A Spatial Model to Determine the Economic Availability of Woody Biomass in Colorado

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PURPOSE

The purpose of this paper is to propose a spatial model that can be used as a tool for making decisions regarding the proper sizing of woody biomass projects that require allocating public and private money and resources. This spatial model determines the cost for sustainably extracting and transporting woody biomass from watersheds in Colorado to a specific location. The model uses current costs, in dollars, and conditions to determine the economic viability of woody biomass extraction.

BACKGROUND

Colorado's recent mountain pine beetle epidemic has resulted in the die-off of lodgepole forests throughout the state. In many locations, more than 90 percent of the mature lodgepole pines have been attacked and died within the last four years. Other blights such as Spruce beetle, mistletoe, and Sudden Aspen Decline have created extensive mortality of other forest tree species. The speed, magnitude, and visual impact of the die-offs have raised public awareness. There is concern about the increased wildfire danger and intensity resulting from the increased fuel loads of dead trees. The danger of catastrophic wildfire threatens not only homes and infrastructure, but also water quality and quantity.

The public and private sectors are working to create new expanded markets for Colorado timber to utilize dead trees as a means to help pay for forest health and reforestation projects. Forest site productivity in Colorado is generally low, primarily due to dry climate, poor soils, high elevations, and cold weather. Trees grow slow and the percentage of high-quality saw timber is low compared to forests in the Pacific Northwest.

Woody biomass for heating and the generation of electricity has been identified as a good way to more fully utilize small diameter trees as well as create economic utility for long-standing dead timber that cannot be used for other commercial wood products. Currently, a number of large and small-scaled, woody biomass projects are on the drawing boards slated to produce electricity or heat. Wood pellet plants are currently operating and more are planned. Due to the extensive forest die-off, we may intuitively assume that there is a large supply of dead trees that can be turned into woody biomass.

The availability of woody biomass is limited by public land use regulations, (e.g. wilderness, roadless, and stream management zones) and physical limitations (e.g. steep slopes, availability of adequate timber volume, and road accessibility). Yet, the most significant limitations are sustainability of a timber supply as a function of Colorado's slow forest growth rate coupled with the high cost to cut, process, skid, load, and haul typical woody biomass. Additional limitations include competition from higher end wood uses and lack of a well-organized supply network.

WOODY BIOMASS SUPPLY MODEL

The goal of the woody biomass supply model is to provide organizations interested in constructing or modifying plants that would use woody biomass with a tool that would provide an estimate of the amount and sustainability of woody biomass in Colorado. This tool could also be used by agencies, organizations and the public to better understand the potential supply of woody biomass.

The following are the critical assumptions that the model is based on -

- Hydrologic Unit Code (HUC) 12 watersheds, which are the smallest watershed units developed by United States Geological Survey, were used as the geographic unit of analysis. Data was summarized for each of more than 2,400 HUC12 watersheds that potentially provide woody biomass for harvesting in Colorado. Local conditions can vary dramatically even within a HUC12 watershed. Soil moisture and nutrient levels, geology, aspect and stand density all dramatically effect growth rate. However, the HUC12 watersheds appear to provide a reasonable geographic unit for evaluating biomass availability and costs for the purposes of this analysis.

- Biomass data was from the USDA Forest Service Forest Inventory and Analysis, Remote Sensing Applications Center[1].

- Private lands are included in this analysis using the same average biomass per acre as that on public lands. Forested private lands were deduced by subtracting the amount for forested public lands from the total forest land in each watershed. The remaining forested lands were classified as private, but may contain some other ownerships.

- No woody biomass is available from wilderness areas, or federal or state parks.

- No woody biomass is available from roadless areas. The roadless areas could be potentially available for woody biomass supply but access is more limited and their administrative status could change. Therefore they were removed from consideration in this analysis.

- The potential for large scale milling of saw logs in Colorado is limited by small diameter trees. For this model it is assumed that harvesting of saw lumber will not significantly decrease the tons of

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[1] USDA Forest Service Forest Inventory and Analysis, Remote Sensing Applications Center. 2008. Mapping U.S. forest bio-mass using nationwide forest inventory data and moderate resolution information. Authors: J.A. Blackard, M.V. Finco, E.H. Helmer, G.R. Holden, M.L. Hoppus, D.M. Jacobs, A.J. Lister, G.G. Moisen, M.D. Nelson, R. Riemann, B. Ruefenacht, D. Salajanu, D.L Weyermann, K.C. Winterberger, T.J. Brandeis, R.L. Czaplewski, R.E. McRoberts, P.L. Patterson, R.P. Tymcio.
Available at; <http://svinetfc4.fs.fed.us/rastergateway/biomass/>

available woody biomass and that byproduct wood waste from lumber mills is not a significant long-term source of woody biomass. Also, scrap construction lumber is not included in the model.

- Because of the cost and potential increased environmental impact, harvesting of trees on slopes that are 60 percent or greater is not economically viable.
- Average yield is 40 tons/acre. This includes various species, age and growing conditions throughout the Colorado Mountain region.
- The cost to cut, skid, deck, and load timber from flat-ground harvesting sites, is estimated at $25/ton, based on current industry costs.
- The cost of cutting, processing, skidding, and decking timber is a function of slope steepness. Slope was incorporated into the model by calculating the average percent slope of all harvested lands in that watershed plus one, times the $25/ton base cost of harvesting. (A watershed with an average slope of 30 percent will yield timber at 1.30 x $25/ton, or $32.50/ton.)
- Highway haul distances were determined over the average of the model by multiplying Euclidian (i.e. straight line) distances by a factor of 1.5.
- Current rates for log truck round-trip deliveries are about $100/hour. An average speed of 40 mph (including loading and unloading) with a 20-ton load, yields a transportation cost of $0.40 per ton-mile.
- Biomass regeneration to optimum usable fuel content (BTUs per ton) is 60 to 80 years based on climate, marginal soils, and density of stands not thinned. Re-harvesting is not economically feasible for at least 50 years.
- A typical planning horizon for major capital improvements is 20 years. The timeframe for evaluating forest sustainability is generally much longer. The regeneration rate or the time for the forest to regenerate to a point that it would make sense economically to harvest it for biomass could be 70-100 years for Colorado. The 20 year planning horizon would have a sustainability rate of 5 percent per year and the forest sustainability rate would be 1 to 1.5 percent.

As documented in many planning documents, such as the White River Forest Plan, the current forest conditions in Colorado generally show a lack of young age-classes. One of the keys to creating a sustainable forest ecosystem is to increase age-class diversity. Therefore, in the first 20 years of a creating a sustainable forest, the harvest rate could be higher than could be sustained later in the plan. For this model, it is assumed that the sustainability rate would be double the long-term forest sustainability rate of 1 to 1.5 percent. The sustainability rate used in the model is 3 percent per year. That is, for any given watershed, 3 percent of the available woody biomass is available any one year. Current infrastructure and competition from other woody biomass buyers might reduce yearly availability.

- Carbon and renewable energy credits are not included in the analysis as it is assumed these subsidies will be included in the price the processing facility is willing to pay for delivered woody biomass.
- The carbon footprint of using less coal (for co-fired coal burning power plants substituting a percentage of woody biomass) should be compared with increased use of diesel for hauling by individual trucks, as part of an environmental cost analysis. This analysis is not included in this model.

VARIABLES

Changes in current and future conditions will significantly impact costs/ton and availability at any given range of price points. Regeneration rates are highly variable based on local site conditions and other unknowns including climate change. Large-scale wildfires and drought are some examples of variables that could decrease the overall regeneration rate.

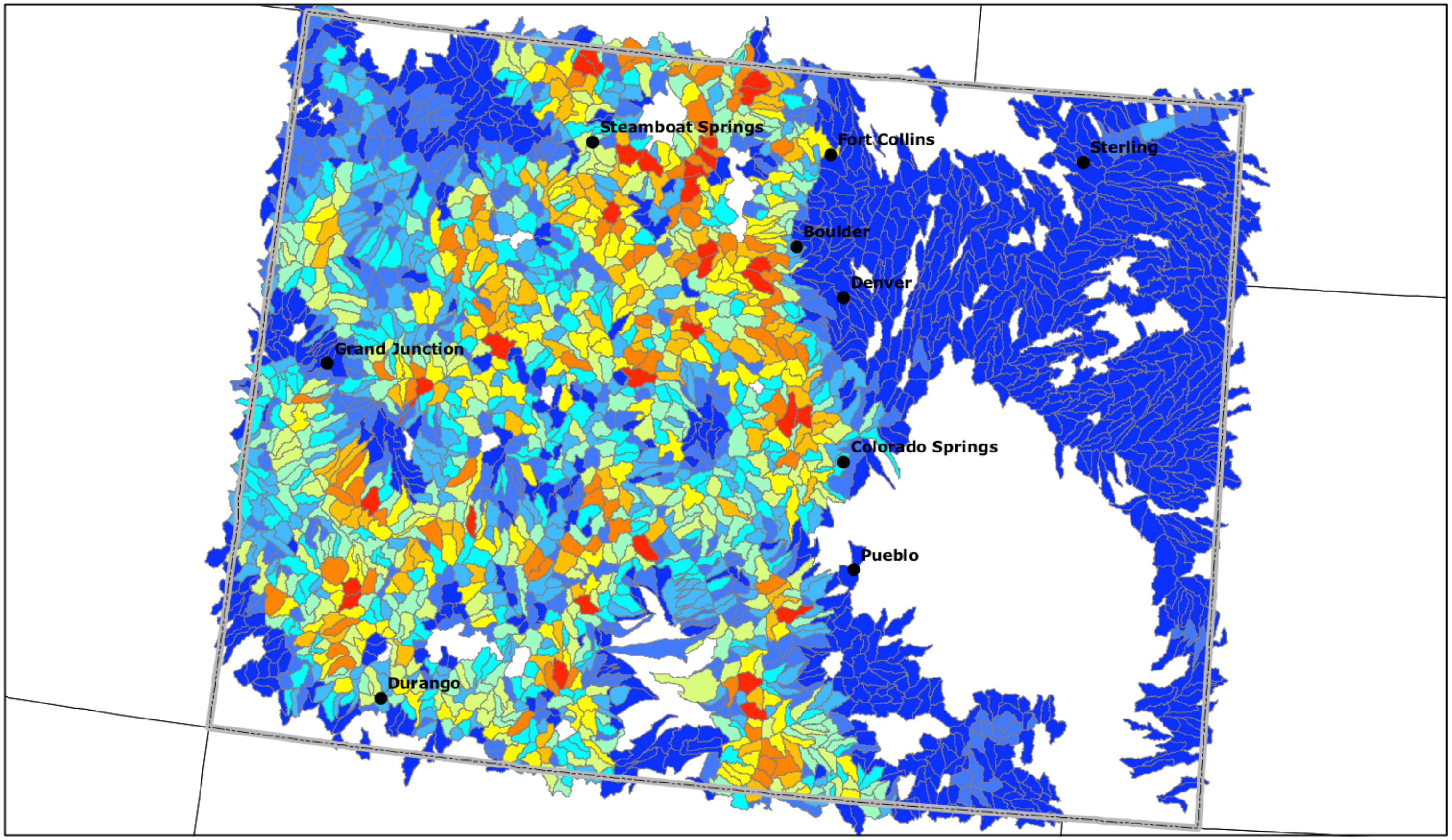
Economic variables include the price of fuel, technological advances, competition for limited woody biomass supply, efficiencies of woody biomass conversion to energy and other factors. Additional variables include administrative and access limitations.

TEST CASE

The model was tested using Colorado Springs as the site for a woody biomass generation facility. Map 1 provides a visual representation of the biomass tonnage available each year. Map 2 provides zones determined by price point range using Colorado Springs as the destination. In Zone 1 (the inner supply zone) the cost of woody biomass delivered is an average of $49 or less per ton. Other zones have woody biomass available at a higher cost. Table 1 uses information from Maps 1 and 2 to calculate the total and yearly sustainable tonnage available within each zone identified in each cost range zone.

The test case includes all of Colorado as a potential source of woody biomass material. Transportation costs can constitute a large percentage of the supply cost. Woody biomass may in some instances be available at a lower cost from out of state sources in New Mexico or Wyoming which are closer than locations in western Colorado. Prospective users of woody biomass in the Colorado Springs example would need to focus on costs that are realistic and competitive with other energy sources such as coal. Table 2 provides a more refined breakdown of Zone 1, which should be more useful as a planning tool for evaluating facility sizing and supply.

Total Sustainable Tons of Woody Bio-Mass per Year



Available Tons of Woody Bio-Mass by Watershed (HUC 12) per Year

Tons

- 1.86 - 730.06
- 730.07 - 1,987.01
- 1,987.02 - 3,374.79
- 3,374.80 - 4,908.92
- 4,908.93 - 6,702.45
- 6,702.46 - 8,911.04
- 8,911.05 - 11,775.70
- 11,775.71 - 16,079.40
- 16,079.41 - 22,120.00
- 22,120.01 - 37,382.73
- No Available Tons

10 5 0 10 20 30 40 50
Miles

The available tons of woody bio-mass by year calculated by the following formula ([available tons of woody bio-mass] * 0.03 [a sustainable rate of harvest factor]). However, there are many instances that parts of a watershed are Wilderness or Roadless areas or National Parks; therefore, the entire watershed is included in the analysis but only the woody bio-mass that is on public and private lands and not in Wilderness or Roadless areas or National Parks are used in the calculation. Depicted here are 2,445 sixth level watersheds (HUC12) whcih contains woody bio-mass.

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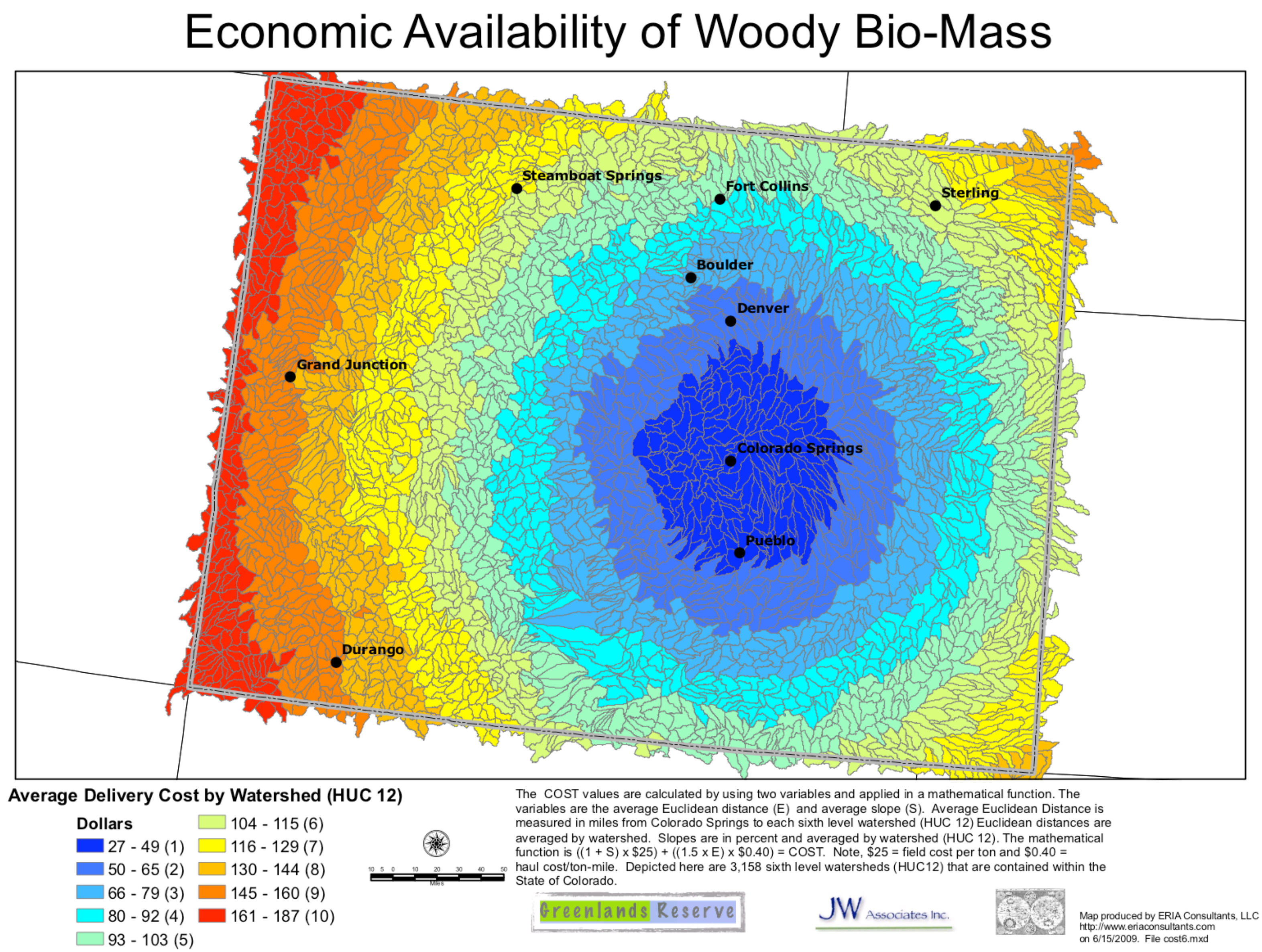
on 6/13/2009. File all_ton12_2.mxd

Map 1.


Economic Availability of Woody Bio-Mass
Steamboat Springs
Fort Collins
Sterling
Boulder
Denver
Grand Junction
Colorado Springs
Pueblo
Durango
Average Delivery Cost by Watershed (HUC 12)
Dollars
27 - 49 (1)
50 - 65 (2)
66 - 79 (3)
80 - 92 (4)
93 - 103 (5)
104 - 115 (6)
116 - 129 (7)
130 - 144 (8)
145 - 160 (9)
161 - 187 (10)
The COST values are calculated by using two variables and applied in a mathematical function. The variables are the average Euclidean distance (E) and average slope (S). Average Euclidean Distance is measured in miles from Colorado Springs to each sixth level watershed (HUC 12) Euclidean distances are averaged by watershed. Slopes are in percent and averaged by watershed (HUC 12). The mathematical function is ((1 + S) x $25) + ((1.5 x E) x $0.40) = COST. Note, $25 = field cost per ton and $0.40 = haul cost/ton-mile. Depicted here are 3,158 sixth level watersheds (HUC12) that are contained within the State of Colorado.
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on 6/15/2009. File cost6.mxd

Map 2.

Table 1. Total and Yearly Available Biomass by Zone

Zone	Cost Range ($)	Total Tons	Tons per Year
1	27 - 49	17,407,998	522,240
2	50 - 65	21,407,306	642,219
3	66 - 79	28,515,671	855,470
4	80 - 92	43,389,692	1,301,691
5	93 - 103	45,286,640	1,358,599
6	104 - 115	45,866,654	1,376,000
7	116 - 129	46,875,033	1,406,251
8	130 - 144	40,023,858	1,200,716
9	145 - 160	31,378,893	941,367
10	161 - 187	11,174,257	335,228
	Totals	331,326,003	9,939,780

Table 2. Breakdown of Total and Yearly Available Biomass within Zone 1

Cost Range ($)	Total Tons	Tons per Year
27 - 29	751,830	22,555
30 - 34	2,962,459	88,874
35 - 39	4,731,418	141,942
40 - 44	4,857,140	145,714
45 - 49	4,105,152	123,155
Totals	17,407,998	522,240

CONCLUSIONS

This paper presents a relatively simple spatial model for evaluating the supply of woody biomass and sustainability of that supply for areas in Colorado. The assumptions that have been used are partially based on experience with harvesting beetle-killed lodgepole pine in the Colorado Mountains. The assumptions can be modified relatively easily, however it appears that the initial assumptions have produced a reasonable result for the example that was used to test the model.

This methodology provides results that estimate the maximum economic availability of woody biomass. The feasibility of achieving that amount of supply to a given location would be subject to other limitations including; social, infrastructure, industrial and capital capacity, and market factors. An example of an infrastructure limitation would be where there is a need for additional roads in the forest to economically transport the biomass out of those areas. Another example of limitations would be where a community may not support the level of truck traffic and the infrastructure (roads) would not support that level of traffic either.

In the Colorado Springs example, the spatial model shows a total of 17,407,998 tons available for delivery to Colorado Springs, at an average cost of $49/ton or less (in 2009 dollars). Applying the 3 percent sustainability factor, the yearly tonnage available is 522,240 tons (Table 1). At an average cost of $35/ton or less the yearly tonnage available is 111,429 tons (Table 2). Further data refinement is necessary and advised to more precisely determine an economical sustainable supply for specific woody biomass facilities in the Colorado Springs area.