Predicting Spatial Distribution of White Locoweed (*Oxytropis sericea*) in the Maxwell Ranch, Larimer County, Colorado

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**Synopsis**


In semi-arid rangeland in the western U.S., there is a need to manage locoweed (*Oxytropis species*) populations because of its toxicity to livestock. We used statistical techniques, along with general linear models (GLM) incorporated into a Geographic Information System (GIS) along with remotely sensed data and soil data to predict the probability of observing white locoweed (*Oxytropis sericea*) in the Maxwell Ranch, Larimer County, Colorado. In the summer of 1999 and 2000, the presence/absence of white locoweed along with Universal Transverse Mercator (UTM) coordinates were collected in the Maxwell Ranch. Stepwise regression was used to select significant variables, such as slope, Landsat 7 band 1, 3, 6 and tasseled cap layer 1, available water content, and organic matter content to include in the model. The overall accuracy of the model to predict the presence/absence of white locoweed was 86%. Logistic regression equations were used to calculate probabilities of observing white locoweed in the study site.

**Key words:** Colorado, General linear models, Geographic Information System, Livestock, *Oxytropis sericea*.

**Introduction**

Locoweed (*Oxytropis* and *Astragalus* species) poisoning has been a problem to livestock producers in the western U.S. Loco in Spanish means crazy, the effect of poisoning by the plant on livestock. The toxin in locoweed is an indolizidine alkaloid, Swansoline, which causes neurological disturbances affecting disposition, locomotion, vision, and appetite, resulting in weight loss and emaciation. Locoweed toxicity also causes abortion and infertility.

1. **Biology of White Locoweed**

   White locoweed (*Oxytropis sericea*) is native to North America and grows from the Yukon Territory east to Manitoba and south to Nevada, New Mexico and Texas. White locoweed occurs in a wide range of plant communities, such as grasslands, forests, and tundra communities. White locoweed grows best on sandy loam soils, and is tolerant of moderate saline soils and low nutrient conditions. Growing season of white locoweed begins early in the spring, and the plants remain green throughout the summer. White locoweed is a perennial, leguminous forb that grows from 15 to 30 cm tall. The plant has a long taproot that enables to absorb water from deep soils. Livestock tend to consume locoweed in late winter or early spring when forage is in short supply, because locoweed is one of the first plants to germinate.

2. **Modeling**

   In this project, spatial statistical techniques were used in conjunction with general linear models (GLM) and GIS to spatially relate remotely sensed data and soil data to predict the probability of observing white locoweed (*Oxytropis sericea*) in the Maxwell Ranch, Larimer County, Colorado. GLM is broadly used statistical methods, which can be used to explore relationships between a particular plant species and environmental variables. The objective of this project was to develop a model to predict the probability of observing white locoweed on the Maxwell Ranch study site. The null hypothesis was that there is no spatial relationship between presence/absence of white locoweed and information extracted from GIS data, remotely sensed data, and soil data.

**Materials and Methods**

1. **Study Site**

   The Maxwell Ranch is located about 64 km northeast of Fort Collins, in Larimer County, Colorado. Elevation ranges from 2003 m to 2280 m, and the plant community is dominated by short grass steppe species. The total area is about 36 km², and the annual precipitation ranges from 381 to 432 mm. Relatively moist areas at high elevation are inhabited by Ponderosa pine (*Pinus ponderosa*), mountain mahogany (*Cercocarpus montanus*) and other shrub species.

   2. **Field Data Sampling**
In the summer of 1999, 47 plots were sampled in locoweed populations by Staraosta\textsuperscript{11}. The density of white locoweed along with vegetation composition by species and Universal Transverse Mercator (UTM) coordinates were recorded at each plot. This data set was used as presence information. In the summer of 2000, absence information was collected on 46 randomly selected plots outside of the locoweed populations. Random UTM coordinates were generated within the boundary of the Maxwell Ranch and outside of the known locoweed populations. GPS readings were taken at each plot. The size of each sample plot was $15\text{ m} \times 15\text{ m}$.

3. GIS Data and Remotely Sensed Data Acquisition

Topographic information and spectral reflectance information, extracted from a variety of digital files, were merged and clipped to fit the shape of the study area. Slope, aspect and elevation were extracted from 1:24,000 Digital Elevation Models (DEM) of Virginia Dale and Table Mountain Quadrangles, Colorado at a 30-m resolution in Arc/Info\textsuperscript{23}. Distances of the sample plots to roads were obtained from Digital Line Graphs (DLG). Soil data layers were extracted from Soil Survey Geographic Data Base. Landsat 7 Thematic Mapper (TM) imagery taken on August 7, 1998 was used to extract seven spectral bands, six tasseled cap layers and Normalized Difference Vegetation Index (NDVI) in grid files. This operation was done in ERDAS-IMAGINE\textsuperscript{31}.

4. Modeling

The presence/absence information, GIS and remotely sensed data were geo-rectified and converted to Arc/Info grid files. These grid files were converted to ASCII files, and point data extracted based on UTM coordinates of the sample plots and then imported to S-Plus\textsuperscript{36}. An Arc Macro Language was used to extract the point data. In S-Plus, the dependant variable, presence/absence information was coded as 0,1 data and then transformed using a logistic transformation. Stepwise regression was used to select variables that best describe the relationship between the presence/absence of white locoweed and the independent variables.

GLM was used to obtain parameter estimates associated with the variables identified from the stepwise procedure. By using the logistic regression equation and grid files associated with the significant variables, Arc/Info GRID was used to develop prediction surfaces of the probability of observing the presence of white locoweed on the Maxwell Ranch at a 30-m resolution where the probability of observing the presence of white locoweed $p(x)$ is

$$p(x) = \frac{\exp(\beta_0 + \beta_1 x_1 + \cdots + \beta_s x_s)}{1 + \exp(\beta_0 + \beta_1 x_1 + \cdots + \beta_s x_s)}$$  \hspace{1cm} (1)

where $x_1, \ldots, x_s$ are independent predictor variables and $\beta_0, \ldots, \beta_s$ are logistic coefficients\textsuperscript{36}. To identify suitable habitat of white locoweed, a threshold probability of observing white locoweed was determined for the GLM model as part of the output. The threshold probability was determined in the program when the number of correctly classified presence and absence plots was maximized.

Results

The stepwise procedure identified significant variables, such as slope (degrees), Landsat 7 TM band 1, 3, 6 and tasseled cap layer 1, available water content and organic matter content in discriminating between the presence/absence of white locoweed. The final regression model used to describe the probability of observing white locoweed populations on the Maxwell Ranch is shown in Table 1. This model was implemented in Arc/Info, GRID to develop a predictive surface of the probability of observing white locoweed on the Maxwell Ranch study site (Fig. 1). The overall accuracy of the model to predict the presence/absence of white locoweed was 86%. The optimal threshold value for outputs of the GLM model, which distinguished suitable from unsuitable habitat, was 0.47.

Discussion

1. Application of Results to Grazing Management

The methods and results of this project may be useful to apply grazing management strategies to reduce losses from locoweed poisoning. One of the most effective management alternatives called \textit{loco and pull} minimizes losses from locoweed poisoning and the cost for controlling the plant. In \textit{loco and pull}, livestock are left in locoweed-infested pastures until visual signs of poisoning are observed, then they are moved to locoweed free areas for rehabilitation\textsuperscript{10,12}. Another grazing management alternative that can be applied with \textit{loco and pull} is called \textit{delayed grazing}, proposed by Ralphs \textit{et al}.\textsuperscript{30}. In this alternative, grazing delays until grasses are actively growing in mid spring. In early spring when locoweed starts growing and grasses are still dormant, cattle are kept in locoweed-free areas, when the grasses begin to grow, cattle are allowed access to locoweed-infested areas since they tend to feed on grasses over locoweed\textsuperscript{13}.

The methods used in this project can be used by ranchers to identify high-risk and low-risk areas more practically and precisely in relatively short period of time and with minimal cost. Ranchers need to collect presence/absence information along with GPS readings, and overlay the field data on GIS layers. Once a locoweed habitat map is produced and
Table 1. GLM regression coefficients and associated statistics for predicting the probability of observing white locoweed on the Maxwell Ranch, Larimer County, Colorado.

<table>
<thead>
<tr>
<th>Variable</th>
<th>coef</th>
<th>std.err</th>
<th>t.stat</th>
<th>p.value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-20.3</td>
<td>1.7</td>
<td>-11.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Slope</td>
<td>-0.28</td>
<td>0.01</td>
<td>-32.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TM band 1</td>
<td>0.3</td>
<td>0.02</td>
<td>13.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TM band 3</td>
<td>0.3</td>
<td>0.02</td>
<td>14.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TM band 6</td>
<td>0.13</td>
<td>0.01</td>
<td>9.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TM TC layer 1</td>
<td>-0.2</td>
<td>0.01</td>
<td>-22.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Available water</td>
<td>-22.3</td>
<td>0.7</td>
<td>-30.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Organic matter</td>
<td>1.1</td>
<td>0.1</td>
<td>20.1</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Threshold values used to identify suitable and unsuitable habitat of white locoweed.

<table>
<thead>
<tr>
<th>Min.</th>
<th>1st Qu.</th>
<th>Median</th>
<th>Mean</th>
<th>3rd Qu.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40</td>
<td>0.47</td>
<td>0.48</td>
<td>0.47</td>
<td>0.48</td>
<td>0.49</td>
</tr>
</tbody>
</table>

**Std. dev 0.02

Overall accuracy of the model to predict the presence/absence of white locoweed.

<table>
<thead>
<tr>
<th>Min.</th>
<th>1st Qu.</th>
<th>Median</th>
<th>Mean</th>
<th>3rd Qu.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.86</td>
<td>0.86</td>
<td>0.86</td>
<td>0.86</td>
<td>0.87</td>
<td>0.88</td>
</tr>
</tbody>
</table>

**Std. dev 0.01

Fig. 1. Predicted habitat of white locoweed on the Maxwell Ranch, Larimer County, Colorado using a general linear model: overall accuracy = 86%, threshold probability = 47%.

High-risk and low-risk areas are identified, ranchers can formulate plans to create locoweed-free pastures. Ideally, a minimum of one-quarter of a ranch's pastures should be locoweed-free to apply alternative management strategies described above.2

2. Recommendations to Improve Predictive Accuracy

The observations based on Landsat TM 7 imagery that white locoweed tended to occur on drier areas could be different if imagery taken earlier in the growing season or in a different year was used. The satellite imagery used in this study was taken on
August 7, 1998 which was late in the growing season implying green vegetation on rangelands might have started drying. We recommend improving the predictive accuracy of the model by including more satellite imagery layers taken in different periods of the growing season. Including different kind of satellite imagery of sensor systems, such as RADAR (Radio Detection and Ranging), LIDAR (Light Detection and Ranging) and high spatial resolution sensor system imagery may be useful in the future study.

References
1) ERDAS (1998) ERDAS-IMAGINE ver. 8.4. ERDAS Inc. Atlanta, Georgia.

要旨
藤沢秀行・ロビン ライク（2003）：コロラド州、ラリマー郡、マックスウェルランチにおけるホワイトロコウィードの空間分布予測. 日草誌 49, 421–424, Colorado State University（Fort Collins, Colorado 80523, U.S.A.）

アメリカ西部の乾燥地帯に自生するロコウィード種は家畜に食害を与える為、分布域の特定および管理が必要である。本研究では、統計、GIS、リモートセンシング、土壤データベースを用い、ホワイトロコウィードの空間的分布をコロラド州、ラリマー郡、マックスウェルランチにおいて行った。ステップワイズ回帰法により選択された変数は GLM（General Linear Model）によりフィットされ、ホワイトロコウィードの分布可能性が研究地域全域で予測された。予測精度は86%であった。

キーワード：家畜、コロラド、GIS、ホワイトロコウィード.