Modeling vegetation pattern using digital terrain data


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Introduction

Distribution of plant species or vegetation of particular locality depend on the distribution patterns of biotic and abiotic site factors

Technique of defining vegetation

• **Classic:** Vegetation and site measurements from scattered samples are analyzed to develop empirical equations relating vegetation composition to measured site variables

• **Modern:** Using GIS

Limitations of classic technique

- Mixed success in even in relatively undisturbed areas because of the *dynamic behavior of plant communities* on spatial and temporal scale (Rowe & Sheard 1981)
- **Inadequate sampling:** Ground samples are not representative enough to model unsampled areas (Generalization error)
- **Sampling bias:** Homogenous stands were selected (Selective sampling)
- **Prediction Error:** Predicted pattern of vegetation is different to the actual pattern
Map of site model variables: Geology, Topography, Soils and other biotic and abiotic factors

GIS Map weighting and overlaying

Predicted vegetation maps

RS Thematic Mapper Simulator (TMS)

Actual vegetation map

Overlay

To analyze spatial pattern of disagreement

Limitations

Very difficult as the errors can originate from map of site variables, actual vegetation and from inadequacies of the site model

Solutions

Expert Knowledge
Statistical test (goodness of fit)
Objectives

- To calculate total area and patch size distribution of observed and predicted oak forest

- To calculate the amount and patch size distribution of predicted vegetation types for the areas of observed oak forest

- To calculate the amount and patch size distribution of observed vegetation types for the areas of predicted oak forest

- To measure the degree of disagreement between predicted and observed maps with respect to geology and topography
Study area

72 km² area NE of Lompoc, California (latitude 34°42’N, longitude 120°27’W)

Climate: Mediterranean, cool summers and mild winters
> 90% annual precipitation falls between Nov and April

Physiographic zones

Burton Mesa
• Marine terrace underlain by marine sedimentary rocks covered with sandstone
• Elevation 100-120m (low land area)
• Maritime chaparral dominated by evergreen shrub
• Multi-stemmed coast live oak
• Coastal sage scrub
• Annual grassland

Purisima Hills
• Northwest-southeast trending anticline of marine sedimentary rocks
• Elevation 225-450m (rolling hill & steep slope)
• Coastal sage scrub
• Chaparral
• Coast live oak woodland
• Coast live oak forest
• Bishop pine forest (*Pinus muricata*)

Disturbances eg. constructions, wildfire, grazing and clearing have persistent effect on actual vegetation and site variables
Methods

- **Vegetation Map**
  - TMS collected in July 1984 (28m resampled to 30m)
  - Accuracy testing (89%)
  - Co-registered in UTM projection
  - 2 vegetation types excluded (willow wood, grassland)

- **Reclassified Geological Map**
  - Geological map (Dibble 1950) digitized using ERDAS in 1:50000
  - Classify
  - Reclassified Geological Map
  - Logical regression model (Regression equations)

- **Predicted Vegetation Map**
  - DEM 30m (USGS)
  - Elevation, Slope, Angle, Aspect, Clear sky solar radiation, Drainage area

- **Reclassified Actual Vegetation Map (4)**

To analyze spatial pattern of disagreement
Results

Table 1. Classification system used to map dominant natural vegetation types in the study region. For logistic regression analysis, oak woodland and chaparral were merged into a "woodland/chaparral" category. Grassland and Willow woodland were excluded from the analysis. Map accuracy for each class is the proportion of samples classified correctly in the TMS-derived vegetation map, based on 141 test sites (see Davis (1987) for details).

<table>
<thead>
<tr>
<th>Class</th>
<th>% Oak cover</th>
<th>Dominant species</th>
<th>Map accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coast live oak forest</td>
<td>&gt;60</td>
<td>Quercus agrifolia</td>
<td>77</td>
</tr>
<tr>
<td>Coast live oak woodland</td>
<td>20-60</td>
<td>Quercus agrifolia, Toxicodendron diversifolium</td>
<td>86</td>
</tr>
<tr>
<td>Chaparral</td>
<td>O-20</td>
<td>Adenostoma fasciculatum, Arctostaphylos spp.</td>
<td>89</td>
</tr>
<tr>
<td>Coastal Scrub</td>
<td>O-20</td>
<td>Salvia mellifera, Baccharis pilularis, Eriogonum comosum</td>
<td>86</td>
</tr>
<tr>
<td>Conifer Forest</td>
<td>O-30</td>
<td>Artemisia californica, Pinyus monophylla, Quercus agrifolia</td>
<td>92</td>
</tr>
<tr>
<td>Grassland</td>
<td>O-20</td>
<td>Bromus spp., Vulpia spp., Avena barbata, Brassica spp.</td>
<td>89</td>
</tr>
</tbody>
</table>

Vegetation Types: Percentage

- Oak Forest: 4.5%
- Oak Woodland and Chaparral: 19.4%
- Coastal Scrub: 20.0%
- Conifer Forest: 2.9%
- Others (residential, cropland, grassland, willow woodland): 53.2%
- Total: 100%
Results

Mapped stands of oak forest averaged 0.51 ha with the size distribution strongly skewed toward 0.09 ha resolution of TMS data.
Results

Coniferous forest is restricted to diatomaceous shale of Sisquoc formation (Cole 1980)

<table>
<thead>
<tr>
<th>Geology</th>
<th>Oak forest</th>
<th>Oak woodland/chaparral</th>
<th>Coastal scrub</th>
<th>Conifer forest</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary deposits</td>
<td>2423</td>
<td>18824</td>
<td>8572</td>
<td>4</td>
<td>18530</td>
</tr>
<tr>
<td>Paso Robles</td>
<td>588</td>
<td>1335</td>
<td>1343</td>
<td>3</td>
<td>1811</td>
</tr>
<tr>
<td>Careaga sandstone</td>
<td>1927</td>
<td>6468</td>
<td>6195</td>
<td>8</td>
<td>2848</td>
</tr>
<tr>
<td>Sisquoc shale</td>
<td>939</td>
<td>5034</td>
<td>1434</td>
<td>500</td>
<td>819</td>
</tr>
</tbody>
</table>

*Table 2. Frequencies and relative percentages of 4 natural vegetation classes and other land cover types on four geologic substrates in the study area (n = 79,605 cells). Percentages for each substrate sum to 100%.*
Results

The proportion of observed oak forest that occurred on predicted oak forest sites was 40% overall but varied substantially between substrates.

60% times that doesn’t fit or Low predicted success, Observed oak forest on Quaternary deposits mapped onto predicted oak woodland sites.

Error is due to:
- Cartography error (Confusion between forest types)
- Ecological error (forest was not restricted on certain locality as model predicted)
Results

The proportion of observed oak forest on predicted oak forest sites also depended strongly on patch size.

Higher the rate of success for large patch size.
Higher error for the smaller patch size.
Excluding the path less than 2 ha in size, 60% of remaining forest occurred on the predicted site.
3 higher patch is perfectly located with in the predicted Oak forest.

Smaller patch size are random.
Larger patch are homogenous and easily depicted in DEM.

Fig. 6. Percent of observed oak forest occurring on predicted oak forest sites as a function of minimum forest patch size analyzed. Asterisks are actual data values. Solid line was fitted using locally weighted regression (Chambers et al. 1983). Broken line shows corresponding percent of observed oak forest on predicted oak woodland sites.
Results

Only 21% of predicted oak forest sites supported oak forest (lowest accuracy)
55% supported oak woodland (Highest accuracy)
24% supported coastal scrub, conifer forest or other cover types

Table S. Relative proportions of observed vegetation/land cover types on areas predicted as oak forest sites, as a function of substrate type (columns sum to 1).

<table>
<thead>
<tr>
<th>Observed vegetation</th>
<th>Quaternary deposits</th>
<th>Paso Robles conglomerate</th>
<th>Careaga sandstone</th>
<th>Sisquoc shale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak forest</td>
<td>0.17</td>
<td>0.14</td>
<td>0.18</td>
<td>0.13</td>
</tr>
<tr>
<td>Oak woodland</td>
<td>0.54</td>
<td>0.24</td>
<td>0.35</td>
<td>0.65</td>
</tr>
<tr>
<td>Coastal scrub</td>
<td>0.14</td>
<td>0.34</td>
<td>0.33</td>
<td>0.06</td>
</tr>
<tr>
<td>Conifer forest</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td>Other</td>
<td>0.14</td>
<td>0.28</td>
<td>0.15</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Fig. 7. Predicted distribution of coast live oak forest based on geology, topography and insolation. Black areas are predicted vegetation other than oak forest. Colored areas are predicted oak forest sites on which mapped existing vegetation was oak forest (red), oak woodland (blue), coastal scrub (green), conifer (white) or other land cover types (yellow). Image orientation and area are as in Fig. 1.
Conclusion

The accuracy depends on
• Substrate (Geology)
• Size of vegetation patch (Ecology)
• Disturbances: Hard to differentiate the disturbed and undisturbed areas (site variable).
• Flaw in Model (Much of the observed oak forest occurred only on lower portion of slopes. It indicates less intense disturbances on lower slope areas)
• Trade off between model complexity and model reliability

Recommendation:
• Accuracy of the data (High resolution DEM)
• Data with less cartographic noise
• Accurate operational process such as digitization and registration

GIS based cartographic technique is not substitute for field sampling and testing technique but is a complement to that technique and useful for analysis of large heterogeneous areas.