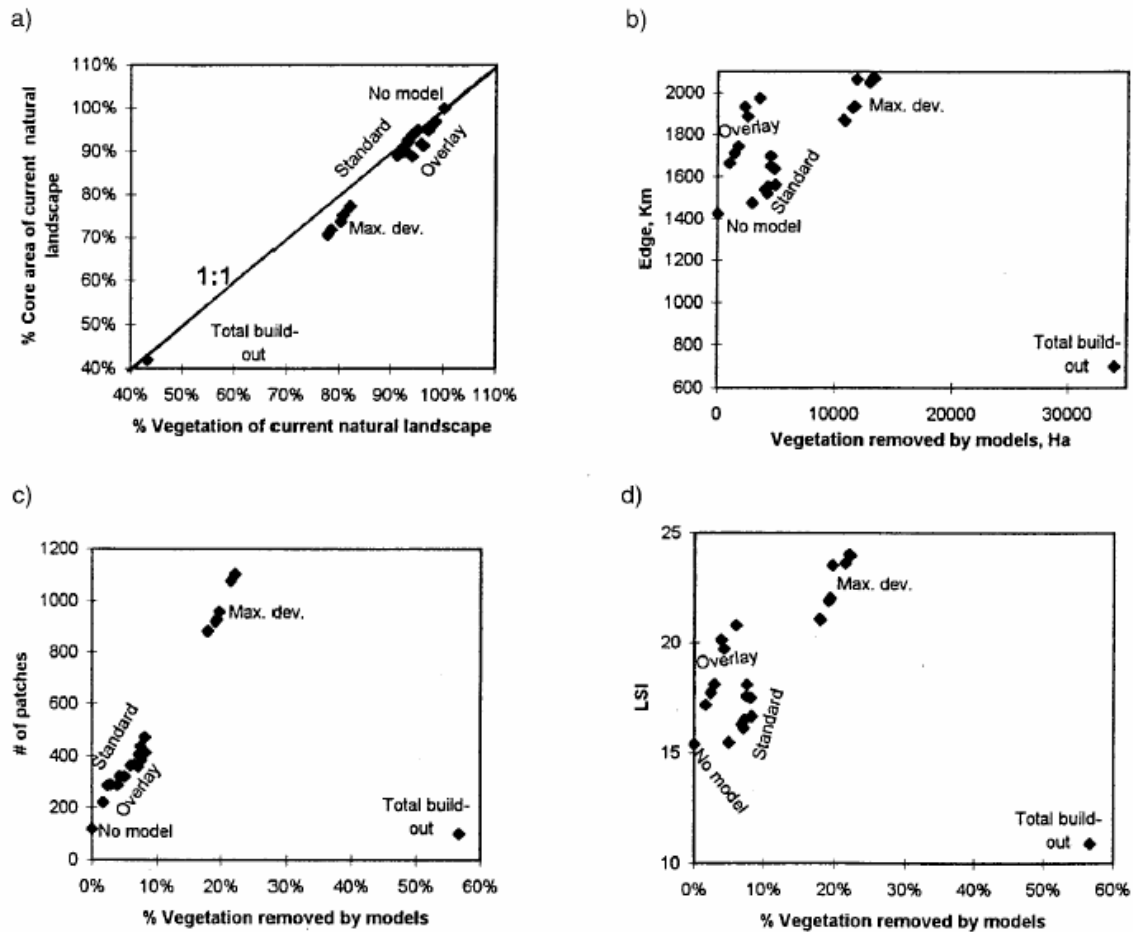


Figure 11. Scattergram Factor Correlations (Franklin and Swensen, 2000)

Scattergrams are a more specialized graphic output relating variables in a numeric manner which increase the depth of analysis, but decrease the information access to readers.

(Franklin, 2000)

Physical environmental modeling, visualization and query for supporting landscape planning decisions

This paper presents a 2D analysis of many factors involved in a landscape planning model used to evaluate a mountain range in south eastern Australia. Bryan uses a considerable amount of factors in his model including Temperature (9 factors), Water (6 factors), Soil (5 factors), and Light (1 factor).

Table 1
Environmental parameters included in the environmental database

Parameter	Units	Source	Gradient	Biological significance
Temperature				
Mean annual temperature	°C	ANUCLIM	Direct	Affects both evapotranspiration and productivity
Maximum temperature of the warmest period	°C	ANUCLIM	Direct	Affects both evapotranspiration and productivity
Minimum temperature of the coldest period	°C	ANUCLIM	Direct	Limiting factor → plant tolerance for low temperatures
Mean temperature of the driest quarter	°C	ANUCLIM	Direct	Limiting factor → plant tolerance for high temperatures and water loss
Mean temperature of the wettest quarter	°C	ANUCLIM	Direct	Affects productivity during period of highest water availability
Diurnal temperature range	°C	ANUCLIM	Direct	Limiting factor → plant tolerance for daily temperature variability
Annual temperature range	°C	ANUCLIM	Direct	Limiting factor → plant tolerance for annual temperature variability
Minimum topographic temperature	°C	SRAD	Direct	Limiting factor → plant tolerance for topographically modified minimum temperature
Maximum topographic temperature	°C	SRAD	Direct	Affects both evapotranspiration and productivity
Water				
Mean annual rainfall	mm	ANUCLIM	Resource/direct	Directly affects productivity, limiting factor at deficient extreme
Rainfall in driest period	mm	ANUCLIM	Direct	Limiting factor → plant tolerance for low moisture availability
Rainfall in wettest period	mm	ANUCLIM	Direct	Limiting factor → plant tolerance for surplus water and low oxygen
Rainfall seasonality	Index	ANUCLIM	Direct	Limiting factor → plant tolerance for seasonal water variability
Annual moisture index	Index	ANUCLIM	Direct	Limiting factor → usually plant tolerance for moisture loss
Soil wetness	Index	WET	Resource/direct	Determines the redistribution of water through runoff, differential infiltration and ground flow
Light				
Relative short-wave radiation ratio	Index	SRAD	Resource/direct	Insolation is both a source of heat and light. Directly affects productivity but also enhances evapotranspiration. Intensity of insolation is more affected by topographic effects, such as aspect and shading rather than latitudinal effects
Soil				
Soil fertility	Index	PIRSA	Resource/direct	Nutrients directly affect productivity, limiting factors at high/low levels
Soil pH	Index	PIRSA	Direct	Limiting factor → plant tolerance for acidic/alkaline soils
Soil rockiness	Index	PIRSA	Direct	Limiting factor → plant tolerance for high osmotic pressure
Soil drainage	Index	PIRSA	Direct	Limiting factor → plant tolerance for poor soil development
Soil salinity	Index	PIRSA	Direct	Limiting factor → plant tolerance for high water/low oxygen levels

Note: PIRSA = South Australian Department of Primary Industries and Resources. Gradient refers to the type of environmental gradient after Austin and Smith (1989).

Figure 12. List of Modeling Factors and Parameters (Brian, 2004)

The author runs a model for a particular land use in a small study area, then uses the SimilarAreas function in ArcINFO 3.2 to find all the raster cells in the entire study area similar to those in the land use model output. Pearson's r and regression analysis were used to correlate the relationships between factors used in the study.

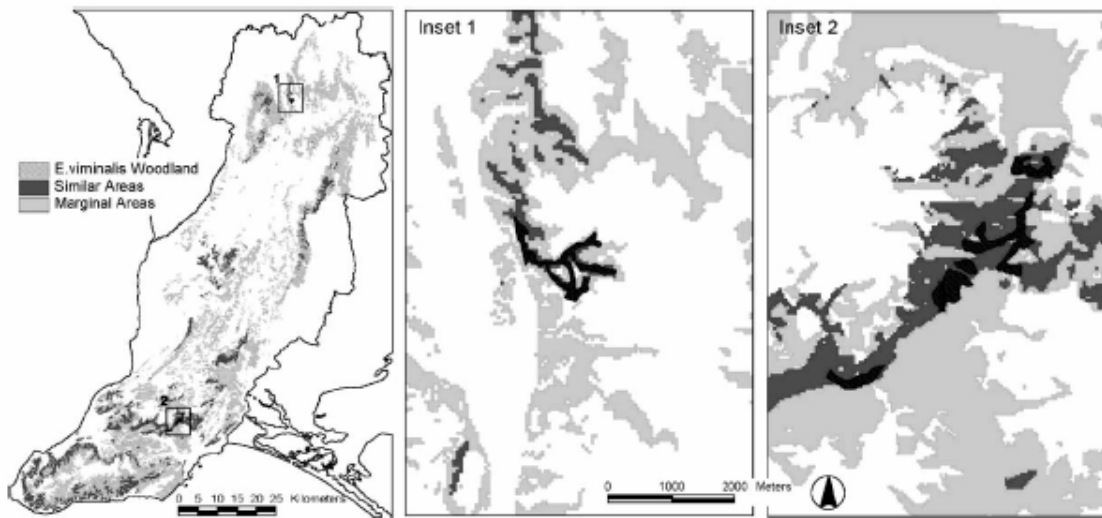


Figure 13. Example Output of SimilarAreas Tool (Brian, 2004)

The author could have easily added 3D maps to the study by extruding the DEM, which would have shown correlation between topography and the model output. A high degree of statistics used and excellent GIS 2D applications make this paper one of the best reviewed in terms of user understanding and well founded scientific methodology. 3D visualization of the raster overlays would have been an excellent addition.

KANSAS DEPARTMENT OF WILDLIFE AND PARKS RECREATION SURVEYS

Recreation studies provide an assessment of recreation users at a state park. It provides a valuable, standard, comprehensive use baseline and assesses facility use patterns that enhance future planning and development decisions. Since only 2.5 % of the state is in public ownership, the Kansas Department of Wildlife and Parks has only a small quantity of land to manage for the estimated 59% of Kansans who visit state parks each year (KDWP, 1993). Recreation studies, or user surveys, are designed to identify and document trends, solicit input regarding adequacy of facilities and future recreation needs. The results of recreation surveys are used to develop or Resource Management Assessment (RMA) and a Comprehensive Environmental Impact Statement (CEIS). And at a regional level, Glen Elder State Park is part of a water contract renewal process between the Bureau of Reclamation (B.O.R.) and the Solomon River irrigation districts, designed to address and balance the irrigation district's interests and resource management including ecosystem function, in stream flows, and recreation (KDWP, 1997).

Originally, user surveys were conducted periodically by oral conversations or by return requested mailings. Typically these surveys or conversations were used as forums to air grievances about the park in an anonymous manner, rather than contributions to a scientifically credible park management database. A facility use survey was therefore developed to inventory and document park use and a standardized procedure was established for data collection and recording in the form of an Excel spreadsheet printout. A data collection agent (park personnel) recorded daily data on the Excel form, tabulated the data monthly, then sent each months report to the Statewide KDWP home office in Hays. (KDWP, 1997)

Survey Methodology

The surveys were designed to gather information in a uniform manner during each two year survey period. The criteria were developed to provide information concerning facility use and assess user group size, user origin by county or state if nonresidents, activity, preferences, vehicles, camping unit types, and group composition by adult / child. (KDWP, 1997) Survey strategy consisted of the survey clerk driving slowly through the park recording the vehicle type, origin, permit type, number and age of visitors, watercraft, and camping unit type. The survey clerk would stop at every day use area and speak with all available park users to determine activity and facilities used. In some cases, verbal contact was not necessary to deduce activity or facility use (i.e. Visitors with an empty boat trailer in their site eating fish for dinner had been boating and fishing and had used the boat ramp and fish cleaning station), but activity deduction was only used if the park user was absent during the survey period. (Author's personal experience, 2004)

Sampling schedules were randomly drawn for each month of the survey. Each month contained twelve survey periods with six selected for weekends and six selected for weekdays. Three, four hour time periods were established for the daily survey periods, 8am-12pm, 12pm-4pm, 8pm-4pm, and randomly assigned to each of the 12 monthly survey periods. Only one survey period per day could exist, and all holidays were automatically included in each month's survey. (KDWP, 1997)

Survey Schedule: Glen Elder State Park, Kansas							
May, 27-August 15, 2004							
JUNE							
		1	2	3	4	5	6
Week 1	Mon	Tues	Wed	Thur	Fri	Sat	Sun
		8am-12pm		4pm-8pm		12pm-4pm	
	7	8	9	10	11	12	13
Week 2	Mon	Tues	Wed	Thur	Fri	Sat	Sun
	12pm-4pm		8am-12pm		12am-4pm		12am-4pm
	14	15	16	17	18	19	20
Week 3	Mon	Tues	Wed	Thur	Fri	Sat	Sun
		4pm-8pm		4pm-8pm		4pm-8pm	
	21	22	23	24	25	26	27
Week 4	Mon	Tues	Wed	Thur	Fri	Sat	Sun
	8am-12pm		4pm-8pm		12am-4pm		8am-12pm
	28	29	30				
Week 5	Mon	Tues	Wed				
	12pm-4pm		4pm-8pm				
JULY							
				1	2	3	4
Week 1				Thur	Fri	Sat	Sun
					12pm-4pm	4pm-8pm	
	5	6	7	8	9	10	11
Week 2	Mon	Tues	Wed	Thur	Fri	Sat	Sun
		12pm-4pm		12pm-4pm			12pm-4pm
	12	13	14	15	16	17	18
Week 3	Mon	Tues	Wed	Thur	Fri	Sat	Sun
	12pm-4pm		4pm-8pm		12pm-4pm	8am-12pm	
	19	20	21	22	23	24	25
Week 4	Mon	Tues	Wed	Thur	Fri	Sat	Sun
		4pm-8pm		8am-12pm		8am-12pm	
	26	27	28	29	30	31	
Week 5	Mon	Tues	Wed	Thur	Fri	Sat	
	12pm-4pm		8am-12pm		12pm-4pm		
AUGUST							
							1
Week 1							Sun
							12pm-4pm
	2	3	4	5	6	7	8
Week 2	Mon	Tues	Wed	Thur	Fri	Sat	Sun
		4pm-8pm		8am-12pm		8am-12pm	
	9	10	11	12	13	14	15
Week 3	Mon	Tues	Wed	Thur	Fri	Sat	Sun
	12pm-4pm		12pm-4pm		12pm-4pm		4pm-8pm
Notes							
*All surveys are in 4 hour blocks: 8am-12pm, 12pm-4pm, 4pm-8pm							
*Survey Weeks are alternating Tuesday/Thursday and Monday/Wednesday/Friday							
*Weekends surveys alternate Saturday and Sunday each week							
*Time blocks were chosen randomly							
*Schedule Method developed from KDWP							
and U.S. Bureau of Reclamation User Survey 1996-7 by Bryce Lawrence							

Table 4. Sample User Survey Schedule (Developed by author, 2004)

The overall goal of the survey is to assess the demand for outdoor recreation at a Kansas State Park, provide an updated baseline of information to evaluate current management and assist in determining future needs. Objectives to meet this goal include: documentation of current facility use, update the visitation formula for each facility providing a differentiation between weekdays, weekends and holidays for both peak use and off seasons, determine the composition of the groups visiting the facilities, determine the types of vehicles used by those groups, determine the types of permits used by the groups, determine the primary and other activity of each group, determine the reason a group chose to visit, provide an input method to gauge the department's application of resources toward visitor needs and facilities, provide a medium to solicit comments of visitor needs, indicate facilities or operational improvements perceived by the visitor, and evaluate the system of information gathering used to update the park. (KDWP, 1997)

METHODOLOGY

The focus of this paper is to use Glen Elder State Park as a study site to develop a model for park managers or regional park directors, which can be used to gauge the revenue generated in a day use area related to an areas potential for environmental degradation, and to store user survey information in a queryable database to help guide management. The model, developed in ArcGIS, uses the ArcGIS ModelBuilder tool to create a template so a consistent model can be applied to different parks by changing a few input variables. This model template is titled the Recreation Related Degradation model (RRD). The process of creating and running the Recreation Related Degradation model (RRD) has three parts. Part I is the creation of an environmental vulnerability map, which has six steps: 1) create a slope map, 2) create a soil capability class map, 3) map the presence of native vegetation on the site, 4) create a rangeland productivity map, 5) combine native vegetation and rangeland productivity, 6) use a weighted overlay to combine the three resultant maps in to an environmental vulnerability map.

Part II of the model building process is the creation of a social value index of each day use area, which are delineated by observations from a user survey, or predefined by the park managers. Part II has six steps: 1) Obtain user survey information for a time period from a park manager, or conduct a proprietary survey (see background for user survey methodology), 2) Load survey data into a digitized shapefile of the day use areas in the study site, 3) Rank day use area visitation for one set of day use are polygons, 4) copy the shapefile and rank the polygons in order of revenue generated, 5) convert the shapefiles to raster layers, 6) Use weighted overlay to combine the two values.

Part III of the model building process is the combination of environmental vulnerability and social value, to create a final map depicting day use areas which may

experience recreation related degradation, and can be done in methods. The first method is to combine final environmental vulnerability raster with social value raster using ordinal combination (plus tool) tool to create a final raster map of cells with a value of least to most vulnerability to degradation. This method is concise, but doesn't represent the influence environment, revenue, and visitation has on the final value of a raster cell, therefore an alternate process was developed. A color overlay technique can be used to overlay the final environmental vulnerability raster map with one 63% opaque day use polygon layer ranked with revenue values, and one 63% opaque day use polygon layer ranked with visitation values. Use a green color ramp for vulnerability, a blue color ramp for revenue and a red color ramp for visitation to produce a color coded value gradient representing intensity and interaction of values per day use are. This method is similar to the color gradient method used by McHarg for the Fresh Kills Landfill study (McHarg, 1993).

The Model Builder tool was utilized to facilitate the process of file manipulation and combination. ModelBuilder is a bubble diagram design tool for diagramming solutions to spatial analysis problems (Ormsby et al, 2001). Essentially, ModelBuilder allows the user to sequence a set of toolbox operations, allowing the changing of parameters for each object in the sequence. The advantage to the digital ModelBuilder tool is that factors, parameters and combination methods can be quickly and easily changed then the model recalculated by literally pressing the "play" button. The advantage is that once a model is developed, it can easily be adjusted to account for more / less variables, different site conditions, or added to other models. For a more detailed overview of ModelBuilder, see (Ormsby et. al, 2001: ch. 20)

Operational Definitions

This section utilizes ESRI vocabulary from the help screen in ArcMap, ArcToolbox, or ArcCatalog. References to these terms occur throughout the above text. It is recommended that further instructions or questions refer to Ormsby et al, 2001, the actual ArcGIS catalogues which come with the program, or the ArcGIS help screen. Further literature for advanced GIS database management includes (Zeiler, 1999 and 2004).

Further ArcGIS instruction can be obtained directly through ESRI by visiting their website www.esri.com. ESRI also offers an Authorized Training Program for individuals interested in learning all aspects of the program. ESRI does not currently offer a certification in the use of GIS, rather, individuals who are authorized ESRI instructors are able to instruct courses developed and tested by ESRI.

Study Site

Glen Elder State Park is a 1,400 acre park located 12 miles west of Beloit, Kansas on U.S. Highway 24. The park is located on the north shore of 1,300 acre Waconda Lake and encompasses the dam area to the granite creek bridge. The confluence of north and south forks of the Solomon River is located six miles to the southwest of the state park. Waconda Lake was finished in 1972 and primarily built for flood control on the Solomon River and irrigation for downstream farm operations.

Glen Elder Lake State Park Solomon River Basin, Kansas

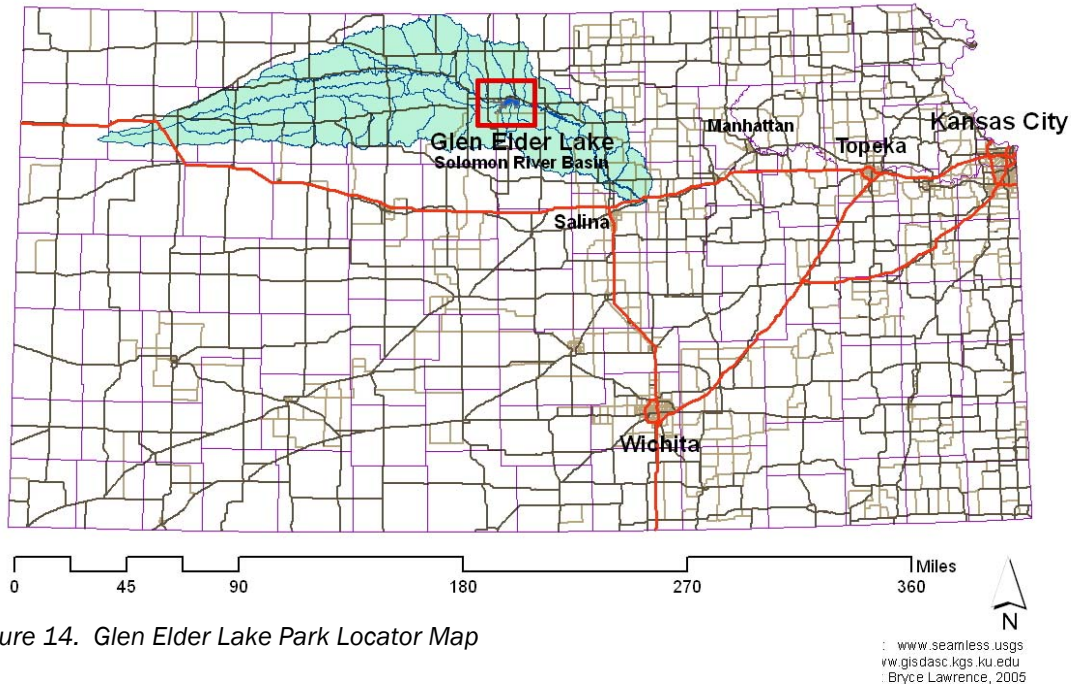
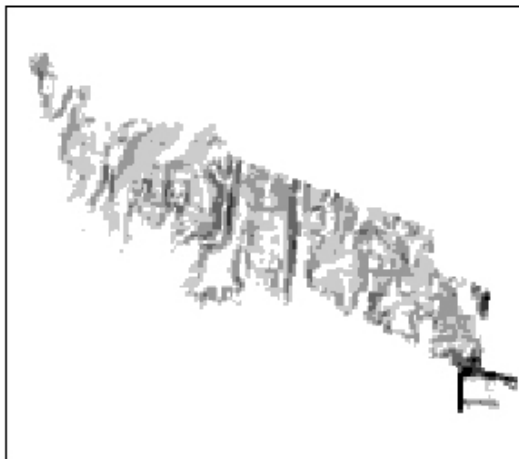


Figure 14. Glen Elder Lake Park Locator Map

Environmental Factor Justification

The factors used in the model to predict areas susceptible to degradation are slope percent, capability class, rangeland productivity, presence or lack of native vegetation, total visitation of an area, and total revenue generation of an area (figure 15). These factors were combined using weighted, ordinal rankings, to make the model represent the authors observations made during the summer of 2004. All factors were ranked on a scale of 1-10, so maximum and minimum values would be normalized when combined. If varying scales would have been used (i.e. 1-3, 1-7, and 1-10), factors with a higher maximum value would assume a higher weighting when combined with a factors with a lower maximum value.



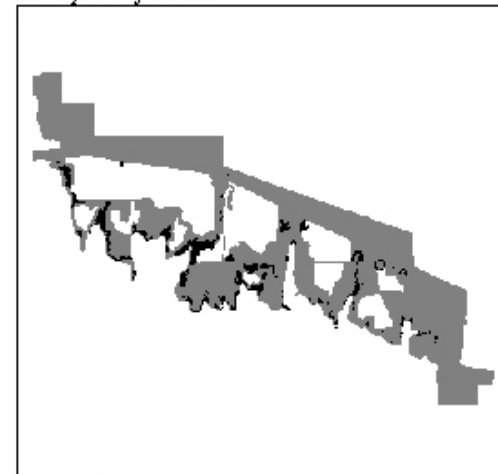
a. Slope Percent



b. Capability Class



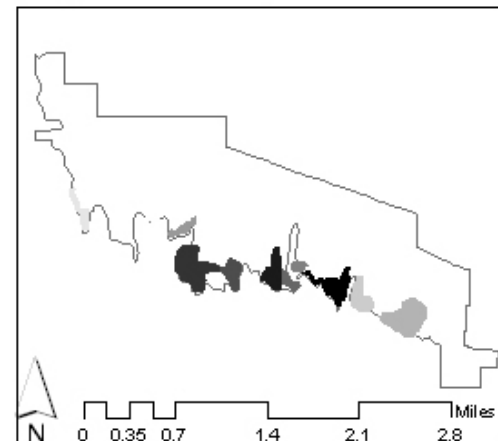
c. Rangeland Productivity



d. Vegetation Vulnerability



e. Total Visitation Rankings



f. Total Revenue Rankings

Figure 15. a) Slope Percent values ranging from 1% to 27% b) SCS capability class values ranging from I to VI c) SCS rangeland productivity values ranging from 4,000 - 6,000 lb/ac d) Native Vegetation Index values ranging from presence to no presence e & f) Total visitation and revenue ranking by day-use area showing low values in white and high values in black.

Data Source: Kansas Data Access Support Center
Cartographer: Bryce Lawrence

A justification for use of each factor is given below, but it should be noted that the model was developed inductively from the author's gestalt observations of degradation on the study site during the survey period of June, July, and August, 2004. Many different factor and weighing combinations were tested during the development of the model, but the factor and weighting combinations shown below in the final RRD model most accurately reflect the observations made by the author.

Slope was chosen as a factor of erosion based upon the difficulty of secondary vegetational succession on high slopes after disturbance and the increased risk of rill erosion on exposed high slope soils. Areas with low slope percentages were given values of 1 and areas of high slope percentages were given values of 10. (figure 15a)

Reclassification	
Old values	New values
0 - 0.5	1
0.5 - 2	2
2 - 4	3
4 - 8.33	4
8.33 - 10	5
10 - 15	6
15 - 27.04	7
NoData	NoData

Table 5. Slope Value Reclassification

Capability Class was utilized as a factor because the capability classes represent a composite index of limitations based upon soil composition, nutrient capacity, water capacity, depth to bedrock, native vegetation community, erodability, and seasonal fluctuation. Soils ranked as I, with no restrictions, were given the lowest value of

vulnerability because these lands have the least soil limitations and can recover very quickly after visitor overuse or other disturbance. Soil types ranked VIII, many restrictions, were given the highest value of vulnerability because these soils have the least nutrient capacity, water availability, or thickness, and have a slow recovery time after visitor overuse or other disturbance. (figure 15b).

Reclassification	
Old values	New values
I	1
II	2
III	3
IV	4
VI	5
NoData	NoData

Table 6. SCS Capability Class Reclassification Table

Rangeland productivity is an estimated quantity of grain production possible in one year in a soil types. Rangeland productivity is measured in pounds of grain yield per acre and is typically used for farmers to estimate potential crop production on their land. Rangeland productivity was chosen as a factor in this model at Glen Elder State Park because grain producing tall grasses is the native vegetation type in the region, and it was felt that areas with a high potential for grain crop production would also be areas with a high potential for yielding highly productive native tall grass communities. Soils with low productivity in pounds / acre were given a low value of vulnerability in the model, and soils with the highest productivity rate were given the highest values of vulnerability (figure 15c).

Reclassification	
Old values	New values
1,000-4,000 lbs/ac	3
2,000-4,000 lbs/ac	2
3,000-5,000 lbs/ac	1
NoData	NoData

Table 7. SCS Rangeland Productivity Reclassification

Presence of native vegetation was considered because native vegetation is better adapted to disturbance and climate fluctuations than non-native vegetation, therefore being better able to stabilize soil and reduce the need for irrigation. The vegetation was delineated using a 1991 ortho-image and ground truthed by the author. Native vegetation communities were assigned high values of vulnerability because of their importance in helping this site regenerate the native tall grass communities which existed before a flood in 1991 destroyed all vegetation on the site, putting into motion a mixed native / introduced secondary vegetational succession. Mixed vegetation is given a medium value of vulnerability because these communities are viewed as transitional communities which can become full native communities with proper horticultural management. Non-native vegetation (crops) on site were given the lowest value of vulnerability because damage or loss of these grain crops would not affect the above stated goal of returning the site to its native tall grass community. Rather, in mixing of native plants into a crop field would be viewed as an improvement in the quality of the land because native tall grasses have better roots, use less water, and have a higher percent of protein than most grain crops. (figure 15d)

Reclassification	
Old values	New values
2	1
3	3
4	5
6	7
9	10
NoData	NoData

Table 8. Vegetation Vulnerability Reclassification

Total visitation rates and total revenue are displayed as individual polygons according to delineated day use areas. Day use area delineation includes all the campsites, roadways, shoreline, facilities, and natural amenities associated with designated user areas. Total visitation is the sum of all observed visitors in a day use area each day for the total number of days in the study period. Total revenue per day was derived from the formula below, and then summed for the entire survey period. (figure 15e and 15f)

$$\text{Revenue per Day Use Area} = [(\sum \text{yearly camping permits} \times 105\$) + (\sum \text{daily camping permits} \times 12\$) + (\sum \text{annual vehicle permits} \times 45.5\$) + (\sum \text{daily Vehicle permits} \times 8\$)]$$

Figure 16. Formula for Estimating Revenue from User Survey

Visitation is viewed as a multiplier for environmental vulnerability. Low visitation in an area allows a site to grow or recover at its own rate without human impact, and areas with high visitation multiply the environmental vulnerability because of the human intrusion of cars, RV's, footpaths, human waste, trash, and plant harvesting.

Areas with low visitation were given low values of vulnerability because the human intrusion on that area is minimal, and areas with high visitation are given high values of vulnerability because of the higher amount of human intrusion.

Reclassification	
Old values	New values
6	1
7	1
18	2
36	3
51	4
70	5
72	6
277	7
503	8
769	9
777	10
NoData	NoData

Table 9: Day Use Area Total Visitation Reclassification

Revenue is also viewed as a multiplier for environmental vulnerability because areas which generate high revenue are areas with many site improvements, such as paved roads, concrete RV pads, restroom and showering facilities with septic systems, RV dump stations, boat ramps, and marinas. The users who pay for the use of these facilities are high impact users who travel to the park in high impact vehicles such as fuel consumptive RV's or SUV's, and encourage increased site development. Therefore, an area with high revenue has a high value of vulnerability because of the environmental effects of high visitation and the increased site development of the area drawing higher permit prices. Areas with low

revenue have low values of vulnerability because these areas have few site improvements and experience low visitation, resulting in low environmental impact.

Reclassification	
Old values	New values
107	1
107 - 111	2
111 - 300	3
300 - 1219	4
1219 - 1501	5
1501 - 4355	6
4355 - 4770	7
4770 - 5998	8
5998 - 9166	9
9166 - 13390	10
NoData	NoData

Table 10. Revenue Reclassification

It is important to note that an area with high visitation and few site improvements may generate less revenue than an area with less visitation, but higher day use permit prices. It is important for the park manager to think critically about the results of the RRD model output and the site infrastructure of an area.

ModelBuilder Process

ArcGIS Model Builder was used to combine the six factors presented above. Figure 17, below, shows the complete raster model builder process necessary to create the RRD model. In the diagram, ellipses represent data files, squares represent conversions, modifications, joins, weightings, or reclassifications, and arrows represent direction of flow.

Once a raster model is created in Model Builder, data layers can be interchanged, added, subtracted, re-weighted, re-ranked, or reclassified, and quickly re-run according to the objectives of a project determined by land owners, planners, or a panel of experts. The foldout figure 17 shows the raster model building process with reclassification tables and map factor images substituted for the squares and ellipses of the ModelBuilder program, to increase process clarity.

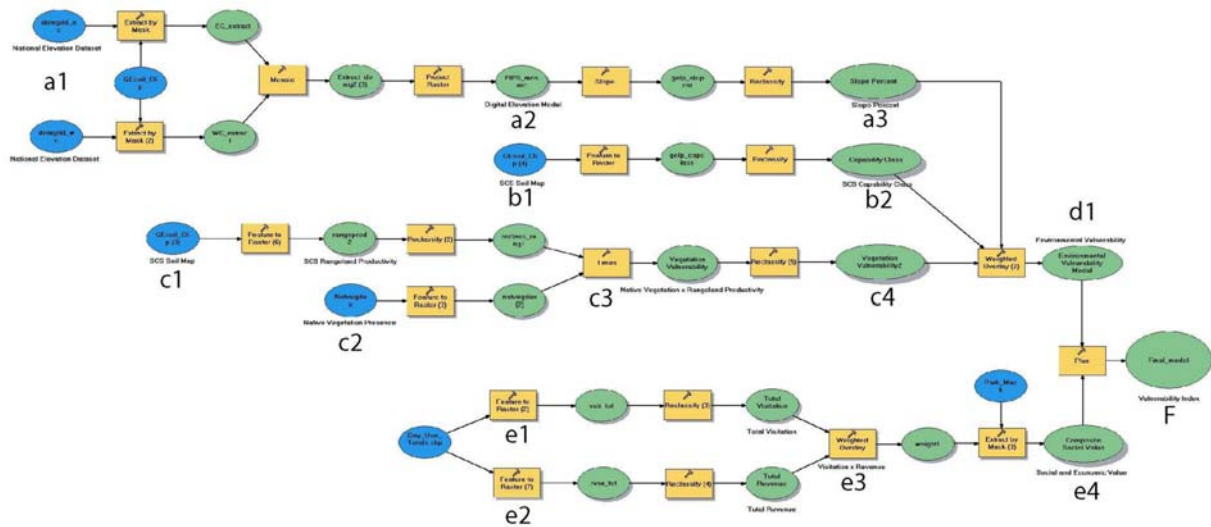


Figure 17: ArcGIS model builder diagram depicting entire raster modeling process necessary to identify areas susceptible to recreation related degradation.

Following Figure 17, path a1 to a3 is the combination of USGS National Elevation Datasets clipped to the GELP boundary, converted to slope percentage, and then reclassified 1-10. Path b1-b2 is the conversion of a SSURGO soil boundary layer to raster cells based on capability classification values then reclassified from 1-10. Path c1 to c3 is the conversion of SSURGO soil boundary layer to raster based upon values of rangeland productivity, reclassified 1-3 and multiplied by the native, non-native, or mixed vegetation index also classified 1-3. The product is reclassified 1-10 to create a vegetation vulnerability index (c4). Native plant presence was combined to produce a ranking of the productive potential of existing native plant communities, with the lower ranking meaning non-native, low productive capacity communities, and the higher value meaning native, high productive capacity communities. Slope (a3), capability class (b2) and vegetation vulnerability (c4) area combined in a weighted overlay with a 40%, 35% and 25% ranking respectively to create an environmental vulnerability index (d1, Figure 18).

Slope was given the greatest weighting because an existing unvegetated slope is directly vulnerable to erosion from water, wind, or human impact. Capability class was given a higher weighting than vegetation because differences in soil units are causal factors for presence of native vegetation, and therefore an indicator of where native vegetation is most likely to occur. Capability class is given a lesser weight than slope because no soil type is more vulnerable than exposed land, yet different soil types will erode at different rates based upon the characteristics of that soil types. Vegetation vulnerability was given the lowest weighting because vegetation quality and community type depends directly upon slope percent and soil capability class. Essentially, this factor was a detail of the more important overriding factors of slope percent and soil type, which was important in distinguishing differences in environmental vulnerability within soil units.

Weighted overlay table

Raster	% Influence	Field	Scale Value
⤴ Slope Percent	45	Value	↶
		1	1
		3	3
		4	4
		5	5
		6	6
		7	7
		9	9
		10	10
		NODATA	NODATA
⤴ Capability Class	30	Value	↶
		1	1
		3	3
		5	5
		7	7
		10	10
		NODATA	NODATA
⤴ Vegetation Vulnera	25	Value	↶
		1	1
		3	3
		5	5
		7	7
		10	10
		NODATA	NODATA

Table 11. Environmental Vulnerability Weighted Overlay

Environmental Vulnerability Index

Glen Elder State Park, Kansas

- Based on:
 - Slope
 - Capability Class
 - Rangeland Productivity
 - Presence of Native Vegetation

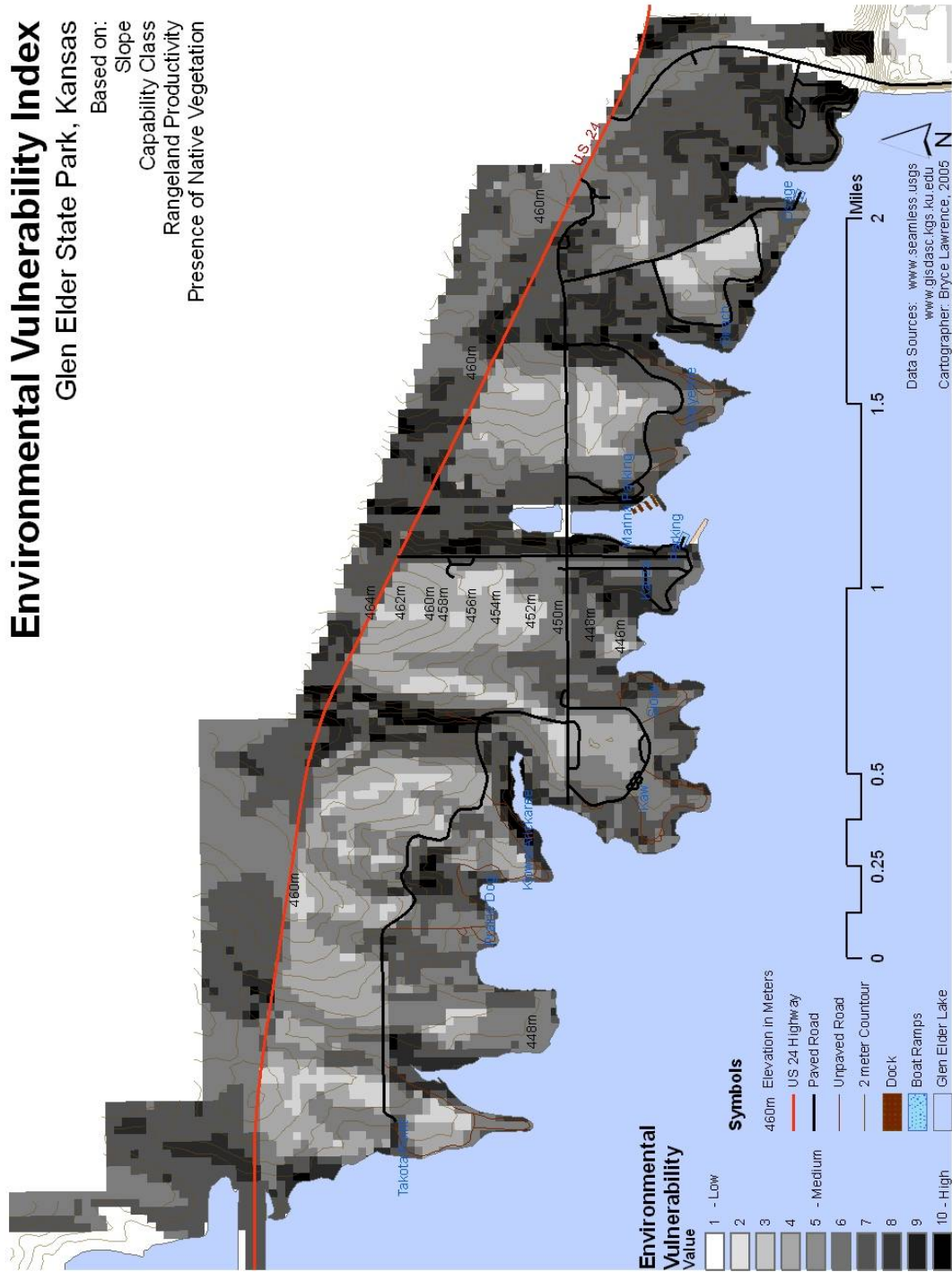


Figure 18. Environmental Vulnerability Model

Path e1 to e4 is the ranking of day use areas by total visitors and total revenue combined in a 50% 50% weighted overlay classified 1-10 to develop a composite social value (e4). The visitation rate and revenue production area weighted equally because these values represent a composite index of human interaction on the site, and because there is a high degree of multicollinearity between the two variables, meaning that if these two factors would have been considered separately, there would have been a high probability of double weighting the importance of human impact, resulting in "blackened out" day use areas with high visitation and revenue and white areas with low visitation. By grouping the factors and creating a composite social index, the value of human impact is essentially the mean between the value of revenue and the value of visitation. These two factors are viewed as having equal impact and therefore were combined with a 50% / 50% weighting.

To create the RRD model, the user combines the social value raster layer with the environmental vulnerability raster layer in an ordinal combination, using the plus tool. By using ordinal combination instead of a linear or weighted linear technique, the user assumes equality between visitation, revenue, and environmental vulnerability. Ordinal combination was chosen over weighted overlay because when combining high values of vulnerability with even a 5 or 10 percent weighted influence on visitation and revenue, the vulnerable area decreased in numeric value, thus appearing to decrease in vulnerability. However, by adding visitation, an area is likely to have an increased environmental impact; therefore the outcome of the model should be an increase in raster cell value. Ordinal combination assures that the value of areas with environmental vulnerability which area overlaid by visitation, will keep their original value, plus the value of visitation. The recognized drawback to this method is that an area with low vulnerability and high visitation

may appear to have equal value to an area with high vulnerability and low visitation (figure 19).

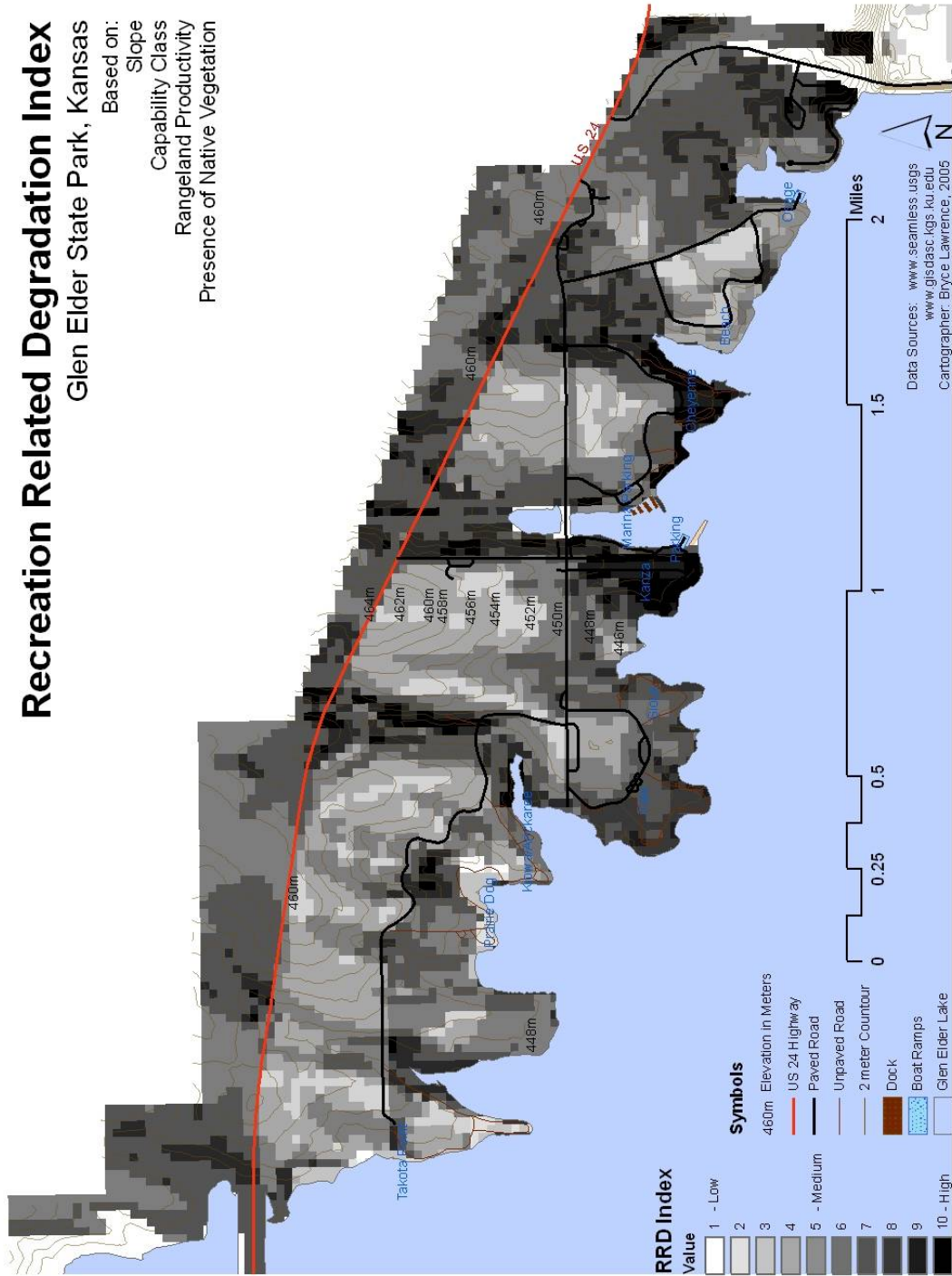


Figure 19. Recreation Related Degradation (RRD) Model

To solve the problem of misrepresentation using ordinal combination, a second overlay map is created, the color factor overlay, which assigns prime color gradients individually to the three factors of environmental vulnerability, visitation, and revenue, to derive a color index portraying the influence of interaction among the variables. Green is applied to environmental vulnerability, red applied to visitation, and blue applied to revenue. The resulting color overlays show orange as a green/red combination, purple as a blue/red combination, teal as a blue/green combination, and dark purple gradient when all three factors combine. By using the RRD model and the color overlay together, intensity and interaction is shown (*figure 20*).

Step by step instructions including screen captures of the weightings used above are included in appendix 1.

Recreation Related Degradation: Day Use Area Color Overlay

Glen Elder State Park, Kansas

Based on:
 Visitation
 Revenue
 Environmental Vulnerability

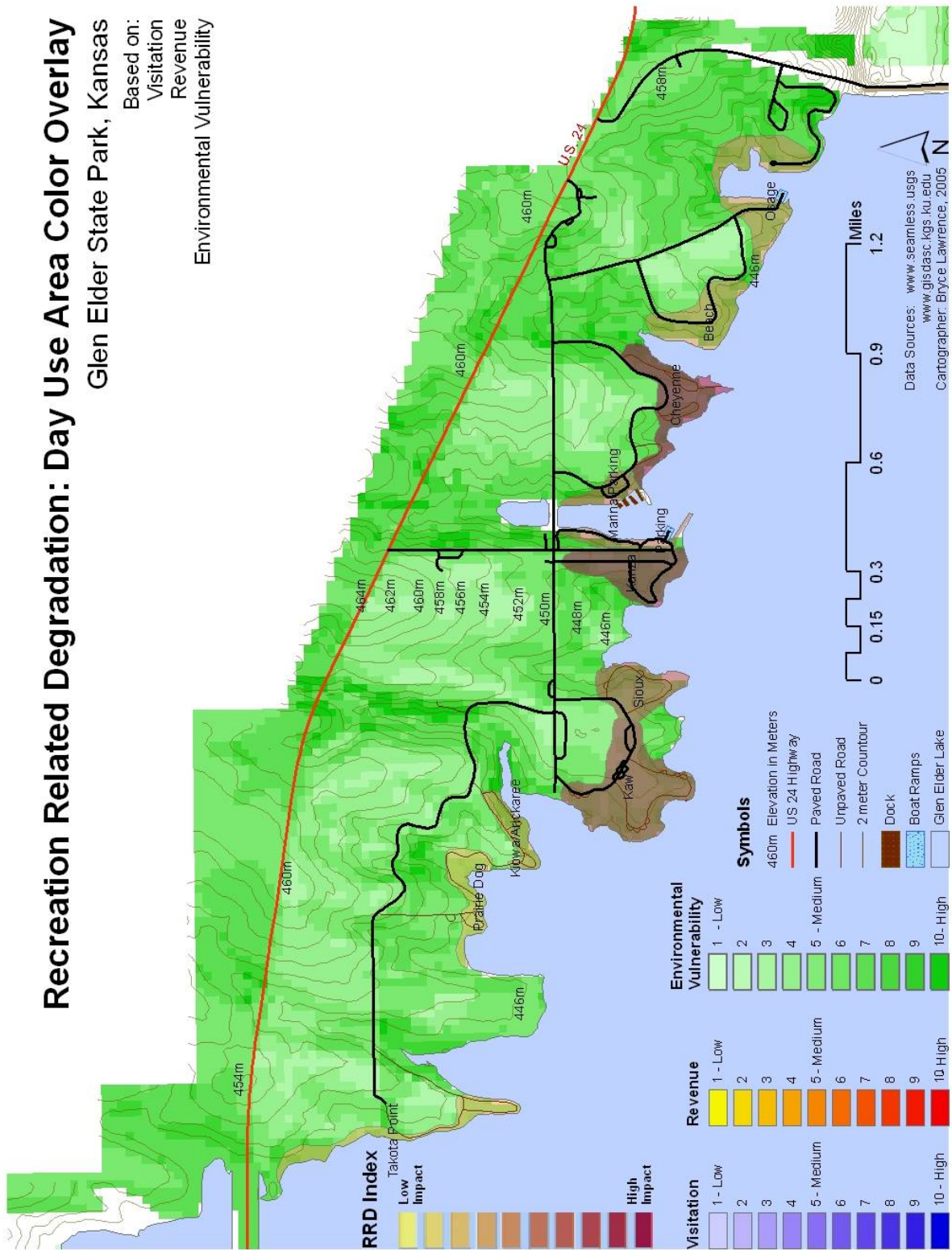


Figure 20. Environmental Degradation, Visitation, and Revenue Color Overlay

RESULTS

A concise summary of the two month user survey and detailed color overlay maps for day use areas is presented in this section. As was mentioned above in the last paragraph of the methodology, the best way to apply the model is by using the RRD and the color overlay map together to identify vulnerable areas and understand the interaction of factors causing vulnerability in the day use areas. Park managers can query the attribute tables of the day use area polygons to understand the links between potential for degradation, the people who use the park, user activities, and the facilities most heavily impacted. Environmental restoration programs needed to restore an area can be derived from this data. The data can be viewed as full tables in the appendix.

Based upon the final raster model (figure 3), the primary day use areas most susceptible to degradation are the Kanza, Cheyenne, Sioux, Kaw, Kiowa and Arickaree areas. The secondary day use areas most vulnerable to degradation are Osage and the Beach. The day use areas least susceptible to degradation are Takota Point and Prairie Dog. The final model shows the highest index of vulnerability related to soils in riparian zones with a presence of native vegetation, a seasonal flood regime, and high slope values. Areas not susceptible are in the upland areas planted with crops, not near riparian zones, nor in day use areas. The test data set for the development of this model was generated during the months of June and July of 2004. The data set is not large enough to be statistically significant, rather it serves as a brief glimpse of user characteristics and a test set from which to develop, query, and test the qualitative functionality of the model.

A brief summary of attribute table data, degradation possibilities and social value for each area will now follow.

OSAGE

Visitor Attributes

The majority of visitors in the Osage area were adults, followed by children and seniors. There was less than one absentee camper with an annual permit present per survey day. Recreational Vehicles were the most commonly occurring vehicle, followed by trucks, then cars. Fishing boats and empty boat trailers were most common in the parking lot, followed by jet ski trailers and ski boats. Annual vehicle permits were the most common permit, followed by daily vehicle permits, and daily camping permits. The most common activity of users in Osage was camping, followed by boating, fishing, and relaxing with alcoholic beverages. The most commonly used facilities in the area were the primitive camping facilities, boat ramp, and beach shoreline, followed by the restrooms and the fish cleaning station.

Recreation Related Degradation: Osage Area Color Overlay

Glen Elder State Park, Kansas

Based on:
Visitation
Revenue
Environmental Vulnerability

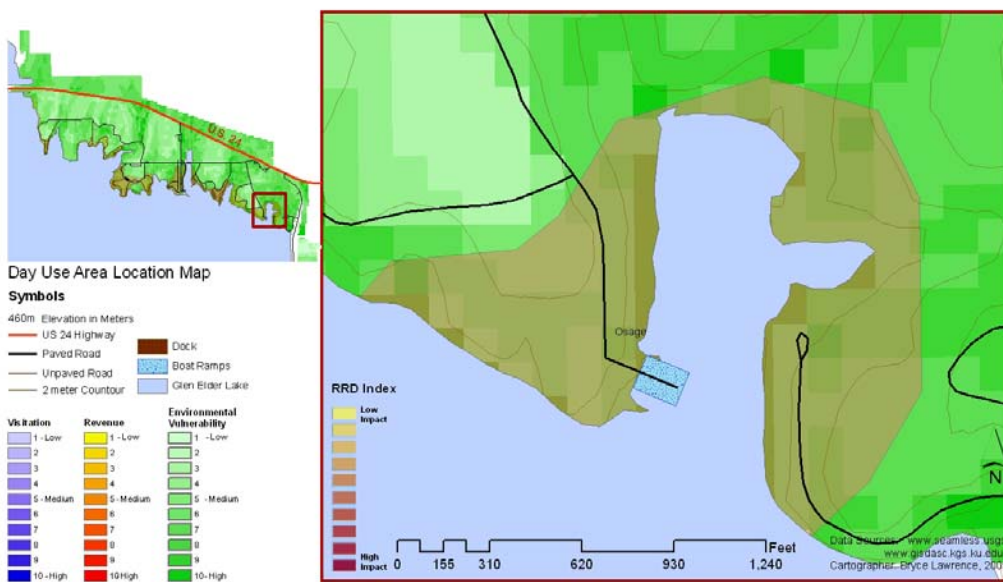


Figure 21 Osage Area Color Overlay Map

Visitation Rate, Revenue, and Potential for Degradation

The Osage area has a light red or salmon color value meaning that there is a low user population and low revenue production in this area in comparison to other day use areas in the park. The total number of visitors observed in Osage area was 55, with an estimated revenue generation of \$1505.10 dollars, and an average revenue per visitor of \$27.54. There are two 30 meter x 30 meter raster cells of black, predicting a high environmental vulnerability in those areas due to presence of native vegetation on sloping soils. However the majority of the environmental model is medium to light grey, indicating medium to low potential for degradation.

BEACH

Visitor Attributes

All visitors at the designated Beach area were adults or children at an equal rate of one adult to one child. The most common vehicles observed were vans and RVs, followed by cars and trucks. No watercrafts were observed at the Beach. There was a low number of vehicle permits, with an almost equal rate of daily and annual permits. The most common activity was swimming, followed by picnicking, relaxing with alcohol, and camping. The most commonly used facilities at the beach were the shoreline and restrooms, followed by the playground and sun shelter.

Visitation Rate, Revenue, and Potential for Degradation

The Beach has a yellow / pink color indicating a low user frequency and low revenue production. The total number of visitors observed was 36, the total estimated revenue

related to the Beach area was \$299.50 dollars, and the average earned revenue per visitor is \$8.31. There are several raster cells of medium to dark grey, indicating medium to high potential for degradation associate with steep slopes above the shoreline, and presence of native vegetation in the riparian zone.

CHEYENNE

Visitor Attributes

The majority of visitors in the Cheyenne area are children, followed by adults, then seniors. There is a high number of absentee RVs parked on site during the summer months, which generate revenue as annual camping permits. RVs were the most frequently observed vehicle in the area, followed by trucks, cars and SUVs. Ski boats were the most common watercraft, followed by fishing boats, then Jet Skis. Annual Vehicle permits were most dominant followed by daily vehicle permits and daily camping permits. Camping and relaxing with alcoholic beverage were the most common activities, followed by fishing, picnicking, jet skiing and swimming. The most

Recreation Related Degradation Color Overlay: Beach, Cheyenne, and Marina Areas

Glen Elder State Park, Kansas

Based on:
Visitation
Revenue
Environmental Vulnerability

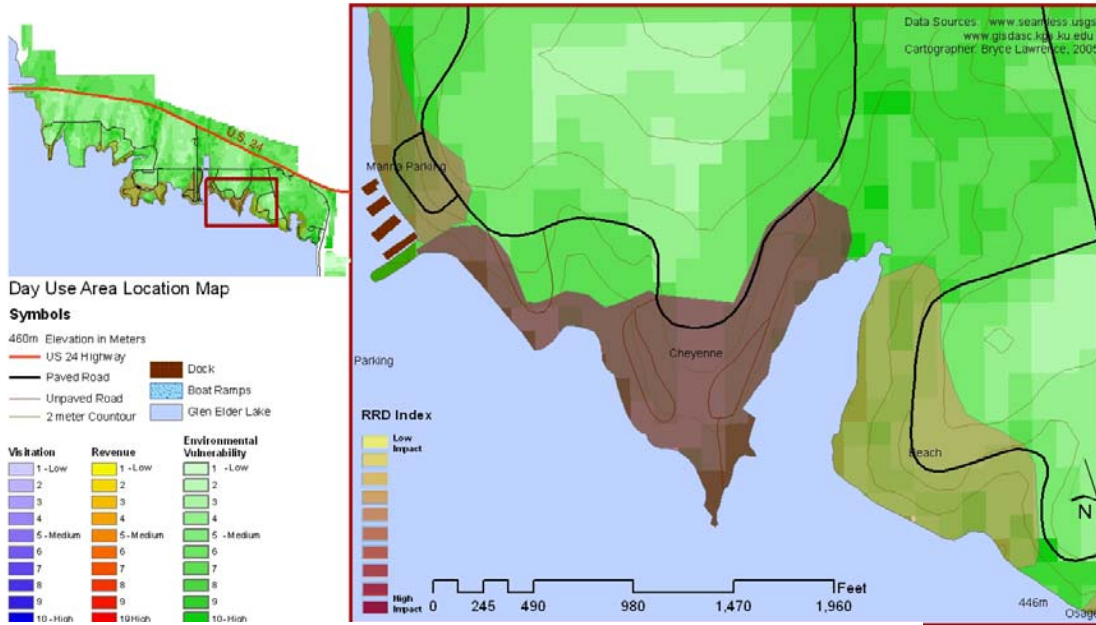


Figure 22. Beach, Cheyenne, Marina Color Overlay Map

used facilities were the primitive campsites and restrooms, followed by the showers, utility camp sites and beach shoreline. Almost every major activity observed in this site related to the area shoreline.

Visitation Rate, Revenue, and Potential for Degradation

Cheyenne is colored in a deep purple color, indicating a high rate of visitation and high revenue. The total number of visitors recorded was 502 people and the total estimated revenue related to the area was \$13,390 dollars. The average revenue per visitor in Cheyenne area is \$26.67 dollars. Much of the Cheyenne area is in the medium grey on the vulnerability index, thus representing a medium potential for recreation related degradation. There are no areas of high potential for degradation in Cheyenne.

MARINA

Visitor Attributes

The marina is a parking lot where people parked their cars to get on their boats, therefore only eight people were seen during the observations. Most visitors came in trucks to haul their boats or equipment, followed by cars, then SUVs. Fishing boats were the most common boat types. Almost all permits were annual permits, and the primary activities were boating and fishing.

Visitation Rate, Revenue, and Potential for Degradation

The marina parking has a medium purple hue on the color overlay indicating a medium economic and visitation impact. The recorded number of vehicles and peoples is 147, the total revenue during observation period was \$5,998 dollars, and the average revenue per visitor was \$40.80 dollars. Several areas area indicated as vulnerable by the RRD index is associated with high slope.

Recreation Related Degradation Color Overlay: Kanza, Ramp Parking, and Marina Parking Areas

Glen Elder State Park, Kansas

Based on:
Visitation
Revenue

Environmental Vulnerability

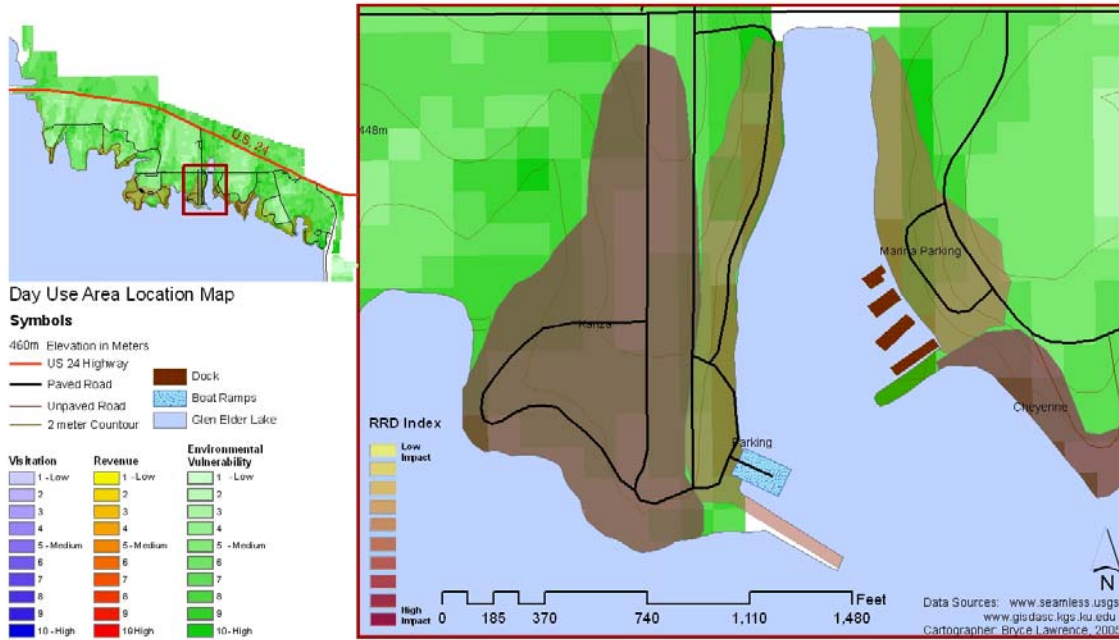


Figure 23. Kanza, Ramp Parking, Marina Color Overlay Map

BOAT RAMP PARKING

Visitor Attributes

The boat ramp is also a parking lot and the count of visitors is added to the count of cars during the observation period. The greatest number of visitors were adults, driving trucks, SUVs, or cars. All observed boats were fishing boats. Over 90% of all permits were annual permits, with only a few daily vehicle permits. The only observed activities were boating or fishing. The boat ramp, dock and shoreline were the most used facilities.

Visitation Rate, Revenue, and Potential for Degradation

The boat ramp area has a medium purple composite index indicating a medium value of degradation potential among the areas. The RRD model shows several high vulnerable areas neat the shoreline of the ramp area where slopes increase. There were 190 observed visitors and \$4,355 of revenue earned, with a total revenue per person of \$22.91 dollars.

KANZA

Visitor Attributes

Kanza experienced the most visitation in the observation period, with most visitors being adults, then children, then seniors. The overwhelming majority of vehicles were RVs followed by trucks, then cars and SUVs. Fishing boats were by far the most common watercraft followed by Jet Skis and ski boats. The greatest number of permits were annual permits followed by 1/5th as many daily vehicle permits and day camping permits. The primary activities were camping and relaxing with alcoholic beverage, followed by fishing, boating, picnicking and swimming. Primary facility use was the utility camp sites, restrooms, and showers, followed by primitive campsites and the RV dump station.

Visitation Rate, Revenue, and Potential for Degradation

Kanza experienced the most visitation and generated the most revenue, therefore it has the deepest purple color. The RRD index indicates medium environmental vulnerability with no maximum values. The greatest vulnerability is in the riparian corridor to the west of the day use area. There were 542 visitors during the observation period, which generated \$12,990 dollars, which is \$23.96 dollars revenue per visitor.

Recreation Related Degradation Color Overlay: Kaw and Sioux Areas

Glen Elder State Park, Kansas

Based on:
Visitation
Revenue

Environmental Vulnerability

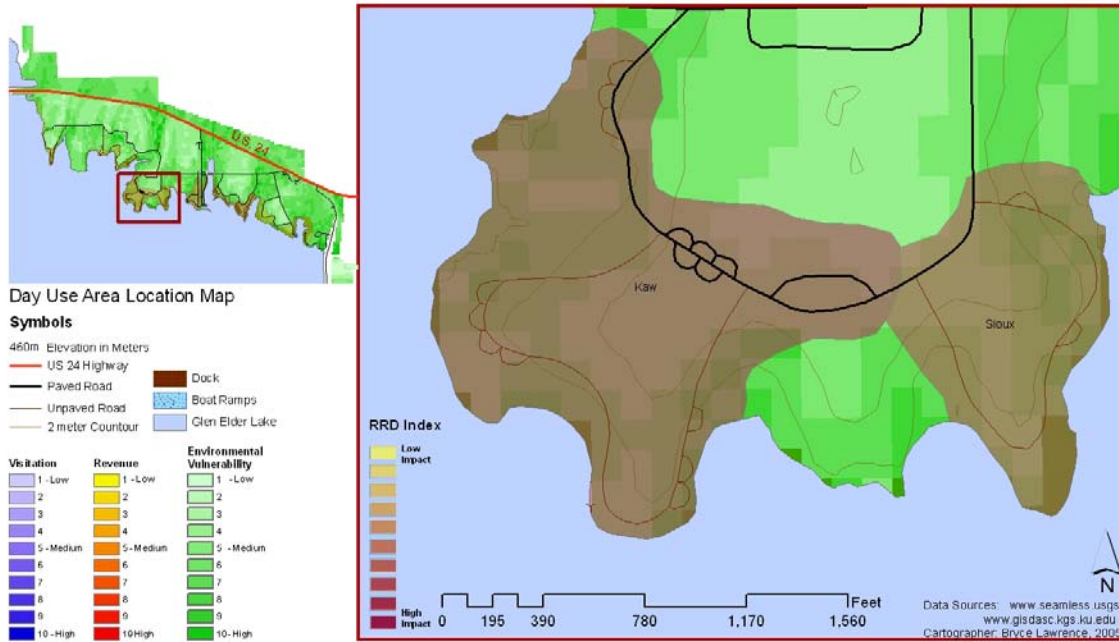


Figure 24. Kaw and Sioux Color Overlay Map

SIoux

Visitor Attributes

A majority of visitors at Sioux were adults, followed by children then seniors. The most commonly observed vehicle was RVs, followed by trucks, cars, SUVs, and one van. The most common watercrafts observed were fishing boats, then ski boats, Jet Skis, and human powered boats. The most common permit was the annual vehicle permit at 90 permits, followed by 20 daily permits and 10 daily camping permits. The primary activity was camping, with picnicking, swimming, fishing, and relaxing with alcoholic beverage as secondary activities. The most frequently used facilities were the primitive camping facilities and the restrooms, followed by the beach shoreline, showers, and boat ramp.

Visitation Rate, Revenue, and Potential for Degradation

Sioux area has a medium purple hue indicating medium to medium high potential for recreation related degradation. The RRD index indicates higher areas of environmental vulnerability associated with shoreline as compared with upland areas. Total visitation for the observation period was 277 people, with a revenue generation of \$4,770 dollars. The total revenue per visitor was \$17.22 dollars.

KAW

Visitor Attributes

The highest number of recorded visitors during the observation period was adults and children, followed by seniors. RVs and trucks were the most common vehicles, followed by cars, SUVs and vans. Few watercrafts were observed in this area in comparison to other areas, with the majority of the watercraft being fishing boats or Jet Skis, followed by ski boats and human powered boats. Annual vehicle permits were observed the most, with an even number of daily vehicle and daily camp permits. The primary activity was camping, with secondary activities of relaxing with alcoholic beverages, picnicking, fishing, swimming, and boating. The primary use facilities were the primitive camping sites, restrooms and showers. Secondary facilities used were the dock, boat ramp, and utility camp sites.

Visitation Rate, Revenue, and Potential for Degradation

The Kaw area has a medium to dark purple hue indicating a medium to high potential recreation degradation impact. The RRD model indicates that the most vulnerable areas within the Kaw area are near the shoreline where slope values are higher and native

vegetation is present. Total visitation recorded was 372 persons, with \$9166.5 of revenue earned. The rate of revenue earned per visitation for Kaw area is \$24.64 per visitor.

KIOWA / ARICKAREE

Visitor Attributes

Kiowa and Arickaree areas experienced much less visitation than other day use areas. The highest number of visitors was adults, followed by children, then seniors. Parked RVs were the most common observed vehicle in this area followed by trucks, cars, SUVs and vans.

One fishing boat and one human powered vehicle were observed. Almost all permits observed were annual permits, followed by daily vehicle permits, and then daily camp permits. Camping and relaxing with alcoholic beverage were the primary activities, with picnicking, swimming, boating and fishing being the secondary activities. The primitive camp sites were the most frequently used facilities, with the showers, restrooms, and beach shoreline observed as secondary use facilities.

Recreation Related Degradation Color Overlay: Prairie Dog and Kiowa / Arickaree Areas

Glen Elder State Park, Kansas

Based on:
Visitation
Revenue

Environmental Vulnerability

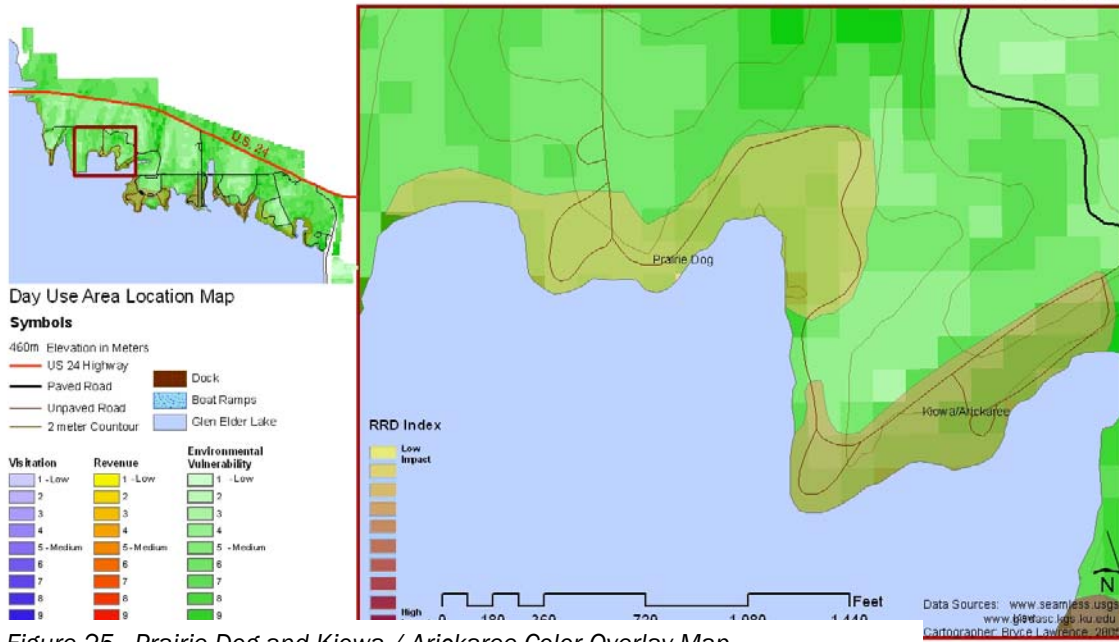


Figure 25. Prairie Dog and Kiowa / Arickaree Color Overlay Map

Visitation Rate, Revenue, and Potential for Degradation

Kiowa and Arickaree has a brownish / yellow, or light purple hue, indicating a medium to low potential for recreation related degradation. The RRD model indicates that many environmentally vulnerable areas exist in this area related to quick slope changes and presence of native vegetation. There were 27 recorded visitors, with \$1219.5 dollars of revenue earned. The average revenue per visitor is \$45.16 dollars.

PRAIRIE DOG

Visitor Attributes

Prairie Dog experienced very little visitation during the observation period. There were six observed adults, four observed cars, and no watercraft. Two annual permits and two daily vehicle permits were observed. The observed activities were camping, picnicking, and swimming, and the facilities used are the restrooms, beach shoreline, showers, and primitive camping facilities.

Visitation Rate, Revenue, and Potential for Degradation

Prairie Dog has a light yellow hue indicating a relationship between revenue and environmental vulnerability. The RRD index shows medium to light grey hues, indicating a medium to low environmental vulnerability in the area, but a high vulnerability in the riparian corridor to the northeast of the site related to presence of native vegetation and erodable soils. There were six total observed visitors and an estimated \$107 dollars revenue during the observation period. Average revenue per visitor is \$17.83 dollars.

TAKOTA POINT

Visitor Attributes

Takota Point experienced low visitation during the observation period. There were adults and children observed, using, cars, trucks or SUVs. Two annual vehicle permits, one daily permit, and one daily camp permit were observed. The primary activities were camping, fishing, picnicking, and swimming, with the shoreline being the primary facility used.

Visitation Rate, Revenue, and Potential for Degradation

Prairie Dog has a light peach hue, indicating an interaction between environment and revenue. The RRD model indicates potential for recreation degradation exists along the shoreline areas where use is the highest and a change in slope occurs between two soil types. There were seven total visitors generating an estimated \$111 revenue. Average revenue per visitor was \$15.85 dollars.

Recreation Related Degradation Color Overlay: Takota Point Area

Glen Elder State Park, Kansas

Based on:
Visitation
Revenue

Environmental Vulnerability

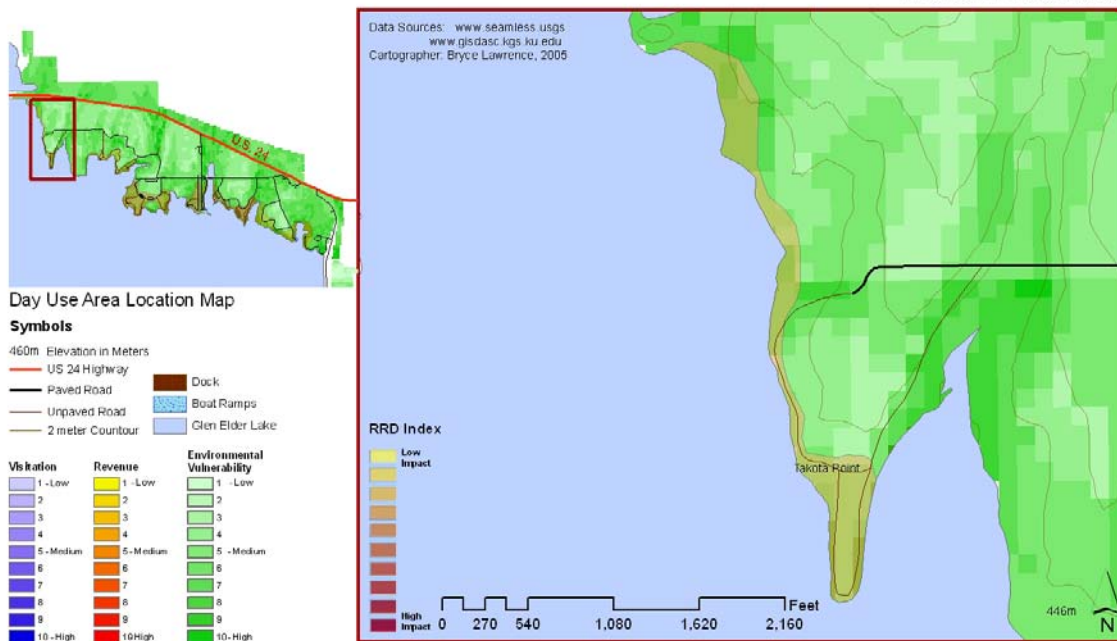


Figure 26. Takota Point Color Overlay Map

CONCLUSIONS

Applying the RRD Model, Color Overlay, and Attribute Tables for Park Management

Park managers or regional park directors can apply the attribute table information derived from user surveys to understand specific types of uses and users of a vulnerable area, and develop site specific remedies. The following is an example scenario of this process.

The Kaw day use area experienced a high number of children and adults arriving in cars, trucks and RVs with annual vehicle and camping permits. They were camping, fishing from boats, swimming, and picnicking in an area with high revenue generation and high rates of potential degradation near the shoreline and riparian zones with a presence of native vegetation.

Preventative measures against degradation might include shoreline stabilization using native cuttings, keyed in root wads with lunker logs for fish habitat and bank stabilization, a designated swimming beach with regular maintenance, and a designated boat / jet ski boarding area armored with native limestone slabs as steps down to the beach. The suggested improvements to the area would promote the biotic health and human enjoyment of the day use area, while protecting it for future users. The cost of the project can be compared to the yearly revenue generation of the area (9, 665\$) to determine the time period for return on investment.

It is important to note that all day use areas at Glen Elder State Park have higher values of degradation associated with the lake shore line than the upland. This phenomenon occurs because of a noticeable existing grade change at the shoreline caused by continual flood pool elevation change, presence of native wetland vegetation, and the high rates of water related visitor use such as boating, fishing and jet skiing. The shoreline warrants the most management attention in all day use areas because it is the most used

natural resource area among all the day use areas according to the day use area attribute tables (see appendix)

The model presented in this paper is probably most applicable to regional or state park directors who need concise information regarding many parks in a region or state. A regional director may have such a report for each park in his / her office, with a book for each park, so decisions regarding management funding, natural resource allocation, game shortages, natural disasters, or site improvements can be addressed quickly.

FUTURE CONSIDERATIONS

Statistical Validation

A future continuation of this study would be the statistical validation of the selected factors influencing recreation related degradation based on multivariate regression. The multivariate regression statistic is used to determine the existence and strength of relationship between selected independent variables a user believes to affect a single dependent variable. This technique requires a sample size of 30 or more dependent observations with more than 20 different values, 3 or more independent factors, and a null hypothesis (H_0). The null hypothesis for the RRD model in a future study would be: *There is no relationship between high values of observed land degradation and high values of observed visitation, revenue, and environmental sensitivity.*

For the RRD model to meet the needs of the multiple regression technique, multiple parks would need to be analyzed to meet the need of 30 dependent observations, and the value index of RRD which is currently 1-10, would need to be increased to a larger range of 1-20. The multivariate regression analysis used to test the validity of the RRD model is:

Observed Recreation Related Degradation (\hat{y}) = (b_1)Slope percent + (b_2)percent of native vegetation + (b_3)rangeland productivity + (b_4)capability class + (b_5)revenue per day use area + (b_6)visitation per day use area

Expressed as:

$$\hat{y} = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6$$

where

$$a = \text{mean of } y - b (\text{mean of } x)$$

and

$$b = \frac{\sum (x - \text{mean of } x) (y - \text{mean of } y)}{\sum (x_i - \text{mean of } x)}$$

Figure 27. Regression Statistic

The important results of the Multivariate Regression analysis for this study would be the R^2 value and the F value. The R^2 value determines the strength of the independent factors to explain the dependent factor. For each independent factor an R^2 value will be determined, with ranges from perfectly explained (1) to perfectly unexplained (0). The F value determines the overall significance of the model to explain recreation related degradation. F value also ranges from 1, for absolute significance, to 0, for no significance, and is important because it is the value from which one would accept or reject the null hypothesis (H_0)

The formulas for R^2 and F value are:

$$R^2 = 1 - \frac{\sum (y_i - \hat{y})^2}{\sum (y_i - \text{mean of } y)^2}$$

where

$$\hat{y} = a + bx$$

and

$$F = R^2 \frac{(n-2)}{1 - R^2}$$

Figure 28. R Square Value and F Value

Geodatabase development

Database design integrated with the attribute table is the next step to improve the functionality of the RRD model and park management system. The current method of data accumulation in the KDWP is based upon Excel tables gathered at the local level, which are then sent to a regional office to be compiled. The regional office has a maser database which links all the data in a relational database to both organize the data and create queries. A yearly data download is made available to local offices in Excel tables which can be used by the local park staff to make graphs, maps, observations, or judgments.

With a GIS, data in a relational database can be related to a polygon on a map, allowing the user to define important attributes and ask the database to show all the locations with that mix of attributes. The development of a relational database integrated into the master regional database would be a powerful tool for understanding the relationships over time of a broad range of social, environmental, economic, and political factors. This data structure designed in access would be something like the conceptual day use area data structure shown in *Figure 29*, and would fit inside a larger relational database linked to all Kansas State Parks. Kansas Department of Wildlife and Parks, Corps of Engineers, and Bureau of Reclamation may want to consider developing a joint geodatabase venture to catalogue visitor, vegetation, wildlife, and fisheries surveys, stream gauging stations, point source pollution monitoring sites, and reservoir level fluctuations to understand hydraulic fluctuations and user interactions on a regional or statewide scale.

The development of a geodatabase would also allow a temporal component to be added to the model. If many years of survey data, previously stored in an excel file would be loaded into a geodatabase, models could be developed showing change over time of parks, regions, or states. By developing a temporal component to the model, the model would become a predictive tool, rather than simply a descriptive tool. Change over time analysis could predict; biomass changes, user preference, water quality, vegetation quality / invasive species, wildlife habitat and quantity, or lake level changes.

A geodatabase component was intended to be included in this paper, but was not due to time constraints and lack of technical expertise. During the process of model creation, the user survey data was loaded into shapefile attribute tables, converted into excel tables, and imported into access tables. The relational database imbedded in figure 29 is an access database which the author was not able to get working properly. With some

access programming training to create relational databases and some ESRI geodatabase training, the author would be able to create a relational geodatabase with the capabilities of linking day use areas together in a park database, and linking park databases in a regional database.

GPS Integration and User Survey

A system of handheld GPS computer interfaces would improve field data collection to create daily tracks of user surveys, so accurate use, origin, and permit type can be logged and automatically entered into a database. Many handheld units (palm pilots or other Garmin brand devices) also have wireless data links which would allow a day's survey information to be automatically uploaded to an excel file, which in-turn updates a parks geodatabase. The monthly report could then be associated with a regional geodatabase update.

Sample Relational Database Structure

Kansas Department of Wildlife and Parks

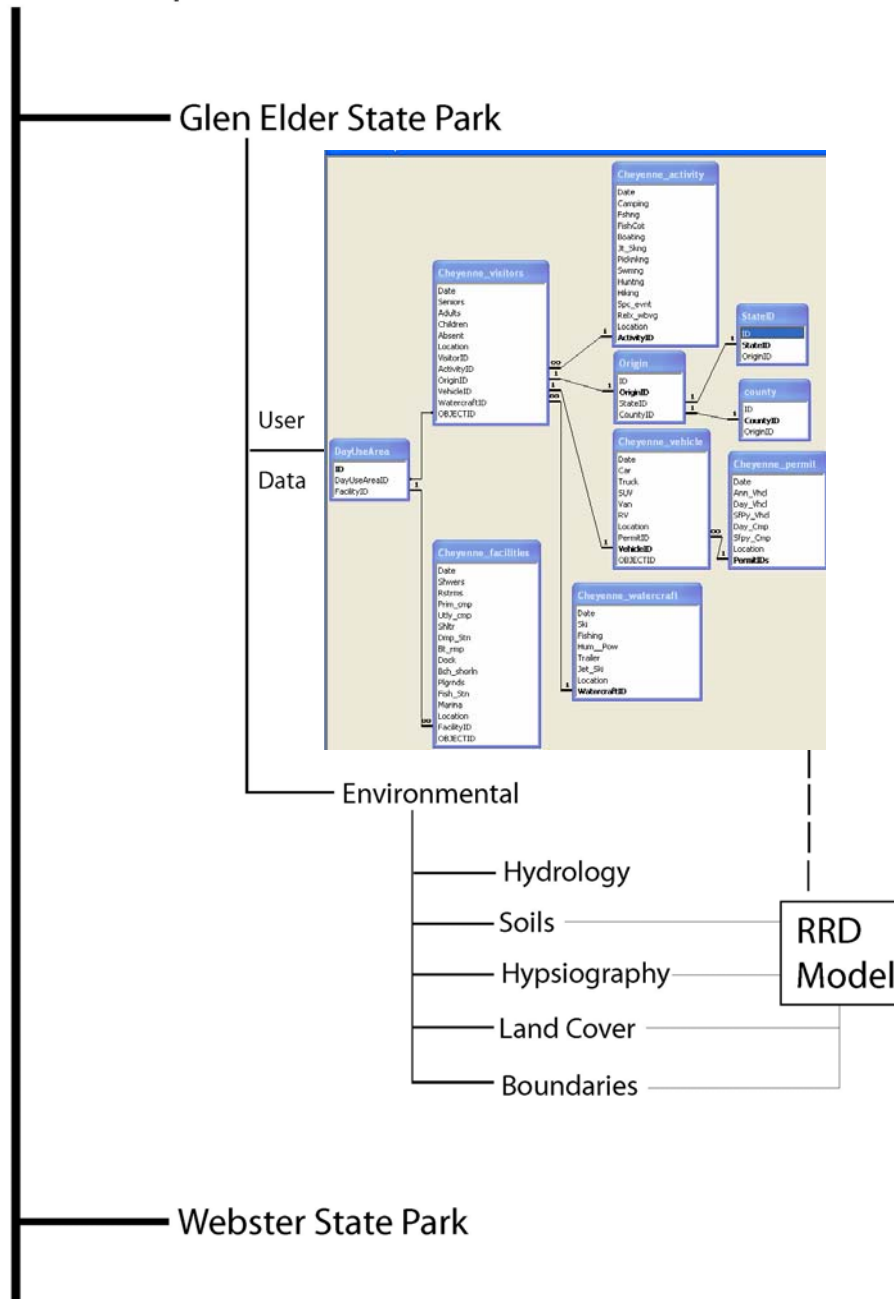


Figure 29. Conceptual Relational Database Structure for KDWP, Developed in Conjunction with Dr. Hutchinson

Development of Vector Based Site Scale Analysis

One of the great advantages of a GIS model is the adaptability to scales. The raster model presented here is at a spatial resolution of 30 meters x 30 meters, which is good for large scale planning and resource management, but not so good for site scale analysis or many urban planning analyses. By switching to a vector base analysis the same analysis as presented above can be performed at a smaller scale. The most common vector files are the ArcGIS .shp (shape file) which can be created in ArcGIS, or AutoCAD files, which can be imported into ArcGIS. Both these file types can have attribute tables which express information, perform queries, or be used to create map overlays which derive vulnerability and suitability analyses.

The benefit to raster modeling is that it aids in the quantification of an area numerically, which has benefits for statistical analysis. The drawback to raster modeling is the cell size, typically 30m x 30m. However, many raster elevation models are available at 1 meter x 1 meter resolution, and it is very likely that better resolution will be available in the near future.

The benefit to the vector model is that it allows the user to cut, clip, overlay, express values, and query information (census for example) in a smaller scale than what is possible with raster cells, and many times with pre-existing AutoCAD drawings that are imported and georeferenced. Vector layers can also be used to calculate irregular volumes, such as cut / fill, a body of water, or an amount of snowfall. The drawback is that there are not as many complex mathematical relationships in the ArcGIS toolbox for combining vector layers. Typically vector layers are used to create color overlay analyses, such as those introduced by McHarg.

Statistics vs. Color Overlay

For the sciences, opaque color overlays giving a percent of opacity to a factor which determines that factors overall weight, is not a valid method because it does not have a statistical basis. For the architecture, planning and design professions this statistical hump is not necessarily as limiting, and in fact, it is this authors suggestion that the ability to perceive color differences, understand the strength of factor interactions based on that color combination, and derive a meaningful analysis from a color overlay with associated survey or user data to support analysis, is what separates architecture, planning and design from the sciences. This author also suggests that analyzing a color overlay and running a numeric statistic are similar analytical operations which can derive similar solutions. Statistics is a more widely accepted method for validation among the sciences, can be displayed using formulas, ends in a concrete numeric result, and are repeatable tests from which to begin an Aristotelian analysis of dependent and independent factor relationships. Color overlay has a qualitative result (ie. the area has a yellow /purplish hue indicating medium impacts) which can be interpreted in different ways, does not leave the user with a concrete numeric result, and is more difficult to repeat.

This author suggests that a combination of quantitative and qualitative methods should be used for overlay mapping. By using a regression technique, strong relationships between dependent and independent factors can be identified to ensure proper selection of variables. The statistically validated variables can then be employed for color factor overlay and utilized as plastic guidelines for planners and architects.

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APPENDIX 1

Step 1: Environmental Vulnerability Raster Model

Create slope map from digital elevation model

1. Download National Elevation Dataset (NED) from USGS Seamless Data Distribution website (www.seamless.usgs.gov).
2. Create new site boundary polygon shapefile from georeferenced ortho-image or scanned map.
3. Clip NED based on site boundary.
4. Use 3D analyst to convert NED to slope.
5. Reclassify slope values (*Table 5*). (note in this example the shapefile classes are on the left (in percent) and the new reclassified value area on the right (ranked/ordinal)).

Reclassification	
Old values	New values
0 - 0.5	1
0.5 - 2	2
2 - 4	3
4 - 8.33	4
8.33 - 10	5
10 - 15	6
15 - 27.04	7
NoData	NoData

Table 5. Slope Value Reclassification

Create soil capability class rankings for site

1. Download MUSYM soil polygons from local state run data source (many universities around the US have data clearing houses for their state). These data sets were paid for by government funded programs or grants and are therefore public property, Being creative in the search for free geospatial data is critical to keeping the cost of a project down. Satellite

imagery and ortho-images are often the most difficult to obtain free, and can cost from 25-1000's of dollars depending on the area and scale.

2. Use SCS soil survey to obtain capability classifications for all soil types on site and create a new column in the attribute table of the MUSYM data

3. Reclassify soil polygons on site with category I being least vulnerable and category VIII as most vulnerable (*Table 6*)

Reclassification	
Old values	New values
I	1
II	2
III	3
IV	4
VI	5
NoData	NoData

Table 6. SCS Capability Class Reclassification Table

Native Vegetation Map

1. Determine areas of native, non-native and mixed vegetation from aerial photo interpretation and field studies. This step is done with a vegetation field survey of the study site by a vegetation geographer or other ecologist. GPS units are used to define native, mixed and non-native polygons on the ground and upload the elevation points to a shapefile.
2. Create new column in vegetation polygons attribute table and add the values of 1 for nonnative vegetation units, 2 for mixed, and 3 for native units.

3. Develop map of rangeland productivity rankings for all soils on site

Rangeland Productivity

4. Use the local SCS soil survey to obtain rangeland productivity classifications for all soil types in study area and ascribe the classification to a new column in the attribute table of the musym polygon shapefile.
5. Reclassify values with highest productivity being most vulnerable and lowest productivity being least (*Table 7*).

Reclassification	
Old values	New values
1,000-4,000 lbs/ac	3
2,000-4,000 lbs/ac	2
3,000-5,000 lbs/ac	1
NoData	NoData

Table 7. SCS Rangeland Productivity Reclassification

Vegetation vulnerability index: native vegetation presence x rangeland productivity

1. Use the times tool in ArcToolbox to multiply the two values together to create a native vegetation index for the site
2. Reclassify the product with lowest value being least vulnerable (lowest productivity with crops being vulnerable, and highest productivity with native vegetation being most vulnerable (*Table 8*).

Reclassification	
Old values	New values
2	1
3	3
4	5
6	7
9	10
NoData	NoData

Table 8. Vegetation Vulnerability Reclassification

Environmental Vulnerability Raster Model

1. Use weighted overlay to combine slope, native vegetation index and capability class in a final raster layer with the highest value raster cells being the highest valued habitats and vegetation, and the lowest values being the least valued habitats and vegetation (Table 9). Figure 18 presents the environmental vulnerability map.

Weighted overlay table			
Raster	% Influence	Field Value	Scale Value
⤴ Slope Percent	45	Value	↩
		1	1
		3	3
		4	4
		5	5
		6	6
		7	7
		9	9
		10	10
		NODATA	NODATA
⤴ Capability Class	30	Value	↩
		1	1
		3	3
		5	5
		7	7
		10	10
		NODATA	NODATA
⤴ Vegetation Vulnerability	25	Value	↩
		1	1
		3	3
		5	5
		7	7
		10	10
		NODATA	NODATA

Table 9. Environmental Vulnerability Weighted Overlay

Step 2: Defining Social Values

Visitation

1. Draw polygons of user areas based on predetermined boundaries by existing park maps, or by observed boundaries during user survey.
2. Compile user survey data in attribute tables, formatted as described in the background, and populate each day use area with the record data (create new column for each attribute and add the numbers to the data table).
3. Convert day user areas polygon feature to raster.
4. Rank day use areas based on number of visitors from lowest visitation area to highest visitation area (*Table 10*)

Reclassification	
Old values	New values
6	1
7	1
18	2
36	3
51	4
70	5
72	6
277	7
503	8
769	9
777	10
NoData	NoData

Table 10. Day Use Area Total Visitation Reclassification

Revenue

3. Convert day user areas polygon feature to raster.
4. Rank day use areas based on revenue (*Table 11*) created from licenses observed on vehicles in the area, as described above in *Figure 16*, the section environmental factor justification.

Reclassification	
Old values	New values
107	1
107 - 111	2
111 - 300	3
300 - 1219	4
1219 - 1501	5
1501 - 4355	6
4355 - 4770	7
4770 - 5998	8
5998 - 9166	9
9166 - 13390	10
NoData	NoData

Table 11. Revenue Reclassification

Revenue x Visitation

1. Combine the values 50/50 using a weighted overlay to create a raster output of combined visitation and revenue values for each day use area, with the highest value raster cell having the greatest visitation and producing the greatest revenue.

Weighted overlay table			
Raster	% Influence	Field	Scale Value
⤴ Total Visitation Ran	50	VALUE	↩
		1	1
		2	2
		3	3
		4	4
		5	5
		6	6
		7	7
		8	8
		9	9
		10	10
		NODATA	NODATA
⤴ Total Revenue Ran	50	VALUE	↩
		1	1
		2	2
		3	3
		4	4
		5	5
		6	6
		7	7
		8	8
		9	9
		10	10
		NODATA	NODATA

Figure 12. Visitation and Revenue Weighted Overlay

Step 3: Combine Environmental and Social Values

Final Raster Map (RRD Model)

1. Combine the environmental vulnerability model with the social values using the ArcGIS plus tool (ordinal combination) to create the RRD raster model.

Color Coded Overlay

1. Open the Environmental vulnerability model, visitation layer, and revenue layer in an ArcMap session.

2. Assign a green gradient to environmental vulnerability (63% opacity), a red gradient to visitation (63% opacity), and a blue gradient to revenue (63% opacity).

APPENDIX 2

Operational Definitions

The definitions included in this section are copied directly out of the ArcGIS help screen to help the reader understand ESRI specific terminology which occurs throughout the text, and specifically the methodology. Further instruction or definition should refer to the ArcGIS manuals or help screens

Shapefile

A folder can contain [shapefiles](#), which store geographic features and their attributes. Geographic features in a shapefile can be represented by points, lines, or polygons (areas). The folder might also contain dBASE tables, which can store additional attributes that can be joined to a shapefile's features.

Create a New Shapefile

1. Select a folder or folder connection in the Catalog tree.
2. Click the File menu, point to New, and click Shapefile.
3. Click in the Name text box and type a name for the new shapefile.
4. Click the Feature Type dropdown arrow and click the type of feature the shapefile will contain.
5. Click Edit to define the shapefile's coordinate system.
6. [Select, import, or define a new coordinate system](#), then click OK.

It's highly recommended that you define the shapefile's coordinate system now; however, you can postpone this step until a later time.

7. If the shapefile will store polylines representing routes, check Coordinates will contain M values.
8. If the shapefile will store three-dimensional features, check Coordinates will contain Z values.
9. Click OK.

The new shapefile appears in the folder's contents.

Georeferencing

Raster data is commonly obtained by scanning maps or collecting aerial photographs and satellite images. Scanned map datasets don't normally contain spatial reference information (either embedded in the file or as a separate file). With aerial photography and satellite imagery, sometimes the locational information delivered with them is often inadequate, and the data does not align properly with other data you may have. Thus, in order to use some raster datasets in conjunction with your other spatial data, you often need to align it, or [georeference](#)—it to a map [coordinate system](#). A map coordinate system is defined using a map projection (a method by which the curved surface of the earth is portrayed on a flat surface). When you [georeference your raster dataset](#), you define its location using map coordinates and assign a coordinate system. Georeferencing raster data allows it to be viewed, queried, and analyzed with other geographic data.

Weighted Overlay

Overlays several rasters using a common measurement scale and weights each according to its importance. The two input rasters have been reclassified to a common measurement scale of 1 to 3. Each raster is assigned a percentage influence. The cell values are multiplied by their percentage influence, then added to create the output raster. For example, consider the top left cell. The values for the two inputs become $(2 * .75) = 1.5$ and $(3 * .25) = .75$. The sum of 1.5 and .75 is 2.25. Because the output raster from Weighted Overlay is integer, the final value is rounded to 2.

Downloading Data

Free data can be downloaded from many state and national sources. Most states have at least one university with a university that hosts a state wide geospatial database that has been used in state sponsored research. National datasets such as USGS, USDA, NOAA, NPS, ESRI, Tiger, US Census, Datagateway, or Geography Network contain a broad range of geospatial data such as hydrology, digital elevation, land use, roads, railway, state, counties, and census boundaries. Most data is downloaded as a zipped file then unzipped onto a harddrive. Some data is already converted into shape files, and some data is unzipped as a .e00, dem, or other file type. Using the ArcCataloge ArcView 8x toolbar the user can convert these file types into shapefiles or raster layers.

Clipping

If you need the shape of a [data frame](#) to be something other than rectangular, you can clip your data frame to meet your map specifications using the Clip to Shape data frame property.

ArcMap will use a shape that you specify to clip the drawing of a data frame. For example, you can draw a graphic circle in a data frame and clip your data frame to it. Clipping results in drawing only the region of the data frame bounded by the circle, with nothing drawn in the space between the edges of the circle and the bounding box of the data frame.

ArcMap can use the following as cglipping shapes:

- Any shape you draw with the Draw toolbar inside a data frame
- All the features in a specific layer, for instance, a state or country polygon boundary
- Any selected feature in a specific layer

- A rectangle defined by specific coordinates that you supply

3D Analyst

The 3D Analyst toolbar in ArcMap allows the user to create contour, slope, aspect, hillshade, viewshed, and line of sight maps and cross-sections from a NED or DEM. Volume calculations of cut/fill, area and volume calculations, reclassify, and surface conversions of raster to features, raster to TIN, and TIN to raster.

The NED (national elevation dataset) or DEM (digital elevation dataset) surface is a compilation of blocks with assigned elevation points that simulates a 3D surface. A TIN is a triangulated area network. A TIN creates a surface later from the NED by connecting the centroid (center point) in each raster cell with lines that simulate a 3D surface. For 3D rendering, area and cross section calculations a TIN surface is more realistic and accurate. For Raster Models, like the one here, 2D NED surfaces are better because they are divided into standard sized units which aids the factor combination process.

Slope

The Slope function calculates the maximum rate of change between each cell and its neighbors, for example, the steepest downhill descent for the cell (the maximum change in elevation over the distance between the cell and its eight neighbors). Every cell in the output raster has a slope value. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. The output slope raster can be calculated as percent of slope or degree of slope.

When the slope angle equals 45 degrees, the rise is equal to the run. Expressed as a percentage, the slope of this angle is 100 percent. Note that as the slope approaches

vertical (90°), the percentage slope approaches infinity. The Slope function is most frequently run on an elevation dataset, as the following diagrams show. Steeper slopes are shaded red on the output slope raster. It can also be used with other types of continuous data, such as population, to identify sharp changes in value.

Reclassify

You may want to reclassify a range of values to an alternative value and another range to another alternative value. For example, in a building suitability model for a house, on the input landuse raster all the residential and human activity range from 0 to 9, the forest values range from 10 to 19, and the agriculture from 20 to 29. You may want to assign a suitability of 1 to the landuse values 0 through 9 (the human activity), a 5 to landuse values between 20 and 30 (the agriculture), and a 10 to landuse values between 10 and 19 (the forest). It would be tedious if you would have to explicitly specify each existing landuse value and then the alternative values since there are many values.

The capability of reclassifying ranges of values becomes even more critical when reclassifying continuous data. For example, if you were reclassifying elevation values for a bird habitat model, you may want to reclassify elevation values of 1000 to 1500 meters above sea level to a 10, 750 to 1000 to a 8, and so forth. Since elevation is a continuous surface, cell values may include values such as 1005.34, 1324.50, 743.89, 312.45, etc. It would be very difficult and time consuming to explicitly specify each individual elevation value on the input raster and its corresponding alternative value. Also, chances are, you would never need to for most analysis because most analysis would be applied to elevation values that are grouped into ranges

ArcToolbox

ArcToolbox is the ESRI program controlling the conversion formulas for ESRI GIS. Every graphic overlay, statistical calculation, or surface analysis is accessible through this interface. When building in ModelBuilder the toolbox is a useful user interface for dragging and dropping commands between layers.

Upload using GPS Points

To make the vegetation map this author used a GPS to ground truth observations made from orthoimages or elevation datasets. Vegetation groups are encircled while holding the gps and making notes on the map, then the points are uploaded to a shapefile and coded with the information from the map notations. The method is accurate to within 14 cubic feet with most handheld GPS units, and accurate to within 1 or 2 cubic feet with a Trimble backpack unit.

Times Tool

Multiplies the values of two rasters on a cell-by-cell basis.

Plus Tool

Adds the values of two rasters on a cell-by-cell basis.

APPENDIX 3

CHEYENNE																
	Visitors				Vehicles					Watercraft					Permit Type	
Date	Seniors	Adults	Children	Absent	Car	Truck	SUV	Van	RV	Ski	Fishing	Hum__Pow	Trailer	Jet_Ski	Ann_Vhcl	Day_Vhcl
5/29/2004	0	23	36	0	2	0	2	2	9	8	0	0	0	0	12	3
6/2/2004	0	10	0	14	0	5	0	0	5	0	1	0	0	0	19	0
6/3/2004	0	9	2	0	3	4	1	0	0	0	4	0	0	0	4	1
6/5/2004	0	28	3	3	2	8	0	0	13	2	0	0	0	0	18	0
6/6/2004	1	0	0	2	1	1	0	0	3	1	0	0	0	0	3	0
6/8/2004	0	0	0	15	0	0	0	0	15	0	0	0	0	0	15	0
6/11/2004	0	4	2	14	0	2	0	0	5	0	0	0	0	0	5	0
6/15/2004	4	0	2	17	0	2	0	0	17	0	0	0	0	0	19	0
6/17/2004	0	6	6	17	0	5	0	0	20	1	0	0	0	0	20	0
6/21/2004	4	3	1	16	3	3	0	0	21	0	1	0	0	0	20	2
6/24/2004	2	2	0	19	0	1	0	0	5	1	1	0	0	0	5	0
6/25/2004	2	22	17	14	3	7	3	0	8	4	2	0	0	1	10	4
6/27/2004	2	16	32	10	0	9	2	0	12	4	1	0	0	5	5	0
6/28/2004	2	0	0	3	0	2	1	0	3	0	0	0	0	0	0	0
6/30/2004	4	0	3	18	1	1	0	0	4	2	0	0	0	0	4	0
7/2/2004	4	38	29	16	7	17	2	0	30	3	6	1	0	2	22	8
7/7/2004	0	0	0	14	1	0	0	0	14	0	0	0	0	0	14	0
7/12/2004	2	4	2	11	0	3	0	0	18	0	1	0	0	0	4	0
7/16/2004	0	2	0	13	1	0	0	0	14	0	0	0	0	0	2	1
7/20/2004	0	0	0	16	0	0	0	0	16	0	0	0	0	0	16	0
7/22/2004	0	0	0	5	0	0	0	0	5	0	0	0	0	0	5	0
7/27/2004	2	2	0	14	0	20	0	0	2	0	0	0	0	0	3	1
7/30/2004	4	8	8	14	0	5	0	0	6	0	1	0	1	0	3	3
8/1/2004	3	27	39	2	5	9	4	0	11	3	1	0	0	1	6	5
9/5/2004	0	14	66	0	11	22	6	0	29	1	6	0	0	4	22	16
Totals	36	218	248	10	40	126	21	2	285	30	25	1	1	13	256	44
Total Visitors	502															
Total Revenue	13390			1078.3												
Revenue per Visitor	26.674														11648	352

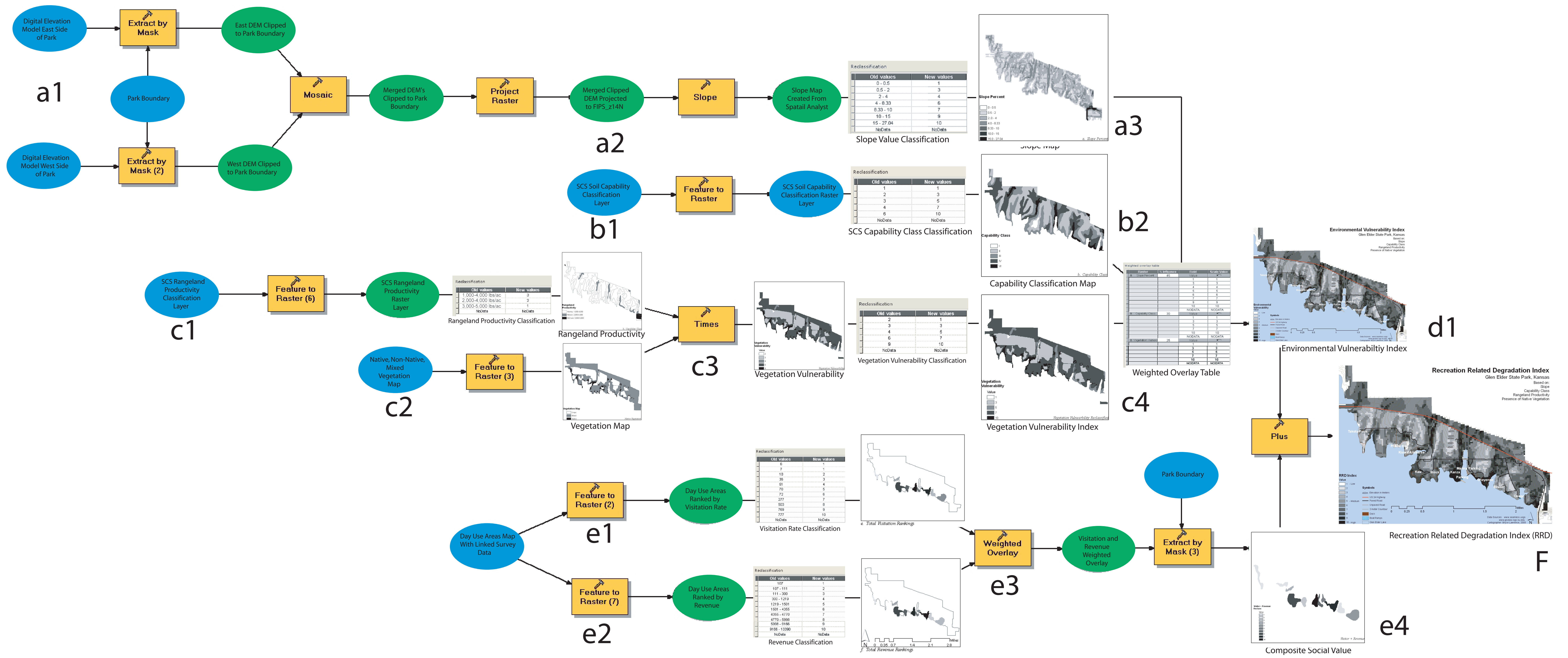


Figure 17: ArcGIS ModelBuilder diagram depicting entire raster model modeling process necessary to identify areas susceptible to recreation related degradation