

AN ABSTRACT OF THE THESIS OF

Naomi H. Wilkins for the Masters of Science in Physical Science Presented on November 25, 1997.

Title: Analysis of Forest Change at Fort Leavenworth, Kansas using Landsat Thematic Mapper Data

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Landsat Thematic Mapper (TM) imagery was used to analyze seasonal and interannual change of forest stands in Ft. Leavenworth, Kansas for the years 1987, 1988, 1990, and 1994. In preprocessing the scenes were haze corrected. Differential GPS coordinates taken in the field and points from paper maps were used in the resample. The area of study was isolated from all other areas with the use of ISOCLUST an unsupervised classification module. Boolean images were produced using RECLASS and the GROUP modules for the July scenes. The boolean images were multiplied by the normalized difference vegetation index (NDVI) values for analysis of the July scenes.

In the analysis of the July scenes, the July 1987 NDVI values had the highest mean. So the July 1987 boolean image was used as a mask for all the other images. The mask was

multiplied by the NDVI values for each of the scenes. The histogram statistics were analysis for each date.

The July 1987 mean NDVI value was the highest for all the dates. In visual analysis, July 1987 had the largest extent and the most vigorous vegetation of all the scenes. In visual analysis of the June, July, and October 1988 images the most vigorous vegetation was in valleys and low-lying areas reflecting the drought conditions of that year. However, the study-forest mean NDVI values for 1988 did not reflect a drought year. The mean NDVI values in July 1988 and July 1994 have comparable results with similar values. The lowest mean occurred in July 1990. Visual interpretation of July 1990 revealed a year of low vegetation vigor. This can reflect a lag in the health of leaves to drought conditions which started in 1988 and continued into 1989.

**Analysis of Forest Change at Fort Leavenworth, Kansas
using Landsat Thematic
Mapper Data**

A Thesis

Presented to

the Physical Science Department

Emporia State University

In Partial Fulfillment

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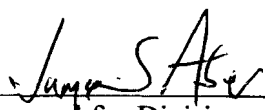
Master of Science

Earth Science Concentration

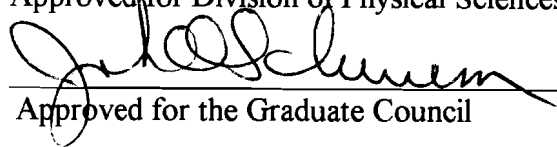
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Approved for Division of Physical Sciences



Approved for the Graduate Council

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Chapter One

INTRODUCTION

Landsat System

To study the earth, the Earth Resources Technology Satellite (ERTS-1) was launched on July 23, 1972 by NASA. The satellite, which was later renamed Landsat 1, was designed for the repetitive coverage of the earth surface between 81 degrees north latitude and 81 degrees south latitude. Landsat 1 was in sun-synchronous orbit and covered the same ground area every 18 days. It carried an instrument called the multispectral scanner (MSS). A second satellite was launched in January 22, 1975. The satellite was called ERTS-B, which was later renamed Landsat 2. Landsat 3 was launched on March 5, 1978. The first satellite with the thematic mapper (TM) aboard was Landsat 4 which was launched on July 16, 1982. The thematic mapper provides advanced multispectral scanning in seven bands. This sensor provides higher spatial resolution in images and sharper separation in the spectral region compared to the MSS. Landsat 5 was launched on March 1, 1984. Landsat 5, like Landsat 4, has a thematic mapper aboard. Landsat 5 orbits at an altitude of 705 km and covers the same ground area every 16 days. The thematic mapper on Landsat 5 is the system that is currently in operation.

The operation of the Landsat system was the responsibility of NASA up into the early 1980's when the National Oceanic and Atmospheric Administration (NOAA) took over operations in the first part of 1983 as a result of the Land Remote Sensing Act passed by Congress in June 1984. The act covered the transfer of the Landsat system into private

operation and ensured the continuity of data. In the later part of 1985 the system was commercialized. The Earth Observation Satellite Company (EOSAT) took over operation of the Landsat components. EOSAT is licensed by the Government for the commercial sale of data through other distributors. In late 1992, the Land Remote Sensing Policy Act was passed by Congress. This act established a basis for the pricing policy of image data and has a step for the continuation of the collection of data.

In the early 1970's U. S. Geological Survey EROS Data Center (EDC) formed a partnership with NASA to archive and distribute the Landsat data. EDC still retains primary responsibility for the archive of Landsat data for the federal government.

Ft. Leavenworth

A study of the Ft. Leavenworth area is done using Landsat TM data. The data was recorded from the Landsat 5 thematic mapper and Figure 1 shows the area covered by full scene.

Ft. Leavenworth lies in the Middle Missouri Subbasin. The Missouri River is located on the eastern side of Ft. Leavenworth. Figure 2 shows the region covered by TM data in the form of a digital elevation model (DEM). Lower elevations are in light blue and lie in bottom lands of river valleys. The highest elevations are displayed in red and lie in the western portion of the region. A portion of the study area lies on a ridge top, which can be seen as an the enclosed area on the DEM.

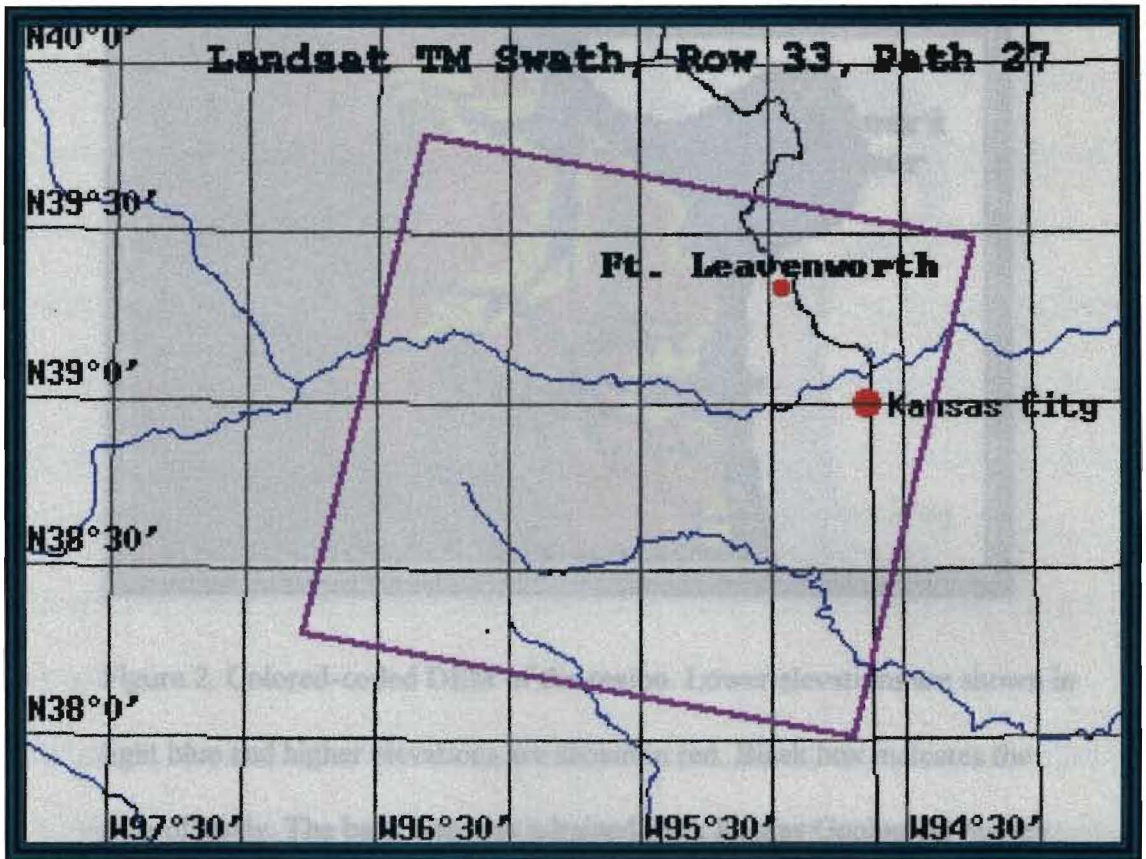


Figure 1. Full scene covered in a swath, row 33, path 27. The study area is located at Ft. Leavenworth.

The region is underlain with Pennsylvanian bedrock. Figure 3 shows the three groups which make up the Upper Pennsylvanian Series in the region. These groups are the Shawnee, Douglas, and Lansing Groups. The bedrock is gently dipping sedimentary strata composed mainly of limestone, shale, and some sandstones. Unconsolidated material include glacial and alluvial deposits.

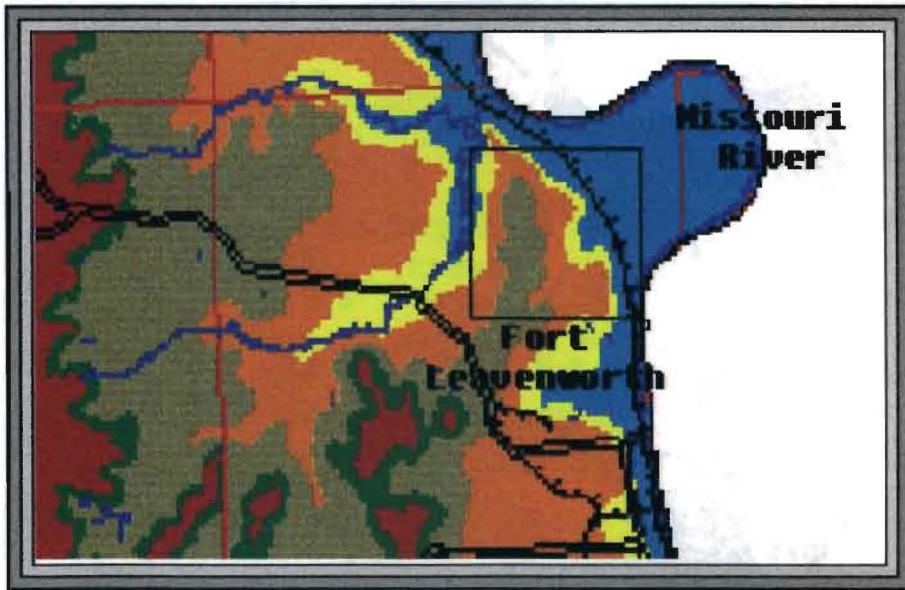


Figure 2. Colored-coded DEM of the region. Lower elevations are shown in light blue and higher elevations are shown in red. Black box indicates the area of study. The base map was obtained from Kansas Geological Survey.

Forested Area

The area under study is a preserved hardwood forest. Maximum age of the trees in the forest is approximately 150-200 years old. In the forest ecosystems the study area is considered to be the old forest or undisturbed area. The old forest is composed of ash, box elders, buckbrush, cottonwood, hackberry, oak, pawpaw, pecan, silver maple, sycamore, and walnut trees (M. Nowak, personal com.).

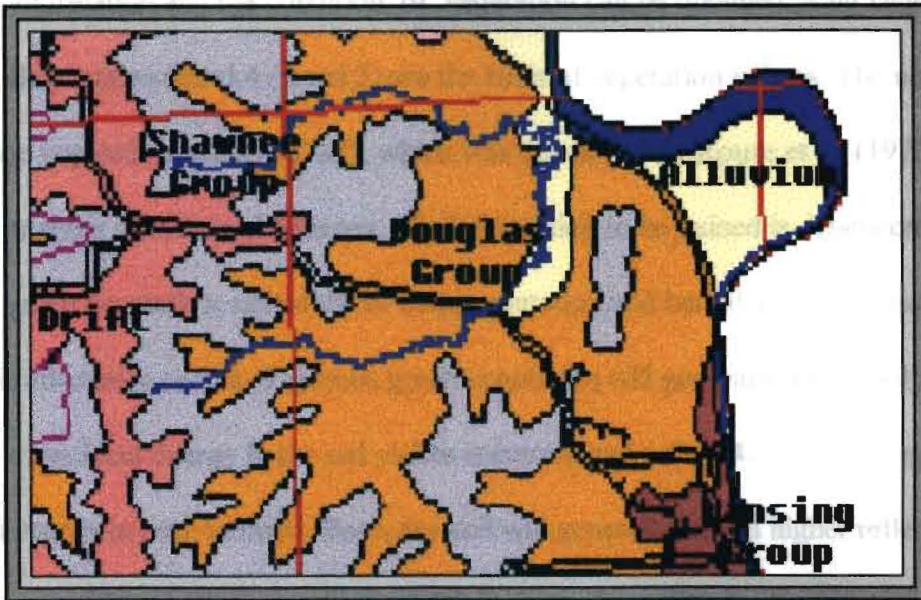


Figure 3. Location of the Lansing, Douglas, and Shawnee Groups of the Pennsylvanian series in the region. In the area where the Shawnee group lies in the Douglas group this ridge is known as the Oread Escarpment. The base map was obtained from the Kansas Geological Survey.

Methods

The northwestern section of Ft. Leavenworth, Kansas is analyzed for seasonal and interannual change in the forested area. This is done with visual interpretation and statistical analysis of TM data with the use of the IDRISI software.

In preprocessing the scenes are haze corrected and resampled. The TM data are then processed with the goal of reducing the number of bands to singular pixel values that can be assessed for change in conditions of the forested area.

Basic information and the condition of vegetation can be obtained using vegetation indices. Band ratios (band 4 / band 3) are the basis of vegetation indices. The normalized difference vegetation index (NDVI), which was developed by Rouse et al. (1973), was used to analysis data from the scenes. The information to be gained is dependent on healthy green vegetation, unhealthy or dead vegetation and bare dry soils having different spectral reflectance curves. Vigorous green vegetation will generally absorb 80 to 90 percent of incident energy in the red visible spectrum and reflect 40 to 50 percent of the incident energy in near-infrared. Bare, dry soil will generally have a higher reflectance value than healthy vegetation and lower reflectance values than dead vegetation in red visible spectrum. Bare, dry soil will generally have lower reflectance values in near-infrared. So in general the brighter the pixel NDVI the more active vegetation present.

To isolate the data that represented the forested area under study a technique similar to the iterative self-organizing data analysis technique (ISODATA) was used. This method was developed by Ball et al. (1965). In Idrisi this is called ISOCLUST, which is an unsupervised classification used to isolate clusters with algorithms. Further isolation involved the use of the GROUP module and RECLASS module. This produced a boolean image (forested area 1, all other areas 0). This image was multiplied by NDVI values for the analysis of the July data. The July 1987 boolean image was used as a mask for all the other scenes. The mask was multiplied by the NDVI values for each scene. Histograms were used in the analysis of the scenes.

Scope of the Study

This study is part of a larger study in which the results will be compared to tree-ring cores and climatic information. This is done to see how TM imagery corresponds to climatic change and the growth of tree-rings. The response of tree-rings growth to climatic change can be seen in the size of the growth ring. Smaller growth rings can signify a change in growing conditions. Comparing tree-ring growth to climatic conditions can show that in years with drought there is a corresponding reduction of tree-ring size.

In the analysis of the climatic variables, four sites were analyzed for change. Figure 4 shows the general location of the recording stations. The sites are Saint Joseph, Mo., Kansas City International (KCI) airport, Leavenworth, Kansas, and Atchison Kansas.

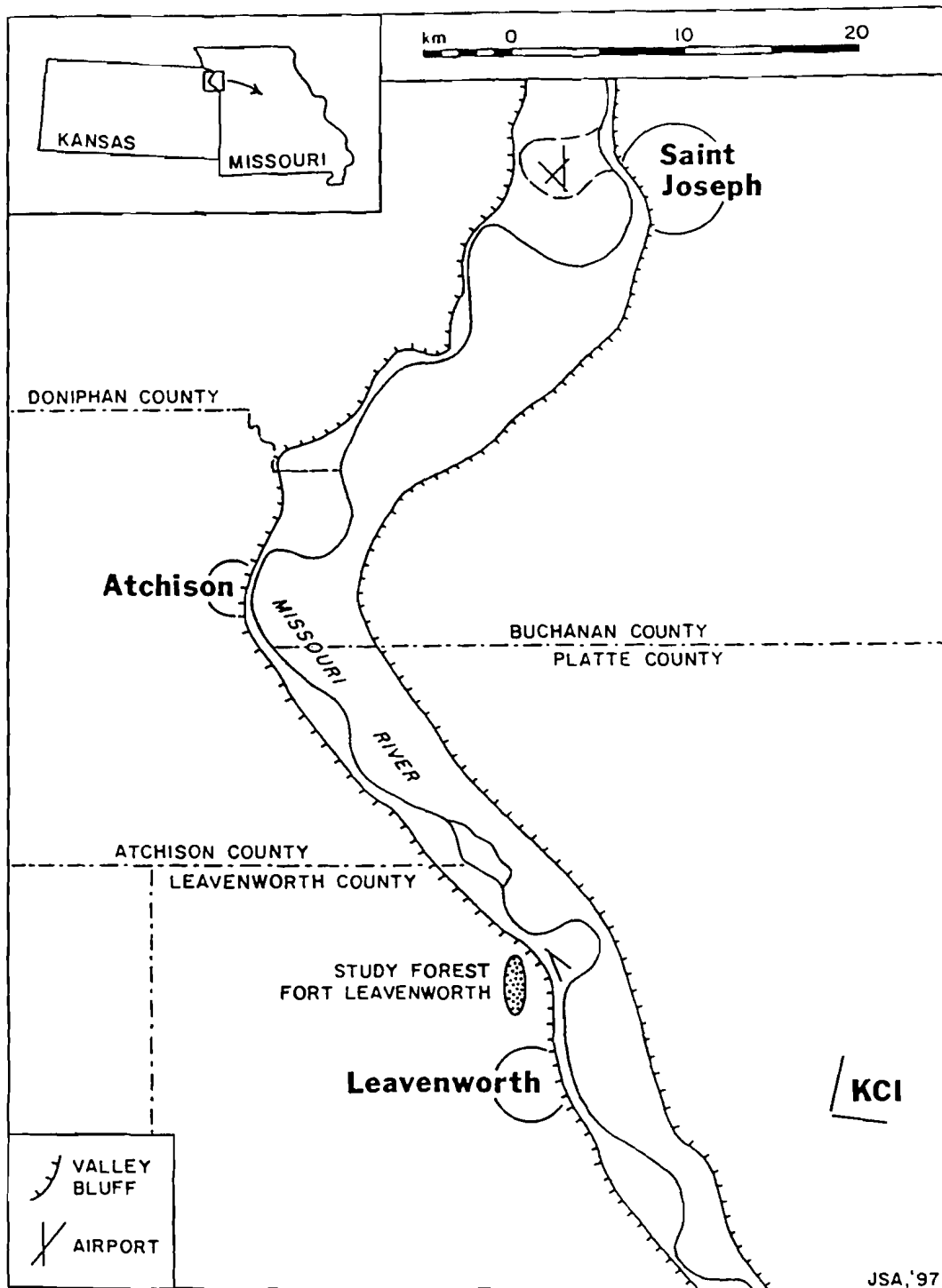


Figure 4. General location of climatic recording stations used in the larger study. The study forest area is shown north of Leavenworth, Kansas.

Chapter Two

PREVIOUS STUDIES

Forest Studies

The analysis of forested areas involving the use of Landsat TM data is still a fairly young field of investigation. Many large scale studies are done to see if the process will give good results and be cost effective. In forest change much of the information is outdated, which makes it difficult to reach decisions on management and policies. Forested areas can lie in very remote locations making it difficult to obtain accurate information. Areas that were inaccessible before can be studied with the use of remote sensing.

A study done by Sader and Widde (1992) used Landsat multispectral (MSS) and Thematic mapper (TM) data to demonstrate a new and simple technique to display and quantify forest change at five to ten year intervals. This corresponds with the U. S. Forest Service survey cycle. In Maine softwood forests are a major economic resource. The study was conducted to see if it would be timely and cost effective for statewide analysis of forest change and monitoring of the forests. In the study, a normalized difference vegetation index (NDVI) was used as a means of showing major increases or decreases in green leaf biomass. Harvesting is likely to cause a decrease in NDVI values and regeneration of trees is likely to cause an increase in NDVI values. A study done by Bauer et al. (1994) provided the basis for the Minnesota Department of Natural Resources and USDA Forest Service to define and begin to implement an annually updated statewide inventory system which utilizes multirate Landsat TM data to detect changes in forest cover.

The reduction of forest and woodland habitats has prompted the development of resource management tools to assist in future forest conservation. The conservation and preservation of forests are vital because of their role in global carbon cycling and species diversity (Bormann, 1985). A study done by White et al. (1995) in California used TM data and a geographical information system (GIS) to map forest at Lassen Volcanic National Park. The knowledge of forest species composition is an integral part of designing and implementing resource management policies in a national park. The study showed that the use of an unsupervised classification or clustering technique in TM data can generate generic level maps (tree genera) with an accuracy of 73 percent, but the identification of tree species using only spectral data may be difficult. The study used the generic level maps modified with terrain data in a GIS to produce forest species maps at an accuracy level of 58 percent.

A study by Schriever and Congalton (1995) in New Hampshire used TM data to evaluate seasonal variability as an aid to cover-type and/or land classification in the northeast. Data from May (bud break), September (leaf on), and October (senescence) were used to explore whether different leaf phenology would improve the ability to generate forest-cover-type maps. The classification of forest cover type with the use of satellite imagery can define cover types at the stand level. In seasonal variability, the October classification accuracy was highest. The hypothesis was that the difference in hardwood foliage reflectance characteristics (e.g., leaf biomass, water moisture, and chlorophyll absorption) between species would be at a maximum during autumnal

senescence. Classification of the May imagery was better than the September imagery because of bud break. Some species break bud sooner than others, and chlorophyll adsorption rates, water moisture levels, and leaf biomass levels should be distinctly different between species in May. The study found that classification of TM data can discriminate specific hardwood species, and the use of different images during a season may facilitate mapping of specific species more effectively.

The study of the environment using Landsat TM data on forest areas can include leaf area index (LAI), according to Herwitz et al. (1990). The leaf area index is an expression of the leaf area of a plant community relative to a unit area of terrain. The LAI is thought to reflect the primary production capacity and the photosynthetic ability of a plant community. It can be used to monitor the health of a community over time. Reduction in LAI may reflect changes caused by water stress, pollution, pests, and diseases. Field methods for obtaining LAI includes destructive sampling of trees.

In the study TM band 4/3 ratio data were compared to field work of LAI to see if they correlate. In previous studies, they had seen significant correlation between the ratio data and LAI. The TM data were used to determine if the ratio data could detect changes in LAI quickly and nondestructively in central Massachusetts. In the study, no significant correlation could be found between the ratio data and LAI. When compared to LAI in the thinned forest the ratio data showed a comparable reduction of 20% over the time studied to the calculated LAI of 28%.

Chapter Three

METHODOLOGY

Processing of Landsat TM Scenes

The Landsat TM scenes were processed on a PC with the use of the Idrisi software. The series of scenes that was processed was taken from row 33, path 27. Coverage of each scene is a 185 x 185 km swath. The first group of scenes includes July scenes from 1987, 1988, 1990, and an October scene from 1988. The datasets were received on CD's from U.S. Geological Survey EROS Data Center in Sioux Falls, South Dakota. The second group of scenes was received in ERDAS format from the Kansas Applied Remote Sensing Center, Lawrence. This group included scenes from 1994 in May, July, September, and a scene from June 1988. Table 1 lists the scene dates and the scene ID numbers.

Table 1. Scene dates, ID numbers, and Sun elevation.

SCENE DATE	SCENE ID	SUN ELEVATION
07/23/87	5027033008720410	58
06/07/88	5027033008815910	62
07/25/88	5027033008820710	58
10/13/88	5027033008828710	38
07/15/90	5027033009019610	58
05/23/94	5027033009414310	59
07/10/94	5027033009419110	58
09/28/94	5027033009427110	41

Preprocessing

The first group of scenes was loaded into the PC from writeable CD's, and the files were renamed to include an *.img extension for use in Idrisi. A documentation file was made using information from the header file. A header file is included with the scenes and provides information about the scenes. The information included pixels per line, which was used as columns, and lines per data file, which was used as rows in the documentation file. The pixel spacing was 28.5 m. The pixel spacing (resolution) and units of measure were rounded to 0.03 kilometers for use in the data set. The number of columns was multiplied by the resolution to determine maximum X coordinate, and the number of rows was multiplied by resolution to determine maximum Y coordinate. The minimum X and Y coordinates were set at zero. The reference system used was a plane grid. Zero and 255 were used as minimum and maximum cell values in the scenes. The value units were listed as the TM band for each file. The documentation files for the four scenes were changed separately because the number of columns and rows changed in each of the four scenes. The four scenes included seven images of spectral bands one through seven.

The second group of scenes was loaded into the PC from writeable CD's, but the initial preprocessing was different from the first series of scenes because of the change in formatting. The second group of scenes was in a generic BIL format which included all bands, 1 - 7 in one file per scene. These files were imported into Idrisi using the BILIDRIS module which is a BIL-format to Idrisi conversion module. The BILIDRIS module separates the bands into individual files based on the number of bands indicated. The number of columns and number of rows for the conversion were taken from the header

file. Seven bands (1 - 7) were made for each of the four scenes. Further preprocessing was the same for both the first and the second group of scenes.

A window was extracted from each scene using the leftmost cell of an old missile site at Ft. Leavenworth, Kansas as a marker in each of the scenes. To determine the upper left corner for the extracted image, 400 was subtracted from columns and 200 was subtracted from rows. To find lower right corner 699 was added to upper left corner in columns and 499 added to rows. The extracted or windowed image was 700 x 500 cells, which can be displayed on a high-resolution monitor without any reduction.

Composites

The combination of bands 1, 2, 3, 4, 5, and 7 are used to enhance features in the scenes. Table 2 shows the part of the spectrum each band represents.

A color composite can be made with the combination of different bands to represent the blue band, green band, and the red band in the COMPOSIT module. A natural-color composite would have band 1 as the blue band, band 2 as the green band, and band 3 as the red band (Figure 5). False-color composites use other combinations of visible and/or infrared bands. The false-color composites were made using band 3 as blue, band 4 as green, and band 5 as red (Figure 6). This combination shows active vegetation in greens. This was done for general examination of forested areas within the study region.

Table 2. Landsat TM band number, spatial resolution, spectral color and the wavelength range.

Band Number	Resolution (Meters)	Spectral Color	Wavelength Range (Microns)
1	30	Blue-Green	0.45-0.52
2	30	Green	0.52-0.60
3	30	Red	0.63-0.69
4	30	Near Infrared	0.76-0.90
5	30	Mid Infrared	1.55-1.75
7	30	Mid Infrared	2.08-2.35

Natural-color Composite



Figure 5. Natural-color composite of the Ft. Leavenworth vicinity. The Red rectangle indicates the study-forest location. Active vegetation is shown in shades of green.

Cultural features and bare ground shown in white to light blue.

False-color Composite

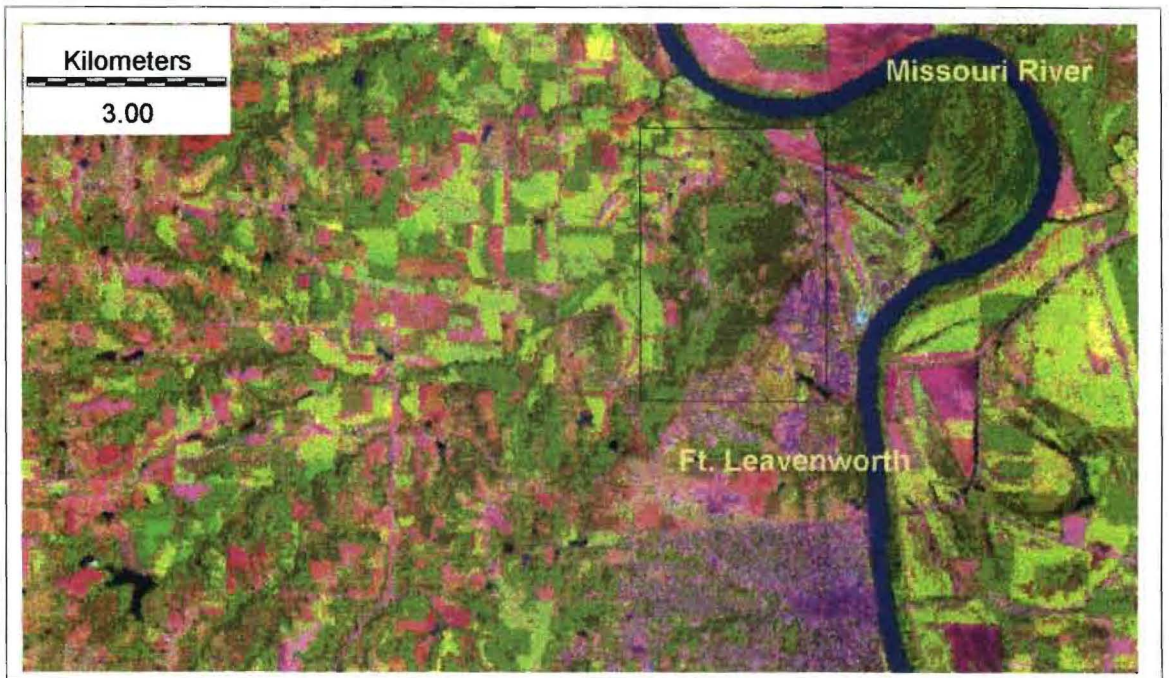


Figure 6. False-color composite of the Ft. Leavenworth vicinity. The black rectangle indicates study-forest location. Active vegetation is shown in shades of green. Cultural features and bare ground are shown in pink to purple color.

Radiometric Preprocessing

Image restoration is the goal of radiometric preprocessing. Image restoration is the effort to remove the undesirable influence of atmospheric interference, system noise, and sensor motion (Campbell, 1996). As the sun rays, the largest source of electromagnetic radiation, interact with the atmosphere and the surface of the earth, energy is transmitted, absorbed, reflected, scattered, or re-emitted. Each object on the earth has its own characteristics or spectral signature in the way it reflects, adsorbs, transmits, scatters, or re-emitts radiation. This information can be used to remove or minimize undesirable effects. Many things can affect the spectral response pattern or the spectral signature of the remotely sensed data. Some of the conditions may include sun angle, cloud cover, water vapor, aerosols, dust, weather, topography, time of day, and plant conditions.

The scenes are haze corrected to minimize atmospheric effects. This is done by using a dark body or open water body as a basis for correction, because they have values at or near zero in the infrared portion of the spectrum. This value is used to correct all others band values. The value 1.0 was used in the scenes for haze correction. A histogram of each image was prepared to determine the actual minimum values. All minimum values were set at 1.0 by either adding or subtracting determined values with the use of the SCALAR module. Figure 7 shows a histogram for a clear atmosphere and a hazy atmosphere.

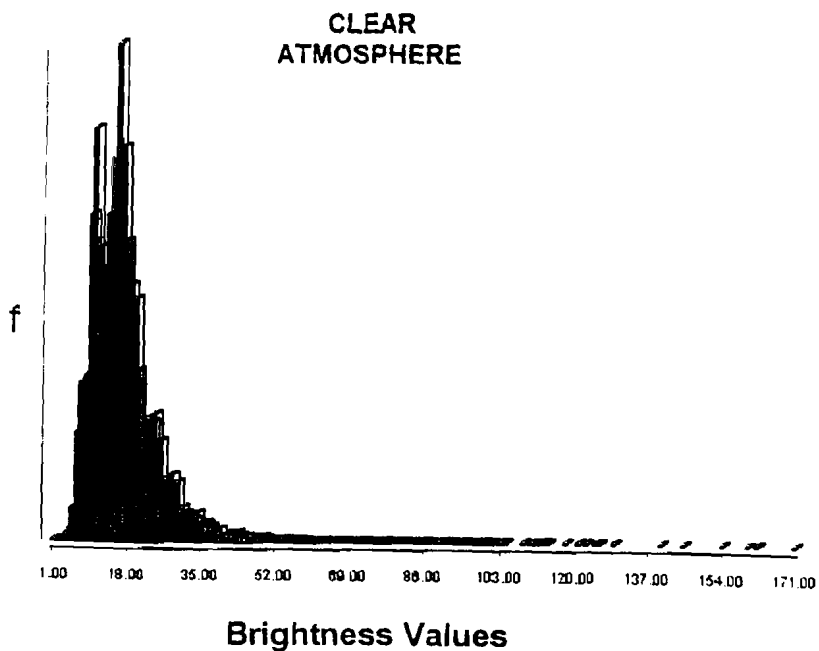
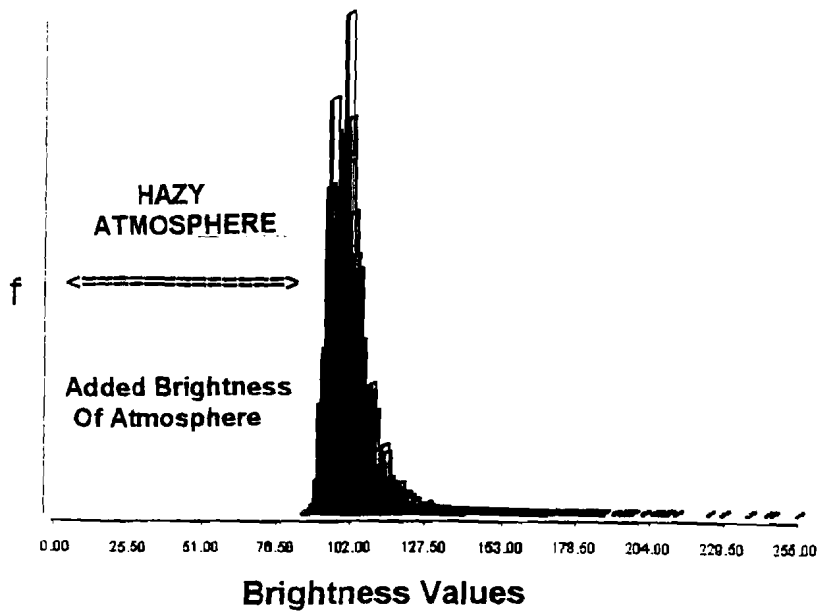


Figure 7. Top figure shows a hazy atmosphere in band 1. The added brightness of the atmosphere caused the lowest value to be 86 in the histogram. The bottom figure shows a clear atmosphere with a low value of one.

Resampling

The scene files were resampled geometrically using the ten ground coordinates from the GPS unit (see field methods) and six UTM coordinates determined from paper maps. A correspondence file, which contains old x/y coordinates in the original scene and new x/y coordinates for the resampled scene, was made in the EDIT module. The old x/y values were determined with the use of a map of the Ft. Leavenworth area with the marked features used to take GPS coordinates. These coordinates were located by displaying the scene on the monitor and with the use of the computer mouse. The coordinates taken from the scene were recorded as the old x/y values. The ten GPS coordinates were used as the new x/y values. Six features which appeared on the paper maps and on the Landsat TM scenes were used for the resample of the area outside Ft. Leavenworth. Old x/y coordinates were taken from the scenes and new x/y values were determined from the paper maps.

In the resample, the reference system was changed from a plane grid to a UTM-15 (Universal Transverse Mercator projection, Zone 15) reference system. The resample solves an equation that determines the relationship of the output cell value based on the location of the input cell value. This is called a rubber-sheet transformation. The use of nearest-neighbor interpolation transfers the value of the input cell closest to the position in the output cell. The bounding UTM coordinates (maximum x/y and minimum x/y) for the resample were determined from paper maps. These coordinates were picked on the basis that they lie outside the scene area. The bounding coordinates used in the resample are

minimum x: 319.6 km E, maximum x: 342.5 km E, minimum y: 4348.0 km N, and maximum y: 4366.9 km N. The number of columns for the resampled scenes was determined by taking $\text{max } x - \text{min } x / \text{resolution}$ ($342.5 - 319.6 / 0.03 \text{ km}$). The number of rows for the resampled scenes was determined by taking $\text{max } y - \text{min } y / \text{resolution}$ ($4366.9 - 4348.0 / 0.03 \text{ km}$). The number of columns used in the resample was 763, and the number of rows was 630.

In the resample of an area, a table displays the results of the resample and positional error of the x/y coordinates. A copy of the results of the resample for each of the scenes is located in chapter five. Table 3 is a description of the area where the control points are located and the coordinate pairs used in the resample.

Table 3. Differential GPS coordinates for ground control points.

FT. LEAVENWORTH, KANSAS-- 22-23 MAY, 1997

(UTM zone 15)

Ft. Leavenworth Map (location of coordinates marked on map)	
1. Southwest corner parking lot, skeet shooting range.	0332.840 km E, 4357.995 km N.
2. Bell Point, southwest corner large storage/parking area.	0332.758 km E, 4358.725 km N.
3. South end ridge, northeast corner water tank.	0332.746 km E, 4357.513 km N.
4. Airport runway, center of south end.	0335.355 km E, 4358.549 km N.
5. Airport runway, center of north end.	0334.762 km E, 4360.249 km N.
6. Service area east of airport, northwest corner of parking lot.	0335.820 km E, 4359.953 km N.
7. Northwest corner of fort at Coffin Road.	0333.051 km E, 4360.251 km N.
8. Circular tanks, east side of ridge top.	0333.293 km E, 4359.133 km N.
9. Southeast corner of Warehouse Road.	0334.880 km E, 4355.844 km N.

10. Federal prison, southeast corner parking lot.

0333.373 km E, 4355.055 km N.

UTM COORDINATES TAKEN FROM PAPER MAPS

Leavenworth Quadrangle Map 1:62,500

11. Road junction, Highway 45, East of Mud Lake.

0339.976 km E, 4354.452 km N.

12. Road junction, East of Hazelwood School.

0340.286 km E, 4362.092 km N.

13. Southeast corner of cemetery in Kickapoo, Kansas.

0330.238 km E, 4362.405 km N.

14. Road junction, West of Salt Creek Valley.

0328.524 km E, 4358.214 km N.

Kansas City Quadrangle Map 1:250,000

15. Road junction, East of Highway 73.

0323.625 km E, 4363.500 km N.

16. Road junction, Northwest of Stellmans Lake.

0322.625 km E, 4355.500 km N.

Field Methods

Differential Global Positioning System (GPS) equipment was taken into the field to acquire UTM coordinates. The differential GPS unit was donated to the university by Lowrance Electronics of Tulsa, Oklahoma for better accuracy in field measurements. The GPS unit has an accuracy of ± 5 meters. This unit uses a base station (Coast Guard Station, Kansas City) with a fixed position to improve accuracy at unknown locations. In the interest of national security, the government has in place selective availability for civilian GPS units. Some of the signals from satellites can be encrypted causing a loss of positional accuracy. The fixed position of a GPS receiver (Coast Guard Station) allows the estimation of the errors from the selective availability, which are applied to the readings of the mobile GPS unit to improve accuracy. The UTM coordinates were corrected with a signal received from the base station.

The readings or UTM coordinates were recorded in field notebooks and on small scale maps provided by Matt Nowak (Natural Resources Director) at Ft. Leavenworth. Features were selected on the basis that they would be clearly visible and distinct in the Landsat TM scenes. The coordinate pairs and the map information were used in the resample of the TM scenes.

Processing

The preprocessed scenes were used to construct slope-based vegetation indices. Ratio images were made using infrared/red ratio (band 4 / band 3). Normalized difference vegetation index (NDVI) images were made in the OVERLAY module using the equation

first - second / first + second (band 4 - band 3 / band 4 + band 3). Raw NDVI values are fractional numbers ranging from -1.0 to +1.0. The NDVI's were further processed by using the SCALAR module to first add a value of 1.0 to the image, then multiply the image values by 100. This was done so the values fall within the byte-binary range of 0-255.

The TASSCAP module can be used to determine changes in vegetation indices from year to year. This is an orthogonal transformation developed by Kauth and Thomas (1976). It takes TM bands 1, 2, 3, 4, 5, 7 and transforms the bands into four new bands with the use of a global coefficient. The new vegetation index bands include the soil brightness index (SBI), green vegetation index (GVI), yellow vegetation index (YVI) and non-such index (NSI). The coefficients used for the transformation of the bands in the green vegetation index are $(GVI) = (-0.24717TM1) + (-0.16263TM2) + (-0.40639TM3) + (0.85458TM4) + (0.05493TM5) + (-0.11749TM7)$. Addition of the negative coefficients on the visible bands minimizes background soil effects and the positive coefficients on the near infrared bands enhance the green vegetation.

The soil brightness index can be used in determining soil moisture conditions. The green vegetation index shows green vegetation cover or biomass on the ground. The yellow vegetation index can show information on decaying vegetation or dry vegetation. The fourth index band, non-such index, has to do with atmospheric noise.

The July scenes were utilized in determining which year (1987, 1988, 1990, 1994) had the maximum growth. These scenes were chosen because there was a July dataset for each of the study years. The July scenes are cloud free, which is difficult to find earlier,

because of the rainy spring season. Sun elevations are fairly high in the July scenes so there is less shadowing effects (see Table 1).

Two methods were derived to isolate the forested areas in the July scenes. The first method uses the TASSCAP Vegetation Indices. The three indices (SBI, GVI, YVI) and a false-color composite (bands 2, 3, 4) were used in ISOCLUST to isolate the area of interest (see chapter four). The second method uses bands 3, 4, 5, 7 and a false-color composite (bands 2, 3, 4) with ISOCLUST to isolate areas of interest (see chapter four). The ISOCLUST module performs an unsupervised classification method, which uses a clustering algorithm to form numerical clusters of pixels based on spectral location. The method makes passes through the data forming new mean vector assignments and partitions for each iteration. The first iteration uses the mean and standard deviation of each band entered (bands 3, 4, 5, 7) as the feature space for the twenty clusters. The pixels are compared to the cluster mean and grouped with the cluster which is nearest. The second iteration starts out with a new mean for the cluster. The new mean is based on spectral location or the actual location of the cluster. This involves analysis of the following parameters: minimum members in a cluster (%), maximum standard deviation, split separation, and minimum distance between cluster means. Then the entire process is repeated with each candidate pixel once again compared to the new cluster means and assigned to the nearest cluster mean (Jensen, 1996). The process is continued until there is little change, or in this case three iterations of the pixels were done. The number of clusters is chosen based on a histogram which shows the graphical range and distribution

of data. Twenty clusters were picked for the scenes because this was the maximum allowable.

The study area was further isolated by determining which cluster values represented the forest region. These values were determined by field studies, maps, and visual interpretation of the scenes. A boolean image was made from the scene with the RECLASS module. The forested areas (determined values) were reclassified with a value of one (1) and all other areas were reclassified as zero. The boolean image shows the forested area colored and all other areas black (see chapter four). The GROUP module was used to group together all connected pixels with the same identifier. This isolated the forested area of interest from other forested areas. The value that represented the forested study area was reclassified to the value of one and all other areas were reclassified to zero. The boolean image was multiplied by the NDVI image in the OVERLAY module. This gave the study-forest pixels the NDVI values and left all other values as zero. A histogram of each July scene was constructed for analysis (see chapter five).

The July 1987 scene showed maximum growth of vegetation among the four July scenes. On this basis, the boolean image that represents the July 1987 forested study area was used as a mask for all the other scenes. The mask was used to multiply the NDVI values in each of the scenes. A histogram of each scene was used in the analysis of seasonal and interannual change of the forested study area (see chapter five).

Chapter Four

ANALYSIS

Analysis of TM Data

In the qualitative analysis of the TM data visual interpretation is used to examine the data in image form. Multispectral images were made by combining bands 1, 2, 3, 4, 5, and 7. Table 4 lists the bands and the information that can be obtained from each band.

Table 4. Lists the bands and the information that can be obtained (Avery et al., 1992).

BAND	INFORMATION FROM EACH BAND
1	Water penetration, Capacity to show the difference in rock and soil surfaces from vegetated surfaces, smoke plumes, cultural features.
2	Water turbidity, sediment content in water, plume (algae) population in water, different classes of vegetation, cultural features.
3	Distinguish soils from vegetation, depiction of snow cover, discrimination of rural and urban areas.
4	Distinguish condition of vegetation and different types of vegetation, showing water bodies, distinguish wet and dry conditions of soils, identify flooded areas, swamps, and coastal wetlands.
5	Water content in leaf tissue, soil moisture content, ferric iron, distinguish between snow and cloud cover.
7	Water content in vegetation, soil moisture content, hydrous materials.

In the visual interpretation of an image spatial information such as location, orientation, texture, size, and shape of features can be obtained. Figures 8-15 show a series of false-color composite images (bands 2, 3, 4) used in the initial visual interpretation. The composites depict scenes from July 1987, June 1988, July 1988, October 1988, July 1990, May 1994, July 1994, and September 1994. False-color composites show active vegetation in shades of red. Water bodies appear in shades of black to blue except for the Missouri River. Cultural features such as roads, buildings, and the airport runway are shown in a cyan color. Bare ground or fallow lands are depicted in shades of green to cyan.

In the visual analysis of the scenes, the July 1987 image shows maximum growth in active vegetation throughout the scene. The July 1994 image appears to more growth because of the dark tone of the image but has slightly less vegetation than the July 1987 image. The July 1988 image has the least amount of vegetation in the July images because 1988 was a drought year.

Seasonal change can be seen in the 1994 images. Emergence and early growth can be seen the May 1994 image. Fields are seen as the bare ground of plowed fields or new growth of planted crops. Expanded growth of vegetation during the growing season can be seen in the July 1994 image. The harvesting of winter wheat is done in July. The onset of senescence and harvesting of other crops can be seen in the September 1994 image.

JULY 1987

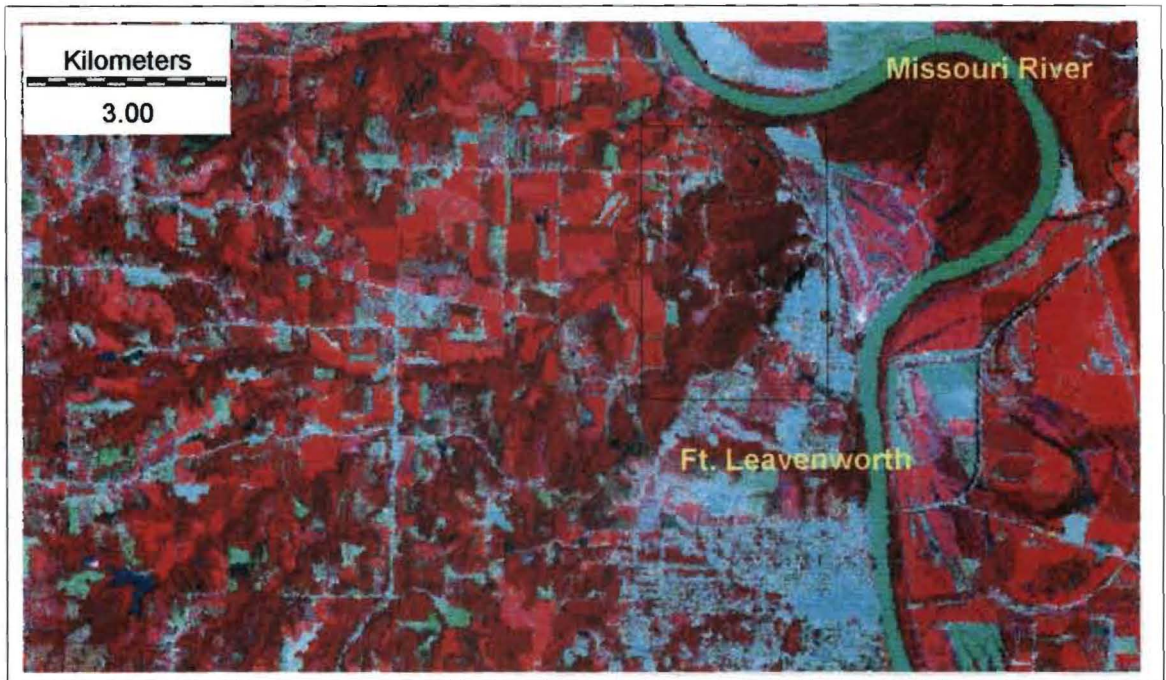


Figure 8. False-color composite of Ft. Leavenworth vicinity. Active vegetation is displayed in shades of pink to red. Cultural features and bare ground are shown in a cyan color. Water bodies appear in shades of black to blue.

JUNE 1988

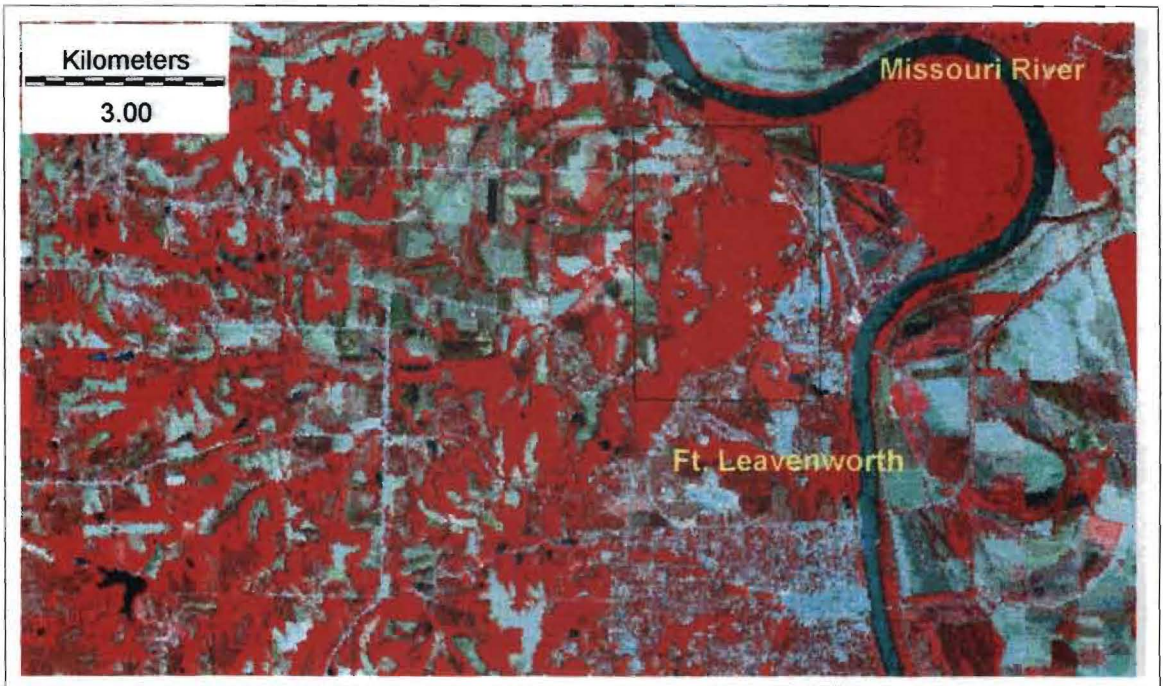


Figure 9. False-color composite of Ft. Leavenworth vicinity. Active vegetation is displayed in shades of pink to red. Cultural features and bare ground are shown in a cyan color. Water bodies appear in shades of black to blue.

JULY 1988

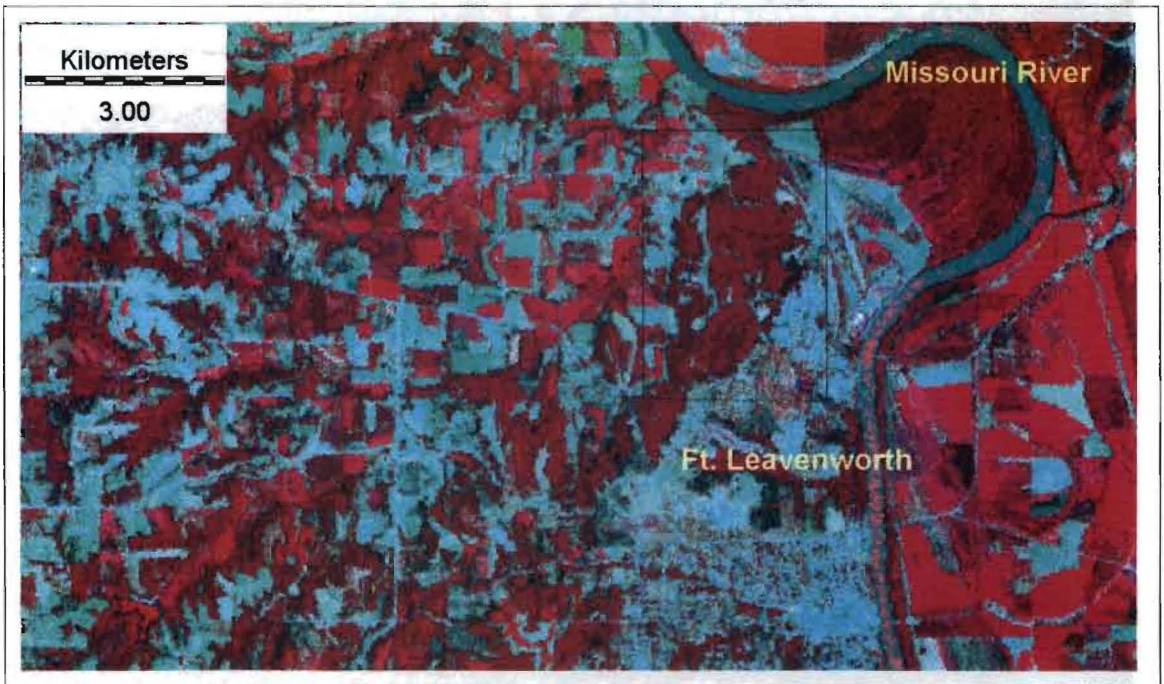


Figure 10. False-color composite of Ft. Leavenworth vicinity. Active vegetation is displayed in shades of pink to red. Cultural features and bare ground are shown in a cyan color. Water bodies appear in shades of black to blue.

OCTOBER 1988

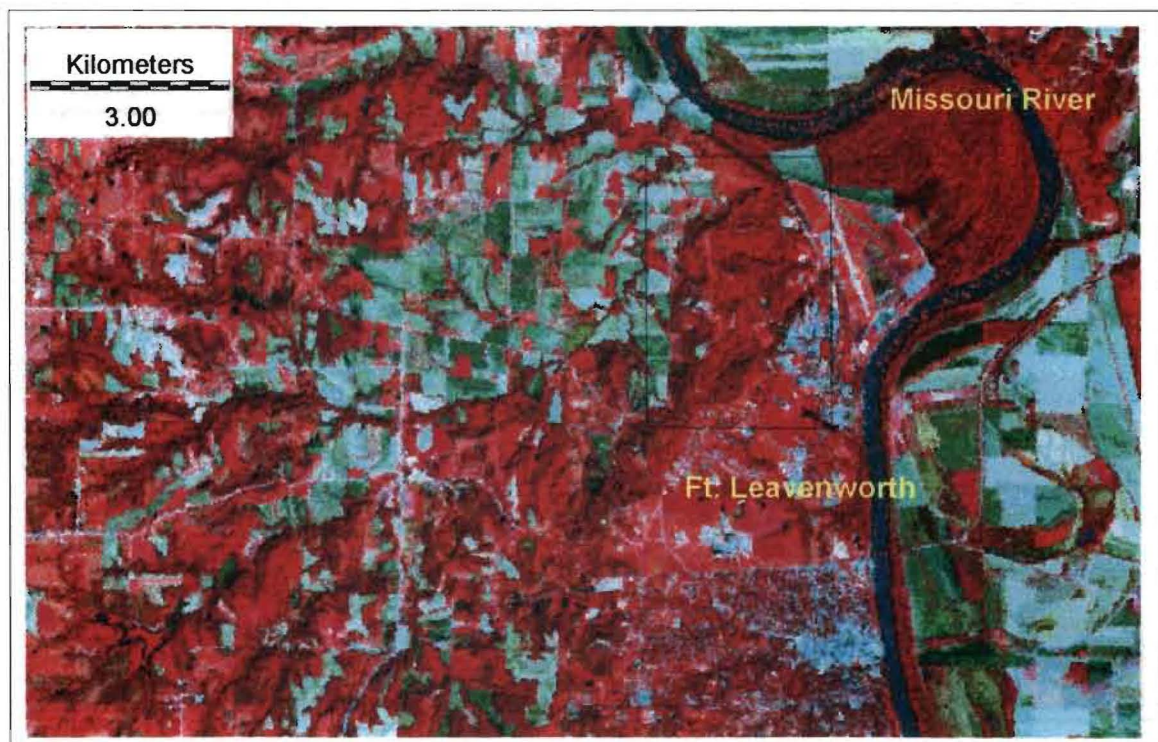


Figure 11. False-color composite of Ft. Leavenworth vicinity. Active vegetation is displayed in shades of pink to red. Cultural features and bare ground are shown in a cyan color. Water bodies appear in shades of black to blue.

JULY 1990



Figure 12. False-color composite of Ft. Leavenworth vicinity. Active vegetation is displayed in shades of pink to red. Cultural features and bare ground are shown in a cyan color. Water bodies appear in shades of black to blue.

MAY 1994



Figure 13. False-color composite of Ft. Leavenworth vicinity. Active vegetation is displayed in shades of pink to red. Cultural features and bare ground are shown in a cyan color. Water bodies appear in shades of black to blue.

JULY 1994

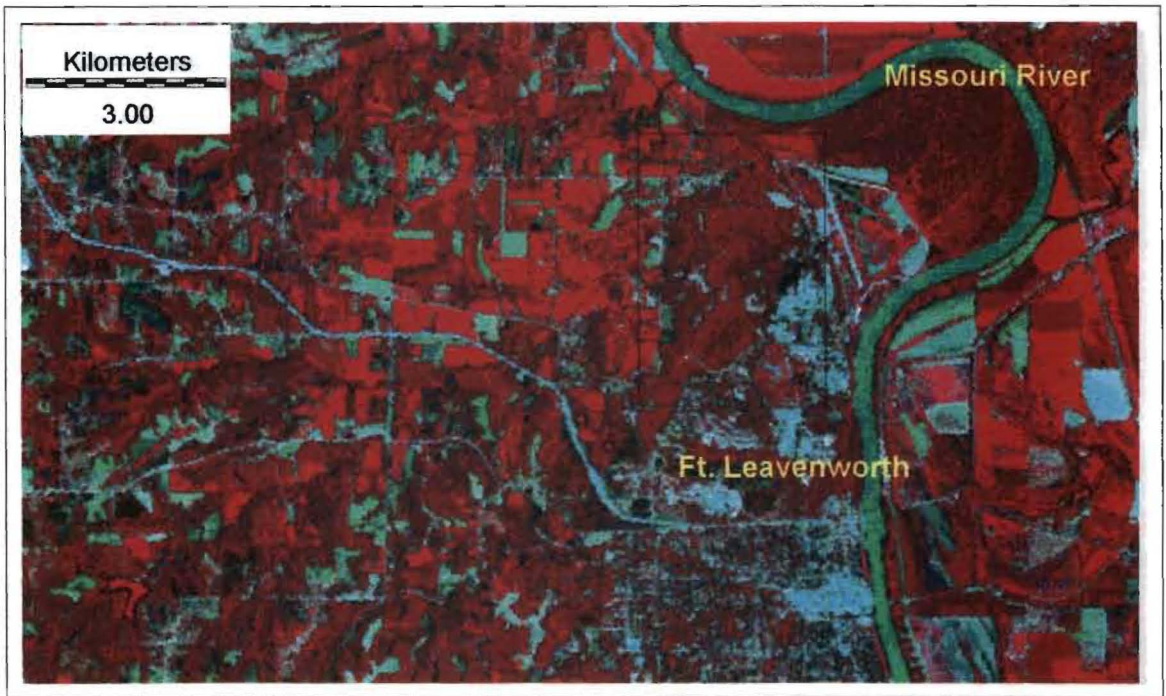


Figure 14. False-color composite of Ft. Leavenworth vicinity. Active vegetation is displayed in shades of pink to red. Cultural features and bare ground are shown in a cyan color. Water bodies appear in shades of black to blue.

SEPTEMBER 1994



Figure 15. False-color composite of Ft. Leavenworth vicinity. Active vegetation is displayed in shades of pink to red. Cultural features and bare ground are shown in a cyan color. Water bodies appear in shades of black to blue.

Image Enhancement

Many landscape features reflect visible and infrared radiation in similar amounts causing low contrast in brightness values. Image enhancement is used to improve contrast between landscape features. Vegetation indices can be used as a quantitative measure of biomass or the vigor of vegetation. In the visual analysis of vegetation, NDVI's are used to examine the distribution, abundance, and vigor of the vegetation over time. Figures 16-23 show the NDVI's used in the visual interpretation of vegetation.

The NDVI's show the most active vegetation in shades of green. The higher the pixel value the darker the green. Yellow portrays less active vegetation and some man made features. Bare ground, plowed fields, water bodies, and some man made features are shown in shades of brown.

The July 1987 NDVI image has the largest amount, extent, and vigor of the vegetation in all the images. In the 1988 NDVI images the largest extent of vigorous vegetation is along valleys and low-lying areas. In 1988 there was a drought which caused a lack of vegetation in some areas and less vigorous vegetation growth in others. The July 1990 NDVI shows the lowest values in vigorous vegetation of all the images. This suggests some kind of strain on the vegetation. The July 1994 NDVI shows fairly vigorous vegetation but not to the extent of the July 1987 NDVI image.

The tasselled cap transformation uses the difference in growth stages to plot vegetation and soils in three dimensions. The resulting bands (brightness, greenness, moisture (yellowness), and non-such) are in the form of images. Figures 24-32 show a

JULY 1987

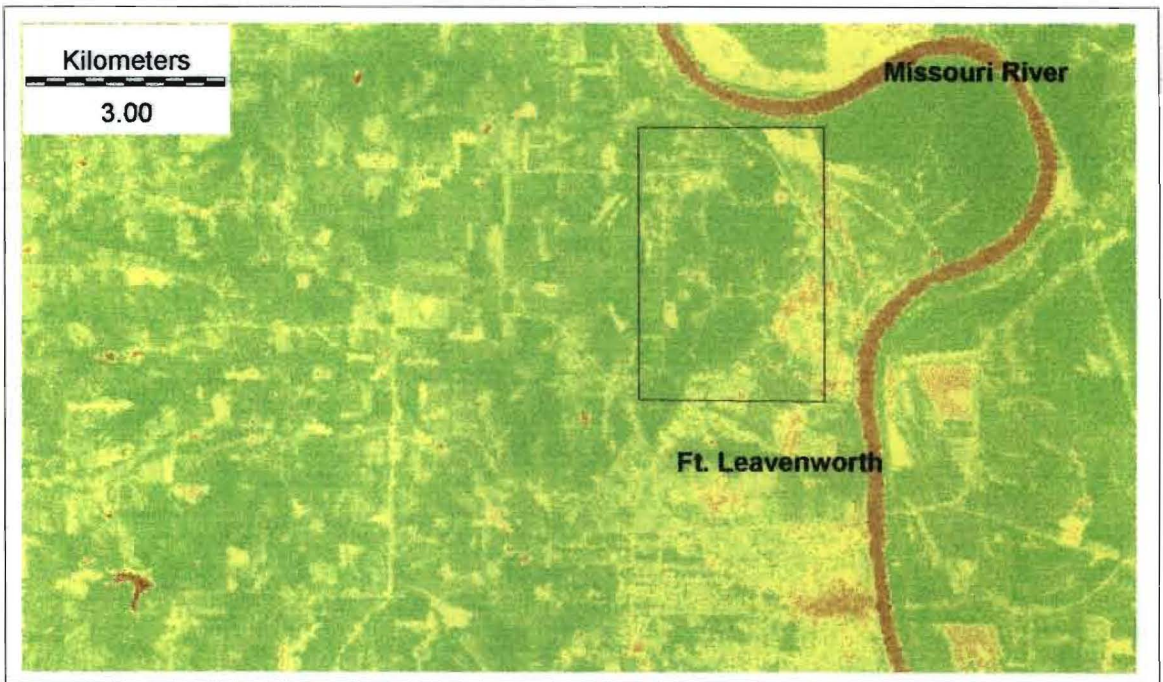


Figure 16. NDVI image. Active vegetation shown in shades of green. Yellow shows less active vegetation and some cultural features. Bare ground, plowed fields, water bodies, and some cultural features shown in shades of brown.

JUNE 1988

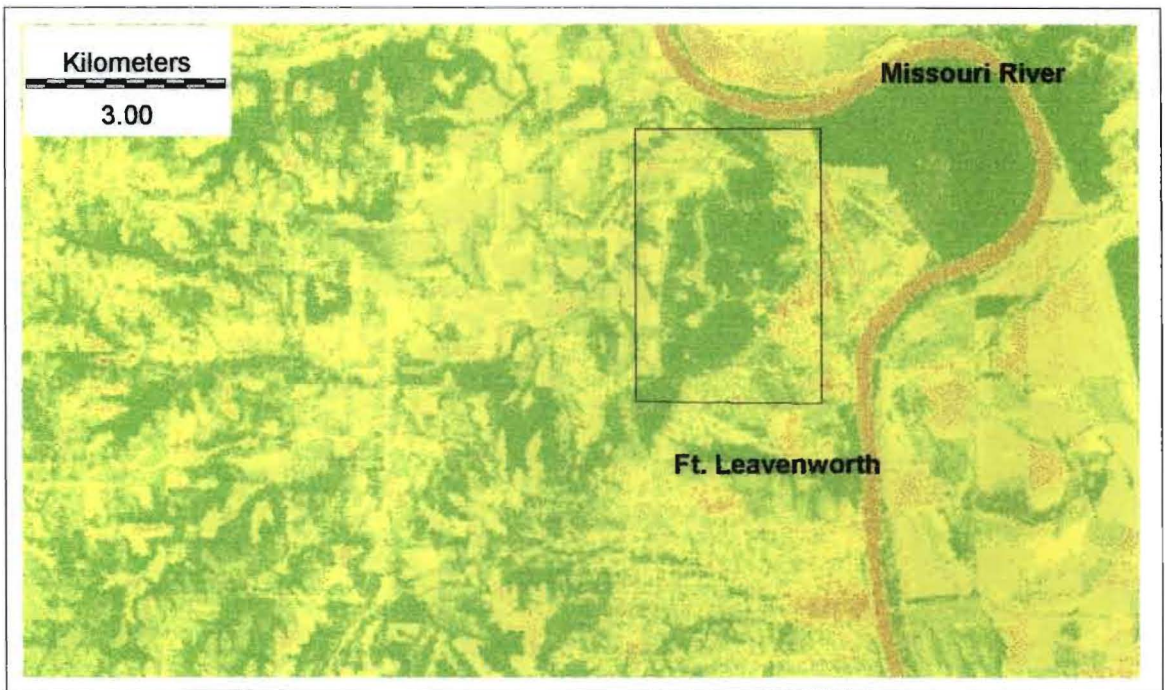


Figure 17. NDVI image. Active vegetation shown in shades of green. Yellow shows less active vegetation and some cultural features. Bare ground, plowed fields, water bodies, and some cultural features shown in shades of brown.

JULY 1988

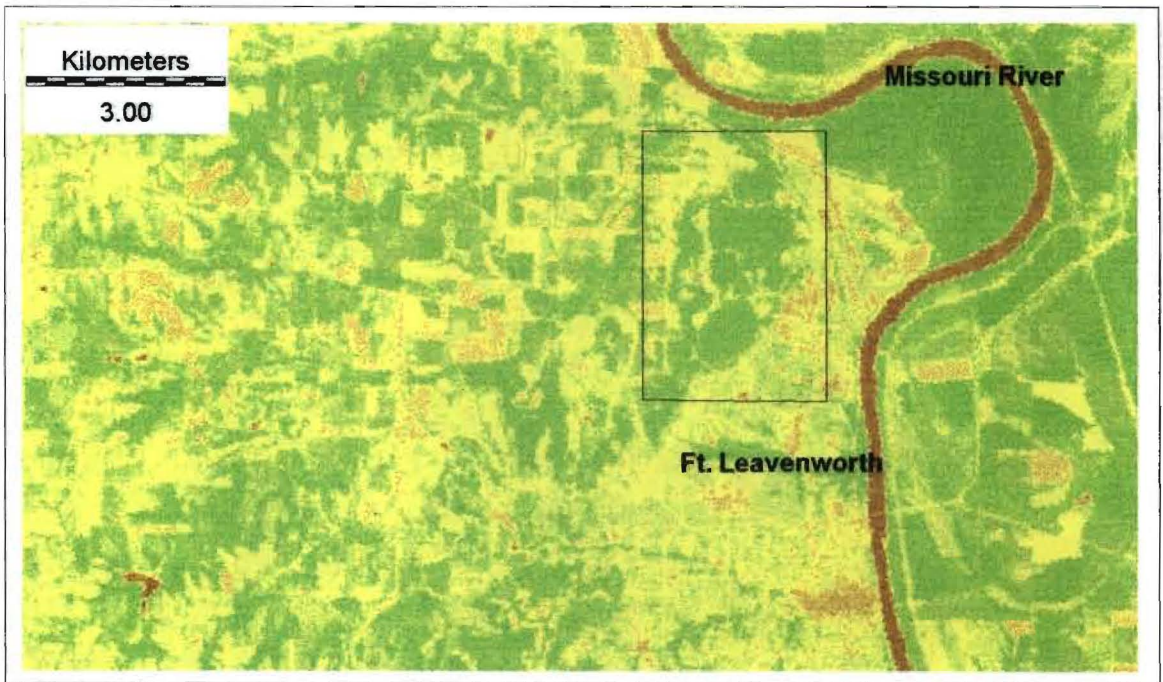


Figure 18. NDVI image. Active vegetation shown in shades of green. Yellow shows less active vegetation and some cultural features. Bare ground, plowed fields, water bodies, and some cultural features shown in shades of brown.

OCTOBER 1988

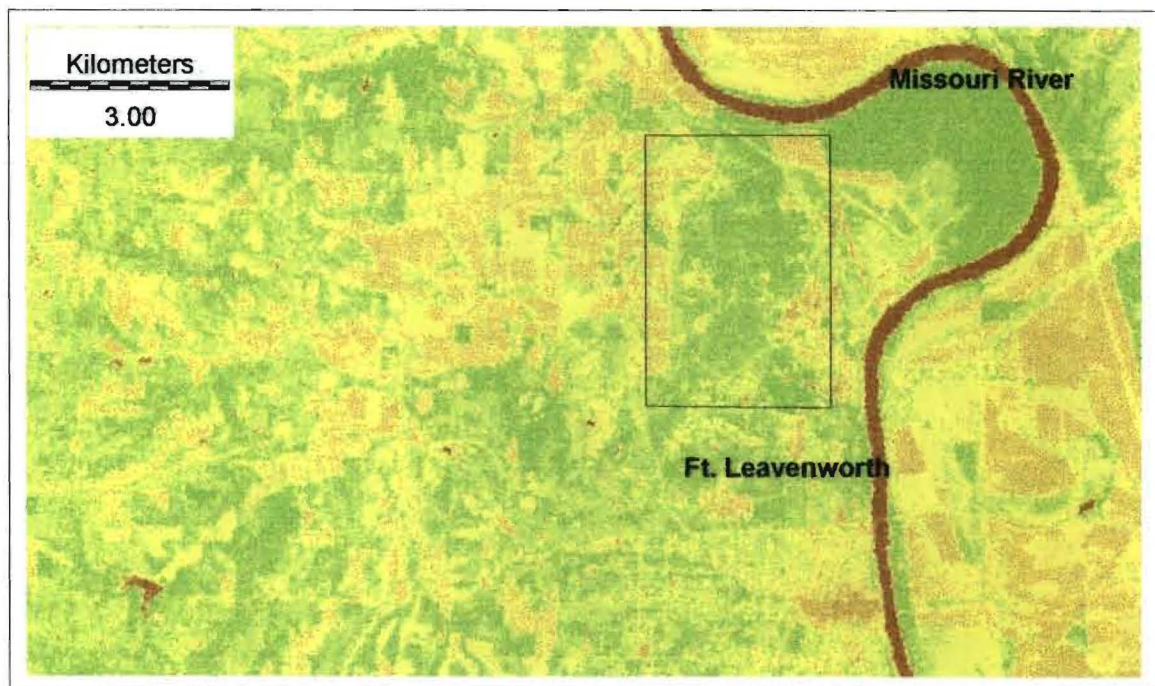


Figure 19. NDVI image. Active vegetation shown in shades of green. Yellow shows less active vegetation and some cultural features. Bare ground, plowed fields, water bodies, and some cultural features shown in shades of brown.

JULY 1990

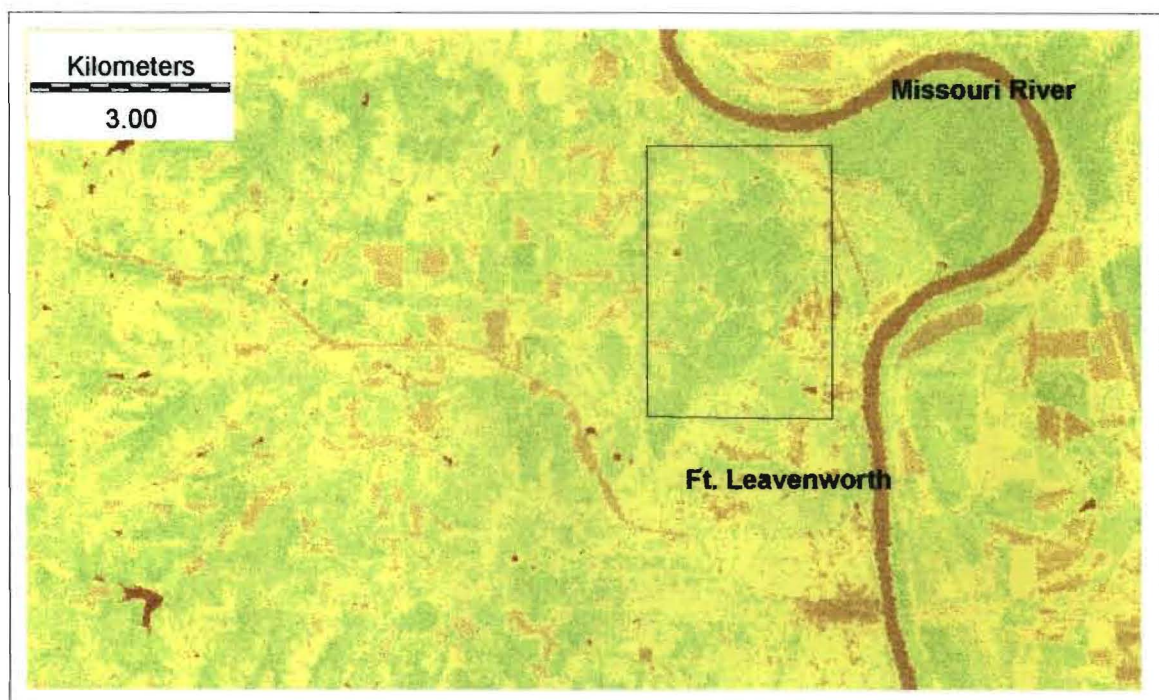


Figure 20. NDVI image. Active vegetation shown in shades of green. Yellow shows less active vegetation and some cultural features. Bare ground, plowed fields, water bodies, and some cultural features shown in shades of brown.

MAY 1994

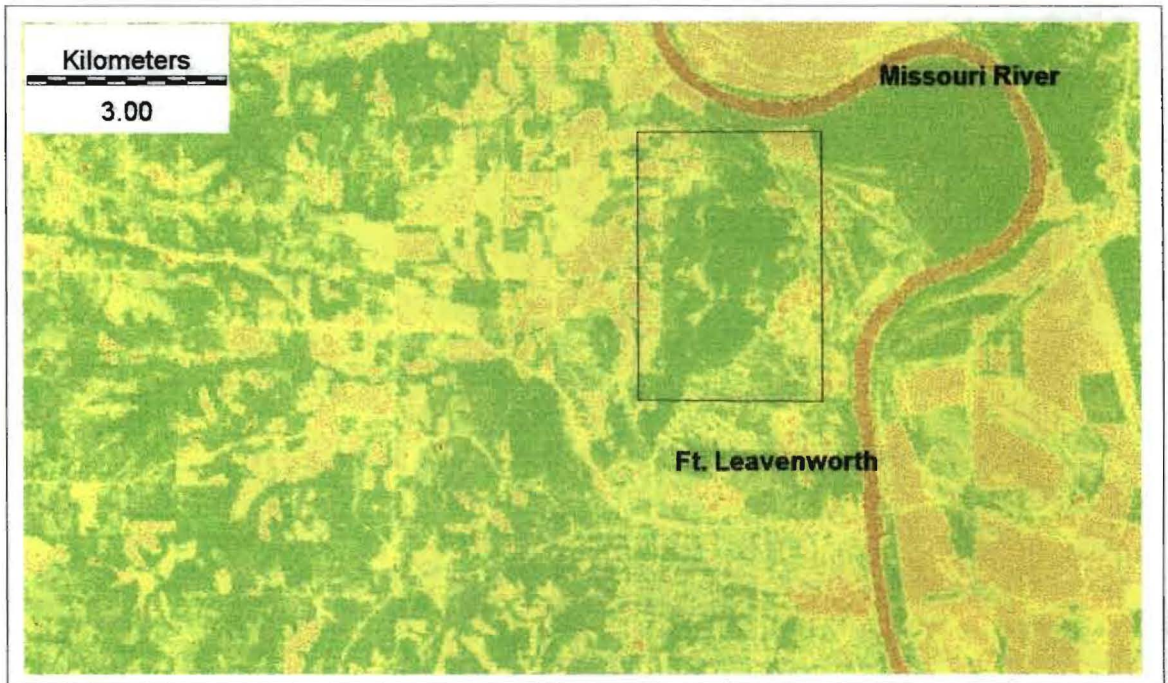


Figure 21. NDVI image. Active vegetation shown in shades of green. Yellow shows less active vegetation and some cultural features. Bare ground, plowed fields, water bodies, and some cultural features shown in shades of brown.

JULY 1994

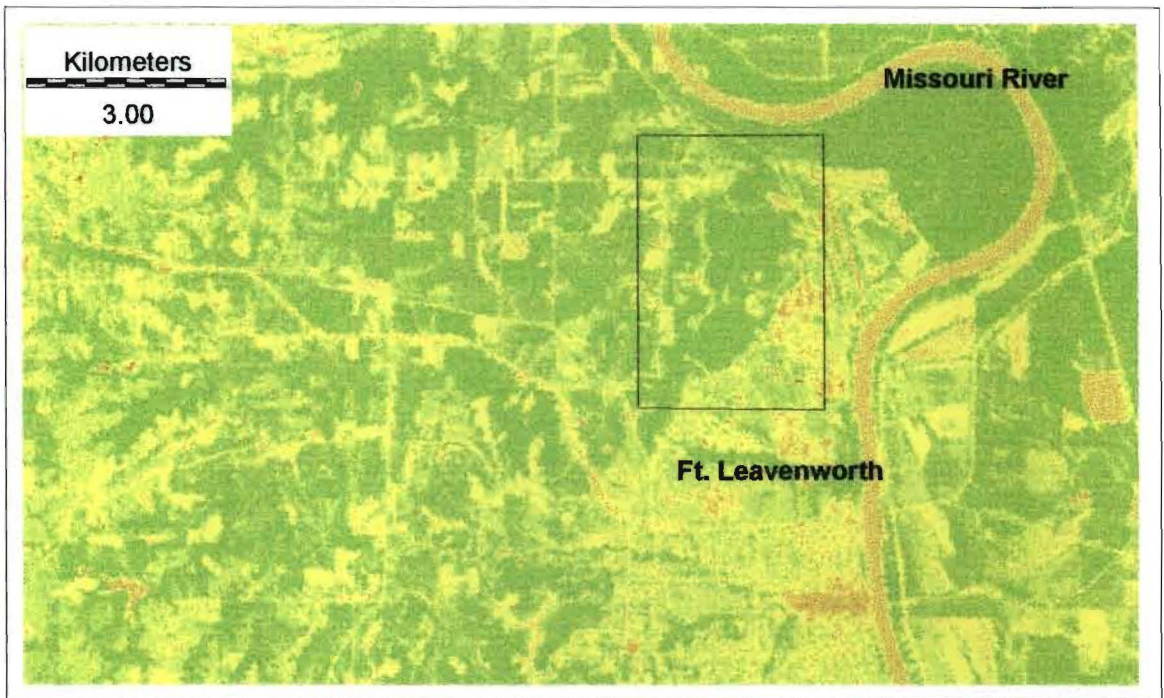


Figure 22. NDVI image. Active vegetation shown in shades of green. Yellow shows less active vegetation and some cultural features. Bare ground, plowed fields, water bodies, and some cultural features shown in shades of brown.

SEPTEMBER 1994

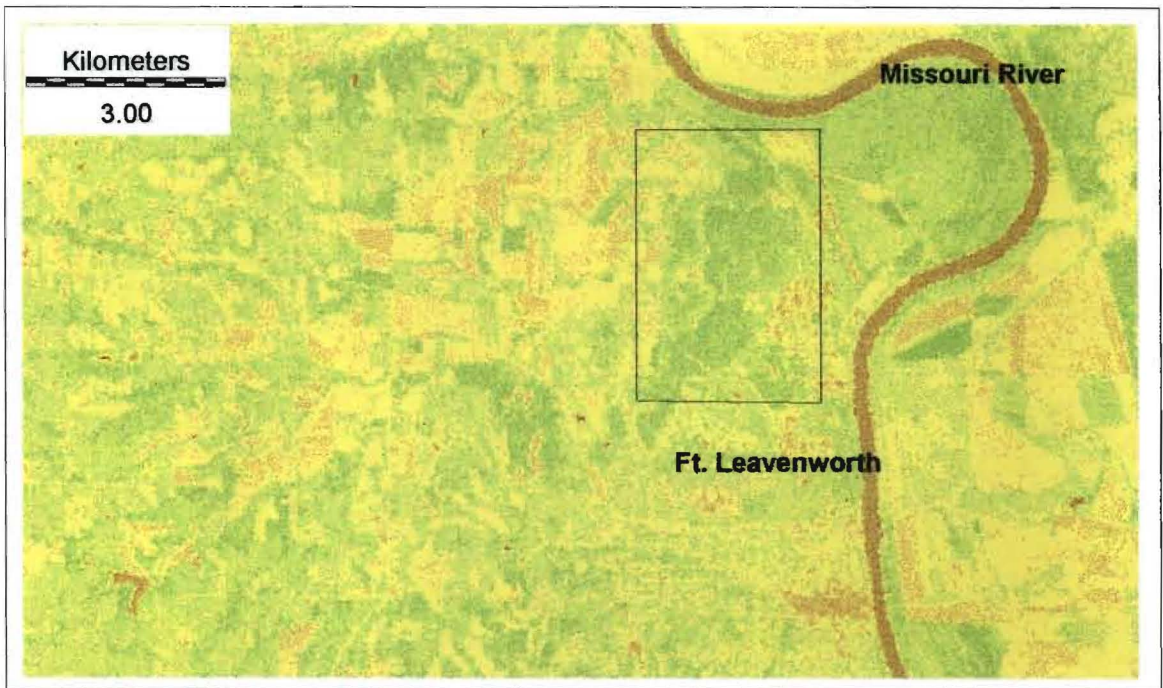


Figure 23. NDVI image. Active vegetation shown in shades of green. Yellow shows less active vegetation and some cultural features. Bare ground, plowed fields, water bodies, and some cultural features shown in shades of brown.

MAY 1994

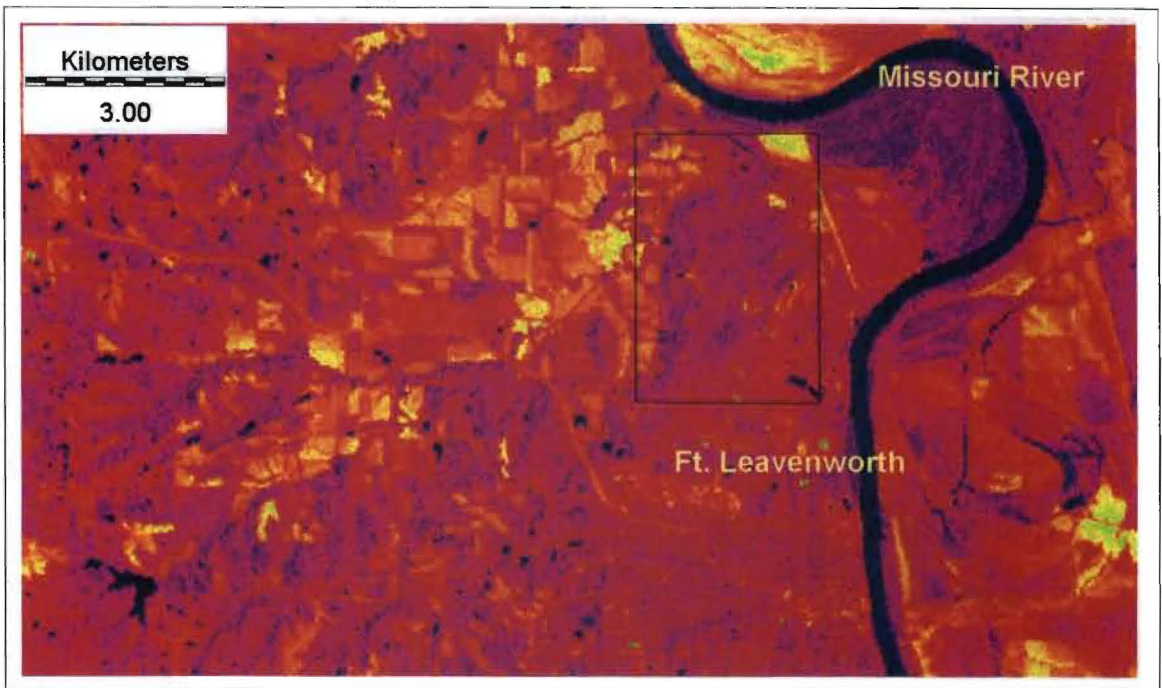


Figure 24. Brightness image. Crop lands have the highest soil brightness and are displayed in yellow-green. The lowest values are seen in forests and some crop lands as blue-purple.

Water bodies are shown in black.

JULY 1994

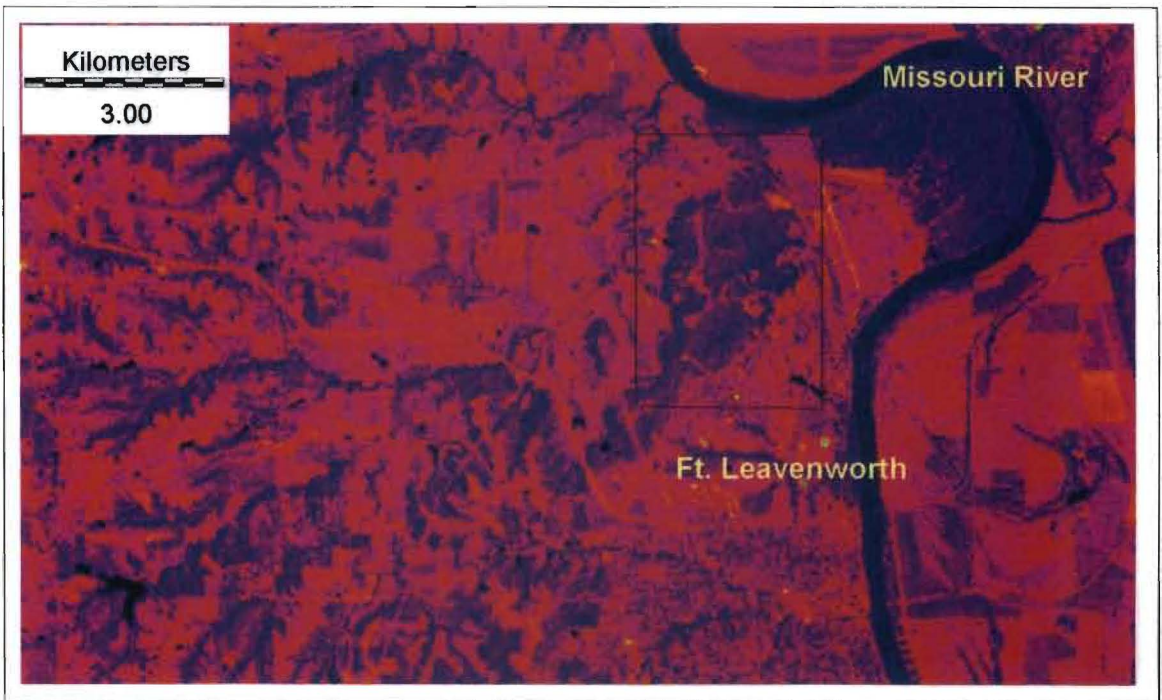


Figure 25. Brightness image. Crop lands have the highest soil brightness and are displayed in yellow-orange. The lowest values are seen in forests and some crop lands as blue-purple. Water bodies are shown in black.

SEPTEMBER 1994



Figure 26. Brightness image. Crop lands have the highest soil brightness and are displayed in yellow-orange. The lowest values are seen in forests and some crop lands as blue-purple. Water bodies are shown in black.

JULY 1994

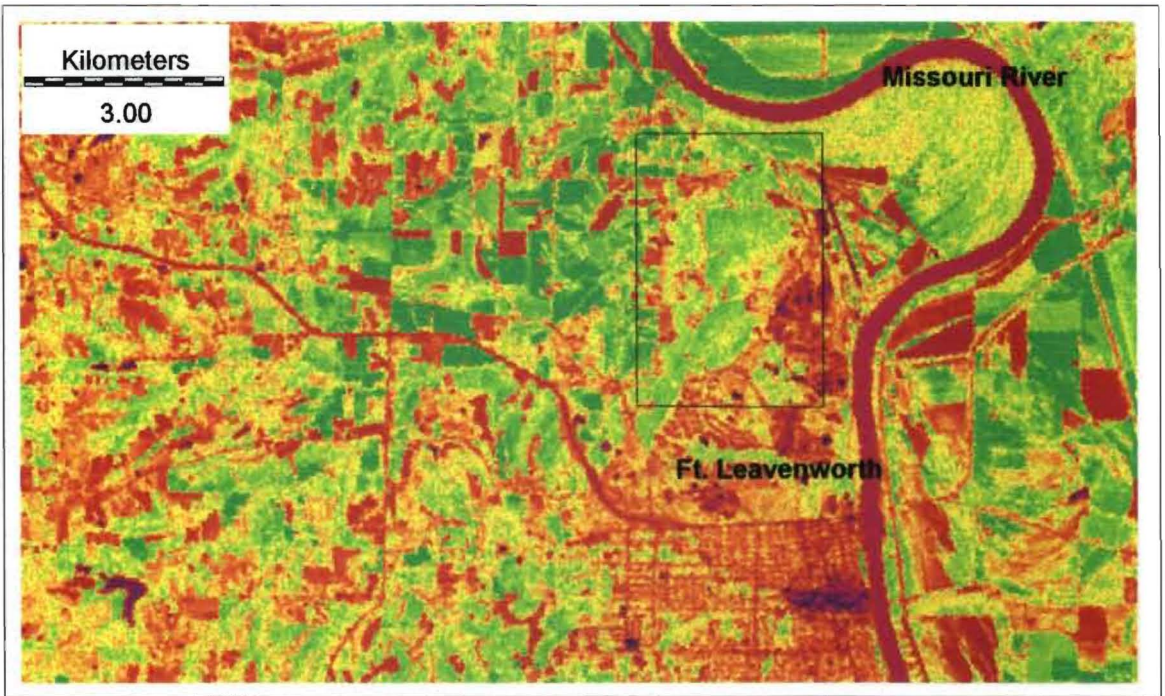


Figure 28. Greenness image. Vigorous vegetation in shades of green. Bare ground, cultural features, and some crop lands shown in shades of blue to orange. Some water bodies displayed in blue.

SEPTEMBER 1994

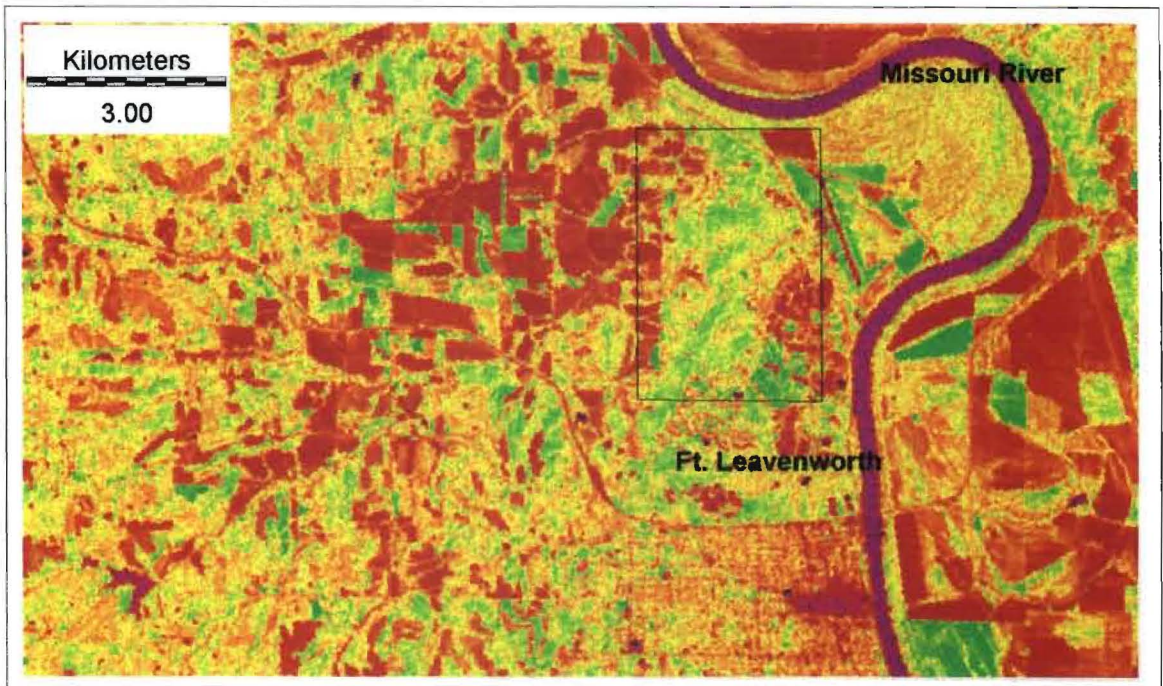


Figure 29. Greenness image. Vigorous vegetation in shades of green. Bare ground, cultural features, and some crop lands shown in shades of blue to orange. Some water bodies displayed in blue.

MAY 1994

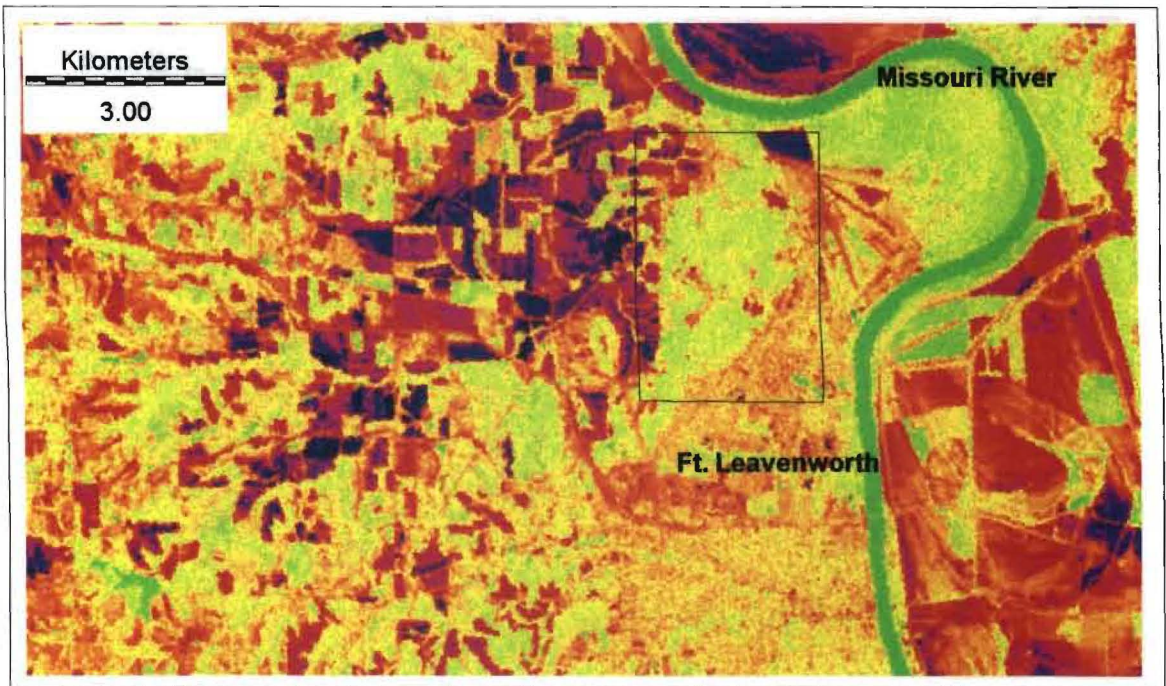


Figure 30. Moisture image. Water bodies are displayed in green and have the highest moisture values. Lower moisture values in bare ground and some crop lands are shown in shades of blue, pink, red, and orange.

JULY 1994

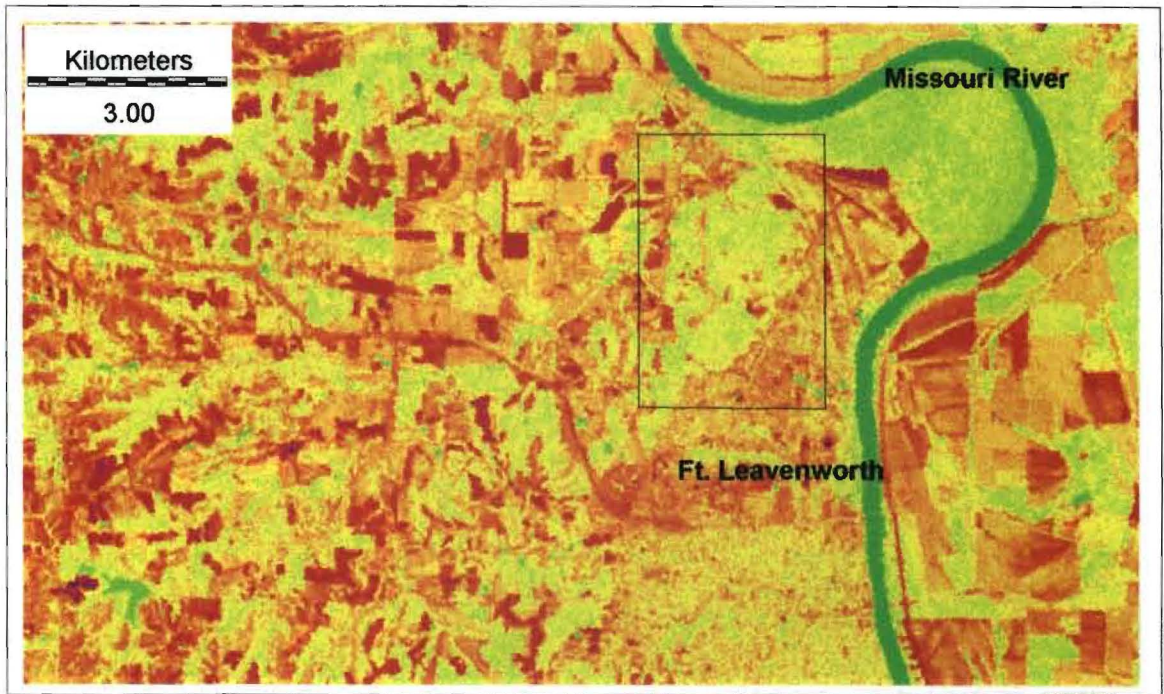


Figure 31. Moisture image. Water bodies are displayed in green and have the highest moisture values. Lower moisture values in bare ground and some crop lands are shown in shades of blue, pink, red, and orange.

SEPTEMBER 1994

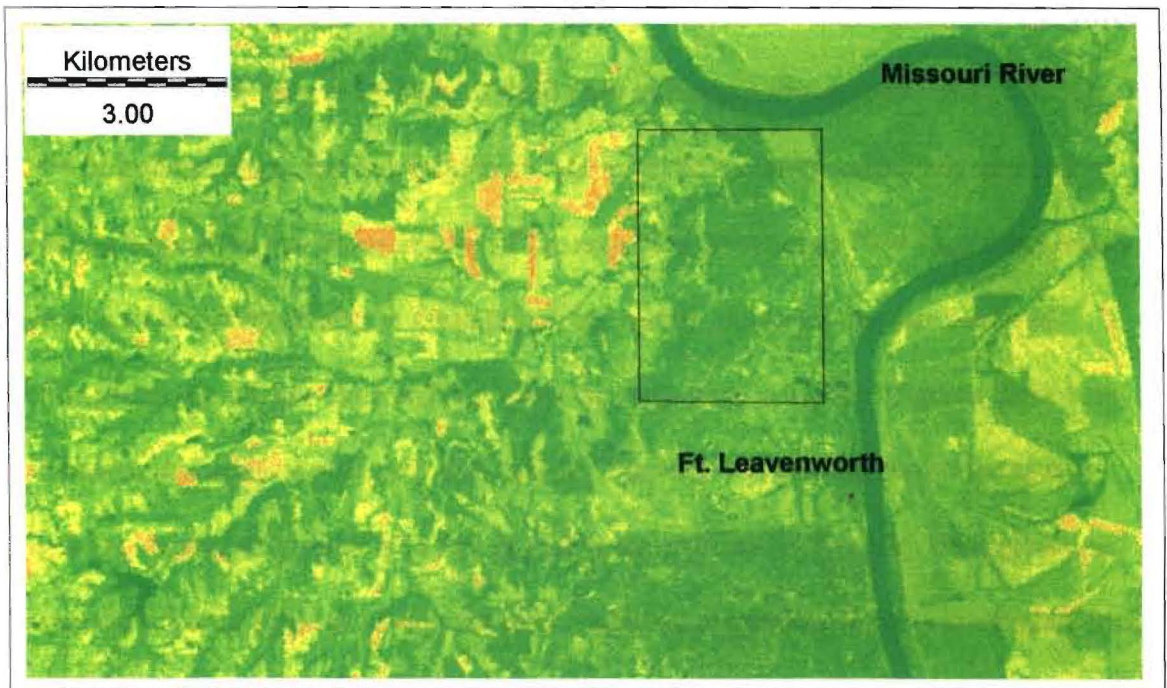


Figure 32. Moisture image. Water bodies are displayed in green and have the highest moisture values. Lower moisture values in bare ground and some crop lands are shown in shades of blue, pink, red, and orange.

series of tasselled cap images (brightness, greenness, moisture). The images show the progression of soils and vegetation through a growing season in 1994.

The expected seasonal transition of brightness and greenness images would be high brightness at the start of the growing season and some greenness. Then lower brightness and higher greenness during the growing season. Increasing soil brightness as the senescence of vegetation occurs and there is less greenness.

The brightness images have the highest values portrayed in yellow-green and the lowest values in blue. The May 1994 image shows high soil brightness in crop lands. The July 1994 brightness image has less brightness and more darkness in color. This means that growing vegetation has covered a lot of the area. The September 1994 brightness image shows a return of brightness in areas where harvesting and senescing has occurred.

The greenness images have actively growing vegetation in shades of green. Bare soils are shown in shades of pink, red, and orange. The May 1994 image shows the most vigorous vegetation growth is in forests and some crop lands. The July 1994 greenness image shows crop lands as having the most vigorous vegetation. Forests are slightly less vigorous than crop lands. The September 1994 greenness image shows some vigorous vegetation in portions of the forests and some crop lands. Shades of orange show the senescent of trees in the forested areas. The combination of greens to orange in the forested areas show the different stages of tree growth.

The moisture images have the highest values in shades of green and the lowest values in blue. The higher the moisture content the brighter the pixel according to Jensen (1996). In all the moisture images water bodies are portrayed as having the highest moisture content.

In the May 1994 image some forests and crop lands have high moisture values. Bare ground and plowed fields are shown in black to blue and pink to orange. The July 1994 image shows high values in forests and some crop lands. Vegetation has covered much of the scene so many of the low values are not seen. Bare ground and harvested fields are displayed in reds. The September 1994 image has a surprising overall moisture content.

Cluster Analysis of the Forested Area

In the analysis of the forested area, the forests had to be isolated from all other areas. This was accomplished by clustering like values together. The first method uses the tasseled cap bands (brightness, greenness, yellowness) with a false-color composite (bands 2, 3, 4) to form the clusters. The second method uses bands 4, 5, 6, 7 with a false-color composite (bands 2, 3, 4) to form the clusters. Figures 33 and 34 show the results of the cluster analysis. As can be seen, both of these methods gave the same results. Since the second method took less time it was used in further processing of the July images. RECLASS and GROUP were used to isolate the forest clusters from other clusters. A boolean image was made for each of the July scenes. This image was multiplied by the NDVI values for analysis.

Quantitative Analysis

A histogram of each July scene was analyzed for range of values and mean value of data (see figures 35 and 36). July 1987 had the greatest range in values and the highest mean value in vegetation. Based on this and the visual interpretation of the scenes, the July 1987 boolean image was chosen as a mask for all the images. Figure 37 shows the mask that was used to multiply the NDVI values in each of the scenes. A histogram of each of the scenes was used for analysis (see figures 38-41).

In the quantitative analysis of the scenes, July 1987 has the highest value in the NDVI mean. This means that 1987 had the most vigorous vegetation, and that conditions were favorable for growing forests in 1987. In the years 1988 and 1994 there is a decrease in

JULY 1987

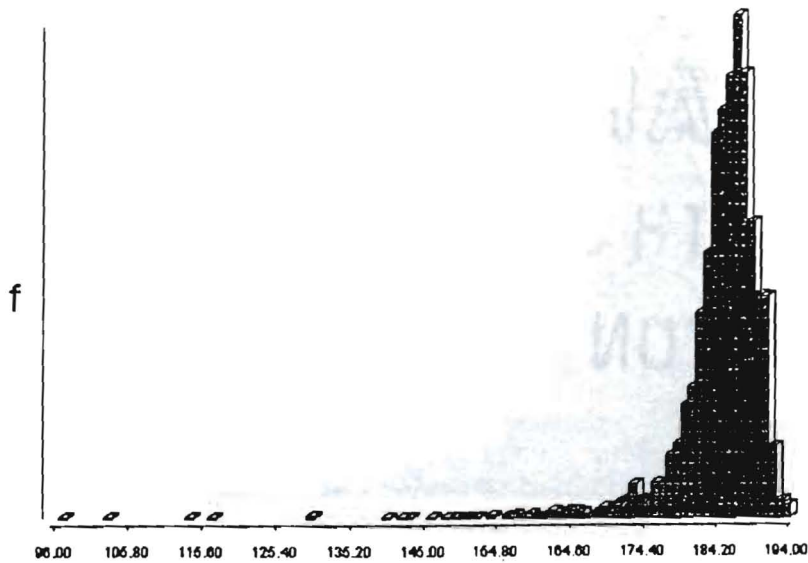


Figure 33. Cluster Analysis using tasseled cap bands. Forested areas indicated in blue and cyan colors.

JULY 1987



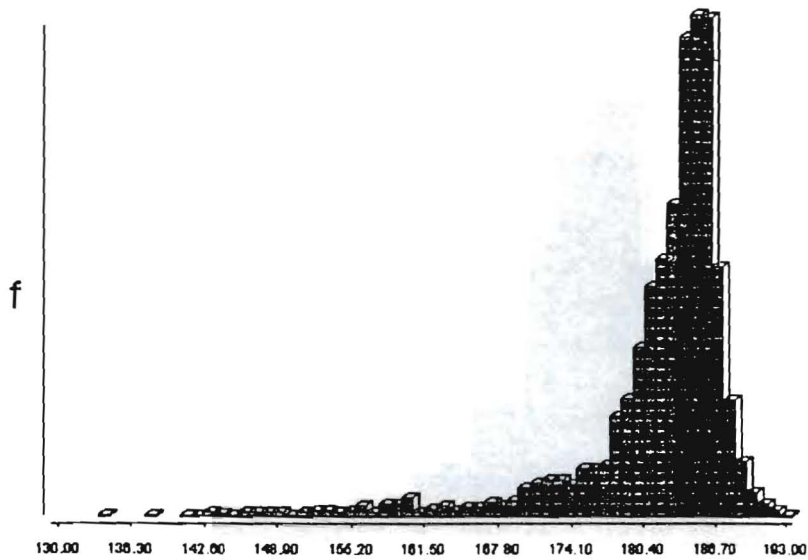
Figure 34. Cluster Analysis using bands 3, 4, 5, and 7. Forested areas indicated in blue and cyan colors.



Histogram

Class width :	1.0000
Display minimum :	96.0000
Display maximum :	194.0000
Actual minimum :	0.0000
Actual maximum :	194.0000
Mean :	184.9038
Stand. Deviation :	5.8012
df :	4137

based on 4138
values within range (out of 178942)

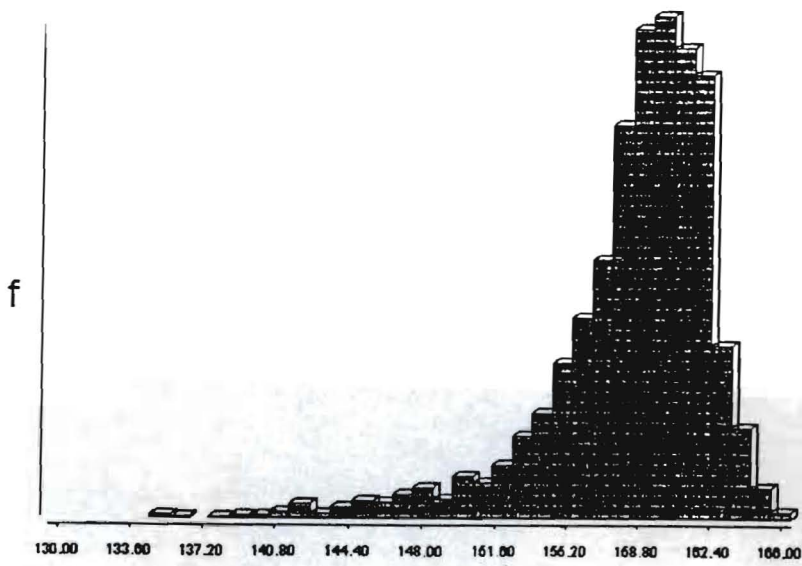


Histogram

Class width :	1.0000
Display minimum :	130.0000
Display maximum :	193.0000
Actual minimum :	0.0000
Actual maximum :	193.0000
Mean :	181.8678
Stand. Deviation :	6.6300
df :	3873

based on 3874
values within range (out of 182560)

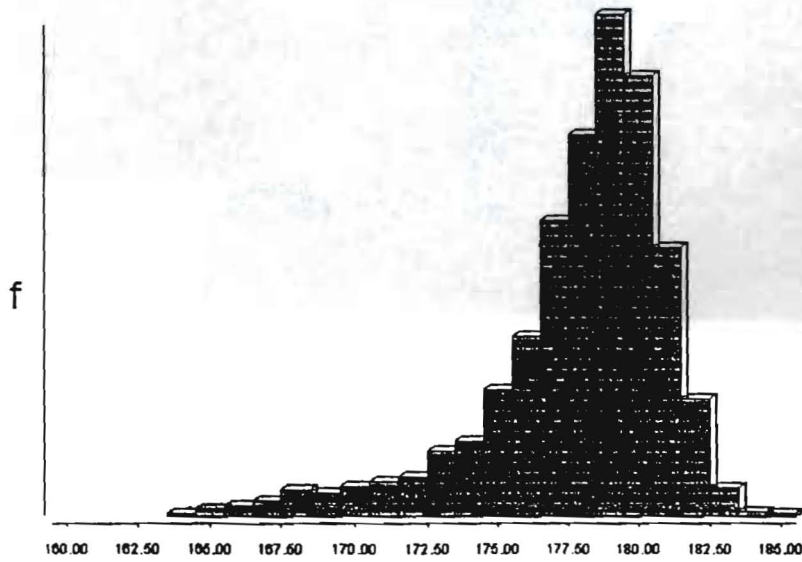
Figure 35. Histogram of July 1987 and July 1988 NDVI values.



Histogram

Class width : 1.0000
 Display minimum : 130.0000
 Display maximum : 166.0000
 Actual minimum : 0.0000
 Actual maximum : 166.0000
 Mean : 158.4740
 Stand. Deviation : 3.9670
 df : 4250

based on 4251
 values within range (out of 183480)



Histogram

Class width : 1.0000
 Display minimum : 160.0000
 Display maximum : 186.0000
 Actual minimum : 0.0000
 Actual maximum : 186.0000
 Mean : 177.8510
 Stand. Deviation : 3.1516
 df : 4248

based on 4249
 values within range (out of 181050)

Figure 36. Histogram of July 1990 and July 1994 NDVI values.



Figure 37. Mask of July 1987 study-forest area (brown).

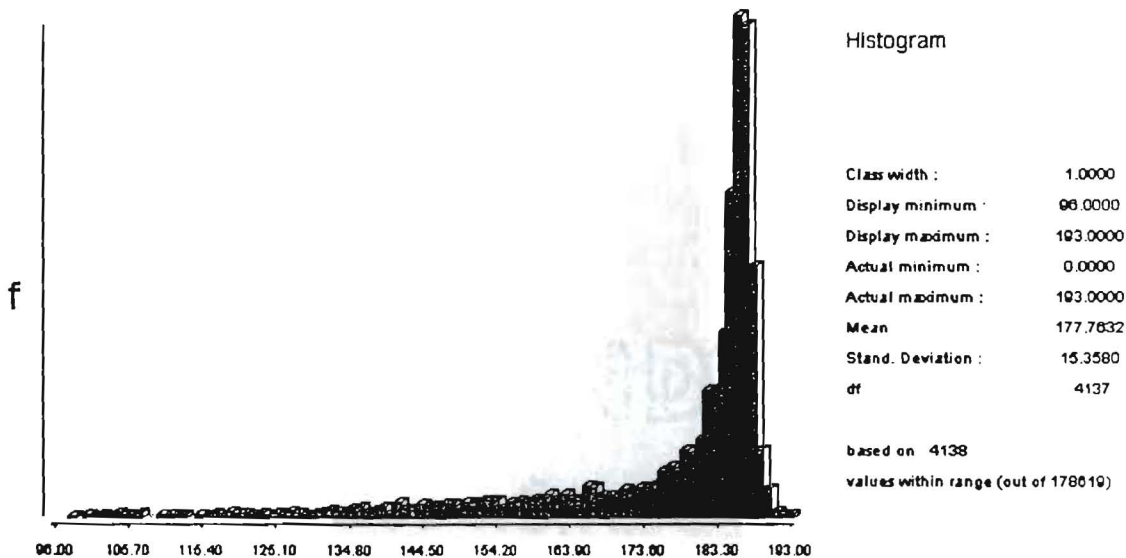
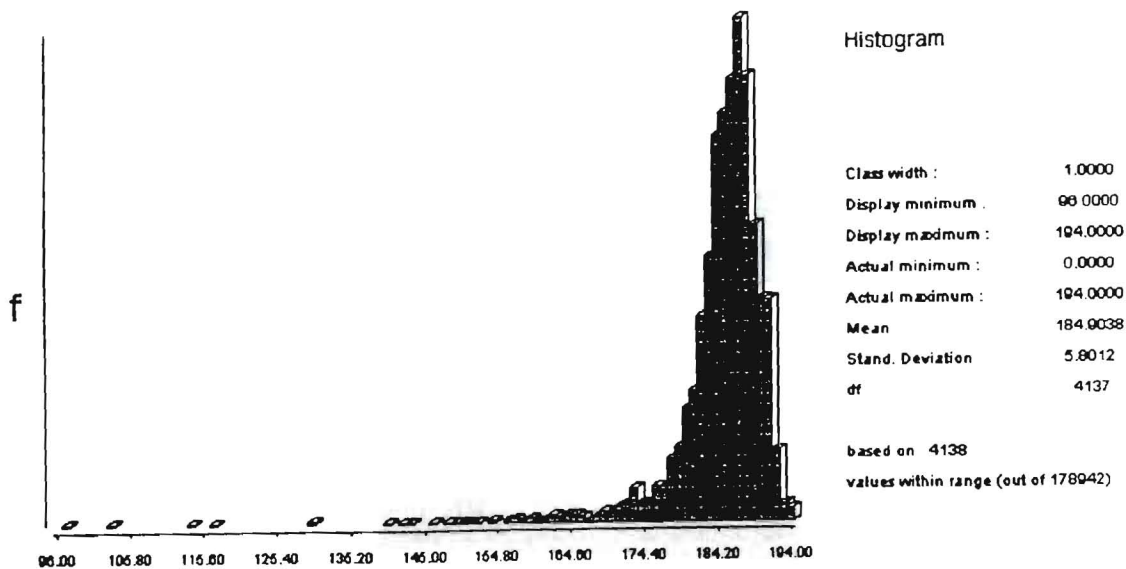
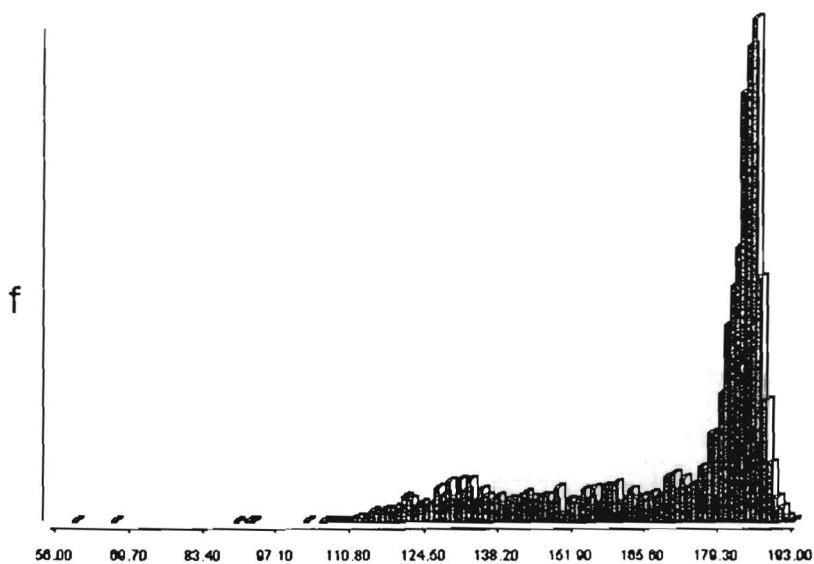


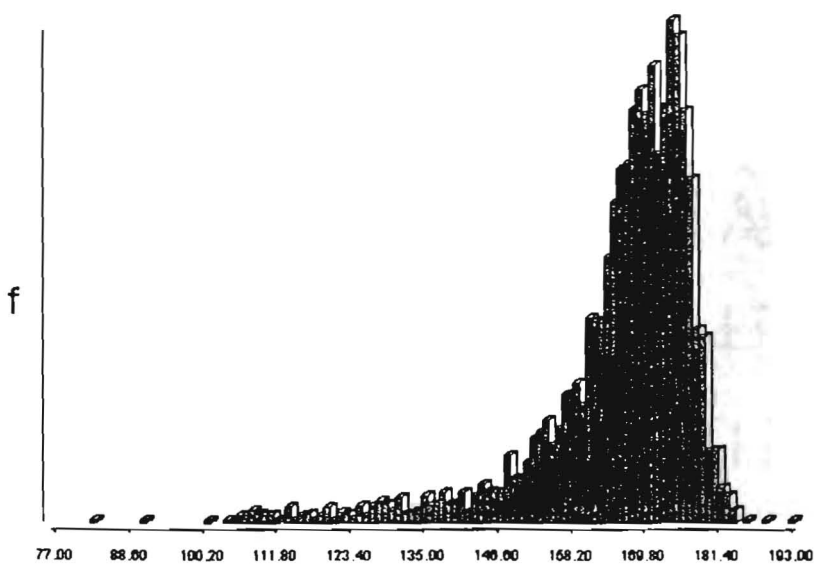
Figure 38. Histogram of July 1987 and June 1988. NDVI values based an masking.



Histogram

Class width :	1.0000
Display minimum :	56.0000
Display maximum :	193.0000
Actual minimum :	0.0000
Actual maximum :	193.0000
Mean :	171.5460
Stand. Deviation :	20.3682
df :	4137

based on 4138
values within range (out of 178942)



Histogram

Class width :	1.0000
Display minimum :	77.0000
Display maximum :	193.0000
Actual minimum :	0.0000
Actual maximum :	193.0000
Mean :	165.9966
Stand. Deviation :	12.1259
df :	4137

based on 4138
values within range (out of 178942)

Figure 39. Histogram of July 1988 and October 1988. NDVI values based on masking.

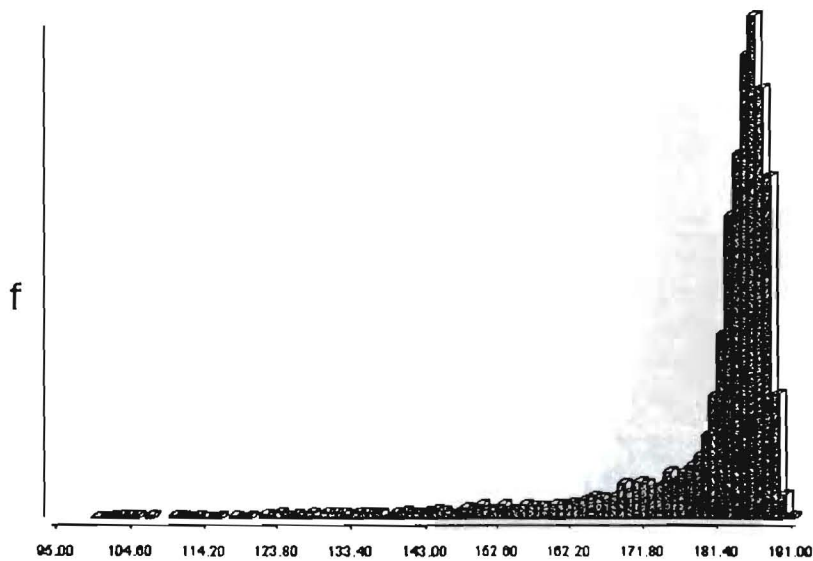
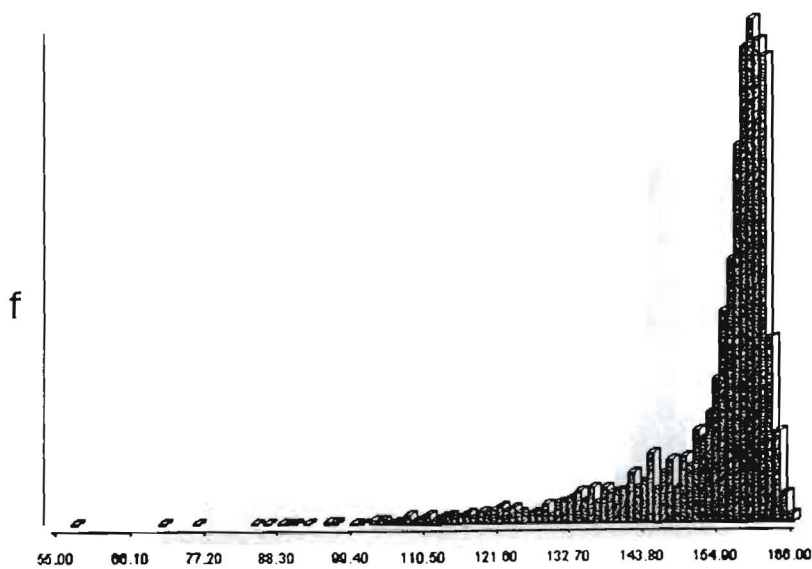
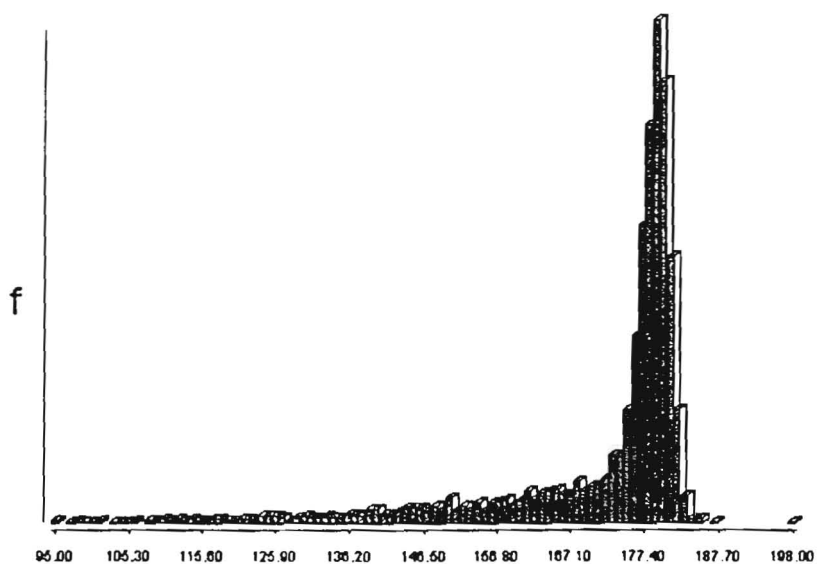


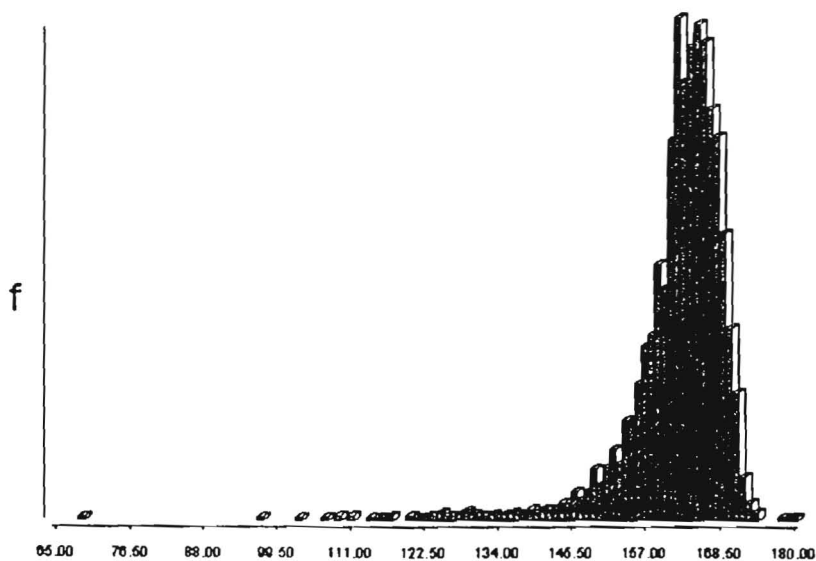
Figure 40. Histogram of July 1990 and May 1994. NDVI values based on masking.



Histogram

Class width	1.0000
Display minimum	95.0000
Display maximum	198.0000
Actual minimum	0.0000
Actual maximum :	198.0000
Mean	171.9272
Stand. Deviation	13.9981
df	4133

based on 4134
values within range (out of 178295)



Histogram

Class width :	1.0000
Display minimum	65.0000
Display maximum :	180.0000
Actual minimum	0.0000
Actual maximum :	180.0000
Mean	161.9497
Stand. Deviation	7.5582
df	4137

based on 4138
values within range (out of 178942)

Figure 41. Histogram of July 1994 and September 1994. NDVI values based on masking.

the mean from spring to fall. Forests are more vigorous in the spring than summer or fall. The mean values for July 1994 and July 1988 are similar. The July 1990 mean is lowest of all the NDVI means. Conditions were apparently less favorable for tree growth in the study-forest area in 1990.

Chapter Five

RESULTS

Resample Results

The resample results are in the form of tables. The following tables are the results, taken from Idrisi, for band 1 in each of the scenes. The tables show the coefficients used in the back transformation of the new coordinate system (UTM) to the old coordinate system (plain). The control points, old x/y, new x/y are used in the transformation. The residual represents the error introduced by each control point. The residual error of each point can be used to determine which points need to be corrected or omitted from the transformation. High residual errors in the control points can lead to high overall error of all the control points. The total root mean square (RMS) error describes the typical positional error of all the control points in relation to the equation. It describes the probability that a mapped position will vary from the true location (Idrisi, 1997). Since the GPS unit had an accuracy of ± 5 meters, 5 meters was used as a acceptable overall RMS error. The overall RMS error can be seen at the end of the table (Tables 5-12). The RMS error is multiplied by ground units of one pixel (30 meters) to derive overall positional error of the control points. If the positional error is less than 5 meters the resample is accepted.

Table 5. JULY 1987 Resample : Summary of Transformation

Coefficient	X		Y		
b0	739.3258076431520750		-4445.4093710944289300		
b1	1.0326091386763765		0.2187361768685099		
b2	-0.2169030099971252		1.0378797141061256		
Control Point Old X Old Y New X New Y Residual					
1.	137.739400	150.42330	332.840000	4357.99500	0.049401
2.	137.589400	151.119600	332.758000	4358.725000	0.116906
3.	137.817500	149.895100	332.746000	4357.513000	0.075154
4.	140.272200	151.503800	335.355000	4358.549000	0.098388
5.	139.293900	153.118400	334.762000	4360.249000	0.118092
6.	140.410200	153.088400	335.820000	4359.953000	0.064987
7.	137.529400	152.770300	333.051000	4360.251000	0.097063
8.	138.039500	151.647800	333.293000	4359.133000	0.118845
9.	140.338700	148.566100	334.880000	4355.844000	0.117328
10.	138.988400	147.451500	333.373000	4355.055000	0.093626
11.	145.787800	148.664600	339.976000	4354.452000	0.329253
12.	144.587400	156.461700	340.286000	4362.095000	0.112567
13.	133.904400	154.649000	330.238000	4362.405000	0.270813
14.	133.092600	149.908200	328.524000	4358.214000	0.223432
15.	127.114600	154.216300	323.625000	4363.500000	0.082986
16.	127.782600	145.693400	322.625000	4355.500000	0.057803
Overall RMS =	0.147955		Overall Positional error = 4.43865 meters		

Table 6. JUNE 1988 Resample : Summary of Transformation

Coefficient	X		Y		
b0	714.9430727607395970		-4435.2510244152508700		
b1	1.0318095406561163		0.2238997396368001		
b2	-0.2137695339977199		1.0364492086429422		
Control Point	Old X	Old Y	New X	New Y	Residual
1.	126.751200	156.005500	332.840000	4357.995000	0.107499
2.	126.571900	156.752000	332.758000	4358.725000	0.109804
3.	126.809200	155.579000	332.746000	4357.513000	0.041136
4.	129.286500	157.152100	335.355000	4358.549000	0.107716
5.	128.283900	158.788400	334.762000	4360.249000	0.092221
6.	129.424100	158.714100	335.820000	4359.953000	0.094802
7.	126.519400	158.392300	333.051000	4360.251000	0.107278
8.	127.045500	157.285600	333.293000	4359.133000	0.121881
9.	129.350200	154.244700	334.880000	4355.844000	0.097290
10.	128.006900	153.123100	333.373000	4355.055000	0.088964
11.	134.787200	154.337600	339.976000	4354.452000	0.315116
12.	133.545800	162.143900	340.286000	4362.095000	0.117667
13.	123.104400	160.313000	330.238000	4362.405000	0.215023
14.	122.088700	155.539400	328.524000	4358.214000	0.241717
15.	116.082400	159.790800	323.625000	4363.500000	0.036302
16.	116.776600	151.278500	322.625000	4355.500000	0.043769
Overall RMS =	0.141241		Overall Positional error = 4.23723 meters		

Table 7. JULY 1988 Resample : Summary of Transformation

Coefficient	X		Y		
b0	685.3603609965357460		-4442.8485608584014700		
b1	1.0322429709737344		0.2180395438738190		
b2	-0.2041266288233317		1.0386640725934697		
Control Point	Old X	Old Y	New X	New Y	Residual
1.	139.362900	156.162800	332.840000	4357.995000	0.055454
2.	139.162900	156.858000	332.758000	4358.725000	0.109618
3.	139.392900	155.622600	332.746000	4357.513000	0.084197
4.	141.828500	157.268100	335.355000	4358.549000	0.072345
5.	140.968300	158.838700	334.762000	4360.249000	0.167685
6.	142.062900	158.804600	335.820000	4359.953000	0.102418
7.	139.179400	158.572300	333.051000	4360.251000	0.080154
8.	139.603000	157.388200	333.293000	4359.133000	0.110669
9.	141.834300	154.298600	334.880000	4355.844000	0.141830
10.	140.547800	153.248200	333.373000	4355.055000	0.057252
11.	147.365200	154.424900	339.976000	4354.452000	0.340406
12.	146.143600	162.193700	340.286000	4362.095000	0.109781
13.	135.762800	160.401900	330.238000	4362.405000	0.172175
14.	134.666200	155.625100	328.524000	4358.214000	0.220196
15.	128.655500	160.011100	323.625000	4363.500000	0.103645
16.	129.372700	151.423400	322.625000	4355.500000	0.063834
Overall RMS = 0.143388 Overall Positional error = 4.30164 meters					

Table 8. OCTOBER 1988 Resample : Summary of Transformation

Coefficient	X		Y		
b0	697.7812513264070730		-4443.0469839848228700		
b1	1.0345164563366298		0.2210350587146510		
b2	-0.2079880615212417		1.0382847146725638		
Control Point	Old X	Old Y	New X	New Y	Residual
1.	135.690000	155.260500	332.840000	4357.995000	0.101799
2.	135.487900	156.008000	332.758000	4358.725000	0.097225
3.	135.747900	154.752600	332.746000	4357.513000	0.099431
4.	138.190200	156.441800	335.355000	4358.549000	0.051461
5.	137.253900	158.020400	334.762000	4360.249000	0.112425
6.	138.418300	157.948400	335.820000	4359.953000	0.113963
7.	135.690500	157.630200	333.051000	4360.251000	0.271035
8.	135.943000	156.543200	333.293000	4359.133000	0.101165
9.	138.228300	153.460700	334.880000	4355.844000	0.122100
10.	136.888700	152.375100	333.373000	4355.055000	0.058677
11.	143.719700	153.584400	339.976000	4354.452000	0.338404
12.	142.514300	161.384700	340.286000	4362.095000	0.124912
13.	131.950500	159.591300	330.238000	4362.405000	0.265174
14.	131.033600	154.815200	328.524000	4358.214000	0.237225
15.	124.995500	159.081000	323.625000	4363.500000	0.047430
16.	125.701100	150.562300	322.625000	4355.500000	0.070553
Overall RMS = 0.162781 Overall Positional error = 4.88343 meters					

Table 9. JULY 1990 Resample : Summary of Transformation

Coefficient	X		Y		
b0	718.1866989027184900		-4510.3672680218296600		
b1	1.0384841674129040		0.2067126064905738		
b2	-0.2118341260294372		1.0549956529052551		
Control Points	Old X	Old Y	New X	New Y	Residual
1.	140.676800	156.126600	332.840000	4357.995000	0.028989
2.	140.449600	156.799700	332.758000	4358.725000	0.060009
3.	140.668200	155.543600	332.746000	4357.513000	0.029197
4.	143.113500	157.218100	335.355000	4358.549000	0.046497
5.	142.273300	158.673600	334.762000	4360.249000	0.221956
6.	143.348600	158.743600	335.820000	4359.953000	0.039140
7.	140.497900	158.468500	333.051000	4360.251000	0.108494
8.	140.863000	157.343200	333.293000	4359.133000	0.059864
9.	143.123500	154.242100	334.880000	4355.844000	0.114901
10.	141.833200	153.191800	333.373000	4355.055000	0.082854
11.	148.958500	153.768800	339.976000	4354.452000	0.150489
12.	147.436700	162.141200	340.286000	4362.095000	0.197974
13.	137.060800	160.367700	330.238000	4362.405000	0.155922
14.	135.935800	155.577900	328.524000	4358.214000	0.242677
15.	129.968000	159.891000	323.625000	4363.500000	0.119547
16.	130.635500	151.394300	322.625000	4355.500000	0.063521
Overall RMS =	0.126749		Overall Positional error = 3.80247 meters		

Table 10. MAY 1994 Resample : Summary of Transformation

Coefficient	X		Y		
b0	674.9237847270560450		-4415.0526235927245600		
b1	1.0336020013089740		0.2187370777094872		
b2	-0.2005821830829291		1.0322796835432015		
Control Point	Old X	Old Y	New X	New Y	Residual
1.	144.845900	156.335800	332.840000	4357.995000	0.092286
2.	144.605900	157.086000	332.758000	4358.725000	0.075536
3.	144.838400	155.806900	332.746000	4357.513000	0.100252
4.	147.298200	157.479800	335.355000	4358.549000	0.063760
5.	146.421900	159.028400	334.762000	4360.249000	0.159418
6.	147.520200	158.992400	335.820000	4359.953000	0.104317
7.	144.555400	158.716200	333.051000	4360.251000	0.083234
8.	145.031900	157.587200	333.293000	4359.133000	0.109942
9.	147.388200	154.568600	334.880000	4355.844000	0.086755
10.	146.037800	153.428100	333.373000	4355.055000	0.113771
11.	152.827200	154.645800	339.976000	4354.452000	0.328492
12.	151.604300	162.412200	340.286000	4362.095000	0.152967
13.	141.378100	160.581200	330.238000	4362.405000	0.225497
14.	140.080100	155.861400	328.524000	4358.214000	0.276232
15.	134.137800	160.158000	323.625000	4363.500000	0.082786
16.	134.775700	151.659300	322.625000	4355.500000	0.052443
Overall RMS = 0.152517 Overall Positional error = 4.576551 meters					

Table 11. JULY 1994 Resample : Summary of Transformation

Coefficient	X		Y		
b0	755.7947558057203420		-4518.4075239006197100		
b1	1.0391035238066402		0.2070557839913807		
b2	-0.2197548422479088		1.0569622542810322		
Control Point	Old X	Old Y	New X	New Y	Residual
1.	143.943500	156.723300	332.840000	4357.995000	0.027057
2.	143.733400	157.449600	332.758000	4358.725000	0.053826
3.	143.973500	156.189100	332.746000	4357.513000	0.027734
4.	146.428200	157.839800	335.355000	4358.549000	0.025664
5.	145.527900	159.388400	334.762000	4360.249000	0.152418
6.	146.590200	159.388400	335.820000	4359.953000	0.056004
7.	143.685400	159.100300	333.051000	4360.251000	0.073079
8.	144.213500	157.977800	333.293000	4359.133000	0.072157
9.	146.547800	154.960800	334.880000	4355.844000	0.066917
10.	145.167800	153.788100	333.373000	4355.055000	0.040939
11.	152.242300	154.398000	339.976000	4354.452000	0.119734
12.	150.737400	162.779700	340.286000	4362.095000	0.169588
13.	140.275500	161.031300	330.238000	4362.405000	0.164089
14.	139.240200	156.258900	328.524000	4358.214000	0.256296
15.	133.275500	160.528500	323.625000	4363.500000	0.162497
16.	133.901000	152.022400	322.625000	4355.500000	0.030439
Overall RMS = 0.114882 Overall Positional error = 3.44646 meters					

Table 12. SEPTEMBER 1994 Resample : Summary of Transformation

Coefficient	X		Y		
b0	708.9314980010094590		-4432.6676156169269200		
b1	1.0330358548272809		0.2184108697938756		
b2	-0.2086759348985012		1.0364199889700245		
Control Point	Old X	Old Y	New X	New Y	Residual
1.	143.379500	156.663300	332.840000	4357.995000	0.080870
2.	143.163400	157.413600	332.758000	4358.725000	0.078608
3.	143.397500	156.129100	332.746000	4357.513000	0.098820
4.	145.858500	157.798100	335.355000	4358.549000	0.069036
5.	144.963300	159.298600	334.762000	4360.249000	0.217972
6.	146.043500	159.358700	335.820000	4359.953000	0.064667
7.	143.169400	159.064300	333.051000	4360.251000	0.088452
8.	143.583500	157.923800	333.293000	4359.133000	0.096130
9.	145.948500	154.862200	334.880000	4355.844000	0.101208
10.	144.598200	153.721800	333.373000	4355.055000	0.116728
11.	151.342200	154.960800	339.976000	4354.452000	0.356399
12.	150.164300	162.727200	340.286000	4362.095000	0.114368
13.	139.705500	160.956300	330.238000	4362.405000	0.217264
14.	138.644100	156.177100	328.524000	4358.214000	0.258956
15.	132.675300	160.484000	323.625000	4363.500000	0.051983
16.	133.365800	151.974300	322.625000	4355.500000	0.063379
Overall RMS = 0.154305 Overall Positional error = 4.62915 meters					

Histogram Results

Table 13 presents a summary of the statistics derived from the histograms of the isolated areas in the July images. The HISTO module was used on the isolated areas derived from ISOCLUST. Table 14 shows the statistics of all the images. The results came from the isolated areas derived from the mask.

Table 13. Summary of the July NDVI histograms.

Date of the TM data	JULY 1987	JULY 1988	JULY 1990	JULY 1994
Class Width	1.0	1.0	1.0	1.0
Actual minimum	0.0	0.0	0.0	0.0
Actual maximum	194.0	193.0	166.0	185.0
Mean (%)	184.9 (100%)	181.9 (98.4)	158.5 (85.7)	177.9 (96.2)
Study-forest area (Km ²)	3.73	3.49	3.83	3.52

In the summary of the July histograms, 1987 has the highest NDVI mean value. The lowest NDVI mean value is in 1990. The mean NDVI value of 1988 is a little less than 1987 and higher than 1994.

Table 14. Shows a summary of the histograms of all the images based on July 1987 mask.

Month/Year	Minimum	Maximum	Mean (%)	Stan. Dev.
July 1987	0	194.0	184.9 (100)	5.8
June 1988	0	193.0	177.8 (96.2)	15.4
July 1988	0	193.0	171.5 (92.8)	20.4
Oct. 1988	0	193.0	166.0 (89.8)	12.1
July 1990	0	166.0	154.1 (83.3)	11.4
May 1994	0	191.0	180.0 (97.3)	12.9
July 1994	0	198.0	172.0 (93.0)	13.9
Sept. 1994	0	180.0	162.0 (87.6)	7.6

In the summary of the NDVI mean values of all the images, July 1987 has the highest mean value. July 1990 has the lowest mean NDVI value. The mean NDVI values show a decrease over the course of individual years. The highest mean NDVI values in 1988, 1994 are in June and May. The July images show a decrease in mean NDVI values when compared to the earlier scenes. The October 1988 and September 1994 NDVI values show even further decline.

Chapter Six

CONCLUSIONS

In the study of the preserved forests in Ft. Leavenworth, 1987 was a good year for vegetation growth. This was indicated in the mean NDVI value (Table 14). The mean value reflected the visual interpretation of the July 1987 image, showing a year of maximum extent and vigor in vegetation. Visual analysis of 1988 showed that the vegetation was under severe stress. The stress was due to a drought that began in 1988 and continued into 1989. In the tasseled cap bands the July 1988 moisture image revealed high moisture conditions. This may be a reflection of rainfall occurring close to the time the image was taken. The moisture images in the tasseled cap bands are probably more reflective of recent ephemeral events than overall trends. The tasseled cap bands for brightness and greenness reflected the expected outcome with the highest soil brightness in 1988 and the most greenness in 1987. In visual analysis of 1990, low vigor is reflected in vegetation. The mean NDVI values is the lowest for all the scenes (Table 14). One possibility for this is that the growth of tree leaves suffered a delayed response to the drought of 1988-89. In 1994 vegetation is fairly healthy overall, but not as good as 1987.

In the related study of the tree-ring cores, 1987 was a good year for woody growth. The tree-ring for 1988 was minimal, meaning that 1988 was not a good year for woody growth. The woody growth of trees apparently responds quickly to climate change. Tree-ring growth was nearly normal in 1990. In 1994 there was a small decline in tree-ring growth.

The use of NDVI values for the analysis of climatic variations may not indicate the most recent events but may reflect the health of the canopy. On the level of individual leaves response may be delayed during unfavorable climatic events. If drought conditions occurred after leaf growth, the response of the leaves may not reflect the drought conditions in a particular year. Although, certain tree species may respond more quickly than do others, the results of this study are based on overall canopy reflectance. Therefore, the canopy might not reflect the drought conditions until subsequent years. Additional years of data, especially July 1989 and July 1991, would be necessary to confirm the conclusions presented here.

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Analysis of Forest Change at Ft. Leavenworth, Kansas using Landsat Thematic Mapper Data

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