The impact of off-road vehicle traffic on soils and vegetation on rangeland in southeastern Montana and photographic monitoring of the effects

by John Walter Foster

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Range Sciences
Montana State University

Abstract:
Simulated off-road vehicle (ORV) traffic was initiated on mixed prairie in May 1976 with monthly treatments of 2, 8, and 32 trips through September 1976. The treatments included evaluations of uphill and downhill travel on both north and south slopes.

The study was conducted northeast of Ashland, Montana, on the Ashland Division, Custer National Forest. Data collection included: aerial and ground photography, vegetational canopy cover, phenology, . soil moisture, soil bulk density, soil surface strength, depths of. cracks created by wheel weight and motion, and infiltration measurements.

The photographic monitoring, both ground and aerial, indicated that Kodak Ektachrome Infrared Aero 2443 film was superior in ascertaining the levels of use in May, June, and July. Color imagery was superior in distinguishing treatment levels in August and September. It was determined that photographic monitoring success was contingent upon the number of ORV trips and the phenology of the vegetation.

The vegetation canopy cover response was most noticeable at the 32-trip treatment level throughout the study. The 8-trip treatment response varied according to the phenology of the vegetation. The 2-trip treatment response did not indicate any significant losses in comparison to control, except in August and September. Forbs had the least tolerance, shrubs had an intermediate tolerance, and grasses had the greatest tolerance for ORV traffic impact.

The soil response was largely contingent upon the soil moisture during the treatment in relation to the number of trips. The bulk density data did not show any differences among treatments. The soil surface strength did show significant increases as the number of trips increased, except in August and September. The major soil cracking, a result of the May treatment, increased in depth as the number of trips increased. The infiltration measurements indicated that there was a loss of infiltration rate as the number of trips increased.

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Date 13 June 1977

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A thesis submitted in partial fulfillment
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of

MASTER OF SCIENCE

in

Range Sciences

Approved:

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MONTANA STATE UNIVERSITY
Bozeman, Montana

August, 1977

ACKNOWLEDGEMENT

The author wishes to express appreciation for the continuing wise counsel of his major advisor Dr. Gene F. Payne whose commitment to the discipline of scientific inquiry has been a model for generations of graduate students. And to Drs. John E. Taylor, D. E. Ryerson, Stephan R. Chapman and Gerald Neilsen for their insights and many constructive comments. Also, he extends a word of thanks to the U. S. Forest Service, Custer National Forest, Ranger Charles McGlothlin for his enthusiasm and donation of the study area.

He is grateful to Mr. David Litz for the special skills and perceptions brought to the diagramatic presentations of the research and to Mr. Wayne Leininger for his expertise in taxonomy and aerial photographic techniques.

The author is indebted to Mrs. Betty G. Seaver for the days of typing freely given. Her critical intelligence and invaluable understanding leave him in her debt.

The endless patience, cheerful devotion and encouragement of the authors wife Roxanne was a treasured support throughout the entire project. And it must not be forgotten that it was her ORV whose impact is herein described.

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ABSTRACT

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INTRODUCTION

In greater numbers than ever before people with abundant leisure and the affluence to own off-road vehicles (ORV's) are creating dramatic pressures on all accessible terrain in all areas of the country (Lichtenstein 1976, Rickland and Slaughter 1973). In 1972 the president of the United States directed attention to this contemporary phenomenon and its meaning for federal landholdings. He noted in an executive order that "an estimated five million off-road vehicles--motorcycles, minibikes, trail bikes, snowmobiles, dune buggies, all-terrain vehicles, and others--are in use . . . and their popularity continues to increase rapidly." He went on to say that "the widespread use of such vehicles on 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 public lands."[1/]

The International Mountain Section of the Society for Range Management shared the president's concern about ORV's. Its "Benchmarks" statement in 1976 acknowledged the legitimacy of ORV activity under the multiple-use concept that guides the management of

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[1/] U.S., President, Executive Order 11644, "Use of Off-road Vehicles on Public Lands," Federal Register, 37 (1972), 2877.

public lands, but stressed that there must be minimal conflict with other uses and minimal contravention of the values of the land resource.[2/]

The Bureau of Land Management of the U.S. Department of the Interior has promulgated general regulations pursuant to a presidential order.[3/] However, the variety among the kinds of public lands and the variety of ORV uses mean that there must be a unit-by-unit approach. Once regulations are developed, the resource manager must determine how best to apply them to the benefit of his jurisdiction.

Basic to the rangeland resource manager's responsibilities is the monitoring of the impact of ORV's upon vegetation and soils. Measurement must be made at intervals, it must be of acceptable accuracy, it must be readily available, it must be such that it can be reliably interpreted, and it must not be excessively costly in manpower, money, or time. The question then becomes, which measurement technique fulfills these requirements? The answer may be found in a technique that has been successful in the identification of crop disease and crop damage and many other resource-monitoring

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[2/] International Mountain Section, Society for Range Management, "Benchmarks," Newsletter, January, 1976.

[3/] Jack O. Horton, "Public Lands--Use of Off-road Vehicles," Federal Register, 39 (1974), 13612.

applications: aerial photography. The serviceableness of aerial photography within the armamentarium of the rangeland resource manager was investigated with the following objectives in mind:

1. To monitor the ORV use with aerial and ground-level photography.
2. To determine the effects of ORV traffic upon soil and vegetation, testing these effects over gradients of (a) time (monthly), (b) slope or aspect, and (c) ascending and descending travel.

REVIEW OF THE LITERATURE

Background

Research having to do with off-road vehicles (ORV's) has been concerned largely with commercial or military aspects, and to a lesser degree with the capability of the soil to withstand and support traffic stresses. Studies related to recreation, i.e., those focusing on campgrounds and pathways, deal with motorcycle, horse, and foot traffic (Dale and Weaver 1974) and with vegetative growth and reproduction (Westoff 1967, Liddle and Greig-Smith 1975, Lutz 1945). Research keyed to agriculture has led to the redesigning of tractors and tires for greater power efficiency and locomotion (Bekker 1969, 1961). Only a part of the findings from these types of studies on soil compaction has relevance for the rangeland ecosystem.

Photography

Rangeland remote sensing by means of aerial photography is rapidly developing into a very useful tool (Carneggie 1970, Driscoll 1971). While techniques employing panchromatic, infrared, and color photography to study plant distribution (Schulte 1951) continue to be refined, it is important to consider the value of the product to the potential user in respect to the limitations of this medium.

In the Mojave Desert the U.S. Geological Survey and the Bureau of Land Management are currently applying National Aeronautical and Space Administration satellite imagery to determine the presence or absence of motorcycle use by monitoring plumes stemming from wind and water interaction originating from ORV disturbance of the soil surface (Nakata et al. 1976, Wilshire and Nakata 1976). This research has been the only attempt thus far to correlate ORV use with ground truth data (related surface information).

Colwell (1956) suggested that near-infrared imagery (Fig. 1) is useful in detecting diseases that interfere with the internal reflection of light in leaves. Investigators have monitored (with infrared imagery) stresses upon agronomic crops caused by, among other diseases, stem rust (*Puccinia grammis tritici*) on wheat (Keegan et al. 1956), potato blight (Manzer and Cooper 1967), tobacco ring spots (Burns et al. 1969), and treated cotton (*Gossypium hirsutum*) plants (Gausman et al. 1970).

Carneggie and Lauer (1966) established that infrared color film is superior to color imagery in detecting such variables as vegetation boundaries, grazed and ungrazed pastures, annual and perennial vegetation, forage crops (tame pasture vs. rangeland), understocked and nonproductive waste areas, the presence of water for livestock, moisture conditions, and eroded areas along stream banks. In addition, Carneggie and Reppert (1969) applied large-scale, 70 mm aerial photography to the definition and identification of cattle trails;

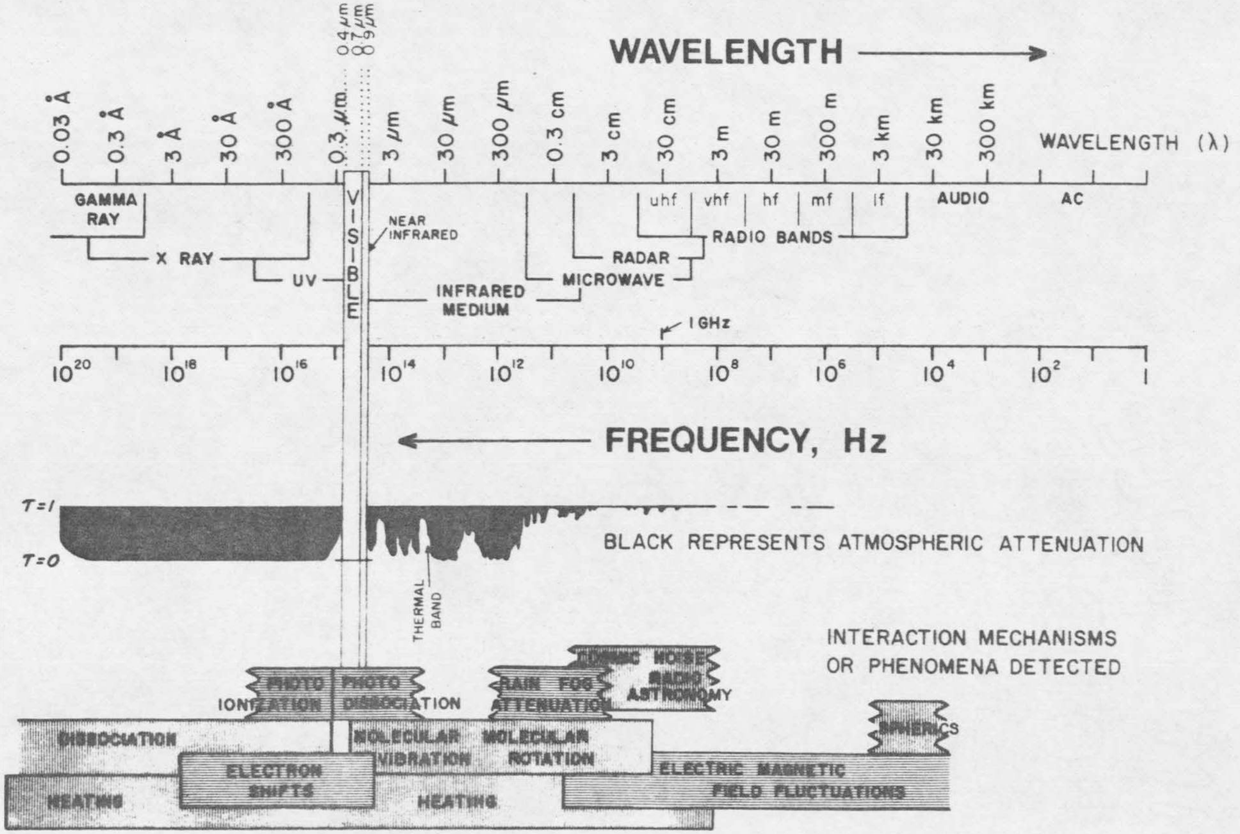

FIG. 1. THE ELECTROMAGNETIC SPECTRUM. (SUITS, 1975)

such factors as trail depth and number of droppings were correlated with the estimated use.

Physical limitations to scattering of light in vegetative tissue

The spectral response of the inner cellular tissue is dependent upon leaf geometry, morphology, physiology, soil site, and climate (Gates 1970). The reflectance and transmittance of the incident radiation is dependent upon a water solution within the pigmented cells (Gates 1970). Small amounts of light are reflected from the cuticle or upper epidermis (Fig. 2); however, much of the light is transmitted to the mesophyll (Gates et al. 1965). Within the mesophyll of dicotyledon vegetation, long palisade parenchyma cells tend to form along the upper portion in the direction from which light enters (Gates et al. 1965). The cells contain as many as 50 chloroplasts, within which are grana particles (Esau 1965). The grana particles are the site for chlorophyll and are primarily responsible for the scattering of incident light. The scattering is caused by the approximate size of the grana particles correlated with the wave lengths refracted (Gates 1970).

In addition to the grana refraction, the index of refraction within the mesophyll is altered by the air-water interface; this is the Fresnel effect (Gates 1970). The intercellular refraction index in the air spaces is 1.00, and the water refraction index is 1.33.