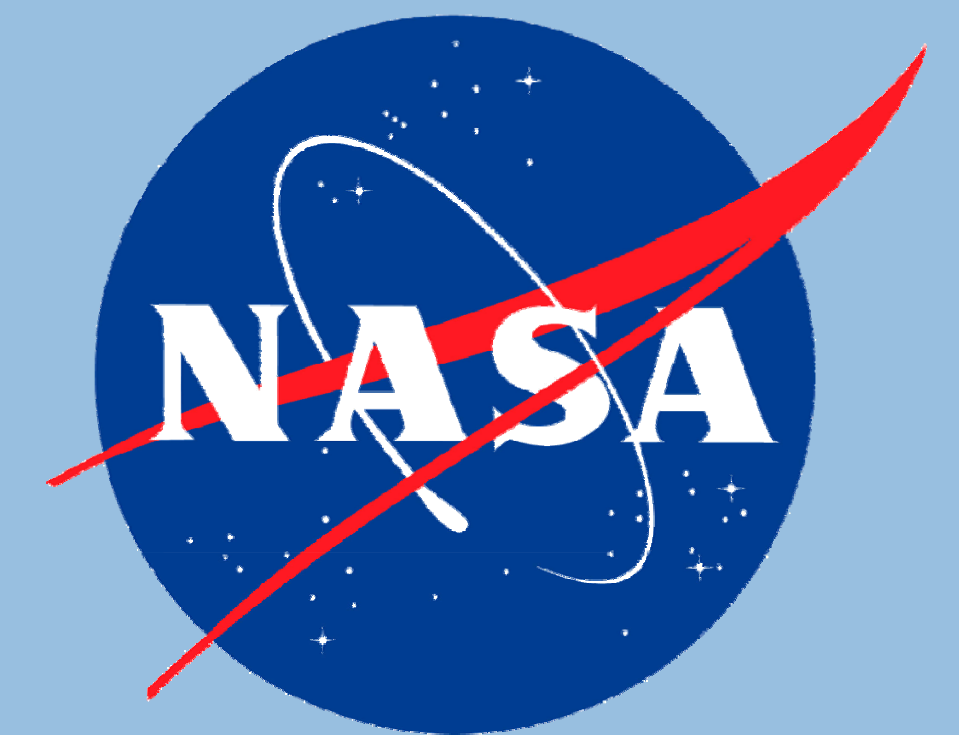


Multi-Temporal Land Cover Analysis in the Mid-Willamette Basin, Oregon: Assessment of Riparian Forest Canopy Using Landsat Thematic Mapper Data

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Abstract

The 11,500 sq. mi. Willamette Basin is home to 70% of Oregon's population and is associated with an extensive post-settlement history of land cover modification. Existing assessments estimate that between 30 and 44% of riparian zones have been subject to anthropogenic disturbances, which in turn have negatively impacted TMDL levels for temperature and sediment loading (Oregon DEQ, 2009). As such, riparian forest restoration is cited as one of the primary management objectives needed to improve habitat quality. This study involves a regional multi-temporal land cover analysis utilizing Landsat Thematic Mapper (TM) satellite imagery and supervised image classification to document changes in canopy cover (Landsat acquisition years 2000 and 2009).

The rectangular study site (Figure 1) is oriented north-south and extends from Yamhill to Eugene, occupying a 3,133 sq. mi. footprint that captures the dynamic land-use interface between urban centers, lowland riparian habitats, and Oregon Coast Range forests. Landsat 5 TM data for the study site were acquired via the USGS Global Visualization Viewer with multispectral imagery including 6 reflected bands suited for quantifying broad-scale land cover regimes, including vegetation. Classification training sites for water, forest, and agricultural land-cover categories were selected to accurately represent within-class spectral variability. A supervised classification scheme was employed to compare training signatures against the six reflective bands in each image year. A maximum likelihood algorithm was utilized to delineate land-cover classes with overlapping spectral signatures. Other processing techniques included radiometric normalization of brightness values, and derivation of NDVI and Tasseled Cap vegetative indices. Final classification accuracy was assessed by randomly assigning 100 spatially distributed point samples per class and comparing each to available ground truth.

Two distinct land-use domains were delineated within the study area and separately analyzed to provide increased classification accuracy. The Oregon Coast Range domain, characterized by steeper slopes and timber management, transitions into a lower-gradient valley-agriculture subregion. Preliminary land-cover analyses reveal a 12% and 2.65% decline in canopy cover for the Coast Range and valley-agriculture domains, respectively. Results from this study have implications for monitoring riparian vegetation, which is essential for healthy streams and native fish habitats. This remote sensing survey produces regional land cover information suited for a wide spectrum of applications, including land management, landscape metric analyses and watershed planning.

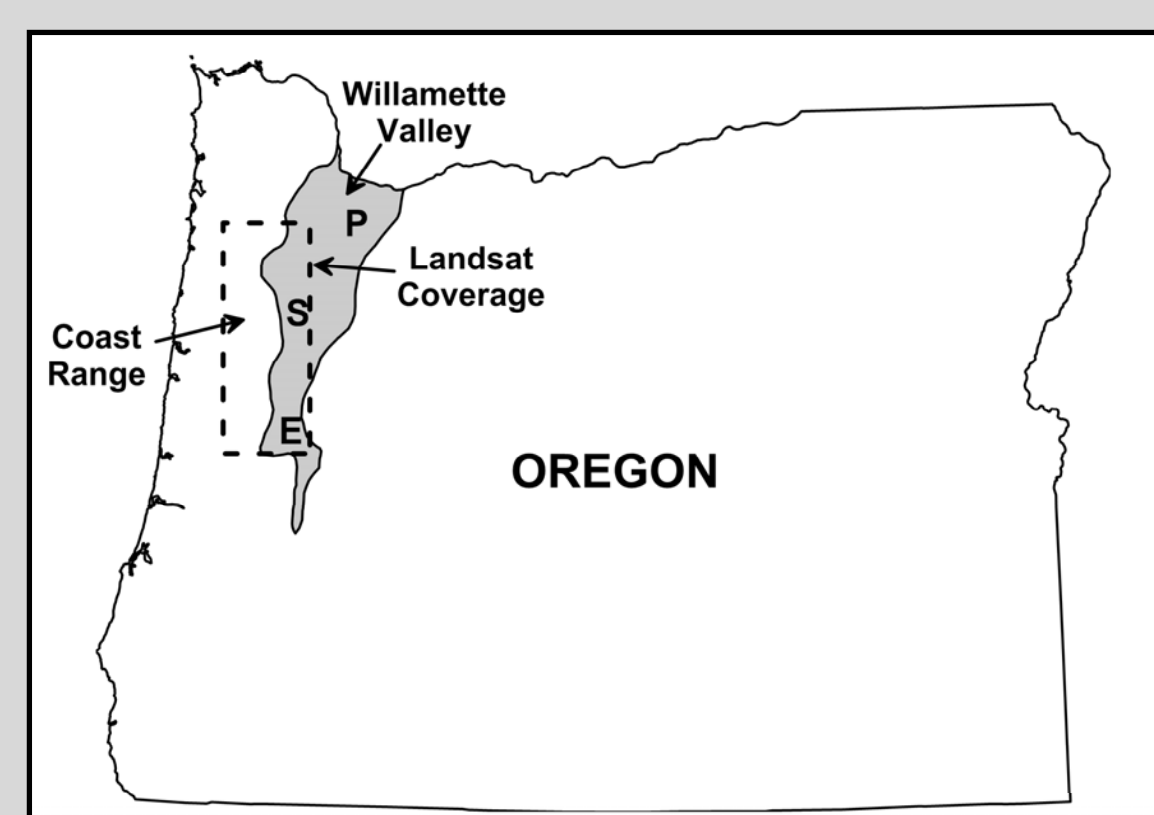


Figure 1: Location of study site (P=Portland, S=Salem, E=Eugene).

Methodology

Stock algorithms and toolboxes in ArcGIS 9.3.1 and IDRISI Taiga were used to process and analyze remote sensing data. Landsat TM imagery encompassing Oregon's Willamette Valley was acquired from the USGS GLOVIS data center for the dates of July 15, 2000 and July 24, 2009. Image classification and analyses were confined within a 811,881 hectare bounding polygon. The 811,881 hectare study site was selected by manually defining a North-South oriented bounding rectangle that appropriately captures the interface between Oregon Coast Range forests and lower-gradient Willamette Valley agricultural zones. Two subregions were delineated and separately classified in order to ensure accuracy. These two subregion masks, the Oregon Coast Range and Willamette Valley Floor land-use domains, were separated by analyzing elevation and satellite imagery data. Figure 2 demonstrates how elevation data were utilized to produce a slope map that effectively reveals the relationship between land cover and topography. The study site was split into subregions by heads-up digitizing a polyline at the 5° slope break between the valley floor and western foothills. A supervised classification with maximum-likelihood algorithm was used on each subregion to delineate informational classes from spectral classes. "Water", "canopy cover", and "no canopy-agriculture" training sites were identified to represent within-class spectral variability. 1999 and 2009 urban boundary polygons from the Oregon Department of Transportation were subsequently combined with imagery to result in a total of four informational classes. Total canopy area and percent change were derived from the final classified imagery. Classification accuracy was assessed by randomly assigning 100 spatially distributed point samples per class and comparing each to false color composite Landsat images (bands 4,3,2). This combination of Landsat bands is ideal for interpreting ground truth information because it makes vegetation appear as shades of red, a result of near infrared light reflection from photosynthesizing plants. Vegetative indices (NDVI, Tasseled Cap) were evaluated for each year to qualitatively assess differences in plant biomass.

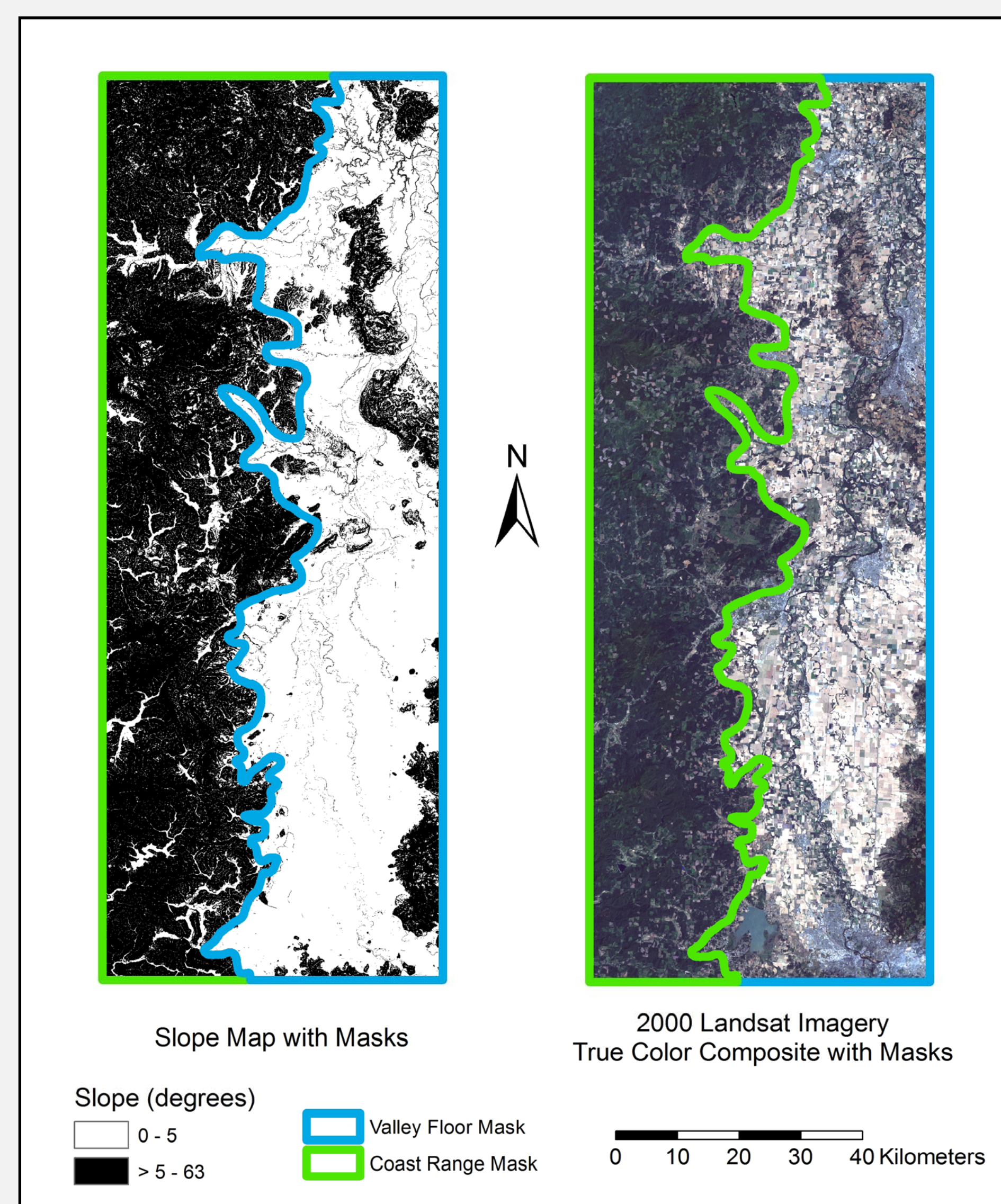


Figure 2: Prior to image classification, a slope map was generated from elevation data to assess the relationship between land cover and topography, thereby assisting in the delineation of two subregion masks: the Oregon Coast Range and Valley floor. Western slopes greater than 5° were correlated to high density Coast Range forests and provided a study site dissecting line.

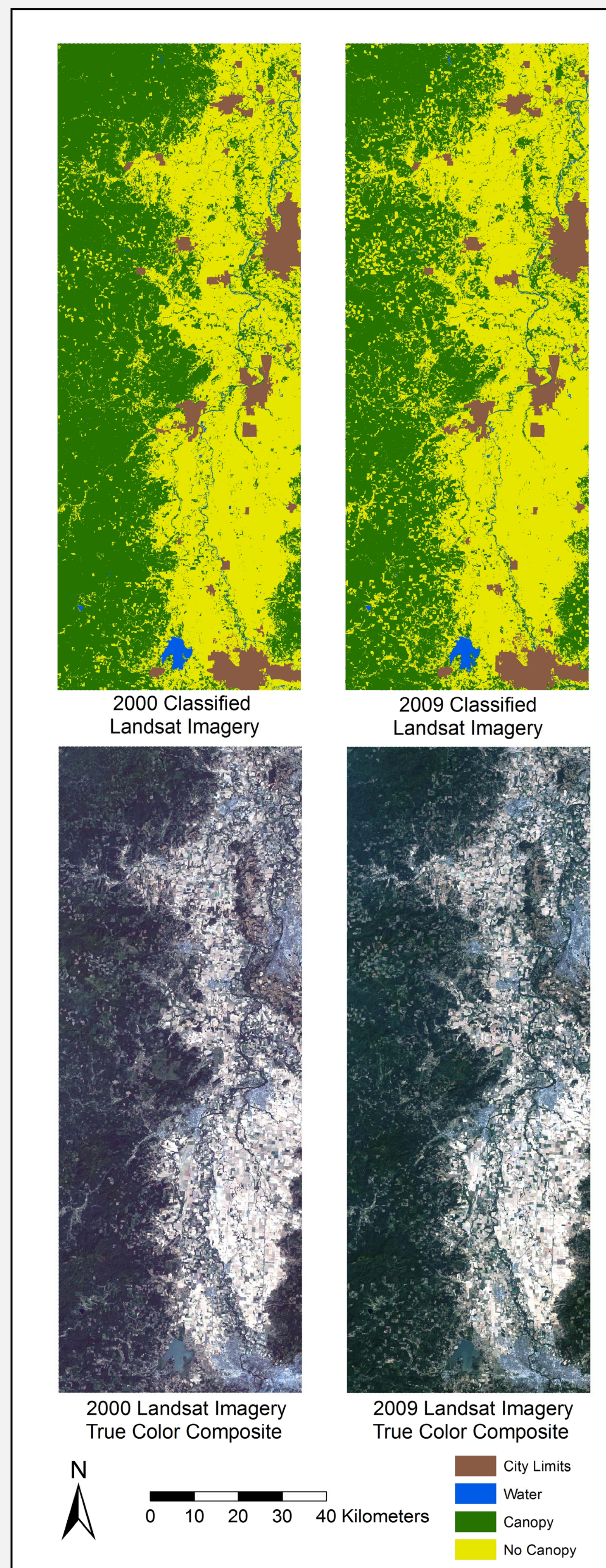


Figure 3: True-color composite Landsat imagery (bands 3,2,1) of the study area for summer season, 2000 and 2009. Image classification for each year occurred via separate analysis of subregion and subsequent concatenation of results. The use of two sub-domains decreased spectral variability and expedited the process of selecting appropriate training sites for water, canopy, and no canopy/agriculture. Supervised classification resulted in a land-use model that was symbolized with three classes; city limit bounding polygons were added via post-processing using GIS functions. The city limit spatial data were delineated subsequent to image processing to minimize initial classification errors resulting from spectral heterogeneity in the urban mosaic environment. Results of areal land-change analyses for Coast Range forest cover, valley-floor agriculture, and riparian canopy between 2000 and 2009 are presented in Table 1.

Total Area of Study Site (Hectares)	811,881
Total Area of Coast Range Mask (Ha)	402,217
Total Area of Valley Floor Mask (Ha)	409,664
2000 Total Area Canopy Cover - Coast Range (Ha)	348,386
2000 Total Area Canopy Cover - Valley Floor (Ha)	53,919
2009 Total Area Canopy Cover - Coast Range (Ha)	306,615
2009 Total Area Canopy Cover - Valley Floor (Ha)	52,490
2000-2009 Coast Range Canopy Area Change (%)	-11.99
2000-2009 Valley Floor Canopy Area Change (%)	-2.65

Table 1: Spatial statistics calculated from classified Landsat imagery revealing a decrease in canopy cover for each subregion. The Oregon Coast Range domain lost greater than four times more canopy than the valley floor sub-region.

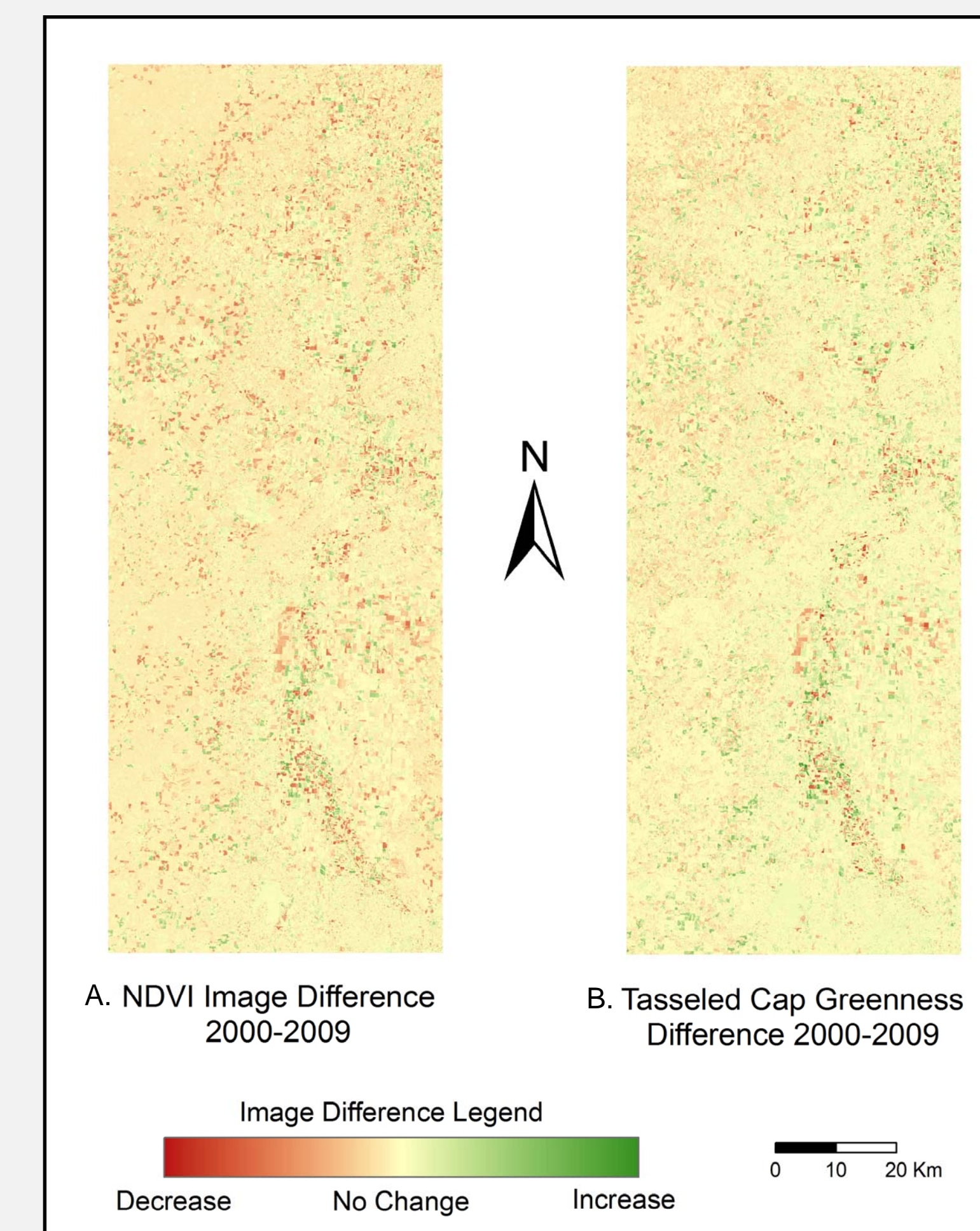


Figure 4: Results of vegetation change analyses. Two image differencing techniques were evaluated for assessing vegetative change between 2000 to 2009. Tasseled Cap vegetative index was calculated for each year before application of image differencing. A Normalized Difference Vegetative Index (NDVI) was calculated for each year and the older data were subtracted from the newer (Figure 4A). The resulting image displays increases and decreases in plant biomass. Tasseled cap greenness bands were used to derive Figure 4B.

Results

Spatial statistics calculated from 2000 and 2009 classified Landsat imagery (Table 1) show a net decrease in forest canopy cover for the Oregon Coast Range and Willamette Valley floor sub-domains. While total area for both domains is sub-equally divided, the Coast Range experienced greater than four times canopy reduction in a nine-year period, compared to that of the valley-agriculture setting. Areas of Coast Range forest regeneration did occur between 2000 to 2009, but were negligible compared to the net ~12% canopy reduction. A 2.65% reduction of vegetation occurred within the valley-floor mask. This lower-gradient subregion contains riparian zones bounded

Results Cont.

by agriculture land-use regimes. Image differencing of vegetative indices (Figure 4) suggests a trend of decreasing plant biomass over the nine year evaluation period. NDVI and Tasseled Cap greenness indices reveal similar distributions of changes in vegetative vigor. Final classification accuracy was assessed by randomly assigning 100 spatially distributed point samples per class and comparing each to available ground truth (Table 2). The supervised classification for 2009 produced slightly more accurate results. Observed sources of classification error resulted from spectral similarities between forest canopy and valley agriculture in portions of the Landsat study scene.

Class	2000 Accuracy	2009 Accuracy
Water	94%	99%
Canopy / Vegetation	91%	98%
No Canopy / Agriculture	94%	95%

Table 2: Error matrix for land-cover classification.

Analysis

Highest levels of vegetative change occurred within the Coast Range domain, which is characterized by steeper slopes and commercial timber management. The limited canopy regrowth that did occur during the nine-year period is offset by a broad patchwork of newly harvested timber stands. A 2009 analysis of the Upper Willamette sub-basin pointed to high levels of fine sediment and sparse vegetation as primary habitat stressors (Oregon DEQ, 2009). When timber is stripped away as is evident in the Oregon Coast Range, overland flow of water increases and exacerbates soil erosion. In turn, soil erosion leads to siltation of waterways that suffocates fish eggs and organisms, alters aquatic habitats, and increases water turbidity. Lower levels of vegetative change occurred within the Willamette Valley domain, which is more controlled by urban planning and agricultural management systems. This remote sensing survey produces regional land cover information suited for a wide spectrum of applications including land management, landscape analyses and watershed restoration.

Acknowledgements

Funding for this project was secured through an undergraduate research grant from the NASA Oregon Space Grant Consortium. The authors would like to thank NASA and Oregon Space Grant for their continued efforts in advancing institutional research. Dr. William Schoenfeld at Western Oregon University is acknowledged for his efforts in facilitating Space Grant outreach to WOU students.

Data Sources & References

- Mulvey, M., Leferinck, R., & Borisenko, A. Oregon Department of Environmental Quality. (2009). *Willamette basin rivers and streams assessment*. Hillsboro, OR.
- NASA Landsat Program, 2000. Landsat TM scene L5046029_02920000715, L1T, USGS, Sioux Falls, 7/15/2000.
- NASA Landsat Program, 2009. Landsat TM scene L5046029_02920090724, L1T, USGS, Sioux Falls, 7/24/2009.
- Oregon Department of Transportation, City limits and city annexations for the State of Oregon. <http://www.oregon.gov/DAS/EISPD/GEO/alpha.html>
- Oregon Geospatial Data Clearing House, Statewide 10 meter DEM. <http://gis.oregon.gov/DAS/EISPD/GEO/data/dems.html>