Best Management Practices for Protecting Water Quality in Bioenergy Feedstock Production

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In the quest to develop renewable energy sources, woody and agricultural crops are being viewed as an important source of low environmental impact feedstocks for electrical generation and biofuels production (Somerville et al. 2010, Berndes and Smith 2013). In countries like the USA, the bioenergy feedstock potential is dominated by agriculture (73%) (Perlack et al. 2005). In others like Finland the largest potential comes from forest resources. Forest bioenergy operational activities encompass activities of a continuing and cyclical nature such as stand establishment, mid-rotation silviculture, harvesting, product transportation, wood storage, energy production, ash recycling, and then back to stand establishment (Neary 2013). All of these have the potential to produce varying levels of disturbance that might affect site quality and water resources but the frequency for any given site is low (Berndes 2002, Shepard 2006, Neary and Koestner 2012). Agricultural production of feedstocks involves annual activities that have a much higher potential to affect soils and water resources. The way forward relative to assessing the soil and water impacts of bioenergy systems and the sustainability of biomass production rests with three approaches that could be used individually but are more likely to be employed in some combination (Neary and Langeveld 2013).

These approaches are: (1) utilizing characteristics that can be quantified in Life Cycle Assessment (LCA) studies by software, remote sensing, or other accounting methods (e.g.,greenhouse gas balances, energy balance, etc.; Cherubini and Strømman 2011); (2) measuring and monitoring ecosystem characteristics that can be evaluated in a more or less qualitative way (e.g., maintaining soil organic carbon) that might provide insights on potential productivity and sustainability, and (3) employing other proactive management characteristics such as Best Management Practices that are aimed at preventing environmental degradation.

Life Cycle Assessment

Life Cycle Assessment has been used to estimate the environmental impacts of biomass energy uses. Typically they examine greenhouse gas (GHG) emissions, CO_2 emissions, energy balance, and some indirect effects. Cherubini and Strømman (2011) reviewed 94 LCAs, most of which were papers published in scientific journals. More than half of the studies were from North America and Europe. Increased numbers of South Asia, Africa, and South America can be found. About 50% of the studies limited the LCA to GHG and energy balances without considering contributions of bioenergy programs to other impact categories such as soils and water. They concluded that there are a number of issues and methodological assumptions in currently used LCA approaches that make it impossible to quantify environmental impacts from bioenergy programs. Some of the key indirect effects issues strongly depend on local operations, vegetation, soil, and climate conditions that render accurate assessment of environmental effects very problematic. Although policymakers claim that methods exist for assessing environmental impacts on soil and water, the scientific foundation for estimating indirect effects of bioenergy programs is constrained by the lack of adequate validation research, accurate assessment methods, and the relative infancy of the LCA process. Cherubini and Strømman (2011) clearly pointed out that determination of environmental outcomes of bioenergy production is complex and can lead to a wide range of results. They stated that the inclusion of indirect environmental effects in LCA represents the next research challenge and not the immediate incorporation into the methodology.

Sustainability and Productivity

In regard to the second approach, soil quality monitoring was developed as a means of evaluating the effects of forestry and agricultural management practices on soil functions that might affect site productivity (Neary et al. 2010). A number of soil physical, biological and chemical parameters, which have linkages to soil productivity have been proposed as forming a minimum monitoring set. The way forward relative to assessing soils impacts and the sustainability of biomass production systems rests with proactive proper soil management and not reactive monitoring for screening the condition, quality, and health of soils relative to sustaining productivity (Johnson 2010, Burger et al. 2010). Evaluation of soil condition thus would lead to a time-trend analysis that can in turn be used to assess the sustainability of land management practices and bioenergy programs. However, even though sustainability is the stewardship goal of land management, more specific definitions of its goals and attributes is often complex and open to considerable interpretation (Allen and Hoekstra 1994, Moir and Mowrer 1995). Many scientists have attempted to answer the "what," "what level," "for

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whom," biological or economic," and "how long" questions of sustainability. Allen and Hoekstra (1994) clearly pointed out that there is no absolute definition of sustainability, and that it must be viewed within the context of the human conceptual framework, societal decisions on the state of ecosystem to be sustained, and the temporal and spatial scales over which sustainability is to be judged. In short, this approach is loaded with considerable uncertainty and lack of consensus.

Best Management Practices

Absent some breakthrough in validating a key set of soil parameters that will predict soil productivity and sustainability trajectories, the most sensible approach is the third, specifically the development, implementation, monitoring, and assessment of "Best Management Practices" (BMPs) (Neary 2013). Collectively, a large number of BMPs for forestry and agriculture have been developed throughout the world because of national regulatory demands and the international development of "Codes of Land Management Practice" (Neary 2014). The BMPs in the Codes and regulations cover traditional forestry and agricultural activities. New BMPs have been developed for bioenergy applications such as energy production facilities, ash recycling, and short-rotation cropping. Best Management Practices were originally developed in the 1970s for water quality protection but now extend to other environmental concerns such as sustainability. An important part of BMP utilization is the cycle of application, monitoring, evaluation, refinement, and re-application. Research and development studies play a key part in the refinement and communication of improved BMPs. Existing studies of BMP effectiveness have demonstrated that most BMPs, if applied correctly, are very effective in mitigating or preventing adverse soil and water quality impacts. Some jurisdictions have mandatory BMPs but others operate completely under voluntary systems.

The key components of successful BMP-based codes of practice for bioenergy systems, whether voluntary or mandatory, revolve around the cyclical strategy of planning, implementation, monitoring, evaluation, adaptation, and renewed implementation. The minimum number of BMPs needed should come out of the planning process and is dependent on resources to be protected, site physical characteristics, regulatory requirements, and overall organization and operation goals. These will obviously vary from site to site, region to region, country to country, and organization to organization. Life cycle analysis should always be included in order to identify all water and ecological impacts. The next step is crucial. Monitoring and evaluation should be conducted routinely in order to decide if selected BMPs are effective and can be reapplied, or if they need to be modified, researched further, or discarded. Research and development studies play a key part in the refinement and communication of improved BMPs. They are also crucial in validating the effectiveness of BMPs. This is especially important where local environmental conditions or operational standards are unique. Best Management Practices ensure that bioenergy programs can be a sustainable part of land management and renewable energy production. There are a number of management practices that are accepted as means of reducing or eliminating the environmental effects of forestry operations, agriculture activities, and energy production (Minnesota Forest Resources Council 2005, USDA Forest Service 2012) These are collectively known as BMPs (Loehr et al. 1979, Lynch et al. 1985). This term is used in many domains from accounting and tourism to forestry. It implies that there is a widely acceptable combination of management actions that under most conditions ensure desirable outcomes.

In forestry and farming, the term BMP usually refers to practical and economic operational procedures and practices that eliminate or keep risks to environmental quality at an acceptably low level (D'Arcy and Frost 2001, Broadmeadow and Nisbet 2004). In most instances the key environmental parameter is water quality, and the focus of BMPs in both forest and agricultural management is the Streamside Management Zone (SMZ) (Neary 2014). However, as discussed in this paper, BMPs exist and can be used for all life cycle phases of forest products and bioenergy feedstock production. For example, one BMP for forestry operations is to keep machinery out of waterways (Phillips et al. 2000). Another set minimizes road stream crossings by efficient design of main roads and skidder tracks. Still others establish sediment control treatments such as gabions, sediment fences, straw bales, or wattles, and ditch-line diversions in order to trap sediment onsite and minimize sediment runoff into streams at road crossings (New Zealand Forest Owners Association 2012, USDA Forest Service 2012). Still other BMPs exist for wood-processing facilities like sawmills and pulp and paper manufacturing plants as well as power transmission lines pipelines associated with bioenergy production facilities. Not all BMPs are necessarily accepted by all stakeholder groups or land managers as providing the desired environmental outcome for all sites.

The term BMP can be misleading if "Best" is understood to imply that better practices do not exist. There is always the possibility that new scientific knowledge and practical experience can be used to improve a currently accepted BMP or create new ones. Best Management Practices are effective, practical, structural or non-structural methods which prevent or reduce environmental degradation. In the

forestry and bioenergy context, they are used most commonly to protect water resources, and are usually developed to achieve a balance between environmental protection and the production of woody and herbaceous crops within natural and economic limitations (Aust et al. 1996).
Codes of Practice are collections of BMPs that are, if compulsory, prescribed in regulations and guidelines, and therefore require compliance. The BMPs embodied in Codes of Practice may be applicable to all or any combination of target groups, e.g., forestry operations on public and private land, and in small or large areas. Forest practices in many developed countries tend to be regulated in this manner. However, BMPs and Codes of Practice can also be voluntarily developed and adopted, which is more common in the agricultural sector (Logan 1993). BMPs can be general in nature or tailored to specific activities such as bioenergy production. General BMP guidelines are designed to sustain forest or agricultural resources such as cultural resources, soil productivity, riparian areas, visual quality, water quality, wetlands, and wildlife habitat. They are applicable to activities such as road construction and maintenance, harvesting, site preparation, pesticide use, reforestation, stand tending and thinning, fire management, and recreation management. Specific BMPs are activity-specific guidelines which are unique to an activity and designed to work with general guidelines to provide an integrated framework needed to ensure forest or agricultural resource sustainability.

Rationale for the Use of Best Management Practices

The use of BMPs in land management for bioenergy objectives requires additional effort and expense to follow guidelines and achieve objectives (Richardson et al. 2002). This fact logically raises a number of questions for land managers: "Why are we doing this?," "What is the advantage for my farm/forest?," "Who is making me incorporate these practices?," "What is the economic value?," etc. There are many answers that are obvious in the short-term and long-term. These include but are not limited to:

- State and National environmental regulations,
- Agency regulations and goals,
- Private land management objectives,
- Land manager desires to seek certification for marketing purposes,
- Corporate/individual commitment to sustainability goals,
- Recognition of the productivity benefits of BMPs,
- Desire to integrate multiple ecosystem services into land management,
- Cultural and religious legacy,
- Personal conservation heritage,
- Desires to emulate successful examples of good natural resources management.

For forest bioenergy programs, BMPs are essential to ensure long-term productivity and sustainability because management of forests for bioenergy objectives often involves intensification of forest access, harvesting, and disturbance (Dyck and Bow 1992, Richardson et al. 2002). Since many forest bioenergy producers seek certification of sustainability through the Forest Stewardship Council (FSC), the Program for the Endorsement of Forest Certification (PEFC), or other certification systems, adoption and use of BMPs is a necessity (Janowiak and Webster 2010, Scarlat and Dallemond 2011). This paper provides an overview of BMPs used in bioenergy feedstock production (Buford et al. 2011). It discusses development of BMPs, types of BMPs, and examples of their implementation (Neary et al. 2010). While most forestry BMPs are directly applicable to forest bioenergy programs, there are some aspects of the forest bioenergy life cycle that are different from production forestry and require unique BMPs. These include slash harvesting, woody biomass storage, power generation, powerline right-of-way maintenance, and ash recycling. Agriculture has its own set of BMPs, many of which are common to forestry ones. However, the intensity of agriculture activities necessitates a unique set of BMPs tied to the frequency and degree of land disturbance activities.

Summary

The report that summarizes forestry and agriculture BMPs in the context of multi-feedstock bioenergy programs was published by the International Energy Agency, Bioenergy Task 43 (Neary 2014). Since BMP usage and development is an iterative process, evolution of individual BMPs to deal with site-specific and feedstock-specific issues is to be expected. Use of BMPs requires on-going assessment, monitoring, and refinement to craft these practices to best suit local conditions. Best Management Practices ensure that forest and agricultural bioenergy programs can be a sustainable part of land management and renewable energy production.

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