Development of Biomass Best Management Practices for Mississippi

MISSISSIPPI STATE UNIVERSITY™ EXTENSION

Forest woody biomass (FWB) is a renewable raw material component that can produce both electricity and transportation fuel, as well as a number of value-added products. According to the U.S. Department of Energy (2016), forest biomass includes

- any wood waste from forest harvesting, processing mills, and landfills;
- wood cut during silvicultural treatments such as thinnings, fuel reduction, and regeneration cuts;
- dedicated plantations grown specifically for biomass; and
- forest conversion such as urban expansion and right-of-way clearings.

A major effort for the use of biomass was to develop advanced biofuels (second-generation biofuels) made from renewable biomass, such as wood. These biofuels could be easily mixed in a petroleum refinery or used in producing renewable jet fuel. These advanced biofuels must also be economical enough to readily fill in the area that petroleum now occupies. In each case where oil was less plentiful and costly, interest and investment in renewables increased; however, within a few years, the petroleum industry bounced back with a reduction in price and an increase in supply of crude oil and gasoline, which reduced investment in renewables.

When crude oil becomes less accessible and more expensive, petroleum products increase in price, and the market reacts by exploring renewable energy options. However, each time this occurs, petroleum costs quickly decline and result in a loss of investment in renewable energy and fuel. This situation could be seen during the oil embargo in the 1970s and during the restricted supply of crude oil from the Middle East in the early 2000s.

While the production of a second-generation biofuel continues to be elusive, the biomass pellet market in the southeastern United States continues to grow. This market is key to the replacement of coal in electrical production for the United Kingdom and European Union. When greenhouse gas (GHG) emissions and global climate change were linked, many countries adopted GHG standards requiring energy and fuel production with lower CO_2 output. The United Kingdom and Europe enacted legislation that has greatly limited, or in some cases eliminated, the use of coal in electrical production. As a result, the wood pellet market has grown to meet the demand.

The United States, especially the south, has seen a dramatic increase in wood pellet plant construction (Bloomberg, & Ernest & Young, 2013). The pellet market grew from 6 million tons in 2006 to 25 million tons in 2014. Worldwide pellet consumption has been predicted to increase to 59 million tons by 2020, with a vast majority of the pellets used in Western Europe to produce electricity (O'Carroll, 2012). This increase still only accounts for 1 percent of the projected total forest products market (Stewart 2015). By converting electrical power plants to biomass power plants, Europe continues to be an expanding market (Bloomberg, & Ernest & Young, 2013).

With the growth of the market, pellet production has changed. The emphasis is on clean chips that contain less than the regulated ash content, which was set at less than 3 percent. While the pellet market has expanded, it is still primarily located along the coast and waterways such as the Mississippi River and Tennessee-Tombigbee where there is access to major deep-water shipping ports in Baton Rouge, Louisiana, and Mobile, Alabama.

Although fossil fuels like coal and petroleum continue to be the primary source of energy in the United States, the need for a renewable energy source grows. This energy source must provide not only electrical power and transportation fuel, but also a wide array of products developed through the petro-chemical industry. Although ethanol has been produced through the fermentation process (also known as a first-generation fuel), it is an additive, not a substitute, for gasoline, and ethanol is only suitable for current combustion engines at levels under 15 percent. Biofuels that could be used in any quantity with petroleum-based gasoline are called second-generation or drop-in fuels. Unfortunately, the production of such a fuel from wood-based systems has been much more difficult than expected. Fortunately, research and development in the field of renewables, including tree-based material, has produced new renewable products such as carbon fiber and polymer.

The focus on renewable energy has brought woody biomass to the forefront as a possible source of electrical power and an important part of the production of biofuels. In 2005 and 2011, the Department of Energy released a report known as the Billion-Ton Report. This report indicated that the southern United States is the prime area for production of woody biomass due to its extensive forestland base and the current infrastructure supporting the growth and harvesting of forests as the raw material for numerous wood products (Perlack et al., 2005; U.S. Department of Energy, 2011).

The southern forest covers approximately 212 million acres over 13 states. Approximately 89 percent of the forestland is owned by nonindustrial private forest (NIPF) landowners. Currently, Mississippi ranks fourth in total forested acreage with approximately 19.7 million acres, with more than 13 million acres belonging to NIPF landowners. The aboveground biomass of this forest area has been estimated to be approximately 856.6 million dry tons. Loblolly/shortleaf pine accounts for the largest portion of Mississippi's biomass at 7.3 million acres, followed by oak/hickory at 5.1 million acres, oak/gum/cypress at 2.6 million acres, and oak/pine at 2.1 million acres (Oswalt, 2013).

With such a large forestland base and the economic importance of forestry to the state of Mississippi, an additional product such as biomass could play a significant role in Mississippi's economy and renewable energy production. According to the U.S. Department of Energy (2011), logging residue as a woody feedstock (raw material) for bioenergy or biofuel production is viable, especially when heavy slash levels were left following harvest. Today, the biomass market offers value for the excess logging slash that was once considered waste. The biomass market may also include undesirable trees ranging from 1 to 5 inches in diameter and tree tops and branches of any trees greater than 5 inches in diameter at breast height (DBH).

If biomass markets continue to increase, logging residue and small trees that were once considered waste will become valuable (U.S. Department of Energy, 2011). This scenario has stimulated concerns from the public that a developing biomass market could result in total destruction of forests with severe negative environmental consequences to soils, water, wildlife, and biodiversity. Although the use of biomass in Mississippi has been extremely limited, the development of best management practices (BMPs) is needed for the use of biomass. This document stands as the initial proactive step, and it should be modified as more research is acquired.

Definition of Forest Woody Biomass

For the purposes of this publication and for the development of BMPs for biomass use within the state of Mississippi, forest woody biomass is defined as any tree or portions of a tree harvested for the primary use of producing renewable energy. These include

- living stems
- poorly formed or damaged stemwood (the bole of the tree)
- large and small branches
- bark
- topwood (crown of the tree)
- foliage

It is important to note that any remaining woody material measuring more than 3 inches at the small end will be referred to as coarse woody material (CWM), whereas woody material measuring less than 3 inches at the large end will be referred to as fine woody material (FWM). CWM and FWM apply to biomass harvesting only when a stand undergoes a complete removal of trees for a variety of products, including biomass. FWM and foliage form the primary source of nutrients that are needed for maintaining site sustainability following a transitional harvest. A transitional harvest is when whole trees, portions of trees not fit for market, and/or residuals that are unsuitable for higher-value products are removed (either whole or after further processing on-site) for forest woody biomass. In addition, the phrase "transitional harvest" implies that all of the economically viable trees will be removed from the site and then the forest will be artificially or naturally regenerated.

Therefore, FWB may be any renewable woody fiber obtained from natural or plantation stands for use in biomass markets. In the past, FWB, such as culls, non-merchantable species, and various unused portions of trees resulting from more traditional forest harvests were left on-site. Excessive FWB left on-site makes site preparation for artificial regeneration quite costly. Therefore, removing excess forest woody biomass material as a marketable product may ease the transition from harvest to a newly regenerated stand as well as provide an additional source of income.

Possible Sources of Forest Woody Biomass

1. Logging slash from either thinnings or transitional harvests deemed excessive based on specific site soil type. Logging slash includes topwood, coarse woody material, and unused portions of trees that are only sellable on the biomass market.
2. Any wood that is harvested during intermediate silvicultural operations, such as precommercial thinnings or stand improvement treatments.
3. Any type of salvage wood resulting from extreme weather events, insect attacks, or disease.
4. Transitional harvests where trees are sold for specific products ranging from poles to biomass. Other aspects falling under this type of harvest include:
   a. Removal of the entire aboveground portion of the tree (stem, branches, and foliage), either chipped on-site or transported off-site for later chipping
   b. Residuals unsuitable for higher-value products removed whole or after processing on-site

The main issue with each of these sources is damage done to the site during the entry and removal process. Currently, whole-tree harvesting has the greatest probability of site damage because both small- and large-diameter trees, along with branches and leaves, can be harvested, chipped, and transported off-site. The increased use of nonmerchantable trees limits the amount of woody material left on-site and may cause harm to soil/site sustainability as a result of excessive erosion, loss of organic matter, and loss of nutrients. In addition, frequent entries and excessive removal of residuals will damage the site's ability to sustain growth and maintain biodiversity at both the micro- and macro-environmental levels.

In the eastern United States, using forest woody biomass to produce renewable energy has brought about a variety of concerns. Measures for addressing these concerns follow:

Concern 1: Producing renewable energy from the forest may lead to more frequent and intensive harvests of trees, including commercially undesirable species, small-diameter trees, bark and log slash, and crowns and limbs of conventionally harvested trees. These frequent harvests of trees and waste materials will transform our healthy viable forests into waste areas.

Response 1: The use of logging residue has garnered a lot of attention. Initially, it was believed that the surplus logging residue would serve as a major biomass component. However, the vast majority of forest stands, especially pine plantations, do not have an excess of logging residue, and these BMPs are being designed so that logging residue is not removed from those types of stands. Yet this is not true for all stands; whether or not there is excess logging residue depends on the stand makeup and the type of harvest. Specific species, especially natural hardwood stands, and sawtimber harvests could produce an overabundance of logging residue, but the economic viability of removing this type of low-valued material is still highly questionable.

Concern 2: There is a possibility that natural stands found on public lands may be harvested for biomass. This would limit the multiple-use concept and significantly affect the biodiversity of these sites.

Response 2: As the use of logging residue is limited and there is a shift toward clean chip production in biomass, this concern has not gone unheard. Currently, there is very little desire or need to explore the use of natural stands. In fact, the production of a second-generation biofuel using forest woody material is extremely limited. In addition, the southern pulp and paper industry continues to shrink in size, placing considerable acreage in need of the thinning. Some of this void has been filled with the development of pellet plants, especially in those areas that are close to the Gulf Coast, resulting in lower transportation cost of overseas pellet shipments.

Although the pellet industry continues to grow, it focuses on pine plantations, where the first thinning (typically designated as a pulpwood thinning) has become the primary source of pellets. These thinnings provide a material that counts toward a pine plantation's added-value products, therefore falling under the BMPs for traditional forest products. To date, there has been only minimal harvest in natural pine, pine/hardwood, or hardwood stands either publically or privately owned. In many cases, the stands that were harvested were degraded, so harvesting provided restoration toward a more diverse and productive site.

Concern 3: Could biomass harvesting negatively impact hardwood plantations that were developed under the Farm Bill?

Response 3: With the passage of the 1985 Farm Bill, thousands of acres in Mississippi were taken out of agricultural production and placed into hardwood plantations under the Conservation Reserve Program (CRP), using primarily oak species. These CRP plantings were designed to remove marginal agricultural land and place this acreage into a system that would lower soil erosion and increase water quality. This was an attractive offer, as an annual payment was contracted for either 10 or 15 years. In the case of reforestation, the acreage saw not only a land use change but also improved wildlife habitat.

Many Mississippi landowners are now looking to thin these stands for a number of reasons but are finding markets for this type of wood extremely limited. Careful planning and thinning of these plantations would not only aid in wildlife enhancement but also improve the development of the remaining trees. As with pine management, thinning in hardwood plantations would produce clean chips for biomass, and, like pine, would fall under Mississippi's traditional forestry BMPs. Thinning would allow the landowner to capture some revenue from the biomass market while providing open areas for wildlife cover and, if available, continuing to develop the better hardwood component through time.

Concern 4: If short rotation wood crops (SRWCs) are grown as feedstock for the production of renewable energy and fuel, could they endanger agricultural land suitable for food production, thus impacting the amount and cost of food?

Response 4: SRWCs are mainly grown on agricultural land that was once forested but today is only marginally capable of producing any type of agricultural crop. To date, no commercial SRWC plantations have come online in Mississippi; however, researchers are investigating the potential by evaluating growth and economic viability. SRWC systems would be grown under very intensive management to maximize woody biomass growth. In addition, these types of plantations would be limited by proximity to the manufacturing facility (within a 35- to 50-mile radius) in order to reduce transportation cost and the overall cost of the feedstock. The main objective of SRWC plantations is to maximize yields so that there would be little need, if any, to use native forest stands or productive agricultural land for biomass production.

Traditional Forest BMPs versus Forest Woody Biomass Guidelines

Traditionally, BMPs have primarily focused on erosion because of its effect on water quality. For the state of Mississippi, the latest edition of *Best Management Practices for Forestry in Mississippi* (Mississippi Forestry Commission, 2008) covers the range of silvicultural and harvesting aspects for both upland and wetland site types. Within each site type, specific considerations are addressed for different stream classes (for example, perennial and intermittent streams, ephemeral streams, drains) and the slope of the surrounding land.

Specific limitations have been designed based on the stream class to ensure that erosion is controlled, which keeps sediment from entering streams. Consequently, these guidelines ensure site sustainability through soil protection. Mississippi BMPs provide an additional layer of restrictions for harvesting within wetland types due to the proximity of water and the saturated nature of the soils, which can lead to soil damage.

The forest woody biomass BMPs address biomass harvesting and the need to maintain sustainability of sites, but BMPs also address water-quality protection. Soil erosion is not only an important factor in non-point sources of pollution; erosion also degrades the soil profile by removing nutrients that are critical to plant growth. The loss of nutrients, such as nitrate (NO_3), increases substantially following harvesting and fertilization, yet very few reports have shown concentrations greater than EPA primary drinking-water standards.

Besides nitrates, high levels of suspended sediment concentrations in stream waters have been reported following road construction, harvests, and regeneration, especially if these practices coincided with intense storms (Binkley & Brown, 1993). Mississippi's traditional forest BMPs provide the necessary steps to maintain water quality from various forest management activities.

The first step is creating streamside management zones (SMZs), which protect against surface water runoff and, therefore, maintain stream water integrity by limiting chemicals and fertilizers from entering streams. The second step is removing all debris from streams. It is also necessary to re-vegetate any bare soil near the boundary of the SMZ as quickly as possible to keep sediment from moving into the streams.

Mississippi's forestry BMPs have been very effective in protecting water quality over various soil regions within the state following traditional harvesting (Cristan et al., 2016). Studies by Keim and Schoenholtz (1999) and Carroll et al. (2004) showed the effectiveness of SMZs in protecting water quality and stream habitat. However, there has been very little research on the effectiveness of BMPs in protecting water quality where all logging residues have been removed. Currently, biomass removal employs conventional harvesting techniques, which should result in very little difference unless soil conditions were different during harvesting operations.

As a result, Ice et al. (2010) suggested that traditional BMPs should be effective in protecting water quality for both traditional and biomass harvesting.

Today, the vast majority of pellet production comes from first thinnings in pine plantations. This material traditionally was used for the pulpwood market. It is important to note that this type of harvest falls under the forestry BMPs and does not meet the criteria described as biomass harvesting. However, a limited amount of woody biomass within the state is being produced through whole-tree harvesting, and this material is blended with clean chips at a ratio no higher than 30 percent in order to maintain low ash content. These types of operations represent a very small percentage of the harvest and are the operations addressed by the forest woody biomass BMPs.

Forest Woody Biomass Removal Limitations

Removing logging residue from a site may have a two-fold effect. Increased traffic may occur when initial conventional harvests are followed by biomass removals, resulting in greater soil exposure, increased erosion, and increased sediment entering streams. A study conducted by Barrett et al. (2016) in the *Virginia Piedmont* evaluated 10 clearcut sites of between 15 and 80 acres that were conventionally harvested and 10 sites where biomass harvests were added to the conventional harvest. Their findings indicated the overall amount of soil erosion was 0.8 tons per acre per year. The sites where biomass was harvested had significantly less heavy slash piles because this material was used, but these sites still had greater than 10 percent heavy slash over the entire site. Visual observations during site visits in Mississippi indicated that substantial amounts of harvest debris are left on the site because of economic and operational limitations.

What remains unclear is the future demand for forest products and whether it can be met with possible land base changes. Fox (2000) stated that, if faced with less forest acreage, improving site quality and productivity could offset the land base loss. Currently, product limitations and lower stumpage prices have many NIPF landowners considering a change from forestry to other possible markets. If demand for renewable energy increases, the additional draw of woody biomass from the existing forest land base will complicate these scenarios.

Removing excess forest biomass from a site should indicate that the resource is not being wasted but rather used in a productive manner. However, overuse of the residual logging material, as well as more frequent harvesting, could lead to negative site consequences. In an effort to define the most suitable soil characteristics to protect the forest/site sustainability when removing biomass, soil suitability maps were developed for Mississippi. These maps are similar to the soil suitability map developed by South Carolina (South Carolina Forestry Commission, 2012).

Table 1 shows three limitation classes of soil/site properties that influence soil productivity and soil sustainability. Soil limitation classes for forest biomass ranged from slightly limiting to very limiting. The limitation classes were the basis for a biomass soil suitability map and a biomass potential map (based on broad landscape features of Mississippi rather than specific soil types). Table 1 specifies soil characteristics that were determined to be the most appropriate for the overall diversity of geologic and landscape features of Mississippi. Within some of these large landscape areas, there will be specific soils, topography, or hydrology that should be excluded from biomass harvesting as well as from biomass production systems.

Table 1. Mississippi soils suitability classes for biomass harvesting to be used in the development of Mississippi biomass best management practices.

Soil/site property	Slightly limiting	Moderately limiting	Very limiting
Water depth (cm)	>120	30–120	<30
Restriction depth (cm)	>100	60–100	<60
Percent sand (%)	<40	41–59	>60
Available water capacity (cm)	>18	14–18	<14
Slope (%)	<20	20–35	>35
CEC (cmol/kg)	>10	5–10	<5
Percent OM	3–5	>3	<1 or >10
Thickness of a horizon (cm)	>24	8–24	<8
Site index	>75	65–75	<65

Table 1 helps identify specific Mississippi sites and soils where biomass removal will negatively impact soil productivity and forest site sustainability because of nutrient loss. Table 1 also identifies soil types that have the potential for high biomass productivity. More specifically, soil limitations that combine erosion potential, water availability, depth of water table, and nutrient availability provide a guide to the extent of potential biomass removals. Current recommendations for the amount of logging residues to be left on-site are at least 30 to 35 percent (U.S. Department of Energy, 2016; Springer et al., 2017; Skog & Stanturf, 2008). However, on steep soils greater than 35 percent or on deep sandy soils where moisture and nutrient loss is greater, greater amounts of logging residue should be left. Appropriate additional steps should be taken to negate the soil/site impact.

The specific soil properties listed in Table 1 give reason for limiting forest woody biomass removal on soil types such as loess (because of its erosive nature and deep sandy soils where moisture- and nutrient-holding capacity are limited). Forest management practices, such as prescribed burning and using herbicides, as well as climatic conditions may contribute to sediment and nutrient loss and poor stream quality.

This publication has not addressed dedicated energy plantations because, at this point, there are no commercial energy plantations in Mississippi that are solely focused on biomass production. This type of plantation could play a significant role in woody biomass production in the future, but the cost is still being researched.

Conclusion

Developing biomass BMPs for Mississippi is a proactive step taken not only to avoid future problems, but to further understand how and to what extent specific processes of harvesting and removals impact site sustainability. The word *biomass* has been closely defined with pellet production. In Mississippi, the vast majority of pellet production is from the first thinnings of pine plantations, and only limited amounts of whole tree biomass removals have been undertaken. The thinning of young pine plantations is not considered to be part of biomass harvesting but rather a traditional harvest commonly used by the pulp and paper industry.

Biomass harvesting implies that a forest stand is under the process of a complete harvest and that various wood products, including the possibility of biomass, are being removed from the site. Therefore, the biomass BMPs are typically complementary practices to the traditional Mississippi forestry BMPs that serve to limit site impacts and ensure water quality. Biomass BMPs provide an additional layer of protection to the sustainability of the site by limiting the amount and extent of removal of both coarse and fine woody material. While the sustainability of every site is important, the primary focus has been on the thick and thin loess soils and the deep sandy soils.

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