Biomass

Photo from Steve John, Agricultural Watershed Institute

What is Biomass?

Biomass is recently living leaves, shoots, stems, stalks and flowering parts of herbaceous or woody plants. Biomass does not include grains or other starchy portions of plants. Biomass can be produced in agricultural, forestry, and agroforestry systems. Plants grown purposely for biomass, and particularly when grown under contract, are termed "dedicated bioenergy crops", or simply "dedicated crops". Agriculturally produced biomass includes annual and perennial grasses as well as residues from crops grown for food and feed, such as corn stover. However, crop residues are beyond the scope of GLBW and not further considered here. Forests provide multiple types of biomass including residues from timber harvests and timber stand improvement activities but these activities too are beyond the scope of GLBW are not further considered here. Agroforestry is a source of herbaceous and woody biomass including short-rotation woody species such as hybrid poplar (*Populus* species) and willow (*Salix* species), and perennial grasses grown as alley crops.

Biomass can be processed into bioenergy and bioproducts, including, for example:

- Space heating: combustion in small-scale and distributed heating systems such as stoves, furnaces, boilers or other unit capable of burning pelletized or shredded biomass
- Biopower and co-generated electricity: combustion is used to convert biomass alone or along with petroleum fuels (usually coal or natural gas) into power that is distributed
- Combined heat and power: biomass-burning units provide power and/or steam to a factory, hospital, or centralized heating district (e.g., a campus) while process waste heat from combustion is captured and used
- Biofuels: biomass is converted through fermentation, pyrolysis (heated in the absence of oxygen) torrefaction (a lower temperature form of pyrolysis) or gasification (heated without combustion and in the presence of oxygen) into solid, liquid or gas fuels for use in power plants, industrial processes (e.g., steel production), residential/decentralized heating, and transportation fuels (currently emerging at commercial scales)
- Biochemicals: basic and specialty chemicals, resins, paints, lubricants and solvents
- Biomaterials: engineered materials such as plastics, foams, rubber, sorbents, and dimensional products for building construction

- Livestock feed: lower-quality forage is treated to make the plant nutrition more available to ruminants
- Other materials and uses: livestock bedding, landscaping mulch, mushroom compost, and construction site stabilization materials

Plantings for biomass don't necessarily have to go to an industrial use. Biomass can be used on-farm as an energy source or livestock agriculture (e.g., bedding). Biomass is one type of CLC strategy. Some biomass plant species may have multiple CLC uses and can overlap with perennial forage or perennial grain, for example. That means biomass production is a potentially flexible practice with regard to marketing. Whether a biomass crop that is suitable as forage, for example, can be flexibly sold in different markets from year-to-year will depend on demand and whether the grower is obligated under contractual terms to deliver biomass to a specific buyer over a period of years. Also, industrial buyers may require contracts that include terms of biomass quality which may impinge on a crop's flexibility in other markets. Similarly with perennial grain crops; if a market is unavailable for the perennial grain, or weather or other conditions in a given year render the grain crop unsuitable as food or feed, then sale as a biomass crop may be an option.

Land Suitability and Placement of Biomass

Biomass plantings can be suitable for a broad range of growing locations and circumstances. Biomass crops can be established on large acreages but can also be used in buffer strip plantings or other limited configurations to address erosion and nutrient runoff. Perennial biomass crops make exceptionally good plants for filter and buffer areas and can be grown as alley crops in agroforestry systems. The extensive root systems and above-ground tissues of herbaceous and woody perennial plants will capture and hold soil and farm nutrients that may otherwise run off a cropped field. Some biomass species are very drought tolerant – such as native warm-season grasses, which makes them a good choice for drier and more erodible soils. Other biomass species are tolerant of short-term flooding – such as short-rotation willow species and some perennial grasses, which makes them a good choice for low-lying areas.

Many native perennial grasses suitable for biomass production are cold hardy and tolerant of a wide range of growing conditions, although selection of variety or cultivar is important to ensure suitability for any specific location. Native warm-season perennial grasses can succeed on land that is marginal for corn production, for example. Because of their lower value compared to cash grain crops, perennial biomass crops are not usually grown on highly productive soils. Marginality of a field can be agronomic or economic, and can take a variety of forms: high water table, frequent flooding, droughtiness, high erodibility, high level of runoff or leaching, short growing season, and other soil or climate factors that can limit productivity of commodity grain crops. Negri et al. (2014) modeled total biomass yields of 5.3 tons/acre for corn and 21.4 tons/acre for Miscanthus on the same marginal ground. Assuming 50% stover and 50% grain for the corn; a price for corn of

$3.50/bu and price for stover of $85/ton (Eric Rund, 2014); the gross income for corn on this marginal ground would be:

95 bu/ac grain* $3.50/bu = $332.50
2.67 tons/ac stover * $85/ton = $227.12

Total gross income = $559.62/ac

Assuming the same biomass price as corn stover for the Miscanthus, $85/ton (Eric Rund, 2014), the gross income for the Miscanthus crop on the same marginal acres would be:

21.4 tons * $85/ton = $1,819/ac

Perennial biomass crops can have higher income potential than corn or other commodity row crops on marginal acres, but they also provide excellent protection against soil erosion and runoff. In the Upper Midwest, on average, 31% of applied nitrogen is lost from row-cropped fields (Delgado and Follett, 2010). Negri et al. (2014) found nitrate leaching under Miscanthus was 60% to 70% less than under corn on marginal ground. Also, locating a perennial biomass crop downslope from row-cropped areas enables the biomass crop to trap nutrient-rich runoff and utilize at least a portion of the nutrients thus preventing them from entering ground and surface waters.

Biomass and conservation lands

Dedicated biomass crops such as perennial grasses and short rotation coppice trees are the only source of renewable energy that can also provide ecosystem services on a landscape scale. Nutrient loss reduction, wildlife habitat and biodiversity, and soil conservation are among the major conservation benefits that can be provided by strategic selection, placement, and management of bioenergy crops grown in monocultures or polycultures. Research and on-farm demonstrations can assess synergies and trade-offs for coproduction of harvestable biomass and ecosystem services and evaluate landscape design to integrate Multifunctional Perennial Cropping Systems into farmland dominated by annual row crops.

Iowa State University researchers are leading the innovative Science-based Trials of Rowcrops Integrated with Prairie Strips, or STRIPS project. Their research shows that strips of prairie grown on field contours are an affordable option for farmers and land owners seeking to garner multiple conservation benefits. The STRIPS protocol for reduction of soil erosion and nutrient runoff from row-cropped fields involves strategic placement of relatively small areas of native perennial grasses and flowering plants. While these diverse prairie mixtures should generally remain undisturbed during the growing season to serve as habitat for pollinators, songbirds and other wildlife, a late-fall harvest of biomass from the strips is possible. Indeed, maintenance of the prairie strips like all grasslands, requires periodic disturbance such as harvest or mowing to remain healthy. The biomass from these "maintenance" activities potentially could be used for production of bioenergy and bioproducts. See more about Prairie STRIPS in the additional materials associated with this manual, or visit www.nrem.iastate.edu/research/STRIPs/.

Harvest and sale of biomass is possible from other types of conservation plantings as well. Riparian buffers and grassed waterways, for example, if installed under USDA/NRCS's Environmental Quality Incentive Program (EQIP) can generally be harvested occasionally to maintain the stand. Often the harvest from these areas is used for livestock forage, but the biomass market is another possibility. See more about use of the EQIP program in the "EQIP and CLC" chapter in this manual.

Biomass and agroforestry

In simple terms, agroforestry is intensive land-use management combining trees and/or shrubs with crops in integrated production systems for multiple products and benefits. Riparian buffers of permanent vegetation, grassed waterways, and alley crops (agricultural or horticultural crops cultivated in wide alleys between rows of trees or shrubs) are agroforestry practices that potentially can include biomass production. Short-rotation woody crops area received much attention as bioenergy and bioproduct feedstock, and their cultivation is well known. Perennial grasses can be grown as alley crops for biomass. Research at the University of Missouri Center for Agroforestry (www.centerforagroforestry.org) indicates that switchgrass and other warm-season grasses can be grown economically in nut tree alleys with up to 50% shade. In other geographic regions, switchgrass can be feasible as a bioenergy alley crop with loblolly pine and cottonwood.

Biomass and livestock feed

Some crops with utility as biomass can also have adequate forage quality for some classes of livestock, depending on timing of harvest. Switchgrass (*Panicum virgatum*), for instance, is a native warm-season perennial grass that has been developed as a forage. It can be grazed by cattle or harvested for hay. It is also grown as a dedicated biomass crop for biofuels at commercial scales. See for example, the Chariton Valley Biomass Project in southeastern Iowa (www.iowaswitchgrass.com/), and Abengoa Bioenergy's operation in Hugoton, Kansas (www.abengoabioenergy.com/web/en/2g_hugoton_project/). Other warm-season and even some cool-season grass forages are potentially also "dual use" crops. Reed canarygrass (*Phalaris arundinacea*), for instance, is frequently used in earlier growing stages as hay or grazing but can produce a very large tonnage per acre as a mature crop.

Major feed suppliers are now looking at biomass-type plant species with low forage quality as a potential source of livestock feed. The high lignin content of most biomass-type plants makes them unsuitable for livestock feed in their whole form. However, processing the biomass by grinding it and chemically treating it renders the material more amenable to digestion by ruminant livestock. Thus, processing of low-quality herbaceous biomass into livestock feed represents another potentialmarketing pathway. Use of slaked lime (calcium hydroxide; CaOH) to expose more surface area of the biomass to ruminant digestion is one processing method (Cecava, 2014). Use of a combination of physical and chemical processes is an emerging technology for pretreatment of biomass for either livestock feed or bioenergy uses. See for example the Ammonia Fiber Expansion (AFEX; www.glbrc.org/news/michigan-afex-pilot-plant-provides-fodder-cattle-feed-trials.)

Small-scale and distributed heating and power systems

Biomass has low bulk density, and therefore lower energy density compared to coal, for example. Transport costs for biomass can be prohibitively high at longer distances. Also, commodity markets for biomass do not yet exist (although efforts are underway to transform diverse forms of grass biomass into consistent, quality-controlled commodity products). Some experts in the biomass field, therefore, see distributed biomass heating systems as a promising avenue for marketing and use of biomass. Localized systems can draw their biomass feedstock from a radius that makes transportation costs manageable. These localized systems can be as small-scale as a biomass-burning furnace that heats the machine shop building on a farm; and in fact, substitution of bioenergy systems for liquefied petroleum (LP) gas uses on the farm is a highly recommended way to simultaneously support putting acres into biomass and cut the farm's fuel bill. An example from east central Illinois showed a pay price of $85/ton for Miscanthus. One ton of Miscanthus would replace 170 gallons of LP gas at a cost of $364, for a savings of $279 (Eric Rund, 2014). That savings rate would allow rapid repayment of investment in a biomass-burning system.

Distributed bioenergy systems can also be larger-scale. One example is a biomass boiler system that serves a Virginia nursing home and requires 2,000 acres of dedicated biomass to supply it (Tom Canam, 2014). On a still larger, but still localized, scale; Koda Energy (www.kodaenergy.com/) is operated by the Mdewakanton Sioux in Shakopee, MN.

Profitability of biomass

Perennial biomass grown under contract to a defined user of biomass can be a stable source of farm income without the price volatility seen in commodity grain markets. Localized biomass users – businesses using biomass as their heating fuel, for instance; or factories with a CHP system – need a dedicated and nearby source of biomass for their operations, and typically pay a stable price for it. Farmers who devote acreage to biomass for these types of localized buyers can generally count on steady annual profit from those acres – especially since perennial biomass crops tend to be very hardy, without the disease or insect pressures that plague row crop monocultures, and tolerant of temporary flooding or drought. An example in east central Illinois showed a $181/ac net income from Miscanthus in every year once the stand was established. Corn at $6.50/bu returned $364/ac net; but at $3.49/bu the corn returned a net loss of $173/ac. Those returns would give an average return from corn of $95/ac/year if corn alternated yearly between $6.50/bu and $3.49/bu, which surely cannot be depended upon. Miscanthus in that example is the crop with the more stable profit potential and could easily outperform corn financially in a 5-year average (Eric Rund, 2014).

References:

Bioenergy Landscapes for Water Quality and Greenhouse Gas Reduction. November 2014. M. Cristina Negri*, Herbert Ssegane and Patty Campbell. Energy Systems Division, U.S. Department of Energy.
http://misadocuments.info/Cristina_Negri_Argonne_2014.pdf

Harvest and Supply of Native Grass for Bioenergy. 2014. Tom Canam, Eastern Illinois University.
http://greenlandsbluewaters.net/Tom_Canam_Native_Grass_Bioenergy_2014.pdf

Multi-fuel Biomass Boilers are Key to Midwestern Biomass Markets. 2014. Eric Rund, Green Flame Energy.
http://greenlandsbluewaters.net/Eric_Rund_GreenFlameEnergy_2014.pdf

Processing Methods to Improve the Feed Value of Perennial Grasses. 2014. Michael Cecava, Director of Feed Technology Research, Archer Daniels Midland Company.
http://greenlandsbluewaters.net/Mike_Cecava_ADM_2014.pdf

Using Cover Crops and Cropping Systems for Nitrogen Management. Chapter 9 in *Advances in Nitrogen Management for Water Quality*. Edited by Jorge A. Delgado and Ronald F. Follett. 2010, 424 pages, hardcover. Soil and Water Conservation Society. ISBN 978-0-9769432-0-4.
http://www.swcs.org/documents/filelibrary/advances_in_nitrogen_management_for_water_quality/ANM9_A41356AAD3B6A.pdf