An Approach to Open Space Planning Based on the Principles of Landscape Ecology: An Application to Greater Roanoke Area

by
Rekha Rao

Thesis submitted to the faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
Masters of Landscape Architecture

Approved:

Professor Lee Skabelund

Professor Eran Ben Joseph

Professor John Randolph

May 5, 1997
Blacksburg, Virginia

Key words: landscape ecology, landscape planning, county open space planning

An Approach to Open Space Planning Based on the Principles of Landscape Ecology: An Application to Greater Roanoke Area

by
Rekha Rao

(ABSTRACT)

Committee Chairperson: Professor Lee Skabelund
Department of Landscape Architecture

The population of Greater Roanoke Area during the last decade grew by ten percent. The recent growth has changed the countryside. The agricultural lands in this area has been replaced by sprawling housing subdivisions and strip commercial development. Greater Roanoke Area and its surrounding areas now face problems of traffic congestion, visual and environmental degradation due to commercial and residential growth. Greater Roanoke Area will need an innovative open space plan which preserves the natural character and unique qualities of the place. Many other regions and counties in the United States share similar concerns and needs.

There has been parallel progress in the field of landscape ecology and landscape planning for better understanding of our environment. The primary goal of this thesis is to use concepts from both of these fields with an intent of developing an approach which will help both planners and landscape architects to plan and design for open space in a way that meets long term ecological needs and concerns. This thesis develops a process whereby an optimum spatial pattern for Greater Roanoke Area (one that maintains biodiversity, protects natural and cultural resources, improves water quality, protects soils, and increases productivity) is derived. This open space planning approach can in turn be used to guide other regions and counties in developing ecologically grounded open space plans.

Spatial attributes, functions and the change dynamics of the landscape are targeted and analyzed to provide a foundation for an open space plan. Management priorities are then established for protecting, enhancing, and restoring agricultural lands, forest lands, wetlands, streams, and special sites. The tools for preserving open space areas are education, community involvement and government regulations.

Acknowledgments

I would like to thank my committee chairperson Professor Lee Skabelund and my committee members Professor Eran Ben Joseph and Professor John Randolph for their encouragement and support. I am particularly grateful to Lee Skabelund for his mentoring, patience, and dedication.

A special thanks to my husband, parents, and my aunt for their patience, encouragement, and support. I would also like to thank Matt Miller from the Fifth Planning District Commission, Dave Morton and Blair Jones from the Fish and Wildlife Information Exchange, and Janette for helping me in the data collection. I would also like to thank Kalpana for helping me edit parts of the thesis document.

Table of Contents

List of Figures

List of Tables

Chapter 1 Introduction

Humanity has been altering natural ecosystems for centuries (Diamond, 1994). However, it is only in the past two centuries that these alterations have become very significant. This is attributed to a combination of factors which includes industrialization, extensive use of fossil fuels, and rapid population growth (Cairns, 1995; Lewis, 1996; Ayres, 1956). The availability of cheap energy has helped many people throughout the globe achieve a high standard of living, but it has alienated them from nature. Cheap energy has also allowed unprecedented growth throughout the globe. This has, to a large extent, led to the degradation of natural ecosystems resulted in the extensive loss of plant and animal species.

The environmental problems we face today include poisoned air, polluted water, and depletion of resources. The depletion of resources frequently leads to irreversible damage in the human timeframe to landscapes and ecosystems and may result in desertification, salinization, soil erosion, and habitat loss (Lyle, 1994). There are lessons to be learnt from the past. Ancient civilizations were aware of the consequences of environmental degradation. As early as 360 BC, the noted Greek philosopher Plato realized the importance of natural processes in ecosystems though he did not describe it in those terms. He warned his countrymen about the dangers of overuse of land (Forman, 1987). One of the factors attributed to the decline of the ancient civilizations in the Middle-East and Mediterranean regions was overuse of land resources which subsequently led to salinization and desertification of the landscape (Diamond, 1994).

"Before the agricultural revolution, alteration of natural systems was carried out mainly by setting fires, selective hunting, and modest clearing of forests" (Cairns, 1995:18). These changes were temporary, and the modified systems reverted back to their original state through time. The origins of agriculture, which can be traced to the last ice age, brought a more permanent change to landscapes and ecosystems (Forman, 1995). During the agricultural revolution, land was cleared for growing specific crops. This involved modification of natural seasonal rhythms of certain perennial and annual plants such as rice, wheat, and corn (Forman, 1986). It was done by plowing and working the soil. Intensive agricultural practices helped to increase the carrying capacity of the land for human populations. Even so, vast tracts of terrestrial ecosystems remained undisturbed (Ehrlich, 1993). Because human populations were relatively small, and technology and affluence relatively modest, the modifications and wastes generated during this period were more easily incorporated into natural systems. The industrial revolution saw a demand for minerals and fossil fuels. During this period, agricultural systems began to depend heavily on fossil fuels as a way to achieve higher productivity. The wastes generated by contemporary industries and societies were not easily incorporated into natural systems (Cairns, 1995).

The environmental problems we face today are at both a regional and global scale. The global problems we face today include depletion of the ozone layer, global warming due to the greenhouse effect (Schneider, 1989), the rapid loss of plant and animal species (Cairns, 1991), the persistent problems of desertification in the semi-arid regions of the world, and the loss of prime agricultural land. Both developing and developed countries of the world face problems related to resource depletion. In developing countries this problem is due to explosive population growth, and in developed countries it is due to high energy and resource consumption. According to Lewis "The United States has five percent of the world's population but it consumes twenty four percent of the world's resources" (1996:5). Many regions of the world face problems of urban sprawl due to lack of planning and the dependence on automobile transportation. Hence, it is necessary to establish connections between man and nature through the preservation and creation of open spaces for the well being of humans and for the broad range of plant and animal species (Lewis, 1996).

1.1 Degradation of North American Landscapes

Contrary to common belief, the degradation of the North American landscape began long before the European expansion into the continent. A well documented example is that of the Anasazi civilization in the New Mexico region (Diamond, 1994). This barren New Mexico landscape was once covered with forests and supported a variety of wildlife. Deforestation led to erosion, and ultimately this landscape was converted into a desert. The physical record of this change is the gigantic pueblos located in the New Mexico desert. However, the ecological degradation during the Anasazi civilization was at a regional scale. The European expansion into the continent that occurred after the fall of the Anasazis led to a more rapid degradation of ecosystems and at a much larger scale. Within a short period of time, people spread across the entire continent. This expansion into less touched areas was accompanied by a doubling of the European population. The combined introduction and use of fossil fuels led to massive deforestation and elimination of vast numbers of species (Ehrlich, 1993). The ploughing of the prairies and the great plains to feed increasing human populations and a disregard for the land and species brought large mammals such as the bison to near extinction (Ehrlich, 1993). The extensive use of fossil fuels in United States began with the discovery of the internal combustion engine (Ayres, 1956). The age of automobiles had dawned, and distance was no longer a real constraint. People moved to places far away from their place of work. Houses and subdivisions encroached on the surrounding landscapes and replaced agricultural lands, forests, and wetlands. Animals with large home ranges and higher tropic levels were the first to disappear due to loss of habitat and fragmentation (Forman, 1986). Stream pollution increased due to runoff from urban areas and agricultural lands, and there was a general reduction in the diversity and richness of natural landscapes.

1.2 The Need for Regional Open Space Planning

The emergence of cities from villages were in large part due to improvements in plant cultivation and storage of food. The chief determinant of large scale urbanization was proximity to fertile agricultural lands. Yet paradoxically the growth of most cities eventually covered these fertile lands (Mumford, 1956). In North America at the turn of the century, the regional matrix was either agricultural land or natural area. But today the matrix of many regional landscapes in the United States is urban and/or suburban lands.

According to Steinitz (1978), the key problem faced by regional landscapes is urbanization. Rapid urbanization has led to homogenization of landscapes and loss of regional identity (Steinitz, 1978). A significant problem associated with urbanization and suburbanization is fragmentation of natural and agricultural ecosystems (Forman, 1987). Fragmented landscapes hampers the movement of animals, birds, and seeds. They also reduce the potential food sources and habitat size for wildlife (Forman, 1987).

Greater Roanoke Area provides a useful case in point. During the last decade the population of the county grew by ten percent (Edwards, 1995). "It is predicted that by 2030, Roanoke Valley and the New River Valley will be a home to 602,000 people. This is a 17% increase from the early 1970s" (McCue and Vertefeulle, 1995:A1). The recent growth has changed the countryside. The fertile, verdant countryside has been replaced by sprawling housing subdivisions, and strip commercial development (Roanoke Times Editorial, 1995). The growth in Greater Roanoke Area has also affected neighboring counties (McCue and Vertefeulle, 1995). Greater Roanoke Area and its surrounding areas now face problems of traffic congestion, and visual and environmental degradation due to widespread commercial and residential growth (Jackson, 1995).

It may be argued that what Greater Roanoke Area needs is an innovative open space plan which preserves the natural character and unique qualities of the place. In order to do this, planners, developers, citizens, and county leaders must look beyond the surfaces. Landscape structure is important but landscape functions, in essence the processes at work and roles that various ecosystems and elements play, must also be considered and the potential for change understood and accounted for.

1.3 Research Problem and Goals and Objectives of this Thesis

The main objectives of the thesis are:

- To develop an open space planning approach for counties based on the principles of landscape ecology;
- To integrate theoretical aspects of landscape ecology with the regional landscape context and existing county plans for the use and protection of open spaces; and

- To develop an open space planning approach that could be used by all counties and regions interested in protecting the ecological integrity of their landscapes through time while meeting the socio-economic needs of the citizens within these areas.

The primary goal of this thesis is to develop a process whereby an optimum spatial pattern for counties and regions (one that maintains biodiversity, protects natural and cultural resources, improves water quality, protects soils, and increases overall productivity) is derived. The proposed approach to open space planning is based on theories related to landscape ecology. Spatial attributes of the landscape (patches, corridors, networks and dominant mosaic patterns) are analyzed to provide a foundation for the open space plan. In 1969, Ian McHarg introduced an approach to analyzing landscapes that linked design with the environment. *Design with Nature* was a text written to try and convey how linkages between landscape design and the surrounding environment could be made. McHarg sought to connect planning and ecology by overlaying maps of soil, hydrology, topography, vegetation, elevations, wetlands, etc., to identify the locations of the most suitable or appropriate future land uses. The use of principles from landscape ecology goes a step further. Landscape ecology considers structure, function, and change to analyze and manage landscapes.

In tandem with my first goal is my desire to help re-establish the ecological integrity of counties and regions through ecological planning. According to Noss (1995), the concept of ecological integrity is broader and more biocentric than sustainability. The term “ecological integrity”, in context of the natural environment, was first used in 1949 by Aldo Leopold in his book *Sand County Almanac* in context to land ethics. Noss argues that ecological integrity can be maintained when changes caused by humans are within the functional, evolutionary and historical limits characteristic of each ecosystem (1995).

The thesis involves the following activities:

- Assessment and evaluation of ecological planning theories articulated by landscape ecologists and planners such as Richard Forman, Ian McHarg, John Lyle, Frederick Steiner, and Phil Lewis.
- Development of a an approach that can be applied to regional and sub-regional landscapes based on these theories.
- Modifications to traditional open space planning approaches to deal with issues related to loss of biodiversity, air and water pollution, and environmental degradation.
- Assessment of the existing greater Roanoke area open space plans, *Roanoke Valley Greenway Plan* and *Roanoke River Corridor* study.
- Discussions with the Fifth Planning District Commission and planners working for Roanoke. Because Roanoke is revising its Open Space Plan this thesis project should be a useful contribution to their planning process.

At the outset of this thesis it should be noted that this approach is limited to the analytical part of the planning process with the primary concern being the protection of natural systems. Open space plans must incorporate public participation and political processes if it has to be effective. This thesis does not address these processes in detail.

It should also be noted landscape ecology is a transdisciplinary field. It covers a wealth of knowledge from other fields such as geography, ecology, biology, geology, geomorphology, etc. This thesis is limited to a small part of these disciplines. Also, landscape ecology is relatively a new field. Hence, many of the theories related to landscape ecology have not been time tested. Moreover, landscape ecology is not a perfect science. This is because ecosystem processes are complex and not fully understood. It is important to consider that this thesis is just a start for planners and landscape architects who seek to incorporate ecological principles into county and regional open space planning processes. Much work lies ahead!

1.4 Organization of this Thesis

Chapter 1 provides background information on the need for ecological and regional open space planning. It states the goals and objectives of the thesis and briefly explains the thesis approach. It also establishes the scope and mentions a few limitations of this thesis. Finally, it explains the organization of the thesis.

Chapter 2 reviews the literature most relevant to open space planning from a landscape ecology and ecological planning point of view. The chapter explains the approaches used by various landscape planners and landscape ecologists to analyze landscapes and discusses the use of ecological planning principles for open space planning. The landscape planners and landscape ecologists studied include Richard Forman, Ian McHarg, John Lyle, Frederick Steiner, and Phil Lewis.

Chapter 3 presents case studies for the Town of Dunn, Wisconsin Open Space Plan and the Durham County, North Carolina Open Space Plan.

Chapter 4 explains the approach developed to analyze and design open space plan for regional and sub-regional landscapes. The approach is primarily based on the literature review and the two case studies summarized in chapters 2 and 3.

Chapter 5 presents an application of the open space planning approach to Greater Roanoke Area. The chapter also presents data collection, background information and previous studies done for the county. Data collection includes information on geomorphology, land cover and wildlife. The chapter reviews the Roanoke Valley Open Space Plan, Roanoke Valley Greenway

Plan and Roanoke River Corridor Study. The chapter has relevant maps to show how landscape ecology principles can aid us in preparing spatial plans for counties and regions.

Chapter 6 presents the conclusions for this thesis. A discussion of the strengths and the weaknesses and practical applications of the open space planning approach is provided as an evaluation of the work herein.

Chapter 2 Literature Review

2.1 Use of Ecological Principles in Landscape Architecture

In North America the use of ecological principles in landscape architecture had humble beginnings. It began with the use of native plants for landscaping. The concept of landscapes as systems, and the systematic analysis of landscapes emerged much later (Zube, 1986). The use of native plants for landscaping originated in the Midwest. The Midwest landscape architect O. C. Simmonds used native plants in his designs as early as 1880 (Zube, 1986).

The concept of 'landscape as systems' was used by Olmsted in his designs for parks in New York City and Boston. In 1866 Frederick Law Olmsted and Calvert Vaux designed Prospect Park as a part of a larger system of open spaces for New York City. Olmsted designed a more elaborate open space plan for Boston. The aim of Boston Open Space Plan was to reestablish the integrity of the degraded drainage system, improve sanitation, regulate stormwater, and restore the salt marshes (Spirn, 1985 cited in Zube, 1986). Boston in the late 1800's faced problems of flooding and pollution due to increased urbanization. Olmsted designed an open space system for Boston around the existing drainage system.

The systematic analysis for studying landscapes was developed by Warren Manning. Warren Manning was one of the earliest landscape architects to use overlay method for landscape analysis. According to Manning, responsible planning should be based on the knowledge of physical resources and the cultural conditions of a place (Zube, 1986). It was Ian McHarg in the east and Phil Lewis[1] in the mid-west, who introduced a rational, multidisciplinary approach to landscape planning (Zube, 1986). Regional and sub regional plans were prepared based on comprehensive field studies and suitability analysis. Suitability analysis involved evaluating lands for human use by selectively overlaying information obtained from studies of geology, hydrology, soils, plant ecology, wildlife, and land uses. The lands were then ranked based on their suitability for conservation, passive recreation, residences or industries (McHarg, 1969). McHarg's method was further developed by Carl Steinitz and Julius Fabos in the 1970's and the 80's. Carl Steinitz and Julius Fabos used computer programs to do complex landscape data analysis (Zube, 1986). Computers allowed for much greater flexibility in overlaying and comparing landscape variables.

---

[1] Lewis later on expanded on this concept and introduced a totally different perspective into regional based ecological planning. In his book *Tomorrow by Design: A regional Design Process for Sustainability* (1996), Lewis emphasized the importance of scale in landscape planning. He also emphasized the importance of linking urban and natural systems into the regional planning process. Lewis advocated involvement of citizens and the use of educational tools in regional landscape planning, similar to Steiner's call for frequent and active public participation in ecological land planning efforts.

John Lyle was perhaps one of the first landscape architects to formally discuss the importance of sustainability in large scale landscape planning. Lyle linked principles of ecology and landscape ecology with land planning. His ideas were strongly influenced by the works of Eugene Odum (Lyle, 1985). It was Frederick Steiner (1991) who introduced the ecological planning model for regional planning processes. He suggested "the inventory and analysis of biophysical and socio-cultural information to suggest opportunities and constraints in decision making about the use of the landscape" (Steiner 1991:15). Community education, citizen involvement, administration, and implementation strategies played a very important role in this ecological planning model.

The field of landscape architecture and landscape ecology developed independently from each other. It is only in the past few decades that landscape architects and planners such as Ian McHarg, John Lyle, Frederick Steiner, Phil Lewis, and others, and landscape ecologists such as Richard Forman, Michel Godron, A. P. A. Vink, and others, have tried to link the two fields together. The field of landscape ecology has contributed a lot to the regional landscape process.

2.2 Background Information on Landscape Ecology

Neveh and Lieberman (1984) describe landscape ecology as a field of modern ecology. However at a workshop held by landscape ecologists in 1983, landscape ecology was described as a synthetic intersection of many related disciplines that focus on spatial and temporal patterns. As such landscape ecology is viewed as a transdisciplinary field encompassing knowledge from fields such as geography, geology, biology, and soil sciences (Forman and Zonneveld, 1989; Risser et al, 1984).

Landscape ecology has a geographical and biological background (Forman, 1986; Vink, 1983). The roots of landscape ecology can be traced to central and east Europe. Troll, a German biogeographer, used the term landscape ecology in 1938 while studying land use problems in East Africa (Turner, 1989; Neveh and Lieberman 1984; Vink, 1983). Troll used aerial photographs to study and analyze landscapes. Remote sensing data such as aerial photographs allowed visual examination of large areas of land. Aerial photographs permitted landscape ecologists to study broad landscape spatial patterns (Way, 1973). This was an important step in the history of landscape ecology since analysis of spatial patterns and relationships is the basis for landscape ecology.

In the United States, Aldo Leopold was perhaps the earliest spokesmen to introduce the landscape perspective in ecology. One of Aldo Leopold’s early writings, *A Sand County Almanac (1968)* has been very influential in increasing the awareness of relationships between landscape and ecology (Risser et all, 1983) The field picked up momentum in the late 1970’s and 1980s with the works of Forman, Zonneveld, Neveh, Lieberman, Risser, Vink, and others. Today it is a well researched area. Richard Forman’s book on landscape ecology *Land Mosaics*

(1995) is especially useful to landscape architects and planners. This book contains information on the practical applications of landscape ecological principles for regional planning. A further help for planners and landscape architects is the book *Landscape Ecological Planning in Landscape Architecture and Land Use Planning* (1996) written by Wenche Dramstad et al. This book gives simplified ecological planning models and guidelines that can be used by landscape architects and planners to plan and design landscapes based on landscape ecological principles.

2.3 Landscape Ecology Theory

The books and articles written by Vink (1983), Neveh and Lieberman (1984), Forman and Zooneveld (1986) and Forman and Godron (1986) are perhaps the clearest in explaining the theories used by landscape ecologists for studying landscapes. The books written by Vink (1983), and Neveh and Lieberman (1984) discuss the theoretical aspects in landscape ecology and its application to land use planning. These books also discuss in detail approaches used by some landscape planners and ecologists in land use planning. Some of the methodologies described in the book are Generalized Ecological Model by Van der Maarel and Dauvellier developed in Netherlands (1978) and METLAND model developed by Fabos and Caswell in Massachusetts (1977). The article written by Forman and Zooneveld (1986), discuss the history and theory of landscape ecology. The book written by Forman and Godron (1986) gives a brief introduction to landscape ecology and discusses at length the relationship between landscape structure, function, and change.

The theories of landscape ecology sets foundation for the discussion of approaches used by Richard Forman, Ian McHarg, John Lyle Frederick Steiner, and Phil Lewis for landscape planning. The approaches, discussed later in this chapter, use some of the ecological theories (explicitly or by implication) discussed below.

1. All living systems in the biosphere are open systems. There is continuous exchange of energy, nutrients and minerals between these systems and between the atmosphere and these systems (Neveh and Lieberman, 1984; Vink, 1983; Forman and Zooneveld, 1986).
2. Ecosystems are made up of elements that interact with each other. These elements are necessary for the overall functioning of the ecosystem. The classification of these elements are based on their functional attributes in the system's energy or matter flow, e.g. producers, consumers, and decomposers (Neveh and Lieberman, 1984).
3. Landscape ecology uses simplified, abstract models to represent complex ecological systems. It uses the concept of black boxes to analyze functional attributes of any systems. In other words, elements from each tropic levels are considered as black boxes (see Figure 2.1). The individual structure or function of these elements are not considered for analysis of ecosystems, rather the interactions between these tropic levels are critical for the ecosystem functioning (Neveh and Lieberman, 1984; Forman and Zooneveld, 1986).

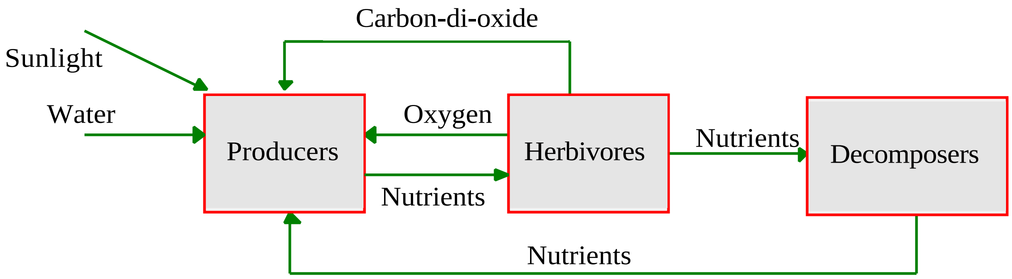

Figure 2.1: Interactions BetweenTropic Levels

4. Landscape ecology considers ecosystems as holistic entities where the total ecosystem is greater than the sum of its parts (Neveh and Lieberman, 1984; Forman and Zooneveld, 1986).
5. Ecosystems work on the principle of self stabilization and self organization[2]. It has negative and positive feedback systems which help maintain the ecosystem in relative equilibrium (see Figure 2.2) (Neveh and Lieberman, 1984; Vink, 1983).

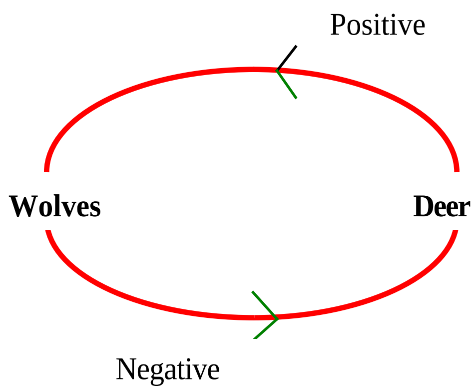

Figure 2.2: Positive and Negative Feedback System

6. The aim of landscape ecology is to achieve a balance between natural ecosystems, agricultural bio-ecosystems, rural-techno ecosystems and urban ecosystems (Neveh and Lieberman, 1984).
7. The term "landscape" has a variety of meanings. Landscape painters consider landscape as an aesthetic element. "In earth sciences like geomorphology, geology, soil science, and vegetation science, landscape is used to indicate the pattern of individual surface patches belonging to each of the land attributes that are the subject of these sciences" (Forman and

[2] An example of this is the feedback system between wolves and deer. Wolves feed on deer. An increase in the deer population leads to a corresponding increase in the wolf population. As the wolf population increases the deer population decreases. This in turn decreases the wolf population and the cycle repeats.

Zooneveld, 1986:5). Landscape ecology considers landscape as a group of ecosystems and encompasses concepts from the previous definitions of landscape. Ecosystems are the result of certain factors acting on them. These factors may be biological (biotic components), physical (abiotic components such as soil, geology, and climate) or noospherical (related to human beings). "These factors form a complex three dimensional phenomena which can be recognized visually as horizontal patterns of mutually related elements and vertically as mutually related strata. It also includes a fourth dimension which is time" (Forman and Zooneveld, 1986:5).

8. Every landscape has a distinct vertical and horizontal structure (see Figure 2.3). This three dimensional structure is formed as the result of interactions between energy, materials, and species. Landscapes are dynamic systems and change over time. Landscape ecology focuses on studying these spatial and temporal patterns to help us understand how landscapes and ecosystems function and change over time.

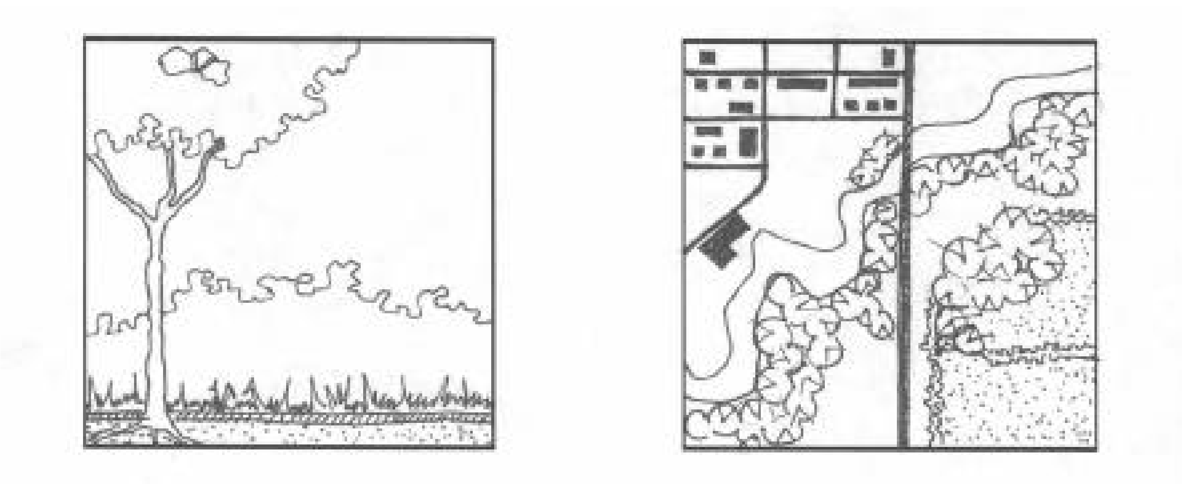

Figure 2.3: Vertical and Horizontal Structure

There is a strong link between landscape ecology and landscape architecture. Both landscape ecology and landscape architecture closely consider spatial patterns to plan for, manage, and modify landscapes. Landscape ecology links environmental issues with landscape planning and looks at landscapes in four dimensions, i.e., the vertical structure, the horizontal structure, and time. Frequently traditional landscape architectural planning processes compartmentalizes[3] landscape analysis whereas the landscape ecological planning process follows a more integrated approach that links the landscape structure with processes producing them.

[3] Landscape elements such as geology, vegetation, soils, and wildlife are studied in isolation rather than interrelated elements.

2.4 Defining Open Space

Studies on open spaces have shown that there is no single definition for an open space or a open space plan. Each of the open space planning books that was referred to included a different definition for an open space. The definition proposed by Forman is quite broad. According to Forman "an open space plan is the one that provides for an integrated system of land and water resources and should be supported by a rational basis for land use decision making" (1995:462). An open space plan is prepared by locating and analyzing broad patterns of vegetation and land uses in a landscape. The connectivity and functions of these areas are also considered in the open space plan. This forms the basis for planning open spaces. Landscape connections and landscape processes are thus paramount in open space planning derived from an ecological basis.

According to Lewis (1996), open space for regional areas includes areas with timber, rivers, small farms, and historic sites. These areas are located between large urban constellations. In Wisconsin, Lewis called a large area of open space the "driftless area". Open spaces may function as biosphere reserves for agricultural/forestry production and/or as recreation areas. The open space also includes environmental corridors and large parks within urban constellations. Open spaces are areas that play an active part in air and water quality improvement (Lewis, 1996).

Open Space in the Roanoke County Comprehensive Plan refers primarily to recreational resources, but also incorporates some environmentally sensitive areas such as floodplains, drainage areas, steep slopes, and unstable soils. These areas are considered individually rather than in integrated units. In the *Town of Dunn Open Space Preservation Handbook*, the phrase "open spaces" relates to natural areas such as woodlands and wetlands. In Durham County Open Space Plan, open spaces are environmentally sensitive areas and natural resource lands. Environmentally sensitive areas include stream and floodplains, lands that lie within critical watershed, and lands that should not contain suburban and urban development due to environmental reasons. Natural resource lands are lands that are owned by federal, state, county or city government and the lands identified in the Inventory of Natural Areas and Rare Species of Durham.

For this thesis project, Forman's definition of open spaces, which is, open spaces are areas that provide for an integrated system of land and water resources, was adopted. The land resources considered for the study are woodlands, agricultural lands, shrublands, and small special sites (wetlands, karst features, and sites with threatened and endangered species). The water resources considered for the study include rivers and streams.

2.5 Planning for Regional Landscapes: A Review of Five Approaches

Landscape planning and landscape ecology have evolved independently of each other. The main focus of landscape architecture and planning is the use and design of landscapes for humans. The land characteristics and cultural characteristics are carefully examined and analyzed. Human land uses are then placed on the landscape so as to have least impact on the land. The focus of landscape ecology is on theoretical aspects rather that practical applications to land use planning. However in the past few decades, landscape ecologists, such as Richard Forman, Michel Godron, and landscape architects and planners such as Ian McHarg, John Lyle, Frederick Steiner, and Phil Lewis have developed ecological planning approaches that link both fields together.

2.5.1 Richard Forman's Approach to Ecological Planning

Richard Forman's approach to ecological landscape planning is based on the principles of landscape ecology. According to Forman (1995), landscape ecological planning should consider the broad spatial context, closely examine the spatial structure, function, and temporal changes and then use the knowledge gained to plan and manage landscapes.

2.5.1.1 Consideration of Broader Spatial Context

The landscape under study should be considered in context to other landscapes in the region. The spatial context should extend well beyond the actual boundaries of the site. Forman (1995) also recommends that a detailed evaluation of the surrounding region ten times larger than the study area should be done.

2.5.1.2 Examination of an Area's Spatial Structure, Function, and Temporal Changes

Every landscape has a unique spatial structure made up of different landscape elements. This unique structure is formed as the result of climatic variations, topography, aspect, and human disturbance. Forman and Godron (1986) use descriptive terms such as patch, corridor, and matrix to describe the structure of landscapes. This structure is found in all landscapes including manmade landscapes. In any landscape, each individual ecosystem (landscape element) can be recognized as a patch with significant width, a narrow corridor or as the background matrix. The examples of patches and matrix are woods, fields, suburbs, and urban areas. The examples of corridors are streams, hedgerows, roads, powerlines, and trails. There is a constant flow of material, energy, and species from one ecosystem to another. An approach based on the principles of landscape ecology focuses our studies on the spatial structure and interactions between different landscape elements. These landscape elements are dynamic and change over time.

According to Forman and Godron (1986:24-28), there are seven emerging principles in landscape ecology that relate to structure, function, and change of an ecosystem. The principles also relate to landscape heterogeneity and disturbance. These principles establish a strong foundation for Forman's approach to analyzing and planning for landscapes and regions.

1. *Landscape Structure and Function*: Landscapes are usually heterogeneous and differ structurally in the distribution of species, energy, and materials.
2. *Biotic Diversity*: Land heterogeneity decreases the abundance of rare interior species and increases edge species and species requiring more than one habitat.
3. *Species Flow*: The expansion and contraction of species has a major effect on and is controlled by landscape heterogeneity.
4. *Nutrient Distribution*: The rate of redistribution of mineral nutrients increases with disturbance intensity.
5. *Energy Flow*: An increase in heterogeneity increases flows related to heat energy and biomass.
6. *Landscape Change:* Undisturbed landscapes become homogenous in time. Moderate disturbance of a landscape rapidly increases heterogeneity while severe disturbance of a landscape may increase or decrease landscape heterogeneity.
7. *Landscape Stability:* The physical stability of a landscape may indicate the absence of biomass. Landscapes that have low biomass usually recover faster from disturbance, for example prairies and grasslands. Landscapes that have high biomass, for example, wetlands and mature forests, are usually very resistant to disturbance.

2.5.1.3 Use of Landscape Ecology to Plan and Manage Landscapes

The planning process proposed by Richard Forman seeks to integrate the concepts of landscape ecology into physical planning. The aim of this approach is to design an optimum landscape structure, in other words, one that is sustainable[4]. Forman suggests that the Aggregate Outliers Principle may be an helpful way of planning for and managing sustainable landscapes. This principle states that "one should aggregate land uses, yet maintain corridors and small patches of nature throughout developed areas, as well as outliners of human activity spatially arranged along major boundaries" (1995:437). Based on this principle, a regional plan should seek to retain large patches of natural vegetation. Large patches are ecologically important. Large patches protect aquifers and low order streams, provide habitat for large home range species, permit natural disturbance regimes to occur in which many species can interact and evolve[5], and maintain a range of microhabitat proximities for multihabitat species. Smaller patches of vegetation are also important as they provide habitat for species with smaller home ranges. Small vegetated patches also act as stepping stones for species to recolonize an area following local extinction. Thus an ideal landscape needs a variety of grain sizes[6] with both coarse and fine grain matrices. In

[4] According to Forman a sustainable landscape is an area in which ecological integrity and basic human needs are concurrently maintained over generations. Here integrity means capability of supporting and maintaining a balanced, integrated and adaptive community of organisms.

[5] Natural disturbance such as forest fires leads to elimination of climax plant communities and the establishment of pioneer species.

[6] According to Forman (1995), grain size is the measure of the average area of enclosed patches in a matrix.

addition to large and small patches, a regional open space plan should at least have two types of corridors. Natural vegetation corridors maintain natural processes such as the tempering of surface water runoff and the increase in species movement and viability. The second corridor type is composed of diverse fine scale land uses that promote efficient use of the land.

The spatial attributes to be targeted are patches, corridors, and network and matrix.

1. *Patches*: Patch size for a natural area should be decided on minimum patch size needed for maintaining biodiversity. Small natural area patches in a landscape should act as stepping stones for species movement between large patches.
2. *Corridors*: Corridors can act as barriers, conduits or sources for species, energy, and matter based on their size, shape, and type. For example, wide road corridors act as barriers for the movement of animals and are sources of pollution whereas wide riparian corridors permit the movement of species across the landscape and are sources for some species. In landscapes impacted by man, natural corridors should be as wide as possible and manmade corridors such as roads should be as narrow as possible.
3. *Network and Matrix:* Network and matrix attributes have wide implications on landscapes. For example, landscapes with urban matrix are sources of water and air pollution. They have concentrated flows of energy and nutrients. Urban matrix has negative impact on the overall landscape. Landscapes should have natural area matrix with patches of urban areas or an even mix of both.

The ecological characteristics to be targeted during the planning process include the following: (1995: 454)

1. Maintenance of healthy populations of migratory fish from first order streams to the mouth of major rivers;
2. Maintenance of viable populations of important species;
3. Planning for wide ranking species[7];
4. Planning for the needs of multihabitat species;
5. Protecting prime agricultural soils from overuse or loss by construction of buildings and paved surfaces;
6. Designing to concurrently enhance interior and edge game species.

2.5.1.4 Concord Open Space Plan

The approach used by Forman for the Concord Open Space Plan incorporates principles of landscape ecology. The broad objective of this plan is to prepare “an open space framework that provided for an integrated system of land and water resources, supported by a rational basis for land use decision making” (1995:462).

[7] Species from different tropic levels are targeted for analysis. The species are either producers, consumers or decomposers.

The first step in the planning process is identification and analysis of major town and landscape wide features. Landscape types identified includes built, natural, and agricultural areas. Linear elements identified includes wildlife corridors, water protection corridors, and human corridors. Small special sites such as ecological habitats, geologic features, historic sites, recreational areas, water resources, scenic spots, educational institutions, and town infrastructure are identified. All of this information is mapped. The identified special sites are evaluated for their rarity[8] and recovery or replacement time[9]. They are then compared and ranked for their open space potential.

The second step is synthesis and overall land protection priorities. The large areas, major corridors, and special sites are overlaid and linked to each other. The study found that eighty percent of the special sites overlapped with the large natural and agricultural patches, and water and wildlife corridors. The landscape elements are prioritized for protection based on their open space value and relationship to each other.

2.5.1.5 Conclusions

The following issues should be considered while planning for open spaces:
Planning should extend beyond the actual boundaries of the site, town or county. This is because the issues that affect the town, county or site are not restricted to its jurisdictional boundaries. For example, at the county scale watershed boundaries usually extend beyond county boundaries. Hence, channelization of upstream areas in one county can cause flooding in the downstream areas of adjacent county.

Large areas of natural vegetation should be protected when planning for open spaces. It is important to connect large vegetated areas with smaller patches of vegetation or natural corridors. This is because well connected landscapes with large patches of vegetation will help maintain biodiversity. Small areas of natural vegetation provide home species with smaller home ranges, promote stormwater infilteration, filter air pollutants, and act as stepping stones for species movement between large patches of vegetation. Land uses should be aggregated wherever possible. This is because large patches of natural areas have more ecological benefits than a number of small isolated patches of natural areas. Prime (or best) agricultural soils should be protected from urbanization. Riparian corridors should be maintained throughout the landscape. Riparian corridors help in connecting independent landscape elements and protect streams from pollution and other kinds of degradation. Protecting streams from pollution will help in maintaining healthy populations of aquatic animals.

---

[8] Sites that are nationally rare are given greater value than those at state or local level.
[9] Special sites that require centuries to recover from disturbance are ranked higher than those sites that take decades or years to recover.

2.5.2 Ian McHarg's Approach to Ecological Landscape Planning

McHarg is one of the earliest landscape architects to shift from a purely design oriented study and analysis of regional open space planning to a more scientific multidisciplinary approach. He introduced systematic approach to regional planning which is based on the principles human cooperation and biological partnership.

The first step in the regional planning process is data collection and analysis. Data on geology, lithography, climate, topography, soils, etc. are collected and mapped. The layering of maps for analysis should follow a chronological sequence beginning with the oldest evidence (geology) and proceeding toward the present (land cover) where each layer is dependent on the underlying ones and each augmented the total explanation. For example, current morphology, with climate and lithology (gross character of rock) is used to explain the pattern of rivers and streams, distribution of groundwater, relative quantities of water, and the physical properties associated with water. The pattern, distribution and properties of soil are identified by looking at the sediment movement. Plant communities are then classified and mapped based on climate, topography, hydrology and soils. This is followed by the mapping of wildlife based on habitat and range.

Human interests, in relation to natural and cultural factors, are also studied and mapped. The natural and cultural factors to be studied and/or mapped are water problems (high and low water flows and water quality), unique sites (scenic corridors, areas of geologic or vegetative interest, recreation areas - land and water based, historic sites and structures), mineral resources (coal, limestone, sand and gravel), slopes (which encourage and/or limit access and development), and water resources.

The second step is the preparation of suitability maps. The main purpose of suitability analysis is to find out areas that are propitious or detrimental for a prospective use. This idea of intrinsic suitability underlies McHarg's work. In his study of potential lands for open space in Philadelphia, he sought to identify areas that perform work for humans, areas that offer protection from natural hazards, areas unique and/or precious (scenic corridors, areas of geologic or vegetative interest, recreation areas, historic sites and structures), and areas that are vulnerable or sensitive. From these layers of information, intrinsic suitabilities are be derived for agriculture, forestry, recreation, and urban use.

The last step in this process is finding out the degree of compatibility between land uses. This involves looking for multiple compatibilities or incompatibilities between different land uses and between land uses and natural determinants. An alternate suitability map is prepared based on this information. The alternate suitability map suggests primary and secondary land uses for each area of the county.

2.5.3 John Lyle's Approach to Ecological Planning

According to Lyle, ecosystem design draws its concepts from the field of ecology. "It considers the landscape as a dynamic whole" (1985:194). As with Forman, Lyle also uses the concept of identifying structure and function in landscape analyses. Lyle uses the term "structure" to refer to plant and animal composition along with their abiotic elements. This differs slightly from Forman's description of structure as he uses the term structure to describe the overall landscape pattern, specifically ecosystems and their connecting elements. Lyle uses the term "function" to refer to the flow of energy and materials. Energy flows through a system follow the first and second law of thermodynamics. Material flows refer to water and chemicals that flow through the ecosystem in closed cycles. "Human beings alter this cycle by speeding up this process" (1985:196). Locational factors also play an important role in ecological design. This is because structure and function vary with location. These variations are produced due to geology, landform , climate, and other factors. Human impacts are likewise very significant because "human beings alter ecosystems to create their own patterns. Sometimes these patterns fit into the evolved pattern and sometimes they don't" (1985:197).

The concept of structure and function are important because of their influence on stability and sustainability of human ecosystems. They also provide conceptual basis of designing human ecosystems. Humans create landscapes that often have simple structures which may in fact be monocultures that depend on high energy inputs. Humans have created landscapes such as agricultural lands that do not necessarily co-evolve with other organisms of the ecosystem. According to Lyle (1985), man-made environments should have more complex structures and functions.

2.5.4 Frederick Steiner's Approach to Ecological Landscape Planning

Steiner's ecological planning method proposes the "use of biophysical and sociocultural information to suggest opportunities and constraints for decision making about the use of landscape" (1981:15). The steps proposed by Steiner for this process includes:

1. Identification of the Problem*:* The first step in the ecological landscape planning process is the identification of specific planning issues. These issues may range from land-use conflicts to resource protection concerns.
2. Establishment of Goals: Goal setting is an important part of any planning process. Goals help in articulating an idealized future situation.
3. Analysis at the Regional and Landscape and Site Levels*:* Three scales of landscape analysis - regional, local, and site, need to be addressed. The regional level analysis involves the analysis of watersheds and drainage basins. The planning process at local level involves inventory and analysis of socio-cultural, biological, and physical elements. The analysis of

biological and physical elements involves establishing bivariate[10] relationships between different elements of the landscape. This is because each pair of landscape elements i.e., soils, climate, geology, water, wildlife, physiography and vegetation are linked to each other through spatial connections and processes. The information obtained from the bio-physical analysis is then translated into suitability maps and is important frame of reference for site scale planning efforts.

4. Development of Concepts: This step involves developing planning options for the future based on the suitability analyses previously performed.
5. Development of Landscape Plans*:* Landscape plans involve making strategies for development at the local scale. This involves making flexible guidelines for conservation, development, and rehabilitation of the land.
6. Involvement of Citizens*:* The landscape plan thus prepared is explained to citizens. The model also recommends that citizens be involved in all steps of the planning process.
7. Development of Detailed Designs: Detailed design gives form to the concepts developed. It involves the spatial arrangement of elements usually at the site scale. Such site scale designs contribute to or undermine the integrity of larger landscapes and are thus important test beds for the application of our planning ideals.
8. Implementation of Plans and Designs*:* At local level the design can be implemented by means of land purchase, control on use of the land, voluntary covenants, transfer of development rights, zoning, and performance standards.
9. Monitoring and Evaluation of Plans and Designs*:* Planning is a long term process. Hence the developed plans and designs should be monitored and evaluated during and after implementation. Amendments and changes should be made to the plan based on the new information.

The ecological planning model proposed by Steiner involves establishing bivariate relationship between different physical and biological elements of the landscape. This is the limitation of this method since it restricts ecological planning process to analysis of bivariate relationships. In reality, relationships between landscape elements are complex and multivariate. For example, the riparian vegetation and adjacent land use has major implication on stream water quality and base flow which in turn affects the aquatic animals. Hence, multivariate relationships between different physical and biological elements should be considered while planning for regional landscapes. The implementation strategies used in this model will be a useful tool for the approach I am proposing for county open space planning. Steiner emphasizes the importance of community involvement at every step of the planning process in this ecological planning model. This is important for the long term success of the plan.

---

[10] Bivariate relationships involves establishing connections between two landscape elements where one landscape element directly affects the other. For example, there exists direct connection between soils and geology, vegetation and wildlife, streams and vegetation, etc.

2.5.5 Phil Lewis' Approach to Regional Planning

According to Lewis (1996), the regional planning process can and should be linked to ideas relating to sustainability[11]. To attain sustainability it is important for both designers and community members to change their attitudes towards landscapes. Complex patterns and textures of the landscape should be treated as a work of art. These landscapes patterns should be preserved and respected. This is because landscape patterns are linked to the larger pattern within which they are embedded, and to the smaller patterns that are embedded in it. The regional planning process involves protection, restoration, and enhancement of the life support system.

It is important for planners to guide human development so that new developments maintain the dynamic balance between natural and cultural resources. Some of the regional patterns to look for while designing include toxic patterns, flood patterns, cropland patterns, aquifer recharge patterns and groundwater patterns. The planning process should have a holistic and interdisciplinary approach.

Lewis emphasizes the importance of scale in open space planning. Sustainability should be planned at three scales, i.e., national scale, regional scale and local scale. At the national level, the growth of urban areas should take the form of constellation of stars or donuts, where large open spaces are not only enclosing cities but are also enclosed by it. Such open spaces may include biosphere reserves and agricultural lands. At regional level the urban areas should be connected with transportation corridors and E Ways[12], and the urban growth should be channeled along these corridors. This will help contain urban sprawl. He suggests using railroads as connecting corridors since they have two important attributes of sustainability. They are economical and consume less energy than any other modes of transportation. At local levels it is important to educate the public about sustainability by using tools such as E Ways, Awareness Centers[13] and Academies for Sustainable Design[14]. The important regional resources to be considered in the planning process includes food supply, water resources, open spaces, and energy resources.

2.5.6 Discussion and Synthesis of Approaches

Open space planning process should be holistic and interdisciplinary. Experts from various disciplines such as geography, geology, biology. landscape ecology, etc. should work hand in

[11] Sustainabity according to Lewis is the degree to which our methods of using the life support system (earth and all its resources that support life) will provide our descendants with as good a life as ours or better and also preserving or restoring the environment in which they live so as to be stable in the relationships of all parts of the system.
[12] E-Ways are ecological, aesthetic, educational, and recreational corridors.
[13] Awareness centers are places where local values and visions can be displayed for education and public participation.
[14] Academy for Sustainable Design are places where requirements for carrying regional planning process will be met with respect to staff and equipment.

hand with the open space planners. The larger regional context should be considered while planning for open spaces. Open space planners should strive to achieve balance between manmade systems with natural systems. Sustainability should be planned at all scales. This includes national, local, and site scales.

Multivariate relationships between physical and biological elements should be considered while planning for regional landscapes. The layering of maps for analysis should follow a chronological sequence beginning with the oldest evidence and proceeding towards the present where each layer depends on the underlying ones and each augments the total explanation.

Every landscape has a unique structure and pattern. These landscape patterns should be respected while planning for open spaces. The overall landscape structure should be designed for biodiversity and sustainability. It is also important to maintain beneficial flows and eliminate negative flows between different landscapes elements. Forman's Aggregate Outliers Principle (one should aggregate land uses, yet maintain corridors and small patches of nature throughout developed areas) should be considered while planning for open spaces at the regional scale. Large areas of natural vegetation should be protected when planning for open spaces. It is important to connect large vegetated areas with smaller patches of vegetation or natural corridors. This is because well connected landscapes containing large patches of vegetation will help maintain biodiversity. Small areas of natural vegetation provide home species with smaller home ranges, promote stormwater infilteration, filter air pollutants, and act as stepping stones for species movement between large patches of vegetation. Urban, suburban, and other intensive land uses should be aggregated wherever possible. This is because large patches of natural areas have more ecological benefits than a number of small isolated patches of natural areas. Prime (or best) agricultural soils should be protected from urbanization. Riparian corridors should be maintained throughout the landscape. Riparian corridors help in connecting independent landscape elements and protect streams from pollution and other kinds of degradation. Protecting streams from pollution will help in maintaining healthy populations of aquatic animals.

Public participation is an important part of the regional open space planning process. The local community should be involved in the open space planning process as much as possible in order for the long term success of the plan.

Chapter 3 Case Study Reviews

The research is conducted by doing case studies of two open space plans, one is the Town of Dunn, Wisconsin Open Space Plan and the other is the Durham County, North Carolina Open Space Plan. The open space plan prepared for the Town of Dunn received *Renew America National Environmental Award* in 1995, and is picked for this study as a model plan (Lewis,1996:145). Although the plan is done for the town, the approach has application at the county and regional scales. The Durham County Open Space Plan is chosen for this study because Virginia's Fifth Planning District (which includes Roanoke County) is proposing an open space plan for Greater Roanoke Area based on the Durham County Open Space Plan. The case studies briefly covers approaches that are adopted by these towns for their open space plan and highlights ideas that can help in future open space planning efforts.

3.1 Town of Dunn, Wisconsin Open Space Plan

The Open Space Plan for the Town of Dunn was done by an interdisciplinary team from University of Wisconsin along with local and regional citizen groups (Lewis, 1996). A review of the final planning document/Handbook (1979) is the basis for the following discussion.

It should be noted at the onset that the plan provides practical solutions for preserving open spaces at county scale. The handbook accompanying the plan also provides guidelines that could be used by other counties to preserve their open spaces. The main goal of this Open Space Plan is natural systems preservation.

There are four phases in the open space planning process and these include inventory of resources, open space functions, tools for preservation, and study area analysis.

3.1.1 Inventory of Resources

The inventory is done in five steps. The first step in this process is the inventory of the town's geology and water resources. Under geology and water resources, the items inventoried includes surface geology, subsurface geology, groundwater, and surfacewater resources.

The second step in the inventory process is researching and recording the natural history of the town and the changes that occurred in the town due to development. The maps used for the study includes archeological sites map and the 1873 Dane County atlas.

The third step is the inventory and classification of woodlands in the Town of Dunn and this step involves extensive field studies. The woodland classification is based on the plant community type. Trees species in each of these woodland communities are noted.

The fourth step in the open space planning process is to inventory existing wetlands. The Town of Dunn has a sizable number of wetlands, hence a detailed inventory of the wetlands is done. The inventory includes a detailed description of each wetland in the town. The study also describes the potential threats faced by each of these wetlands. The wetlands of Dunn support significant wildlife populations.

The fifth step involves the inventory of wetland wildlife. Location of major bird flight corridors in the town are noted. This part of Wisconsin is renowned for its fishes and has a sizable fish population in its numerous freshwater lakes and streams. An inventory of fishes is done for each one of these lakes and streams.

The last step in the inventory process is the inventory of historic and archaeological sites in the town. The important archaeological sites inventoried includes effigy mounds, cemeteries, camp sites and villages.

3.1.2 Open Space Functions

The primary purpose of the Town of Dunn Open Space Plan is natural systems preservation. Wildlife is an important element in any natural system. Wildlife can be protected by preserving its overall habitat including places of movement. The habitat to be preserved for wildlife includes feeding, nesting, resting, burrowing, wintering and migratory sites. It is very important to protect the corridors used for movement by these species. Wildlife species chosen for the study are those that are familiar to people. The broad categories of wildlife studied are birds of prey, song birds, waterfowl, upland game birds, marsh and shore birds, rodents, game fish, pan fish, rough fish, snakes, turtles, frogs, salamander and invertebrates. A wildlife habitat matrix is prepared for identifying land use impacts on the wildlife. The goal to preserve plant and animal habitats is based on the assumption that plant and animal diversity are needed for long term stability. Animals are viewed as an important part of Town of Dunn's community since they play an important part in the overall ecological process.

The second purpose for preparing the open space plan is the aesthetic quality preservation. This involves preservation of hedgerows, roadside vegetation, and views to and from the wetlands. The study recommends preserving high quality vistas to the lake, and the use of natural colors and materials near open space resources. The plan also recommends avoiding concentration of night lights in the dark rural areas.

The third purpose of the open space plan is to protect surface water quality. Surface water quality can be protected by preserving open space resources and by creating hedgerows, vegetative buffer strips along streams and intermittent drainageways and safeguarding wetlands. It is also important to control runoff problem at the source. The study recommends the use of non-structural flood control methods to prevent floods or flood impacts. The hundred-year flood area is considered appropriate to achieve this purpose.

According to Town of Dunn open space planners, for an open space plan to be successful, it should also provide education and spiritual enrichment for the residents. Close and regular contact with natural landscapes or landscape elements will result in growth of emotional ties to the land and help in re-establishment of important relationship existing between man and natural processes. It is also important to preserve historic and cultural resources. The resources that are recommended for protection includeds outstanding architecture, traditional American Indian campsites, and early farmsteads. The plan also recommends using physical elements of landscapes to limit the growth the community. Use of natural boundaries will help to define the edge of the town, prevent urban sprawl, and assist in preserving the identity of the town.

3.1.3 Tools for Preservation

The third phase in the open space planning process is tools for preservation. The main strategies for open space preservation focuses on responsible private ownership, education, regulations, and public service controls. The following are the tools recommended by the planning committee for preservation of open spaces.

Responsible Private Ownership: This is the most desirable way to preserve open spaces. The responsibility of protecting open spaces should be on people rather than governments or agencies because such stewardship will help to strengthen the link between man and nature.

Public Education and Organization: The plan recommends providing education about the value of open spaces in schools and local organizations. The plan also recommends providing education through youth group activities, resource sharing, and the local media. Public education and organization is important for long term protection of open spaces.

Land Use Regulations and Public Service Controls: The town's environmental and open space goals can be done by land use regulations and public service controls. This can be done by either recommending changes in planning review process, zoning and subdivision regulations, performance standards or public service controls. An open active and effective site plan review process is critical to the success of regulatory means of protecting open space.

Public Acquisition of Property Rights: The plan recommends that *acquisition of property* should be used only if other strategies are not effective or possible. The town should be involved in acquisition if the land adjacent to the open space is threatened by development and if this development negatively affects the functions of open spaces. The town should work hand in hand with non profit organizations such as The Nature Conservancy or the Department of Natural Resources to publicly acquire property rights.

Erosion and Sedimentation Control: It is not sufficient to simply preserve open space; we must also control negative flows into natural open space systems. As a primary example, sediments from adjacent land uses such as construction sites and farmlands may end up in streams, wetlands and lakes. High inputs of sediments can result in the loss or degradation of plant and animal habitat. Hence protection of open spaces also involves development of a sedimentation and erosion control program. The plan recommends control of erosion at the site level. Any development, including road construction should relate to natural features of the land. Care should be taken to protect the bare soil from raindrop erosion. It is also important to maintain the infiltration function of the soil to the maximum extent possible and keep runoff velocities as low as possible. Permanent control system should be also be developed to prevent the release of excessive stormwater runoff caused by new development. Vegetated swales and detention or retention areas can be created to help slow and hold runoff from developed land.

3.1.4 Study Area Analysis

This is the final phase of the open space planning process. The town is divided into different sections and, each of these sections is studied in detail. A Cultural resource map and an environmental system overlay map are prepared for each section and analyzed.

Cultural resource maps are prepared by identifying boundaries of floodplains, agricultural and non agricultural land use, landownership patterns, and sanitary districts for each section. Identification of landownership patterns helps in locating the places where future threats to open space system occur. For example, because absentee landowners are more likely to keep land for speculative purposes than a resident landowner it is important to identify landownership with this degree of detail. Identification of sanitary districts are also extremely important since they relate to the direction of future urban growth.

An environmental system overlay map is prepared by locating major elements of an open space system. This includes drainage patterns, springs, steep topography, woodlands, and wetlands. Woodlots are rated based on the size, species composition, ownership and previous disturbance patterns, cultural sites, etc. Rating scale used for this purpose is “good” “fair”, and “excellent”. The woodlots that are ranked “excellent” adjoin water bodies, wildlife habitat or have some outstanding aesthetic quality. Woodlands noted as “good” had near-natural character and a good balance of native plant species. The woodlots ranked as “good” show effects of moderate disturbance from grazing or logging. This is indicated by either absence of certain species or sparse vegetation. The woodlands ranked as fair show signs of declining health or severe disturbance. The normal size of some of these woodlots range from four acres to fifty five acres. Ranking helps in prioritizing woodlots for preservation. Archeological sites that fall within the open spaces are also identified for preservation.

3.2 Durham County, North Carolina Open Space Plan and The Durham County Open Space Corridor System

In 1989 the Durham County adopted the Durham County Open Space Program and Action Plan. One of the top priorities listed in the Durham County Open Space Plan is the preparation of an Open Space Master Plan. The Durham County Open Space Corridor System represents the first step in the County’s Master Plan endeavor.

3.2.1 The Durham County, North Carolina Open Space Plan

The Durham County Open Space Plan was prepared by the Durham City- County Planning Department in consultation with some landscape architecture and planning firms.

3.2.1.1 Goals and Objectives

The main goals and objectives of the Durham County Open Space Plan are to identify and protect water courses, critical environmental lands and natural resources, to preserve open spaces for recreational purposes, and to provide additional open space for residents of the county. Durham County faced growth pressures and the existing open spaces and farmlands were threatened by overuse and suburban development.

3.2.1.2 Inventory and Analysis

The first step in the inventory process is the identification of open spaces. The open spaces identified includes rivers, streams, floodplain lands, land described in the Inventory of Natural Areas and Rare Species of Durham County, public open space lands, and public institutional lands and major destination points within the County, The City of Durham Trails and Greenway System, and strategic lands.

Rivers, streams and floodplains identified includes 36 major and minor streams, 20,000 acres of flood plain areas and 166.16 miles of stream corridors. The land described in the Inventory of Natural Areas and Rare Species of Durham County include 52 sites with areas ranging from one acre to 450 acres. The identified sites have rare plant communities, aquatic habitats, breeding areas for animals, animal migration corridors or scenic route for recreation. Public open space lands identified includes four major lakes owned by the federal government, 1500 acres of state owned lands , 17 acres of county land and city owned parks that are more than 40 acres. The public institutional lands include lands owned by public universities, public schools, cemeteries, and historical and archaeological sites. The trails and greenways proposed by The City of Durham Trails and Greenway System for Durham City is also studied. Strategic lands are lands that did not fall under categories mentioned above but is important open spaces for the county. Strategic lands include Duke forest, private golf courses, abandoned railroad corridors, public utility corridors, etc.

The second step in the open space planning process is making recommendations for protecting the critical open spaces identified in the first step. The three techniques recommended for open space preservation are management, government regulation and acquisition.

The last step in this process is the establishment of open space program. This step involves participation of the local community in the open space program. The citizen inputs are then incorporated in the open space plan and modified accordingly before its implementation.

3.2.2 The Durham County Open Space Corridor System

In 1992 the Durham County Open Space Corridor System was prepared by the Durham County Open Space Planning commission and is a part of a master plan prepared for Durham County. The Durham County Open Space Corridor System is done in three stages. They is inventory, analysis and policy recommendations.

3.2.2.1 Inventory

The Durham County open space corridor planning processes has two steps. The first step is an inventory of the existing natural resources and the second part is a detailed analysis of the resources surveyed. The resources inventoried during preparation of the open space corridor system are geology, major water courses, watersheds, environmentally significant areas (ecological, historical and archaeological areas), locations of rare species within the county, and existing public or publicly accessible land. A citizens’ survey is also conducted to identify rivers, streams, and plant and animal habitat that need to be protected, and areas of the county that need trails and greenways. Existing open space planning efforts by Durham County and State of North Carolina is also reviewed during the early stages of the planning process. Those preparing the open space corridor system recognizes the importance of effective coordination between city and county planning efforts.

3.2.2.2 Analysis

The next stage in this process is analysis of the Durham County landscape. For the purpose of analysis the county is divided into three parts-northern, eastern, and western part. The analysis is a two part process. The first step is to provide general guidelines and the second step is to make detailed plans for each corridor identified in the analysis. The corridor plan recognizes the importance of site specific decisions in relation to the overall system. Any recommendations made during the second step (detailed plans for each corridor) would supersede the ones made by general guidelines. The corridor plan identified some major stream corridors for preservation since studies show that three-fourths of the rare species identified are located near six major stream or river corridors. Natural corridors and trail corridors are the two types of corridors identified for preservation and protection. The undeveloped land along county's most significant rivers and streams are designated as natural corridors. The natural area corridors containing rare and endangered are made inaccessible to people for recreation. These lands are proposed to be preserved in an undeveloped state by public acquisition, conservation easements, new subdivision regulations or any other method suitable for the particular site or landowner. The second type of corridors are trail corridors. A trail corridor is a narrow strips of land along streams and railroad right of way. The aim of a trail corridor is to link all existing and proposed Durham City urban trails and greenways.

The recommended corridor width is 200 feet from each side of the riverbank or the width of the hundred-year floodplain whichever is smaller. These widths are considered sufficient for wildlife protection and to absorb impacts from adjacent development. For trail corridors which sides or runs along streams, a 100 feet wide corridor is proposed along either side of the stream. The width of the railroad corridor is equal to the width of the railroad easement.

3.2.2.3 Policy Recommendations

Policy recommendations to support the open space corridor system include working with the landowners who own lands along the corridor or adjacent to a permanently protected corridor; clustering of residences adjacent to the open spaces; and a requirement for landowners/developers to set aside lands for open spaces in new developments near protected open spaces. Landowners with properties on the corridors or adjacent to the corridors can get tax credits, tax reduction and greater use of the adjacent open space if they preserved their land as an open space. The plan also requires the landowners to set aside land for open space when the land or property adjacent to a natural area is subdivided. Clustering of residences is also encouraged in residential developments adjacent to open spaces. The plan recommends that the County Planning Department work in partnership with local communities and with the private and non-profit organizations. The corridor plan also recommends that the other county plans and activities be made compatible with the proposed corridor plan.

3.3 Discussion of Case Study Reviews

The Positive aspects of The Town of Dunn Open Space Plan is:
The Open Space Plan was implemented in 1979 and since then the Town of Dunn has accommodated a growth of 13 percent without significant loss of natural resources (Lewis, 1996). The Open Space Plan accounts for both natural and cultural factors in the open space plan. The

planners did a thorough inventory of natural resources where they took into account the geology (surface and subsurface geology), hydrology, woodlands, wetlands, fisheries and wildlife of the region. The primary aim of the open space plan is natural systems preservation and wildlife habitat protection. The wildlife habitat is considered in its entirety, i.e., feeding, nesting, resting, borrowing, wintering, and migratory habitat sites. The planners realized the importance erosion and sediment control and education for long term open space protection. All natural areas larger than four acres are considered for the analysis, i.e., natural areas larger than four acres are potential open spaces. These areas are then prioritized for protection based on their structure and function. The Town of Dunn planners also recommend that the public acquisition of property should be used as a last alternative for open space preservation.

Shortcomings of the Town of Dunn Open Space Plan are that planners did not deal with the larger spatial context and did not account for higher tropic level animals in their open space plan.

Positive aspects of the Durham County Open Space Plan are:
The county planners did a thorough inventory of the county's open spaces in the open space plan and presented a detailed action plan for the protection and acquisition of open spaces. In the corridor study, planners emphasize the importance of coordinating the activities of various agencies and the importance of protecting lands adjacent to the protected open spaces and recognize the importance of detailed analyses. Any recommendations made in the detailed corridor plan supersed the ones made in the general plan.

Shortcomings of the Durham County Open Space Plan and Durham County Open Space Corridor System includes the following:
The open space plan does not account for the larger spatial context. Even though the farmlands are recommended for protection, no farmlands are identified for protection. The open space lands are not prioritized for protection. The open space plan lack detailed analysis of the open spaces identified in the data collection stage. The planners recommend involvement of the public only in the last stage of the planning process. The open space planners did not deal with issues related to biodiversity in their open space plan.

Several commonalties in the Town of Dunn and Durham County open space plans are that the study areas are broken down into smaller units for detailed analyses. The planners did a thorough inventory of their natural resources. Both plans recognize the importance of working with the property owners and non profit organizations for long term protection of open spaces. Open space planners acknowledge the importance of zoning regulations for enforcing the open space plan.

Chapter 4 An Approach to Open Space Planning Based on the Principles of Landscape Ecology

This chapter presents an approach to enhance and preserve open spaces at the county scale using the principles of landscape ecology. The proposed open space planning approach integrates theoretical aspects of landscape ecology with the regional landscape context and existing county plans for the use and protection of open spaces. It should be noted that the approach presented here has been developed with the idea that we need to understand the structure, function, and dynamics of a landscape throughout time. In order to reach such understanding our analysis and planning efforts will likely need to be supplemented by more detailed field studies and a thorough collaboration with citizens and players from many disciplines.

The major stages in the proposed approach for open space planning based on the principles of landscape ecology (see Figure 4.1) are:

1. Establishment of goals
2. Data collection for the region and the county
3. Study of the landscape at the regional scale
4. Delineation of dominant land cover types at the county scale
5. Inventory and analysis of landscape elements
    - Identification and classification of patches, corridors, and special sites
    - Analysis of structure, function and change dynamics of the patches, corridors and special sites
6. Establishment of management strategies for protecting and enhancing open spaces
7. Development of the preliminary open space plan
8. Selecting tools for open space preservation

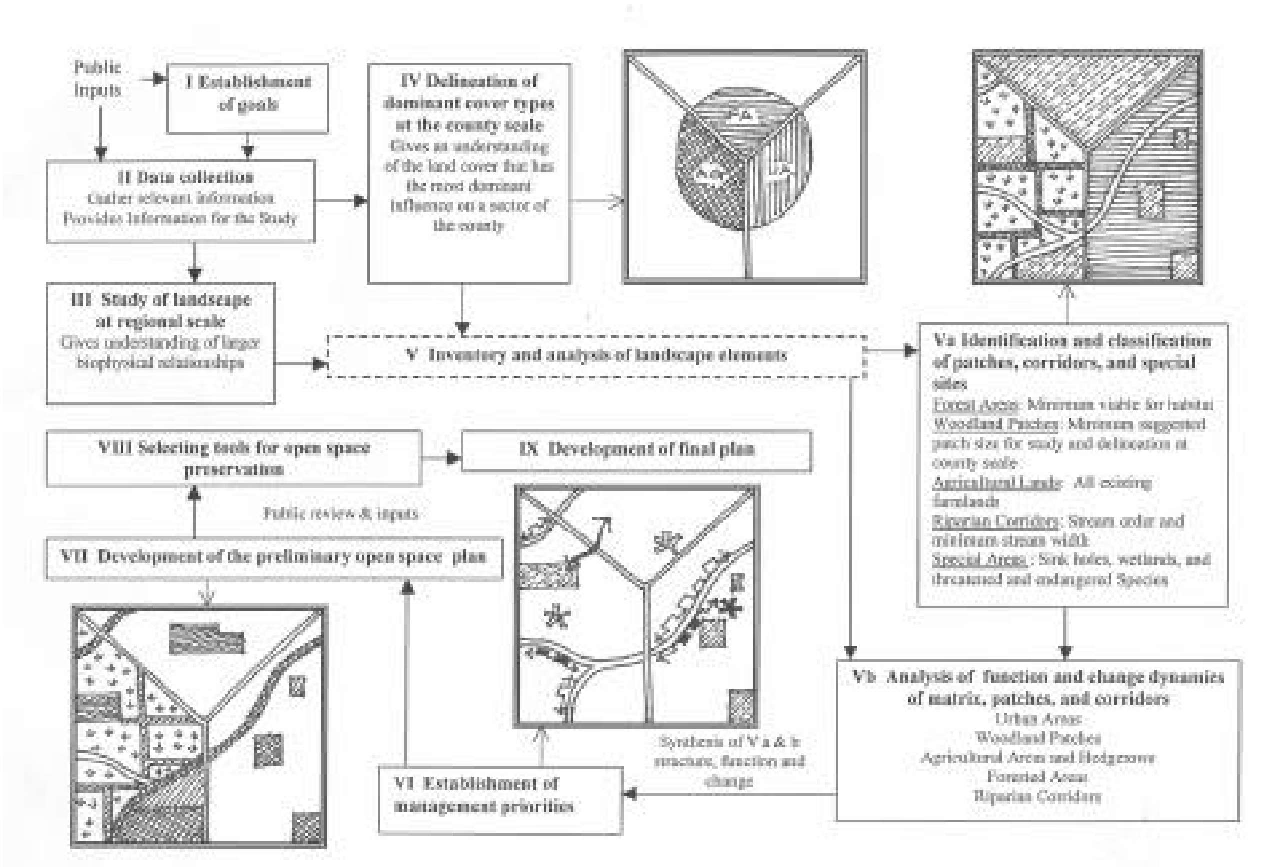

Figure 4.1: Approach to Open Space Planning Based on the Principles of Landscape Ecology

4.1 Establishment of Goals

Goal setting is an important part of any planning process. Goals help in articulating an idealized future situation. This process should involve public participation. This thesis is limited to the analytical part of the open space planning process. Hence public participation has not been considered in depth for any stage of the open space planning process described below.

Early involvement of community members is important because the success of an open space plan is ultimately dependent on the involvement and cooperation of the people in implementing the open space plan.

4.2 Data Collection for the Region and the County

Landscape ecology focuses on understanding the spatial and temporal patterns of the landscape through the study and analysis of its various ecosystems and their interrelationships. Hence, landscape ecological planning involves collecting a broad range information about the biophysical processes of an area, for example, geomorphic structure, hydrogeology, vegetation, and wildlife. Data collection should begin with the inventory of older elements and then proceed to the youngest.

This is because the older components (geomorphic structure) influence the more ephemeral elements (vegetation and wildlife) (Steiner, 1991; McHarg, 1969). It is important for people to be involved in the data collection. They can be a source for information on land use and the natural history of a county. Community members may be willing to work as volunteers and assist in the data collection.

4.2.1 Review of Prior County Studies and Plans

It is important to collect information on prior studies and plans done for the county because these studies/plans give a wealth of useful information on the county. It is also important to link prior studies/plans with the proposed open space plan.

Prior studies and planning documents can be obtained from university and community libraries, planning districts, town, county and city planning departments, and planning/landscape architecture firms. Prior studies and planning documents can provide important insights about the values and goals of county residents and previous planners and may include essential baseline information.

4.2.2 Mapping Existing Open Spaces in the County

This section involves mapping the areas that already have some protected open space status. Such protected open spaces may be owned/managed by federal, state, county or city governments or may be owned and managed by private or non-profit groups interested in open space use and preservation. Proposed open spaces should relate to the existing protected open spaces and thus the mapping of existing open spaces in the county is an essential early step in the process.

4.2.3 Learning the Natural History of the County

North American landscapes have experienced rapid changes in the past 200 years as the result of European expansion across the continent. Since European settlement, the land cover in many parts of the United States has experienced a dramatic change from mature or old-growth forest to agricultural land, and from agricultural lands back to forests, and urban and suburban land. During this period many of the wetlands in the United States were drained or filled to make room for residential and commercial development. It is important to have data on the evolution of land use changes in the county so that open spaces may reflect the county's natural history.

Data on the natural history of a county can be obtained from university and community libraries, the Historical Society, Natural History Museums, and local historians and ecologists.

4.2.4 Compiling and Mapping Natural Resources Data

4.2.4.1 Geomorphic Structure and Hydrogeology

Geomorphology is a study of the configuration and evolution of landforms or the study of land surface and the processes producing them. Regional geology and climate interacting with topography (landform) and hydrology establish the base upon which organisms develop and interact. The geomorphic structure is the oldest component of any landscape and is generally quite stable and a long term landscape characteristic (Steiner, 1981; Ruhe, 1975 as cited in Forman, 1986). It is important to study the geomorphology of a region because it gives planners the capacity to visualize the landscape in three dimensions (Steiner, 1991). In tandem with the fourth dimension of time, this three dimensional perspective is critical for understanding regional and county landscape structure and dynamics. Regional geomorphologic structure and processes have a strong influence on the hydrological processes, land use, vegetation, and wildlife patterns and functions throughout the region and at the county and local scales.

"There is a strong relationship between geology and the occurrence, movement, and quality of ground water and surface water" (Breeding and Dawson, 1976). The factors that control groundwater are rock type and geologic structure. Groundwater is formed when rainwater moves into the ground through porous rocks or through the gaps and crevices in rocks. Aquifers are formed when impermeable rocks act as reservoirs and allow water to move. The movement of water (both surface and groundwater) is closely controlled by topography and geology. Groundwater moves constantly over extensive distances from areas of recharge to areas of discharge. The areas of discharge are streams, springs and wells. Streams thus originate at the points of groundwater discharge (Breeding and Dawson, 1976). Streams have a strong network system. Smaller streams join to form larger streams. Larger streams join to form rivers. Rivers finally join the sea. The water from the sea returns to the land in the form of rain to complete the hydrologic cycle.

Data on geomorphic structure can be obtained from university (geological) libraries, the United States Geological Survey (USGS), and the state divisions of mineral resources. Information on groundwater can be obtained from the USGS, state water control board publications, local water centers, and planning offices. Information on surface water can be obtained from state departments of natural resources and/or environmental protection agencies, and USGS topographic maps. Local volunteer groups such as 'Save our Streams" and other environmental groups may also be active in monitoring streams, rivers, and lakes and may have published data on stream quality. Information on floodplain and flooding potential can be obtained from Federal Emergency Management Agency (FEMA) maps and from local planning and engineering offices (public or private).

4.2.4.2 Land Cover and Vegetation

The land cover in any region is influenced by human activities and natural processes. Humanity has been altering landscape patterns for centuries. Landscape patterns in the United States and much of the world were altered initially by setting fires and subsequently by clearing and cultivating the land followed by rapid industrialization and large scale urbanization. In natural areas the plant composition changes following a natural disturbance such as fire or floods. In event of a natural disturbance the pioneer species (typically herbaceous species) are replaced by shrub and woodland associations unless soil type, climate or elevation limits the growth of woody dicots. Topographic variations and natural disturbance typically lead to a fairly heterogeneous mix of land cover types across a region although one cover type may be dominant.

The land cover type has a major influence on the wildlife. Large wooded areas support animals such as bears, panthers, and wolves whereas prairie and grasslands support animals such as ground squirrel and mice. Vegetation type and structure also influences the wildlife. Among woodland areas, pine forests support species such as pine warbler whereas riparian corridors support species such as beaver and mink. The current mix of woods, shrubland, grassland, and agricultural areas that make up many of our landscapes throughout North America serve as prime habitat for deer, squirrel, and song and game birds. Suburban and urban areas support fewer species which are adapted to the physical structure of towns and cities, for example, starlings, pigeons, and various rodents. Natural processes and biological diversity are thus profoundly influenced by land cover.

Data for land cover and vegetation can be obtained from landsat image, digital spot image and land use maps for the county and the city. State Natural Heritage offices can provide information on rare, threatened or endangered plant species. Much of this information can now be obtained from the internet in digital format or in hard copy from the state department of transportation and local planning offices.

4.2.4.3 Wildlife

Wildlife plays an important role in an ecosystem's energy flow. Wildlife also play an important role in nature's complex system of metabolism and creation. Species diversity is necessary for maintaining the ecological integrity of the land. According to McDonough, "What prevents living organisms from running and veering into chaos is the intricate and symbiotic relationship between millions of organisms, no two of which are alike" (1994:11).

Data collection for wildlife involves collecting information on the key species[15] and any rare, threatened or endangered species in the region. In order to determine key species the planner should consult with biologist and ecologists about the types of species found in the area, and which species have habitat requirements that correspond to the largest number of other organisms. Since it is impossible to study every organism individually (within the time constraints of preparing an open space plan) key species can serve as surrogates for the integrity of larger communities, associations or landscape types and thus for other species of wildlife.

Data on habitat requirements for wildlife can be obtained *Habitat Suitability Index Models* prepared by the Department of Game and Inland Fisheries. The Nature Conservancy has information for many areas within United States and other countries. State Natural Heritage offices, the US Fish and Wildlife Service and state departments of natural resources can provide information on rare, threatened or endangered animals and other wildlife data needs.

4.2.4.4 Special Sites

Special sites are small, specific areas that have open space values. The special sites to be considered for an open space plan at the county scale are ridgetop areas, areas with rare, threatened or endangered species, karst areas, and wetlands.

Data for special sites can be obtained from USGS topographic maps and from National Wetlands Inventory maps. In Virginia the list of federally threatened and endangered species and state rare species can be obtained from the Department of Conservation and Recreation’s Natural Heritage Division.

4.3 Study of the Landscape at the Regional Scale

The study of landscapes at the regional scale involves analysis of overriding patterns of the region surrounding the county of interest. This includes the study of regional geomorphologic structure and processes in order to comprehend their influence on the land use, vegetation and wildlife of the region.

In considering regional geomorphic structure and process it is important to remember that landforms are produced by major geologic processes such as plate tectonics, glaciation, and erosion and deposition. Plate tectonics relates to movement of large continental size rock shields. It is the forces of plate tectonics that have produced the mountains we see in the landscape today. Glaciation and erosion and deposition smooth landscapes. Landscapes with mountains that have jagged ridges are young in geologic time whereas the mountains with smoother ridges are older. All landscapes are in the process of being weathered and reshaped as a result of interaction of between geology and climate. Weathering may be external (as with surface erosion and

[15] Key species are animals that require specialized habitat type, large areas of habitat or multi-habitats for survival.

deposition) or internal (as with rocks dissolving beneath the earth's surface). Examples of external weathering are readily apparent in nearly all landscapes, being most noticeable as canyon and gullies. An example of internal weathering is highlighted by the karst topography found in regions with cold temperate climates. Karst topography landscapes are produced when limestone crumbles and dissolves due to freezing and thawing of the ground (Forman and Godron, 1986).

These overriding geomorphic patterns avail the planner with information about the stage upon which the open space plan is to be framed and which will influence its ultimate implementation.

4.4 Delineation of Dominant Land Cover Types at the County Scale

At the county scale, the landscape is broken down into dominant land cover types for detailed study and analysis. Major land cover types are identified based on differences in the structure. The major cover types are identified from satellite images and mapped. The areas delineated for study may be urban, agricultural, natural or a fairly even combination of urban, agricultural or natural areas, for example, agricultural-natural, suburban-agricultural, and urban-natural. Classifications are based on the land cover type that is most extensive and well connected. The dominant spatial type or area, also referred to as the matrix by Forman and Godron (1986), surrounds and cements independent landscape elements together. Functionally the matrix has a significant influence on the dynamics of the landscape. Urban land cover type is predominantly made up of structures built by man either for living, socializing, and working or for transportation. These areas are usually characterized by the absence of vegetation but contain some species adapted to the urban and suburban structure. Agricultural land cover type chiefly consists of crop or pastureland. Hedgerows, woodlots, and riparian corridors usually punctuate agricultural landscapes. Natural land cover type consists of extensive areas of indigenous vegetation as the matrix. Though from the air natural landscapes may look homogenous, they are typically heterogeneous and contain many different ecosystem types. Natural areas can be either woodlands, savannas, prairies, deserts or wetlands. The agricultural-natural land cover type has large agricultural lands interspersed with large natural areas or fairly even mix of the two types. Urban-agricultural land cover types have low and medium density residential units interspersed with agricultural lands. The urban-natural land cover type consists of urban or suburban areas interspersed with natural areas. Parts or all of cities or communities may fall within these last two categories (urban-agricultural and urban-natural).

At the regional scale it is very important to consider major networks in the landscape because these networks (or interconnected corridors) have a major influence on landscape structure, function, and change. Such networks may include major roads, highways or rivers.

The three dominant land cover types, urban area, agricultural areas and forested areas, are discussed in detail below.
Urban Areas: The matrix in an urban unit is the built form. Urban areas have remnant patches of natural units or agricultural lands which may be isolated or well connected through corridors. These natural units are areas that have been left partly or wholly undisturbed by man. The natural units found in urban areas are usually woodlots and shrublands. The main types of corridors in an urban areas are remnant or altered riparian corridors and roads. Riparian corridors in an urban area are usually very narrow or lack vegetation particularly if the stream has been channelized.

Agricultural Areas: Agricultural areas are lands set aside by man for food production. Agricultural lands include cropland, pastureland, orchards, and vegetable fields. In North America, agricultural lands tend to be structurally simple, highly productive, and non diverse ecosystems. Agricultural lands have been the most persistent form of man-made landscapes. Most agricultural landscapes are monocultures and depend heavily on fossil fuels. They are unstable systems since they need to be constantly managed to prevent new sequence of natural succession (Lyle, 1984).

Forested Areas: Forested areas are areas that have indigenous vegetation as the matrix. In many parts of the world forest ecosystems are located on mountain slopes. This is because the flat lands and fertile valleys have been cleared for agriculture or/and for building purposes. The types of patches and corridors found in forested areas are woodlands, clear cut areas, environmental patches, meadows, roads, riparian corridors, and powerlines.

The products associated with stage four will be a plan showing the dominant land cover types and major networks for the region that surrounds the county of interest.

4.5 Inventory and Analysis of Landscape Elements

4.5.1 Identification and Classification of Patches, Corridors and Special Sites

Every landscape has a unique pattern. These patterns are formed due to geologic processes, variations in climate and topography, natural and human disturbance, vegetation types, natural succession, and wildlife habitat interactions. The most identifiable patterns in a landscape are the patches, matrix, and corridors (Forman, 1986). “Patch, matrix, and corridor are the visible effects of energy, nutrient and species fluxes in a landscape” (Hulse, 1988). Matrix, patch, and corridor are the form-defining characters for a landscape.

The first step in the inventory and analysis of landscape elements is the identification of landscape patterns from satellite images. The landscape patterns to be identified within an area are the ones that relate to open spaces, namely natural areas, agricultural lands[16], natural corridors (riparian corridors and hedgerows) and some man made corridors such as powerlines and roads.

The next step is the abstraction of the visual patterns observed on the satellite images. Here the observed patterns are converted into diagrams that describe the formal characteristics of the landscape element.

4.5.1.1 Identification of Patches of Major Ecological Importance

The size of an open space is of major ecological importance since it has implications on the biodiversity of an ecosystem. In particular, forested area and woodland patch sizes are of primary ecological importance in a county open space plan.

Minimum Viable Forested Area: In order to determine the minimum viable forested area the planner should consider the habitat requirements of key species, endangered species and/or organisms of higher tropic levels (Forman and Godron, 1986). Rather than focus on just one species, Forman and Godron recommend that planners consider habitat sizes needed for a variety of organisms in different tropic levels as habitat size and type can vary for organisms in each tropic level. *Habitat Suitability Index Models* prepared for wildlife species by the United States Fish and Wildlife Service have shown that small herbivorous mammalian species such as squirrels require a minimum habitat area of one acre (0.4 hectares) while large predator birds such as Barred Owl require a habitat size ranging anywhere from 600 to 1000 acres (240 to 400 acres). Considering patch size alone is insufficient because the survival of many animal species is not simply dependent on the habitat size but also proximity to habitat types and safety from pollutants and excessive disturbance.

Considering organisms of higher tropic levels is difficult since many of these species, especially mammals, have been eliminated by humans because they were considered as either dangerous or they competed with man for food. A classic example is the wolf. These species, native to Virginia and much of the United States, were completely eliminated in some parts of the country by man because they attacked and preyed on livestock. Thus in general it is suggested that species that are less aggressive and which do not compete with or harm man should be considered for protection. Species that should be modeled to determine appropriate habitat sizes should typically belong to higher tropic level or require large habitats. The black bear is an example of an animal which fits this description and does not typically compete with or harm man. Rare and endangered species should also be considered as potential prospect for modeling habitat sizes.

Minimum Woodland patch Size in Urban and Agricultural Areas: The patch sizes considered here specifically relate to woodlands. Studies done by J. B. Levenson (1981) on the eastern

[16] Agricultural lands are considered as open spaces since they have a vegetative structure, support wildlife and other animals and are a necessity for human survival.

deciduous biome indicate that woodlots that are more than ten acres (four hectares) should be protected[17]. In the open space plan prepared for the Town of Dunn, Wisconsin the minimum woodlot site selected for study is approximately four acres (1.6 hectares)[18]. However the area under study for the Town of Dunn is much smaller than the land area of most counties and thus required detailed analyses beyond the scope of most county open space planning efforts. For the county scale the minimum suggested patch size to be preserved is suggested to be 10 acres (4 hectares). Areas smaller than 10 acres (4 Hectares) should be considered when more detailed site or landscape plans are developed.

4.5.1.2 Identification of Corridors and Special Sites

Riparian Corridors: Small riparian corridors are made up of the stream and its adjacent vegetation. Large riparian corridors are made up of the stream and its geomorphic floodplain[19] (Forman and Godron, 1986). A large stream riparian corridor usually contains patches of wetlands within the corridor because the stream's geomorphic floodplain is saturated for at least a part of the year (Smith and Hellmund, 1993). Riparian corridors are the most connected element in many landscapes and are often the major links between large natural areas. Riparian corridors have a hierarchical structure with streams classified as first order, second order, third order or fourth order stream (and so on) based on their location and the number of streams that feed into the stream of interest. According to Forman (1995), the perennially running stream highest in elevation is a first order stream; a second order stream is formed when two first order streams merge. It follows that a third order stream is formed when two second order stream meet and so on. Second to the fourth order streams exhibit distinct pool and riffle pattern. Streams of higher orders have more convoluted forms, are much slower and deposit greater amounts of sediments (Forman, 1995). The support of aquatic animals is dependent on the stream type and adjacent landscape structure and location.

Human interference is the most penetrating influence in a riparian corridor. Riparian corridors should be as wide as possible to offset this risk factor to plants, animals, and water quality (G. Merriam and D. A. Saunders, 1993). Creating wide riparian corridors is generally not possible in

---

[17] Some species such as Fagus grandiflora which have specialized and low dispersal potential need minimum of four hectares for long term survival. Experiments done by Levenson indicated that species richness increased when the island size increased to 2.3 acres. But these islands functioned essentially as edge communities. Species richness decreased when the island size was larger than 2.3 acres because species tolerant to interior mesic conditions became established in the woodlot. The species richness ceased to decline (i.e. stabilize) when woodlot size was around 3.8 acres.

[18]The Open Space Handbook for the Town of Dunn does not specifically explain on how they came up with the minimum size for woodlots. The smaller woodlots are not necessarily the woodlot that was preserved since various other factors such as adjacent land use, the species composition, and ownership of the land are also considered for the open space plan.

[19] The floodplain is an area adjacent to the stream channel that is periodically inundated with water. Geomorphic floodplains is an area within which the stream meanders over centuries and is limited by upland terraces on either side (Smith and Hellmund, 1993).

landscapes dramatically altered by humans and so in urban areas this "wide as possible" strategy may take on a new meaning "wide as feasible". According to Budd et al (1987) the width of riparian corridors should be decided on the basis of soil condition, nutrient and sediment flows, hydrology, and local biological integrity. Adjacent land use is also an important consideration because forest clear cutting, dense housing development, and intensive agricultural lands will require wider corridors or stream buffers if functions and values are to be maintained. Smith and Hellmund (1993) recommend that experts be consulted on the exact widths for each of these specialized cases. As a rule of thumb, for riparian corridors to maintain their ecological functions, it is important to include at minimum the stream's geomorphic floodplain and a strip of upland vegetation along at least one side of the stream (Forman, 1995; Smith and Hellmund, 1993; Durham City-County Planning Department, 1993).

Hedgerows: Hedgerows are semi-natural corridors located in large agricultural landscapes and are classified based on their origins. Hedgerows have either been planted by humans, are naturally regenerated or are remnants of the original woodlands (Forman and Godron, 1986).

The width and structure of the hedgerow are important considerations, especially if hedgerows are to function as wildlife habitat. In a study for Ontario, Canada hedgerow corridor widths ranged from 9 to 36 feet (3 to 12 meters) and had minimum length of about 0.62 miles (1 kilometer). Studies have shown that wider corridors (13 to 36 feet) are used by medium sized mammals such as raccoons and birds. Wide corridors also served as breeding grounds for small rodents. Narrower corridors (3 to 12 feet)were used by smaller mammals, invertebrates, and birds. Hedgerows connecting riparian corridors or patches of woodland or forested areas can function as a travel route for animals. Species diversity is higher in hedgerows that have a good vertical structure, i.e., a mix of trees, shrubs, herbs, and grasses (Forman and Godron, 1986; Merriam and Saunders, 1993).

Special Sites: Special sites are areas that have some important functional attribute. Special sites include waterbodies, aquifer recharge areas, caverns, sinkholes, ridgetops, and wetlands. According to Lamm and Vandewalle (1979), ridgetops are important groundwater recharge areas in the Ridge and Valley Province. Landfill sites, truck yards and other concentrated sources of pollution should not be placed on ridgetops (Lamm and Vandewalle, 1979). In certain areas of Greater Roanoke Area, endangered plant species are located on ridgetops. Waterbodies, caverns, sinkholes, and wetlands are also sensitive resource areas which can be negatively impacted by unwise land use practices. Such areas act as sinks or sieves for pollutants and thus deserve special protection.

4.5.2 Analysis of Function and Change Dynamics of the Matrix, Patches, Corridors, and Special Sites

Functional attributes (flows) of different landscape elements need to be analyzed if we are to determine how ecosystems and landscape elements interact and in order to plan for their future use and management (whether such areas be included as formally designated open space or serve as buffer areas to designated open space). Flows between landscape elements can be positive or negative. Positive flows are flows that are beneficial to ecosystems while negative flows are flows that are harmful to ecosystems. Flows are caused by movement of energy, nutrients and species between landscape elements. Wind, water, people, and animals are transport mechanisms for these flows (Forman and Godron, 1986). An example of a negative flow is the movement of fertilizers and pesticides from agricultural fields into stream corridors. Here, water is the transport agent with fertilizers and pesticides polluting streamwaters and affecting species diversity in the riparian corridor. An example of a positive flow is the dispersal of seeds by wind from one woodland to another thus increasing the genetic diversity of the forest. Note however, that the flow of invasive plants by seed to the woodland may be considered as a negative flow.

4.5.2.1 Functional Analysis of the Matrix or Land Cover Type

Urban Areas: Natural ecosystems are characterized by cyclical flows where water and nutrients are constantly replenished while urban ecosystems are more often characterized by one way flows. In urban areas the surrounding land (for example, mines, agricultural lands, oil fields, pasture lands, watersheds, and forests) are sources for energy. The atmosphere, water and the adjacent landscape are the sinks for the wastes generated by urban systems (see Figure 4.2).

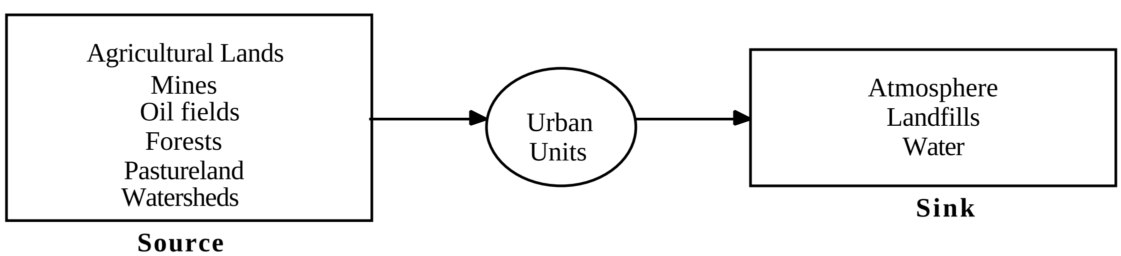

Figure 4.2: Flows in Urban Units

One way flows should be minimized or avoided since they ultimately result in resource depletion and ecosystem degradation (Lyle, 1994).

Natural units within urban areas have numerous functions with the magnitude of their functions being dependent on their size and structure. Natural units within the urban areas serve as sinks for stormwater and carbon dioxide[20] and are a source for seeds, wildlife, and oxygen. In addition natural units are important for recharging aquifers, protecting soils, and for maintaining

[20] Carbon dioxide is present in the atmosphere in small quantities and becomes a pollutant when present in the atmosphere in high concentrations. It is obtained as a byproduct when fossil fuel, wood or coal is burned.

biodiversity within urban areas. Thus retaining and creating new natural ecosystems within urban areas is of high importance in order to offset negative impacts related air, water, soils, vegetation, and animals.

Agricultural Areas: Many of the present day agricultural practices are unsustainable since they need three to five times more energy inputs than final outputs (Lyle, 1984). Agricultural landscapes are typically sustained with pesticides and fertilizers during their growth process. Agricultural areas are one of the major polluters of streams and groundwater systems since the runoff from agricultural lands often contains high levels of pollutants such as fertilizers, manure, and pesticides. These negative flows have a major effect on the landscape structure. Intensive agricultural management practices can destroy the soil structure and harm local wildlife populations. Many of the pasturelands adjacent streams face problems of stream pollution due sedimentation caused by uncontrolled livestock access to streams.

Agricultural areas can also have some positive flows by providing habitat for smaller animals and insects and food for birds. Agricultural lands provide an essential source of food for people. Well managed agricultural lands help in soil retention and provide visual amenities.

Forested Areas: Large natural areas of native vegetation are important for protecting aquifers and streams, biodiversity, interior species and the connectivity of low-order stream network. Large natural areas also provide microhabitat proximities for multihabitat species, habitat for species with large home ranges and permit natural disturbance regimes in which species evolve and persist (Forman, 1995). The main issue that affects large natural areas is fragmentation or the loss of habitat due to forest cutting and change in land use. Fragmentation affects nearly all ecological patterns and processes, from genes to ecosystem functions. Fragmentation can lead to an increase in the number of generalist species, multihabitat species, exotic species, nest predation, and species extinction rates. If severe enough, fragmentation will decrease the interior species richness and populations of large homerange species. Severe fragmentation will disrupt natural hydrological flows, nutrient recycling, overall productivity, and gene flow (Forman, 1995).

Woodland Patches: Woodland patches are remnant patches found in urban, suburban or agricultural landscapes. They are important for maintaining species diversity in urban, suburban and agricultural areas. Woodland patches filter air and water pollutants, provide habitat for small homerange species, act as stepping stone for species movement between large forested areas, protect soils, and provide recreation and visual amenity.

Riparian Corridors: Vegetation along the streambanks is important for maintaining the health of the stream. Riparian vegetation provides habitat for a variety of birds and animals while streams provide water, an essential resource for all organisms. Vegetation along smaller streams shades the stream, and helps to retain streamwater temperatures in a range compatible for aquatic life.

Fallen logs and branches from the overhead vegetation also create fish habitat in a stream (Forman, 1995). Riparian vegetation provides organic food material for aquatic organisms which form the base of the food chain in aquatic ecosystems. Streambank vegetation slows the velocity of water and increases water infiltration. Vegetation also helps to maintain stream baseflows. "Riparian wetlands perform the important role of flood reduction because they allow floodwater to spread horizontally, to infiltrate soils, and to be released slowly" (Smith and Hellmund, 1993:75). Riparian corridors thus serve many vital functions whether they are surrounded by urban, agricultural or forested land.

Hedgerow: Hedgerows define agricultural field boundaries and helps to prevent soil erosion, break winds and provides habitat for predators that prey on crop pests and other animals (Lyle, 1984). In large agricultural areas, hedgerows are sources for native species and help in maintaining higher levels of biodiversity.

Special Sites: Special sites are areas that have sinkholes, caves, wetlands or threatened and endangered species. Sinkholes are surficial depressions that are formed due to subsidence or collapse of unconsolidated materials into void spaces created by the dissolution of the underlying carbonate bedrock. Pollution of groundwater resources is a major problem in karst areas because sink holes represent points of inputs into the groundwater. Liquid wastes dumped into the sink holes can enter the groundwater system undiluted through underground channels. Dumping of solid wastes into the sinkholes can also contaminate the groundwater (Hubbard, 1988). Caves are void spaces created by the dissolution of the underlying carbonate bedrock. Many of the rare or endangered species are found in caves. Wetlands are areas that are inundated with water for at least a part of the year and support semi- aquatic plant species. Wetlands are characterized by high plant and animal diversity (Weller, 1994).

4.6 Establishing Management Strategies for Protecting and Enhancing Open Spaces

Establishing management strategies for protecting and enhancing open spaces often involves planning and design solutions for landscape units that have negative flows including the development of methods to increase biodiversity, the establishment of connections between different natural areas, and the creation of riparian, woodland and wetland buffers. All management strategies proposed and implemented should be appropriate to the site and its surroundings. In some cases, the required changes may necessitate changing the adjacent land use(s) particularly where current use would continue to generate negative flows to other areas (Forman and Godron, 1986). Management strategies should be established based on structural and functional analysis of landscape elements and by input from local community members.

The following management strategies are presented for urban areas, agricultural areas (including hedgerows), forested areas and riparian corridors.

4.6.1 Urban Areas

1. Agricultural Lands in Urban Areas: Because remnant agricultural lands within urban areas are threatened by growth pressures prime farmlands should be preserved for agricultural and conservation purpose. Residential, commercial and industrial uses built on agricultural lands should set aside land that has the potential to contribute to the ecological health of the area and its surroundings as open space. Clustering of residences and other buildings should be encouraged for new developments. Agricultural lands within urban areas can be converted to greenhouses, orchards or natural/semi-natural open spaces since they typically have good soil structure (Lamm and Vandewalle, 1979). Orchards and greenhouses will provide fresh fruits and vegetables to urban areas. Agricultural and natural/semi-natural open spaces within urban areas can also function as stormwater retention and infiltration areas, as a sink for airborne pollutants, as a possible location for passive recreation, and as wildlife habitat for small mammals and birds.
2. Woodland Patches in Urban Areas: Because natural units within urban areas are threatened by growth pressures, natural open spaces within urban areas should be preserved and used for storm water retention and infiltration, air quality improvement, passive recreation, and retention of biodiversity. Decisions about what to preserve and/or use can be made by establishing priorities regarding natural units that remain in urban areas. For example, larger natural units with wetlands, well connected stream corridors, and high plant and animal diversity would be ranked highest in terms of protection importance. Such areas should be given highest management priority and specific strategies for preservation and protection. On the other hand a small isolated patch of open space less than ten acres (four hectares), with little or no diversity and low quality soils would be ranked lowest at the county planning level.
3. Road Corridors: Because it is insufficient to preserve only large natural units, stepping stones (in the form of small patches or corridors linking large forested patches) should be provided (Forman, 1996). As much as possible street and yard plantings should use native upland vegetation. Native trees and shrubs provide a seed source for larger areas while providing other ecological services such as increasing groundwater recharge and tempering urban climates (Levenson, 1981).
4. Restoration and Creation of Wetlands: Because streams in urban areas face pollution problems (caused chiefly by stormwater runoff from paved area), wetlands, wetponds and swales should be created or restored in urban areas to retain, clean, and infiltrate water. These areas will also provide habitat for some wetland plant and animal species and provide other ecological services.

4.6.2 Agricultural Areas

1. Agricultural Lands: Wherever possible, large areas of agricultural land should be preserved. Ideally a sufficient amount of agricultural land should be retained to provide locally grown food and fodder.
2. Hedgerows: In large agricultural areas, farmers and agrobusinesses should reintroduce hedgerows or protect existing hedgerows. "Hedgerows in agricultural landscapes break wind, shelter crops and soil, harbor predators that feed on crop pests, and provide food for a great number of species" (Lyle, 1984:203). In creating new hedgerows or enhancing existing hedgerows, property owners should simulate all vegetation layers by planting vertical and horizontal layers.
3. Buffers Between Agricultural Lands and Forests: Encourage planting of shrubs between woodlands and agricultural patches or in forested edges. It should be at least seven meters (approximately 20 feet) in width. These transition areas provide food, nesting cover, escape cover for wildlife (Virginia Department et al).
4. Pastureland: In pastureland encourage the replacement of fescue pasture with native grasses suitable for pasture use as native grasses require little or no fertilizers, are not affected by parasites, and provide for excellent wildlife nesting areas. In heavily disturbed soils, native grasses require only minimum amounts of fertilizers to regenerate the soil (Virginia Department et al, 1995).
5. Recycling of Nutrients: Because the four basic resources needed for agriculture include land, water, nutrients, and energy, and cities can give all but land in large quantities, urban energy systems should be linked with agricultural systems (Lyle, 1984). Biologically treated wastewater and stormwater can be used for irrigation and to recycle nutrients. Energy can be obtained from substances such as tree trimmings, garbage, and refuse (which are often regarded as waste products in cities). The heat dissipated from the urban areas create a heat island effect which can be beneficial for food production since it lengthens the growing season (Lyle, 1984).
6. Buffers Between Streams and Agricultural Lands: Wherever possible vegetated buffers should be introduced between agricultural lands and perennial streams to help in controlling stream pollution and sedimentation. Buffers should be large enough to provide filtering effect for agricultural stormwater runoff. Where agricultural best management practices are in place and slopes less than 10%, buffers of 25 feet (8 meters) may be sufficient. Much larger buffers are preferred in areas with steeper slopes or where agricultural best management practices are not in place.
7. Protection of Soil Structure: Conservation tillage practices such as chisel plowing, zero tillage, and till planting should be encouraged in agricultural areas (Lamm and Vandewalle, 1979). Cash crops are encouraged in areas with gentle slopes. In these areas, rotation and strip crop farming should be encouraged. Cash crops are not recommended in areas with slope and soil limitations. These practices will help in protecting soil structure and controlling pest outbreaks.

4.6.3 Forested Areas

1. Diversity of Habitats: Because some species require early successional forests while others require old growth forests or wetlands, the diversity of habitats in forested areas should be retained. Retain all habitat types within these large natural areas: habitats of rare and endangered species, multihabitat species, species requiring specialized habitats, etc.
2. Minimum Patch Sizes: Minimum patch sizes for natural areas should be based on the habitat needs of wildlife populations that need large home ranges.
3. Landfill Areas: The future landfill areas for the county should not be located close to areas with karst features or near streams since they are potential sources for groundwater pollution.
4. Logging and Hunting : In order to prevent fragmentation of forested lands and mitigate the effects of fragmentation in highly fragmented areas, logging and hunting should be regulated and closely monitored in forested land. If logging must occur, locate cuts so as to avoid or minimize negative flows into the forest interiors. For example cuts should not provide stepping stones into core areas. As a rule of thumb, logging activities should be carried out at least 100 feet from any stream edge (E. S. Corbett et al, 1978 as cited in Smith and Hellmund, 1994).
5. Animal Movements: Protect existing large forested areas and connect them to one another through the provision of natural corridors. Such corridors facilitate animal movement between these areas.
6. Special Sites: Protect special sites such as wetlands, ridgetops, caves, and sinkholes within these large forested areas.
7. Larger Spatial Context: Design recreation areas and plan for the use and conservation of open spaces taking into consideration the larger spatial context, and establishing open space connections with surrounding counties and the region.
8. Powerline Corridors: Because the management of many powerline corridors focuses on preventing tree growth along the powerline corridors (the corridors being maintained as grassed areas by the use of herbicides or cutting), maintenance of these areas as mixed grass and shrublands should be used as a way to achieve greater ecological greater ecological benefits than intensively managed grassed corridors (Forman, 1995).

4.6.4 Riparian Corridors

Diversity of Habitat: In riparian corridors protect the headwaters of each watershed, and sections of all streams by providing and protecting vegetative buffers along these streams. Protecting the headwaters will improve water quality (Smith and Hellmund, 1993). Protected riparian corridors should include critical areas such as streams with steep or erodable soils, areas with high biodiversity, aquifer recharge areas, and other sensitive lands.

Streambank Erosion: Because erosion along streambanks is often caused by uncontrolled stream access by livestock, livestock should have limited or no access to streams. This can done by fencing riparian corridors and providing alternate water sources away from stream corridors. Structures near Riparian Corridors: Buildings should be placed on areas outside of the 100-year floodplains. In areas where the depth to groundwater is less than six feet, houses should be built on stilts and must be connected to sewage treatment facility . This will help prevent basement flooding and groundwater pollution. Care should also be taken not to build structures on natural drainageways (Lamm and Vandewalle, 1979).

Riparian Corridor Vegetation: Simulate all vegetation layers in riparian corridors including groundcover, shrubs, vines, and trees as studies have shown that species diversity is greater in corridors with all vegetative layers (Forman, 1986). Gaps in a corridor do not necessarily reduce the movement of all species, however, care should be taken to see that corridors are not bisected by major roads (G. Merriam and D. A. Saunders, 1993; Forman, 1986). Where roads must cross riparian corridors provide room for movement of species along stream or river beneath the bridge and outside the annual floodplain. Where culverts must be used, oversized to create natural bottoms and area for passage by small mammals.

4.7 Development of the Preliminary Open Space Plan

Preliminary county open space plan is prepared based on the information obtained and synthesized during the inventory, analysis and management development phases of the process. At this stage it again important and useful to actively involve local citizens and use their input to refine the preliminary open space plan. Maps and diagrams of the landscape patterns and management strategies should be used to explain the concepts to the local citizens. Management strategies and the physical description of open space plan can then be modified and a final county open space plan prepared. Open space planning process based on the principles of landscape ecology is a part of a larger planning process and needs to be overlayed with political and social plans.

4.8 Selecting Tools for Open Space Preservation

County environmental and open space goals can be implemented through responsible private ownership, education, government land use regulations and incentives. In the United States, most of the open space land near cities and towns are under private ownership. As it is not feasible to buy all of this land to conserve open spaces an open space plan must successfully encourage private owners to take individual and collective responsibility for protecting forest, riparian, and agricultural areas. Involvement of people during the planning process is essential for the success of the open space plan. Educating people about the importance of conserving natural resources is another way of providing long term protection to open spaces. Environmental education should start in schools. This can be done by organizing field trips or lectures for the school children by local government agencies or non profit organizations. Education can also be offered through local media, libraries, and organizations such as YMCA or YWCA and the local media. The open space planning process should engage local citizens by soliciting their ideas and involving them in decision-making about their county landscape. It should be noted that the tools for open space preservation are optional measures that would take political discourse to review and select the most appropriate ones.

Regulatory measures such as density bonuses, conservation overlay zone, resource overlay zones planned unit development ordinances, graded zoning, and erosion and sediment control should also be used for protecting open spaces. The non regulatory measures that can be used for open space protection are easements, agriculture and forest districts, and land acquisition from willing sellers.

4.8.1 Regulatory Programs

Density Bonuses: This is a type of incentive zoning given to developers who provide amenities such as parks and trails. Through this ordinance the developers will be allowed to have greater densities than normally would be allowed.

Conservation Overlay Zones: Conservation zones allow for greater density of buildings in one part of the property so that the rest of the property can be conserved as an open space.

Resource Overlay Zones: This ordinance can be used to protect undeveloped land along streams. This ordinance places restrictions on development in areas that contain sensitive or historical resources.

Planned Unit Development Ordinances: This ordinance requires that a certain percentage of the property to be set aside as open space for new housing developments.

Graded Zoning: Areas near open spaces can be zoned in such a way that low density areas are placed near the open space and the high density areas are placed further away from the open space. This will decrease the impact of development on the open space (Environment et al, 1978).

Erosion and Sediment Control: It is not sufficient to simply preserve open space. It is also vital to control flows into the natural systems. This is because sediments from adjacent land uses such as construction sites and farmlands may end up in streams, wetlands, and lakes. This will ultimately result in loss or degradation of plant and animal habitat. It is also important to maintain the infiltration function of the soil to the maximum extent possible and keep run off velocities as low as possible. A permanent control system should be developed to prevent the release of excessive stormwater runoff caused by new developments. Erosion should be controlled at the site level (Environmental et al., 1978).

4.8.2 Non Regulatory Programs

Easement: An easement involves the purchase of partial rights to a piece of land. The purchase of easement limits the use of the land by the owner. The property owner gets some tax benefits for doing this. Easements can be used for protection of areas that have critical wildlife habitat, protection of aquifer recharge areas in private lands, conservation of agricultural lands and preservation of rural character of the town (Steiner, 1991).

Agriculture and Forest Districts*:* This is a land conservation and preservation measure that can be enacted within the county when the property owner agrees to limit development on their land for a certain period of time. The owner is given tax incentives for doing this.

Land Acquisition: The town should be involved in acquisition only if the land adjacent to the open space is threatened by development and if this development negatively affects the functions of the open space. The town should work hand in hand with non profit organizations such as *The Nature Conservancy* or state agencies such as the *Department of Conservation and Recreation* to publicly acquire property rights.

Chapter 5 Application of the Open Space Planning Approach to the Greater Roanoke Area, Virginia

In this chapter, the open space planning approach developed in Chapter 4 is applied to Greater Roanoke Area, Virginia. In review, The eight stages in this approach include:

1. Establishment of goals
2. Data collection for the region and the county
3. Study of the landscape at the regional scale
4. Delineation of dominant land cover types at the county scale
5. Inventory and analysis of landscape elements
   - Identification and classification of patches, corridors and special sites
   - Analysis of structure, function and change dynamics of the patches, corridors and special sites
6. Establishment of management strategies for protecting and enhancing open spaces
7. Development of the preliminary open space plan
8. Selecting tools for open space preservation

5.1 Establishment of Goals

Goal setting is an important part of any planning process. Goals help in articulating an idealized future situation. This process should involve public participation. This thesis is limited to the analytical part of the open space planning process. Hence public participation are not been considered in depth for any stage of the open space planning process described below.

Early involvement of community members is important because the success of an open space plan is ultimately dependent on the involvement and cooperation of the people in implementing the open space plan.

5.2 Data Collection

Greater Roanoke Area is located in the headwaters of Roanoke River Basin in southwest Virginia. More than seventy five percent of the Greater Roanoke Area lies in the Roanoke River Basin and a rest of it is in the James River Basin. Greater Roanoke Area is intersected by a valley seven miles wide and is sandwiched by two narrow ridges and valleys. The valley to the northwest is called Catawba Valley, the one to the south is called Back Creek Valley (Jack, 1912:14). Greater Roanoke Area has the largest metropolitan concentration in the Roanoke River Basin. (State Water et al, 1988).

Data collection includes gathering information from existing studies, field studies, experts from other disciplines and the public. The information regarding the data collection phase is covered in detail below. However, the application of the open space approach did not deal with this aspect of the planning process in data collection due to time constraints.

5.2.1 Existing Studies for Greater Roanoke Area

5.2.1.1 Discussion of Previous Greater Roanoke Area Open Space Plans

The first comprehensive plan for Roanoke was prepared in 1928 by the landscape architect John Nolen. In this plan Nolen proposed acquisition of land for neighborhood parks and creation of a parkway system along the county's major streams. He proposed parkways along Roanoke River, Tinker Creek, Mud Lick, Murray's Run, Franklin Road, and Garden City. But the parkways were never implemented due to the lack of money for acquisition and implementation.

The 1965 *Roanoke Valley Open Space Plan* is the earliest comprehensive open space plan done for Greater Roanoke Area. This regional open space plan covered Greater Roanoke Area and Botetourt County. By 1965 Roanoke already had some significant open spaces such as the Blue Ridge Parkway, Appalachian Trail, Havens Wildlife Management Area, Jefferson National Forest, and Carvins Cove. The main aim of the 1965 plan was to create open spaces in the urban and urbanizing regions of Roanoke. The open space planners proposed creating open spaces in new subdivisions and additional parks, totlots, and athletic fields in urban areas. The plan also recommended creation of the Roanoke River Parkway and provision of water-based recreation in watershed impoundment areas. The planners also proposed designating a protected floodplain zone along the Roanoke River. The suggested techniques for open space preservation are zoning and easements. Zoning and easements were both a new concept in the Roanoke Valley then. The planners proposed designating zoning as a tool to preserve agricultural lands, floodplains, and to enforce cluster zoning. They also proposed working with the state government to acquire larger open spaces.

5.2.1.2 Roanoke Valley Greenway Plan

The 1995 Greenway Plan was prepared by the Greenways Incorporated for the Fifth Planning District Commission, County of Roanoke, Roanoke City, Vinton, and Salem. The goals of the greenway plan are to:

- Provide a non-motorized transportation facility;
- Provide addition recreation resources and non-motorized public access to existing recreational resources;
- Provide education of the county's cultural and natural history to the county residents and visitors;
- Utilize greenways as an economic development marketing tool for Roanoke Valley;

- Utilize greenways for stream corridor protection, stormwater management, provision of vegetation and wildlife habitat, and reduction of non-point source water pollution.

The greenway planners propose creating a network of greenways that links natural and man-made systems. They propose using railroad corridors, stream corridors and roads for the greenways. A network of 58 greenway routes are identified for Roanoke area of which sixteen of are along streams and rest are along roads and abandoned railroads.

Tools for preservation are an important part of the greenway plan. The tools for preservation proposed for Roanoke Valley Greenway Plan are greenway easements, zoning ordinances, and land acquisitions. Because of the importance of these tools in protecting open space, they are discussed in detail below.

<u>Greenway Easements</u>: The purpose of the greenway easement is to establish a legal contract regarding the specific use or protection that greenway lands will receive. The owner retains all the rights to the property other than those that have been granted by the easement (Greenways Inc., 1995:49). Some of the greenway easements proposed are conservation easements and preservation easements. A conservation easement puts permanent limits on the use or development of the land in order to protect the natural resources of the land. Conservation easements qualify for federal tax deductions and state tax credits. Preservation easements are easement to protect the historical integrity of a structure or important elements of the landscape by sound environmental management practices.

<u>Zoning Ordinances</u>: The following types of regulations are proposed for greenway protection:

- *Reservation of Land*: This regulation does not involve transfer of property rights but constitutes an obligation by the property owner to keep the property from any development.
- *Conditional Zoning:* "Conditional Zoning is used to create public or private greenways through special conditions voluntarily offered by the property owner requesting rezoning. The conditional zoning allows the owner to perform some act or make site improvements to make the proposed rezoning more compatible with the surrounding area. This mechanism allows planning officials to accommodate the property owner without conflicting with the County Land Use Plan" (Greenways Inc., 1995:50).
- *Buffer/ Transition Zones:* Buffer and transition zones are areas between two adjacent incompatible land uses. Such zones help to preserve greenways that function as buffers between incompatible land uses.
- *Density Bonuses:* This is a type of incentive zoning given to developers who provide amenities such as parks and trails. Through this ordinance developers will be allowed to have greater densities than normally would be allowed in a zone.
- *Conservation Overlay Zones:* Conservation zones allow for greater density of buildings in one part of the property so that the rest of the property can be conserved as open space.

- *Resource Overlay Zones:* Resource overlay zones can be used to protect undeveloped land along streams. This tool places restrictions on development in areas that contain sensitive or historical resources.
- *Planned Unit Development Ordinance*: This ordinance requires that a certain percentage of a property to be set aside as open space for new housing developments.
- *Agriculture and Forest Districts:* This is a land conservation and preservation measure that can be enacted within the county where property owners agree to limit development on their land for a certain period of time.

Land Acquisition: The third method proposed by Greenways Incorporated for the development and protection of greenways is land acquisition. Some of the ways in which land can be acquired are through donations, tax incentives, simple purchase, easement purchase, bargain sale, condemnation, and impact fees.

5.2.1.3 Roanoke River Corridor Study

The main aim of this 1990 study is to document the existing conditions of the Upper Roanoke River Corridor and to recommend protection for the corridor based on the problems identified. The project also includes detailed recommendations for the implementation policies. The study area includes a part of the Roanoke River from its headwaters in Roanoke and Montgomery counties to the upper reaches of the Smith Mountain Lake in Franklin County. The width of the study area corridor is 750 feet from the edge of the floodplain. The environmental factors considered for the study includes critical wildlife and plant habitats, non-tidal wetlands, migratory bird congregation areas, and karst areas.

The corridor study includes the following recommendations:

1. *Construction Overlay Zone:* A Construction Overlay Zone is proposed along the Roanoke River. The corridor study recommend that no buildings or structure be permitted in the 100-year floodplain or within 100 feet of the edge of the river, whichever distance is shorter.
2. *Vegetative Buffers*: A buffer width of 100 feet or more is proposed along the river corridor. The study also recommend preservation of the indigenous vegetation along the river corridor. In agricultural lands the 100 feet buffer should be managed according to Best Management Practice for agricultural lands.
3. *Erosion and Sediment Control:* Within the conservation zone any land disturbing activities occurring on land greater than 2500 square feet must comply with the local Erosion and Sediment Control Ordinance.
4. *Use Restriction:* The following uses are proposed as restricted within the Conservation Overlay Zone: mining and extraction of natural resources, drilling, sanitary land filling, underground storage of any chemicals or petroleum products, feedlots, land application of sewage sludge or reclamation of sewage and industrial wastes.

The study also identifies areas within the Conservation Overlay Zone that have significant plant and wildlife populations. Special status plant species are located in areas between Glenver and Lafayette. Two areas that have significant migratory bird congregation populations are the wetlands near the Roanoke Regional Sewage Treatment Plant and Veterans Administrative Hospital. The Veterans Administrative Hospital has a semi-permanent colony of yellow-crowned night herons which are listed under the state special concern category.

5.2.2 Existing Open Spaces

Most of the large open spaces in Roanoke are located on mountain slopes. There are small patches of natural vegetation along the Roanoke Valley, Catawba Valley and Back Creek Valley. The Catawba and Back Creek Valleys have patches of agricultural land, crop fields and shrublands. The largest protected open spaces in Greater Roanoke Area are the Blue Ridge Parkway, the Appalachian Trail, Havens Wildlife Refuge, the Jefferson National Forest and Carvins Cove (See Figure 5.1).

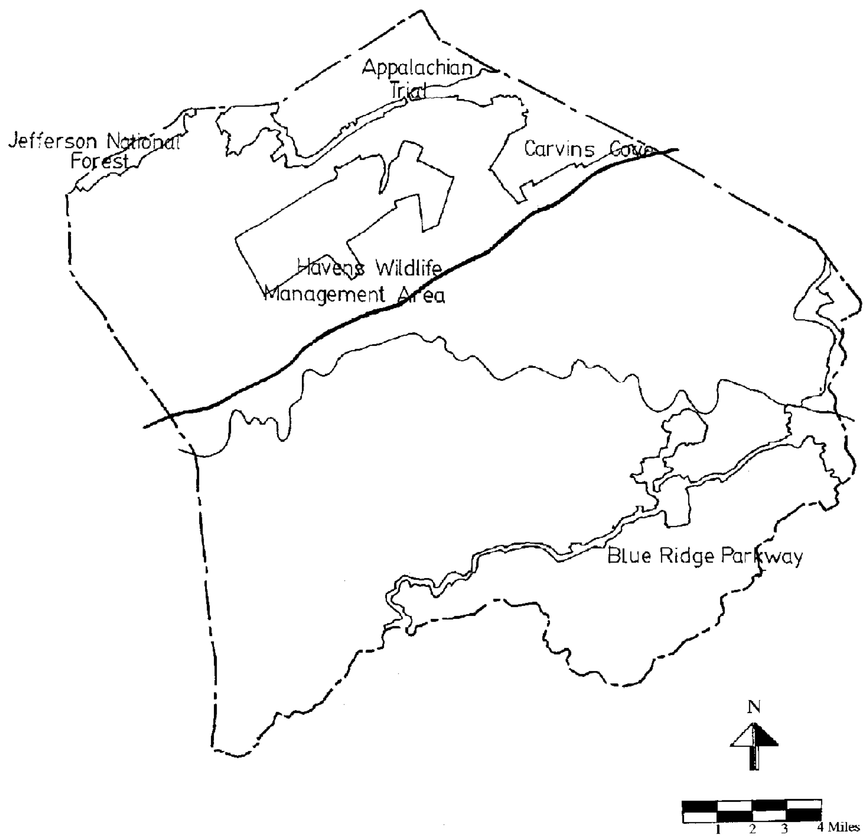

Figure 5.1: Protected Open Spaces in Greater Roanoke Area

The Blue Ridge Parkway was constructed in the 1930's. This 469-mile long parkway extends from Shenandoah National Park in Virginia to the Great Smokey Mountains National Park in North Carolina (Lord, 1992). This parkway is built for the recreation motorist. Along its route the parkway supports a variety of wildlife.

The Appalachian Trail runs along the northern part of Roanoke County. This multi-state hiking trail was designed in 1937 and extends from Maine to Georgia. This trail has the potential to serve as a natural corridor between various large natural areas in Eastern United States for many years to come.

Havens Wildlife Management Area is primarily a mixed oak forest with stands of pitch pine (*Pinus rigida)* on the southwest slopes (Giles 1988 cited in Mason, 1994). Havens Wildlife Management Area and nearly the entire Ridge and Valley Province of the Eastern United States was dominated by oak-chestnut forest but as a result of blight, chestnuts have been replaced by chestnut, red, and scarlet oak. Broader valleys in the ridge and valley province in Virginia has white oak as a common species (Mason, 1994:14).

The Jefferson National Forest was established in 1936. The forest extends 200 miles along the Appalachian mountains. It covers over 705,192 acres of land in 19 counties of Virginia, two counties of Kentucky and one county of West Virginia. The forest primarily has eastern hardwood forest type within the 50-90 year age class. Some of the wildlife found here include bear, deer, trout, turkey, raptors and song birds. These forest lands are used chiefly for timber harvesting and recreation (Forest Service et al, 1991).

Carvins Cove is located in the northern part of Greater Roanoke Area. A part of Carvins Cove lies in the neighboring Botetourt County. This large forested area has a reservoir that supplies water to the Greater Roanoke Area. Carvins Cove Reservoir which is owned by the City of Roanoke also functions as a public fishing facility. Carvins Cove Reservoir, besides receiving runoff from its watershed, obtains water diverted from Tinker and Catawba creeks (State Water et al, 1988).

5.2.3 Natural History Data

In any area, land use changes over time. Greater Roanoke Area within a span of 200 years has undergone tremendous change. The forested landscape was transformed into a agricultural landscape by the first European settlers. Over the years agricultural landscape has slowly been replaced by second growth forest, and urban and suburban development.

5.2.3.1 Pre-European Settlements

When the first Europeans settlers laid their eyes on the Roanoke Valley, they described it as a fertile land surrounded by mountains on all sides. This abundantly watered land was covered with forests except at the center where the Indians had cleared few hundred acres of land to provide pasture for deer and buffalo herd which came to lick salt from the marshes around saline springs (White, 1982). The salt marshes were the remnants of an inland sea that receded millions of years ago after the formation of the mountains (The Writers' et al, 1942). The marshes, Long Lick and the Big Lick were drained and became the center of Roanoke city. Most of the valley was in pristine condition before the Pre- European settlement because Roanoke Valley was never a permanent settlement for the Indians (White, 1982). Roanoke Valley functioned as a pathway and hunting ground for Indian tribes in the region.

5.2.3.2 European Settlements

By the mid-1700's Roanoke had permanent European settlements in each of the valleys. The early white settlers cleared the land for plantations. Early records also show that wheat and corn were the principle crops of Roanoke Valley. The valleys of Catawba were used for grazing and stock yards.

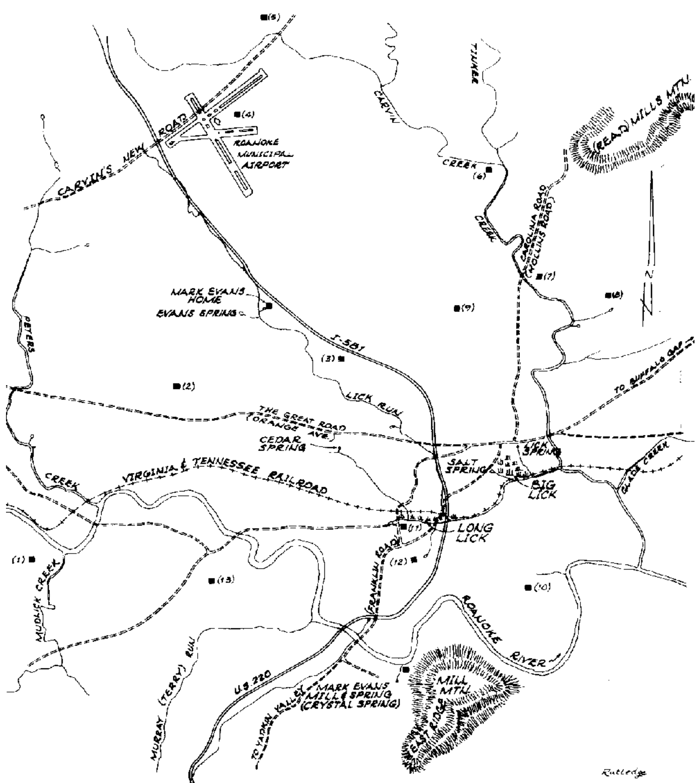

Figure 5.2: Roanoke During -European Settlement

Source: Roanoke 1740-1982 by Claire White

5.2.4 Natural Resources Data

5.2.4.1 Geomorphic Structure and Hydrogeology

Greater Roanoke Area lies at the junction of the Blue Ridge and the Ridge and Valley physiographic regions. The major physiographic elements found in the county include the Blue Ridge Mountains, the Fort Lewis-Brushy Mountain-Catawba Complex of the Ridge and Valley Province, and the Roanoke Valley. Greater Roanoke Area is located along the "hinge point" between the northern and southern Appalachians (Breeding and Dawson, 1976:20). Hence this area has complex folding and faults along the Ridge and Valley areas. The long and narrow parallel folds of the Ridge and Valley was formed due to the tectonic movement followed by thousands of years of weathering and erosion. The ridges are made up resistant sandstone and conglomerates while the valleys consist of limestone and weaker shale. The folds are dissected with numerous streams that forms a trellis drainage pattern on the landscape (Strahler, 1970). Some of the important perennial streams identified in the county are Catawba Creek and Mason Creek in the northwestern part of Roanoke; Tinker Creek, Peters Creek and Carvins Creek in the northeastern part of Roanoke; Mud Lick Creek at the center of the county; and Back Creek and Little Back Creek in the southern portion of Roanoke.

5.1.4.2 Land Cover

Each valley in Roanoke has a fairly distinct land cover type. Roanoke Valley is completely urbanized while Catawba Valley and Back Creek Valley have retained some agricultural land cover. The Catawba Valley consists of pastureland while the Back Creek area has a mixture of pastureland, field crops and low-density residential land cover.

The mountains are covered with forests. Second growth oak-chestnut forest is the dominant forest type through out Roanoke (Braun, 1950). Mixed mesophytic forests are confined to coves and lower ravines slopes. The American chestnut (*Castanea dentata)*, previously the dominant species in the oak-chestnut forest was largely eliminated due to chestnut blight. Red, chestnut, and scarlet oaks are now dominant. Where oaks do not dominate, secondary communities of white pines (*Pinus strobus)* on the north-facing slopes, Virginia pine (*Pinus virginiana)* on south-facing slopes and tuliptree (*Liriodendron tulipefera)* near the coves are the dominant species (Braun, 1950 cited in Mason, 1995). In non-urbanized areas, the broader valleys of Ridge and Valley Province have white oak (*Quercus alba)* as common species.

5.2.4.3 Wildlife

For the purpose of this study, data is collected for five key wildlife species. Data is collected for mammalian species from the higher tropic level including the Black Bear and Bobcat (see Table 5.1). Habitat information is also collected for birds that need large areas of habitat or require specialized habitat types. The birds studied are the Piliated Woodpecker, Pine Warbler and Barred Owl.

Table 5.1: Habitat Types for Key Wildlife Species

Name	Habitat Type	Minimum Habitat size	Notes
Black Bear	Appalachian Oak Forest	In Appalachian Oak Forest, the mean home range is 42 square kilometers for males and 15 square kilometers for females	Clearcuts are beneficial but need mature forests stands for cover and for denning
Bobcat	Early successional to mid successional forests; also found in thicket stumps and logging debris; require grass, forbs/shrub habitat	20 square kilometers is the optimum size to maintain viable populations	Bobcats are more tolerant to human land use than bears
Pine Warbler	Seral Pine Forest (35 -100 yr. old)	10 acres (4 hectares)	
Piliated Woodpecker	Mature forest close to water (not more than 150 kms); nests in mesic stands close to waterbodies	325 acres (130 hectares) of contiguous habitat	Key indicator species needs snags for nesting and dead wood for food source i.e., ants
Barred Owl	Deciduous woodlands, riparian and lowland areas	600 to 1000 acres (240 to 400 hectares)	Requires snags and perching areas with cavities

1.2.4.4 Special Sites

The special sites considered for this study are sites inhabited by threatened and endangered species, areas with karst features (sinkholes and caves), and wetlands.

Threatened and Endangered Species*:* Eleven threatened and endangered bird and fish species are considered for this study. The information for this is obtained from the BOVA[21] Report. The threatened and endangered plants are located in parts of the Jefferson National Forest, Fort Lewis Mountain and in the Poor Mountain Natural Area Preserve. The invertebrates are located near Roanoke College in Salem. The report did not list any threatened and endangered reptile, amphibian or mammalian population for the county. The main threats faced by these species are habitat loss, clean agricultural practices, water impoundments, pollution, sedimentation, and channelization of streams. Table 5.2 indicates the four fishes listed as rare, threatened or endangered for Greater Roanoke Area species. Table 5.3 indicates the six birds and one mammal listed as rare, threatened or endangered for Greater Roanoke Area species. Generalized locations of threatened and endangered species are also considered for the study (see Figure 5.3).

[21] BOVA (Biota of Virginia) is an extensive compilation of information on the threatened and endangered wildlife species by Virginia Department of Game and Inland Fisheries.

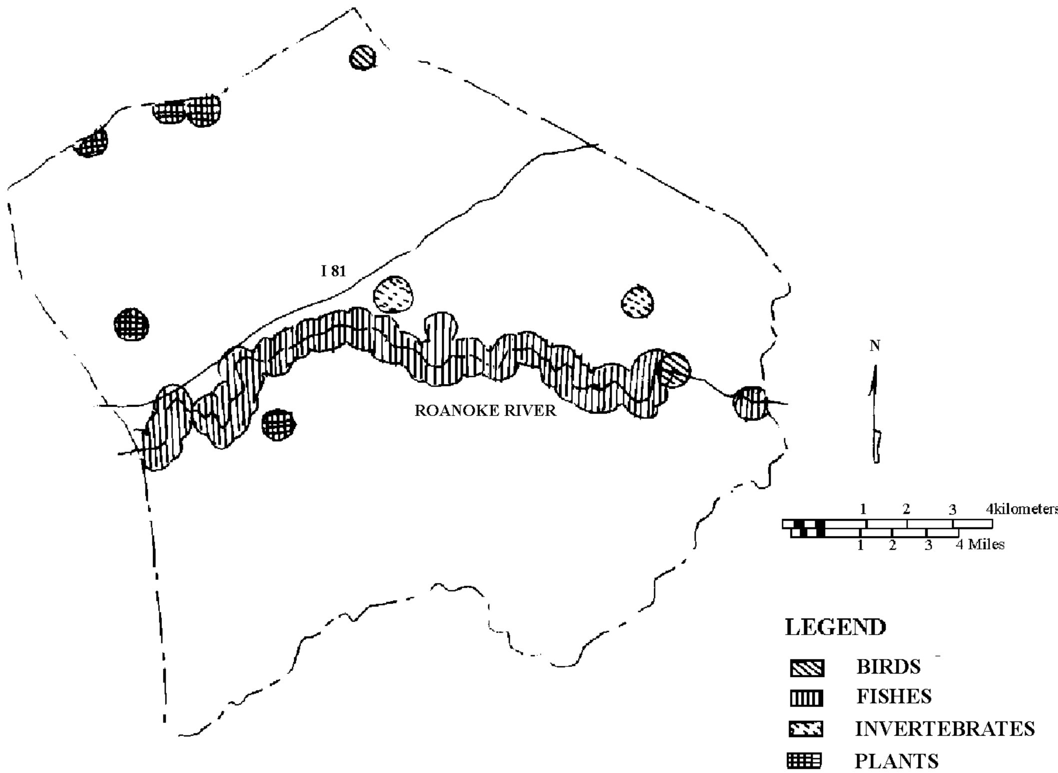

Figure 5.3: Location of Threatened and Endangered Species in Greater Roanoke Area
Source: Virginia Department of Game and Inland Fisheries

Table 5.2: Habitat Types and Management Strategies for Threatened and Endangered Fishes

Name	Location/Habitat Type	Minimum Habitat size	Management Strategies
Rustyside Sucker	Smaller streams in the Roanoke River drainage; residents of montane or upland streams	Human disturbance; destruction of riparian vegetation; siltation and sedimentation	Controlling sedimentation; restricting/regulating human disturbance of populations; maintaining undisturbed/ undeveloped areas
Orangefin Madtom	Roanoke River drainage above Salem	Creating impoundments; channelization; sedimentation; pollution of streams	Restrict or regulate human use of habitats; control sedimentation and pollution (thermal, chemical, physical); possible dams should be dry dams or permanent impoundments that have multiple level water release to retain natural temperature regimen in tailwaters.
Roanoke Bass	They are found in the Upper Roanoke River	sedimentation and pollution; creating impoundments; introduction of Rock Bass species	Restrict or regulate human use of habitats and human disturbance of populations; mitigate the effects of sedimentation and pollution

Table 5.3: Habitat Types and Management Strategies for Threatened and Endangered Birds and Mammals

Name	Habitat	Threats faced	Management Strategies
Brown Creeper	Dense coniferous, deciduous or mixed woodlands and wooded swamps with standing dead trees. The birds breed in the higher elevations of the mountains and the valley. They are also found in the Blue Ridge Parkway	Habitat loss, new construction and poisons	Restoration of mixed woodlands and swamps
Yellow Crowned Night Heron	Freshwater and salt water marshes, ponds, wooded swamps; need trees for nesting; found in the wetlands near Veterans memorial Hospital in Salem	Habitat loss	Restoration of mixed woodlands and swamps
Upland Sand Piper	Dry upland fields, hay fields of alfalfa and clover, railroads, highway right of way, shrubland, etc.	Intensive agriculture, urbanization and destruction of grasslands	Non intensive agricultural practices. Protection of pastureland and shrubland
Loggerhead Shrike	Upper Roanoke River, Blue Ridge Parkway and Havens Wildlife Management Area; need closely grazed pasture with hedgerows	Clean farming, application of insecticides or pesticides and reforestation	Developing and maintaining edges/ ecotones, hedgerows, haying, mowing and timber harvesting
Red breasted nuthatch	Upper Roanoke River in the mountains and valleys with elevations greater than 3500 feet; coniferous forests or mixed woodlands	Application of insecticides and pesticides	Needs snags and downed logs.
Bald Eagle	Upper Roanoke River in large wooded areas adjacent to river and streams	Road construction, powerlines, pesticides, loss of habitat, timber harvesting	Provide riparian corridors with large trees, restrict human use of Bald Eagle habitat, control sedimentation and develop or maintain water holes
Indiana Bat	Caves, wooded and semi wooded areas near streams	Impoundments, vandalism, mining, pesticides and insecticides	Protect caves from human disturbance i.e., caving during winter months, vandalism and spelunking ; prevent ground water pollution; control livestock access to streams; maintain riparian vegetation along streams

Karst Topography: Karst features are found in the Ridge and Valley physiographic region of Virginia. Karst features include sinkholes and caves. Sinkholes are surficial depressions that are formed due to subsidence or collapse of unconsolidated materials into void spaces created by the dissolution of the underlying carbonate bedrock. Pollution of groundwater resources is a major problem in karst areas because sinkholes represent points of inputs into the groundwater. Liquid wastes dumped into the sinkholes can enter the ground water system undiluted through underground channels. Dumping of solid wastes into the sinkholes can also contaminate the groundwater (Hubbard, 1988). In Greater Roanoke Area, majority of the karst features are found along the Catawba Valley and on the northern portion of the Roanoke Valley (See Figure 5.4).

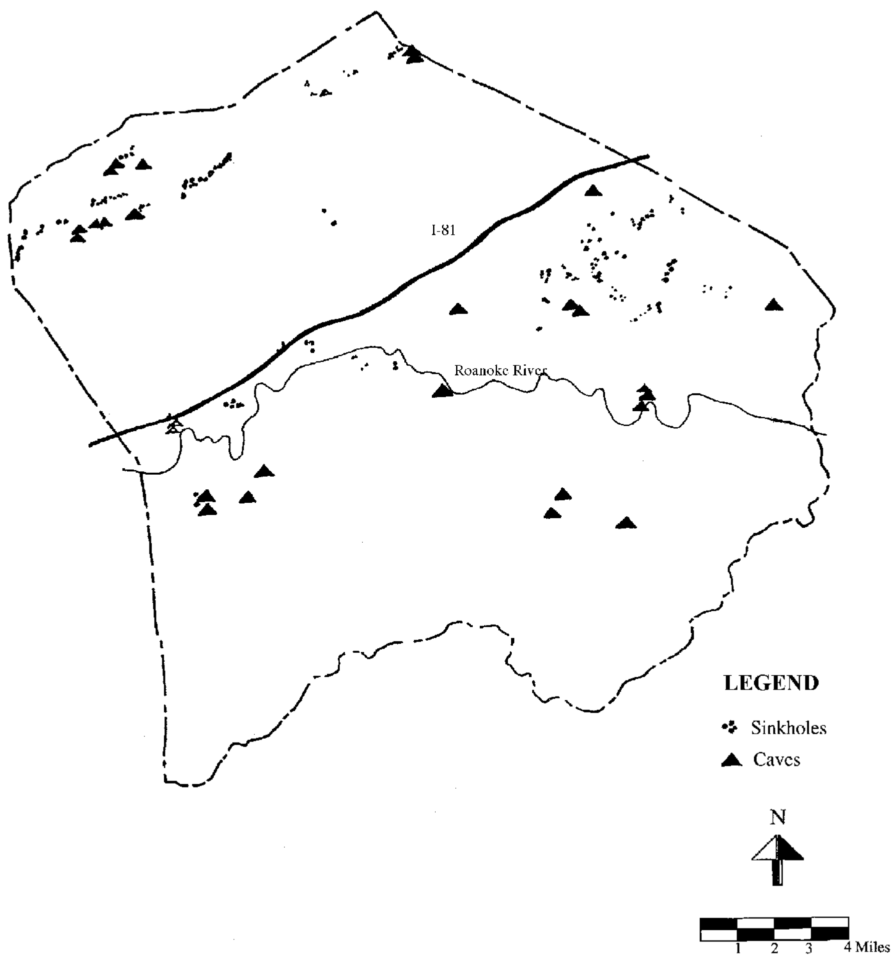

Figure 5.4: Location of Karst Features in Greater Roanoke Area
Data Source: Virginia Division of Mineral Resources

Wetlands: Wetlands are areas that are inundated with water for at least a part of the year and support semi-aquatic plant species. Wetlands are characterized by high plant and animal diversity (Weller, 1994). Greater Roanoke Area has relatively few wetlands because of steep slopes and well drained soils (United States et al, 1990). In Greater Roanoke Area most of the wetlands are located near the major streams and in the Back Creek area (see Figure 5.5).

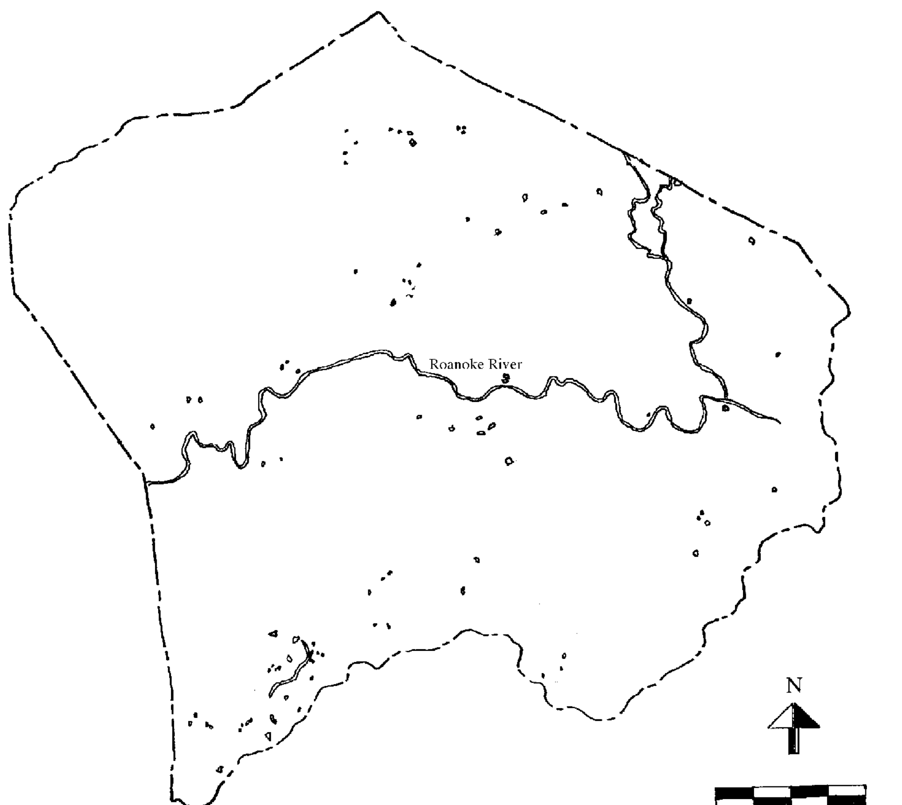

Figure 5.5: Location of Wetlands in Greater Roanoke Area
Source: Fish and Wildlife Information Exchange, Virginia Tech, Blacksburg

5.3 Study of the Landscape at the Regional Scale

Greater Roanoke Area has large forested areas on steep mountain slopes. These areas have remained vegetated due to their steepness although nearly all forested lands in the county have been cut at least once since European settlement. The forested valleys were cleared for agriculture by the first European settlers. Over the past two centuries the agricultural lands have been gradually replaced by urban and suburban development. The steep mountains act as barriers to the spread of urbanization from Roanoke Valley to the adjacent Catawba and Back

Creek valleys. Numerous streams that dissect the vegetated mountain slopes provide abundant water to the valleys and encourage growth in the region along valley floors. These large forested areas have the potential to be more strongly linked to the forested lands in the southern and northern Appalachian Mountains to form a contiguous bioreserve in the Appalachians.

5.4 Delineation of Major Land Cover Types at the County Scale

The broad spatial patterns for Roanoke are delineated using the 1992 digitized spot and landsat images. At the county scale spot images and landsat images are extremely useful in identifying broad visual patterns. Three major areas and two dominant land cover types are identified within Greater Roanoke Area. They are Forested Area 1, Urban Area 2, and Forested Area 3. The Forested Area 1 is located north of Interstate 81 and has forested land as the major cover type. The Urban Area 2 is located between the Interstate 81 and Roanoke River and has urban land (includes dense residential development) as the major cover type. The Forested Area 3 is located south of Roanoke River and has forested land as the major cover type (see Figure 5.6).

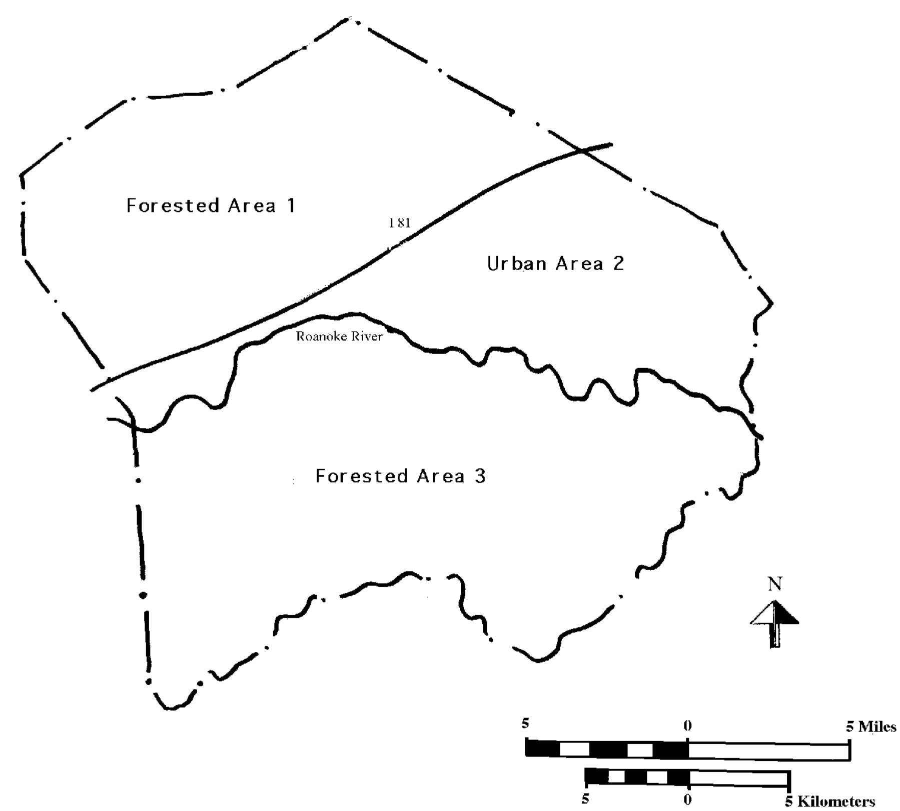

Figure 5.6: Major Land Cover Types in Greater Roanoke Area
Data Source: 1997 Spot Mosaic Image and 1997 Landsat Image

5.5 Inventory and Analysis of Landscape Elements

5.5.1 Identification and Classification of Patches, Corridors and Special Sites

- The first step in this process is identification of landscape structure from the spot image mosaic. The county spot image has three tones (see Figure 5.7). The light tone (white to light gray areas) indicate severely disturbed land. These areas include landfills, quarries, mines, large paved areas, buildings, and roads. The medium tone gray areas indicate moderately disturbed land. This includes low density suburban development, playgrounds, parks, agricultural lands and shrublands. The darker tone (dark gray areas) indicate forested land. The landsat image (see Figure 5.8) can be used for identifying more detailed information including major forest types (deciduous and coniferous forest), disturbed land, herbaceous land (agricultural and medium density residential areas), and shrubland (grasslands and abandoned lands). The stream corridors can be identified from topographic maps. For more detailed studies specific aerial maps (for example 1:16,000 and 1:24,000 scale) should be referred to.

Figure 5.7: Spot Mosaic Image of Greater Roanoke Area

Data Source: Fish and Wildlife Information Exchange, Virginia Tech, Blacksburg

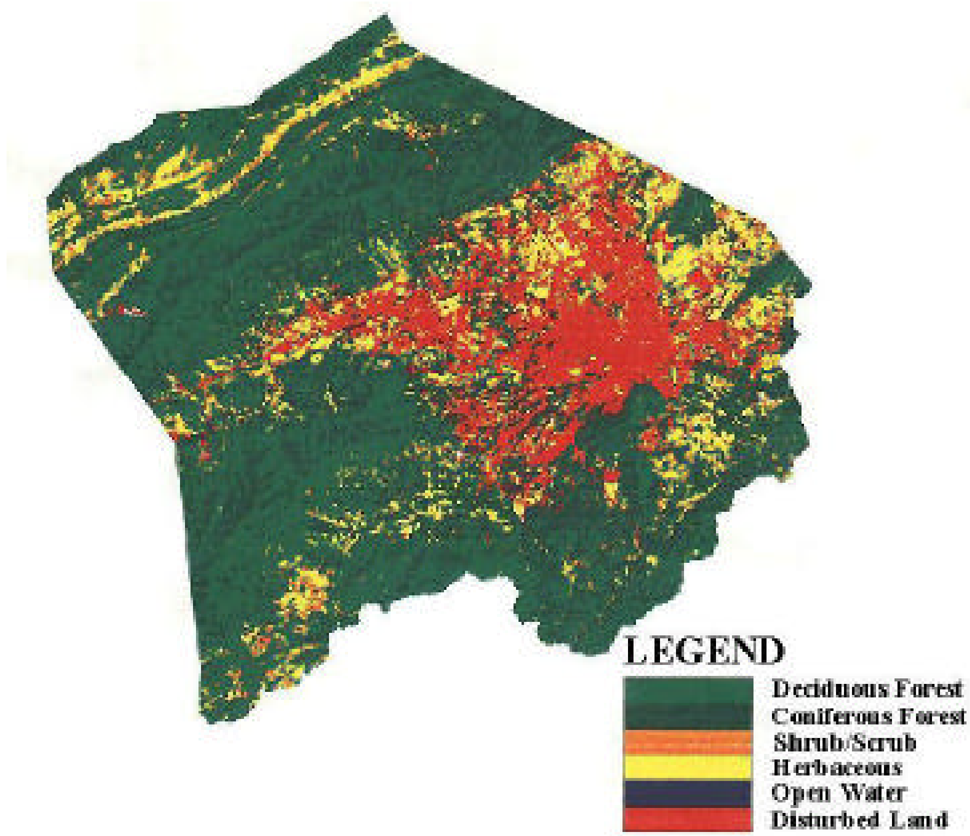

Figure 5.8: Landsat Image of Greater Roanoke Area

Data Source: Fish and Wildlife Information Exchange, Virginia Tech, Blacksburg

- The second step in this process is diagramming the primary landscape patterns identified in each of the major areas (Forested Area 1, Urban Area 2 and Forested Area 3, see Figure 5.9, 5.10, and 5.11). Primary landscape patterns include perennial and intermittent stream corridors, powerline corridors, roads, forested areas, agricultural areas, residential areas, protected open spaces, and special sites.
- The third step is delineation of medium density residential areas from the city and county land use maps.
- The last step is classification and prioritization of forested areas within Urban Area 2. The forested areas are classified further based on their size and attributes. Each of these forested areas are then prioritized for protection. The patches with maximum number of attributes should be give highest priority for protection.

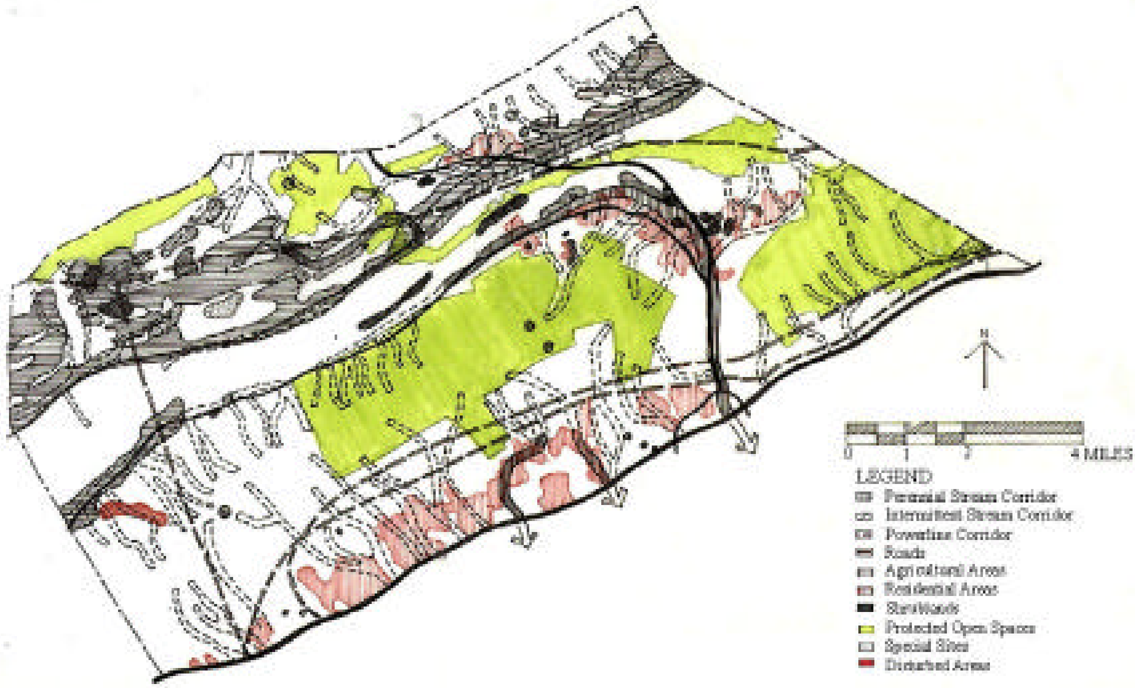

Figure 5.9: Structural Analysis of Forested Area 1

Data Source: USGS Topographic Map, Spot Mosaic Image, Landsat Image, Wetlands Map, Karst Features Map, and Threatened and Endangered Species Map

Figure 5.10: Structural Analysis of Urban Area 2

Data Source: USGS Topographic Map, Spot Mosaic Image, Landsat Image, Wetlands Map, Karst Features Map, and Threatened and Endangered Species Map

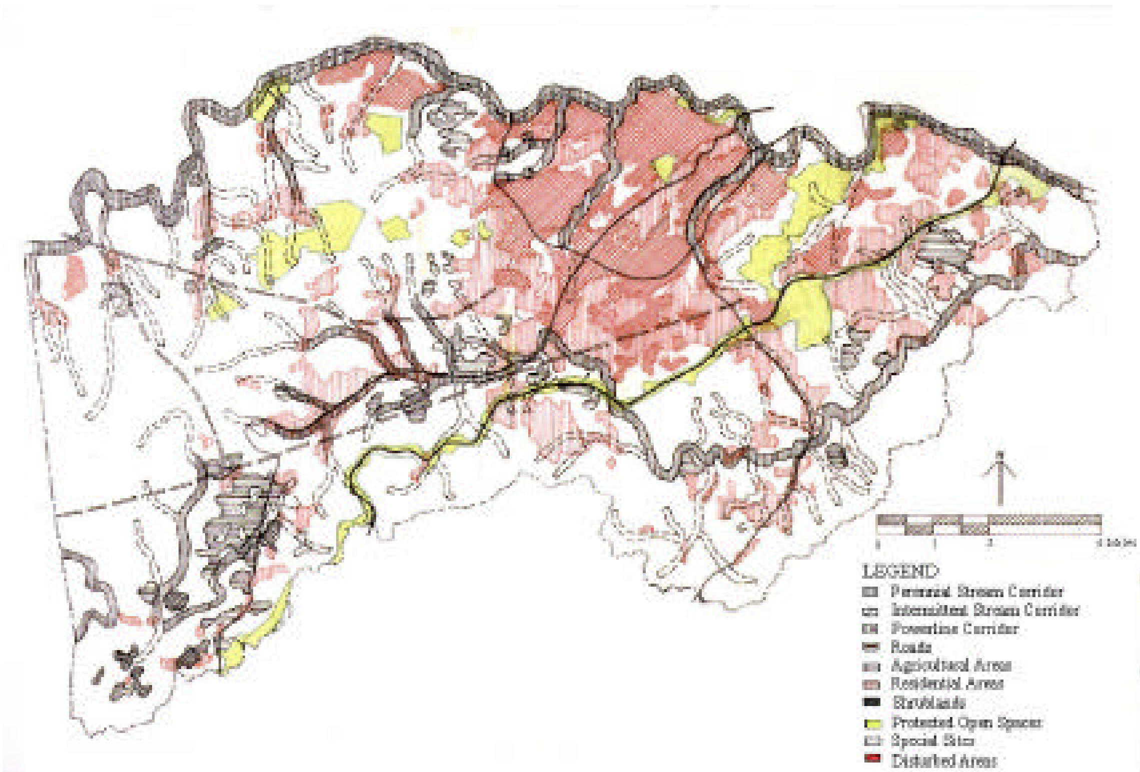

Figure 5.11: Structural Analysis of Forested Area 3

Data Source: USGS Topographic Map, Spot Mosaic Image, Landsat Image, Wetlands Map, Karst Features Map, and Threatened and Endangered Species Map

5.5.1.1 Forested Area 1

In Forested Area 1, the matrix is the large expanse of contiguous woodlands along Catawba and Fort Lewis Mountains. Most of land along these mountains are public lands including Havens Wildlife Management Area, Carvins Cove and Jefferson National Forest along North Mountain.

The patch types are identified from the landsat image, Roanoke County Extension map and land use map. The major patch type in Forested Area 1 is pastureland. There are smaller patches of scrubland and urban land in the valleys. The valley is surrounded by forested land on either side. Residential patches occur along the Catawba Valley Drive and Mason Creek. The major type of corridor found in forested areas are stream corridors. The slopes along the Fort Lewis mountains are highly dissected by numerous streams. Field studies done around this area indicate that many of the second order and third order streams adjoining pastureland and residential areas have little or no streamside vegetation and have highly eroded streambanks. There are three major powerline corridors along the Fort Lewis Mountain. Forested Area 1 has significant areas of karst topography. These sites are located in the limestone valleys. Forested area 1 contains several wetlands near Mason Creek. Special sites containing rare and endangered plant species are identified in the Jefferson National Forest. There is an operating landfill on the western part of the Fort Lewis Mountain.

Figure 5.12: Wetlands Near Mason Creek

Figure 5.13: View of Mason Creek

5.5.1.2 Urban Area 2

Urban Area 2 is highly urbanized with few isolated patches of natural and semi-natural areas. The area has high density of parking lots, residential units and roads with very few patches of agricultural land. This area also has stream corridors, parts of which have been channalized and have very narrow or no riparian corridors. Urban Area 2 has a dense network of man made corridors. Urban area 2 has little or no vegetation.

Figure 5.14: View of Roanoke River Near Downtown

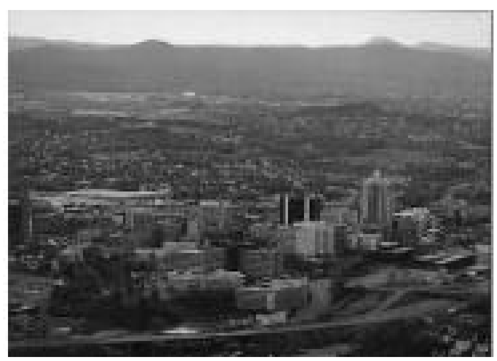

Figure 5.15: View of Downtown Roanoke

5.5.1.3: Forested Area 3

Forested Area 3 is located south of the Roanoke River. The eastern part of this area is urbanized while the western part has large areas of woodlands. The Back Creek Valley has pasturelands, orchards and low density residential areas. The major type of corridor found here are stream corridors. Field studies indicate that many of the second order and third order streams adjoining pastureland, orchards, and residential areas have little or no streamside vegetation and have highly eroded streambanks. There are powerline corridors along Poor Mountain and Bent Mountain.

Forested Area 3 has areas with karst features and a landfill site on the northern slopes of Poor Mountain. There are several sites on the ridges of Poor Mountain which contain a globally rare shrub called Pirate Bush. The Poor Mountain Natural Area Preserve protects the world's largest population of this globally rare shrub, which is restricted to only a handful of sites in the mountains of Virginia, Tennessee, and North Carolina.

Figure 5.16: Orchards in Forested Area 3

Figure 5.17: View of the Back Creek

5.5.2 Analysis of Function and Change Dynamics of the Patches, Corridors, and Special Sites

Energy and nutrients flow from one landscape element to another. Their movement is dependent on transport mechanisms such as water, wind and species. Energy and nutrient flows can be positive or negative. Positive flows are flows that are beneficial to ecosystems while negative flows are flows that are harmful to the ecosystems. An example of a negative flow is the movement of fertilizers and pesticides from agricultural fields into stream corridors. Here, water is the transport agent. The fertilizers and pesticides pollute streamwaters and this in turn affects species diversity in the riparian corridor. An example of a positive flow is the dispersal of seeds by wind from one woodland to another, thus increasing the genetic diversity of the forest. Note however , that the flow of invasive plants by seed to the woodland may be considered as a negative flow. Flows are identified for Forested Area 1, Urban Area 2, and Forested Area 3.

5.5.2.1 Flows through Forested Area 1 and 3

- The demand for single family housing has altered parts of Forested Area 1 and 3 as residential development has expanded into these rural forest landscapes.
- Prevention of fires and lack of logging in forested areas have created mature interior forests on mountain slopes that are susceptible to intense fires[22].

[22] Prevention of fire in pine forests also leads to establishment of pine species that are weak and susceptible to insect attacks (Helm and Johnson, 1995).

- Stream headwaters in Forested Area 1 are well protected due to large forested areas along the ridges while the stream headwaters in Forested Area 3 have residential development near it.
- Road and powerline corridors restrict the movement of certain types of ground moving animals.
- Streams adjacent to roads, agricultural lands, and residential areas have negative flows related to pollution and sedimentation due to absence of riparian corridors.
- Man-made wetlands near Roanoke Sewage Treatment Plant attract waterfowl and act as a sink for some wetland plants and animals.
- There is possible pollution of groundwater and surfacewater from landfill sites located close to caves and stream corridors.
- Forests are important habitat for many plants and animals. Large forested areas have a diversity of habitat such as meadows, wetlands, and rivers. This increases overall biodiversity of plant and animal species in Forested Areas land 3.

5.5.2.2 Flows through Urban Area 2

- Excessive stormwater runoff occurs due to large percentage of built areas. Thus, as development continues the velocities and amounts of stormwater will increase. There is also a potential problem of surface water pollution in Urban Area 2 due to the combined effects of polluted stormwater runoff, and absence of vegetation along streambanks.
- There is possibility of groundwater pollution in areas with karst topography. There are large number sinkholes in areas close to the Roanoke airport.
- There is potential habitat for large home range species in forested areas along the eastern part of Urban Area 2 which are contiguous to forested land in the adjacent county.
- Forested areas within urban Area 2 have a large amount of forest edge which creates conditions for invasion by exotic species. Exotic species alter natural ecosystems by competing with native populations[23].

5.6 Establishment of Management Strategies for Protecting and Enhancing Open Spaces

Establishing management priorities for protecting and enhancing open spaces involves finding design solutions for landscape units that have negative flows while increasing biodiversity and establishing connections between different landscape elements. Recommendations include creating or protecting existing buffers, proposing management strategies appropriate to site and surroundings, and in some cases changing the adjacent land use (see Figure 5.18, 5.19 and 5.20).

[23] Some of the common exotic species found here are kudzu, tree of heaven, royal paulownia and Japanese honeysuckle. These few species are found in large numbers. They change the appearance of forested areas and affect plant dynamics. Species such as kudzu and honeysuckle form continuous cover over forest edges and forest floors, inhibiting the establishment and growth of native species

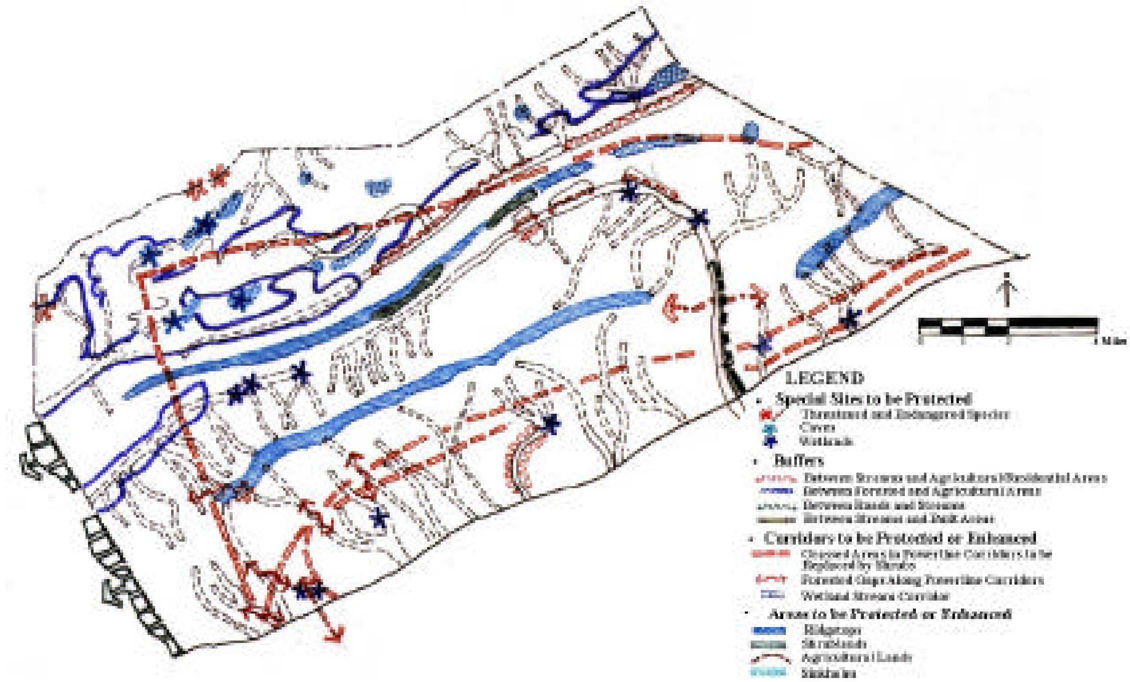

Figure 5.18: Management Strategies for Forested Area 1

Data Source: Structural Analysis Map

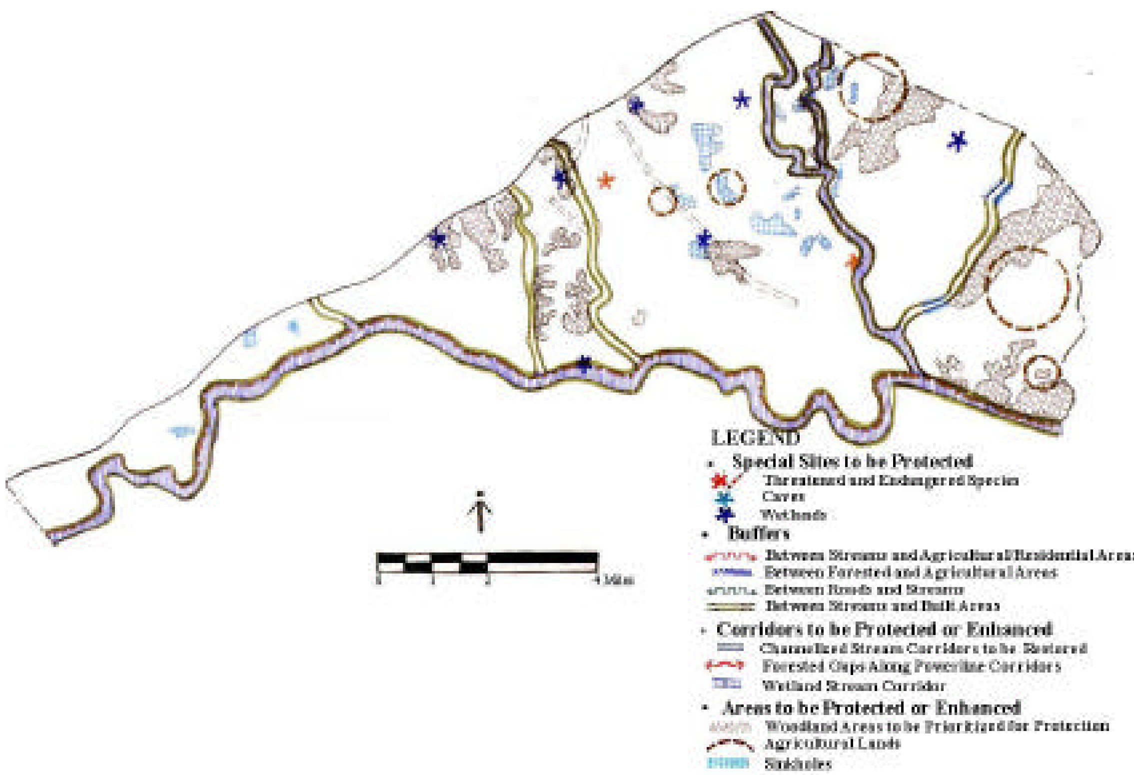

Figure 5.19: Management Strategies for Urban Area 2

Data Source: Structural Analysis Map

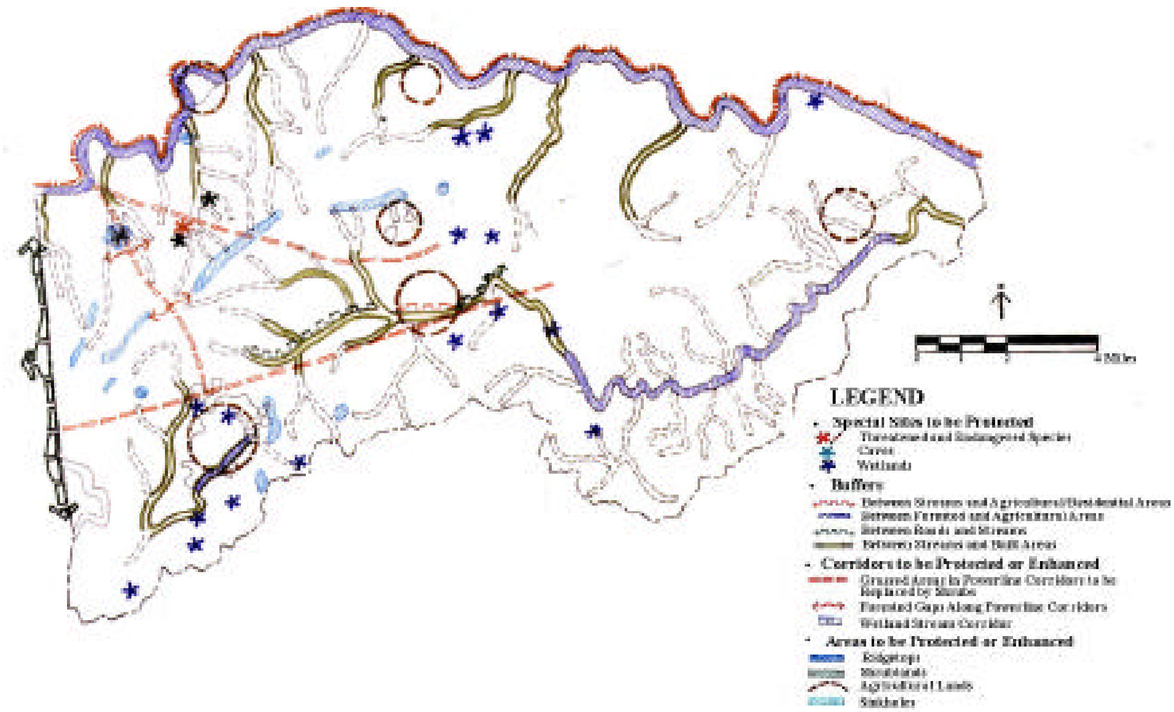

Figure 5.20: Management Strategies for Forested Area 3
Data Source: Structural Analysis Map

5.6.1 Management Strategies for Forested Area 1 and Forested Area 2

1. Diversity of Habitats: Maintain the diversity of habitats in forested areas. Some species require early successional forests, pure pine stands, old growth forests, wetlands or a combination of these habitat types. Retain all habitat types within these areas.
2. Minimum Patch Size: Minimum patch size for forested areas should be based on the habitat needs of wildlife populations requiring a large home range. The large forested areas within the county are found to be contiguous with the forested areas in the adjacent counties. Hence these areas have potential for supporting wildlife populations that need large home ranges. Protect these areas from large scale developments and intensive uses. Prevent fragmentation of forested lands and mitigate the effects of fragmentation in highly fragmented areas.
3. Landfill Areas: The future landfill areas for the county should not be located close to areas with karst topography or near streams since they are potential sources for groundwater pollution.
4. Logging and Hunting: Regulate logging and hunting in forested land. Hunting and logging activities should be regulated during wildlife breeding season and in areas close to locations of endangered and threatened species.
5. Animal Movements: Connect the large forested areas within the county by providing natural corridor (bridges or underpasses) across/beneath major roads such as Interstate 81 at locations

of known animal movements. Important animal movement corridors can be determined by field observations and by documenting road kills.

6. Special Sites: Protect the special sites such as wetlands, ridgetops, caves, and sinkholes within large forested areas.
7. Larger Spatial Context: Plan for the use and conservation of large forested areas taking into consideration the larger spatial context, and retaining open space connections with surrounding counties and the region.
8. Powerline Corridors: Maintain semi-stable shrublands along powerline corridors (Forman and Godron, 1986). Semi-stable shrublands have more ecological benefits than simple grassed corridors. In certain areas of the corridor, powerlines jump through swales with steep slopes. Maintain tree cover and protect these swales because such gaps act as potential corridors for the movement of wildlife.
9. Wildlife: Some caves in Forested Area 3 are open to tourists all year round. These caves are used by bats during the winter and should be closed during winter months to provide places of refuge for these animals.
10. Riparian Corridors: Within Forested Area 1 and Forested Area 2, agricultural lands and urban areas are frequently located close to streams. This has led to the destruction of riparian corridors and forest patches near streams. Maintain riparian corridors and some mature forests near waterbodies. This will create habitats for birds and mammals such as woodpeckers bats, and will help to buffer stormwater runoff flowing into streams. Simulate all vegetation layers within riparian corridors. This includes groundcover, shrubs, vines and trees. Priority should be given to retain indigenous vegetation along the ridges of Fort Lewis Mountain and Catawba Mountain. This will help in protecting the headwaters of Catawba Creek and Mason Creek. Protect the sections of streams with steep or erodible soils by providing vegetative buffers along these streams. Include critical areas such as intermittent stream, gullies, swales, aquifer recharge and discharge areas within the riparian corridors.
11. Hedgerows: Encourage the use of hedgerows in pasturelands and in medium density residential areas to separate property lines. Simulate all vegetation layers in these hedgerows. Hedgerows help to break wind, shelter crops and soil, harbor predators that feed on crop pests, provide food for a great number of small species" (Lyle, 1984:203).
12. Buffers: Encourage planting of shrubs (approximately 20 feet wide) between woodlands and pastureland and along forested edges. These transition areas provide food, nesting cover, escape cover for wild animals (Virginia Department et al).
13. Agricultural Lands and Pasturelands: Large areas of agricultural land in the Catawba Valley should be preserved. In pastureland the erosion along streambanks is mainly caused by uncontrolled stream access by livestock. Limit livestock access to streams by fencing riparian corridors and providing water sources away from the stream corridors. In pastureland, encourage the replacement of fescue pasture with native grasses. Native grasses. require little or no fertilizers and are less affected by parasites. Pastures with native grasses provide for excellent wildlife nesting areas. In heavily disturbed soils native grasses require only

minimum amounts of fertilizers to regenerate the soil (Virginia Department et al, 1995). Another alternative is to diversify the vegetation on pastures (Lamm and Vandewalle, 1979). Vegetation diversification also helps to control pest outbreaks. Introduce buffers between pasturelands/orchards and perennial streams as buffers help to control stream pollution and sedimentation.

14. Constructed Wetlands: Construct stormwater wetlands near major roads to filter, breakdown and/or contain roadway pollutants. These areas will naturally provide habitat for wetland wildlife species. Construct wetlands for sewage treatment. Studies have shown that constructed wetlands can be very effective and efficient method for sewage treatment. Constructed wetlands are generally much more cost effective and require less maintenance than conventional treatment plants particularly in rural areas or areas at a great distance from the sewage treatment facility. Constructed Wetlands provide habitat for wildlife, consume less energy, absorb greenhouse gases, and purify air (Gillette, 1996). Greater Roanoke Area has a single large mechanized sewage treatment plant. More localized sewage treatment wetlands that process wastes near the source should be built in the county. The nutrients from domestic sewage (after primary treatment) can be removed by using aquatic plants such as water hyacinths, duckweed, reeds, cattails, etc. Water hyacinths not only absorb nutrients rapidly but also have high protein content and thus make excellent cattle feed and can be used for producing fuel (Lyle, 1985).

5.6.2 Management Strategies for Urban Area 2

1. Remnant Agricultural Lands: The remnant agricultural lands and forested land within urban areas are facing growth pressures. All agricultural lands within the Roanoke and Salem cities have been zoned for residential uses. Residential areas built on agricultural lands should set aside some land as open space. Clustering of residences should be encouraged in these areas to save more ecologically important areas for open spaces. The agricultural lands in urban areas can also be converted into greenhouses, orchards or natural/semi natural open spaces since they likely have a good soil structure (Lamm and Vandewalle, 1979). Natural/semi natural open spaces within urban areas will function as a stormwater retention and infiltration area, a sink for airborne pollutants, a passive recreation area and as habitat for small mammals and birds.

   Woodlands and Parks: Because woodland areas within the county are facing growth pressures, the existing woodland areas have been prioritized for protection. Large woodland areas with wetlands or in close proximity to stream corridors should be given highest priority for preservation and protection. An example of this is shown in Table 5.4[24] and figure 5.21.

[24] The open space prioritization has been applied to only areas fifty acres or larger due to time constraints and lack of field studies. But this has to be applied to all woodland areas larger than 10 acres. Areas smaller that 50 acres should also be supplemented by detailed field studies.

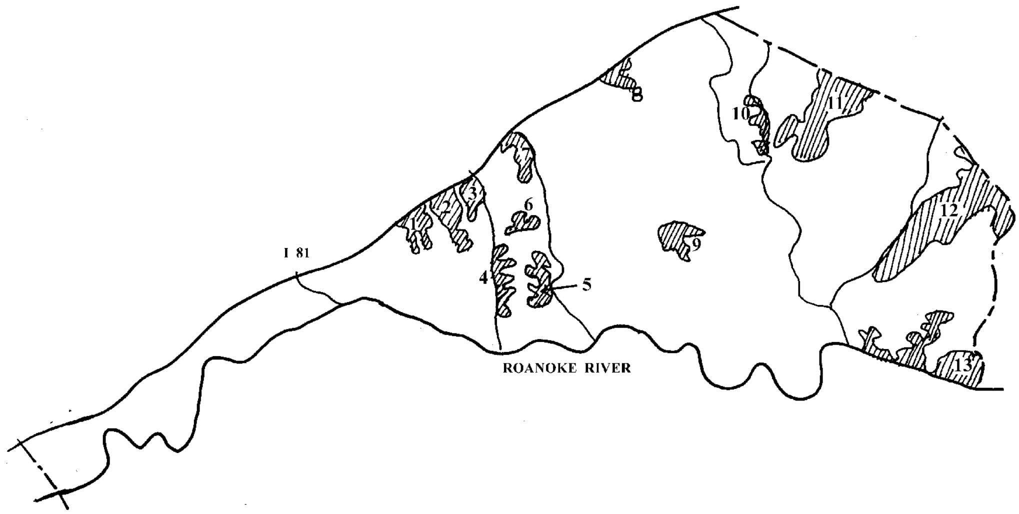

Figure 5.21: Patch Analysis for Urban Area 2

Table 5.4: Patch Analysis for Woodland Areas in Urban Area 2

Patch Number	**Intact Size (Acres)**	**Adjacent to other Patches**	**Is linked to Riparian Corridors**	**Contains Special Sites**	**Protected Open Spaces**	**True Value Rating**	**Protection Priority**
	4 - Large 3 - Medium 2 - Small*	YES/ NO 2/ 0	YES/ NO 2/ 0	YES/ NO 2/ 0	YES/ NO 2/ 0		1-3 - low 4-6 - Medium 7-10- High 11-14 - Very High
1	50-100 2	2	0	2	2	8	H
2	100-300 3	2	0	0	0	5	M
3	50-100 2	2	2	0	0	6	M
4	50-100 2	0	2	0	2	6	M
5	100-300 3	2	2	0	2	9	H
6	50-100 2	0	0	0	0	2	L
7	100-300 3	2	2	0	2	9	H
8	50-100 2	0	0	0	2	4	M
9	100-300 3	0	0	2	2	7	H
10	100-300 3	2	2	2	2	11	VH
11	>300 4	2	2	0	2	10	H
12	>300 4	2	0	0	2	8	H
13	100-300 3	0	2	2	0	7	H

> 300 acres - Large; 100-300 - Medium; 50-100 acres small

This open space prioritization can be applied to all urban and suburban areas/patches in Urban Area 2 and Forested Area 3. Exotics should be controlled in these remnant woodland areas. Some of the methods recommended by the Handbook of Forestry Management are cutting Burning, and mowing (Helm and Johnson, 1995).

3. Riparian Corridors: Some of the streams and rivers along this stretch of the county have been channalized. Where feasible, priority should be given for restoring these channalized streams to their natural condition. Natural stream bottom and bank structure will help to decrease the velocity of water, assist in infiltration, and decrease pollution. Riparian vegetation along the streambanks should be restored to provide habitat, hold soils and filter surface water runoff into streams. Some species such as red osier dogwood (*cornus stolonifera*) have been shown to remove excessive nutrients and can be used where excessive nutrient inputs to streams are a concern.
4. Street and Yard Plantings: Encourage use of native plants in street and yard plantings in the urban areas of Roanoke. These trees will provide seed source for larger patches within these areas (Levenson, 1981). Street trees and small patches within urban units will also assist in groundwater recharge.
5. Wetlands: Streams in urban areas face the pollution problems caused by runoff from paved areas and roads. Where there is sufficient space, wetlands or wetland swales can be created or restored to retain, clean and filter water. These areas will also provide habitat for some wetland species.
6. Floodplains: Buildings should be placed on areas outside floodplains where the depth of groundwater table is more than six feet (two meters). This will help prevent basement flooding and groundwater pollution. Care should also be taken not to build structures on natural drainageways (Lamm and Vandewalle, 1979)

5.7 Development of the Preliminary Open Space Plan

A preliminary open space plan is prepared for Greater Roanoke Area using the structure analysis and management strategy plans for each area (Forested Area 1, Urban Area 2 and Forested Area 3). At this stage it is useful to involve local citizens so that management strategies and the preliminary open space plan can be modified based on their input and so that public help can be solicited to support and implement the open space plan. Given the time limitations in completing this thesis, no active public participation process is undertaken to develop the preliminary open space plan, however, the principles discussed in the approach can help to guide the public participation process (see Figure 5.22). Open space planning process based on the principles of landscape ecology is a part of a larger open space planning process and needs to be overlayed with political and social plans.

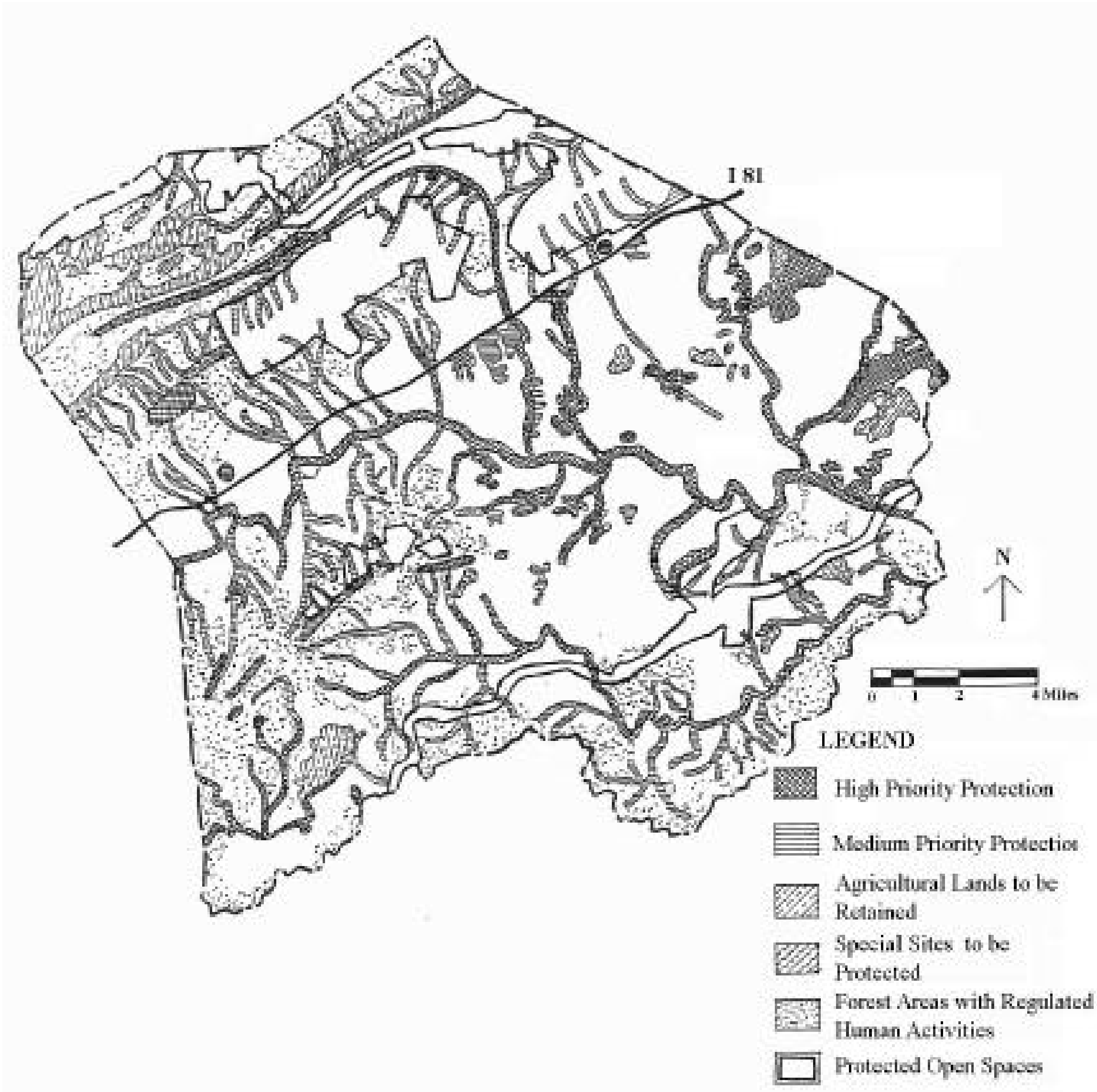

Figure 5.22: Preliminary Open Space Plan Based on the Principles of Landscape Ecology

The high priority open spaces (see Figure 5.22) includes perennial stream corridors, shrubland, wetlands, large woodland patches, and ridgetops. They are considered under this category for the following reasons:

1. Perennial Stream Corridors: In Roanoke, many streams support or feed into streams that support endangered or threatened species. The BOVA Report indicates that the main threats faced by these species are habitat loss, clean agricultural practices, water impoundments, pollution, sedimentation and channelization of streams. Protecting stream corridors will help in protecting these species. Also, streams form natural connections between large forested lands.

2. Shrublands: Shrublands receive high priority for protection because of their rarity. They are important for multihabitat species. With clean agricultural practices and prevention of fires in agricultural and forested lands, they are the only refuge for species that require early successional forests.
3. Wetlands: They are important because of their rarity in the valley. They have high biodiversity and support a lot of wildlife population including some endangered species.
4. Large Woodland Patches: Large woodland patches are important because of their rarity in urban areas. They are important for retaining biodiversity in manmade landscapes. Woodland patches filter air and water pollutants, provide habitat for small homerange species, act as stepping stone for species movement between large forested areas, protect soil structure, and provide recreation and visual amenity.
5. Ridgetops: Ridgetops should receive high priority for protection because they are visually sensitive areas, have endangered species, and many streams originate near ridgetops.

Medium Priority Protection open spaces includes intermittent stream corridors, smaller woodland patches with lesser attributes. They are considered under this category for the following reasons:

1. Intermittent streams: The intermittent streams are important for overall ecological integrity . But in Roanoke, most of the intermittent stream areas have almost intact riparian corridors. So they have been considered for medium priority protection.
2. Woodland Patches: The woodlands patches under medium priority protection are smaller than the ones under high priority protection and have lesser attributes than them.

Other areas to be protected are agricultural lands and large forested areas**.** Roanoke has lost agricultural lands in the valley due to urbanization. There are very few of them remaining in the Roanoke Valley. Agricultural lands face constant growth pressures and hence should be protected from further development. If development must occur then cluster development must be encouraged and a part of the land should be retained as open space. Agricultural lands can be converted into passive recreation areas. Large forest areas should have limited human activities i.e., logging, hunting or low density residential development so that the land retains its ecological integrity. In case of residential development, large areas of land should remain as forested land rather than mowed lawn.

5.8 Selecting Tools for Open Space Preservation

Tools for preservation are important for implementing the Greater Roanoke Area Open Space Plan. The plan will be successful only if it has a strong implementation strategy. The Comprehensive Plan prepared for Roanoke County in 1928 by Nolen emphasized the need for protecting natural resources. The plan proposed creating a parkway and a protected floodplain zone along the Roanoke River. Parts of the plan were not implemented due to lack of public support and implementation strategy. In contrast the Town of Dunn Open Space is successful because it is backed by a strong implementation strategy. Greater Roanoke Area's environmental and open space goals can be implemented through responsible private ownership, education and government land use regulations.

The tools for open space preservation are discussed in detail in chapter 4. Some of the tools are already a part of the Greater Roanoke Area zoning ordinance. Others should be incorporated and used for protecting open spaces.

Chapter 6 Conclusions

For an open space plan to be successful, a thorough inventory of natural resources in the region and county is very important. This includes information on the wildlife, land cover, and the natural history of the place. Detailed analyses can be done only if the sufficient data is collected for the region and county. The analyses should be backed by a strong implementation strategy. Ideally, the community should be involved in the open space planning at nearly every step. And, as open space planning is an ongoing process, the plan should be reviewed, updated and modified periodically as new data becomes available or as land use changes occur and bring new pressures to the region and county.

In review, the main objectives of the thesis are:

- To develop an approach to open space planning for counties based on the principles of landscape ecology;
- To integrate theoretical aspects of landscape ecology with the regional landscape context and existing county plans for the use and protection of open spaces; and
- To develop an open space planning approach that could be used by counties and regions interested in protecting the ecological integrity of their landscapes through time while meeting the socio-economic needs of the citizens within these areas.

Each objective is individually addressed below.

Objective 1: To develop an approach to open space planning for counties based on the principles of landscape ecology

The proposed approach can be applied to most counties in the United States including highly urbanized or rural areas. However, certain parts of the approach will have to be modified to suit a particular situation. For example, highly urbanized landscapes will not typically have large areas of natural vegetation. In this case it would not be possible or sensible to plan for wildlife that require large home ranges.

Objective 2: To integrate theoretical aspects of landscape ecology with the regional landscape context and existing county plans for the use and protection of open spaces

The proposed approach incorporates the landscape ecological concepts proposed by Forman, Lyle, and Steiner. The approach also incorporates some concepts from the Dunn County Open Space Plan. Concepts from Forman's approach is used in the second, third and fourth stages of the approach namely:

study of the landscape at the regional scale,

delineation of dominant land cover types at the county scale, and

inventory and analysis of landscape elements.

Based on Forman's theories the approach takes into consideration the broad spatial context of the site and incorporates the Aggregate Outliers Principle[25]. Lyle's ideas are used for reestablishing natural processes in manmade systems and linking agricultural systems to urban systems. Steiner's concepts are mainly used during the data collection and implementation stage. The concept of prioritizing open spaces for protection and preservation is derived from the Dunn County Open Space Plan.

Objective 3: To develop an open space planning approach that could be used by counties and regions interested in protecting the ecological integrity of their landscapes through time while meeting the socio-economic needs of the citizens within these areas
The open space plan should meet the aspirations of the people. Hence, the success of an open space plan is very much dependent on the active participation of the local community in the planning process. Involvement of local government officials is likewise important for successful, implementation of an open space plan based on the principles of landscape ecology. The proposed approach involves the local community at every stage of the planning process from the data collection to the implementation stage.

Usefulness of the Project
The open space plan approach can be applied to any county in the United States. In addition, this approach acknowledges the importance of public participatory process for open space planning and recommends community involvement right from the goal setting stage.

The proposed approach has many advantages over conventional open space planning and is useful for protecting open spaces at the county scale

1. The conventional methods of open space planning are not adequate for preserving the biodiversity and ecological integrity of the landscape. The main objectives of the open space approach based on the principles of landscape ecology are ecological integrity and maintenance of biodiversity.
2. The approach provides long term protection to open spaces. The conventional methods of open space planning are frequently inadequate to protect natural areas, farmlands, and sensitive lands over the long term.
3. The shortcoming of a conventional open space plan is that it is restricted to the jurisdictional boundaries. The proposed open space planning approach looks beyond the county boundaries.

The approach proposed in this thesis should be used by more planners and landscape architects because it has far more advantages than most conventional methods. Table 6.1 compares conventional open space planning approach and the proposed open space planning approach based on the principles of landscape ecology.

[25] One should aggregate land uses, yet maintain corridors and small patches of nature thoughout developed areas.

Table 6.1: Advantages of Landscape Ecological Based Open Space Planning Over Conventional Methods

Open Space Planning Based on Landscape Ecology	Conventional Open Space Planning
Landscape ecology based open space planning aspires to maintain the ecological integrity of the land by considering in a more comprehensive way the interactions between natural and cultural variables. Biodiversity is considered to be of prime importance.	The conventional open space plan does not take into account the concept of recycling nutrients and energy back into the natural system. It also does not explicitly acknowledge into the importance of maintaining biodiversity in a county and the surrounding region.
Areas to be preserved as open spaces are selected based on sound ecological principles and not solely on the political, social, economic, and recreational demands.	The open space plans prepared by conventional methods are chiefly focused on the political, socio-economic and recreational demands of the county.
In this approach, flows of energy and nutrients within natural systems, and changes in landscape structure through time are considered in addition to the structure.	Conventional methods deal with finding the best possible ways of preserving open space based on existing structure and function.
Landscape ecology based open space planning includes concerns and expertise from other fields as data inputs and in the decision making process. Experts from the fields of biology, ecology, geology, hydrology, fisheries and wildlife, forestry, and agriculture are consulted.	Conventional open space planning methods do not necessarily need experts from other fields during the planning process, and thus are too simplistic in approach. The planner and the landscape architect use their best possible judgment on deciding where and how open spaces are to be preserved.
The success of the open space plan is dependent on the involvement of local community in the planning process. This is because many of the management strategies proposed require people to change their conventional way of looking at landscapes. The approach relies less on zoning ordinances and acquisition as “the way” to protect open space, and relies more on active participation and education for maintaining the ecological integrity of the land.	Conventional open space planning methods rely more on zoning ordinances and land acquisition for preserving open spaces. Involvement of the local community is part of the process but may not be seen as critical to its short and long term success.
In an ideal situation all open areas are worth preserving. However, there is always demand on the land for development. In this approach open spaces are prioritized for preservation and protection in a manner emphasizes that the ecological integrity of the land needs to be retained when open undeveloped lands face development pressures.	Conventional methods lack an explicit focus on establishing a hierarchy for selecting and managing open space lands based on the goal to retain the ecological integrity within the county and region.
The approach looks beyond conventional jurisdictional boundaries for study and analysis.	The open space plan is restricted to the jurisdictional boundaries of the county.

Limitations of the Approach

Economics and Time Constraints: There is a lack of sufficient data on species and land cover type, and could well be a lack of input from experts in many disciplines due to limitations in time, staff, and budget that would be required to undertake such a comprehensive open space planning study. The success of this approach is also dependent on the active participation of the public. The open space planning process would need active public involvement if community has to participate in protecting and maintaining the proposed open spaces in public and private lands. Active participation is not easily engendered and requires time and resources that are often lacking. Moreover it might be uneconomical for private property owners to maintain their lands as open spaces.

Political Aspects: The open space plan based on the principles of landscape ecology covers areas with different jurisdictions. The success of the open space plan is dependent on the joint coordinated effort between the town, county and regional planning departments. Its success is also dependent on the coordination of open space planning efforts between adjacent counties.

Social Aspects: To maintain the ecological integrity of the land it is insufficient to simply create new open spaces; people need to change their lifestyles and attitudes. I believe that people should stop relying solely on cars for transportation and should use more non-conventional means of transportation such as mass transit, pedestrian trails, and bikepaths. Open spaces in urban areas are maintained as grassed areas with scattered patches of trees, shrubs, and flowers. As such these areas have very low ecological functions. A diverse mix of native and non-invasive plants and grasses should be established in urban areas which afford such a palette. The question is, how acceptable are these ecological values by the people?

Other Limitations: Landscape ecology is a transdisciplinary field. It covers a wealth of knowledge from other fields such as ecology, biology, geology, geomorphology, *etc*. The approach proposed in this thesis is limited to a small part of these studies. Also, landscape ecology is a relatively new field. Hence, many of the theories related to landscape ecology have not been time tested. Moreover, landscape ecology is not a perfect science. The approach needs to be tested, refined, retested and further refined. There are bound to be weakness in the approach as currently proposed, and these need to be converted into strengths.

Ecosystem processes are complex and not fully understood. Even with expert advice, the management priorities for protecting open spaces are ultimately based on the best judgment of the planner and ultimately the decision makers. Hence, it is important to consider that this approach is a start for planners and landscape architects who want to incorporate landscape ecology as a part of a regional open space planning process.

Natural systems face slow, long term degradation related to air borne toxins from nearby regions. This is visible only at the human scale. The proposed approach does not fully account for this incremental loss of biodiversity. A survey conducted by the American Folklore Center in southern West Virginia indicates that there is a slow deterioration of the forest quality in the central Appalachians caused by air borne pollutants from Kanahwa, Ohio and the Tennessee River basins, and this was apparent to only the long time residents of southern West Virginia (Hufford, 1995).

Further Studies

For open space plan to be successful, the ecological integrity of the land should be maintained at all scales. At a larger regional scale, Lewis's idea of linking large urban areas through corridors and channeling the urban growth along these corridors is a concept worth striving for. Channelizing urban growth along corridors linking urban areas gives opportunity to preserve large open spaces and agricultural lands at a regional scale. The approach proposed in this thesis can be used to link open spaces at the county scale. At the county scale, large natural areas should be preserved. In urban areas within the county, smaller patches of natural areas should be preserved. At a district scale the design principles proposed by Calthorpe and McDonough (1995) for the highly urbanized area of downtown Chattanooga, Tennessee is worth exploring. The proposed design for the revitalization of Chattanooga integrates urban and natural systems. The open spaces are provided in the form of an integrated bicycle-pedestrian greenway, urban parks, and urban forests along freeway right-of-ways (Calthorpe et al, 1995). There have been numerous examples of maintaining ecological integrity in suburban communities. The examples of suburban communities in Belvue, Washington and the suburban community of Village Homes in Davis, California are worth considering (Girling and Helphand, 1994; Thayer, 1994). The principles from landscape ecology should be applied to regional, landscape, and site scale open space planning efforts.

This approach is a start for landscape architects and planners who want to incorporate the principles of landscape ecology in the open space planning process. The approach has been tested for Greater Roanoke Area. The approach should be tested on other counties and modified accordingly. In this thesis, the landscape ecological principles have only been applied at the scale of county open space planning.

Bibliography

Ayres, Eugene, 1956. "The Age of Fossil Fuels" in *Man's Role in Changing the Face of the Earth Vol.1* edited by William L. Thomas Jr. University of Chicago Press, Chicago:367-381.

Braun, E. L., 1950. *Deciduous Forests of Eastern North America*. Macmillan Publishing Company Inc., New York, New York..

Breeding, N. K. and J. W. Dawson, 1976. *Roanoke County Ground Water: Present Conditions and Prospects.* Virginia State Water Control Board, Richmond, Virginia.

Burgess Robert L. and David M. Sharpe, 1981. *Forest Island Dynamics in Man Dominated landscapes*, Springer Verlag, New York.

Budd, W.W., PL Cohen, PR Saunders, and F. R. Steiner, 1987. "Stream Corridor Management in the Pacific Northwest: Determination of Stream Corridor Widths" in *Environmental Management* 11:587-97.

Cairns, John, Jr. 1991. "The Status of the Theoretical and Applied Science of Restoration Ecology" in*. The Environmental Professional* 13:186-194.

Cairns, John Jr. 1995. "Ecosocietal Restoration: Re-Examining Human Society's Relationship with Natural Systems" in *Annals of Earth* 13(1):18-21.

Calthorpe Associates and McDonough Associates, 1995. *A Comprehensive Revitalization Strategy: The South Central Business District Plan*. Unpublished Report.

Diamond, Jared M. 1994. "Ecological Collapse of Ancient Civilizations: The Golden Age That Never Was" in *American Academy of Arts and Sciences* XVLII(5)37-59.

Dramstad, Wenche E. et al, 1996. *Landscape Ecological Principles in Landscape Architecture and Land Use Planning.* Island Press, Cambridge, Massachusetts.

Durham County Managers Office, The County Manager's Open Space Advisory Committee, and Durham County-City Planning Department, 1989. *The Durham County Open Space Plan: Comprehensive Program and Action Plan*, Durham, North Carolina.

Durham County-City Planning Department, 1993. *The Durham County Open Space Corridor System: A Program for Natural Areas and Passive Recreation*. Durham, North Carolina.

Editorial, March 1995. “The Growing Pains of Growth” in *Roanoke Times*.

Edwards, Greg, April 9, 1995. "If it's Here I'll Stay Here" in *Roanoke Times*.

Environmental Awareness Center, 1979. *Town of Dunn Open Space Preservation Handbook*. University of Wisconsin. Madison, Wisconsin.

Ehrlich P. R., 1993. “Scale of the Human Enterprise” in *Nature Conservation 3: Reconstruction of Fragmented Ecosystems: Global and Regional Perspective* edited by Saunders D. A et al. Surrey Beatty and Sons Pty Limited. Chipping Norton, New South Wales.

Forest Service and Department of Agriculture. *Jefferson National Forest General Report to the Public for 1991*.

Forman, Richard T. T. and Michel Godron, 1986. *Landscape Ecology*. John Wiley and Sons, New York.

Forman, Richard T. T., 1995. *Land Mosaics*. Cambridge University Press, New York.

Forman, Richard T. T. and Isaak Zonneveld, 1989. *Changing Landscapes: An Ecological Perspective*. Springer Verlag, New York.

Forman, Richard T. T., 1987. "The Ethics of Isolation, the Spread of Disturbance, and Landscape Ecology" in *Landscape Heterogeneity and Disturbance*. Springer Verlag, New York.

Foster, Richard, Ron Brown and Jan Vertefeulle, March 5, 1995. “Services can’t keep pace with growth” in *Roanoke Times*.

Gilette, Becky, 1996. “Wetlands Treatment: Getting Close to Nature” in *Biocycle* 37(10): 74-76.

Girling, Cynthia L. and Kenneth Helphand, 1995. *Yard, Street and Park*. John Wiley and Sons, New York.

Girling, Cynthia L. and Kenneth Helphand, 1994. *Retrofitting Suburbia: Belvue, Washington*. Unpublished Report, University of Oregon, Eugene.

Greenways Incorporated, 1995. *Conceptual Greenway Plan: Roanoke Valley, Virginia* prepared for Roanoke Valley Open Space Steering Committee, Fifth Planning District Commission, the City of Roanoke, the City of Salem, the County of Roanoke, and the Town of Vinton.

Helm, Amy C. and James E. Johnson, 1995. *A Handbook for Forest Vegetation Management in Recreation and Historic Parks.* Virginia Cooperative Extension, Blacksburg, Virginia.

Hufford, Mary, 1995. "Stalking the Mother Forest: Voices Beneath the Canopy" in *Folklife Center News.* Summer 1995.

Hulse, David. " Are there no Failures among the Stars? Towards a Learning Ecology". Unpublished Report. University of Oregon, Eugene.

Jack, George S., 1912. *History of Roanoke County.* Stone publishers, Roanoke, Virginia.

Jackson, Todd, July 3, 1995. "The Balancing Act" in *Roanoke Times*.

Lamm, Thomas W. and Brian Vandewalle, 1979. *The Land User's Handbook for the Ridge and Valley lands of Southwest Wisconsin*. Environmental Awareness Center, University of Wisconsin, Madison.

Leavenson J. B. 1981. "Woodlots as Biogeographic Islands in Southeastern Wisconsin" in *Forest Island Dynamics in Man Dominated landscapes* edited by Burgess Robert L. and David M. Sharpe. Springer Verlag, New York.

Lewis, Philip H. Jr. 1996. *Tomorrow by Design: A Regional Design Process for Sustainability*. John Wiley and Sons, Inc., New York..

Lord, William G., 1992. *Blue Ridge Parkway Guide*. Menasha Ridge Press, Birmingham, Alabama.

Lovejoy, Thomas E. and David Oren, 1981. "The Minimum Critical Size for Ecosystems" in *Forest Island Dynamics in Man Dominated landscapes* edited by Burgess Robert L. and David M. Sharpe. Springer Verlag, New York.

Lyle, John T., 1985. *Design for Human Ecosystems*. Van Nostrand Reinhold, New York.

Lyle, John, 1994. *Regenerative Design for Sustainable Communities*. John Wiley and Sons Inc., New York.

Mason, Nancy, 1994. *Floral Richness Inventory of an Eastern US Forest*. M. S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Merriam G. and D. A. Saunders, 1993. "Corridors in Restoration of Fragmented Landscapes" in *Nature Conservation 3 Reconstruction of Fragmented Ecosystems: Global and Regional Perspectives* edited by: Saunders, Denis A. et al. Surrey Beatty and Sons Pty Limited, Chipping Norton, New South Wales.

McCue, Cathryn and Jan Vertefeulle, August 3, 1995. "Keeping it Orderly" in *Roanoke Times*.

McDonough, William, February 7, 1993. "Design, Ecology, Ethics and Making of Things". Unpublished paper presented in the Cathedral of St. John the Divine, New York.

McEvoy, T. J., T. L. Sharik and D. W. Smith, 1980. "Vegetative Structure of Appalachian Oak Forest in Southwestern Virginia" in *American Midland Naturalist* 103:96-105.

McHarg, Ian, 1969. *Design with Nature*. Natural History Press, New York

McHarg, Ian, 1971. *Design with Nature*. Doubleday, New York.

Mumford, Lewis, 1956. "The Natural History of Urbanization" in *Man's Role in Changing the Face of the Earth Vol.1* edited by William L. Thomas, Jr. University of Chicago Press, Chicago:383-398.

Naveh, Zev and Arthur Liebermann, 1984. *Landscape Ecology: Theory and Application*. Springer Verlag, New York.

Noss, Reed F., 1995. "Ecological Integrity and Sustainability: Buzzwords in Conflict" in *Perspectives in Ecological Integrity* edited by L. Westra and J. Lemons. Kluwer Academic Publishers, Netherlands:60-76.

Odum, Eugene P, 1971. *Fundamentals of Ecology*. Saunders, Philadelphia.

Odum, Eugene, 1996. *Ecology and our endangered life support systems.* Sinauer Associates, Sunderland, Massachusetts.

Risser, Paul G., Jamer R. Karr and Richard T. T. Forman, 1984. *Landscape Ecology: Directions and Approaches.* Illinois Natural History Survey, Illinois.

Roanoke River Corridor Study Policy, Technical., and Citizen's Advisory Committees, June 1993. *The Roanoke River Corridor: Managing a Strategic Resource*.

Rowe, Stan, 1992. “Landscape Architecture and Ecology: A Call to our Conscience” in *Landscape Architectural Review* 13:25-29.

Schultz, Arnold, 1987. “Planning for Healthy Ecosystems in Landscape” in Architectural Review 8:21-23.

Schneider, Stephen H., 1989. “The Changing Climate” in *Scientific American*. September:70-79.

Smith, Daniel S. and Paul C. Hellmund, 1993. *Ecology Of Greenways: Design and Conservation for Linear Areas*. The University of Minnesota Press, Minneapolis.

State Water Control Board, 1988. *Roanoke River Basin Water Supply Plan*. Richmond, Virginia.

Steiner, Frederick R, 1991. *The Living Landscape: An Ecological Approach to Landscape Planning.* McGraw Hill, New York.

Steiner, Frederick, 1981. *Ecological Planning for Farmland Preservation: A Sourcebook for Educators and Planners.* American Planning Association.

Steinitz, Carl, 1978. "Defensible Process for Regional Landscape Design" in *Landscape Architectural Technical Information Series*. ASLA 2(1):3-32

Strahler, Arthur, 1970. *Introduction to Physical Geography*. John Wiley and Sons, Inc., New York.

Thayer, Robert L., 1994. *Gray World, Green Heart: Technology, Nature, and the Sustainable Landscape*. John Wiley and Sons, New York.

The Writers’ Program of the Work Projects Administration in the State of Virginia, 1942. *Roanoke: Story of County and City*. Stone Printing and Manufacturing Company, Roanoke, Virginia.

Toth, Richard, 1988. “Theory and Language in Landscape Analysis, Planning, and Evaluation” in *Landscape Ecology* 1:193-201.

Turner, Monica, 1989. “Landscape Ecology: Effect of Pattern and Process” in *Annual Review of Ecology and Systematics*. Vol. 20.

United States Department of the Interior and National Park Service, 1990. *Draft Environmental Impact Statement for the Roanoke River Parkway.*

Van der Ryan, Sim and Peter Calthorpe, 1986. *Sustainable communities: A New Design Synthesis for cities*. Sierra Club Books, San Francisco.

Vertefeulle, Jan, Cathryn McCue and Todd Jackson, March 4, 1995. “The Changing Country side” in *Roanoke Times*.

Vertefeulle, Jan, Cathryn McCue and Todd Jackson, March 8, 1995. “Cluster and Colonies” in *Roanoke Times*.

Vink, A. P. A., 1983. *Landscape Ecology and Land Use.* Longman Inc., New York.

Virginia Department of Game and Inland Fisheries, 1995. *Native Warm Season Grasses for Virginia and North Carolina*.

Virginia Department of Game and Inland Fisheries. *Successful Wildlife Plantings.*

Way, Douglas S., 1973. *Terrain Analysis: A Guide to Site Selection Using Aerial Photographic Interpretation*. Dowden, Hutchinson, and Ross, Stroudsburg, Pennsylvania.

Weller, Milton W., 1994. *Fresh Water Marshes: Ecology and Wildlife Management*. University of Minnesota, Minneapolis.

White, Clare, 1982. *Roanoke 1740-1982*. Roanoke Valley Historical Society, Roanoke.

Hubbard Jr., David A., 1988. *Selected Karst Features of the Central Valley and Ridge Province, Virginia*. Virginia Division of Mineral Resources, Virginia. Publication 83.

Zube, Ervin, March/April, 1986. "The Advance of Ecology" in *Landscape Architecture,*. March/April, 1986.

Vita

Rekha Rao was born in Hyderabad, India on July 3, 1971. In 1972, she moved with her family to Bangalore, India. She attended University Visveswaraya College of Engineering, Bangalore University. In 1993, she received the Bachelors in Architecture degree from Bangalore University. She taught for a year as a part time faculty at the Department of Architecture, R.V. College of Engineering, Bangalore University. She came to United States of America in 1994 to pursue her masters degree in landscape architecture. She studied for a year at University of Oregon, Eugene. She continued her master's program at Virginia Polytechnic Institute and State University, Blacksburg. In May 1997, she received her Master's Degree in Landscape Architecture.