Evolution of ORV Trails in the Little Sahara Recreation Area, Utah, 1952 - 1997

A thesis presented to

the faculty of

the College of Arts and Sciences of Ohio University

In partial fulfillment

of the requirements for the degree

Master of Arts

Scott E. Dunfee

November 2008

This thesis titled

Evolution of ORV Trails in the Little Sahara Recreation Area, Utah, 1952 - 1997

by

SCOTT E. DUNFEE

has been approved for

the Department of Geography

and the College of Arts and Sciences by

Dorothy Sack

Professor of Geography

Benjamin M. Ogles

Dean, College of Arts and Sciences

ABSTRACT

DUNFEE, SCOTT E., M.A., November 2008, Geography

Evolution of ORV Trails in the Little Sahara Recreation Area, Utah, 1952 - 1997 (92 pp.)

Director of Thesis: Dorothy Sack

The purpose of this research is to produce a map and develop a model using geospatial technology that reveals the spatial and temporal distribution of ORV trails in the Little Sahara Recreation Area (LSRA) near Lynndyl, Utah, by visually extracting ORV trail features utilizing aerial photographs, spanning a timeframe from 1952 to 1997. The first research objective of this thesis is to map and examine the historical through present-day patterns of ORV trail development in the LSRA, which is located in Juab and Millard Counties, Utah. The second objective of this thesis is to develop a conceptual model that will predict the location and extent of present and future ORV trails in the LSRA and to explore the phenomenon of renegade trails and to validate the performance of the ORV trail prediction model. The modeling portion of this thesis is obtained by modeling user-generated ORV trails and environmental variables which are associated with the propagation of ORV trails using a geographic information system (GIS). GIS data are amassed to identify existing and potential ORV trail locations within the LSRA to produce a final map and model of ORV trails.

Approved: ____

Dorothy Sack

Professor of Geography

ACKNOWLEDGMENTS

First, I wish to thank my wife and children for remaining strong, being patient, and supporting me throughout this endeavor and for understanding when I could not be there as I was otherwise disengaged. It is because of you that I was able to see this through to its completion. I know it has been a long and hard road for all of us. I love you all equally and unequivocally.

Thank you Dr. Lein for your assistance and oversight on the crosstabs and the logistic regression analysis when it was blowing up and not working.

I would also like to take this time to thank my advisor, Dr. Sack, for her continued revisions, guidance, and patience throughout the entire thesis process. I am not sure I could have finished my thesis without your assistance. Thanks!

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 ORV Phenomena

Recreational activities on public lands have continued to grow in the U.S. since the middle of the twentieth century (Toy and Hadley, 1987; Cole and Landres, 1996; Lynn and Brown, 2003). According to Lynn and Brown (2003), those recreational activities involving trails are increasing at the greatest rate. This includes horseback-riding, hiking, and riding off-road vehicles (ORVs). Initially, the types of motorized vehicles that were used for outdoor recreational activities were jeeps, trucks, cars, dune/sand or rail buggies, and motorcycles. With the invention of the first three-wheeler prototype by Honda and the later importing of these vehicles into the U.S. in 1970, it became easier for outdoor enthusiasts to gain access to remote regions in national and state forests, parks, and recreational areas. Sutherland et al. (2001) have suggested that growing population, greater income, more leisure time, and technological advances have contributed to more intensive use of recreational areas (Sutherland et al., 2001). With the advent of ATV technology and the perfecting of the three-wheeler into the modern day ATV (four-wheeler) in 1984, it is now even safer and easier for outdoor enthusiasts to flock to remote locations within public lands, and in the past ten years the trend has been to manufacture wider, heavier, and faster ORVs to respond to the demands of ORV enthusiasts.

ORVs continue to increase in popularity as a form of outdoor recreation in the U.S. By conducting a national survey pertaining to recreation and the environment, Cordell et al. (1999) found that more than 36 million people are involved in some form of

ORV use. The presence of ORVs is enormous and continues to be a growing concern with the United States Forest Service (USFS), Bureau of Land Management, and National Park Service (NPS). In the early 1980s, the USFS estimated that each year nearly 5.3 million ORV visitor days were being documented on its lands (NPCA, 2001). By the early 1990s, ORV use had increased to about 80 million visitor days each year (NPCA, 2001). Between 1982-1983 and 1994-1995, ORV use has expanded by almost 44% (Cordell et al., 1999). The projection for 2020 is 118 million ORV visitor days per year for these recreational vehicles in American national forests (NPCA, 2001). As this trend indicates, ORV riding is extensive and presents a growing concern to the environment and to ecosystems managed by the USFS, NPS, and BLM. One of the most controversial topics pertaining to environmental management is ORV usage and their impacts on natural terrain (Webb and Wilshire, 1983).

ORVs affect both natural and human-constructed aspects of the environment. There are direct environmental consequences of riding ORVs. Riding ORVs disrupts soil equilibrium, damages vegetation, and alters the landscape. ORVs compact soils, destroy vegetation and crusts, and contribute to soil erosion (Belnap, 2002). The most prevalent consequence of ORV use is soil compaction (Wilshire and Nakata, 1976). ORVs are well known to severely damage plant life on sand dunes (Anders and Leatherman, 1987). ORV activities have degraded the aesthetic appeal of beaches, deserts, forests, and mountainsides (Coates, 1985). There are also notable adverse changes to environmental quality in the form of both air and noise pollution. The California Environmental Protection Agency states that more air pollution is produced by using a two-stroke engine for seven hours than by driving a new car for 150,000 km (100,000 miles) (CARB, 2006).

ORV use can also lead to the degradation of wildlife and wildlife habitat. The noise pollution from ORVs has been shown to cause loss of hearing in such organisms as kangaroo rats, desert iguanas, and fringed-toed lizards and to drive spadefooted toads out of their shelters (Lovich and Bainbridge, 1999). Recreational areas used by ORVs display increases in animal mortality, disfigured wildlife, and the degradation of animal habitats as well as reduced populations and diversity in plants, arthropods, lizards, and mammals (Luckenbach and Bury, 1983).

Besides the impacts on the natural environment, vast changes to existing trail networks are generated by riding ORVs. ORV impacts on trail networks include trail widening, eliminating trail switchbacks, and the establishment of renegade trails (Nepal and Nepal, 2004). On public lands, ORV trail networks have originated primarily on an ad hoc basis. These networks are very often based on user-generated trails and with little regard for the environment or for the philosophy of multiple use of the land.

Thus far, little research has been conducted on the planned or unplanned change in ORV trail extent over time in areas open to this type of recreation. Models have been underutilized in investigating how ORVs impact trails and where ORVs promote trail proliferation. A major goal of this thesis is to develop a model that facilitates identification, management, and prediction of authorized and/or unauthorized (renegade) ORV trails within a recreation area.

1.2 Thesis Goals

1.2.1 Purpose

The purpose of this thesis is to ascertain how the ORV trail system has changed through time in the Little Sahara Recreation Area (LSRA) of west-central Utah from the early 1950s to the late 1990s. That trail history is then analyzed to determine if there are predictable patterns of trail growth or abandonment that may be used to supplement the management plans of state and national forest, parks, and recreational areas. This research employs a GIS conceptual model to determine possible parameters that drive the expansion of ORV trails. The goal for this model is to explain ORV trail growth. Because many ORV trails are initially user-generated (i.e., renegade) trails, the model may also enable identification and prediction of the kind of locations that are most susceptible to uncontrolled trail expansion.

1.2.2 Rationale

Investigating the change in extent of ORV trails over time at the LSRA will provide specific results for the study area but may also lead to a better understanding of ORV trail change in general. A formal inventory has not previously been conducted on the history of ORV trail changes (growth/reduction) in the LSRA or apparently in any other public recreation area. It is not currently fully known how, where, when, and why ORV trails at the LSRA have evolved to their current extent. With this knowledge it may be possible to determine preferential environmental settings for trails and to predict future changes in the amount and location of ORV trails in the study area. Being able to determine the probable location of future trails, both authorized and renegade, will lead to the better overall management of the environmental assets in the LSRA as they pertain to the ORV trail network. Furthermore, using the LSRA as a case study to investigate the change in ORV trail extent over time may also lead to a better understanding of ORV trail change in general that can be applied to other public land areas. This may eventually lead to a conceptual model that is able to predict ORV trail patterns and location parameters in a variety of terrain types.

1.3 Definitions

The term off-highway vehicle (OHV) generally encompasses all of the different types of unlicensed motorized vehicles that can be driven off of public highways (paved roads). The types of vehicles that usually fit under this description are motorcycles, rail buggies (open-framed), dune buggies (closed-framed), quad-runners, and three-wheelers (Sierra Club, 2005). Because it tends to cross the boundary between licensed and unlicensed vehicles, the term OHV can lead to problems when trying to manage what types of vehicles are allowed in state and national forests, parks, and recreational areas. The category all-terrain vehicle (ATV) is on the opposite side of the management spectrum. It is limited and only includes quad-runners and three-wheelers, while omitting motorcycles, snowmobiles, and bicycles. The term off-road vehicle (ORV) is a more appropriate all-encompassing word when discussing what types of vehicles are allowed in state and national forests, parks, or recreational areas. It encompasses all motorized vehicles, both licensed and unlicensed, with two, three, or four wheels that can be used for recreation on public lands.

Executive Order (EO) 11644, issued by President Nixon in 1972, provided the basis for the definition of an ORV and established public land areas that these vehicles could operate on legally. According to Executive Order 11644 (USDI, 2005, p. 213), an ORV is:

> any motorized vehicle designed for or capable of cross-country travel on or immediately over land, water, sand, snow, ice, marsh, swampland, or other natural terrain; except that such term excludes (A) any registered motorboat, (B) any fire, military, emergency or law enforcement vehicle when used for emergency purposes, and any combat or combat support vehicle when used for national defense purposes, and (C) any vehicle whose use is expressly authorized by the respective agency head under a permit, lease, license, or contract; and (D) "official use" means use by an employee, agent, or designated representative of the Federal Government or one of its contractors in the course of his employment, agency, or representation.

The term ORV generally includes legally licensed vehicles that operate on public thoroughfares, such as jeeps, trucks, cars, motorcycles, and sport utility vehicles (SUVs). It, however, also includes vehicles such as snowmobiles, quad-runners, three-wheelers, tracked vehicles, and airboats. Because Executive Order 11644 establishes the only legal definition of these vehicles and refers to them as ORVs, the term ORV will be used exclusively in this thesis to represent the wide range of vehicles that are used on trails in public lands.

In 1977 President Carter amended Executive Order 11644 by issuing Executive Order 11989 to ensure the responsible use of ORVs on public lands and to protect the natural resources on them. This Executive Order grants each governmental agency the power to close ORV trails if any significant adverse effects are associated with their use.

Another important piece of legislation concerning the use of ORVs on public land is the Federal Land Policy and Management Act of 1976. This law, more specifically Title 43 Chapter 35 Subchapters 1 (§1701) and 2 (§1702), provides the basis for and definition of multiple use in public lands (USDI, 2007, p. 2):

> The term “multiple use” means the management of the public lands and their various resource values so that they are utilized in the combination that will best meet the present and future needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions; the use of some land for less than all of the resources; a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific and historical values; and harmonious and coordinated management of the various resources without permanent impairment of the productivity of the land and the quality of the environment with consideration being given to the relative values of the resources and not necessarily to the combination of uses that will give the greatest economic return or the greatest unit output.

1.4 Thesis Organization

The remainder of Chapter 1 provides a detailed description of the study area near Lynndyl, Utah. Chapter 2 reviews various trail-impacting agents as well as the physical and biological impacts of ORVs in various environments. Special attention is given to ORV studies in arid and semi-arid regions and to previous research performed in the LSRA. Chapter 2 concludes by summarizing literature on the methods of (1) determining change over time from aerial photographs, (2) extracting road-like features and detecting change from satellite imagery, and (3) using GIS in deterministic and stochastic modeling. Chapter 3 describes how the maps of the ORV trails at four separate years were created and delineated into a digital dataset. It also presents the principal attributes of the trail system at each interval. Chapter 4 analyzes variables relevant to the trail systems to determine of the most important factors in locating new trails. Conclusions and future considerations constitute Chapter 5.

1.5 Study Area

This study was conducted in and around the Little Sahara Recreation Area (LSRA), which is located in the Sevier Desert of west-central Utah. The LSRA lies about 120 km (75 mi) southwest of Salt Lake City and 50 km (30mi) north of Delta, Utah (Figure 1.1).

The specific area of study approximately corresponds to what Sack (1981, 1987) referred to as the Lynndyl dune field. The specific study area encompasses most of the LSRA with the exception of a strip along the western edge and a portion to the northeast of Black Mountain where aerial photograph coverage is lacking. The study area extends from the town of Lynndyl at the southeast to the railroad siding of Jericho in the northeast, and lies between Cherry Creek on the west and Tanner Creek on the east.

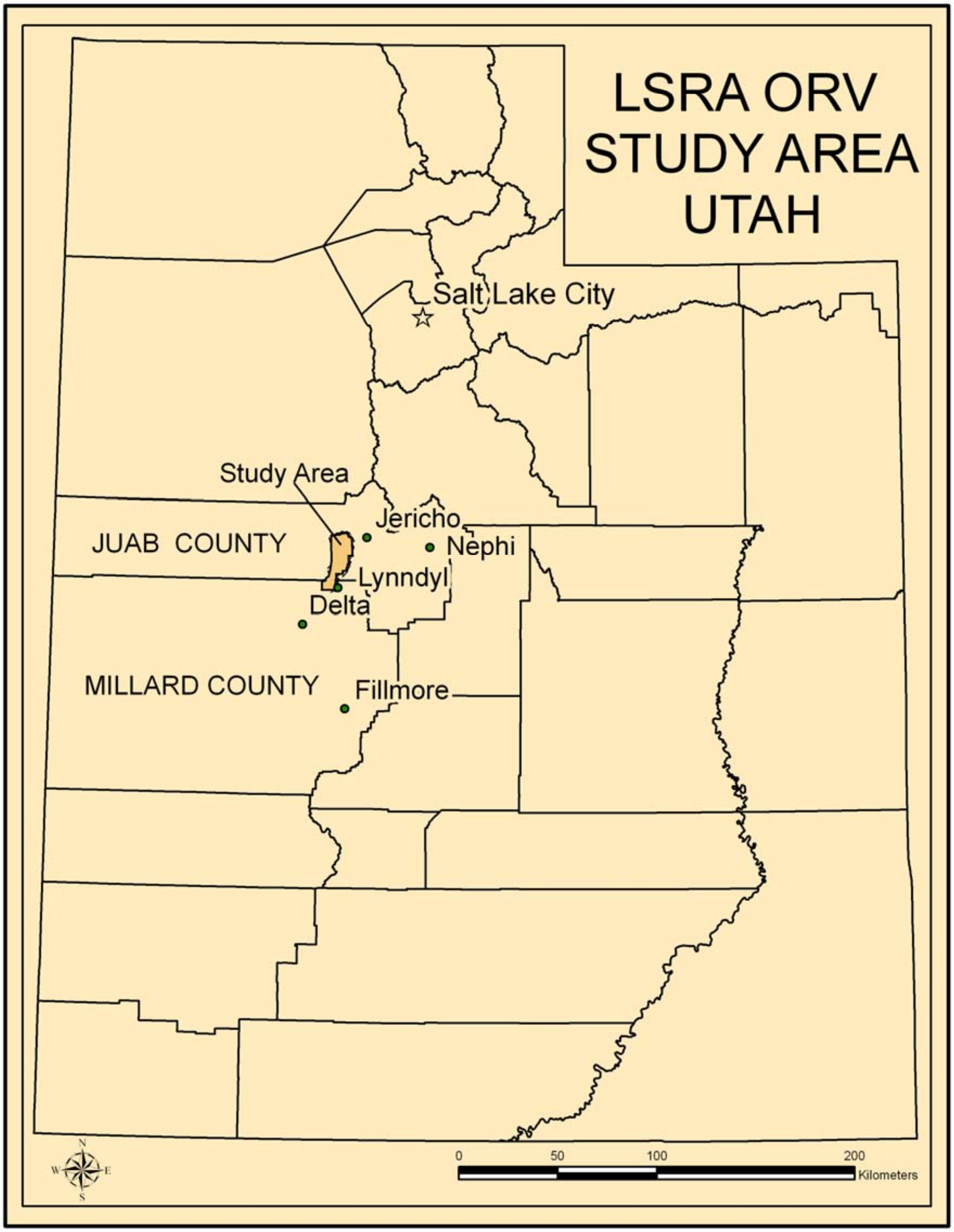

Figure 1.1: Location of study area

The surrounding roads are Juab County Route 1812 to the north, Utah State Route 174 to the south, Desert Mountain Road to the west, and U.S. Highway 6 to the east. The study area covers 239 km^2 (92 mi^2) and is made up of land owned by the BLM and State of Utah. Although the actual study area does not coincide exactly with the boundaries of the BLM recreation area, for convenience it is referred to in this thesis as the LSRA study area (Figure 1.2).

Figure 1.2: Extent of the study area relative to the Little Sahara Recreation Area

The LSRA is the largest of several ORV recreational areas that are overseen by the BLM in Utah. The LSRA is comprised of 254 km^2 (98 mi^2) of sand dunes, sagebrush flats, and sand-covered rocky knolls, with juniper trees at higher elevations. It is one of the few recreation areas in Utah that is primarily dedicated to ORV recreation. The LSRA has four campgrounds as well as the Rockwell Natural Area, which is a wilderness study area closed to vehicle use. The Rockwell Natural Area covers 37 km^2 (14 mi^2) and is home to endangered plant and animal species, such as the four-wing saltbush (*Atriplex canescens var. gigantea*) and the bald eagle (*Haliaeetus leucocephalus*).

The LSRA has a cold-winter, arid climate with an average annual temperature of 10˚C. The average annual precipitation is approximately 20 cm with the majority of precipitation occurring as rain or snow during the spring and winter months (Rosenthal et al., 2005). Over half of the total annual precipitation falls as snow (Peterson, 1972). The dominant vegetation is sagebrush and other desert shrubs; bunch grasses and some juniper trees are also found in the LSRA (Peterson, 1972).

The LSRA is comprised primarily of active and stabilized desert sand dunes of the Lynndyl (or Little Sahara) dune field (Sack, 1987). Sand in the Lynndyl dune field originated from the Sevier River delta of ancient Lake Bonneville, which the dunes partially overlie (Sack, 1987). The dunes reflect a dominant southwesterly sand-transporting wind (Sack, 1987). Elevation in the LSRA ranges from about 1452 m (4,765 ft) in the southwest to 1776 m (5,828 ft) at Black Mountain in the northeast. At 1738 m (5,702 ft) Sand Mountain is the tallest peak in the Sand Hills, a southeast to northwesttrending ridge of sand-covered bedrock that crosses much of the southwestern part of the LSRA (Figure 1.2).

In 1934 the LSRA was established through the Taylor Grazing Act, which enabled the BLM to control much of the western Utah desert (Chesler, 1984). It was not until the 1950s that the first known recreation use was made of this area (Peterson, 1972). Formal establishment of the area for ORV recreation occurred by the late 1960s. The first working draft of the Little Sahara Recreation Management Plan was published in 1972 by Fillmore District Office of the BLM. No evidence or documentation has been found of the existence of a formal ORV trail inventory when the LSRA was established.

The ORV trail system in the LSRA has been created through an ad hoc process of user-generated trails. The absence of an early cohesive plan for use and future development of the LSRA has caused problems for the area (Peterson, 1972). The earliest records that were kept on the different types of recreational uses of the LSRA date from 1964 when very little vehicle activity was noted (Peterson, 1972). It was not until a year later that the Salt Lake and Firebirds Motorcycle Clubs held the first organized ORV sporting event, which was a motorcycle race (Peterson, 1972). Subsequently, this became an annual event. In May of 1970, the first dune buggy hill climb competition was held at the LSRA (Peterson, 1972). Other motorcycle races and dune buggy hill climbs, as well as drag races, were sponsored in the LSRA in the early 1970s (Peterson, 1972). Since the 1970s, the use of ORVs in the LSRA has grown considerably in both popularity and frequency (Figure 1.3).

The LSRA is open all year, but ORV enthusiasts visit the recreational area mostly in spring (March-June) and fall (September-November) and typically on weekends (Dean, 1997). Historically, the largest number of visitors for the year come during Easter and Memorial Day weekends (Dean, 1997). Between 1971 and 1990, 85,000 visitors

Figure 1.3: Pictures of ORVs at the LSRA
Source: http://www.ut.blm.gov/recsite/little.html

per year came to the LSRA (Rahn and Rust, 2000). The LSRA recorded 180,000 visitors during 1999 (Mackelprang et al., 2001). The following year, it had over 187,000 visitors (USDI, 2004). As of 2001, the LSRA received about 213,000 visitors (638,000 visitor days) a year, and by 2020 that number is expected to increase by one third (Long and Blahna, 2001).

CHAPTER 2: LITERATURE REVIEW

Most research on the environmental effects of ORVs has been conducted in arid and semiarid regions and to a lesser extent in forested, coastal, and tundra environments. Previous research focuses on the impacting agents, such as hikers, horses, mountain bikes, and ORVs, and how each affects various environments with respect to such factors as soil compaction, vegetation loss, and trail erosion (Sack and da Luz, 2003).

Little attention has been paid in previous studies to the problem of managing growth in ORV trail networks or in quantifying the extent of authorized and unauthorized (i.e., renegade) trails. Unauthorized trail proliferation is apparently on the rise and may continue to increase unless a viable tool is developed for identifying areas likely to be subject to trail expansion (Nepal, 2003).

2.1 Comparisons of Various Trail Impact Agents

Considerable research has been conducted on the physical and biological effects of various trail-impacting agents. That literature mainly concerns horses, hikers, and motorcycles, but the effects of jeeps, ORVs, and llamas have also been investigated (e.g., Weaver and Dale, 1978; Webb, 1982; Summer, 1986; Cole and Spildie, 1998).

Weaver and Dale (1978) used two undisturbed sites, a forest and a meadow, to measure the impacts from horses, hikers, and motorcycles for 100, 500, and 1000 passes over each environment. The observed variables included percentage vegetation cover, trail width, trail depth, trampling of vegetation, soil compaction, upslope vs. downslope effects, and trail management status (multiple use vs. single use and speed limits). The authors found that horses were most destructive and hikers least destructive on level ground, but motorcycles were even more destructive than horses on vegetated slopes in the forest. Path widths tended to be greatest for horses and least for hikers. Trail depth increased with the amount of use and was greatest on slopes and for horses and least for hikers. Soil compaction also increased with the number of passes and was greater on slopes than on level sites; soils were more compacted by horses than by either hikers or motorcycles. Trail impacts resulting from motorcycles were more severe when traveling upslope than downslope, while trail impacts for horses and hikers were greater when going downslope. Weaver and Dale (1978) generalized that horses do the most damage and hikers the least. The authors made recommendations for ways for hikers, horses, and motorcycles to achieve the fewest impacts on trails.

Webb (1982) investigated how the recreational use of motorcycles compacted soil on an alluvial fan in the California desert. Four trails were created from 1, 10, 100, and 200 ORV passes using a motorcycle. Trail formation began immediately, with the first pass, but damage to vegetation did not occur until ten passes. All of the vegetation was destroyed in association with the 100 and 200-pass trails. Soil compaction and soil density also increased with the number of passes. Most notably, Webb (1982) found that the amount of soil compaction is directly related to ORV speed. Faster moving ORVs cause less soil compaction than ORVs that move more slowly.

Summer (1986) conducted a study in Rocky Mountain National Park, Colorado, where she used three trail sections to represent low (200-600 horse trips/season), medium (4,000-6,000 horse trips/season), and high (6,000-7,000 horse trips/season) amounts of horse traffic (Summer, 1986). She rated trails for erosion severity, with 1 cm/year representing the high to severe erosion category. Results from comparing trail impacts by horses and hikers proved to be inconclusive due to some differences in trail composition. The author determined that trail and mountain slope, geology, soil parent material, type of vegetation, location along the trail, microclimate, runoff, and landform setting, in addition to intensity of use by horses, affected the amount of trail degradation.

Cole and Spildie (1998) used a day in August 1994 at the Lolo National Forest in Montana to have a horse, a llama, and a hiker make anywhere from 25 to 150 passes on their respective lanes of a trail with one lane being reserved for no traffic, as a test lane. The goal was to determine the impact of each agent on trail vegetation. The horse had the greatest effect on vegetation in its respective lane, while no significant difference was found in how the llama and the hiker impacted vegetation.

2.2 Impacts on Trails and Adjacent Areas

Several different types of environmental impacts have been attributed to the use of ORVs. These physical and biological impacts consist of disruption of the soil surface, soil compaction, trail erosion and incision, vegetation loss, and impacts on wildlife.

Adams et al. (1982) used a Ford Bronco and a motorcycle in the Mojave Desert, California, in order to test for soil compaction. Both vehicles were driven over their respective lanes from 1 to 100 times per trial. Results showed that the Bronco produced greater soil strength, which reflects greater soil compaction. The Bronco produced a greater soil compaction depth on wet soil than either the Bronco or the motorcycle did on dry soil. Adams et al. (1982) found more severe impacts on the soil with heavier vehicles and wetter conditions of the trail.

Hinkley et al. (1983) studied accelerated erosion rates caused by ORVs in the western Mojave Desert, California. They reported ORV-induced erosion rates 5 to 50 times greater than natural rates. Because amount of runoff is a key factor determining erosion rates, the authors looked at the effects that ORVs have on runoff volume and frequency. The conclusions from their study show that ORVs cause soil compaction and soil disruption, and these decrease the infiltration capacity of the soil. It is the decrease in soil infiltration capacity caused by ORV use that leads to an increase in the volume and frequency of runoff. Therefore, the authors recommend that ORVs avoid long steep slopes in an effort to restrict the amount of erosion that they cause.

Brattstrom and Bondello (1983) examined the effects of ORV noise on the behavior and on the hearing processes and functions of three species of desert wildlife--the Mohave fringe-toed sand lizard, the desert kangaroo rat, and Couch’s spadefoot toad--in the Colorado and Mojave Deserts of California. They found that noise of ORVs caused hearing loss in these animals, interfered with their capacity to avoid predators, and caused them to behave in unnatural ways that could result in their death.

Kuss and Morgan (1986) used the universal soil loss equation in order to determine the physical carrying capacities of state and national forest land in Maryland and New Hampshire, respectively, for outdoor enthusiasts involved in the various recreational activities. High carrying capacities were associated with landforms of gentle to moderate slope, such as foothills, terraces, and floodplains. These types of terrain represent 50% of each forest. Although the method used by Kuss and Morgan (1986) might be sufficient for estimating soil impacts caused by ORVs, because it does not consider impacts on vegetation or wildlife, it does not generate a complete picture of the impacts of ORVs on forest trails.

Sun and Liddle (1993) focused on vegetation in their research on trampling impacts by people hiking in tropical and subtropical areas. The first to disappear from trampled sites was the upright herbaceous and woody vegetation. The overall coverage of the prostrate vegetation increased slightly with the onset of trampling, but by the end of the experiment there was a slight decrease in its coverage. Tussock vegetation seemed to thrive in trampled areas and tended to move in and take the place of the decreasing upright herbaceous and woody vegetation. Total vegetation and vegetation height decreased at all sites as a result of trampling, with even tall species being absent in heavily trampled areas.

Sack and da Luz (2003) compared the soil compaction and erosion trends associated with seasonal use of trails by ORVs, horse riders, and hikers in Wayne National Forest of southeastern Ohio. They found ORVs to cause considerable trail compaction, significant sediment mobilization, including the throwing of trail sediment to trail-adjacent areas by tires, and potentially high erosion rates even though ORV use is permitted only seasonally.

2.3 ORV Research in Arid and Semi-Arid Regions

Much of the research on the environmental impacts of ORVs has been conducted in arid and semi-arid regions. The most notable study areas are in parts of the Mojave, Sonoran, and Colorado Deserts areas of California, but other desert locations have received study as well. Pioneering researchers, such as R.M. Iverson, R.H. Webb, and H.G. Wilshire, set much of the foundation for subsequent research on the physical effects of ORVs in arid environments.

Iverson et al. (1981) utilized a motorcycle in the western Mojave Desert, California, to learn about the effects that ORVs have on desert soil bulk density, infiltration, runoff, and fluvial erosion. For this experiment, the desert surface was subjected to 0, 1, 10, 100, and 200 passes by the motorcycle. Results showed a logarithmic increase in soil bulk density with an increasing number of ORV passes and that the greatest change in bulk density occurred during the initial passes (Iverson et al., 1981). Soil compaction was shown to reduce infiltration capacity and increase soil strength and runoff capacity. Additionally, ORV use was associated with a distinctive increase in wind and water erosion. Through multivariate statistical analysis the authors were able to identify areas that would most likely be adversely affected by ORVs and suggest other locations that might be more suitable for ORV recreation. The analysis showed that areas least impacted by ORV use would have rainfall of short duration and low intensity, high initial infiltration rates, low slopes, and surfaces with abundant sand and gravel. The authors noted, however, that sites with these characteristics would be subject to increased wind erosion after ORV use (Iverson et al., 1981).

Webb's (1982) work with motorcycles in the Mojave Desert, introduced in Section 2.1, focused on their effects on soil density, penetration resistance, and infiltration properties. Webb (1982) found that the greatest compaction and greatest damage occurred during the first few passes of the motorcycles, and that because loamy sands are the soil textures most prone to compaction, ORVs should be restricted on that type of soil. With a larger number of passes, motorcycles greatly increased the surface density and decreased the infiltration rate of a sandy loam, both as logarithmic functions (Webb, 1982).

Wilshire (1983) investigated whether the route of the annual Johnson Valley to Parker motorcycle race in the Mojave Desert of California was an environmentally acceptable route. He found a large increase in the extent of tracked lands following each annual race. The motorcycle race also compacted the soil and destroyed wildlife, vegetation, animal burrows, and soil horizons. Wilshire (1983) concluded that it was environmentally unacceptable to continue the race through its initial route.

How ORVs affect the biota in the Algodones Dunes of Imperial County, California, was examined by Luckenbach et al. (1983). The researchers chose six sets of paired sites to compare attributes of ORV-impacted sites with sites not experiencing ORV use. The five variables measured at each site were plant density, number of lizard sightings, lizard tail loss frequency, observed impact on mammals (catch and release), and number of animal tracks. Compared to the ORV-used sites, the sites not used by ORVs were found to have twice the number of plant species, 10 times greater plant density and cover, and forty times the volume of shrubby perennials. Undisturbed sites had almost twice as many lizard species and four times as many individuals as the disturbed areas. Lizards observed in the disturbed sites were three times more likely to have lost their tails. Twice the number of mammal species and five times the number of individuals were observed in undisturbed sites than in sites where ORVs were used. Insect and mammal tracks were also much more numerous at the undisturbed than at the disturbed sites. The work by Luckenbach et al. (1983) shows that ORV activities are extremely destructive to the biota at the Algodones Dunes.

The lasting effects of military tank maneuvers conducted in the eastern Mojave Desert from 1942 to 1944 were studied by Prose (1985). Prose (1985) used soil compaction and bulk density measurements from tank tracks, dirt roads, and untracked areas to determine the impact of the vehicles on soil properties. The upper 20 cm of soil had soil resistances 50% greater within tank tracks than on dirt roads, but bulk density values were not significantly different.

Lovich and Bainbridge (1999) summarized the negative environmental impacts of livestock grazing, linear transportation and communication corridors, mining activities, military operations, the occurrence of fires, and the use of ORVs in the Mojave and Colorado Deserts of southern California in an attempt to improve desert management strategies. As one of the major recreational activities in the deserts of California, Lovich and Bainbridge (1999) credit ORV use with soil compaction, loss of vegetation, increase in fire frequency, establishment of invasive species at the expense of native species, wind and water erosion, noise pollution, air pollution, and adverse impacts to wildlife. The study concludes that it could take more than a hundred years and over a billion dollars to recover this area just from the environmental impact of ORVs.

In a desert oilfield of northeastern Kuwait, Brown and Schoknecht (2001, p. 421) investigated the vehicle-generated phenomenon known as the “positive track effect.” In that study, vehicle tracks on the poorly sorted, gypsum-rich soils were found to encourage vegetation growth by acting as small basins for the accumulation of rainwater and wind-blown plant seeds. Ponding of the water helped to dissolve some of the salts locally and encouraged removal of some fine-grained sediments. Germination was much more difficult in the finer grained, more compacted soils of the dry areas between the tracks.

Belnap (2002) sought to establish if and how ORVs affect nitrogen inputs in the soils of the Chihuahuan, Sonoran, Mojave, Great Basin, and Colorado Plateau desert regions of the U.S. The study involved four passes on a dry soil by a four-wheel drive GM suburban. Immediately after driving over the surface, 40 samples were taken to examine for nitrogenase activity at each of the 26 test sites, 10 from each track pass and 10 from outside each track. All 26 sites showed a decline in nitrogenase activity, but only 14 showed a significant decline. Nevertheless, ORV use was detrimental to most of the sites.

Brooks and Lair (2005) investigated the ecological effects of vehicle routes in the Mojave Desert with regard to soils, vegetation, and animals. Altered runoff patterns on desert soils proved to be an important impact of the routes. Both dirt and paved roads encouraged vegetation growth. These same roadways were also responsible for invasive plant species being introduced from ORVs, and for animal death due to vehicle strikes and habitat destruction.

Groom et al. (2007) examined the impact of ORVs on *Astragalus magdalenae* var. *peirsonii* (Peirson’s milk-vetch) in the Gecko Management Area of the Algodones Dunes in Imperial County, California. Three study areas, two closed to ORVs and one where they are allowed, were used to measure density of the plant. The authors determined that ORVs cause a decrease in the plant's density.

2.4 Previous Research in the LSRA

Over the years, several studies have been conducted at the LSRA, ranging from socio-economic studies of ORV users and the Sin Nombre virus in rodent populations to the characteristics and geomorphology of the sand dunes. At least four master's theses and eight professional articles have been written about the LSRA.

Stutz et al. (1975) performed a genetic study on a relic population of a species of four-wing saltbush (*Atriplex canacens*). The LSRA is apparently the only area where that type of giant four-winged saltbush is found.

In 1977, Nelson conducted his master's thesis research on the experience, expectations, and behavior patterns of ORV enthusiasts at the LSRA to try to develop a conceptual model that would guide the process of making effective management decisions. Nelson (1977) found two types of ORV users, those interested in ORV competition and those interested in ORV exploring. Nelson (1977) found affiliation, risk, status, escape, and action/excitement to be the significant experience expectations of ORV users at the LSRA.

Wullstein et al. (1979) studied nitrogen-fixation processes in grasses in the LSRA. Wullstein and Pratt (1981) followed this up with a study of the rhizosheath structure of *Oryzopsis hymenoides* (Indian rice grass). They found that the rhizosheath structure depends primarily on the extent of root hair growth and the bonding between root hairs and sand grains.

In her master's thesis and a later publication, Sack (1981, 1987) analyzed the eolian geomorphology and sedimentology of the Lynndyl dune field, 45% of which is included within the LSRA. She determined the origin of the quartz-rich wind-blown sand as the Sevier River Delta of ancient Lake Bonneville. Her geomorphic map separates the dune field into active (64%), semi-active (17%), and stable (19%) dune areas. The active dune area consists of parabolic dunes, barchans, coalescing barchans, climbing and falling dunes traversing the Sand Hills, and a type of transverse dune called aklé. The semi-active area is a zone across which a medium amount of sand is transported in barchans and parabolic dunes. Sack (1987) described the stable dune area as comprised of vegetated dunes only locally activated by occasional blowouts. She explained the spatial distribution of the various dune forms to be primarily the result of topography that in some places leads to deposition, while elsewhere encouraging sand to move more rapidly across the terrain.

For his master's thesis research, Chesler (1984) coupled a study of sequential aerial photographs (1939, 1952, and 1977) with field observations in order to determine if any anthropogenic factors were affecting the rate of sand dune movement in the LSRA. He concluded that the anthropogenic impact was minimal and that the main variables that significantly affect sand movement are wind velocity, grain size, vegetation, soil water content, and topography. Chesler felt that the tendency for ORV use to occur in spring and fall when soil moisture would be more prevalent lessened the potential anthropogenic impact on dune movement.

ORVs impact the environment yet are considered by many to be a viable and appropriate means of recreation. Policy decisions, therefore, can be contentious and require an awareness and understanding of the multiple types of users of public recreation areas. To help inform decision makers, Dean (1997) studied the characteristics, preferences, perceptions, and fulfillment of expectations of visitors to the LSRA as part of his master's thesis research. Dean (1997) found that most visitors to the LSRA are males (89%), under 36 years of age (50%), have an income over $30,000 (75%), visit the recreation area at least one time a year, stay 1 to 3 nights, and come in groups of 3 to 10 people.

Mackelprang et al. (2001) postulated that the high incidence of the Hantavirus in the deer mouse (*Peromyscus maniculatus*) population of central Utah is due to landscape disturbance by ORVs at the LSRA. The researchers found mean antibody prevalence in trapped rodents in the vicinity of the LSRA to be about 30%, which is up to 3 times higher than that of other locations.

Recent vegetation studies involving the LSRA include work by Gross et al. (2004) and Ludwig et al. (2006) on the *Helianthus deserticola* (desert sunflower) and

Helianthus anomalus (western sunflower), respectively. In anther study, Rosenthal et al. (2005) investigated how *Psoralidium lanceolatum* (dune scurfpea), *Salsola iberica* (Russian thistle), and *Stipa hymenoides* (Indian ricegrass) could live on active sand dunes as well as on adjacent nondunal areas. The authors considered water, soil, and vegetation parameters, and found dune plants to have deeper roots than plants of the same species in nondunal soils.

2.5 ORV Trail Detection and Change Analysis

Little previous research has addressed the topic of using aerial photographs, remote sensing, GIS, or modeling techniques to help identify past, present, and locations of future user-generated ORV trails in federal and state parks or recreation areas. All of these techniques, however, have been used extensively to study change of landscape elements over time and thus are readily applied to the ORV trail research addressed in this thesis.

2.5.1 Aerial Photography Techniques

A great variety of previous research projects have used sequential sets of aerial photographs, most recently in combination with GIS, to investigate how and why specific landscape features have changed over time (e.g., Brown and Carter, 1998; Hessburg et al., 2000; Winterbottom, 2000). Two previous studies have been found that apply these techniques to problems involving ORV trails.

Levin and Ben-Dor (2004) monitored changes in sand dune stability in the Ashdod and Nizanim Dunes of Israel, which are subjected to recreational activities. They used aerial photographs to document changes in dune advance rates for barchans, transverse dunes, and parabolic dunes between 1944 and 1999. The researchers found a significant decrease in dune migration rates over the study period. They noted that dunes in the southern part of the study area (Nizanim) stabilized faster than those in the northern part (Ashdod). Levin and Ben-Dor (2004) posit that anthropogenic recreational activities, such as ORV use and hiking, affected sand dune activity. They suggest that an increase in the density of tracks since the 1960s caused a decrease in natural vegetation on the dunes. This did not lead to the reactivation of the dunes, however, because the recreational activities also led to the introduction of invasive species which have acted to stabilize the dunes. Recreational use of the dunes by hikers and ORV riders therefore caused both an increase and a decrease (through establishment of invading species) of dune activity leaving a mosaic of different stability patches.

Matchett et al. (2004) studied degradation of vegetation caused by ORVs over time at the Dove Springs ORV open area in the western Mojave Desert of Kern County, California. Those researchers used aerial photographs from 1965, 1982, 1994, and 2001 at scales ranging from 1:124,000 to 1:40,000 to delineate this phenomenon. ORV routes and degraded areas were mapped from the digitized photos using ArcGIS. For each year represented by aerial photographs, route densities were calculated. They were found to increase from 7 to 30% between 1965 and 2001, with the greatest change (17%) occurring between 1965 and 1982. There was a clear trend between route density and linear features. Natural as well as artificial linear features, including washes, utility lines, or ORV trails, were found to be associated with increases in trail density.

2.5.2 Remote Sensing Techniques

Although remote sensing systems have not been used to detect and extract ORV trails specifically, some information is available from the literature on related methods and models used in the extraction of road-like features and land-change detection. A few articles are particularly applicable to the topic of ORV trail detection and land-use change analysis.

Bhattacharya and Parui (1997) developed a multi-layer perceptron (MLP) neural network model that was based on a backpropagation algorithm to solve the problem of delineating road-like structures within a remote sensing system. Their MLP model is a layered approach using non-Gaussian image classes that simplifies the image into road and non-road pixels through supervised classification.

Couloigner et al. (1998) applied the concept of Amelioration de la Resolution Spatiale par Injection de Structures (ARSIS), which basically allows a best case resolution image to be achieved from multiple varying spatial and spectral resolutions. The use of ARSI coupled with the use of an unsupervised classification method, to extract urban roads from images of 5, 10, and 20 m resolution, was obtained with a 1.67 m resolution image from the Radiometre Aeroporte Multispectral Imageur sensor. This process uses the unsupervised classification method with the semi-automatic algorithm model to create a template of the urban roads. Systematically, each iteration improves the template by masking the initial urban areas attained through unsupervised classification and performing iterations on the successive outputs. Ultimately, this reclasses the initial output of the outlying areas surrounding the urban class and misclassified pixels until the analyst believes the image represents a clear distinction between the roads that are trying to be extracted and surrounding non-road areas. Couloigner et al. (1998) showed that the 5 m resolution mask performed best in extracting urban roads and yielded the closest to the actual road network that they were attempting to extract. The 20 m resolution mask was only able to extract roads greater than 16 m wide, while the 10 m resolution mask only extracted road wider than 8 to 10 m. This information can be beneficial when determining which spatial and spectral resolution to use when extracting roads or trails of known widths.

Karathanassi et al. (1999) used a parallel thinning algorithm on 5 m panchromatic SPOT imagery to extract urban road networks. The thinning algorithm, also known as a peeling algorithm, is based on thresholds, thinning, linking, and gap filling (Karathanassi et al., 1999). While other features may have spectral signatures similar to urban roads, these same features also have different sizes and shapes. Each binary image that is produced from the original panchromatic image also has varying degrees of completeness and accuracy. The original digital numbers are used to go back and fill in the blanks (gap filling) in order to refine the linear extracted features. The parallel thinning algorithm method is actually based on five algorithms: thresholding, morphological, thinning, linking, and gap filling algorithms. What each algorithm leaves behind or lacks, the next algorithm picks up in classifying the feature properly based on all five algorithms.

A study by Zhang et al. (2002) pertains to the subject of detecting land change using remote sensing that could be applicable to a study of ORV trail density and change over time. Zhang et al. (2002) used 30 m Landsat data to create a gradient direction profile analysis algorithm, based on the supervised classification method of maximum likelihood, in order to identify road density and apply this to detect urban change. This was achieved by adding road density channels as a separate band to the image from year to year to create a new image and employing spectral-structural post-classification comparison and the spectra-structural image differencing classification. The output from the supervised classification was a binary image of roads as ones and background as zeros. The best results in extracting road networks were achieved by using the Landsat TM band 2. "The performance of algorithm models depended mainly on the resolution of the image, the width of the roads, and the contrast of the surroundings" (Zhang et al., 2002, p. 3065).

Wilson et al. (2003) used 30 m Landsat TM data and Landsat MSS imagery from 1985 to 1999 covering a span of over two decades to determine and map urban growth. Their urban change model used the concept of a forest fragmentation model. The model trained the imagery pixel by pixel into 3 distinct classes: developed, undeveloped, and water. The analyst utilizes a 5 x 5 window to count pixels as well as adjacent pixels in order to assign a centroid value which allows a measure of individual and neighborhood pixel changes. Thus, the model generates this pixel grouping and change information into five different types of urban growth classes.

2.5.3 GIS Techniques

Wright et al. (1992) used a GIS to help model soil loss and develop an erosion hazard rating (EHR) system to predict soil erosion due to ORVs on trails in national forests. Those researchers turned to GIS to develop the EHR after finding that the universal soil loss equation inadequately predicted soil erosion due to ORV use. The EHR system developed by Wright et al. (1992) considers multiple variables to derive four factors: soil erodibility, runoff production, runoff energy, and vegetation cover (Figure 2.1). Each of these categories is assigned a value, and an EHR obtained for each site by adding together its four values. A low EHR is less than 4, a moderate EHR is 4-12, a high EHR is 13-29 with vegetation loss and trail erosion, and a very high EHR is over 29 (Wright et al., 1992). Further investigation of sites with high EHR values can be used to determine which of the four factors are responsible for the high overall erosion hazard rating. The study by Wright et al. (1992) demonstrates how GIS can enhance the ability of researchers in identifying ORV-related environmental problems.

Kim et al. (2005) used a stochastic model to generate an optimized solution for locating a highway between two points. Optimization can be with respect to cost, alignment, and other specific or relevant factors. Their work shows that the coupling of a genetic algorithm and a GIS can be an effective tool in the siting of roadways, and therefore could possibly be applicable to ORV trails in state and national forests, parks, and recreation areas. Optimization, for example, can be programmed to be the best land management solution with respect to the state and national forests, parks, or recreation areas environment. A genetic algorithm is an efficient means of searching a large solution space and can provide a wide array of possible solutions and scenarios to a particular roadway alignment, including ORV trails.

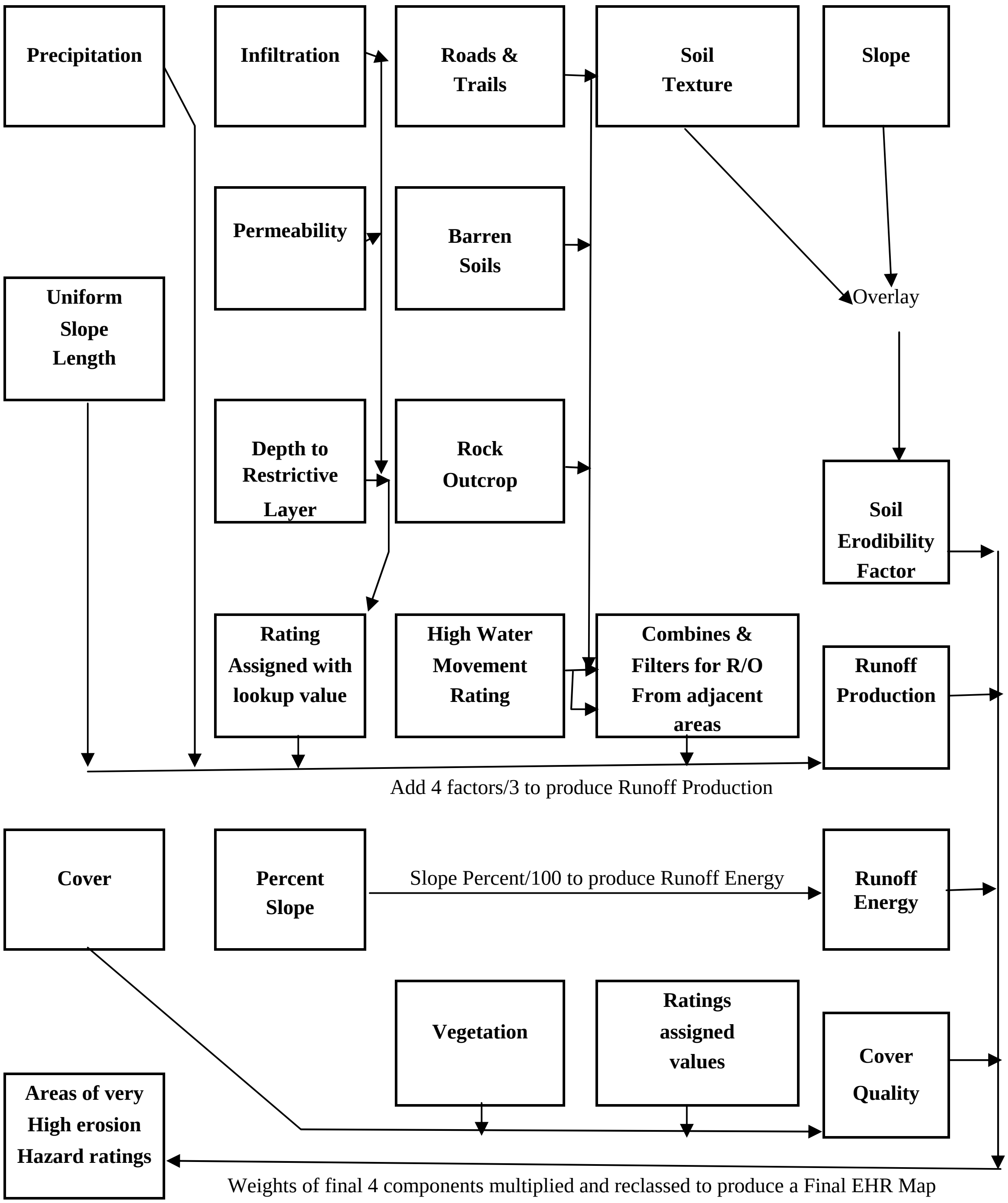

Figure 2.1: Erosion hazard rating (EHR) model flow chart (after Wright et al., 1992)

CHAPTER 3: MAPPING

3.1 Methods

Spatial and temporal changes of ORV trails within the study area were assessed using four sets of hardcopy aerial photographs representing the period from 1952 to 1997. Vertical aerial photographs were obtained for 1952, 1977, 1987, and 1997. All of the photographs were taken in approximately the summer season. Table 3.1 lists the principal attributes of each set of photographs.

Agency/Project	Date of Imagery	Format	Scale
U.S. Department of Agriculture	Aug. 1952	black & white	1:20,000
Bureau of Land Management	July/Aug.1977	natural color	1:32,000
National Aerial Photography Program	June/Aug. 1987	color infrared	1:40,000
National Aerial Photography Program	July/Sept. 1997	color infrared	1:40,000

Table 3.1: Attributes of aerial photographs used in this study

ORV trails were identified on the aerial photographs for each of the four study years by viewing pairs of overlapping photographs stereoscopically with a stereoscope. Trail-like features within the LSRA were drawn onto mylar overlays attached to the aerial photographs of the study area while interpreting the photographs stereoscopically (Figure 3.1). In some instances, it was hard to differentiate whether a feature was a trail or a road. In these cases the feature was mapped anyway and its status investigated later using maps showing road data for Juab and Millard Counties, Utah. This proved to be somewhat of a cumbersome process with the lack of historical roadway data for the study area. Thus, it was determined that the road undoubtedly started out as a dirt trail at some point in time and would be included as a trail in the ORV trail system.

Figure 3.1: 1997 NAPP aerial photograph of ORV trails

In addition, sparse vegetation and the light photographic tone of the active sand dunes made it almost impossible to determine if there are any permanent ORV trails in those areas. Mapped trails extend to the edges of the active dunes, and people obviously ride their ORVs in the active sand dunes, but there is no visible evidence of permanent trails in those areas on the imagery used in this study. However, there is evidence of permanent trails on the leeward side of Sand Mountain. Also, there is a corridor of ORV trails in the active dunes of the Rockwell Natural Area that is apparent in the imagery.

Once all of the trails were delineated onto the mylar, each overlay was scanned into Adobe Photoshop at a resolution of 100 dpi. This relatively low resolution was selected to keep the file size manageable when all the overlays for a year were mosaicked together because each set of photographs had at least 20 overlays.

A digital base map was constructed using ESRI ArcMap version 9.1 of the LSRA study area at a scale of 1:24,000 using relevant portions of the six digital 1986 US Geological Survey (USGS) topographic maps needed to cover the study area. The six USGS topographic maps that provide full coverage of the study area are the Cherry Creek, Maple Peak, Lynndyl NW, Tanner Creek Narrows, Lynndyl West, and Lynndyl East, Utah, 7.5 minute quadrangles. Only one of the four sets of hardcopy aerial photographs representing the period from 1952 to 1997 was available in digital format as a digital orthophoto quadrangle (DOQ). The six DOQs that provide full coverage of the study area are the Cherry Creek, Maple Peak, Lynndyl NW, Tanner Creek Narrows, Lynndyl West, and Lynndyl East. The digital DOQ data had been compiled from a combination of NAPP aerial photography (9/9/1992; 6/24/1993; 6/25/1993; 6/30/1993; 7/16/1997; 9/30/1997; 6/23/1999; and 8/29/1999) and Digital Elevation Models (DEMs) (1/1/1961; 1/1/1970; 2/2/1995; 1/1/1997), which were transformed by the Rocky Mountain Mapping Center and Western Mapping Center, contracting oversight agencies for the state of Utah Automated Geographic Reference Center. The DOQs conform to USGS horizontal accuracy standards with a root mean square error (RMSE) no greater than 7.0 meters. RMSE is the square root of the summed difference of the X and Y coordinates between the projected base/reference image and the unprojected image.

For each study year, the scanned air photo overlays were mosaicked together, then each mosaic was georeferenced to the 1:24,000-scale base map using ERSI ArcGIS version 9. Valid ground control points (GCPs) for georectification were selected primarily from road and trail intersections and available landmarks. Georectification was performed using a third order polynomial transformation. This method was chosen due to fact that there were vast amounts of control points that were used and on some of the air photos the only usable GCPs were located near the photo margins, far from the nadir, where relief displacement is greatest. Pixel resampling was accomplished using the cubic convolution option for a smooth curve through the GCPs. These options helped to reduce the total RMSE for each imagery year that was mosaicked.

An acceptable RMSE can be calculated for each study year by considering the scale of the air photo set and the scan resolution of the mylar overlays. Acceptable RMSE is defined as being less than or equal to 1/2 the map unit size of a cell/pixel. The RMSE should be less than 1/2 pixel, according to several sources (e.g., Dobson et al., 1995; Morisette, 1997). The map unit size of a cell is obtained by determining the number of meters on the ground per pixel of the map overlays. For a trail map overlay traced from 1:20,000-scale air photos and scanned at 100 dpi, the map unit size of a cell is 5.08 m. The target and actual RMSE in meters for each mosaicked year of scanned aerial photographs are shown in Table 3.2.

Photo Year	1952	1977	1987	1997
Target RMSE	2.54	4.06	5.08	5.08
Actual RMSE	8.37	6.15	8.49	8.48

Table 3.2: Target and actual RMSE in meters for each study year

Attaining the target RMSE was difficult. The actual RMSEs, moreover, are not within the recommended margin standard for error of 1/2 the cell size. However, because the actual RMSEs attained were within 2 to 6 m of the target RMSEs, they are thus considered to be within an acceptable error range of tolerance for this study.

Once each of the mosaics was georeferenced the trail system on each was digitized creating four digital ORV trail feature classes in ArcGIS. Proper placement of the trail-like features was achieved using the digital topographic maps and air photo interpretation. The 1997 DOQ was utilized to ensure that no trails had been missed in the stereoscopic interpretation of the 1997 aerial photograph stereo pairs or in the georectification process of the four base maps. Trail-like features that were added at this stage were digitized at a scale of 1:5,000.

A geodatabase was created using ArcCatalog to house all of the data, with the exception of the raster data, and for performing the analyses and computations. The personal geodatabase was created with a projection of UTM 17N and the extent of the state of Utah. A personal geodatabase provides a projection and extent automatically for each added feature class, calculates and adds areas and lengths automatically in the attribute table of each subsequent feature class, and supplies the topology of various feature classes.

3.2 Results

Small-scale maps showing trail density for each individual study year, 1952, 1977, 1987, and 1997, are presented in Figures 3.2 to 3.5, respectively, to illustrate the change in the ORV trail system for each year that aerial photography was available for this study. For convenience of visual comparison, Figure 3.6 encompasses all four study years into one map to facilitate an understanding of how spatial aspects of ORV trails have changed over the years in the LSRA.

Data derived from each of the four, large-scale, digital trail maps using ArcMap statistics include total number of trail segments, total trail length, mean trail length, and mean trail density. The results for each of the ORV trail study years are shown in Table 3.3. Between 1952 and 1997, 946 new trail segments were added representing 302 additional kilometers of trails. During this entire study period, trail density also increased considerably, while the mean trail length decreased over the years. This shows that some of the increase in the number of ORV trails was due to the creation of connections between trails, trail shortcuts, and connections between switchbacks, many of which were likely initiated through renegade, rather than officially sanctioned, activities. The increase in number and density of trails and decrease in trail length is not surprising given the increase in use of the recreation area over time.

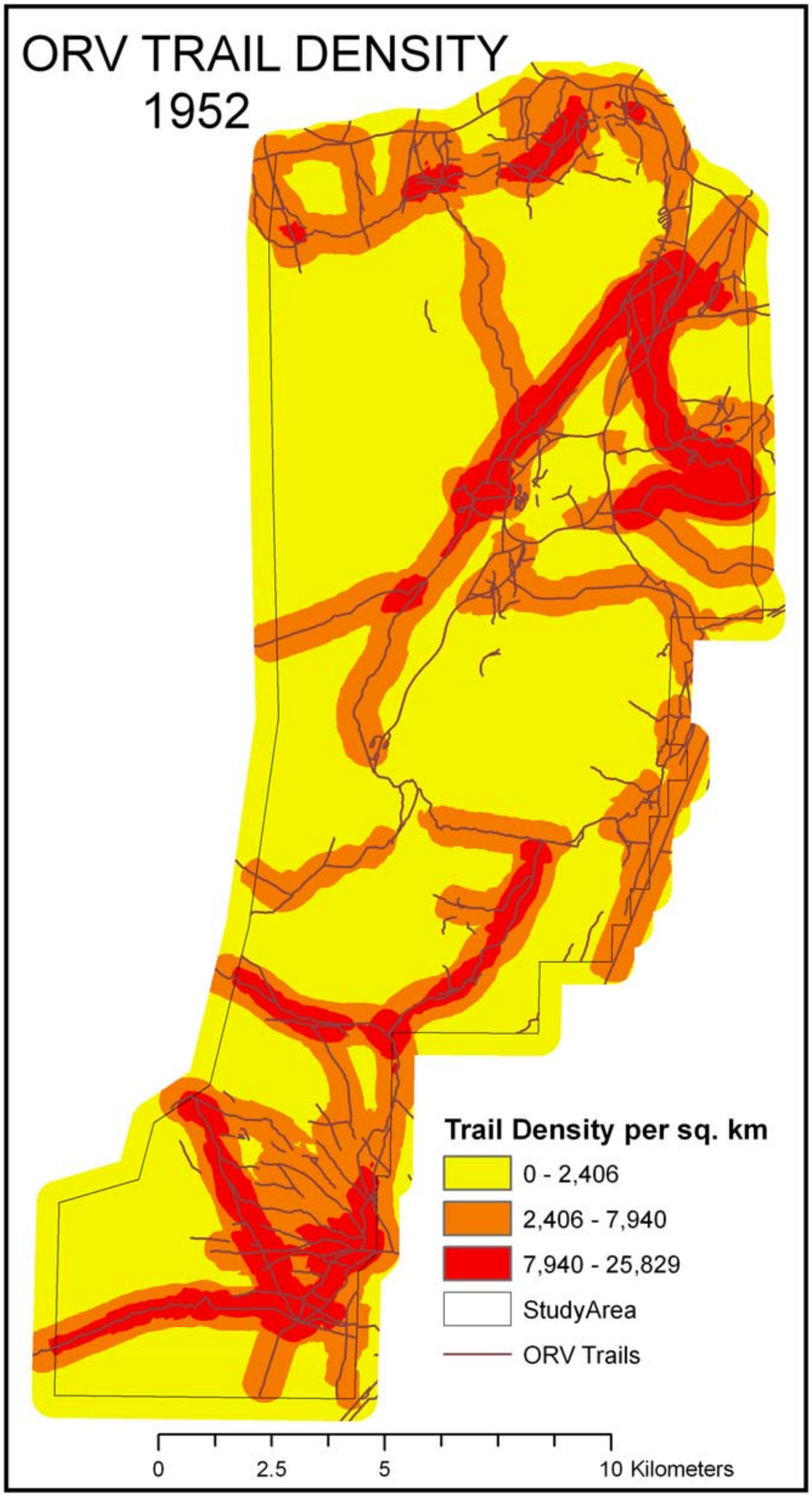

Figure 3.2: ORV trail density 1952

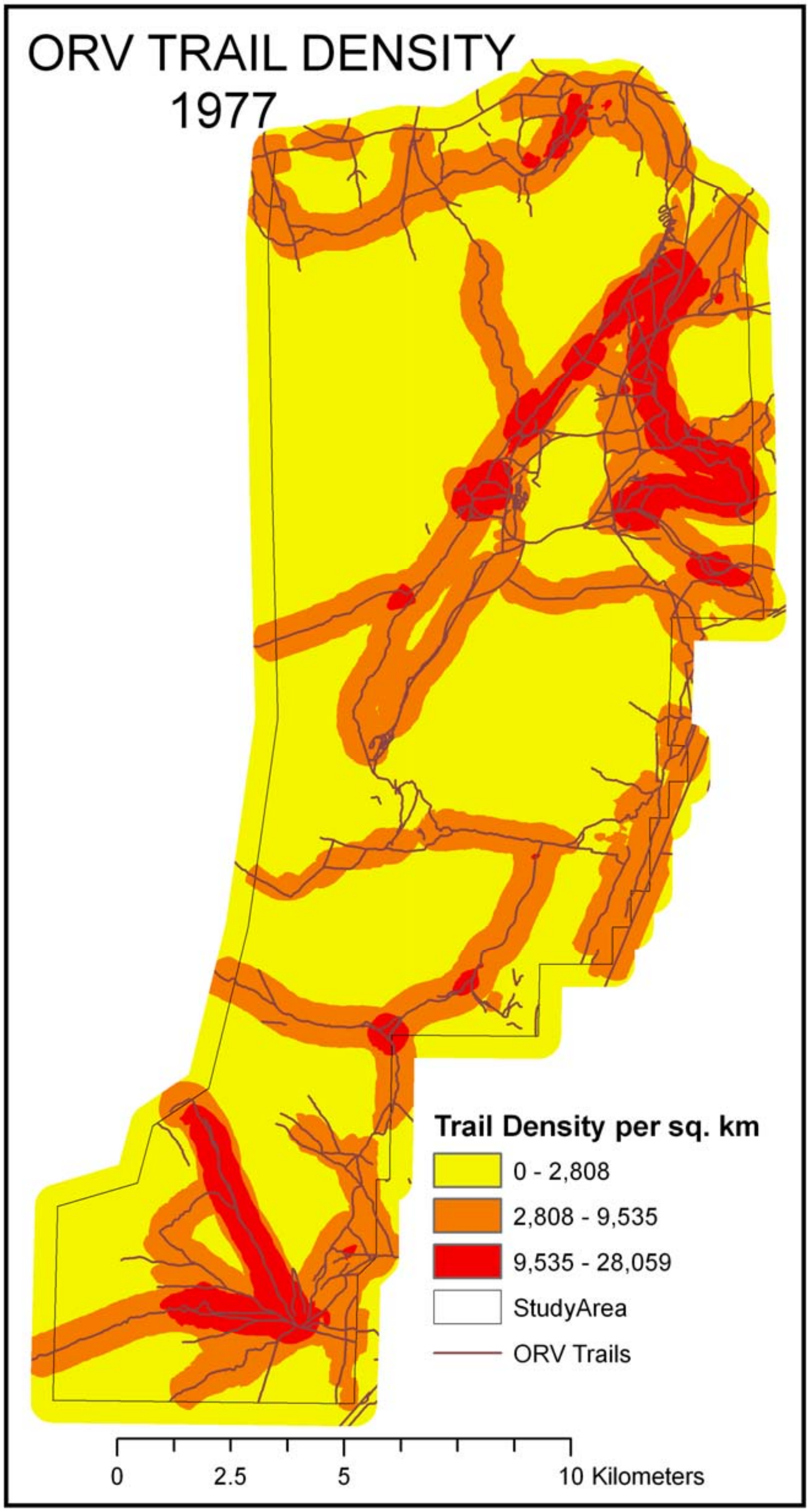

Figure 3.3: ORV trail density 1977

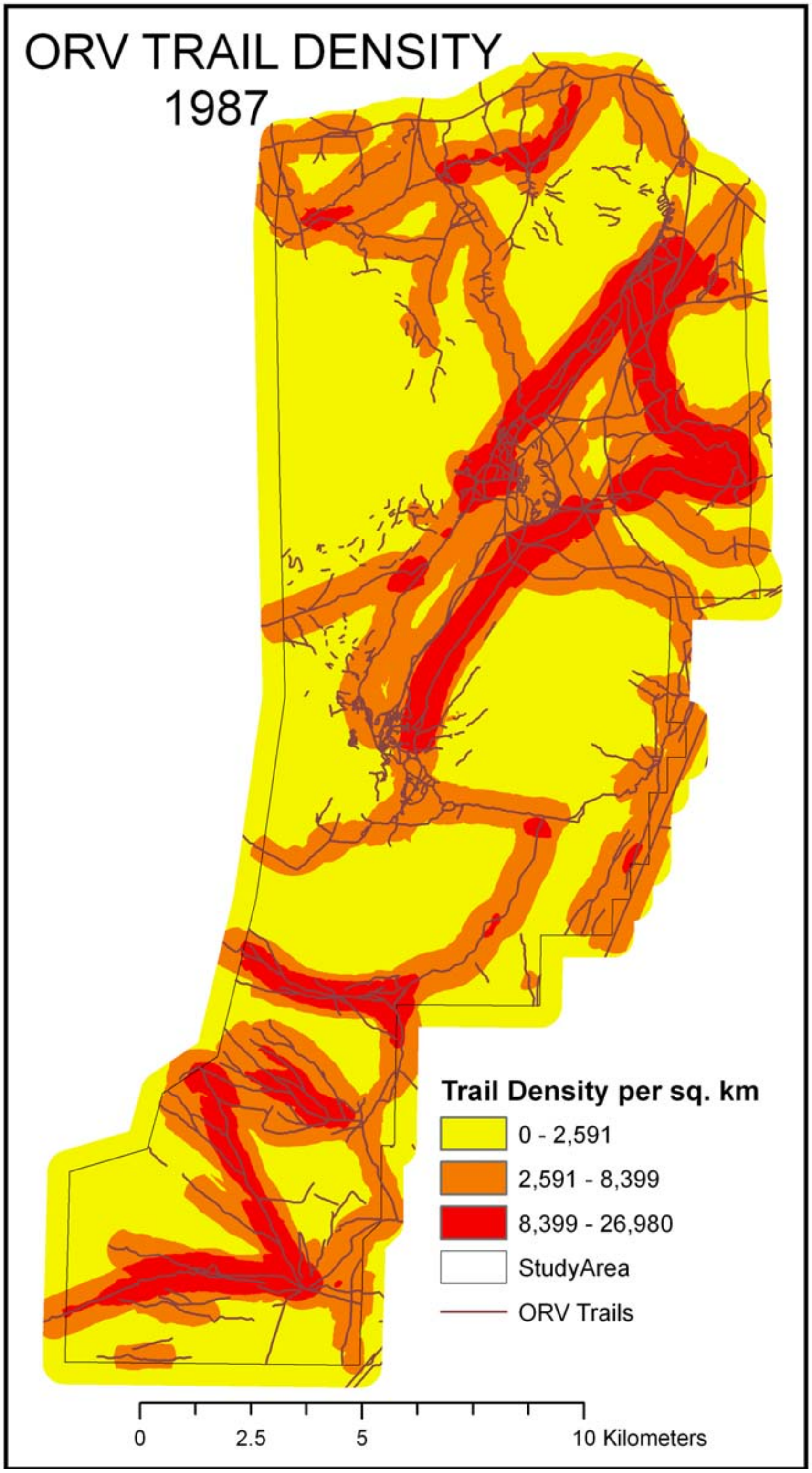

Figure 3.4: ORV trail density 1987

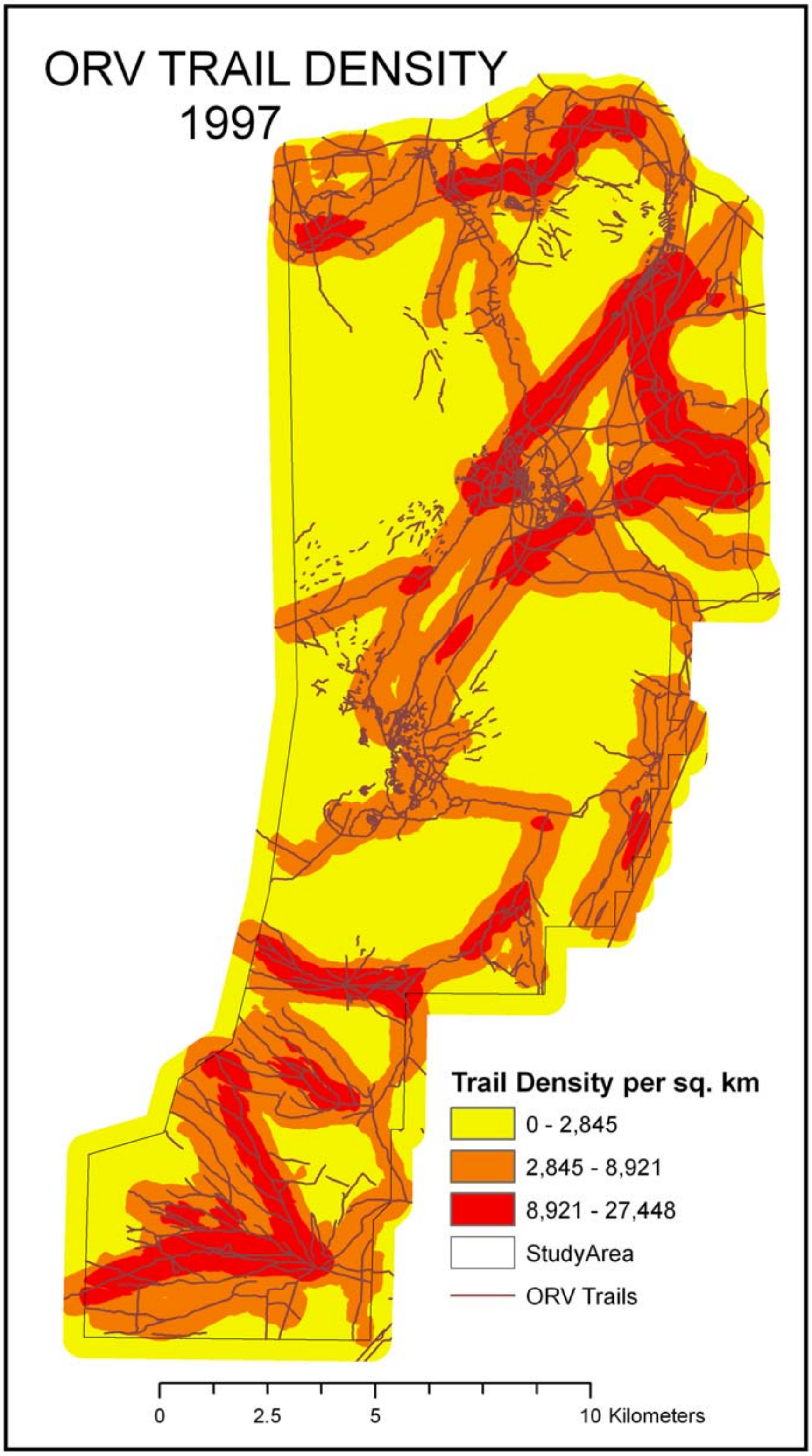

Figure 3.5: ORV trail density 1997

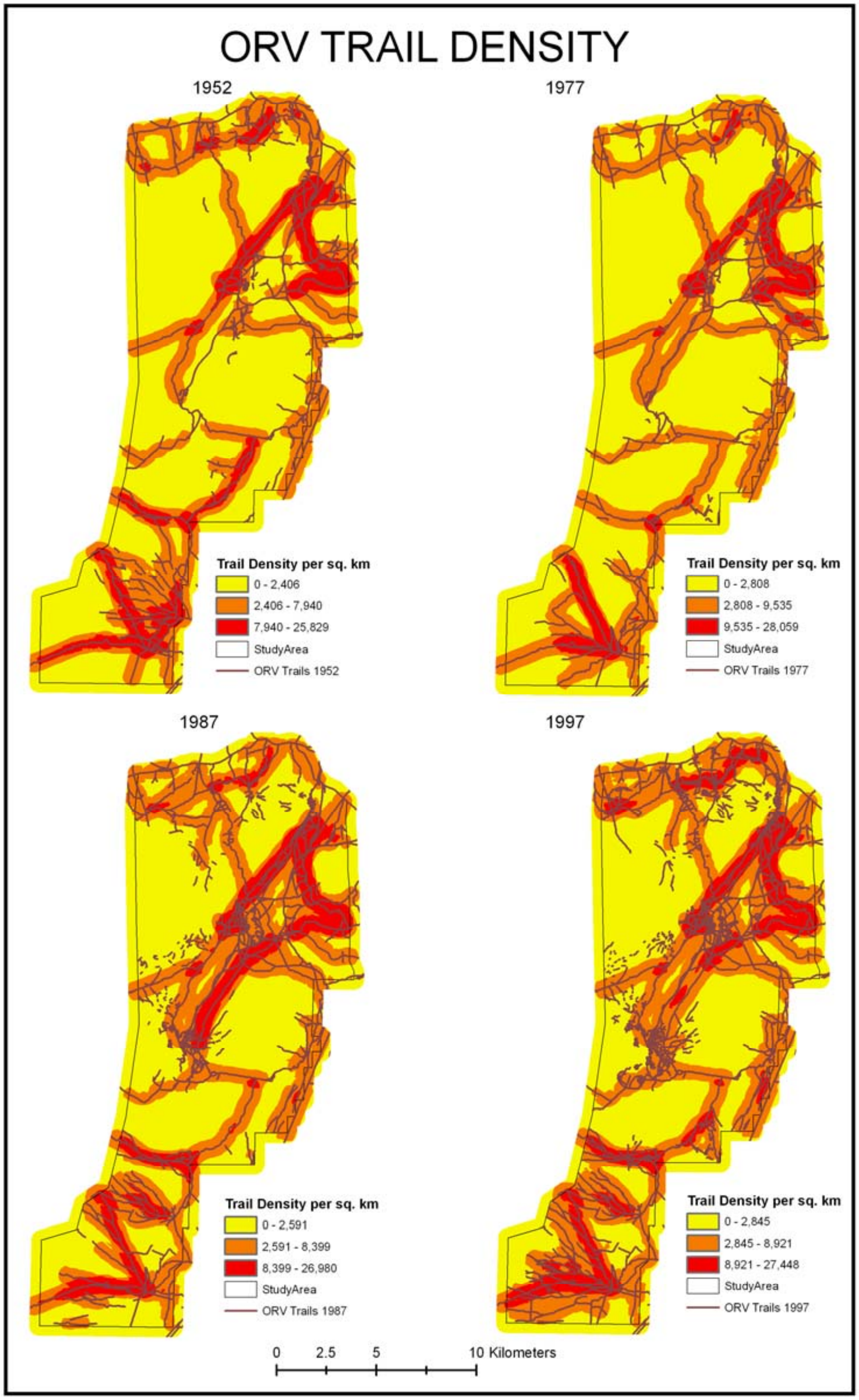

Figure 3.6: ORV trail density by year

Year	# of Trail Segments	Total Trail Length (km)	Mean Trail Length (m)	Mean Trail Density (m/km^2)
1952	408	353	864	615
1977	469	370	789	1544
1987	917	497	542	2076
1997	1354	638	471	2666

Table 3.3: Attributes of the ORV trail system by study year

The change in the trail data between air photo years, and the average annual change in the trail characteristics, are presented in Table 3.4. These data suggest that the expansion of the trail system at LSRA may have started to approach a constant, rather than rapidly accelerating, growth rate.

Interval	Absolute Change in:			
	# of Trails	Total Trail Length (km)	Mean Trail Length (m)	Mean Trail Density (m/km^2)
1952 to 1977	61	17	-75	929
1977 to 1987	448	127	-247	532
1987 to 1997	437	141	-71	590
Interval	**Average Annual Change in:**			
	# of Trails	**Total Trail Length (km)**	**Mean Trail Length (m)**	**Mean Trail Density(m/km^2)**
1952 to 1977	2.4	0.68	-3.0	37.2
1977 to 1987	44.8	12.7	-24.7	53.2
1987 to 1997	43.7	14.1	-7.1	59.0

Table 3.4: Absolute and average annual changes in ORV trail attributes

CHAPTER 4: ANALYSIS

4.1 Logistic Regression Analysis

Binary logistic regression is a statistical technique used to help classify cases into two categories by assessing multiple independent variables observed at those cases. The independent variables can be continuous and/or categorical. The dependent variable, however, is categorical consisting of two classes. In this study, the dependent variable consists of whether a sample site is located on an ORV trail or not; the two classes are yes (1) or no (0). Logistic regression utilizes probabilities (P) and the logit transformation, which is frequently applied to sigmoid distributions. In this study, it estimates the probability of an ORV trail occurring given a site's characteristics on selected independent variables. For each LSRA site included in the analysis, the value of the dependent variable (1 or 0) is already known from air photo interpretation and mapping. In this case, logistic regression is used to identify the independent site variables most strongly associated with trail sites. Binary logistic regression is employed in this study to help determine what factors contribute to the occurrence of ORV trails. The ultimate goal is to construct a model that can help predict where ORV trails are most and least likely to occur. Thus, locations susceptible to ORV trail growth or renegade trails can be identified and monitored on the LSRA and other public lands.

4.1.1 Variable Selection

The first step in the analysis of the LSRA data was to generate a preliminary list of natural and anthropogenic variables that might contribute to ORV trail generation. ORV trail creation may be a purely random, immeasurable process dependent solely upon the whim of ORV riders, but there are several static geographic factors, such as distance from roads, trails, and land cover, as well as management decisions that probably influence where ORV trails are established. Although it might not be possible to determine the specific social, cultural, or psychological factors that influence where new ORV trails are located, associations very probably exist between trail location and various cultural and natural environmental variables that can be quantified. For example, anthropogenic factors, such as accessibility to existing transportation networks, including roads and existing ORV trails, may be measurable and could quite possibly be main factors that put state and national forests, parks, and recreation areas at risk for trail proliferation. Natural environmental variables that may be of significance to the generation of ORV trails are those related to the nature of the physical landscape, such as elevation, slope, and aspect.

The literature that has been written on ORV enthusiasts and their riding preferences was a valuable source of preliminary variables. Nelson (1977) and Dean (1997) specifically addressed the experience, expectations, needs, and behaviors of ORV enthusiasts at the LSRA. Of the utmost importance are the transportation infrastructures and the accessibility to paved roads, which allows ORV users to arrive at the ORV trail network. Secondly, once ORV users have arrived, the recreation area has to have something appealing to offer them. According to Nelson (1977) and Dean (1997), there are three basic types of ORV users which consist of recreation, exploration, or some form of competition. There are also five expectations that can be associated within each of these user groups. In order of importance, these expectations are considered to be thrill, seclusion, camaraderie, environment, and level of danger (Dean, 1997). Thus, Dean's (1997) study showed that ORV riders typically prefer nonconforming areas and trails that test rider abilities. ORV users seek fulfillment through a visually changing landscape as well as the thrill of alternating between high and low elevations and traversing steep slopes. Another important aspect is the escape factor. As a result, popular ORV areas usually consist of remote and/or solitary areas, natural environments, and aesthetically pleasing land characteristics (Nelson, 1977). Dean (1997) found that typically the underlying goal of many ORV users is the sense of satisfaction achieved through recreating in remote areas. Historical sites are of additional interest and can be construed as appeal to ORV riders.

The initial list of 23 possibly significant variables associated with the establishment of ORV trails in LSRA appears in Table 4.1. The appropriateness and practicality of those variables for this study were investigated and assessed in order to develop a final list of variables to be created in ArcGIS and used in the binary logistic regression analysis. Data mining efforts for the variables in Table 4.1 were undertaken online through websites from the Fillmore District of the BLM, the USGS seamless data distribution system at the Earth Resources Observation System (EROS) Data Center, and the Utah Automated Geographic Reference Center (Utah GIS portal website). The historic sites shapefile was more of a point of interest shapefile with very few locations included. It was thus decided to create a shapefile of other recreation points of interest and then combine both one shapefile entitled Points of Interest.

PRELIMINARY LIST OF INDEPENDENT VARIABLES	
NATURAL	ANTHROPOGENIC
Elevation	**Distance to Roads**
Slope	**Distance to ORV Trails**
Aspect	**Distance to Electrical Utilities**
Presence of Hillshade	**Distance to Water**
Scenic Viewshed	**Population Density**
Vegetation Cover	**Housing Density**
Soil Type	**Road Density**
Water Erosion	**ORV Trail Density**
Wind Erosion	**Distance to Land Uses**
Wind Direction	**Proximity to Other Recreation Sites**
Wind Speed	**Proximity to Archaeological Sites**
	Proximity to Historic Sites

Table 4.1: Tentative ORV trail model parameters

Local data on wind and water erosion, wind direction and speed, utilities, population densities, housing densities, and archaeological sites were not readily available for the study site. In addition, the existing literature does not emphasize these as factors important to ORV users, thus they were eliminated and deemed as unimportant and/or impractical to obtain for this research model. Vegetation cover, soil type, and land use variables were converted to shapefiles. Only those preliminary independent variables that were readily available and could be quantified were selected for this study. Fourteen independent variables were chosen for the binary logistic regression analysis (Table 4.2).

LIST OF MEASUREABLE INDEPENDENT VARIABLES	
NATURAL	ANTHROPOGENIC
Elevation	**Distance to Roads**
Slope	**Distance to ORV Trails**
Aspect	**Distance to Streams**
Hillshade	**Road Density**
Viewshed	**ORV Trail Density**
Distance to Vegetation	**Distance to Land Uses**
Distance to Soil Type	**Distance to Points of Interest (POI)**

Table 4.2: Measureable ORV trail model parameters

Elevation, slope, aspect, hillshade, and viewshed were obtained from raster files created from the USGS DEMs of the study area from the Utah GIS Portal website using ArcGIS spatial analyst. The elevation from the DEM is in meters and slope represented as a percentage. ArcGIS quantified aspect by indicating the slope face direction for each raster cell, ranging from 0-360°. Flat areas were classified as a -1; whereas due north was 360, east was 90, south was 180, and west was 270. Hillshade was quantified by considering the illumination angle and shadows, and ranged in value from 0 (darkest) to 255 (brightest). Viewshed was quantified by comparing elevation angle of a cell center with the local horizon to determine extent of visibility. Viewshed values extended from 0 (not visible) to 1 (visible).

ArcGIS spatial analyst 9.1 was used to calculate distances from the roads, ORV trails, streams, and points of interest. From the 1997 shapefile of the LSRA ORV trails, two raster layers were created, one for determining the distance from ORV trails and the other for ORV trail density.

Vegetation cover, land use, and soil type were determined from the National Land Cover Database land use/land cover, and Utah soils, shapefiles. Distances from the sampled ORV trail points were calculated to various land use, land cover, and soils areas. Distance to sand, soil type, and developed land use showed little variation over the area, as did vegetation type, and distance to vegetation. There is little development in the LSRA, soil type is almost all sandy, and vegetation type is almost all comprised of sagebrush. Therefore, these variables were omitted from the data analysis.

Upon further preliminary analysis, the variable of distance to ORV trails was dropped due to collinearity in the data found using SPSS. Ten of the 14 preliminary independent variables listed in Table 4.2 remained for including in the actual regression analysis. These 10 variables are listed in Table 4.3.

INDEPENDENT VARIABLES INCLUDED IN THIS ANALYSIS	
Elevation	**Distance to Roads**
Slope	**Distance to Streams**
Aspect	**Distance to Points of Interest (POI)**
Hillshade	**Distance to ORV Trails**
Viewshed	**Road Density**

Table 4.3: Final ORV trail model variables employed

4.1.2 Site Selection and Data Measurement

The polyline shapefile of the ORV trails that was compiled from the 1997 aerial photographs was utilized to create a point shapefile of the 1997 ORV trails in order to extract sample points for the binary logistic regression. Points sampled from the 1997 ORV trails point shapefile were those determined to be of the most benefit to the analysis--those located wherever trails originated, terminated, and branched off (trail intersections). This selection criterion yielded 2,098 ORV trail sample points. Hawth's analysis sampling tool in ArcGIS was used to select an equal number of random, non-trail sample points for use for comparison in the binary logistic regression model, making the total number of observable cases 4,196. For each of the 4,196 sample points, an identification number, geographical coordinates, and point type were recorded in the database table of the shapefile. Sample points were assigned the value of a 1 (point type 1) for existing ORV trails, while non-trail points were assigned a value of 0 (point type 0). The advantage of using the numbers of 1 and 0 is that the mean can be interpreted as a probability. The mean of a dummy variable equals the proportion of cases with a value of 1 and can be interpreted as a probability (Pampel, 2000).

4.1.3 Binary Logistic Regression Results

The research hypothesis of this thesis is that the creation or location of ORV trails is based on or dependent upon one or more of the final 10 measured variables. The null hypothesis assumes that the creation of ORV trails is a random process. The final 10 variables used in the binary logistic regression in Table 4.3 were measured and assigned a value for each of the 4,196 sample point locations. The binary logistic regression method was used to determine which of the 10 variables would readily and accurately predict the probability of any given location/point being or becoming a place where an ORV trail would or could potentially exist. Relevant statistics for the 10 variables in the binary logistic regression equation appear in Table 4.4.

Variables in the Equation	df	B	Standard Error	Wald Statistic	Signif.	Exp(B)
Elevation	1	.000	.001	.303	.582	1.000
Slope	1	-.001	.005	.053	.817	.999
Aspect	1	-.001	.000	1.544	.214	.999
Hillshade	1	.006	.003	3.645	.056	1.006
Viewshed	1	.017	.106	.025	.875	1.017
Road Dist.	1	-.001	.000	95.586	.000	.999
Stream Dist.	1	.000	.000	6.506	.011	1.000
POI Dist.	1	.000	.000	18.037	.000	1.000
Road Density	1	.000	.000	7.834	.005	1.000
Trail Density	1	.469	.018	686.246	.000	1.598
Constant	1	-3.023	1.323	5.222	.022	.049

Table 4.4: ORV trail explanatory variables in binary logistic regression

The regression coefficient, B, is the average amount that the dependent variable increases when the independent variable increases one unit and the other independent variables remain constant. The B coefficient is basically the slope of the regression line. The larger the value of B, the steeper the slope, and the more the dependent variable changes for each unit change in the independent variable.

Each Wald statistic along with its corresponding level of significance shows how meaningful each independent variable is in the model (Hosmer and Lemeshow, 1989). The Wald statistic is the ratio of the logistic coefficient B to its corresponding standard error (S.E.) squared. If a Wald statistic has a significance value less than 0.05, then it is significant in the model. Assessment of the Wald statistic values reveals that the variables of distance to roads, distance to streams, distance to a point of interest, road density, and trail density within the LSRA study area are statistically significant at the 0.05 level and important determinants of ORV trail location. Elevation, slope, aspect, hillshade, and viewshed were higher than the 0.05 cutoff and thus are not statistically significant as contributors to the ORV trail model.

Exp(B) is the odds ratio of an independent variable's association with a trail site or a non-trail site; the odds with which it is associated with a trail site divided by the odds it is associated with a non-trail site. Exp(B) is the predicted change in odds for a one unit increase in the independent variable. Odds ratios of less than 1 correspond to decreases and odds ratios of more than 1 correspond to increases in odds. Odds ratios close to 1 indicate that a unit change in that independent variable does not affect the dependent variable.

The ten variables used in the logistic regression correctly predicted 73.5% of the trail sample sites and 84.8% of the non-trail sample sites used in the study (Table 4.5).

Observed		Predicted		
		ORVPOINT		Percentage Correct
		0	1	
ORV Point	0 (2098)	1,779	319	84.8
	1 (2098)	557	1,541	73.5
Overall Percentage				79.1

Table 4.5: Binary logistic regression model predictive power

Table 4.6 lists results of tests of significance of the overall logistic regression model for ORV trail presence in the LSRA. The Cox and Snell R-Square and Nagelkerke R-Square results point to only weak or moderate probability, respectively, of the model correctly predicting whether a site is likely to have an ORV trail. The Hosmer and Lemeshow test assesses the overall fit of a logistic regression model. A finding of no

Cox & Snell R^2	Nagelkerke R^2	Hosmer & Lemeshow Test (d.f. = 8)	
		Chi-Square	Significance
0.386	0.515	90.310	.000

Table 4.6: Binary logistic regression model summary

significance corresponds to the model adequately fitting the data, meaning that there is no significant difference between the observed and model-predicted values. Conversely, a significant result of the Hosmer Lemeshow test causes the null hypothesis to be rejected because of a difference between the predicted and observed values. A Hosmer and Lemeshow goodness of fit test statistic with a significance (probability) greater than 0.05 would indicate a well fitting model. In this case, the Hosmer and Lemeshow goodness of fit test statistic is compared to the chi-square distribution with 8 degrees of freedom, which yields a probability of 0.000, indicating that the binary logistic regression model is not a good fit.

Although the model in Table 4.5 predicts trail and non-trail sites fairly well, it cannot be stated with confidence that the location of trails depends on the variables used in the binary logistic regression analysis. Even though the independent variables of distance to roads, distance to streams, distance to points of interest, road density, and trail density are statistically significant variables in the regression analysis, the model is not a good fit, that is, not a statistically significant predictor of ORV trail location, based on the results in Table 4.6. Especially in theory testing, the Hosmer and Lemeshow goodness of fit test is more important than the predictive power, or accuracy of classification, of the model (Menard, 1995). Thus, the binary logistic model developed here is not appropriate for constructing a map of likely future locations of new and renegade trails in the LSRA.

4.2 Crosstabs

4.2.1 Crosstabs Analysis

With the binary logistic regression model not statistically significant, further analysis of the LSRA data was undertaken using a crosstabs data exploration technique. This was used to investigate the possibility that there is a latent pattern or process driving the development of ORV trails which is influenced by such variables as elevation, slope, aspect, hillshade, distance to ORV trailheads, distance to roads, distance to streams, and distance to points of interest in the LSRA.

Nine variables investigated in this thesis were divided into four classes for the crosstabs method (Table 4.7). This was done to explore the notion that subclasses of the data would be helpful in showing if there is a force other than pure randomness driving the process of ORV trail creation at the LSRA. In each case, class 1 was deemed as the most influential and most likely for the development of ORV trails, and class 4 designated the least influential in ORV trail development. Table 4.7 defines the four classes for each ORV trail variable. The classes were selected arbitrarily, based on personal beliefs of what an ORV rider would perceive as ideal locations, times, and conditions while trail riding and exploring at the LSRA.

Variable Class	1	2	3	4
Elevation (m)	1451.91-1550	1550.1-1600	1600.1-1650	1650.1-1752.07
Slope %	0-5	5.01-10	10.01-20	>20.1
Aspect (degrees)	90.1-270 & -1 (flat)	45.1-90	270.1-315	315.1-45
Hillshade	125.1-190	90.1-125	190.1-225	0-90
Dist. to ORV Trailheads (m)	0-400	400.1-800	800.1-1200	>1200.1
Dist. to Roads (m)	0-800	800.1-1200	1200.1-1600	>1600.1
Dist to Streams (m)	0-400	400.1-800	800.1-1600	>1600.1
Dist. to POI (m)	0-2400	2400.1-3600	3600.1-4800	>4800.1
Road Density (m/km^2)	>800.1	500.1-800	200.1-500	0-200
ORV Trail Density (m/km^2)	>750.1	500.1-750	250.1-500	0-250

Table 4.7: Classes set for variables in crosstabs analysis

4.2.2 Crosstabs Results

In consideration of the elevation variable at the LSRA, the typical basin and range layout for this area was duly noted. It was thus hypothesized that the most probable or ideal locations to ride an ORV would be in the lower 100 m of elevation in this study area. The results of this cross-tab exploration are shown in Table 4.8. However, the fact that the majority of both the ORV trail and non-trail sample points are located within elevation class 1 probably merely reflects the distribution of elevations in the study area.

		Elevation Class				Total
		1	2	3	4	
Point Type	0	1,339	294	354	111	2,098
	1	1,244	231	505	118	2,098
Total		2,583	525	859	229	4,196

Table 4.8: Type of sample point versus elevation class

The best places to ride an ORV might be within areas that have a slope percentage between 0 and 5%. This is a safe slope to ride on without the fear of tipping, rolling over, or riding off a shear cliff once topping a steep incline. The results in Table 4.9 show that the majority of existing ORV trail points fall with that slope class. However, that fact that most of the non-trail points lie on the lowest slopes as well, indicates that most of the terrain in the study area consists of slopes between 1 and 5%.

		Slope Class				Total
		1	2	3	4	
Point Type	0	1,387	305	249	157	2,098
	1	1,272	379	254	193	2,098
Total		2,659	684	503	350	4,196

Table 4.9: Type sample point versus slope class

It was proposed that areas facing east and west would be preferable to ORV riders. As shown in table 4.10, this category (class 1) was also where most of the existing ORV trail points and non-trail points were located.

		Aspect Class				Total
		1	2	3	4	
Point Type	0	1,419	154	231	294	2,098
	1	1,308	218	242	330	2,098
Total		2,727	372	473	624	4,196

Table 4.10: Type of sample point versus aspect class

For the hillshade variable, areas that are dimly illuminated and/or dark should be less desirable than areas that are well illuminated. The results show that neither type of sample point was found in the darkest category, and that both occur in the brightest class.

Again, because trends in both types of sample points agree, this result reveals the overall brightness of the terrain at LSRA rather than a preference by ORV riders (Table 14.11).

		Hillshade Class				Total
		1	2	3	4	
Point Type	0	1,927	16	155	0	2,098
	1	1,896	21	181	0	2,098
Total		3,823	37	336	0	4,196

Table 4.11: Type of sample point versus hillshade class

Exploring proximity of sampled ORV trail points to other trailheads reveals that they are all close to other trailheads (class 1). About half of the non-trail sample points lie close to ORV trails, but the rest lie farther from trails. This shows that trails tend to be clustered together, rather than spread evenly over the study area. New ORV trails develop in association with established ORV trails as riders veer off of existing trail networks.

		LSRA Trailhead Distance Class				Total
		1	2	3	4	
Point Type	0	1,224	563	203	108	2,098
	1	2,098	0	0	0	2,098
Total		3,322	563	203	108	4,196

Table 4.12: Type of sample point versus trailhead distance class

People bring their ORVs to recreation areas by established networks of paved roads. The premise behind the exploration of the distance of ORV trails to paved roads is that most ORV riders will stay close to points of entry into the trail system. This pattern shows up in the comparison between the sampled ORV trail points and non-trail points

(Table 4.13). Whereas many non-trail points are in class 1 due to the region's general accessibility, they are better represented than the trail points are in the more distant categories.

		Road Distance Class				Total
		1	2	3	4	
Point Type	0	1,402	322	186	188	2,098
	1	1,861	133	78	26	2,098
Total		3,263	455	264	214	4,196

Table 4.13: Type of sample point versus road distance class

It was hypothesized that ORV trails would be preferentially closer to streambeds, but this spatial tendency is not borne out in the distribution of ORV trail points per stream distance category (Table 4.14). The number of sampled ORV trail points actually decreases with proximity to streambeds. However, the fact that non-trail sample points have the same trend reflects the fact that water courses are rare in the LSRA study area. The cross tabulation results show, however, that ORV riders are not preferentially attracted to the few streambed sites that exist at the LSRA.

		Stream Distance Class				Total
		1	2	3	4	
Point Type	0	21	82	224	1,771	2,098
	1	41	69	311	1,677	2,098
Total		62	151	535	3,448	4,196

Table 4.14: Type of sample point versus stream distance class

It was expected that ORV trail points would be more common in closer proximity to points of interest than sampled non-trail points are. Table 4.15 shows a slight tendency for this trend.

		Points of Interest Distance Class				Total
		1	2	3	4	
Point Type	0	1,407	377	196	118	2,098
	1	1,701	184	121	92	2,098
Total		3,108	561	317	210	4,196

Table 4.15: Type of sample point versus points of interest distance class

The distribution of trail and non-trail sample sites across the density of paved road classes is somewhat distinct from the other crosstab analyses (Table 4.16). The general trend is different for the two types of sites. That non-trail sites are most common in locations of low road densities (class 4) is not surprising. The concentration of ORV sample points in areas of high road densities is expected because ORV riders bring their vehicles to the recreation area by paved roads. However, the secondary peak of ORV trail sites in locations of smallest road density is surprising. This might indicate two different types of riders at the LSRA. One type may represent the mainstream rider that prefers to recreate close to other riders in areas of greatest flexibility in paved-road access, including access to services. The other type may prefer greater seclusion and may not be as dependent on roads and other riders for guidance or bearings.

		Road Density Class				Total
		1	2	3	4	
Point Type	0	880	50	60	1,108	2,098
	1	1359	73	93	573	2,098
Total		2,239	123	153	1681	4,196

Table 4.16: Type of sample point versus road density class

Results of the exploration of the ORV trail density variable appear in Table 4.17. The exploration illustrate the concentrated nature of the ORV trails, with nearly all of the sampled ORV trail points in areas with trail densities of at least 750 m/km^2 (class 1). Although the majority of non-trail points also exist in areas of high trail density, it is closer to half of those sites, with a strong secondary concentration in areas of low trail density, pointing to the tendency of clustered nature of the ORV trail network.

		ORV Trail Density Class				Total
		1	2	3	4	
Point Type	0	1,121	77	88	812	2,098
	1	2,080	9	5	4	2,098
Total		3,201	86	93	816	4,196

Table 4.17: Type of sample point versus ORV trail density class

This exploration of variables with crosstabs underscores the importance of trail density on further trail development, as determined by the binary logistical regression analysis (Table 4.4). Although some riders may seek out more isolated areas far from high paved road densities, most trails form close to pre-existing trails, and most riders apparently stay relatively close to the densest network of paved access points.

CHAPTER 5: RESULTS AND CONCLUSIONS

5.1 LSRA ORV Trail Mapping

Detailed, digital maps produced for this thesis reveal the extent of ORV trails in the LSRA as they existed in 1952, 1977, 1987, and 1997. A small scale rendition of the trail system as it existed in 1997 appears in Figure 5.1. Similar comprehensive mapping showing the growth of an ORV trail system over a 45 year period does not appear to have been previously attempted. Prior to this project, the only trail information available for the study area concerned traverses related to individual racing events that crossed primarily the northern part of the LSRA.

Although it was known that the ORV trail system in the LSRA had grown over the years, this thesis quantifies the extent of that trail expansion between 1952 and 1997. In this 45 year period, the trail system grew by 946 new segments totalling 302 kilometers. ORV trail density increased substantially from 615 m/km^2 to 2,666 m/km^2 over this same period. The highest trail densities, which consist of those over 800 m/km^2, mainly lie in and around the LSRA visitor center, campgrounds, hills and mountains, and in the linear corridors between these locations. The large decrease in mean trail length over the studied interval reveals the tendency for ORV riders to connect existing trails, establish shortcuts, and cut off switchbacks.

In addition to assessing the nature of LSRA ORV trail expansion between 1952 and 1997, this thesis provides historic baseline data for future studies of the changes in the trails at the study site. It also serves as a case study illustrating just how rapid ORV trail expansion can be in recreation areas that allow ORV riding.

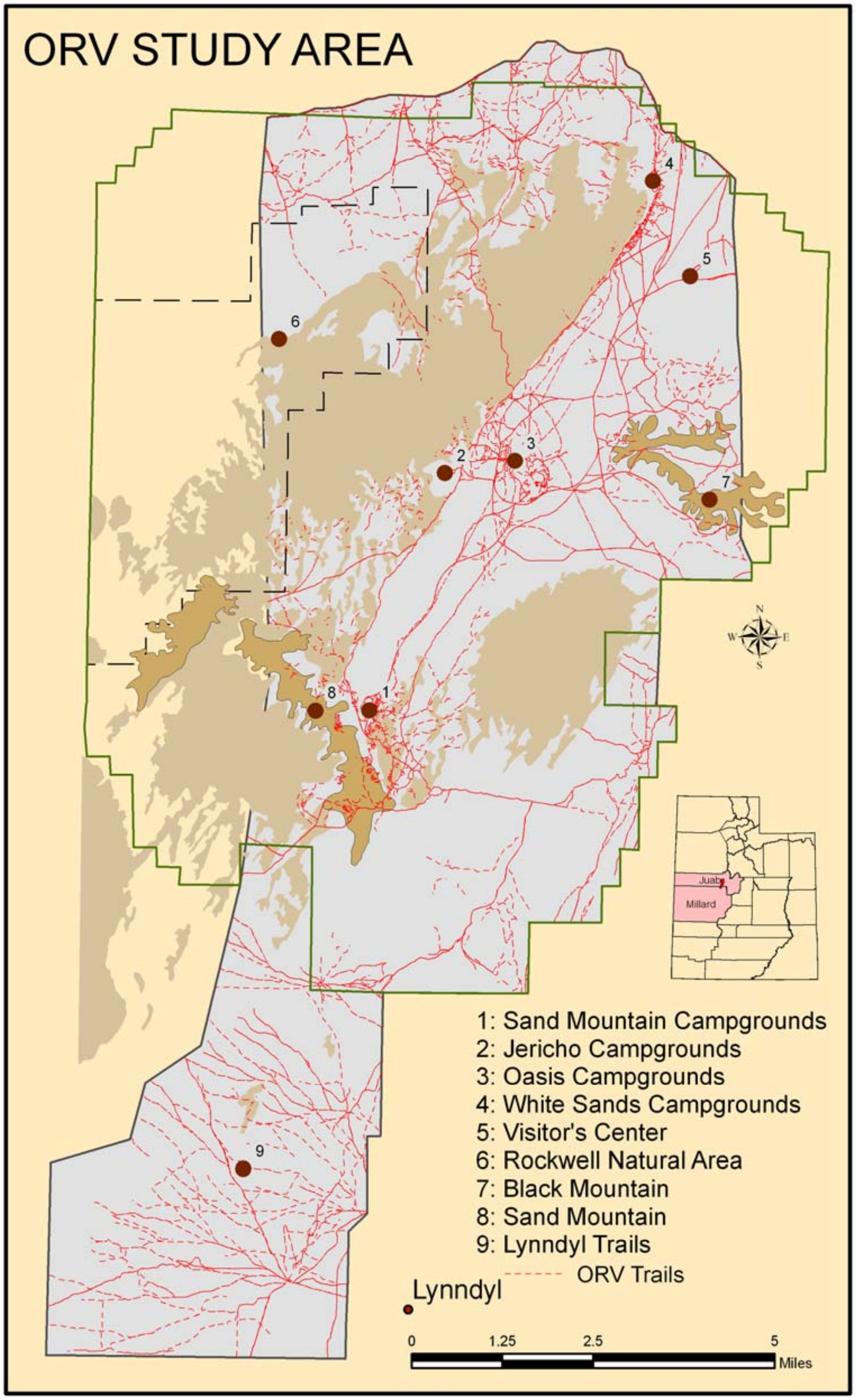

Figure 5.1: ORV trail map of the study area for 1997

5.2 LSRA ORV Trail Modelling and Statistical Analysis

Logistic regression analysis performed on the ORV trail data for the LSRA suggests that distance to roads, distance to streams, distance to points of interest, road density, and ORV trail density are important variables in determining the location of new rider-initiated ORV trails. Most of the natural environmental variables, including elevation, slope, aspect, hillshade, and viewshed, do not significantly indicate where new trails are likely to be established. The predictive ability of the ORV trail logistic regression model derived from the variables collected for this thesis, however, is not substantiated by the Hosmer and Lemeshow test (Fig. 5.2).

Although the initial goal of constructing a statistically significant model that predicts where ORV trails would be most and least likely to appear in the future has not been achieved in this thesis, some locational trends for the trails are identified. Data exploration using cross tabs analysis of different variables for trail points versus non-trail points underscores the tendency for new trails to be established near pre-existing trails. The analysis also suggests that riders tend to create new trails in proximity to points of interest. The preferential formation of new trails in areas with high density of paved roads and, secondarily, in areas with low density of paved roads, reflects that ORV riders access the trail system by means of paved roads, but that some riders are attracted to isolated locations within the LSRA. It is possible that a successful predictive model can be constructed in the future as more sources of data become available at a higher spatial resolution.

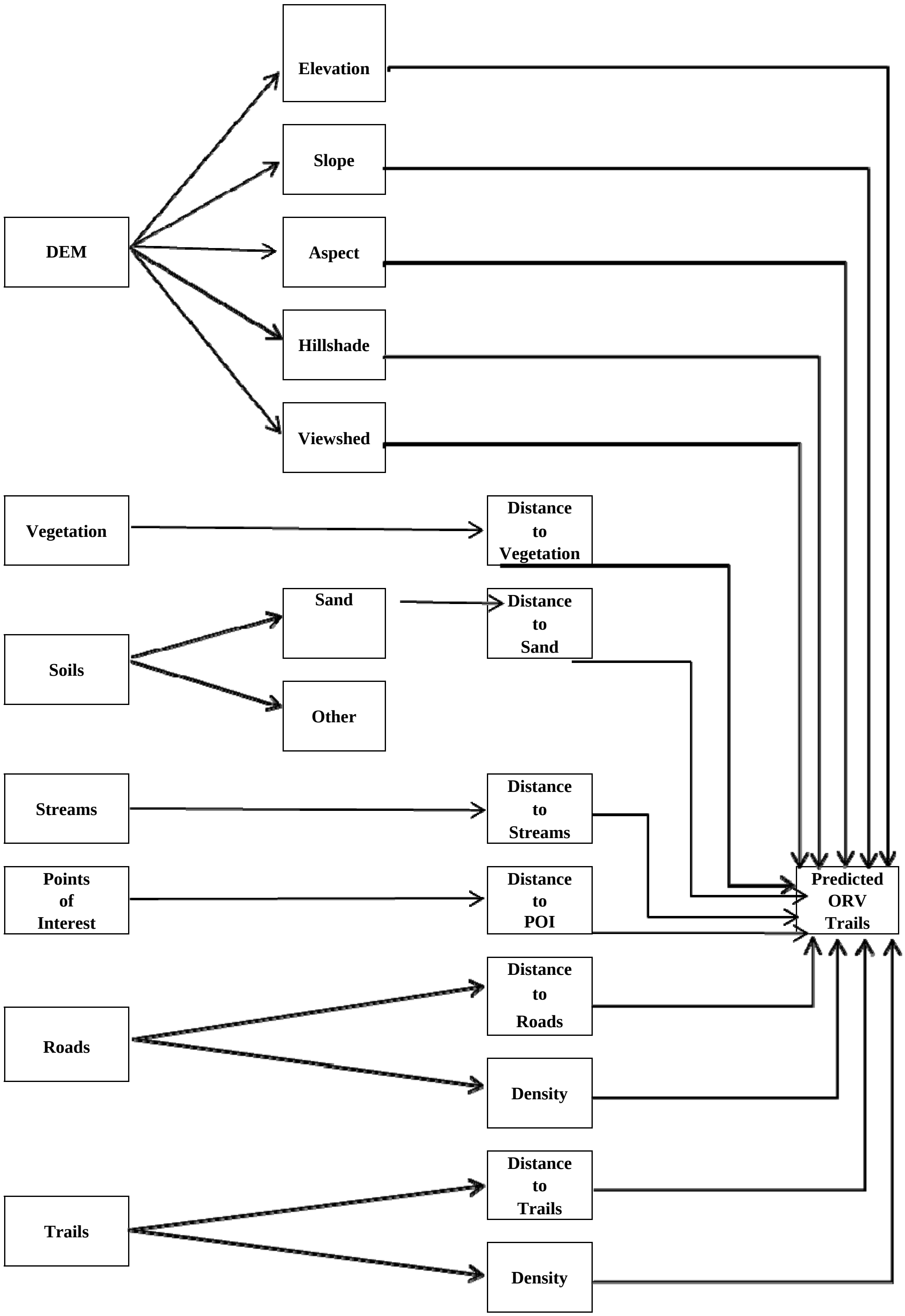

Figure 5.2: Trail model tested in this thesis

5.3 Conclusions and Recommendations

For decades, especially since the 1950s, ORV trail systems made by motorcycles, quad-runners, dune buggies, jeeps, and four-wheel drive vehicles have been expanding outward in state and national forests, parks, and recreational areas, as exemplified in this study of ORV trails in the LSRA. Technological advances in ORVs and an increased popularity of off-roading since the 1950s and 1960s apparently spurred a period of proliferation of ORV trails in these areas. With the advent of the three-wheeler (Honda AR70) it became more economical for Americans to drive off road in these areas at that time. Safety and design improvements to the initial three-wheeler after 1970, and later in about 1984, and the subsequent banning of the three-wheeler for safety reasons, gave rise to a new mode of off-road transportation, the present personal ORV. This latest category of ORV is often described as having as many variations as there are types of environments, including vehicles well suited to riding on sand dunes.

Along with technological development in ORVs, comparatively cheap fuel prices and rising popularity in ORV riding as a form a recreation led to rapidly expanding extent and density of ORV trails in periods represented here by the decades 1977-1987 and 1987-1997. Additional work is needed to determine whether these trends and growth rates have continued into the first decade of the 21st century, and to test the hypothesis that trail expansion rates at the LSRA are representative of other ORV recreational sites.

This thesis research reveals a tendency for ORV trails at the LSRA to concentrate near the visitor center, campgrounds, Sand and Black Mountain, and along linear corridors between these specific features (Figure 5.1). It also shows that new trails become preferentially established in the vicinity of existing trails. This information can help managers of ORV recreation areas in decisions regarding site selection for visitor centers, campgrounds, and other constructed public-use points of interest. The terrain near and between these sites will experience trail proliferation, and thus should not contain local environments that are especially sensitive to ORV impacts. Proper location of public use sites can help minimize renegade trail formation in sensitive locations.

REFERENCES

Adams, J., Stolzy, L., Rowlands, P., Johnson, H. 1982. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. Journal of Applied Ecology 19:167-175.

Anders, F.J. and Leatherman, S.P. 1987. Effects of off-road vehicles on coastal foredunes at Fire Island, New York, USA. Environmental Management 11:45-52.

Belnap, J. 2002. Impacts of off-road vehicles on nitrogen cycles in biological soil crusts: Resistance in different U.S. deserts. Journal of Arid Environments 52:155-165.

Bhattasharya, U. and Parui, S.K. 1997. An improved backpropagation neural network for detection of road-like features in satellite imagery. International Journal of Remote Sensing 18:3379-3394.

Brattstrom, B.H. and Bondello, M.C. 1983. Effects of off-road vehicle noise on desert vertebrates. p. 167-206 in: R.H. Webb and Wilshire (eds.). Environmental effects of off-road vehicles: Impacts and management in arid regions. Springer-Verlag. New York.

Brooks, M.L. and Lair, B. 2005. Ecological effects of vehicular routes in a desert ecosystem. US Department of the Interior, US Geological Survey. 23 p Technical Report, Western Ecological Research Center, Las Vegas, NV.

Brown, G. and Schoknecht N. 2001. Off-road vehicles and vegetation patterning in a degraded desert ecosystem in Kuwait. Journal of Arid Environments 49:413-427.

Brown, J.R. and Carter, J. 1998. Spatial and temporal patterns of exotic shrub invasion in an Australian tropical grassland. Landscape Ecology 13:93-102.

California Air Resource Board (CARB). New regulations for gasoline marine engines. 2006. http://www.arb.ca.gov/homepage.htm

Campbell, J.B. 2002. Introduction to remote sensing, third edition. Guilford Press, New York.

Chesler, B.H. 1984. Characteristics of sand dunes at Little Sahara, Utah. Unpublished M.S. thesis, Utah State University, Logan.

Coates, D. 1985. Geology and society. Chapman and Hall, New York.

Cole, D. and Spildie, D. 1998. Hiker, horse and llama trampling effects on native vegetation in Montana, USA. Journal of Environmental Management 53:61-71.

Cole, D.N. and Landres, P.B. 1996. Threats to wilderness ecosystems: Impacts and research needs. Ecological Applications. 6:168-184.

Cordell, H.K., Betz, C., and Bowker, J.M. 1999. Outdoor recreation in American life: A national assessment of demand and supply trends. Sagamore Publishing, Chicago.

Couloigner, I., Ranchin, T., Valtonen, V.P., and Wald, L. 1998. Benefit of the future SPOT-5 and of data fusion to urban roads mapping. International Journal of Remote Sensing 19:1519-1532.

Cramer J.S. 1991. The logit model. Routledge, Chapman and Hall, New York.

Dean, B.D. 1997. Fulfillment of visitors' expectations and needs for off-road use at Little Sahara Recreation Area. Unpublished M.S. thesis, Utah State University, Logan.

Dobson, J.E., Bright, E.A., Ferguson, R.L., Field, D.W., Wood, L.L., Haddad, K.D., Iredale III, H., Jensen, J.R., Klemas, V.V., Orth, R.J., and Thomas, J.P. 1995. NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation. NOAA Technical Report MMFS 123.

Forest Service Employees for Environmental Ethics (FSEEE). 2005. http://www.fseee.org/index.html?page=http%3A//www.fseee.org/forestmag/0003east.shtml

Grey, W.M.F., Luckman, A.J., and Holland, D. 2003. Mapping urban change in the UK using satellite radar interferometry. Remote Sensing of Environment 87:16-22.

Groom, J.D., McKinney, L.B., Ball, L.C., and Winchell, C.S. 2007. Quantifying off-highway vehicle impacts on density and survival of a threatened dune-endemic plant. Biological Conservation 135:119-134.

Gross, B.L., Kane, N.C., Lexer, C., Ludwig, F., Rosenthal, D.M., Donovan, L., and Rieseberg, L.H. 2004. Reconstructing the origin of Helianthus deseticola: Survival and selection on the desert floor. The American Naturalist 164:145-156.

Hessburg, P.F., Smith, B.G., Salter, R.B., Ottmar, R.D., Alvarado, E. 2000. Recent changes (1930s-1990s) in spatial patterns of interior northwest forests, USA. Forest Ecology and Management 136:53-83.

Hinkley, Bern S., Iverson, Richard M., Hallet, Bernard. 1983. Accelerated water erosion in ORV areas. p 81-96. in: R.H. Webb and Wilshire (eds.). Environmental effects of off-road vehicles: Impacts and management in arid regions. Springer-Verlag. New York.

Hosmer, D.W. Jr. and Lemeshow, S. 1989. Applied Logistic Regression. John Wiley & Sons, New York.

Iverson, R.M., Hinckley, B.S., Webb, R.M., and Hallet B. 1981. Physical effects of vehicular disturbance on arid landscapes. Science 212:915-917.

Karathanassi, V., Iossifidis, C.H.R., and Rokos, D. 1999. A thinning-based method for recognition and extracting peri-urban road networks from SPOT panchromatic images. International Journal of Remote Sensing 20:153-168.

Kim, E., Jha, M.K., Son, B. 2005. Improving the computational efficiency of highway alignment optimization models through a stepwise genetic algorithms approach. Transportation Research, Part B 39:339-360.

Kuss, F. and Morgan, J. 1986. A first alternative for estimating the physical carrying capacities of natural areas for recreation. Environmental Management 10:255-262.

Levin, N. and Ben-Dor, E. 2004. Monitoring sand dune stabilization along the coastal dunes of Ashdod-Nizanim, Israel, 1945-1999. Journal of Arid Environments 58:335-355.

Lovich, J.A. and Bainbridge, D. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management 24:309-326.

Lu, D., Mausel, P., Brondízios, E., and Morain, E. 2004. Change detection techniques. International Journal of Remote Sensing 25:2365-2407.

Luckenbach, R.A. and Bury, B. 1983. Effects of off-road vehicles on the biota of the Algodones Dunes, Imperial County, California. Journal of Applied Ecology 20:265-286.

Ludwig, F., Jewitt, R.A., and Donovan, L.A. 2006. Nutrient and water addition effects on day- and night-time conductance and transpiration in a C_3 desert annual. Oecologia 148:219-225.

Lynn, N.A. and Brown, R.D. 2003. Effects of recreational use impacts on hiking experiences in natural areas. Landscape and Urban Planning 64:77-87.

Mackelprang, R., Dearing, M.D, and St. Jeor, S. 2001. High prevalence of Sin Nombre virus in rodent populations, central Utah: A consequence of human disturbance? Emerging Infectious Diseases 7:480-481.

Matchett, J.R., Gass, L., Brooks, M.L., Mathie, A.M., Vitales, R.D., Campagna, M.W., Miller, D.M., and Weigand, J.F. 2004. Spatial and temporal patterns of off-highway vehicle use at the Dove Springs OHV open area, California. US Department of the Interior, US Geological Survey.

Menard, S. 1995. Applied Logistic Regression Analysis. Sage Publications, Thousand Oaks.

Morisette, J.T., 1997. Using generalized linear models to enhance satellite based land cover change detection. Unpublished Ph.D. dissertation, North Carolina State University, Raleigh.

National Parks Conservation Association (NPCA). 2001. http://www.npca.org/magazine/2001_issues/march_april/beaten_path.asp

Nelson, G.W. 1977. An exploratory investigation into the experience, expectations and behavior patterns of off-road vehicle users in the Little Sahara Recreation Area of central Utah. Unpublished M.S. thesis, Utah State University, Logan.

Nepal, S.K. 2003. Trail impacts in Sagarmatha (Mt. Everest) National Park, Nepal: A logistic regression analysis. Environmental Management 32:312-321.

Nepal, S.K. and Nepal, S.A. 2004. Visitor impacts on trails in the Sagarmatha (Mt. Everest) National Park, Nepal. Ambio 33:334-340.

Pampel, FC. 2000. Logistic Regression A Primer. Sage Publications, Thousand Oaks.

Peterson, J.C. 1972. Little Sahara Recreation Management Plan. US Department of Interion, Fillmore District Bureau of Land Management.

Prose, D.V. 1985. Persisting effects of armored military maneuvers on some soils of the Mojave Desert. Environmental Geology and Water Sciences 7:163-170.

Rosenthal, D.M., Ludwig, F., and Donovan, L. 2005. Plant response to an edaphic gradient across an active sand dune/desert boundary in the Great Basin Desert. International Journal of Plant Science 166:247-255.

Sack, D. 1981. Geomorphic and grain size studies of the Lynndyl Dunes, west-central Utah. Unpublished M.S. thesis, University of Utah, Salt Lake City.

Sack, D. 1987. Geomorphology of the Lynndyl Dunes, west-central Utah. Utah Geological Association Publication 16:292-299.

Sack, D. and da Luz, Jr., S. 2003. Sediment flux and compaction trends on off-road vehicle (ORV) and other trails in an Appalachian forest setting. Physical Geography 24:536-554.

Sierra Club. 2005. http://idaho.sierraclub.org/orv/

Singh, A. 1989. Digital change detection techniques using remotely sensed data. International Journal of Remote Sensing 10:989-1003.

Stutz, H.C., Melby, J.M., and Livingston, G.K. 1975. Evolutionary studies of atriplex: A relic gigas diploid population of Atriplex Canascens. American Journal of Botany 62:236-245.

Summer, R. 1986. Geomorphic impacts of horse traffic on montane landforms. Journal of Soil and Water Conservation 41:126-128.

Sun, D. and Liddle, M. 1993. A survey of trampling effects on vegetation and soil in eight tropical and subtropical sites. Environmental Management 4:497-510.

Sutherland, R.A., Bussen, J.O., Plondke, D.L., Evans, B.M., and Zeigler, A.D. 2001. Hydrological degradation associated with hiking-trail use: A case study of Hawai'Iloa Ridge Trail, O'Ahu, Hawai'i. Land Degradation and Development 12:71-86.

Toy, T.J. and Hadley, R.F. Geomorphology and reclamation of disturbed lands. 1987. Academic Press, Orlando.

United States Department of Interior (USDI), Bureau of Land Management (BLM). 2005. Executive orders. http://www.blm.gov/nhp/index.htm

United States Department of Interior (USDI), Bureau of Land Management (BLM). 2007. The Federal Land Policy and Management Act of 1976. http://www.blm.gov/flpma/

United States Department of Interior (USDI), Bureau of Land Management (BLM). 2006. Rockwell. http://www.blm.gov/nhp/index.htm

United States Department of Interior (USDI), Bureau of Land Management (BLM). 2004. Utah public rewards from public lands 2000. http://www.blm.gov/nhp/pubs/rewards/2000/utah.htm

United States Forest Service (USFS). 2004. http://www.fs.fed.us/r9/wayne/

Utah State University Extension (USUE), Institute for Outdoor Recreation and Tourism. 1998. Long, S.J. and Blahna, D.J. 2001. Results of a statewide OHV owner telephone survey for the Little Sahara Recreation Area and surrounding lands. http://extension.usu.edu/

Utah State University Extension (USUE), Institute for Outdoor Recreation and Tourism. 1998. Reiter, D.K., Blahna, D.J., and Von Koch, R. 1998. Off-highway vehicle four-wheeler survey: Synopsis of 1997 Moab Easter jeep safari findings. http://extension.usu.edu/

Weaver T. and Dale, D. 1978. Trampling effects of hikers, motorcycles and horses in meadows and forests. Journal of Applied Ecology 15:451-457.

Webb, R.H. 1982. Off-road motorcycle effects on a desert soil. Environmental Conservation 9:197-208.

Webb, R. and Wilshire, H. 1983. Environmental effects of off-road vehicles: Impacts and management in arid regions. Springer-Verlag, New York.

Wilshire, H.G. 1983. Off-road vehicle recreation management policy for public lands in the United-States: A case history. Environmental Management 7:489-499.

Wilshire H.G. and Nakata, J.K. 1976. Off-road vehicle effects on California’s Mojave Desert. California Geology 29:123-132.

Wilson, E.H., Hurd, J.D., Civco, D.L., Prisloe, M.P., and Arnold, C. 2003. Development of a geospatial model to quantify, describe and map urban growth. Remote Sensing of Environment 86:275-285.

Winterbottom, S.J. 2000. Medium and short-term channel planform changes on the rivers Tay and Tummel, Scotland. Geomorphology 34:195-208.

Witztum, E.R., and Stow, D.A. 2004. Analysing direct impacts of recreation activity on coastal sage scrub habitat with very high resolution multi-spectral imagery. International Journal of Remote Sensing 25:3477-3496.

Wright, R., McKinsey, D., and Bell, B. 1992. Integrating soil loss standards and geographic information systems in the management of off-highway vehicle parks. GIS/LIS ’92 Proceedings, American Society for Photogrammetry and Remote Sensing, Washington, D.C., p. 835-844.

Wullstein, L.H., Bruening, M.L., and Bollen, W.B. 1979. Nitrogen fixation associated with sand grain root sheaths (rizosheaths) of certain xeric grasses. Physiologia Plantarum 46:1-4.

Wullstein, L.H. and Pratt, S.A. 1981. Scanning electron microscopy of rhizosheaths of Oryzopsis Hymenoides. American Journal of Botany 68:408-419.

Zhang, Q., Wang, J., Peng, X., Gong, P., and Shi, P. 2002. Urban built-up land detection with road density and spectral information from multi-spectral Landsat TM data. International Journal of Remote Sensing 23:3057-3078.

APPENDIX A: EXECUTIVE ORDER 11644

EXECUTIVE ORDER 11644 Use of Off-Road Vehicles on the Public Lands

An estimated 5 million off-road recreational vehicles. motorcycles, minibikes, trail bikes, snowmobiles, dune-buggies, all-terrain vehicles, and others.are in use in the United States today, and their popularity continues to increase rapidly. The widespread use of such vehicles on the public lands.often for legitimate purposes but also in frequent conflict with wise land and resource management practices, environmental values, and other types of recreational activity.has demonstrated the need for a unified Federal policy toward the use of such vehicles on the public lands.

NOW, THEREFORE, by virtue of the authority vested in me as President of the United States by the Constitution of the United States and in furtherance of the purpose and policy of the National Environmental Policy Act of 1969 (42 U.S.C. 4321), it is hereby ordered as follows:

SECTION 1. *Purpose*. It is the purpose of this order to establish policies and provide for procedures that will ensure that the use of off-road vehicles on public lands will be controlled and directed so as to protect the resources of those lands, to promote the safety of all users of those lands, and to minimize conflicts among the various uses of those lands.

SEC. 2 *Definitions.* As used in this order, the term:

(1) “public lands” means (A) all lands under the custody and control of the Secretary of the Interior and the Secretary of Agriculture, except Indian lands, (B) lands under the custody and control of the Tennessee Valley Authority that are situated in western Kentucky and Tennessee and are designated as “Land Between the Lakes,” and (C) lands under the custody and control of the Secretary of Defense;

(2) “respective agency head” means the Secretary of the Interior, the Secretary of Defense, the Secretary of Agriculture, and the Board of Directors of the Tennessee Valley Authority, with respect to public lands under the custody and control of each;

(3) “off-road vehicle” means any motorized vehicle de-signed for or capable of cross-country travel on or immediately over land, water, sand, snow, ice, marsh, swampland, or other natural terrain; except that such term excludes (A) any registered motorboat, (B) any military, fire, emergency, or law enforcement vehicle when used for emergency purposes, and (C) any vehicle whose use is expressly authorized by the respective agency head under a permit, lease, license, or contract; and

(4) “official use” means use by an employee, agent, or designated representative of the Federal Government or one of its contractors in the course of his employment, agency, or representation.

SEC 3. *Zones of Use.* (a) Each respective agency head shall develop and issue regulations and administrative instructions, within six months of the date of this order, to provide for administrative designation of the specific areas and trails on public lands on which the use of off-road vehicles may be permitted, and areas in which the use of off-road vehicles may not be permitted, and set a date by which such designation of all public lands shall be completed. Those regulations shall direct that the designation of such areas and trails will be based upon the protection of the resources of the public lands, promotion of the safety of all users of those lands, and minimization of conflicts among the various uses of those lands. The regulations shall further require that the designation of such areas and trails shall be in accordance with the following.

(1) Areas and trails shall be located to minimize damage to soil, watershed, vegetation, or other resources of the public lands.

(2) Areas and trails shall be located to minimize harassment of wildlife or significant disruption of wildlife habitats.

(3) Areas and trails shall be located to minimize conflicts between off-road vehicle use and other existing or proposed recreational uses of the same or neighboring public lands, and to ensure the compatibility of such uses with existing conditions in populated areas, taking into account noise and other factors.

(4) Areas and trails shall not be located in officially designated Wilderness Areas or Primitive Areas. Areas and trails shall be located in areas of the National Park system, Natural Areas, or National Wildlife Refuges and Game Ranges only if the respective agency head determines that off-road vehicle use in such locations will not adversely affect their natural, aesthetic, or scenic values.

(b) The respective agency head shall ensure adequate opportunity for public participation in the promulgation of such regulations and in the designation of areas and trails under this section.

(c) The limitations on off-road vehicle use imposed under this section shall not apply to official use.

SEC. 4. *Operating Conditions*. Each respective agency head shall develop and publish, within one year of the date of this order, regulations prescribing operating conditions for off-road vehicles on the public lands. These regulations shall be directed at protecting resource values, preserving public health, safety, and welfare, and minimizing use conflicts.

SEC. 5. *Public Information.* The respective agency head shall ensure that areas and trails where off-road vehicle use is permitted are well marked and shall provide for the publication and distribution of information, including maps, describing such areas and trails and explaining the conditions on vehicle use. He shall seek cooperation of relevant State agencies in the dissemination of this information.

SEC. 6. *Enforcement*. The respective agency head shall, where authorized by law, prescribe appropriate penalties for violation of regulations adopted pursuant to this order, and shall establish procedures for the enforcement of those regulations. To the extent permitted by law, he may enter into agreements with State or local governmental agencies for cooperative enforcement of laws and regulations relating to off-road vehicle use.

SEC. 7. *Consultation.* Before issuing the regulations or administrative instructions required by this order or designating areas or trails as required by this order and those regulations and administrative instructions, the Secretary of the Interior shall, as appropriate, consult with the Atomic Energy Commission.

SEC. 8. *Monitoring of Effects and Review.* (a) The respective agency head shall monitor the effects of the use of off-road vehicles on lands under their jurisdictions. On the basis of the information gathered, they shall from time to time amend or rescind designations of areas or other actions taken pursuant to this order as necessary to further the policy of this order.

(b) The Council on Environmental Quality shall maintain a continuing review of the implementation of this order.

RICHARD NIXON

THE WHITE HOUSE,
February 8, 1972 (USDI, 2005)

APPENDIX B: EXECUTIVE ORDER 11989

EXECUTIVE ORDER 11989 Off-Road Vehicles on Public Lands

By virtue of the authority vested in me by the Constitution and statutes of the United States of America, and as President of the United States of America, in order to clarify agency authority to define zones of use by off-road vehicles on public lands, in furtherance of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 *et seq.*), Executive Order No. 11644 of February 8, 1972, is hereby amended as follows:

SECTION 1. Clause (B) of Section 2(3) of Executive Order No. 11644, setting forth an exclusion from the definition of off-road vehicles, is amended to read “(B) any fire, military, emergency or law enforcement vehicle when used for emergency purposes, and any combat or combat support vehicle when used for national defense purposes, and”.

SEC. 2. Add the following new Section to Executive Order No. 11644:

“SEC. 9. *Special Protection of the Public Lands.* (a) Notwithstanding the provisions of Section 3 of this Order, the respective agency head shall, whenever he determines that the use of off-road vehicles will cause or is causing considerable adverse effects on the soil, vegetation, wild-life, wildlife habitat or cultural or historic resources of particular areas or trails of the public lands, immediately close such areas or trails to the type of off-road vehicle causing such effects, until such time as he determines that such adverse effects have been eliminated and that measures have been implemented to prevent future recurrence.

(b) Each respective agency head is authorized to adopt the policy that portions of the public lands within his jurisdiction shall be closed to use by off-road vehicles except those areas or trails which are suitable and specifically designated as open to such use pursuant to Section 3 of this Order.”

JIMMY CARTER

THE WHITE HOUSE,
May 24, 1977 (USDI, 2005)

APPENDIX C: FEDERAL LAND POLICY AND MANAGEMENT ACT OF 1976

Title 43 Chapter 35 Subchapter I §1701

(a) The Congress declares that it is the policy of the United States that—

(1) the public lands be retained in Federal ownership, unless as a result of the land use planning procedure provided for in this Act, it is determined that disposal of a particular parcel will serve the national interest;
(2) the national interest will be best realized if the public lands and their resources are periodically and systematically inventoried and their present and future use is projected through a land use planning process coordinated with other Federal and State planning efforts;
(3) public lands not previously designated for any specific use and all existing classifications of public lands that were effected by executive action or statute before October 21, 1976, be reviewed in accordance with the provisions of this Act;
(4) the Congress exercise its constitutional authority to withdraw or otherwise designate or dedicate Federal lands for specified purposes and that Congress delineate the extent to which the Executive may withdraw lands without legislative action;
(5) in administering public land statutes and exercising discretionary authority granted by them, the Secretary be required to establish comprehensive rules and regulations after considering the views of the general public; and to structure adjudication procedures to assure adequate third party participation, objective administrative review of initial decisions, and expeditious decisionmaking;
(6) judicial review of public land adjudication decisions be provided by law;
(7) goals and objectives be established by law as guidelines for public land use planning, and that management be on the basis of multiple use and sustained yield unless otherwise specified by law;
(8) the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use;
(9) the United States receive fair market value of the use of the public lands and their resources unless otherwise provided for by statute;
(10) uniform procedures for any disposal of public land, acquisition of non-Federal land for public purposes, and the exchange of such lands be established by statute, requiring each disposal, acquisition, and exchange to be consistent with the prescribed mission of the department or agency involved, and reserving to the Congress review of disposals in excess of a specified acreage;
(11) regulations and plans for the protection of public land areas of critical environmental concern be promptly developed;

(12) the public lands be managed in a manner which recognizes the Nation's need for domestic sources of minerals, food, timber, and fiber from the public lands including implementation of the Mining and Minerals Policy Act of 1970 (84 Stat. 1876, 30 U.S.C. 21a) as it pertains to the public lands; and

(13) the Federal Government should, on a basis equitable to both the Federal and local taxpayer, provide for payments to compensate States and local governments for burdens created as a result of the immunity of Federal lands from State and local taxation.

(b) The policies of this Act shall become effective only as specific statutory authority for their implementation is enacted by this Act or by subsequent legislation and shall then be construed as supplemental to and not in derogation of the purposes for which public lands are administered under other provisions of law.

APPENDIX D: FEDERAL LAND POLICY AND MANAGEMENT ACT

Title 43 Chapter 35 Subchapter I §1702

Without altering in any way the meaning of the following terms as used in any other statute, whether or not such statute is referred to in, or amended by, this Act, as used in this Act—

(a) The term "areas of critical environmental concern" means areas within the public lands where special management attention is required (when such areas are developed or used or where no development is required) to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources or other natural systems or processes, or to protect life and safety from natural hazards.

(b) The term "holder" means any State or local governmental entity, individual, partnership, corporation, association, or other business entity receiving or using a right-of-way under subchapter V of this chapter.

(c) The term "multiple use" means the management of the public lands and their various resource values so that they are utilized in the combination that will best meet the present and future needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions; the use of some land for less than all of the resources; a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific and historical values; and harmonious and coordinated management of the various resources without permanent impairment of the productivity of the land and the quality of the environment with consideration being given to the relative values of the resources and not necessarily to the combination of uses that will give the greatest economic return or the greatest unit output.

(d) The term "public involvement" means the opportunity for participation by affected citizens in rulemaking, decisionmaking, and planning with respect to the public lands, including public meetings or hearings held at locations near the affected lands, or advisory mechanisms, or such other procedures as may be necessary to provide public comment in a particular instance.

(e) The term "public lands" means any land and interest in land owned by the United States within the several States and administered by the Secretary of the Interior through the Bureau of Land Management, without regard to how the United States acquired ownership, except—

- **(1)** lands located on the Outer Continental Shelf; and
- **(2)** lands held for the benefit of Indians, Aleuts, and Eskimos.

(f) The term “right-of-way” includes an easement, lease, permit, or license to occupy, use, or traverse public lands granted for the purpose listed in subchapter V of this chapter.
(g) The term “Secretary”, unless specifically designated otherwise, means the Secretary of the Interior.
(h) The term “sustained yield” means the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the public lands consistent with multiple use.
(i) The term “wilderness” as used in section 1782 of this title shall have the same meaning as it does in section 1131 (c) of title 16.
(j) The term “withdrawal” means withholding an area of Federal land from settlement, sale, location, or entry, under some or all of the general land laws, for the purpose of limiting activities under those laws in order to maintain other public values in the area or reserving the area for a particular public purpose or program; or transferring jurisdiction over an area of Federal land, other than “property” governed by the Federal Property and Administrative Services Act, as amended (40 U.S.C. 472) [1] from one department, bureau or agency to another department, bureau or agency.
(k) An “allotment management plan” means a document prepared in consultation with the lessees or permittees involved, which applies to livestock operations on the public lands or on lands within National Forests in the eleven contiguous Western States and which:

> **(1)** prescribes the manner in, and extent to, which livestock operations will be conducted in order to meet the multiple-use, sustained-yield, economic and other needs and objectives as determined for the lands by the Secretary concerned; and
> **(2)** describes the type, location, ownership, and general specifications for the range improvements to be installed and maintained on the lands to meet the livestock grazing and other objectives of land management; and
> **(3)** contains such other provisions relating to livestock grazing and other objectives found by the Secretary concerned to be consistent with the provisions of this Act and other applicable law.

(l) The term “principal or major uses” includes, and is limited to, domestic livestock grazing, fish and wildlife development and utilization, mineral exploration and production, rights-of-way, outdoor recreation, and timber production.
(m) The term “department” means a unit of the executive branch of the Federal Government which is headed by a member of the President’s Cabinet and the term “agency” means a unit of the executive branch of the Federal Government which is not under the jurisdiction of a head of a department.
(n) The term “Bureau means the Bureau of Land Management.
(o) The term “eleven contiguous Western States” means the States of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

(p) The term "grazing permit and lease" means any document authorizing use of public lands or lands in National Forests in the eleven contiguous western States for the purpose of grazing domestic livestock.