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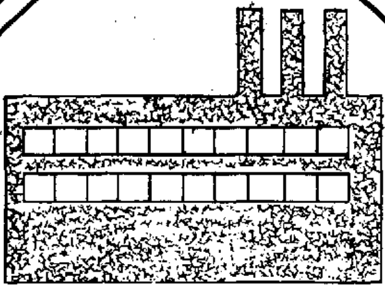
REMOTE SENSING LABORATORY



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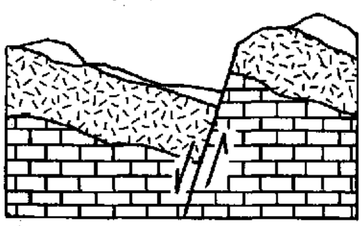

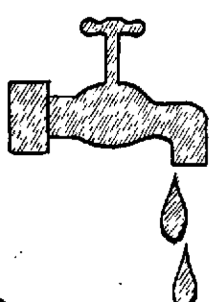

University of Wyoming

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16. Abstract

This project used aerial photography scales 1:43,400 and 1:104,500 to evaluate the usefulness of Skylab color photography (scales 1:477,979 and 1:712,917) and ERTS-1 multispectral imagery (scale 1:1,000,000) for mapping range vegetation types. The project was successful in producing a range vegetation map on the 68,000 acres salt desert shrub type southwestern Wyoming.

Techniques for estimation of above-ground green biomass have not yet been confirmed due to the mechanical failure of the photometer used in obtaining relative reflectance measurement. However, graphs of log transmittance versus above-ground green biomass indicate that production estimates may be made for some vegetation types from ERTS imagery. Other vegetation types not suitable for direct ERTS estimation of green biomass may possibly be related to those vegetation types whose production has been estimated from the multispectral imagery.

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Figure 2. Technical Report Standard Title Page

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CHAPTER I

INTRODUCTION

The Study Project

From 1967 to 1971 the Bureau of Land Management and the University of Wyoming Agricultural Experiment Station conducted a project to assess the impact of various livestock grazing systems on the vegetation and wildlife habitat. The study was conducted west of Baggs, Wyoming on salt desert shrub rangeland controlled by the Bureau of Land Management. In 1973, with the development of the Earth Resources Technology Satellite and the Skylab Satellite Programs and the need for the range manager to monitor changes in his resource area, new research was initiated using the information provided from the space program.

The objectives of this research were: (1) to determine whether or not the multispectral imagery available from the ERTS-1 satellite was useful for mapping the rangeland resource; and (2) to estimate above-ground green biomass by relating it to total scene reflectance, thereby diversifying the applications of remotely sensed data for use in the field by the resource manager.

Neither of these goals were set with the idea of eliminating field work but, to assist it by determining changes in the rangeland and its above-ground green biomass on a regular basis. The development and advancement of remote sensing techniques for range management will allow the conservationist to locate areas which require his attention.

The Study Area

The study was conducted on 68,000 acres of rangeland in the southeastern portion of the Red Desert west of Baggs, Wyoming (Figure 1). Extending through the area are the southern structural rim of the Washakie Basin and a complex system of east-west oriented faults, synclines and anticlines (Gibbens, 1972). The irregular topography extends from 6,200 to 7,200 feet above sea level.

Shales, sandstone or alluvial mixtures of the two make up the major soil parent materials. The often calcareous, brown to pale brown loams make up the majority of the soils described by the Soil Conservation Service. These loams have developed mainly from the Browns Park formation and the montmorillanitic clay soils from residual or transported shales. Both are neutral to very basic in reaction (Gibbens, 1972).

The climate consists of cold winters, broken by a short hot summer. Precipitation ranges from about 8 to 11 inches per annum with the majority of winter moisture

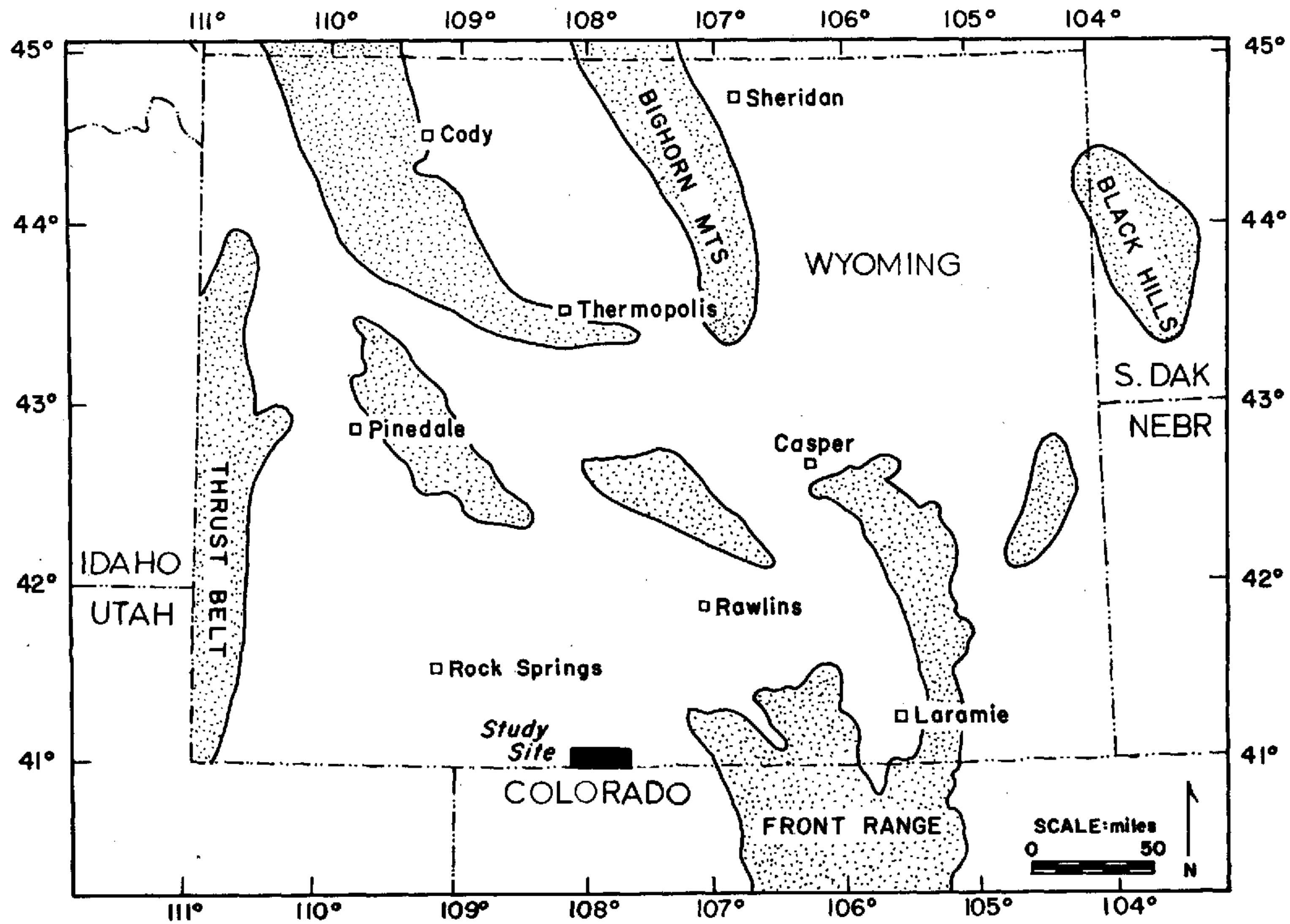

Figure 1. Location of Baggs study site.

in the form of snow. Gibbens (1972) states that the growing season is approximately 96 days.

The vegetation types are usually dominated by big sagebrush (Artemisia tridentata Nutt.) or Utah juniper (Juniperus osteosperma (Torr.) Little). These provide good cover for antelope, mule deer, and sage grouse populations.

Under the Bureau of Land Management supervision, the study area was divided into a four pasture rest-rotation unit, a two pasture deferred unit and one season-long grazing unit. Summer use of the pastures was confined to cattle, with sheep grazing the four-pasture rest-rotation unit during the winter (Figure 2). Between 1967 and 1971, grazing system research was reported by Gibbens et al. (1968, 1969); Gibbens and Fisser (1970); Fisser and Gibbens (1971); and Gibbens and Fisser (1972).

Research Design

Mapping. The base map of all the vegetation types found within the study area was prepared on U.S.G.S. 7.5 minute series topographic maps. The scale was 1:24,000. Information was transferred, using a Bausch and Lomb ZT-4 zoom transfer scope, from colour and colour infrared aerial photography obtained from NASA flights 213 and 248. The scales of these images were 1:43,400 and 1:104,500.

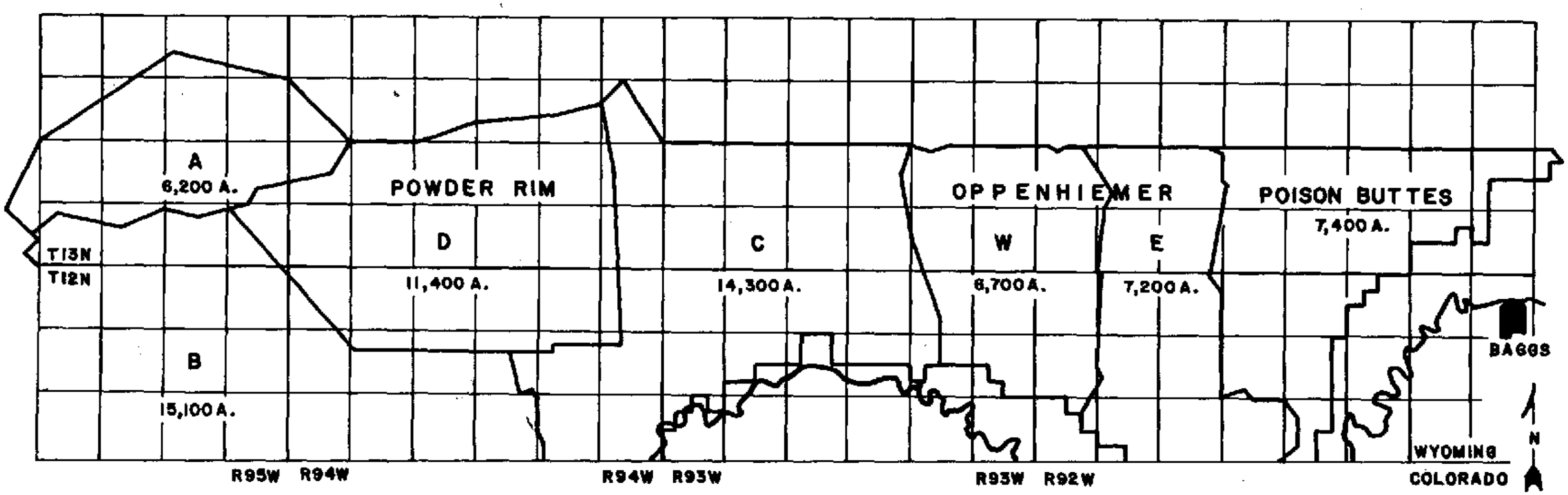

Figure 2. Map of the Baggs study area showing grazing units and approximate acreages (Gibbens, 1968).

Rest-rotation unit: Powder Rim Pastures A, B, C, D.

Deferred unit: Oppenhiemer West and East

Season-long grazing unit: Poison Buttes Pasture

Accuracy of the vegetation type lines was determined by field reconaissance.

The Skylab vegetation map was prepared from colour photographs number 104-S190A and 35-S190B Track 48, Taken on August 4, 1973, enlarged on the aforementioned zoom transfer to a scale of 1:250,000. This map was then enlarged with a Saltzman Projector system to 1:24,000 for direct comparison to the base map. Skylab images S190A and S190B, nine-inch format, were at scales of 1:712,917 and 1:477,979 respectively.

The third vegetation type map was prepared from ERTS image number 1318-17253, band 5, taken on June 6, 1973. This image was enlarged photographically to about 1:250,000, the information mapped directly on the print, and transferred to the Saltzman Projector for enlargement to 1:24,000. Band 5 was chosen over the other bands and the colour composites because of its high contrast and the difficulties encountered in making colour enlargements. Both the ERTS map and the Skylab range type maps covered the entire 68,000 acre study area.

Between 1967 and 1972 the University of Wyoming Experimental Station established 95 vegetation transects in the Baggs study area. Each of these 100 foot transects had 20 evenly spaced 1 square foot plots from which estimates of shrub crown cover and grass and forb basal cover were obtained. In addition to the 95 transects established by Gibbens, 68, new and representative vegetation transects were established in 1974 to adequately type the entire study area. Crown cover and basal cover were obtained for shrubs and for grasses and forbs respectively on these transects using the same procedure followed by Gibbens. Duplication of this method allowed direct comparison of data.

Vegetation types were named for the dominant species in the area of the transect and other transects with similar composition and cover characteristics were grouped to form subtypes of a major type. The major range vegetation types and subtypes were designated on all three vegetation maps.

Above-ground green biomass estimations. Prior to the first ERTS overpass of the 1973 study season, 10, two- by three-meter reference plots were established both in the Poison Buttes pasture and 10, in Pasture C, of the rotation pasture system. Meter readings of relative reflectance were obtained from each of these 20 plots during the five 1973 summer overpasses using a portable photometer manufactured by Science and Mechanics.

In addition to the reflectance readings, photographs of each plot were taken simultaneously using a multispectral camera array. Two of the cameras contained Kodak Panatomic X, FX135, and the other two, Kodak High Speed

Infrared film, HIE135. Both the photometer and the four Miranda EE cameras were equipped with Wratten filters similar to those found on the ERTS satellite. This procedure provided information directly comparable to that received from the satellite.

The filters used for band 4 (green, .5 to .6 μm), band 5 (red, .6 to .7 μm), band 6 (infrared 1, .7 to .8 μm), and band 7 (infrared 2, .8 to 1.1 μm), were Wratten 57, 25, 89B and 87C respectively (Eastman Kodak Co., 1968). Bands 4 and 5 on the photometer were covered with Corning glass filters (#3961) to eliminate infrared light (Corning, 1970).

The relative reflectance measurements and photographs were obtained at the same height, angle, time, and position during each overpass. A small step-ladder, used to get above the shrubby vegetation, provided a clear view of the entire plot when measurements were being taken. The photometer scale, set on channel four, was adjusted using a grey card, Kodak 18%, to read 18. This procedure was conducted to ensure a consistent starting point for all readings. Reference measurements were taken of the sky with and without the filters. Relative reflectance of each plot was recorded with and without filters. Due to the time of each ERTS overpass at 1025 hours, Mountain Standard Time, measurements commenced at 1000 hours and ceased at approximately 1500 hours. This was done to maintain constant lighting conditions throughout the study period. The Poison Butte site was always measured first and the Pasture C site, second.

In addition to the 20 reference plots, 350 plots were established and within which above-ground green biomass was determined. Above-ground green biomass included all green herbaceous material and leaves of shrubs but not perennial branches. The Pasture C and Poison Buttes biomass sites each had 175 of these plots. These plots were set out randomly from 14 representative transects. There were 25, four- by five-foot plots established per transect. A random number table was used to obtain 350, four-digit numbers. The first two digits were paced down the transect and the two remaining digits were paced to the biomass plot. Even numbered plots were paced to the right and odd numbered plots to the left of the transect. All plots were marked with a numbered flag. In 1973, 10 transects, 250 plots, were established and in 1974 four more transects were constructed to compare with the 1973 transects. Two of the 1974 transects were near transects established in 1973 and two comparative transects were in a different part of the vegetation type.

Relative reflectance measurements were obtained for each plot under conditions similar to those occurring during the overpass and using the same techniques. Measurements were taken as soon after the overpass as possible.

Above-ground green biomass was sampled after each overpass using a double sampling technique described by Pechanec and Pickford (1937). In this instance, half of one square foot of the first, the fifth, the tenth, the fifteenth, the twentieth and the twentififth plot was clipped during each estimation session. After the July 30, 1973, overpass 50 plots were clipped in entirety to have an accurate above-ground green biomass weight for comparison with the estimates made on July 31, 1974.

The clipped material was separated into shrubs, grasses and forbs, standing dead and litter. Only the green leaves of the shrubs were weighed. Each set of samples was oven dried at 60° C and weighed to the nearest one hundreth gram. The half square foot weight was multiplied by two to obtain a weight per square foot. The mean weight of each sample set was multiplied by the number of units estimated for the amount of grass and forb, shrub, standing dead or litter on the particular transect. These figures were converted to kilograms per acre. Plots completely clipped were converted directly to kilograms per acre after oven drying and weighing.

Soil moisture was determined by collecting samples of the top inch of soil during each overpass in the 1973 field season and during the 1974 field season, when the comparative transects were being measured for relative reflectance. One soil sample was obtained from each reference plot and six, from each of the clipped aboveground green biomass plot transects during each relative reflectance measurement session. In 1974, soil moisture samples were only collected for the biomass plots.

Relative reflectance information was obtained with a calibrated photometer. The photometer was calibrated using the procedure followed by Raines and Lee (1974). Reference grey cards of known reflectance were then measured and the values were used as a standard for the field meter readings. Meter readings recorded in the field were to be converted to percent relative reflectance by plotting them on the graph of reflectance versus meter reading.

CHAPTER II

LITERATURE REVIEW

Generally, rangelands are those areas not suitable for intensive cultivation. They have therefore been left undeveloped and their native forages used for domestic and wild grazing animals. These vast areas of rough and often remote terrain, contain many different range types, none of which are homogeneous or regular in shape. Since rangelands must be managed correctly to maintain their productivity, they must also be monitored on a regular basis to note changes in condition (Dyksterhuis, 1948).

Vegetation type mapping is an important phase of range inventory and is an indispensable portion of the overall range management plan (Stoddard and Smith, 1955). Early range surveys were conducted on foot with the conservationist walking through the various vegetation types and noting their boundaries on his base map (Brown, 1954). The United States Inter-Agency Range Survey Committee (1937) describes a set of 18 vegetative types to be used in range inventory. Brown (1954) states that types are areas recognized by their aspect or physiognomy. Type names are based on the dominant plant species occupying the study area. They are distinct vegetation units and their subtypes are categories within these major units (Stoddard and Smith, 1955).

Recently, remote sensing has been used to improve mapping accuracy and to reduce the amount of time spent in the field conducting range inventories. Strictly speaking, almost everyone has used remote sensing when viewing an object from a distance so they could see it fully and compare to other areas. In this case, remote sensing is the use of aerial photographs and machine produced images for mapping.

The use of aerial photos for range inventory has been accepted since 1937 (Driscoll,1969). Several film types are available to perform this work. Some of these are, panchromatic black and white, infrared black and white, Kodak Ektachrome (colour) Aero Film, Kodak Ektachrome infrared Aero film and Kodak Aero-Neg Colour System (Avery, 1968). To identify the different features on aerial photographs the interpreter considers size, shape, shadow, tone, texture, topographic location and pattern (Avery, 1968).

Recently, the National Aeronautics and Space Administration (NASA) embarked upon the Earth Resources Technology Satellite (ERTS) Program and the Skylab Satellite Program. These two programs have provided the range manager with high altitude imagery as well as high and low level colour and colour-infrared photographs.

The ERTS-1 satellite orbiting 494 nautical miles above the earth provides scanner data that is routinely converted to black and white imagery of the earth at a scale of 1:1,000,000 (NASA, 1971). The imagery represents four spectral regions, band 4 (green, .5 to .6 μm), band 5 (red, .6 to .7 μm), band 6 (infrared 1, .7 to .8 μm) and band 7 (infrared 2, .8 to 1.1 μm). Skylab photographs S190A and S190B are at scales of 1:712,917 and 1:477,979 respectively in a nine-inch format. Skylab, the first manned space laboratory, orbits at 234 nautical miles above the earth (Mission Requirements and Operations Team, 1973). On August 4, 1973 Skylab data was collected for the Baggs study site. The information included S190B colour prints, S190A colour and colour infrared transparencies and prints, and black and white multiband prints and transparencies. The scales of these photographs on a nine-inch format were 1:712,917 and 1:477,979 for S190A and S190B respectively. Aerial photographs from NASA flights 213 and 248 at scales of 1:43,400 and 1:104,500 respectively and ground truth data are used as control for the interpretations of space imagery. Prior to the receipt of imagery from the ERTS satellite, investigators began research projects to test the usefulness of multispectral data for vegetation mapping. Workers in Wyoming (Evans and Redfern, 1973; Evans and Marrs, 1974; Gordon, 1974) used band 5 and band 7, but band 5 was best for their vegetation research. Some researchers prefer to use color composites made by combining some of the ERTS bands (Bentley, 1973).

Undoubtably, the small scale, 1:1,000,000 is difficult to work with but workers in California report that although the ERTS-1 imagery yielded less detailed information than conventional aerial photographs; the major vegetation type lines were designated 9 times faster than on colour-IR photos at a scale of 1:120,000 and 20 times faster than on 1:15,840 scale black and white photographs (Lauer and Krumpe, 1973). Information on range condition (relative greenness or dryness) is available from these images (Carneggie and DeGloria, 1973). This data however, does not provide the range manager with information concerning the carrying capacity of his land or the type of forage available for his use. Research in Nevada, Tueller and Lorain (1973), indicates that crested wheatgrass pastures can be mapped from ERTS. It should be noted that these pastures are homogeneous in composition and that rangeland is not.

In addition to range type identification, remote sensing researchers are developing methods of estimating forage production. Pearson and Miller (1972), have developed a method of estimating standing crop biomass on the shortgrass prairie in Colorado. They use a hand-held Techtran digital radiometer to take readings of their study plots. The readings were used to compute the estimated biomass and have resulted in a .98 correlation between spectral ratio and dry biomass. Reflectance ground truth was gathered using a field spectrometer laboratory. Vegetation samples were also collected.

The Bureau of Land Management which administers large tracts of rangeland is interested in improving its estimations of ephemeral forage production in arid areas (Bentley, 1973). The development of reliable methods of estimating ephemera forage production from ERTS imagery will save days of field time and will save cattle buyers the many thousands of dollars lost yearly due to speculation. Bentley (1973) used colour composites of ERTS images to distinguish the different amounts of forage. This was accomplished by comparing imagery taken prior to plant growth with imagery taken at the peak of the growing period. The cloud-covered ERTS images received by Bentley (1973) could not be used to predict forage production prior to the growing season.

The above studies indicate current research being performed to assess applications of the multispectral imagery provided by the ERTS program. Similar research in being conducted in Wyoming for the Skylab imagery (Marrs, 1974a, 1974b). The goals of these projects are twofold. First, to develop identification systems and second, to develop production estimation methods oriented towards the user.

CHAPTER III

RESULTS AND DISCUSSION

Mapping

Interpretation of the low level colour and colour-infrared photographs and extensive ground reconaissance resulted in detailed vegetation maps (Figures 3A and 3B). These maps show 12 major range type classifications and 32 subtypes designated by alphabetic symbols. The types and subtypes result from the combination of data gathered from the 163 vegetation transects established in the area. The vegetation types and subtypes, their precent average cover and the number of vegetation transects found in each type are indicated in Table 1.

The Skylab vegetation maps (Figure 4A and B) were compiled from an S190A colour positive and an S190B colour print. It should be noted that areas representing all 12 vegetation types and 29 subtypes were interpreted from the Skylab photography.

The ERTS-1 maps of the vegetation types, Figure 5A and 5B were taken from a photographically enlarged black and white image in band 5 (red, .6 μm to .7 μm). These maps contain with the exception of Type 0, representatives of all vegetation types and 21 subtypes found on Figures 3A and B and on Figures 4A and B.

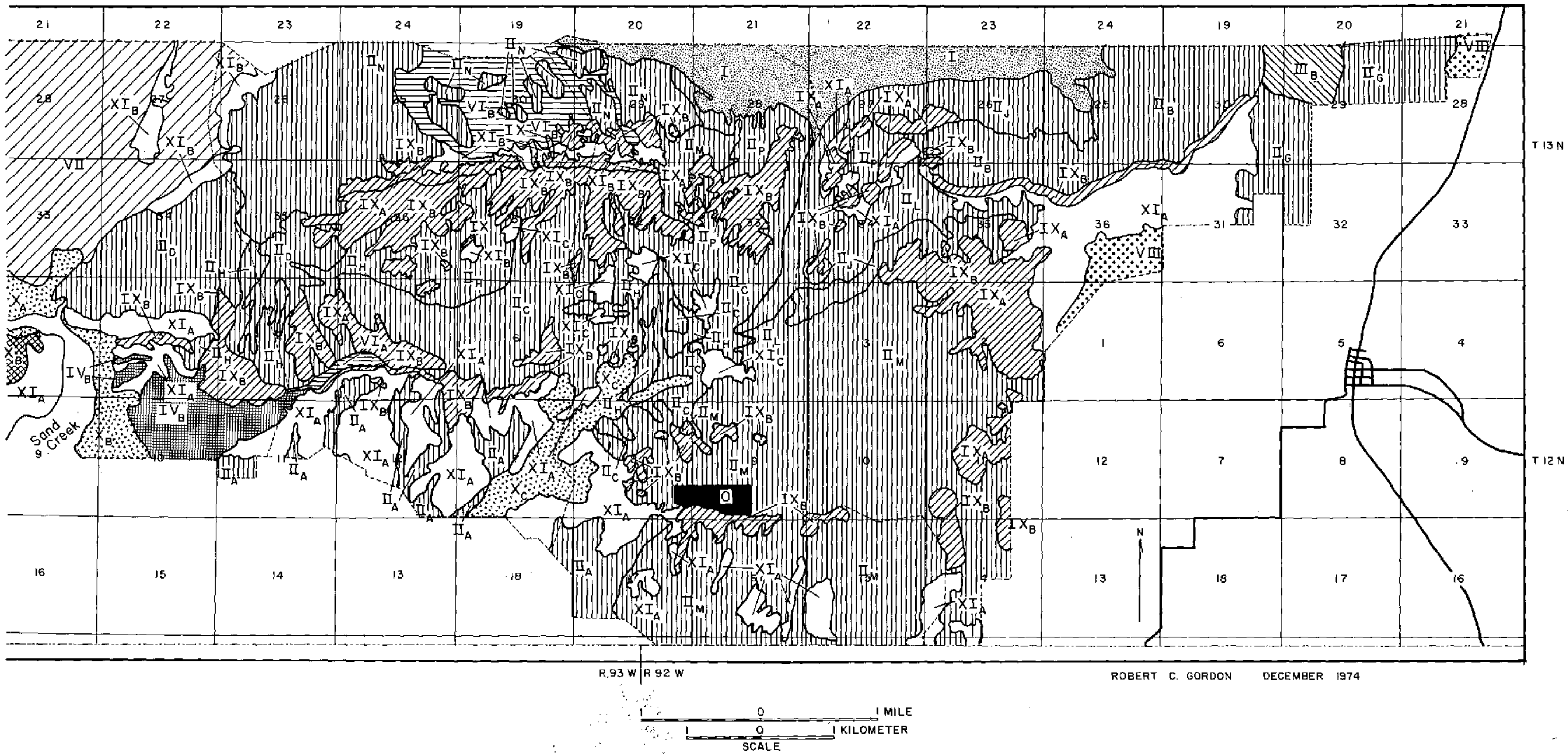

Figure 3A Range vegetation map compiled from low level aerial photography supplemented with ground reconnaissance

RANGE VEGETATION TYPES

Type O	Agropyron cristatum: Crested wheatgrass
Type I	Agropyron smithii -- Artemisia tridentata: Western wheatgrass and basin big sagebrush
Type II	Artemisia tridentata -- Agropyron smithii: Basin big sagebrush and western wheatgrass
Type III	Artemisia tridentata -- Agropyron spicatum: Basin big sagebrush and bluebunch wheatgrass
Type IV	Artemisia tridentata -- Atriplex species: Basin big sagebrush and saltbush
Type V	Artemisia tridentata -- Carex eleocharis: Basin big sagebrush and needleleaf sedge
Type VI	Artemisia tridentata -- Gutierrezia sarothrae -- Agropyron smithii: Basin big sagebrush, broom snakeweed, and western wheatgrass
Type VII	Artemisia tridentata -- Stipa comata: Basin big sagebrush and needleandthread
Type VIII	Artemisia tridentata: Basin big sagebrush
Type IX	Juniperus osteosperma: Utah juniper
Type X	Sarcobatus vermiculatus -- Artemisia tridentata: Black greasewood and basin big sagebrush
Type XI	Bare ground

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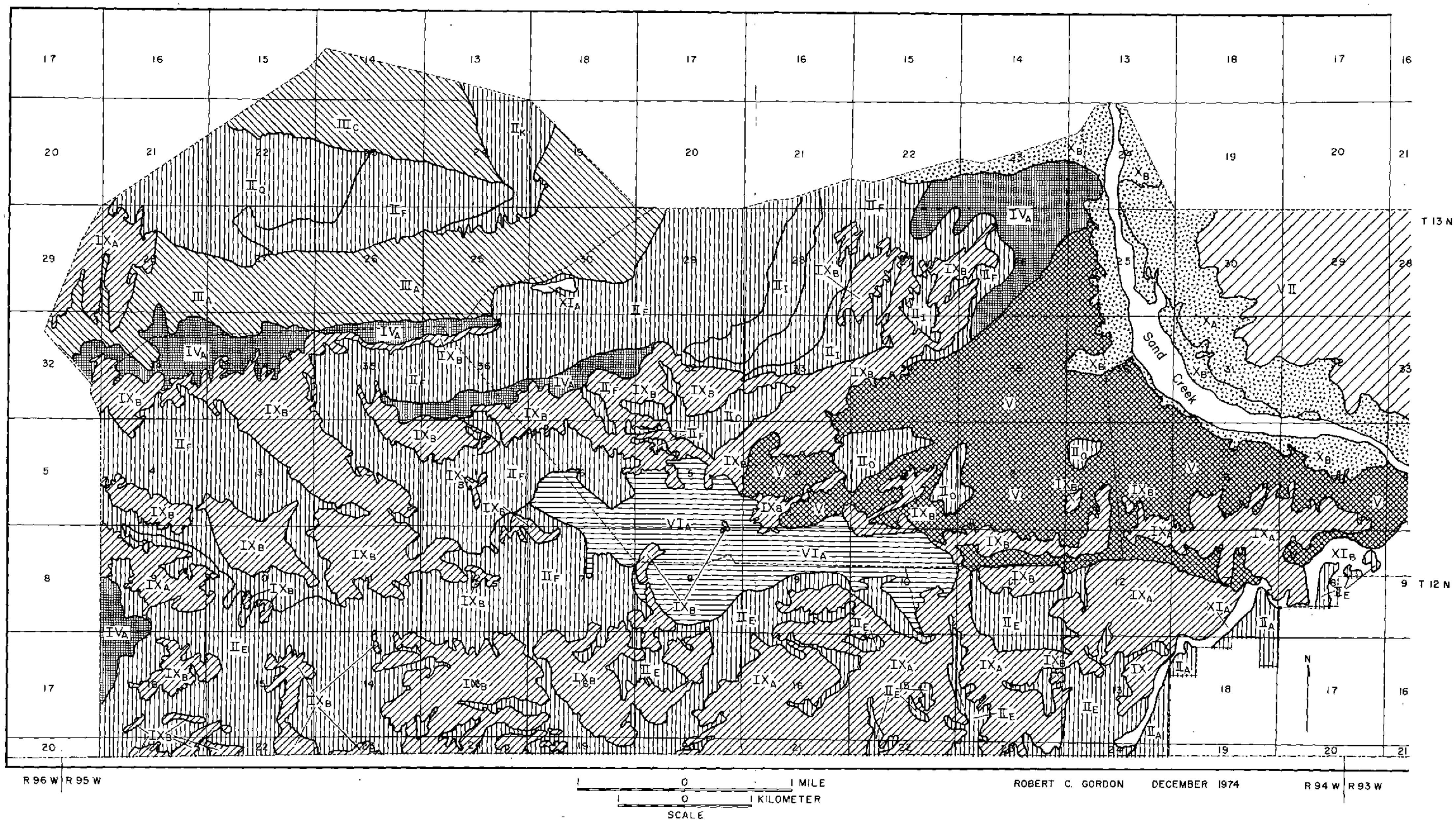

Figure 3B Range vegetation map compiled from low level aerial photography supplemented with ground reconnaissance

RANGE VEGETATION TYPES

Type 0	*Agropyron cristatum*: Crested wheatgrass
Type I	*Agropyron smithii* -- *Artemisia tridentata*: Western wheatgrass and basin big sagebrush
Type II	*Artemisia tridentata* -- *Agropyron smithii*: Basin big sagebrush and western wheatgrass
Type III	*Artemisia tridentata* -- *Agropyron spicatum*: Basin big sagebrush and bluebunch wheatgrass
Type IV	*Artemisia tridentata* -- *Atriplex* species: Basin big sagebrush and saltbush
Type V	*Artemisia tridentata* -- *Carex eleocharis*: Basin big sagebrush and needleleaf sedge
Type VI	*Artemisia tridentata* -- *Gutierrezia sarothrae* -- *Agropyron smithii*: Basin big sagebrush, broom snakeweed, and western wheatgrass
Type VII	*Artemisia tridentata* -- *Stipa comata*: Basin big sagebrush and needleandthread
Type VIII	*Artemisia tridentata*: Basin big sagebrush
Type IX	*Juniperus osteosperma*: Utah juniper
Type X	*Sarcobatus vermiculatus* -- *Artemisia tridentata*: Black greasewood and basin big sagebrush
Type XI	Bare ground

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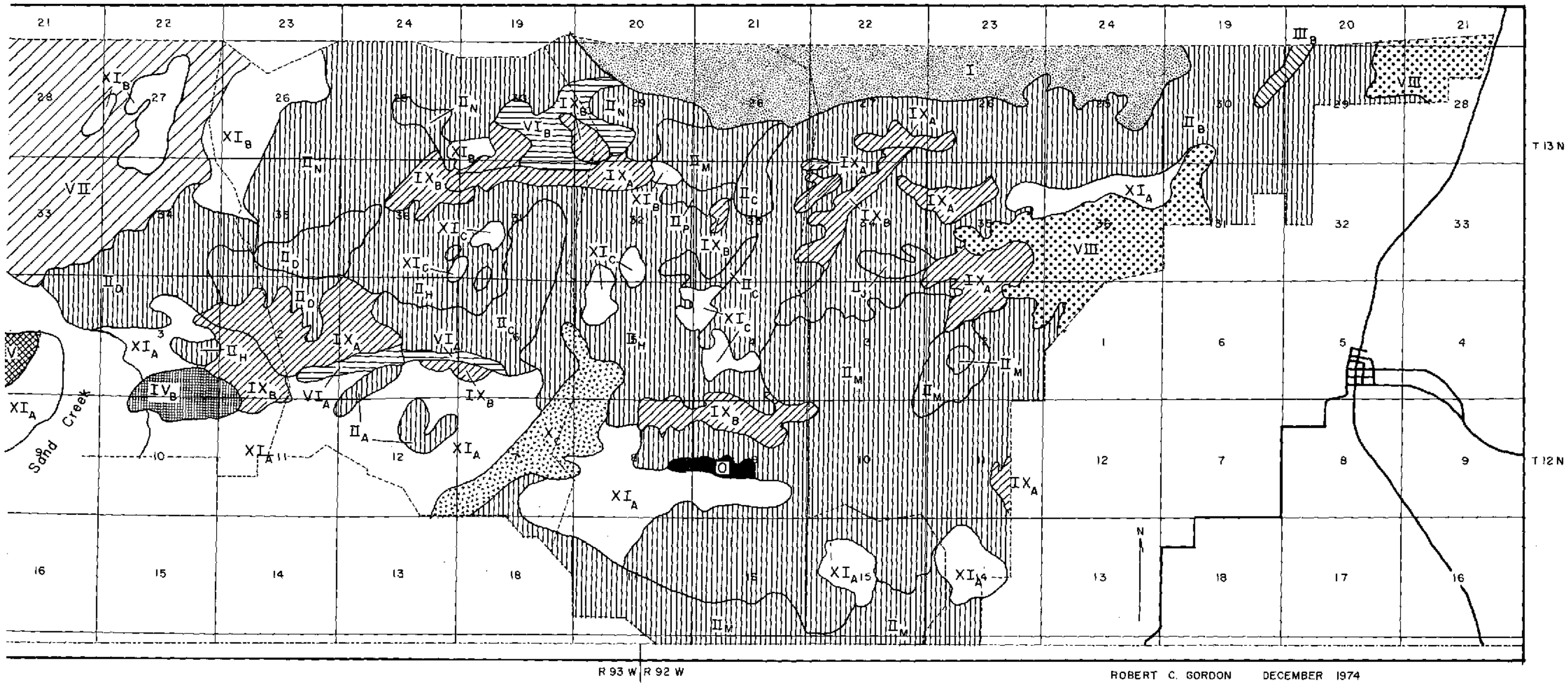

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SCALE

Figure 4A Range vegetation map interpreted from SKYLAB photographs

RANGE VEGETATION TYPES

- Type O — Agropyron cristatum: Crested wheatgrass
- Type I — Agropyron smithii -- Artemisia tridentata: Western wheatgrass and basin big sagebrush
- Type II — Artemisia tridentata -- Agropyron smithii: Basin big sagebrush and western wheatgrass
- Type III — Artemisia tridentata -- Agropyron spicatum: Basin big sagebrush and bluebunch wheatgrass
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- Type V — Artemisia tridentata -- Carex eleocharis: Basin big sagebrush and needleleaf sedge
- Type VI — Artemisia tridentata -- Gutierrezia sarothrae -- Agropyron smithii: Basin big sagebrush, broom snakeweed, and western wheatgrass
- Type VII — Artemisia tridentata -- Stipa comata: Basin big sagebrush and needleandthread
- Type VIII — Artemisia tridentata: Basin big sagebrush
- Type IX — Juniperus osteosperma: Utah juniper
- Type X — Sarcobatus vermiculatus -- Artemisia tridentata: Black greasewood and basin big sagebrush
- Type XI — Bare ground

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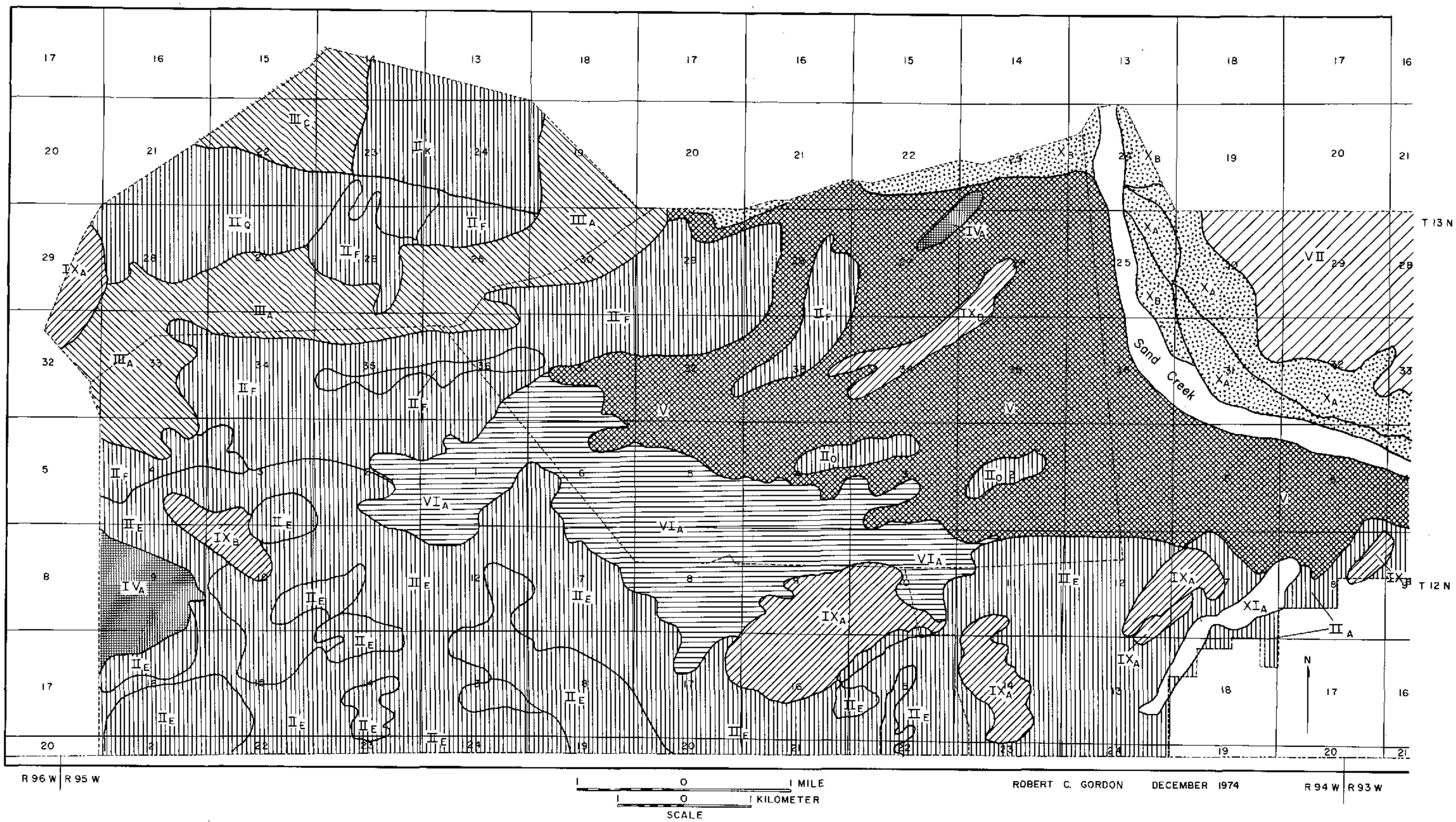

Figure 4B Range vegetation map interpreted from SKYLAB photographs

RANGE VEGETATION TYPES

- Type O — Agropyron cristatum: Crested wheatgrass
- Type I — Agropyron smithii -- Artemisia tridentata: Western wheatgrass and basin big sagebrush
- Type II — Artemisia tridentata -- Agropyron smithii: Basin big sagebrush and western wheatgrass
- Type III — Artemisia tridentata -- Agropyron spicatum: Basin big sagebrush and bluebunch wheatgrass
- Type IV — Artemisia tridentata -- Atriplex species: Basin big sagebrush and saltbush
- Type V — Artemisia tridentata -- Carex eleocharis: Basin big sagebrush and needleleaf sedge
- Type VI — Artemisia tridentata -- Gutierrezia sarothrae -- Agropyron smithii: Basin big sagebrush, broom snakeweed, and western wheatgrass
- Type VII — Artemisia tridentata -- Stipa comata: Basin big sagebrush and needleandthread
- Type VIII — Artemisia tridentata: Basin big sagebrush
- Type IX — Juniperus osteosperma: Utah juniper
- Type X — Sarcobatus vermiculatus -- Artemisia tridentata: Black greasewood and basin big sagebrush
- Type XI — Bare ground

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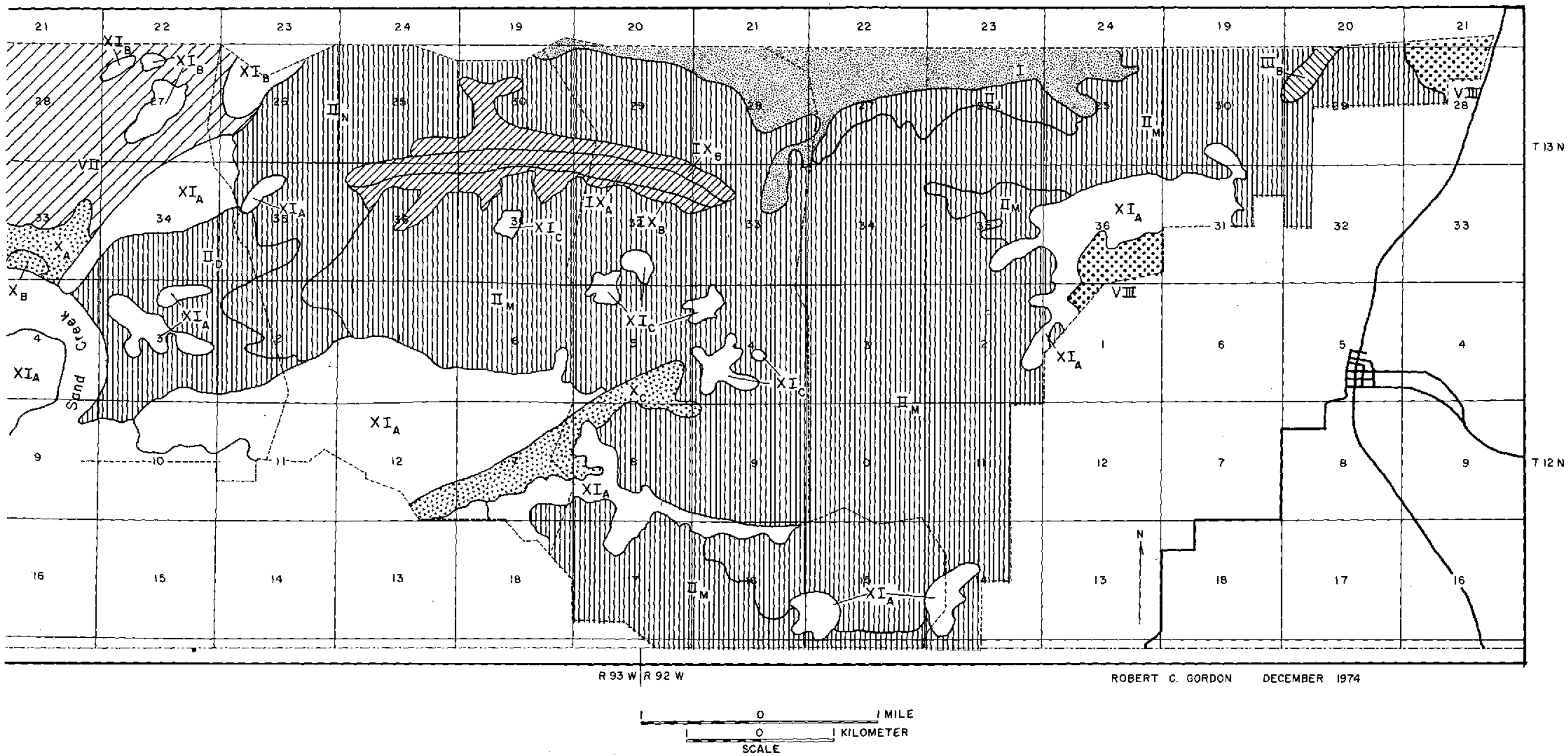

Figure 5A Range vegetation map developed from ERTS-1 imagery

RANGE VEGETATION TYPES

- Type O — Agropyron cristatum: Crested wheatgrass
- Type I — Agropyron smithii -- Artemisia tridentata: Western wheatgrass and basin big sagebrush
- Type II — Artemisia tridentata -- Agropyron smithii: Basin big sagebrush and western wheatgrass
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- Type XI — Bare ground

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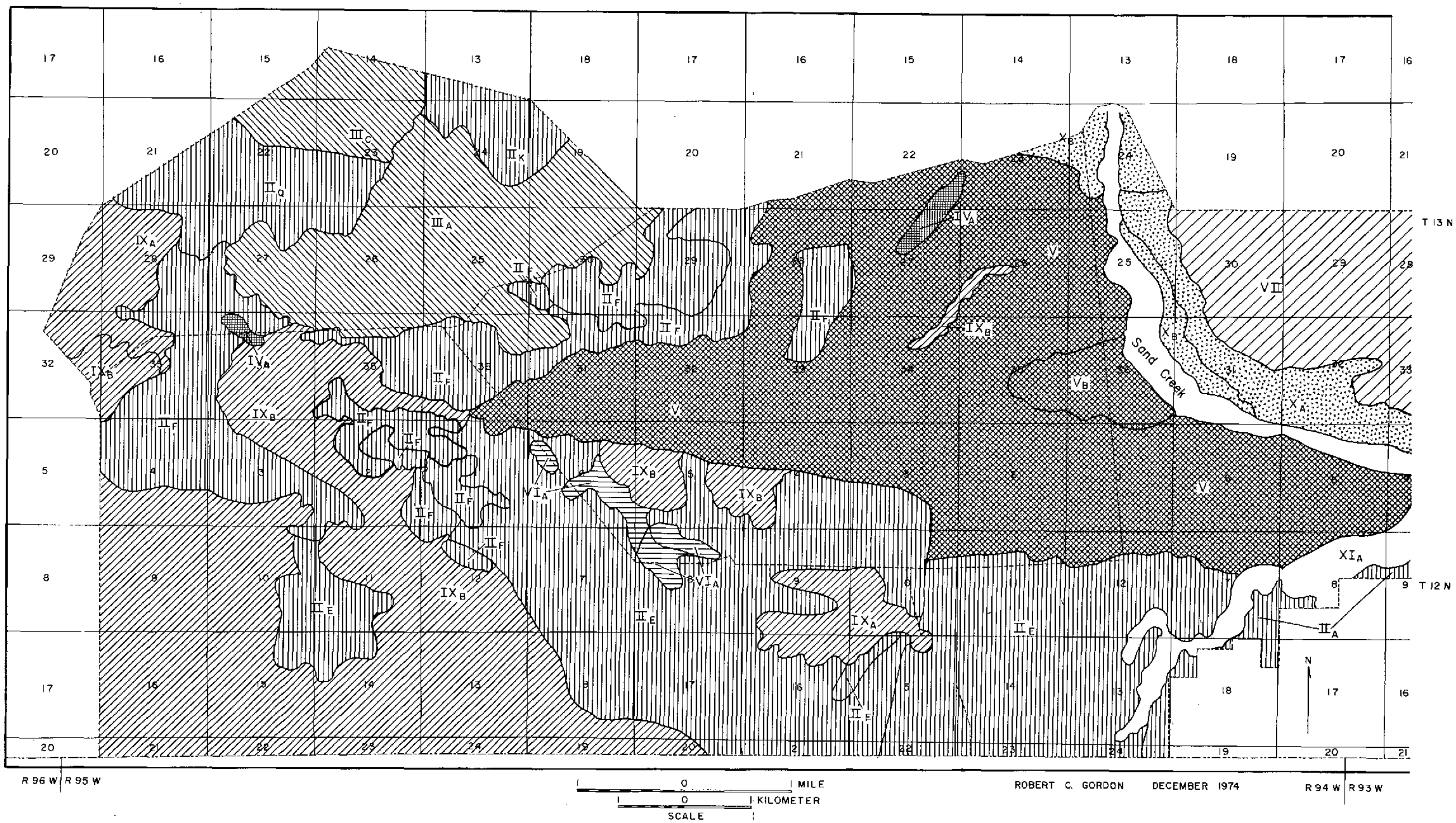

RANGE VEGETATION TYPES

- Type O — *Agropyron cristatum*: Crested wheatgrass
- Type I — *Agropyron smithii* -- *Artemisia tridentata*: Western wheatgrass and basin big sagebrush
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- Type VIII — *Artemisia tridentata*: Basin big sagebrush
- Type IX — *Juniperus osteosperma*: Utah juniper
- Type X — *Sarcobatus vermiculatus* -- *Artemisia tridentata*: Black greasewood and basin big sagebrush
- Type XI — Bare ground

Figure 5B Range vegetation map developed from ERTS-1 imagery

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Table 1. Range vegetation types and subtypes.

TYPE		SUBTYPE	MEAN COVER[A]	TRANSECTS[B]
0	*Agropyron cristatum* Crested wheatgrass		2.24	1
I	*Agropyron smithii* Western wheatgrass and *Artemisia tridentata* Basin big sagebrush		1.03/7.50	2
II	*Artemisia tridentata* Basin big sagebrush and *Agropyron smithii* Western wheatgrass	A	3.14/0.68	3
		B	3.60/3.48	5
		C	4.07/1.28	11
		D	3.70/0.24	2
		E	5.83/0.52	11
		F	6.43/1.98	10
		G	6.70/2.84	1
		H	7.89/0.58	3
		I	6.77/2.73	2
		J	9.35/0.97	2
		K	9.38/0.74	3
		L	8.80/1.34	2
		M	9.80/1.16	14
		N	9.46/0.58	4
		O	14.35/0.99	2
		P	17.56/0.74	2
		Q	17.68/0.67	3
III	*Artemisia tridentata* Basin big sagebrush and *Agropyron spicatum* Bluebunch wheatgrass	A	2.38/1.00	9
		B	2.65/1.76	1
		C	10.80/0.48	2
IV	*Artemisia tridentata* Basin big sagebrush and *Atriplex* species Saltbush	A	3.54/4.39	11
		B	4.18/1.97	2

continued

Table 1. Range vegetation types and subtypes. (continued)

	TYPE	SUBTYPE	MEAN COVER[A]	TRANSECTS[B]
V	Artemisia tridentata Basin big sagebrush and Carex eleocharis Needleleaf sedge		6.63/0.95	9
VI	Artemisia tridentata Basin big sagebrush and Gutierrezia sarothrae Broom snakeweed and Agropyron smithii Western wheatgrass	A B	0.89/1.98/0.74 6.05/1.11/0.95	5 2
VII	Artemisia tridentata Basin big sagebrush and Stipa comata Needleandthread		6.52/0.87	12
VIII	Artemisia tridentata Basin big sagebrush		4.80	1
IX	Juniperous osteosperma Utah juniper	A B	dense open	
X	Sarcobatus vermiculatus Black greasewood and Artemisia tridentata Basin big sagebrush	A B C	0.38/1.62 8.50 9.18/8.60	2 4 2
XI	Bare ground	A B C	white soil red soil mine spoil	1

[A] Mean percent cover per species listed, i.e. Type VII, sagebrush 6.52%/needleandthread 0.87%.

[B] This is the number of transects that are found in each type or subtype.

The one type not represented on the ERTS-1 map was Type 0, a small area of crested wheatgrass. This area was not visible because of its small size and because the decrease in resolution allows the amalgamation of this type with the basin big sagebrush--western wheatgrass type bordering it.

There are several problems associated with the development of the vegetation maps. The major problem with Figures 3A and 3B, drawn from aerial photography, was the poor colour processing across individual images and from frame to frame. The large amount of detail available on these photographs was difficult to group at best, without the added complication of a vegetation type appearing differently on adjacent prints. Most of the mapping was done from colour positives with colour infrared positives serving as a check when more detail was required. Usable colour infrared imagery was not available for the western part of the study area.

The information for the Skylab map was primarily taken from the S190B colour photograph because of its larger scale and higher resolution. Resolution on the S190B print was generally good throughout, although cloud cover was noted in the western part of the study area. Enlargement of this image from 1:477,979 to 1:250,000 on the zoom transfer scope caused a drop in resolution and a decrease in map detail. Smaller details noted on the original image could not be distinguished. Greater detail would be available if the interpreter were to use a computer and the data tapes available from NASA to print a map of the study area.

The production of a map from the ERTS-1 band 5 image required photographic enlargement. Attempts to map the various vegetation types directly on the ERTS image using an overlay failed because the scale of 1:1,000,000 was too minute to allow adequate drafting accuracy. The resolution on image no. 1318-17253-5 was excellent. It was cloud free over the entire study area and a large amount of detail was visible. Although some detail was lost during the enlargement process, 11 of the 12 major vegetation types were distinguished.

Several interpretation problems were encountered on both the ERTS-1 and Skylab images. The major problem was the loss of large amounts of detail when the images were enlarged to a size suitable for visual interpretation. The aforementioned problem was closely linked to the similarity of Types II and IX, the basin big sagebrush--western wheatgrass type and the Utah juniper type on both the Skylab and ERTS images. Heller (1973) also mentions difficulty separating out transitional forest. The basin big sagebrush--needleleaf sedge type also seriously overlaps the basin big sagebrush--western wheatgrass type on both the ERTS and Skylab map. Poor delineation between Types II and VI, the basin big sagebrush--western wheatgrass type and the basin big sagebrush--broom snakeweed--western wheatgrass type was found primarily on the ERTS map.

It should be noted however, that the locations of Type X, the black greasewood--big sagebrush; Type XI, bare ground; Type VII, big sagebrush--needleandthread; Type I, western wheatgrass and big sagebrush; and Type VIII, basin big sagebrush are accurately located on both the ERTS and Skylab maps. Particular attention should be given to the mined areas which were precisely located on part A of each map. The high level of detail available from these maps is in direct conflict with Carneggie and DeGloria (1973) who suggest that only a gross classification such as meadowland, rangeland and forest can be made by visual inspection.

Tonal bias influenced the interpretation of all images, particularly on the ERTS image where tonal contrasts were very subtle. Diazo composites of the ERTS image were not made because resolution loss during processing and enlarging the images negated the advantage of this technique.

The final problems noted in mapping with the satellite imagery were cloud cover and occassional low location accuracy which could be compensated by shifting to known topographic features. These problems were also reported by Heller (1973).

ERTS imagery available in the four different bands allows the interpreter to combine these images in a number of ways. Generally, band 5, the red band, is used for the identification of vegetation types, the relative brightness being inversely proportional to the amount of green vegetation. Band 7, the infrared 2 band has proved extremely useful for hydrologic work as streams and other water bodies are very distinct in this band. The net result of using multispectral imagery shows that a single image or a combination of images may be used to eliminate back-ground information which often makes feature identification difficult. Adding weight to the positive features encountered when using multispectral images are the definite advantages of regular coverage, low cost, the increased rate at which areas may be mapped (Krumpe et al. 1973).

As rangeland research with multispectral imagery continues, the range conservationist must know what distinguishes one vegetation type from another and how to use it. The relative scene reflectance which is, in part, a function of the amount and type of the vegetation is of great assistance in drawing boundaries. The total reflectance from a site is dependent on the soil type, topography, hydrology and geology of the site. The denser the vegetative cover, the less effect the soil has on the signature of the site and vice versa. This, coupled with ground data, interpreter experience, and a general knowledge of the interrelationships between pheneological changes and spectral reflectance characteristics will allow a range manager to interpret more about the vegetation than a novice interpreter. This is because the resource manager can relate what he sees and its location to his past experience. With this background, the rangeman is able to identify the slight vegetative changes in his area.

With the information gained from multispectral imagery, the interpretor has a large-scale map of major vegetation types which he may use as a base to conduct an intensive vegetation survey. In some applications, a map of this scale may be preferrable to a more detailed map.

Estimation of above-ground green biomass

Following the procedure outlined by Raines and Lee (1974), attempts were made to calibrate the photometer used to measure the relative reflectance of the vegetation plots. Unfortunately, the field photometer used in the study malfunctioned, and was not able to produce data that could be used to estimate reflectance. Thus, an absolute relationship between reflectance and above-ground green biomass could not be defined. Since the above was not detected until all field measurements were completed, new data could not be acquired.

Estimates of above-ground green biomass for the Poison Buttes site, Type II M and the Pasture C site, Type VII were completed and are in Tables 2 and 3. Table 4 contains soil moisture data for each of the sites on the days of each ERTS-1 overpass during the 1973 field season and 1974 field season. The areas sampled for a above-ground green biomass and soil moisture are shown in Figure 6.

It was extremely unfortunate that this portion of the project could not be continued to its completion at this time. However, a possible solution to this dilemina would be to plot the biomass estimates against the scene brightness for the Poison Buttes and Pasture C biomass sites. The brightness values were determined by comparison with the reference grey scales on four of the five images obtained during the five overpasses made during the 1973 summer season. Transmittance determinations were made using a Joyce Loebl (MK III CS) Microdensitometer. The June 24, image was not used because cloud cover obscured the study area. The log transmittance

Table 2. Above-ground green biomass in kg/acre for the Poison Buttes site (Type II M)

Date	Shrub	Grass & Forb	Total	Standing Dead	Litter	Total
6/06/73	227.15	328.01	555.25	--	4396.96	4396.96
6/24/73	253.43	161.07	414.50	68.41	1171.34	1239.75
7/12/73	109.64	90.89	200.53	86.21	1007.26	1093.47
7/30/73[A]	203.53	91.23	294.76	61.63	1502.93	1564.56
8/18/73	17.97	30.29	48.26	17.40	286.78	304.18
7/30/74	301.87	216.03	517.90	46.37	1289.56	1335.93
7/30/74[B]	253.87	119.88	373.75	13.17	439.36	452.53

[A] All 25 plots were completely clipped

[B] Comparative site near Poison Buttes

Table 3. Above ground green biomass in kg/acre for the Pasture C site (Type VII)

Date	Shrub	Grass & Forb	Total	Standing Dead	Litter	Total
6/06/73	133.40	63.97	197.37	--	735.55	735.55
6/24/73	63.83	133.13	196.96	48.27	724.60	772.87
7/12/73	15.06	83.57	98.63	70.25	530.75	601.00
7/30/73[A]	111.46	86.49	197.95	33.40	847.42	880.82
8/18/73	131.39	64.09	195.48	21.36	32.82	54.18
7/30/74	67.44	168.77	236.21	25.61	70.56	96.17
7/30/74[B]	42.08	71.78	113.86	16.60	181.43	198.03

[A] All 25 plots were completely clipped

[B] Comparative site near Pasture C

Table 4. Percent mean soil moisture

Date	Poison Buttes (loam soil)	Pasture C (sandy soil)
6/06/73	.73	.22
6/24/73	.46	.08
7/12/73	.24	5.45[A]
7/30/73	4.88	.27
8/18/73	1.03	.41
7/30/74	6.29[A]	.61
7/30/74[B]	1.08	.68

[A] Recent thunder shower

[B] Comparative sites

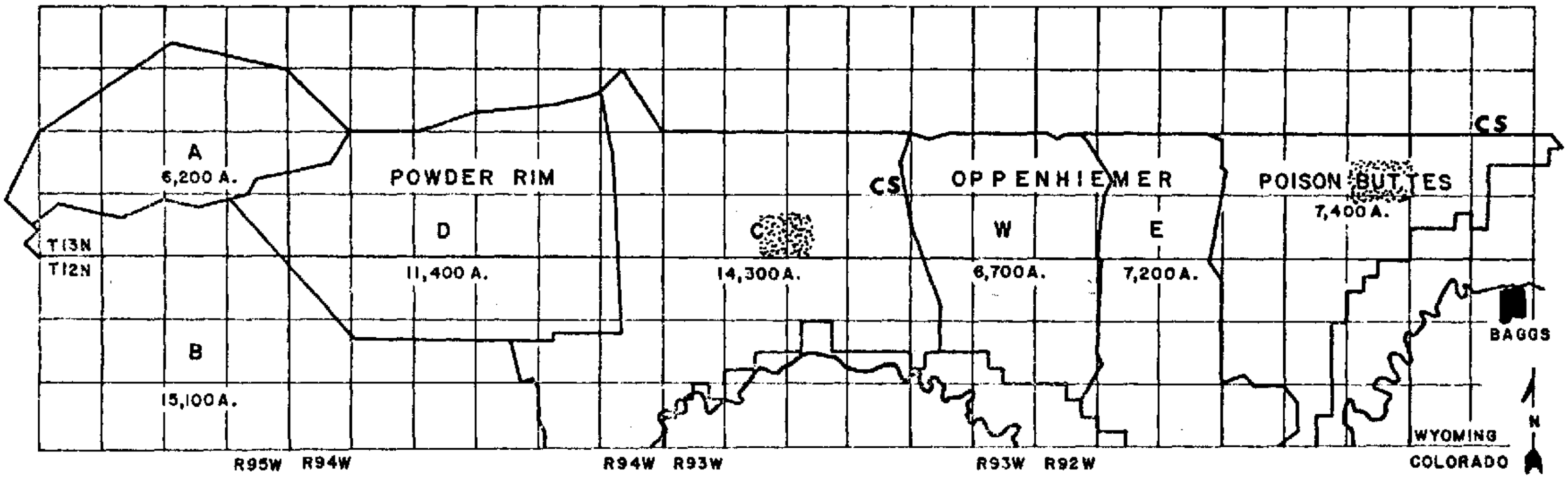

Figure 6. Location of above-ground green biomass transects and comparative sites.

transects

comparative sites **CS**

values were plotted versus above-ground green biomass (Figure 7).

The graph of band 4, Poison Buttes site shows a positive slope which indicates that green band transmittance values vary directly with the amount of above-ground green biomass. This indicates control of reflection of the green electromagnetic radiation (EMR) by vegetation in this area. The graph of the Pasture C site indicates that the reflectance varies independently of above-ground green biomass.

The Poison Buttes site, on the band 5 graph shows a negative slope indicating that red band transmittance varies inversely with above-ground green biomass. This indicates absorption of red EMR by this type. The Pasture C graph, however, indicates as it does in the band 4 graph that the reflectance varies independently of biomass.

The band 6 graph for Poison Buttes indicates absorption of near infrared radiation, .7 to .8 μm, is in the red band, rather than the anticipated reflectance increase. The graph for Pasture C again indicates a lack of direct correlation between above-ground green biomass and scene reflectance.

In band 7 the Poison Buttes graph shows a positive slope of increased reflectance with more vegetation. The points on the Pasture C graph are indeterminant and may

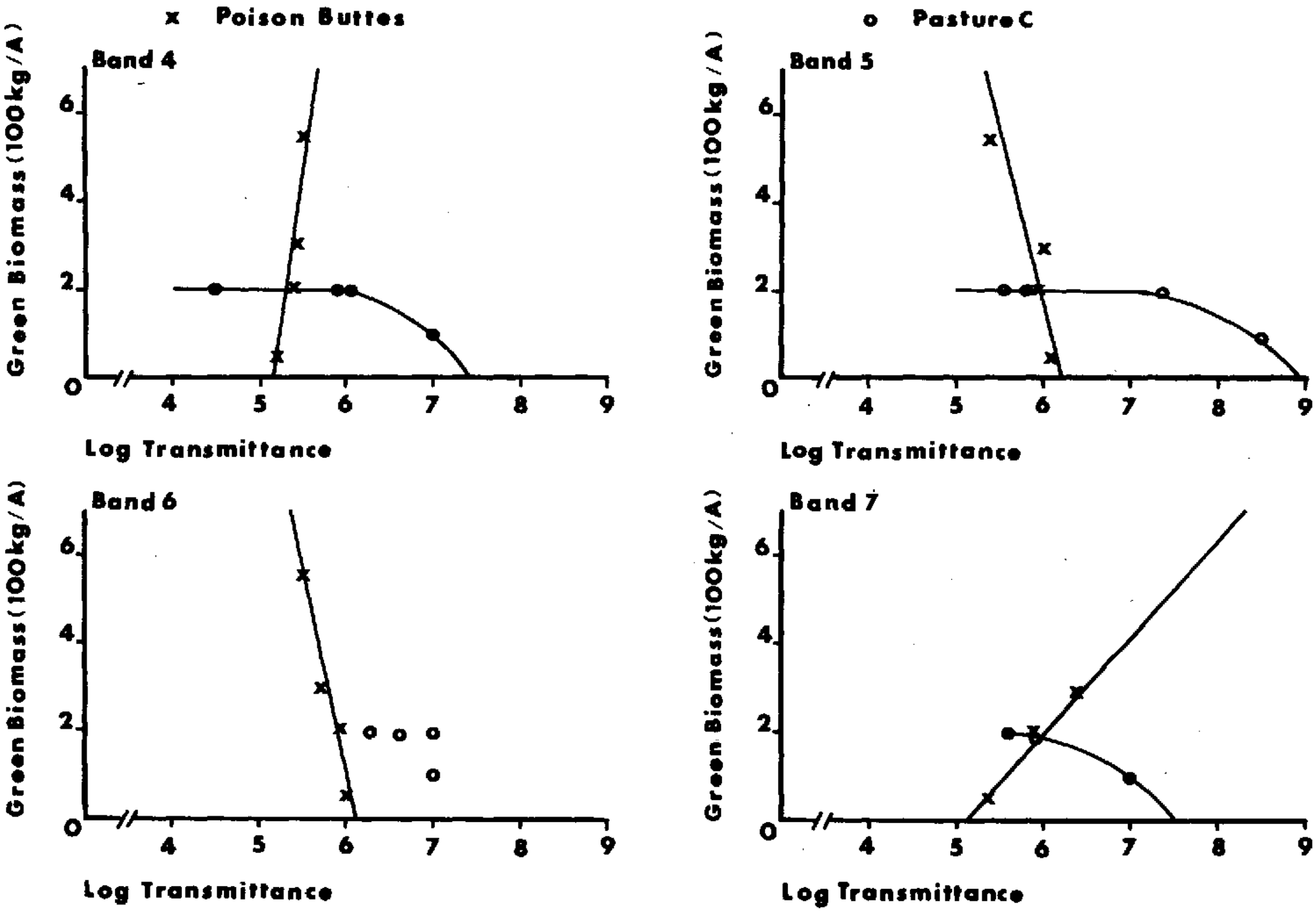

Figure 7. Graphs of log transmittance versus above-ground green biomass.

again suggest independence of the two variables. All the graphs for the Pasture C site indicated no direct correlation between above-ground green biomass and scene reflectance. This lack of direct correlation may be due to the light colour of the soil and the large amount of bare ground. These factors cause the total reflectance to be dominated by the soil reflectance rather than the vegetation reflectance. This procedure was not tested for accuracy of above-ground green biomass estimation because ERTS images for the 1974 summer season were unavailable at the University of Wyoming.

This method was attempted to provide the range conservationist with a simple and inexpensive method of obtaining above-ground green biomass data. This information could then be compared with the vegetation inventory to determine the amounts of forage available to the various grazing animals.

Should further testing prove this method of above-ground green biomass successful, it may complement Rouse, Jr. et al. (1974) whose Transformed Vegetation Index (TVI) is correlated to above-ground green biomass. Rouse, Jr. et al. (1973) imply that sparsely vegetated areas are not suitable for TVI classification.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions

The objectives of this project were: (1) to determine the usefulness of ERTS-1, multispectral imagery for mapping the rangeland resource; and (2) to estimate the above-ground green biomass by relating it to plant reflectance. These projects were established with the idea of assisting the rangeland resource manager in his daily endeavors, not to eliminate him.

The first objective, although hampered by colour bias, cloud cover, loss of detail through enlargement and the resultant poor location association caused by the latter, was successful. Both ERTS and the Skylab images provided useful maps of the range vegetation types. The ERTS-1 map contained representatives of all the vegetation types except one and it was the smallest type. The type not included was a seeded patch of *Agropyron cristatum*, Type 0. The image used was band 5 (red, .6 to .7 μm) and was taken in June, 1973. The map produced from this image would serve as a useful survey base for the resource manager.

Techniques for estimation of above-ground green biomass have not been confirmed due to the mechanical failure of the photometer. However, the graphs of log transmittance versus above-ground green biomass indicate two things. First, it appears possible, for the Poison Buttes site, to estimate above-ground green biomass by relating it to log transmittance. Secondly, for Pasture C, it may be possible to estimate the green biomass produced on this location by relating it directly to an area whose above-ground green biomass can be estimated from the ERTS imagery. These two conclusions may be tested by relating the 1974 summer imagery with the 1974 production data found in Tables 2 and 3.

Recommendations

For quick, accurate and detailed information on forage production, range condition, and range vegetation types and subtypes, rangeland resource managers need a mechanical interpreter which will produce an unbiased hard copy of the required dynamic information. To date, remote sensing has been a useful but visual tool--all the interpreter has been able to do is look at the images. The information is there and until a mechanical method of interpretation is available to write down the results, this new tool cannot be utilized to its fullest potential.

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