Oregon Space Grant Scholarship Program
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Proposal for Senior Undergraduate Research Scholarship

"Land Cover Analysis Utilizing Aerial Photography, Remote Sensing and Geographic Information Systems: Application to Riparian Zones in the Mid-Willamette Basin, Oregon"

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1. PURPOSE

A. Statement of the Problem

Mountainous watersheds are fundamental landscape elements that form an important setting for local ecological interactions, human occupation, and water resource development. The Willamette Basin of western Oregon is one such watershed that is home to over 70% of the state's population and serves as the agricultural hub for the regional economy (Uhrich and Wentz, 1999). Diverse and widespread wetland plant communities once dominated riparian zones in the valley. As settlers rapidly immigrated during the nineteenth century, native habitats were modified for livestock, agriculture, and forestry purposes (Johanessen et. al, 1971). As a result, native wetland, prairie and forest communities now account for less than 10% of their area originally occupied in lowland riparian zones, (Hulse et al., 2002). Anthropogenic disturbance in turn has affected soil substrate conditions, nutrient availability, canopy shading, and riparian hydrology. As such, disturbed zones on the landscape act as conduits for the propagation of non-native species (Pabst and Spies, 1998) and lead to annual economic losses of millions of dollars for public and private landowners (Oregon Department of Agriculture, 2001).

The project proposed herein seeks to quantify historical (1930-2009) land cover change in mid-Willamette Valley riparian zones on multiple spatial scales using remotely sensed imagery. New land-cover data combined with existing ground-based plant surveys in the Luckiamute Subbasin will contribute to understanding the controls on regional distribution of invasive plants and document human-induced changes to riparian ecosystems. Such studies are critical for the design of effective watershed conservation and restoration plans.

B. Project Objectives

To document land-cover change in the mid-Willamette Valley, the proposed project will utilize ground-based plant surveys, historic aerial photographs and NASA-derived Landsat imagery as framework sources to develop a set of decadal-scale riparian land-cover maps (Figure 1, attached at back). Existing data from the Luckiamute Subbasin (Stanley and Taylor, 2009; Taylor et al., 2009) will be utilized as the calibration source to classify historic land use in the greater study area, which covers a ~125 km north-south swath between McMinnville and Eugene, and ~75 km east-west swath between the Coast Range and the main stem of the Willamette. The existing Luckiamute studies have demonstrated a decrease in riparian forest canopy since the 1930's and significant alteration of understory plant communities by invasive species (Taylor et al, 2009; Taylor et al., 2007). The working hypothesis is that similar patterns of riparian zone alteration have occurred along the west side of the Willamette corridor, north and south of the Luckiamute area (Figure 1).

Primary project objectives include: (1) extension of the existing aerial photograph work in the Luckiamute Subbasin, with completion of in-progress riparian land-cover analysis presented by Stanley and Taylor (2009); (2) use of existing ground-based plant surveys (Taylor et al., 2007) and land-cover results in Objective 1 as a calibration platform upon which to base remote sensing analysis of Landsat imagery for the greater study area; (3) use of Geographic Information Systems (GIS) techniques to develop a set of decadal scale (1970's - 2009) land-cover maps for riparian zones in the mid-Willamette Valley (Figure 1); and (4) analysis of changes in measured land-cover areas over the historic time period. Final project deliverables will include Landsat-derived land-cover maps, georeferenced historic aerial photographs, vectorized GIS coverages, and data analyses documenting the degree of decadal changes in riparian land use.

C. Approach

Completion of project objectives requires the acquisition and analysis of remotely sensed data, including low-altitude aerial photography and NASA-based Landsat imagery. A suite of commercially available software tools will be used to conduct image analysis, create GIS land-cover layers, quantify land change, and conduct analyses. These software applications include ESRI ArcGIS, Clark Lab's IDRISI, Golden Software Didger, Leica Image Analysis, and Adobe Photoshop. Historic archives (1930's-1990's) from the University of Oregon Map & Aerial Photography Library will be used for the Luckiamute Subbasin work, in addition to more recent digital imagery (2000's) from the Oregon Geospatial Enterprise Office. All photographs will be orthorectified and manually classified in a GIS, following the procedures outlined by Stanley and Taylor (2009). Landsat archives (1972-2009) for the mid-Willamette valley will provide multi-spectral images of the greater region, thereby allowing use of trainable automated classification algorithms to quantify land cover change. Satellite imagery will be obtained from the U.S. Geological Survey Landsat repository, a long-term joint venture between the USGS and NASA (Behrens, 2009).

2. SIGNIFICANCE

A. Scientific Contributions

Riparian forest zones in the Pacific Northwest are important for watershed function and provide a wide range of ecosystem benefits, including reduced channel erosion, canopy shading, reduced water temperatures, wood recruitment sources, and aquatic habitat structure for salmonid fisheries (Gregory et al., 1991). Maintenance of forest canopy is also important with respect to plant species richness and limiting the occurrence of invasives due to disturbed gap openings (Pabst and Spies, 1999). One of the overarching objectives of this work is to integrate remotely sensed imagery in a way that quantifies the abundance, distribution, and variability of riparian vegetation in the Willamette Valley. Deciphering the controls on spatial distribution of invasive plants in the context of disturbance regime is critical for designing effective watershed restoration plans. To this end, the proposed project will: (1) provide important baseline data on historic land-cover changes in western Oregon, (2) contribute to understanding relationships between riparian zone disturbance and invasive plant distribution, and (3) provide valuable data for design of future conservation projects by community stakeholders.

B. Student Training and Scholarship

If funded by Oregon Space Grant, this undergraduate research project will provide an excellent opportunity for applied experience with GIS and remote sensing techniques, in direct alignment with educational objectives outlined in NASA's Science Mission Directorate (NASA, 2007). This work will expand my knowledge base and provide a firm foundation for my goal of pursuing advanced graduate studies in geospatial technology. In addition, Space Grant support of this scholarship will greatly enrich my professional growth as an Earth Science major at Western Oregon University.

C. Alignment with NASA Mission

The proposed project is highly relevant and directly aligned with NASA's Research and Analysis Strategies, as outlined in the 2007-2016 Science Plan (NASA, 2007), including: (1) "Earth surface-based observations and field campaigns that support science missions", and (2) "Applied information systems with research application to NASA objectives and data." Table 1 (attached at back) provides an alignment matrix showing the relationship between project outcomes and published NASA mission objectives.

D. Significance to Faculty Mentor

The faculty mentor, Dr. Steve Taylor, has been involved with studies in the Luckiamute Basin since 2001. He and other WOU colleagues have extensively utilized this watershed as a local natural laboratory to visit on field trips, support science curricula, conduct research, and engage undergraduate students in multi-disciplinary watershed science. WOU-based Luckiamute studies over the better part of the past decade have covered a wide range of topics including surface water hydrology, geomorphology, environmental chemistry, hydrogeology, botany, plant systematics, environmental quality, stream ecology, and patterns of invasive plant distribution (e.g. Taylor, 2006; Taylor et al., 2002; Taylor et al., 2007; Taylor et al., 2009; Noll et al., 2007; Stanley and Taylor, 2009; Taylor and Dutton, 2009; Dutton and Taylor, 2005). This project represents another installment in this long-term, community-based, academic endeavor.

3. PLAN OF WORK

A. Hypothesis Testing

Based on prior work in the Luckiamute Subbasin, the working hypothesis is that riparian forest cover has decreased significantly on the west side of the mid-Willamette Valley since the 1930's. This forest decline is likely the result of alteration of lowland hydrology and expansion of agricultural lands. Sequential analysis of historic aerial photography and Landsat imagery will be used to quantify land-cover characteristics and provide results that will directly test this hypothesis.

B. Methodology and Procedures

This multi-scale project requires several stages of data acquisition and analysis (Figure 1). An archive of decadal-scale aerial photographs (1936, 1948, 1955, 1963, 1970, 1988,1994, 2000, 2009) will be orthorectified and

georegistered using Didger 4.0 and projected into the UTM Zone 10N coordinate system (NAD 1927). USGS digital raster graphics and orthophoto quadrangles serve as known standards to provide control points for aerial photograph rectification. For each year available in the photographic archive, stream channels will be digitized as polyline shape files using ArcMap 9.3. A riparian-zone bounding polygon will be subsequently generated from channel polylines using a 500-meter buffer that extends along the length of the respective photographs. Supervised polygon classification of land regimes will occur in ArcGIS. From this process, five land-use classes will be delineated: (1) cultivated land without forest canopy, (2) undifferentiated land without forest canopy, (3) sparse forest canopy, (4) moderate forest canopy and (5) dense forest canopy. Ground-truthing from existing plant surveys (1 x 100 m quadrats) will form the basis for calibrating the supervised classification process (Figure 1).

Landsat imagery of the mid-Willamette Valley will be acquired from the USGS EROS data center and composited to highlight riparian zone vegetation. Starting with 1972 imagery, Landsat data will chronologically parallel the aerial photograph archive. Methods of automated classification will be employed using a combination of the IDRISI and Leica Image Analysis software environments. Air photo resolutions (~5 m) are greater than Landsat imagery (~30 m), so the Luckiamute sites will serve as points of reference to train the classification algorithms applied to the greater mid-Willamette study area. Invasive plant species information from previous WOU studies will be combined with remotely sensed data to synthesize a land cover analysis at varying spatial scales (Figure 1).

C. Project Timeline

Proposal Submission:	January 15, 2010
Landsat Acquisition:	February 2010
Photo / Image Rectification:	February-March 2010
Land-Cover Digitization:	March-May 2010
Data Analysis and Synthesis:	May-June 2010

D. Deliverables

Products of this project will include: (1) a historical set of orthorectified and georegistered digital aerial photographs for 20 select localities along the Luckiamute River (one set per decade, per site, 1930's to present; refer to Figure 1 for site locations); (2) classified, riparian land-cover maps for the Luckiamute and mid-Willamette study areas; and (3) data tabulation and analysis of historic changes in vegetative types and land-use components.

E. New Methods

One of the project outcomes will utilize image processing software to produce automated classification of multi-band Landsat data. Certain GIS tools allow the training of signatures for use in automated raster classification. For purposes of enhancing productivity, one of the immediate project tasks will be to develop customized scripts for automating the process of raster classification.

F. Dissemination of Results

The results of this project form part of an ongoing research campaign in the Luckiamute River Basin by the faculty mentor. In addition to academic scholarship, this work is also designed to provide professional training opportunities for students and to link research with public service in support of community watershed restoration. In addition to any Oregon Space Grant outreach activities, it is anticipated that project results will be disseminated via the Luckiamute project web page at WOU (www.wou.edu/luckiamute), at the Spring 2010 WOU Academic Showcase, and at the national meeting of the Geological Society of America in Fall 2010.

4. RELATED REFERENCES

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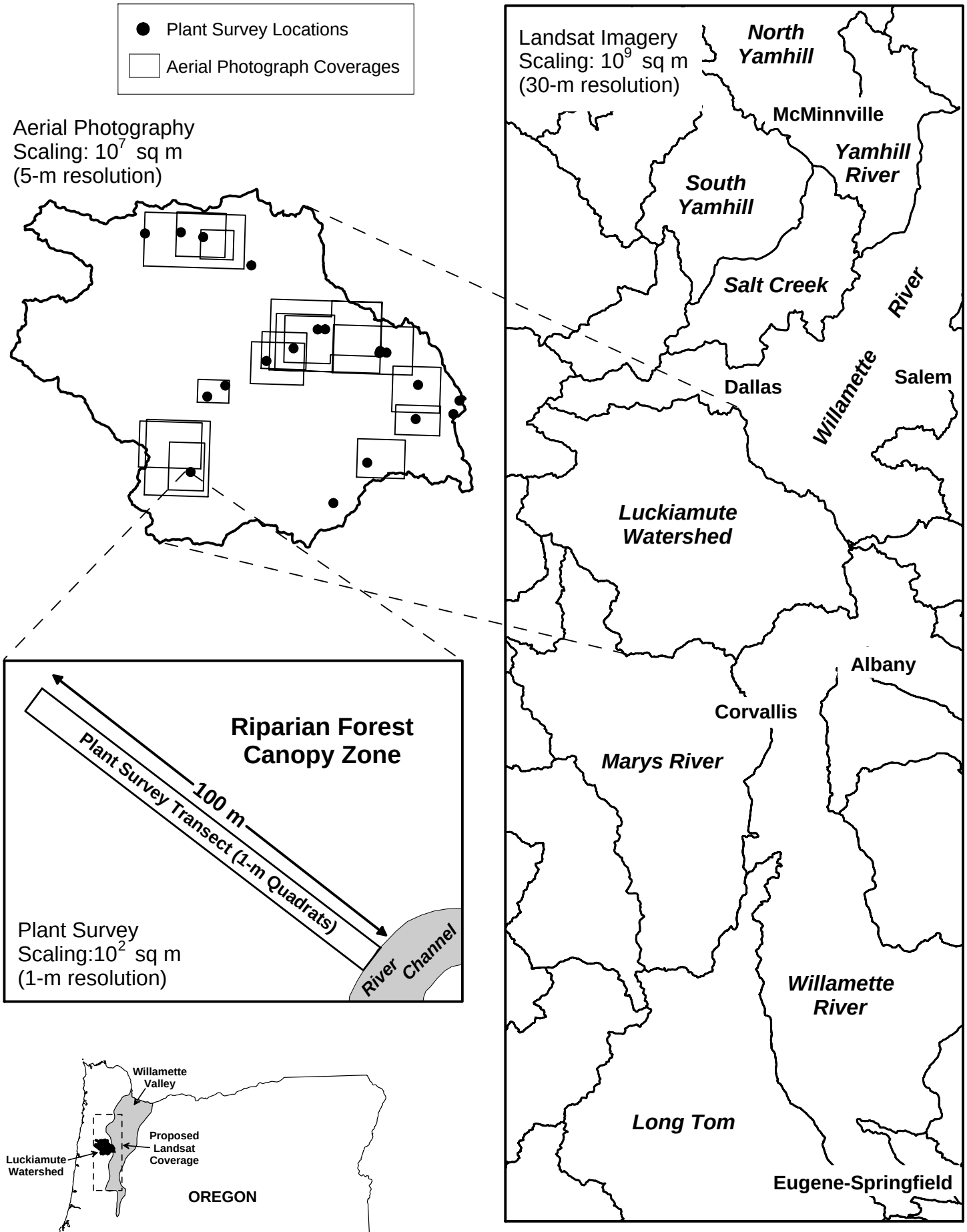

Figure 1. Diagrammatic illustration showing the proposed study area and the nested scaling relationships between regional Landsat imagery, reach-scale aerial photography, and plant survey transects in the riparian zone.

Table 1. NASA mission alignment matrix highlighting key NASA Earth Science objectives in relation to the Willamette land-cover project proposal (Source: NASA, 2007).

		NASA MISSION OBJECTIVES			
		Study planet Earth from space to advance scientific understanding and meet societal needs.	Measure the distribution, abundance, and variability of plants with important ecological and physiological functions, including invasive species.	Document and quantify how terrestrial ecosystems, and land cover and use are changing in response to disturbance.	Determine the consequences of land cover and land use change for human societies and the sustainability of ecosystems.
PROJECT DELIVERABLES	Derivation or regional land-cover maps from multi-band composites of Landsat imagery	X	X	X	
	Analysis of riparian zone diversity using observed data trends.		X	X	X
	Digitization of georeferenced historic aerial photographs.			X	
	Development of riparian land-cover map layers.		X	X	