Large scale aerial photography of native range transects
by James Stuart Anderson

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

Abstract:
The use of remote sensing in locating and describing specific plant communities on rangeland is of considerable value to the resource manager. With this technique, permanent, and precise records of site and vegetation characteristics can be obtained relatively inexpensively. This project's use of aerial photography on rangeland includes the modifications of procedures commonly used in "conventional" aerial photography. Large scale stereoscopic aerial photography (1/3800 to 1/9000) was taken with small cameras throughout the growing season, using color and color infrared film as well as black-and-white. From this, seasonal profiles of plant species and community signatures were examined. Ground truth data consisting of soil moisture, phenology, and photographic ground obliques were collected as promptly as possible following the aerial photography. Spectral signatures from color and color infrared photography were analyzed and compared to detailed vegetative mapping on black-and-white photography of the same area. A unique spectral signature or combinations of spectral signatures during one or more phenological stages differentiated three tree species, four shrub species, two grass species, and three forb species.

The occurrences of these species' discriminating spectral signatures were related to their phonological stages. Their colors were described with the Munsell color notation.

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Signature James S Anderson

Date May 23, 1978

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by

JAMES STUART ANDERSON

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ABSTRACT

The use of remote sensing in locating and describing specific plant communities on rangeland is of considerable value to the resource manager. With this technique, permanent, and precise records of site and vegetation characteristics can be obtained relatively inexpensively. This project's use of aerial photography on rangeland includes the modifications of procedures commonly used in "conventional" aerial photography. Large scale stereoscopic aerial photography (1/3800 to 1/9000) was taken with small cameras throughout the growing season, using color and color infrared film as well as black-and-white. From this, seasonal profiles of plant species and community signatures were examined. Ground truth data consisting of soil moisture, phenology, and photographic ground obliques were collected as promptly as possible following the aerial photography. Spectral signatures from color and color infrared photography were analyzed and compared to detailed vegetative mapping on black-and-white photography of the same area. A unique spectral signature or combinations of spectral signatures during one or more phenological stages differentiated three tree species, four shrub species, two grass species, and three forb species.

The occurrences of these species' discriminating spectral signatures were related to their phenological stages. Their colors were described with the Munsell color notation.

INTRODUCTION

Aerial photography has been used extensively for mapping broad vegetational community stands. Most of this work has been concentrated on the identification of crop, grass, shrub and timber stands from small scale aerial photography.

Positive identification of individual species and plant community stands is often difficult by the use of aerial photography. The reason for this may be unsuitable photographic scale, improper film and filter combinations, lack of steroscopic coverage, photography exposed during a nondiscriminating phenological period, or the lack of quantified spectral signatures characteristic of community stands.

This study is an attempt to use the above criteria advantageously to distinguish, identify, and describe a species' or community's spectral signature from photographic imagery. From this, aerial photography could be used in obtaining permanent, precise data for rangeland inventories and for monitoring changes in vegetation which might result from management decisions.

REVIEW OF LITERATURE

The first photographic imagery process dates back to 1839 when Daguerre produced an image on a silvered copper plate. In 1858, Nadars produced the first aerial photograph from a balloon at a height of 80 meters (M). In 1909, the first photographs from an airplane were taken over Mourmillion by the Frenchman, Maurisse. Later, reconnaisance photography from airships or airplanes played an important role during the first World War (Gernsheim and Gernsheim, 1969).

Since that time, aerial photography has been applied in biological and physical sciences such as archaeology, agriculture, range management, forestry and others (Smith, 1968). According to Parker and Wolff (1965), the extensive varieties of film and filter combinations available today make aerial cameras one of our most powerful tools for remote sensing.

Carneggie and Reppert (1969) reported numerous potentials exist for large scale photography in range inventory, management, and research. Shrub, grass, and forb species were differentiated using color and/or color infrared (IR) aerial photography.

Image Discrimination and Identification

Tone, texture, pattern, shape, size and shadow are useful parameters for interpreting aerial photographs (Driscoll, 1971; and Olson, 1960). Colwell (1954) considers tone contrast between an image and its background as the primary image characteristic for the detection of an object from a single photograph. According to Colwell (1966), and Roger (1953), contrast of the image and its background, resolution of the photographic image, and difference in parallax are factors associated with the recognition of images on aerial photographs.

Factors Affecting Leaf Reflectance

Knowledge of the manner in which solar energy interacts with grassland vegetation is necessary to interpret remote sensing data in this ecological zone (Tucker, 1975). According to Gates (1970), the precise spectral quality and intensity of plant reflectance and emittance depend on leaf geometry, morphology, physiology, chemistry, soil site, and climate. The composition of incident sunlight (Fig.1) coupled with the complexity of plant reflection determine the spectral complexity of reflected light (Gates, 1967).

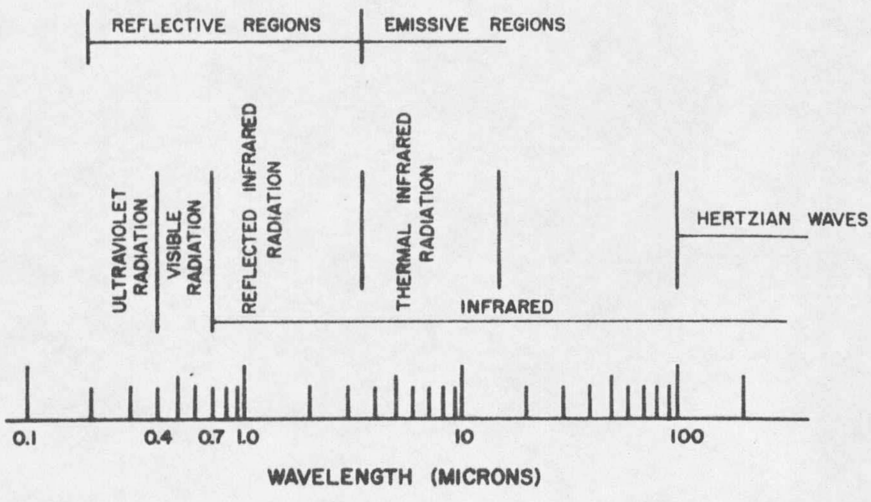

Fig. 1. Portion of the electromagnetic spectrum.

Colwell (1956) stated that a high percentage of green light {500 to 600 nanometers (nm)} is reflected from plants. According to Pearman (1966), the 540 nm wavelength produced the maximum reflectance from plants within the visible spectrum. Billings and Morris (1951) reported 15 percent reflectance from the upper leaf surface at the 550 nm wavelength. This agrees with Shull (1929) who reported 6 to 25 percent reflectance from green light between 540-560 nm.

Lack of strong vegetative reflectance in the visible range can be attributed to the leaf pigments which absorb light (Gausman et al., 1976; Woolley, 1971; Knipling, 1970; Hoffer and Johannsen, 1969; and Gates and Tantraporn, 1952). Tucker (1975) and Colwell (1956) reported that blue light (400 to 500 nm) and red light (600 to 700 nm) are largely absorbed by chlorophyll, while Tucker (1975) and Pearman (1966) reported reduced pigment absorption within the green spectrum of 500 to 600 nm. Moss and Loomis (1952) discovered that plants absorbed 82 percent and transmit 10 percent of the visible region (400 to 700 nm) with maximum absorbance at 680 nm and minimum absorbance at 550 nm wavelengths.

According to Tucker (1975) and Fritz (1967), near or photographic infrared radiation exhibits high or enhanced reflectance from plant material. Billings and Morris (1951) reported 50 percent reflectance from the upper leaf surface in the near infrared wavelength (775 to 1100 nm), while Colwell (1956) reported 80 percent or more vegetative reflectance in the near infrared spectrum (700 to 900 nm). Woolley (1971) found vegetation to reflect or transmit 96 percent of the near infrared (800 to 1100 nm).

Tucker and Maxwell (1976) reported that near infrared reflectance is dependent on internal scattering in the absence of absorption within a leaf, and the inter-leaf scattering, which is dependent on canopy geometry.

Within the plant leaf mesophyll, near infrared radiation passes from hydrated cell walls (refraction index of 1.4) into intercellular air spaces or lacunae (refraction index of 1.0) (Gausman et al., 1970). Willstatter and Stoll (1928) found that an index of refraction of 1.33 for liquid water to 1.00 for air in the intercellular spaces provides an efficient internal reflection at each interface.

According to Gausman and Allen, 1973; Sinclair et al., 1973; Gates, 1970; and Knipling, 1970, spectral reflectance of the near infrared is largely the result of the interaction of the incident radiation with the leaf mesophyll structure. Cell shape and size as well as the amount of intercellular space are probable variables determining the amount of near infrared reflectance (Gausman, 1970; Allen et al., 1969; Gausman et al., 1969; and Gates et al., (1965). Near infrared reflectance was described by Billings and Morris (1951) as being completely independent of the presence of chlorophyll.

Pearman (1966) reported increased reflectance of visible light due to wax and pubescence covering the leaf surface. Pubescence provides an additional interface to incoming solar radiation, which has the effect of scattering light and decreasing the amount of light entering the leaf. In contrast, Gausman and Cardenas (1969) found that leaf pubescence did not increase reflectance within the visible spectrum, although total reflectance within the near infrared waveband (750 to 1000 nm) did increase (Gausman and Cardenas, 1968, 1969).

Leaf dehydration results in tissue collapse which increase the number of airspaces and air-wall interfaces (Gausman et al., 1976). Knipling (1969) established that near infrared leaf reflectance increased in many cases with initial leaf senescence. Weber and Olson (1967) also reported an increase in near infrared leaf reflectance as the leaf dries.

According to Knipling (1969) and Colwell (1956), near infrared leaf reflectance eventually decreases in advanced stages of leaf senescence. Gates (1970) found that a completely dry leaf reflects small amounts of near infrared radiation.

Coulson (1966) measured variation in reflectance from grass turf due to changes in the angle of reflection. He found that wavelengths shorter than 700 nm varied only slightly in reflectance while wavelengths of 796 and 1025 nm showed greater variation. This suggests that the orientation of grass blades is an important variable determining the near infrared reflectance.

Phenological Effects

Plant phenological changes have been recognized as a most useful aid in identifying vegetation from aerial photography (Haefner, 1967; and Sayn-Wittengstein, 1961). A need exists for a better understanding and documentation of the phenology of range species before an optimum date(s) for aerial photography can be recommended (Carneggie and Reppert, 1969).

According to Hoffner et al. (1966), different varieties of a species and variation in maturity of different varieties can affect the response reaching the sensor receiver. Driscoll (1971) found there is no one optimum time during the growing season to obtain aerial photographs for interpreting the complex range environment.

Film and Filters

Stephen (1976) compared panchromatic, color and color infrared films as to their usefulness in vegetational community discrimination. Color IR was found to be most suitable because of its greater range of hue, value, chroma and emulsion sensitivity. This resulted in enhanced and amplified color differences. Driscoll et al. (1970) found color IR film superior to color film for herbaceous species identification. In contrast, Haack (1962) discovered no statistical difference between panchromatic, color and infrared films for forest surveys.

Panchromatic films may be used with a Wratten number 12 or 25 filter. These filters reduce the affect of atmospheric haze by cutting down the passage of ultraviolet and blue light to the film surface.

The Wratten filter HF-3 reduces excessive bluishness in color films caused by atmospheric haze. The Wratten HF-3 filter is primarily an ultraviolet absorber and is not recommended for use at very low altitudes (below 152 meters) or on very clear days (Kodak, 1971).

According to Kodak (1971) and Fritz (1969) a Kodak Wratten number 12 filter should always be used with color IR films, although Colwell (1960) suggests Wratten 15 filter.

DESCRIPTION OF STUDY AREA

This study was conducted at two sites (Halfway Reservoir and McRae Knolls) in southeastern Montana (Fig. 2). Both areas are on the Missouri Plateau, an extensively dissected, unglaciated region of Northern Great Plains {Both Bass (1932) and Sindelar *et al*. (1975) contributed to the above statement}.

The Halfway Reservoir study site (Fig. 3) is located on the Custer National Forest (Fort Howes District), in Powder River County, approximately 40 km southeast of Ashland, Montana.

This study area has numerous outcrops of fine sandstone. Figure 4 is a soils map based on the Powder River Soil Survey (U.S.D.A. Soil Conservation Service *et al*., 1971). Upland bench and creek bottom soils are of the Farland, and Farland Havrelon series complex, respectively, and are in the fine-silty, mixed family of Typic Argiborolls. These soil series are deep, well-drained and of medium texture. The Caba series on side slopes is classified in loamy, mixed, calcareous, frigid, shallow family of Typic Ustorthents. This series is well-drained, medium-textured and less than 50 cm in depth.

The McRae Knolls study site (Fig. 5) is located on the Wallace McRae Ranch in Rosebud County, approximately 13.8 km southeast of Colstrip, Montana.