Spatial modeling of potential woody biomass flow

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Abstract

The flow of woody biomass to end users is determined by economic factors, especially the amount of biomass available across a landscape and delivery costs of biomass to bioenergy facilities. The objective of this study is to develop a methodology to quantify landscape-level woody biomass stocks and potential biomass flows using the currently available spatial database and road network analysis tool. We applied this methodology to a study landscape of approximately 15 million acres around the city of Roseburg in southwestern Oregon. The analysis allows us to produce isocost contour maps that display the supply areas delineated by specific cost thresholds, as well as estimates of the amount of feedstock that can be delivered to specific sites on an annual basis for a specified haul cost. This methodology has the potential of providing useful information for determining the economically efficient scale and optimal location of a woody biomass utilization facility.

Keywords: woody biomass, biomass transportation, network analysis, spatial analysis

Introduction

Forest management activities, such as commercial harvests, fuel reduction thinning, and salvage operations, produce large quantities of forest residues. Interest in expanding the utilization of this biomass as a source of energy has increased significantly in recent years for a variety of reasons (Gan and Smith 2006, Jones et al. 2010). However, lack of information on realistic woody biomass supply and costs of feedstock has been a barrier to investment in woody biomass energy. Although many studies have estimated forest biomass stocks at a variety of scales based on FIA data (e.g., U.S. Department of Energy. 2011), a small body of research is devoted to developing biomass supply models that incorporate land management constraints, realistic treatment scenarios, forest operations research, transportation costs, and economic models of energy production. The objective of this study is to develop a methodology to 1) quantify landscape-level woody biomass stocks potentially available for energy production, and 2) model biomass flows using the currently available spatial database and road network analysis tool.

Past

Methods

Study landscape

The study landscape is approximately 15 million acres located in Southwestern Oregon (Figure 1). The city of Roseburg, OR, is used as a potential location of a new biomass utilization facility for this study. Ownerships within the study landscape include private, USDA Forest Service, US Bureau of Land Management, USDA Forest Service Wilderness, National Park Service, etc. Forest cover in the study landscape was mapped using the Ecological Systems land cover dataset (ESFL) of 2008 in conjunction with the National Land Cover Dataset (NLCD 2001). The ESFL dataset includes 150 land cover classifications, which use the NLCD cover classification scheme. Of those, 47 are forest cover classes, including 4 deciduous forest classes, 33 evergreen forest classes, 5 mixed forest classes, 4 transitional forest classes, and one class for recently burned forest. Though species composition in each class varies, in general, forest classes are at least 10% canopy cover based on NLCD 2001. The state-wide coverage, detailed cover classifications, and relatively recent release date of this land cover model make it the best option for representing the forest area and forest types within the study landscape.

For this study, only forest designated as timberland based on both land cover and landownership is considered to be a source of biomass. Non-timber ownerships include all federal wilderness lands, National Park Service lands, State-owned scenic waterways and waysides, Fish and Wildlife Service lands, land owned by the Nature Conservancy (TNC), and many other categories. Though non-forest regions, including urban areas, can supply biomass in the form of wood waste and land clearing debris, in determining biomass flow for this study, land designated as non-forest is considered to provide zero biomass flow.

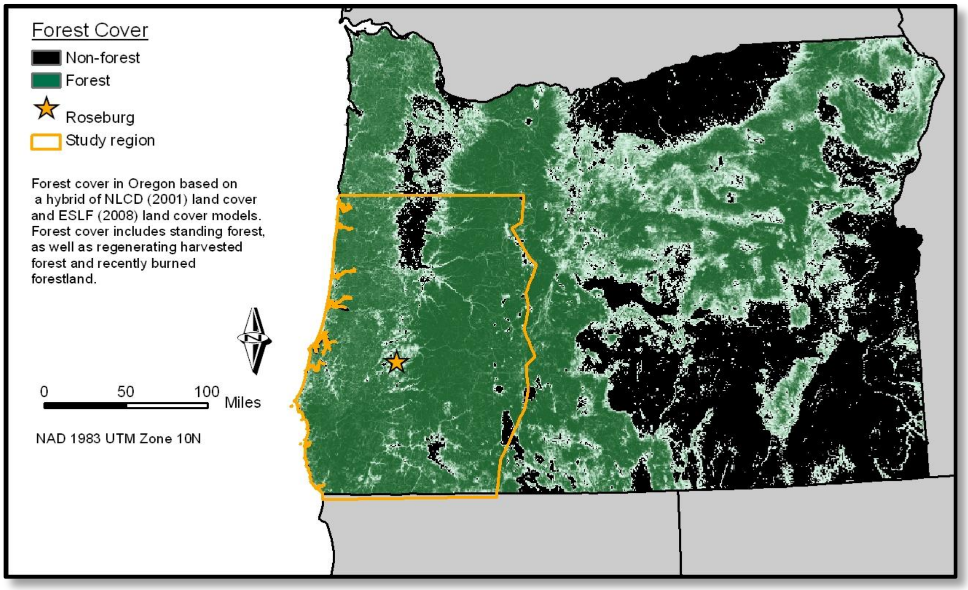

Figure 1. Study Landscape in Oregon.

Estimating the quantity of forest residues

The Timber Products Output (TPO) group of the Forest Inventory and Analysis Program (FIA) conducts periodic surveys of forest industry and other forest products producers and consumers to quantify flows of wood products throughout the country. TPO reports include data on removals of forest residues and roundwood, which includes sawlogs, veneer, pulpwood, fuel wood, and logs for posts and poles and composite wood products. For Oregon, TPO data is reported by county and splits removals into three ownership groups: National Forest, other public, and private. Residue and roundwood removals are reported in thousand cubic feet (mcf) for each ownership within each county. Data from 1996, 2001 and 2006 were used in this study to determine average annual removals of roundwood and residues per county and per ownership class. Conversion factors from USDA Forest Service (2007) and other sources were used to convert removals in mcf to bone dry tons (bdt), and then annual removals were normalized to bdt per acre of timberland. Non-timber forestland was not used in the calculation and is displayed as having zero product flow.

To estimate the quantity of residues potentially available for utilization, roundwood production was multiplied by a conversion factor of cubic feet of recoverable residues per mbf of roundwood harvest, with ratios determined by ownership class, geographic location and harvest type (Howard 1981). A map of the study landscape was then created with predicted recoverable residues in btd per acre of timberland per year for each of the ownership classes within each county. Available residues are finally determined by subtracting actual residue removals reported in TPO data from the predicted recoverable residues. The study landscape is rasterized into 30 x 30 meter grid cells, and each cell is then attributed with the amount of available residues per year per grid cell.

Modeling the flow of forest residues

Road network data for the study landscape were acquired from BLM - Oregon State Office. Spatial data errors included in the original data, such as disconnected links and loops, were detected and corrected. Road links were then built with from and to node pairs and attributed with design speed and distance for road network analysis. A round-trip travel cost in $ per bdt was calculated for each link. We assumed the average truck load and hourly cost to be 20 tons and $110, respectively.

Loading nodes for residue flow were placed along the existing roads with the minimum distance of 1 mile between two consecutive nodes. These loading nodes served as entry nodes for forest residues that are routed by truck to the final destination through the road network system. To estimate residue volume to be entered into each loading node, Thiessen polygons were created from each loading node. The annual amount of residues from each Thiessen polygon was then calculated by summing all biomass flow cells in the polygon. A road network analysis model was built using the road link data, loading nodes, entry volume for each loading node, and final destination location (i.e., Roseburg, OR). NETWORK2000 (Chung and Sessions 2003) was then used to identify the least cost route for each pair of entry and destination nodes.

Preliminary Results

The total amount of forest residues potentially available across the study landscape was estimated at approximately 2 million bdt per year. The amount of residues per acre widely varies with ownership classes ranging from 0 to 5 bdt. Figure 2 shows the total amount of residues in each Theissen polygon ranging from 0 up to over 5,000 bdt per polygon.

The results of NETWORK2000 runs present residue flows from each Thiessen polygon to the final destination with estimated transportation costs. Figure 3 shows estimated costs of residues originated from each Thiessen polygon. The costs widely varied with haul distance and road conditions, ranging from $15.24 to $80 per bdt.

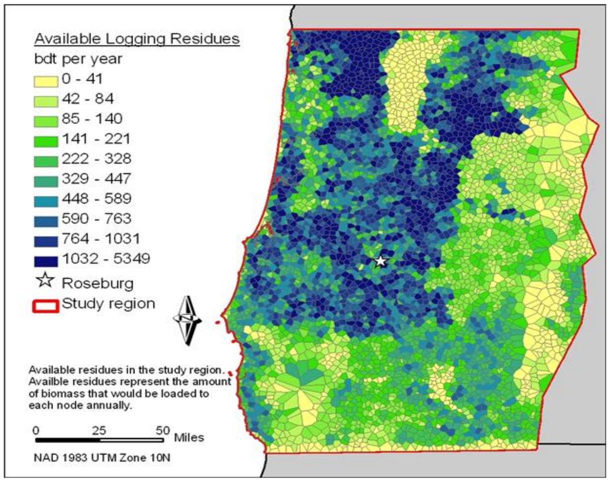

Figure 2. Annual amount of forest resides available in each Thiessen polygon.

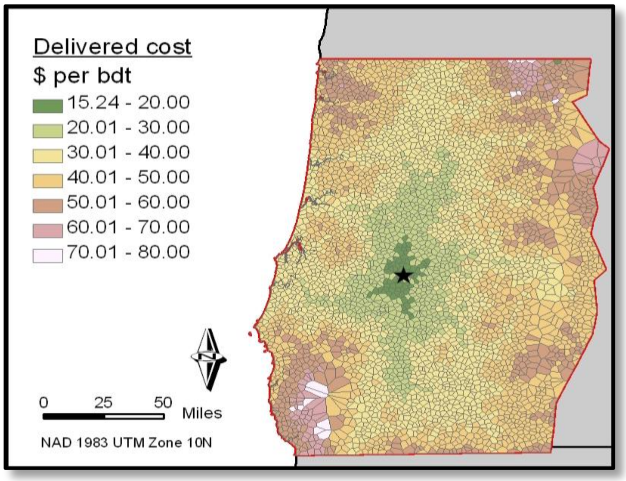

Figure 3. Estimated transportation costs of residues originated from each Thiessen polygon.

Summary

A methodology has been developed to spatially model forest residue stocks, flow, and transportation costs across a large landscape. The application and verification of the methodology is ongoing and has not been completed yet. This study will be completed by year's end and readers are encouraged to contact the authors for detailed methods and additional results. Upon successful completion, this study is expected to provide a useful model to estimate woody biomass supply and costs at different demand scales and facility locations, which will be critical information in determining the economically efficient scale and optimal location of biomass facility.

Acknowledgements

The authors would like to thank Deborah Page-Dumroese, Jim Archuleta, Greg Jones, Tyron Venn, Dan Loeffler and Edward Butler for their useful inputs and discussions, and assisting with spatial data preparation. This study was funded by a Woody Biomass, Bioenergy, and Bioproducts grant from U.S. Forest Service Research and Development, with significant cost match and in-kind support from the University of Montana.

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