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Using remote sensing and Geographic Information Systems for mapping noxious weed infestations within North Dakota

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Leafy spurge *(Euphorbia esula* L.) is a deep rooted, perennial weed with erect stems 40 to 80 cm tall (Stevens 1963). The weed reproduces by both vegetative buds and the production of large quantities of seeds. A native of Eurasia, leafy spurge was first reported in the state of Massachusetts in 1827 (Noble et al. 1979). Leafy spurge now occurs abundantly on the Northern Great Plains of the United States and the Prairie Provinces of Canada where it often forms stands dense enough to displace native plants and restrict cattle grazing (Rees and Spencer 1991).

Determining the extent and distribution of invasive plant populations on grasslands is often difficult because of the expanse and inaccessibility of these areas. The value of remote sensing techniques for grassland assessment is well established (Tueller 1982; Carneggie et al. 1983). Remote sensing technology offers rapid acquisition of data at costs lower than for ground surveys (Tueller 1982; Everitt et al. 1992). Both aerial photography and videography have proven useful for detecting many rangeland plants (Driscoll and Coleman 1974; Gausman et al. 1977; Carneggie et al. 1983; Everitt et al., 1987, 1992, 1993). Advantage is often taken of specific phenological stages to distinguish plant species of interest from others present (Driscoll and Coleman 1974; Everitt and Villarreal 1987; Everitt and Deloach 1990). Leafy spurge produces yellow bracts in late May or early June that give the plant a conspicuous yellow-green appearance (Lacey et al. 1985). We hypothesized that leafy spurge might be distinguishable on aerial imagery in this phenological stage.

Geographic information system (GIS) and remote sensing technology have been integrated for a variety of natural resource applications (Graetz et al. 1983; Eidenshink et al. 1988; Myhre 1992; Richardson et al. 1993; Anderson et al. 1993b), including mapping the distribution of noxious weeds (Dewey et al., 1991; Anderson et al., 1993a; Everitt et al. 1994). Remote observations in georeferenced formats help to assess the extent of infestations, develop management strategies, and evaluate control measures on noxious plant populations.

Leafy spurge was first reported in Theodore Roosevelt National Park in the late 1960's. In 1970 an estimated 13 ha of the park were infested. The infestation increased to 162 ha between 1975 and 1983, and was conservatively estimated as 283 ha in 1986. The objectives of this study were (1) to map and quantify the extent and distribution of leafy spurge within Theodore Roosevelt National Park during the summer of 1993, and (2) to provide information for managing the infestation.

Analysis of the digital park data derived from the 1:24000 scale map indicated that the south unit of Theodore Roosevelt National Park covered approximately 18,676 ha of the North Dakota Badlands. This estimate compares favorably with the official 18,680 ha extent of the park. Leafy spurge area estimates, derived from the aerial photography, accounted for 550 ha (or 3%) of the park. The densest infestations of leafy spurge within the park occurred in the Petrified Forest Plateau region, Knutson Creek, and the floodplain of the Little Missouri River. Small scattered populations of spurge were evident throughout the area south and east of the Little Missouri River and another large population of spurge occurred on the upper end of the Paddock Creek drainage basin. Most of the infestation appeared to be restricted to drainage channels, creek bottoms, and river bottoms. The non-random distribution of leafy spurge within the park is described by the curvilinear relationship:

$$\text{Area} = 64.322e^{-0.01267498d}, \quad (1)$$

where d = the distance from a drainage channel in meters, accounts for almost 100 percent (r^2=0.989) of the variance found in the data. Leafy spurge was not closely associated with other topographic features. Spurge seemed to have a slight affinity for south-easterly aspects and gentler slopes, however, substantial spurge populations existed over all conditions.

Normal color aerial photography was useful in mapping leafy spurge infestations on Theodore Roosevelt National Park. The yellow-green signature of well developed stands of leafy spurge were readily identifiable, but small isolated spurge stands with minimal bract formation were difficult to identify. Research in 1994 will seek to determine how much leafy spurge was missed by this procedure.

The non-random distribution of leafy spurge indicates that some factor(s) increase the likelihood of stand establishment near drainage channels. One contributing factor could be that leafy spurge populations are distributed in direct proportion to the amount of total land area present at varying distances from drainage channels. An analysis of the total surface area of the park demonstrates that for distances between 0 and 320 m from a drainage channel, the amount of surface area decreases linearly. Therefore, the distribution of the weed is not merely a reflection of the amount of available land area.

The observed distribution of leafy spurge could be a function of time, given the primary mode of seed introduction into an area is by surface water movement (accounting for the majority of the stands existing close to a drainage channel) and lateral movement away from a drainage channel is by seedpod dispersal (which requires time for stand establishment, seed production, and dissemination). If the distribution is a function of time, the curvilinear distribution should begin to flatten and approach the total land surface distribution as the spurge populations advance further from the drainage channels. This hypothesis needs further investigation. However, the large isolated stands of leafy spurge found on the upper end of the Paddock Creek drainage basin indicate that other modes of seed introduction (wind, man, wildlife, or domestic animals) are important. Seed deposition by modes of movement other than water and pod dispersal could be selective for drainage channel areas, however, the expectation is that the distribution would be much more random. In the park, where the distribution is so significantly associated with the drainage channels, it appears that factors such as soil moisture could be important influences on the success of leafy spurge establishment. In any case, the data indicate a predictable pattern of stand establishment that park managers may be able to use to combat the spread of leafy spurge.

The GIS was a good base for incorporating the polygons of leafy spurge identified on aerial photographs. Distortions in the photography that were removed by using the GIS to register the data to the USGS orthophoto maps aided in accurately estimating the size of the spurge infestations. The GIS also made it possible to combine the leafy spurge data with other existing data (map features or digital elevation data) and create new information (watershed basin, stream, slope and aspect maps) for a more in-depth analysis of the problem. The joint use of GIS and remote sensing technology proved to be a powerful combination of tools, which provided previously unavailable information about the extent and spatial dynamics of leafy spurge within the park. The results of this study should contribute to the development of a comprehensive leafy spurge management plan for Theodore Roosevelt National Park.

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