USING A GIS AND VEGETATION COVER DERIVED FROM LANDSAT-TM IMAGE CLASSIFICATION TO ASSESS THE HEALTH OF THE KLAMATH RIVER HYDRO-BASIN IN NORTH AMERICA

Lawrence Fox III and Steven A. Carlson, Professors
Departments of Forestry and Natural Resources Planning and Interpretation
Humboldt State University
Arcata, California 95521 USA

CONTENTS

USING A GIS AND VEGETATION COVER DERIVED FROM LANDSAT-TM IMAGE CLASSIFICATION TO ASSESS THE HEALTH OF THE KLAMATH RIVER HYDRO-BASIN IN NORTH AMERICA

Lawrence Fox III and Steven A. Carlson, Professors
Departments of Forestry and Natural Resources Planning and Interpretation
Humboldt State University
Arcata, California 95521 USA

Commission VII, Working Group 3

KEY WORDS: Ecosystem Management, Existing Vegetation, Landsat-TM, GIS, Fisheries

ABSTRACT

We have classified 1994, Landsat Thematic Mapper imagery to create an existing vegetation map of several key watersheds in the Klamath River basin. We present the results for two watersheds in this paper and describe a method for focusing the analysis on the near stream areas in these watersheds. Spectral signatures were developed using hybrid training techniques (both supervised and unsupervised) to accurately classify and map vegetation types and conditions. Our classification system is patterned after an existing wildlife habitats classification commonly used in California, USA; modified to insure accurate classification without compromising its utility for ecosystem management. Our analysis was focused on near stream regions by summarizing land areas by vegetation type within a 180-meter stream corridor. Stream vectors were obtained from existing data files. Our analysis provides a tool which allows a quick assessment of stream side shading vegetation. Since stream temperatures are so critical to the growth and survival of young salmon, protecting and restoring shade-producing vegetation is a major focus of most fishery restoration programs. The maps enable landowners and restoration workers to rate the problems and plan the work around livestock management needs.

INTRODUCTION

Pacific Salmon populations have declined precipitously in the past three decades. Their decline has devastated salmon-dependent coastal communities from central California to Puget Sound in Washington State. The United States Congress has authorized several initiatives to restore salmon, including the 1986 Klamath Act (P.L. 99-552). The Act directs the U.S. Secretary of the Interior to conduct a 20-year-long Klamath River Basin Fisheries Restoration Program. Anticipating the continuing need for information to sustain the Restoration Program's monitoring, evaluation and adaptive management needs, the Program managers recommend the development of a basin wide coordinated information system.

We are developing portions of this information system in cooperation with the U.S. Fish and Wildlife Service - Klamath Basin Ecosystem Restoration Office, the National Aeronautics and Space Administration (NASA) and William M. Kier Associates, Sausalito, California, USA (creators of the Klamath Resource Information System, KRIS). The purpose of this paper is to describe one aspect of our work, the integration of an existing vegetation map, derived from Landsat-TM imagery, with stream vectors obtained from the U.S. Environmental Protection Agency's River Reach File (RF3).

We are delivering both electronic and hard copy maps of individual river basins. The electronic versions of these maps are fully attributed, "raster" data layers that may be incorporated into a Geographic Information System (GIS) such as Arc/INFO or ArcView. We have produced these existing vegetation maps through multispectral classification of 1994 Landsat Thematic Mapper Imagery provided by NASA's Mission to Planet Earth.

METHODS

Landsat image acquisition dates ranged from June 22, 1994 through August 9, 1994 with five of the images acquired between July 8 and 17, 1994. The close proximity of the acquisition dates provided seamless coverage during one, early-summer season of plant phenology, in a time frame surrounding the summer solstice, thereby minimizing the effects of terrain shadowing in the imagery.

Hybrid Signature Development

We developed separate spectral signatures for each Landsat Scene except for scenes acquired on the same day, which were merged before signatures were developed. It was necessary to develop unique signatures for each day of image acquisition due to the slightly different spectral properties of the atmosphere on different days.

We used a hybrid approach to spectral signature development, incorporating both "supervised" and "unsupervised" techniques. Supervised training produces one spectral signature associated with one characteristic location of a vegetation or land cover type. Unsupervised training produces several spectral signatures associated with natural clusters in the multispectral image data, occurring over several areas of a vegetation type or multiple vegetation types. Both techniques are valuable for vegetation mapping: supervised methods, for specific homogeneous vegetation types of special interest to cooperators, and unsupervised methods, for heterogeneous mixed vegetation types or barren areas.

To begin the process, one hundred rectangular regions, each corresponding to a USGS, 7.5 minute quadrangle map, were selected as "training regions" for spectral signature development. We produced color composite images and "unsupervised" cluster maps of these training regions using the ERDAS, ISODATA clustering algorithm with 28 classes. These maps were sent to field inspection teams from cooperating organizations (the California Department of Fish & Game, Bureau of Land Management, Fruit Growers Supply Company, Klamath Tribes and the U.S. Forest Service). The field inspection teams provided feedback on how well our unsupervised classifications represented the vegetation mosaic present in the training regions. In addition to this general, "how are we doing" type of information, the teams measured field plots in specific vegetation types to provide quantitative information on habitat types, percentage of crown closure and tree size.

Spectral signatures were saved from the specific ISODATA classes that were reported to associate with specific vegetation cover types. The field data plots allowed us to also develop additional spectral signatures by "growing" supervised spectral training areas around ground plot locations, using the ERDAS "SEED" function. The SEED function allowed us to grow a spectrally homogeneous area of between 20 and 200 pixels, representing a characteristic vegetation type or land type. The degree of homogeneity of the area was controlled by specifying a multispectral Euclidean distance threshold for inclusion of pixels. Once the threshold was exceeded, the regions stopped growing. After developing a sufficient number of supervised spectral signatures (normally 20 to 60) using the SEED function, we added those signatures to the signatures selected from the cluster maps. The combined signatures were edited to insure that all signatures were spectrally unique and statistically differentiable. We then used those combined signatures to drive a maximum likelihood image classification algorithm over a large area of the image (several training regions). We constrained the classification to a 95 percent probability of inclusion in order to identify pixels that did not fit well into any of the existing spectral classes, as "unclassified."

Pixels left unclassified (normally 10 to 20 percent of the data set) were used to develop new spectral signatures by unsupervised techniques. The ERDAS, ISO-DATA clustering algorithm was applied to the unclassified pixels to develop 10 to 40 new spectral signatures. These new, unsupervised signatures were also combined with the previously developed, hybrid signatures. After adding the new signatures, the signature file was edited again to insure that all signatures were spectrally unique and statistically differentiable. We again used the hybrid signature file to drive the maximum likelihood classification algorithm over the same region. The thresholding process was repeated and the entire unsupervised process was repeated once more, to classify remaining areas of the image, resistant to previous classification. We thus classified 98 percent of the pixels, realizing that 100 percent classification is virtually impossible with the maximum likelihood classifier, when constrained probabilistically. The rationale being that it is better to fail to classify two percent of the image than to classify that two percent into the wrong classes.

Classification results were printed at 1:24,000 scale for distribution to the field inspection teams. The teams provided final review of the signatures and corrected any mislabeled signatures. Their corrections were incorporated into the final classification maps.

RESULTS

Existing Vegetation

Final maps of 1994, existing vegetation were prepared in electronic and hard copy forms. The 0.09 hectare grid cell maps each cover one specific watershed within the Klamath River Basin. The vegetation classification system was developed to be as similar as possible to the Wildlife-Habitat Relationships (WHR) classification system (Mayer and Laudenslayer, 1988). However, spectral signatures from the Landsat Thematic Mapper Sensor sometimes failed to discriminate a specific WHR habitat type. This can occur when the WHR label contains a geographic reference (e.g. valley or coastal) that does not necessarily indicate a different vegetation composition. This can also occur when two or more vegetation types and/or stages, have very similar spectral signatures (e.g. Douglas-fir and white fir of similar size and closure). Sometimes, the spectral signature provided more information than the WHR type. This occurred when the WHR type contained multiple canopy geometries that have very different spectral signatures (e.g. needle-leaf and broad-leaf mixtures). When a spectral difference allowed for finer discrimination than the WHR system, we mapped those specific classes. The spectral classification system as developed from signature analysis is shown in Table 1. The Landsat Habitat Type and its Symbol are on the left. WHR classes included in the Landsat Type are listed in parentheses in the middle column. All discriminated stages of WHR size and canopy closure or zone and substrate class, are listed in the right column. Typical map symbols would be: SHGD (Greenleaf Shrub, closure class D) or MCP5M (Mixed Pine, size class 5, closure class M). We do not label any spectral class with a symbol implying land-use. For example, we do not use labels like: agriculture, crops, cropland, orchard, vineyard, residential, urban, roads, fallow, pasture, etc. We label these areas according to their vegetation cover (or lack there of) as defined by the classes we are using. We do not label any spectral class with a reference to geographic location or geographic shape. For example, we do not use labels like: river, marsh, lake, bay, ocean, coastal...., valley......, etc. We label these areas according to their vegetation condition. This is because spectral signatures recognize surface features of individual pixels as a spectral pattern without regard to where that feature is located, or to what landscape feature that pixel belongs. For example, water in a lake looks like water in a river, to a spectral signature classifier.

The accuracy of the final maps has not yet been assessed in a formal, post classification study. However, the accuracy was constantly assessed during the classification process and the classification system was modified to insure accurate classifications. Whenever any doubt about spectral discrimination was indicated, the classification was generalized to a level that did produce reliable discrimination. We have every reason to believe that formal accuracy assessment will report accuracy levels of between 80 and 95 percent.

GIS, Map Analysis

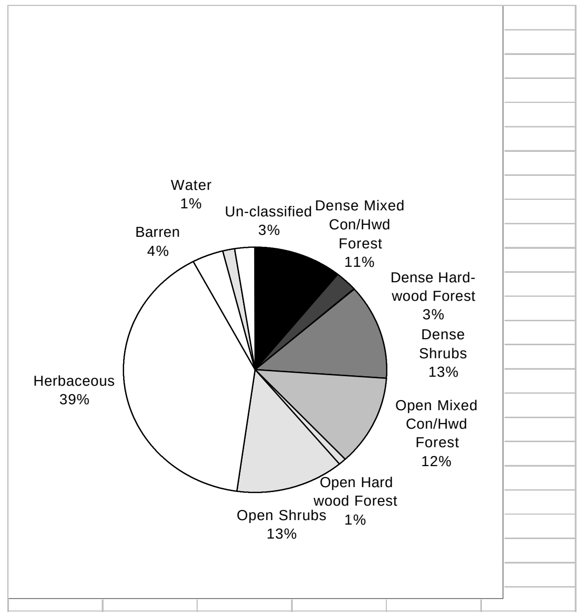
As an example of a fisheries related, GIS overlay analysis possible with the 1994 Existing vegetation maps produced by this project, we constrained the vegetation classification to the area adjacent to streams in two watersheds in the Klamath River Basin. We displayed and summarized the 1994 existing vegetation map for a 180 meter buffer corridor around the stream vectors in these watersheds. Stream information was obtained from the EPA River Reach files (RF3). The 180 meter corridor was calculated by adding three pixels in each direction, at right angles to the stream vector.

This type of analysis allows the inspection of near stream conditions relative to shade producing vegetation. There is considerable evidence that shade producing vegetation provides a critical element in the temperature controlling mechanisms of streams, especially valley streams in the Klamath River Basin. Water temperatures in many streams, within the two watersheds illustrated here, are lethal to young salmonids in the summer months. The normal development of riparian shrub and forest cover near these streams is often retarded by cattle which are allowed to graze up to the water's edge. A popular restoration project is to build fences near the streams to keep the cattle away from the riparian area. This has the double benefit of allowing the riparian forest vegetation to develop (thus shading the stream) and keeping the cattle waste out of the stream. Maps such as these could be used to plan fencing projects in areas where non-forest vegetation dominates the near stream buffer zone.

We color coded the vegetation map to represent general categories of shade producing cover (less shade, warmer colors) and summarized the land area associated with each class. Pie charts (Figures 1 and 2) allow a rapid visual assessment of the relative proportion of shade producing vegetation near the streams in these watersheds. For example, simple visual comparison of the two pie charts immediately communicates that the Shasta River watershed has less shade-producing vegetation than the Scott.

CONCLUSION

Our analysis has yielded a tool which allows a quick assessment of stream side shading vegetation. Since stream temperatures are so critical to the growth and survival of young salmon, protecting and restoring shade-producing vegetation is a major focus of the Klamath fishery restoration program. Where landowner cooperation can be achieved, restoration program workers have constructed fences to exclude livestock from stream banks to allow the vegetative canopy to recover. The maps enable landowners and restoration workers, usually employees of the local resource conservation districts, to rate the problems and plan the work around livestock management needs.



REFERENCE

Mayer and Laudenslayer, 1988. A Guide to Wildlife Habitats of California. California Department of Fish and Game, Sacramento, California. 166p.

Figure 1. A pie chart of vegetation classes within a 180 meter corridor around streams in the Shasta River basin.

Figure 2. A pie chart of vegetation classes within a 180 meter corridor around streams in the Scott River basin.

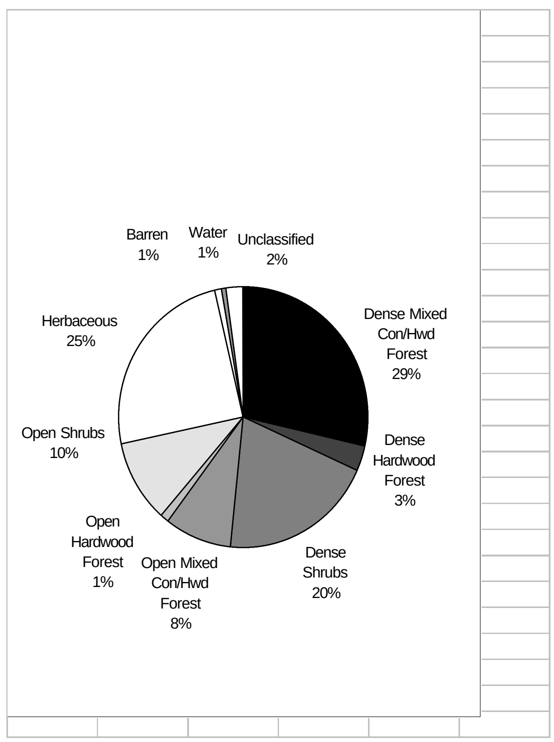


Table 1. Spectral Classification System for the 1994, Existing Vegetation Mapping, Patterned after California's Wildlife-Habitat Relationships (WHR) Classification System (Mayer and Laudenslayer, 1988).

GENERAL TREE TYPES

<u>LANDSAT HABITAT TYPE</u> <u>Symbol</u> <u>Included WHR Types</u> <u>Stages (WHR tree size & closure[1])</u>

(1) Mixed Conifer MCN (SCN, RFR, SMC, WFR, 2S 2P 2M 2D 3S 3P 3M 3D
(Needle-leaf, <20% broad-leaf) KMC, RDW, DFR, JPN, 4S 4P 4M 4D 5S 5P 5M 5D
PPN, EPN, CPC, LPN)

The above classes repeat for all four

LANDSAT HABITAT TYPE	Symbol	Included WHR Types
1A. Mixed Fir (Mapped when possible)	MCF	(SCN, RFR, SMC, WFR, KMC, RDW, DFR)
1B. Mixed Pine (Mapped when possible)	MCP	(JPN, PPN, EPN, CPC, LPN)
(2) Mixed Conifer-Hardwood (Mixed needle-leaf & broad-leaf, >50 % Needle-leaf)	MCH	(MHC, KMC, DFR, JPN, PPN, EPN, RDW, CPC)
(3) Mixed Hardwood-Conifer (Mixed broad-leaf & needle-leaf, >50 % broad-leaf)	MHC	(MHC, MHW, BOP)
(4) Mixed Hardwood (Broad-leaf, <20% needle-leaf)	MHW	(MHW, MHC, MRI, VRI, EUC, ASP)
(5) Mixed Oak Woodland (Oak dominated broad-leaf)	MOW	(VOW, COW, BOW)
(6) Mixed Juniper/Pinyon	MJN	(PJN, JUN)

tree types. WHR tree size classes are:

Size Class	DBH Range (cm)
2	2 - 15
3	15 - 28
4	28 - 61
5	>61

WHR tree canopy closure classes are:

Closure Class	Canopy Closure (%)
S	10 - 24
P	25 - 39
M	40 - 59
D	60 - 100

NOTE 1: We do not discriminate WHR size class 1 for trees since areas containing seedlings < 2 cm in diameter are normally spectrally dominated by the companion vegetation.

GENERAL SHRUB TYPES

LANDSAT HABITAT TYPE	Symbol	Included WHR Types	Stages (WHR shrub closure[2])
Greenleaf Shrub (dominated by green leaves)	SHG	(ADS, MCP, MCH, CSC)	S (10-24) P (25-39) M (40-59) D (60-100) Percent crown closure
Deadstick Shrub (dominated by woody sticks)	SHD	(LSG, BBR, SGB, ASC MCH, CRC, CSC)	S P M D
Soft Shrub (lacking stiff woody stems)	SHS	(BBR, LSG, SGB)	S P M D

NOTE 2: We do not discriminate WHR, “size” (actually maturity) classes for shrubs.

Table 1. Continued.

GENERAL HERBACEOUS TYPES

LANDSAT HABITAT TYPE	Symbol	Included WHR Types	Stages (WHR herb. closure[3])
Dead Grass/Forb (dominated by dead leaves)	GSD	(PGS, AGS, CRP, PAS)	S (2- 9) P (10-39) M (40-59) D (60-100)

			Percentage of herbaceous cover			
Green Grass/Forb (dominated by live leaves)	GSG	(WTM, PGS, AGS, OVN, CRP, PAS)	S	P	M	D
Wet Meadow/Marsh	GSW	(WTM, FEW, SEW)	S	P	M	D

NOTE 3: We do not discriminate WHR height classes for herbaceous types.

GENERAL BARREN TYPES

LANDSAT HABITAT TYPE	Symbol	Included WHR Types	Identified Zones[4]
Snow & Ice	BSI	(none defined)	(none defined)
Soil	BSL	(RIV, MAR, EST, LAC, URB)	2
Gravel/Rock/Talus (includes concrete and asphalt)	BGR	(RIV, MAR, EST, LAC, URB)	2

NOTE 4: We combine WHR Zones 3 & 4 to form Zone 2 (exposed during satellite overpass). We do not discriminate WHR substrates. BGR and BSL types occurring in or near rivers and lakes are spectrally identical to BGR and BSL types occurring on upland sites.

GENERAL AQUATIC TYPE

LANDSAT HABITAT TYPE	Symbol	Included WHR Types	Identified Zones[5]
Water	WTR	RIV, MAR, EST, LAC	1

NOTE 5: We combine WHR Zones 1, 2 & 3 to form Zone 1 (submerged during satellite overpass). We do not discriminate WHR substrates.