## Estimating Available Forest Biomass for Large-Scale Utilization

## Forest BiomassGIS: a cost-benefit model for assessing forest biomass availability

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## Abstract

Federal and state governments are encouraging private investment into biomass-to-energy projects in several western states, based on gross estimates of harvestable biomass. These estimates provide an idea of standing biomass over a region, but do not reflect the range of costs and constraints associated with diverse management objectives (shaped by ownership priorities) and site conditions. Long-term investments will require more precision in estimating available biomass if sustainability and forest health are management objectives. These estimates will require a framework that accounts for forest production rates (growth-and-yield) and harvest and haul costs at the *forest stand* level. The forest stand is the correct unit of analysis and accounting for such estimates, as it is the largest contiguous area with a homogenous forest covertype, and it is the unit at which treatments are administered. Forest Biomass GIS employs a unique framework for assessing available forest biomass by modeling the financial costs and benefits, the energy costs and benefits, and the carbon footprint associated with biomass hauling and harvesting from a stand to a processing facility. The model factors-in a range of cost factors related to terrain, stocking, and equipment capabilities.

## Introduction

In western Montana the federal and state governments are vocally encouraging development of forest biomass production and use, primarily for biofuel, but for other uses as well. The Montana Department of Natural Resources and Conservation estimates the availability of 70.6 million dry tons for Montana (the sum harvest benefit from all trees less than 7” DBH). Within Helena, for example, the DNRC estimates 4.9 million dry tons within a half-mile of an existing road, on slopes less than forty-percent. Some business interests seem to be interested in capitalizing on these resources. The Stoltze Lumber Mill in the Flathead Valley (Montana) that is considering the installation of a 12MW co-generation plant to provide power to 10,000 homes. Stoltze plans to use biomass from its own lands (38,000 acres) from within a 75-mile radius. In nearby northern Idaho, a consortium of large energy interests, including Energy Northwest and Duke Energy, is considering installing one or more 50 MW power generation plants that will depend upon biomass located within 50 miles of a facility.

These estimates provide a starting point for assessing biomass stocks, but they are rough and lack some of the specific considerations that will be important when making investment decisions. For instance, they do not address harvest and hauling costs, variability of terrain, and a diversity of stand-level objectives, which guide management. Furthermore, they do not address variations in stand volume production, variations that can easily doom a financial investment in long-term sustained yield of biomass. If some stands are not economically productive in relationship to the costs of harvesting them and hauling the materials, they cannot be counted as long-term sources of biomass feedstock.

Thus, I propose an assessment framework that addresses comprehensive relevant cost factors and constraints in relation to clearly-defined stand-management objectives and valid stand-volume inventories and growth-and-yield estimates. A valid resource assessment will consider *available* forest biomass based upon stand-management objectives and desired future conditions, current stocking and growth-and-yield estimates, and stand-level harvest, haul and processing costs, including energy use and carbon-footprint. Forest Biomass GIS (FBG) integrates these vital factors into a user-friendly geographical information system, bringing a great deal of precision to investment decisions.

In this paper, I will briefly discuss the importance of using the forest stand as the basic land-unit for biomass assessment and planning, and then briefly discuss the factors relevant to a biomass volume assessment based on stand factors. Finally, I will briefly introduce and describe Forest Biomass GIS.

## The Forest Stand

The forest stand is the basic, atomistic unit for forest analysis, planning and management. A stand is generally a contiguous, homogenous area in terms of composition (species mix) and structure (size distribution), and is usually circumscribed by differences or thresholds in slope and aspect, ownership, past management, disturbance history, roads, etc. Thus, as the smallest contiguous unit with homogeneity of composition and structure, the stand is the smallest land unit sampled for forest structure. The results are tabulated into *stand tables*, which commonly report trees per acre and basal area for various tree species and diameter-classes.

Likewise, the stand is the smallest planning unit, and forest production for a stand is reported in per/area units for that stand. Differences in management objectives become apparent at the stand level. For example, a stand managed for elk hiding cover will differ dramatically than one managed for biomass. As such, the stand is the first level at which a planner determines the sustainability and efficiency of a project – in relation to the management objective. The planner assesses and expresses forest productivity at the stand level in terms of its growth-and-yield, and, likewise, measures costs and constraints at the stand level. Given our management objective or objectives, and given a stand inventory, the planner can determine standing volume as well as projecting growth and yield in the future.

In terms of the larger ecosystem, the stand is the basic building block of the watershed, which consists of a mosaic of varying stands – some of which might easily share the same compositional and structural qualities. Stand objective formulation is constrained or determined by watershed (also known as landscape) level considerations. For example, an overall landscape objective might require limiting the number of stands managed for biomass to an area below some threshold.

## Production Cost Factors

As analysis and assessment occurs at the stand level, so do management treatments, for example, timber harvesting, biomass harvesting, and sanitation-thinning. Thus, costs and benefits manifest at the stand level, and generally, costs and benefits will be homogenous across the stand.

Central to measuring costs and benefits is the awareness of stand productivity, which is measured in terms of growth-and-yield of above-ground, tree-based biomass. Given defined constraints for harvesting (yield), planners typically use a computer application to determine growth-and-yield for a stand, and usually the model is calibrated to a specific region.

Likewise, harvest financial costs will be unique to a stand, due to stocking differences, slope differences, prescription provisions, ownership, and other stand factors. Further, different operators employ differing production systems – production systems being a combination of operator/contractor and the constellation of equipment used on the site. Each of these systems has different costs, which can be compared at the stand level. Harvest cost inputs will rely upon operations research on a number of relationships involved with biomass harvest and haul operations for projection modeling and for current-cost modeling. Current-cost data from these operations should improve operations cost-inputs for projection modeling. Harvest cost factors include terrain, haul distance, equipment type, stocking, prescription, and several other factors, including fuel-use and associated energy use and $CO_2$ emissions.

To assure that long-term management is sustainable, planners should be able to conduct financial and energy-use cost-benefit tracking through all phases of production, as well as a carbon accounting, and should be able to compare cost-benefit ratios (energy and finance) between stands and for and between groups of stands, in the past and present. Likewise, planners should be able to rank stands based on terrain, stocking, and haul distance, and other parameters. Linked to tables from a good G&Y model, a firm should be able to plan for sustained yield of biomass through long-term planning horizons.

Thus equipped, planners can analyze an individual stand, an entire landscape area or watershed, a region, or a set of fragmented stands and ownerships. This type of analysis could be useful to resource agencies, municipalities, or private interests analyzing the resource base for forest biomass development, whether it is a commercial biochar operation, an electrical power generator, or a fuels-for-schools program.

## Forest Biomass GIS (FBG)

Forest Biomass GIS (FBG) is a model for determining forest biomass availability in a geographical area based on forest stand management objectives, stand structure and productivity (short and long term) and production costs and constraints. FBG maintains data on production-related costs (in good detail), energy use, and atmospheric carbon emissions for harvesting and hauling biomass from a stand or group of stands as well as calculating efficiencies (for example, energy returned over energy invested, ERoEI).

FBG will help the production planner to conduct financial and energy-use cost-benefit tracking through all phases of production (harvest and hauling), as well as a carbon accounting. Thus, a planner can answer the question, "How much money must I spend harvesting these three stands, and how many BTUs will the equipment use? How much income am I gaining by selling the biomass? How much energy am I using to harvest compared to the energy embodied in the biomass?" The model can compare cost-benefit ratios (energy and finance) between stands and for and between groups of stands, in the past and present. "Which ten stands have the lowest cost-benefit?" Likewise, FBG can rank stands based on terrain, stocking, and haul distance, and other parameters. Linked to tables from a good growth-and-yield model, FBG can easily be used to plan for sustained yield of biomass through long-term planning horizons.

Currently FBGIS models harvest and haul systems, although biomass processing at facilities could easily be assimilated into the model, as can the related process of sequestering carbon (for example, though charring or pyrolysis). The model treats harvest systems and haul systems separately as combinations of operators and equipment. They are constrained primarily by slope, stocking, and other site factors. Harvest costs can be aggregated or disaggregated at varying texture (coarse or fine), as can the study of productive process (time and motion). The model will be explicit about a methodology for this aggregation and analysis. Likewise, FBG also treats haul systems as combinations of operators and equipment. Cost constraints include slope, weight, road grade, and distance.

To determine biomass loading – or the amount of forest biomass that will be harvested – FBM requires input from at least one other model – the user's preferred regional stand-based growth-and-yield (G&Y) planning and projection model. The G&Y model determines expected harvest yield in relationship to the prescribed treatment at the stand level. A regional G&Y model, in turn, depends upon a cruise or other sampling approach for basic inventory data and site-index or species library for growth rates. For yield rates, the model depends upon compiled inventory data and treatment parameters (level of cut, desired residual structure, etc.).

Harvest cost inputs will rely upon operations research on a number of relationships involved with biomass harvest and haul operations for projection modeling and for current-cost modeling. Current-cost data will improve operations cost-inputs for cost-projection modeling. Harvest cost factors include terrain, haul distance, equipment type, stocking, prescription, and several other factors, including fuel-use and associated energy use and CO2 emissions.

Balancing out the modeling equation, FBG also addresses the energy and financial yields associated with forest biomass in its various forms. Thus, the energy content in green and dry wood is considered, as are current prices and other relevant attributes. The model accounts for (input) energy and financial qualities for various grades of forest biomass stock – including price per ton, energy content and carbon emission.

## Conclusion

The ability to assess the availability of forest biomass based on stand productivity and on harvest and haul costs from the stand will allow investment planners to gain a realistic view of their potential returns or losses. As such an approach will allow investors much more granularity in their land-use decision-making, managers can avoid harvest and haul operations that will not pay for themselves. Further, because most of the forest biomass harvested will supply biomass-to-energy projects, the ability to analyze energy use and carbon emission from a stand will allow a stand-based appraisal of energy efficiency and carbon footprint for a project.