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Evaluation of remotely sensed data for the location of extant populations of *Platanthera praeclara* and high quality tallgrass prairie remnants

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Introduction

In traditional field surveys, map and literature review are coupled with exhaustive field reconnaissance to locate extant populations of rare and endangered species. The ratio of new-populations-discovered to number-of-sites-visited is low using this methodology. Therefore, person-hours and funding may not be used optimally. Logistical difficulties encountered during fieldwork (i.e., landowner information, distance to potential sites) further decreases the efficiency of this methodology.

An effective means for locating high quality natural communities in large areas is satellite remote sensing (Colwell 1967, Griffiths et al. 1993). Indeed, digital data analysis has proven a useful tool for identifying rare species habitat in New England (Sperduto and Congalton 1996) and in the tallgrass prairie region (Lauver and Whistler 1993, Lauver 1995). The fact that all surfaces reflect characteristic spectral signatures is the premise for these analyses (Colwell 1967, Soriano and Paruelo 1992). The spectral signature of rare species habitat can be characterized by comparative analysis of digital satellite data and quantitative vegetation data from known locations of a rare species (Briggs and Nellis 1991). These data are then used in a regional classification of the satellite data to produce a map of potential habitat, thus increasing the likelihood of successfully locating extant populations of rare species (Lauver and Whistler 1993). Also, a spatial database of tallgrass prairie remnants suitable for *P. praeclara* will aid any future reintroduction efforts.

Platanthera praeclara is listed as a threatened species by the United States Fish and Wildlife Service. Likewise, ONHI ranks *P. praeclara* as a G2 (globally rare) S1 (state rare) species. Although historical records for *P. praeclara* exist from Craig and Rogers counties, there are no known extant populations in Oklahoma. *Platanthera praeclara* is a tallgrass prairie species that inhabits moist prairies and sedge meadows (Bender 1987).

The highly fragmented landscape in which prairie remnants and native hay meadows in northeastern Oklahoma presents adifficulty in developing an accurate map of the region. Fescue (*Festuca arundinacea*, an exotic species) dominated pastures are intermingled with native hay meadows and pastures of native grasses degraded by overgrazing and the application of herbicide to reduce forb abundance. Urban encroachment in the vicinity of Tulsa and Bartlesville has also had an adverse impact on native grasslands. However, Lauver and Whistler (1993) and Lauver (1995) were able to overcome these challenges using remotely sensed, digital data.

Remote sensing is the process of obtaining information about a given area through the utilization of sensory devices situated some distance from the area being studied (Colwell, 1967). The value of remote sensing to ecologist is that it allows for the study of natural communities on a large scale. In the past, plant ecologist have been able to sample community composition on a limited scale and, thus, assigning large areas to a vegetation type based on small scale samples.

Approaches to data collection and analysis

Analysis of remotely sensed data

Efforts to map world vegetation date to the early 16th century (Craighead, et al., 1988). But by the 20th century, aerial photography, using both panchromatic and near-infrared sensitive films, became available for ecological work. Colwell (1967) reviewed the use of remote sensing for ecological studies, addressing both academic and management concerns. Colwell discussed the use of photographic techniques, since digital images were not yet available. A common image analysis technique at that time was the use of stereograms, taken with panchromatic film, to evaluate the structure of wet grassy-glades in the Sierras.

Foresters use these methodologies to determine site quality (Colwell, 1967). By measuring tree heights or diameters in an area, the interpreter can ascertain the relative age of the stand. These values are then compared to a series of site index curves so that the stand can be placed into specific site classes. The photo interpreter can recognize trees as deciduous or coniferous based on crown architecture and shadows. The crowns of conifers are typically conical, casting conical shadows, whereas deciduous tress have rounded crowns and shadows. Shrubs can be readily identified by their small diameters and apparent height. Herbaceous vegetation often gives a fine textured appearance (Colwell, 1967).

The 1960's opened a new era in the acquisition of remote sensing data, the availability of instruments that were capable of measuring a wide spectrum of radiation (Jensen 1986). The prototype of modern spectral scanners was launched on broad Apollo 9. Launching of the Earth Resources Technology Satellite, ERTS-A (later renamed Landsat 1), in 1972, made this technology operational. Between July 1972 and March 1984, five Landsat satellites were placed into orbit (Craighead, et al., 1988).

Colwell (1967) stressed, as do others (Colwell, 1967; Brown, 1978; Carter, et al., 1979; Gross and Klemas, 1986; Gross, et al., 1987; Briggs and Nellis, 1989), that remotely sensed data has to be closely coupled with ground observation, also known as ground-truthing. Craighead, et al (1988) describe two methods for classifying vegetation with satellite imagery data: supervised and unsupervised. The unsupervised method involves identifying vegetation classes based on clustering algorithms with little or no ground-truthing. Supervised classification rely upon careful ground-truthing to aid classification algorithms in classifying sites with similar spectral qualities. Like pixels on the image are grouped and assigned a false color value (Craighead, et al., 1988).

The spectral reflectance of a site can tell the investigator a great deal about stand conditions at a site (Wilkie and Finn 1996). Healthy vegetation generally reflects 40 to 50% of the incident near-infrared radiation (0.7 to 1.1 micrometers) and absorbs 80 to 90% of the incident energy in the visible (0.4 to 0.7 micrometers), particularly in the red (0.6 to 0.7 micrometers) (Nellis and Briggs, 1989). On "False color" film, the near-infrared portion of the electromagnetic spectrum activates the visible red dye on the film. Analysis of these bands can indicate the vigor of a plant community (Green et al., 1995).

For the proper interpretation of remotely sensed data, Wilkie and Finn (1995) suggest a multispectral reconnaissance approach. The idea, basically, is that certain wavelengths produce certain bits of information. By supplementing an array of images and photographs from varying wavelengths the greatest amount of information in an area can be extracted.

Vegetation indices are computed by band ratioing. Nellis and Briggs (1989) used bands 4 to 2 and bands 4 to 3 of the Landsat MSS and TM data to develop the ratio of near-infrared to visible energy. These ratios are useful in determining levels of biomass or net primary productivity. Band ratioing is also necessary to remove shadowing in single band data (Nellis and Briggs, 1989). Craighead, et al. (1988) used ratios of band 5 (red) and band 7 (infrared) to determine the signatures of vegetation types in a study of arctic vegetation in northwest Alaska.

Texture analysis, a measure of the relative degree of difference between adigital number (DN) values of picture elements (pixels), has also been used in vegetation study (Nellis and Briggs, 1989). Simple statistical measures of local grey tone levels is one measure of texture. However, this only emphasizes local contrast and do not measure DN frequency through the whole image. So a truly valid measure of texture must also include both contrast and frequency information (Nellis and Briggs, 1989).

A digital image always contains tone and texture, but one property can dominate the other (Nellis and Briggs, 1989). Tone dominates in the portion of an image where there is little variation among discrete grey levels. Texture, though, is the dominant in a portion of the image which has wide variation in the grey levels. Likewise, if a patch is equal in size to the sensors instantaneous field of view (IFOV) and shows one discrete feature, the only property present is tone. As the number of discrete grey levels increases within the patch, so does the dominance of texture (Lillesand and Kiefer, 1987).

Further, texture can be either fine or coarse. Fine texture is described as the lack of spatial pattern as a result of wide variation in grey tone features. Coarse texture is defined as definitive features which extend over many pixels coarse texture (Haralick, et al., 1983). No one textural measure has been agreed upon for all applications. Texture features usually measure the similarity between a central picture element in a subset of the image matrix and the surrounding block of elements (Jensen 1986).

Under these circumstances the investigator has three options. The first is to collect and analyze vegetation data *in situ*. The second is to acquire and analyze aerial photography to produce large scale vegetation maps, and/or the acquisition of MSS data. The final option is to combine the *in situ* and remote sensing approaches (Roller, 1977).

The use of Landsat MSS data for the mapping vegetation is constrained by the need for improved spatial, spectral, and radiometric resolution (Gammon and Carter, 1979). Landsat MSS data was useful for spectral discrimination of large vegetated patches. Landsat TM imagery allows for greater detail in vegetation. However, it's IFOV of 30 X 30 m may not provide enough detail for local and regional mapping requirements (Jensen, et al., 1984).

When using digital imagery to map vegetation, phenology must be considered (Cowardin and Meyers, 1974; Lovvorn and Kirkpatrick, 1982; Wilkie and Finn 1996). Imagery from spring and summer are the most useful for determining species composition because (Lovvorn and Kirkpatrick, 1982). In Maryland, however, it was found that only 3 of the 12 spring vegetation types and 5 of the 14 fall vegetation types could be reliably identified from aerial photographs, implying little difference between seasons (Shima, et al., 1976).

Remote sensing has also been used to map the location of prairie pothole wetlands and tallgrass prairie remnants. Gilmer et al. (1980) estimated the number of prairie glacial wetlands in North Dakota using both Landsat and aircraft MSS data with a resolution of 0.4 ha. However, prairie wetlands range in size from several acres to less than 0.4 ha. Ponds as small as 5 m in diameter could be distinguished using aircraft MSS data. Wetlands were identified by the distinctive reflectance of surface water in band 7. The apparent size and shoreline length were calculated as well as designating the wetland by UTM coordinates. The data file was then used to summarize the number, total area, and size distribution of wetlands in the area.

Change detection is another application of digital imagery. Change detection is importance form of analysis for resource managers involved in long term site monitoring. In the case of *P. praeclara*, changes in site condition over time can be detected using a time series of digital images. Site degradation, as detected via digital image analysis, could motivate resource managers to take appropriate steps to insure the long term viability of a population.

Howarth and Wickware (1981) recommend four steps in the analysis of change using Landsat digital data. One, produce ratios of data from bands 5 and 7 from the two study dates of interest. Band ratioing is one of the simplest methods for detecting change. A color composite of the two ratioed images will vividly show areas of change. Two, Produce a supervised classification for the two ratioed images using ground truth data. Three, develop a change matrix for the area to determine the major environmental changes. These data and a knowledge of the ecology of the area in question will allow the researcher to make a statement concerning the nature and causes of change. Four, binary theme prints and conflict character assignment maps should be generated to allow the investigator to analyze the spatial character of change and, thus, identifying it's location and extent.

In a study of change along the Peace River, following the construction of a dam in 1968, Howarth and Wickware (1981) applied these procedures. Due to low water flow following construction of the dam, it was noted that vegetation adapted to drier conditions began to invade areas once inhabited by wetland plants. This trend was successfully reversed by the construction of a weir. Howarth and Wickware (1981) felt these activities provided an excellent opportunity to evaluate the use of remote sensing data in successional studies.

The band 5 ratio of Peace River study area images displayed the brightest tones in relation to water level changes (Howarth and Wickware, 1981). The brightest tones for vegetation change were obtained from the band 7 ratio. In producing a color composite, the red gun was assigned the band 5 ratio and the blue and green the band 7 ratio. This resulted in red coloration for areas of water level change, and blue coloring for areas of vegetation change. Areas with little vegetation change were displayed in tones of brown and grey, and white.

Simply displaying change by band ratioing offers the investigator limited ability to determine change (Howarth and Wickware, 1981). However, statistical analysis can be conducted to using digital data to determine change in areal extent of vegetation types. The results of such analysis can be expressed as percentage change between two or multiple dates or by generation of a change matrix. This allows investigators to interpret specific changes for a vegetation type from one year to the next.

Christensen, et al. (1988) approached the problem of change detection using an unsupervised method on up to 50 natural clusters. Vegetation clusters were identified on 1981, 1983, 1984, and 1985 MSS images of the study area. All images were registered to the 1981 image. Using minimal distance criteria, clusters were then assigned to one of six vegetation or landcover classes. Vegetation types were extracted from a 3 X 3 pixel area (17 X 17 m). Information thus gained was reduced to a 10 X 10 m effective area by weighting each pixel in the sampling area by around a central pixel (Christensen, 1988).

The problem of mixed pixel (e.g., pixels containing multiple vegetation types and, therefore, a unique value which may not cluster with a particular vegetation type) can be overcome by manually "seeded" clusters (Jensen, 1986; Christensen, et al., 1988; Finn and Wilkie, 1995). In this procedure, new "centers" for the original clusters are picked by the clustering algorithm. New points are then placed between clusters known to contain two or more vegetation classes, or mixed pixels. Migration of mixed pixels to the new intermediate centers should occur and homogenous pixels should remain in their original cluster. The new mixed cluster was then assigned to a vegetation class. Seeding provides more flexibility in supervised classification of clusters, permitting a closer match of MSS vegetation maps to ground reference data.

Lauver and Whistler (1993) used Landsat TM data to locate high quality tallgrass prairie remnants and potential habitat for rare species in Anderson County, in northeast Kansas. They used a hierarchical classification scheme to develop an unsupervised map of the study area. This discriminated between grassland and non-grassland areas. Grassland areas were then ground-truthed and a supervised classification conducted. The use of a Normal Difference Vegetation Index (NDVI), which employed bands 2, 3, 4, 5, and 7, were successful in differentiating high quality grasslands. Lauver and Whistler (1993) found that plant water status and biomass were the most reliable indices for locating tallgrass prairie remnants and potential habitat for rare species. The high quality tallgrass prairie remnants thus identified containing several populations of *Asclepias meadii* (Meads' milkweed), a federally listed threatened species.

A similar technique was used by Lauver (1995) to locate populations of *P. praeclara, A. meadii*, and *Gryllotalpa major* (the prairie mole cricket), a federal candidate. An NDVI analysis and a ratioing technique using bands 2, 4, 5, 7 was conducted on a series of Landsat TM images. Nine sites were found to harbor populations of *A. meadii*.

Vegetation sampling

Sampling points for vegetation studies can be placed along a transect line or be randomly distributed (Kent and Coker, 1992). Transects are typically arranged parallel to an environmental gradient. For example, if a researcher is interested in the influence of elevation on vegetation distribution, a transect can be ran from the bottom of a slope to the crest. Either arrangement is useful when characterizing the vegetation types present in an area. However, it might be more appropriate to place transects perpendicular to the gradient in order to minimize variability in species composition as a result of change in environmental composition.

Sampling points can be established suing either plot or plotless methods. Plotless methods include the point-center quarter, wondering quarter, and point-intercept frame. The point-center quarter method is used then forest vegetation. It involves the establishment of the transect line and the placement of sampling points at regular intervals along the transect. At each sampling point, the biologist divides the area into "quarters" of a circle around the sampling point. Within each quarter, the distance to the nearest tree is recorded as well as the species and diameter at breast height (DBH). These data are used to calculate the density, frequency, and basal area for individual species in the study area and for all species in the study area. A similar procedure is followed for the wondering quarter method.

The point-intercept frame is an accepted technique for sampling grassland vegetation. The frame stands upright over the vegetation. The upper member of the frame holds ten pins. When sampling vegetation, the biologist records the species plant which the pin comes into contact with, or "intercepts." This technique also involves the establishment of a transect. At regular or random intervals, the point-intercept is placed on the ground and the species "intercepted" recorded. This technique has been in use for many years, particularly among range managers who use point-intercept frames for vegetation monitoring and site characterization.

Plot methods are widely employed by vegetation scientists. They several advantages over plotless methods (as with all methodologies, however, these advantages must be evaluated relative to the research questions being asked). One advantage is the ability to "nest" plots, which allows the research to address the effects of scale in vegetation sampling. One example is the Whitaker plot, named after the prominent plant ecologist Robert Whitaker. A Whitaker Plot is square in layout and is 100 meters on each side. This is further stratified into subplots of 10 meters. Ten meter plots can be further subdivided into plots 1 meter on a side, 0.5 meter, 0.25 meter, etc. Such stratification allows for the sampling of large plants, particularly trees, at the 10,000 m^2, shrubs and understory trees at the 100 m^2, and various herbaceous strata at the 1 m^2 level and below.

In general, the size of a plot depends upon the research objective. Characterization of grassland and other herbaceous vegetation types (i.e., wetlands) may only require a number of plots at the 100 m^2 or 1 m^2 and below level (Brower et al. 1989). This is particularly true when characterizing the vegetation of a given area. However, smaller plots may be necessary when attempting to detect the response of plant species to environmental gradients. For example, 0.5 m^2 arranged along a transect parallel to a soil saturation gradient in wetlands is effective in detecting changes in species composition and abundance.

The type of data collected within a plot depends upon the growth forms present. For example, if trees and large shrubs are growing within the plot, the number of stems are counted and DBH is recorded for each species. For small shrubs, tree seedlings, and herbaceous species, the percent cover is typically estimated (Mueller-Dumbois and Ellenberg 1974). The percent cover is visually estimated and assigned to a cover category. In some cases, percent cover is estimated in increasing cover classes of five percent. This approach is appropriate when one is attempting to detect changes in species abundance, such as in gradient analysis studies. For vegetation characterization studies, a pre-established scale can be employed, such as the one developed by Rexford Daubenmire (Kent and Coker, 1992). This approach is also useful when sampling grassland vegetation in large plots. One difficulty with visually estimating percent cover is that each observer may arrive at a different value for the same species. Cover scales such as Daubenmires' help to reduce such errors (Barbour et al. 1987).

Recommendations

The use of satellite imagery to locate extant populations of *P. praeclara* in Oklahoma should be modeled after Lauver and Whistler (1993). Although quantitative sampling methods for grasslands were reviewed here, it does not appear to be necessary to sample vegetation in this fashion for such a study. Successful studies such as Lauver and Whistler (1993), Lauver

(1995), and Sperduto and Congalton (1996) used quantitative vegetation data. It would also be valuable to combine remotely sensed data with Geographic Information System data layers for soils, elevation. These data proved valuable in the work of Sperduto and Congalton (1996) in their search for the orchid *Isotria medeoloides* (small whorled pagonia).

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