Sustainability Indicators for Woody Biomass Harvesting

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Summary. Bioenergy production has significantly increased in the last decade and the President's call to substitute one-fifth of gasoline consumption in the next decade is expected to further this surge. This surge includes unleashing cellulosic ethanol produced from wood and plant residues. However, concerns are being raised on whether or not cellulosic ethanol production and conversion is economically viable, socio-culturally tenable, and ecologically sustainable. In order to avoid potential pitfalls and ensure the sustainability of wood based biofuel systems a set of indicators needs to be developed. Some of these indicators can be based on similar standards on forestry certification, energy balances, greenhouse gas emission reductions and codes and guidelines for biomass harvesting. This paper discusses sustainability indicators encompassing ecological, economic, and social principle for harvesting woody biomass that is used to produce bioenergy. A suite of approaches for implementation of a woody biomass certification system and the extent to which existing standards and certification systems reflect these indicators is elaborated. A way forward to promote these operational strategies is also suggested.

Key words. *Woody biomass, certification, standards, sustainability criteria, sustainable forest management, biofuels*

Introduction

Similar to many other parts of the world, energy demand in the United States (U.S.) far exceeds energy supply, paving way for increased focus towards augmenting energy sources such as bioenergy. The quest for bioenergy is reflected in the Energy Independence and Security Act (EISA) of 2007 targeting 36 billion gallons of biofuels by 2022. Out of this 21 billion gallons are designated from cellulosic sources alone.

Forestlands, an important source of cellulosic biofuels feedstock, are expected to play an important role in meeting the national biofuels target. Forestlands occupy about 749 million acres of land i.e. about 33% of the total geographical area of the U.S. and can contribute significantly towards ensuring supplies of woody biomass for bioenergy. Perlack et al. (2005), estimated that over 1300 million dry tons (MDT) per year of biomass is potentially available for biofuels of which over 368 MDT of biomass can be produced or collected from U.S. forests related sources. This is about 260 percent of current estimated woody

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biomass[6] use of 142 million dry tons. About 80 percent of this forest based biomass is estimated to come from private forest lands, mostly from eastern U.S. The bulk of biomass could be from perennial crops, while additional 17-28 million tons can be through biomass from Conservation Reserve Program land.

Historically bioenergy products came through wood that could not be economically used for production of lumber, pulp, paper and other timber products. This has been changing with increased use of wood for energy purpose. There are situations where in biomass for energy is the only product harvested from forest (Mead et al. 2008). The whole supply chain of bioenergy from forest stand to consumer is important for establishing sustainability, however, in this paper we focus on sustainability aspects of forest biomass harvesting[7] for bioenergy use. The aim is: (i) to develop indicators for woody biomass harvesting that are ecologically tenable, socially acceptable and economically feasible and (ii) to investigate ways of operationalizing these indicators.

The paper is structured as follows: the need for woody biomass harvesting indicators in the future country energy system is discussed in Section 2. Section 3 suggests how sustainability criteria and indicators in existing certification systems can be retained/modified for woody biomass harvesting. The strategies that can be used to operationalize these indicators are discussed in section 4. Section 5 provides conclusions and makes suggestion for future.

Why Woody Biomass Sustainability Indicators?

Wood-based bioenergy can provide a myriad of social benefits such as improving returns from forestlands and providing “green jobs”. Utilizing small diameter trees for energy can also improve the health and vitality of forests by reducing chances of pest attacks and catastrophic wildfires. However, unabated and unplanned diversion of forest stands for bioenergy can lead to negative consequences for local people and flora and fauna, depletion of soil nutrients (Burger, 2002), adverse impacts on water quality (Neary, 2002), and long term soil productivity (MFRC, 2007), and harmful climatic impact due to an increase in Green House Gas (GHG) emissions through large scale land use changes (Fargione et al. 2008; Searchinger et al. 2008). Countries such as the Netherlands and the United Kingdom have recognized that if sustainability concerns are not addressed, bioenergy production and utilization can be a threat to the environment and economy. The Dutch Government even set up a commission to develop sustainability criteria for bioenergy production and to incorporate them into national renewable energy policies.

Various institutions and certification groups like American Tree Farm System (ATFS), Sustainable Forestry Initiatives (SFI)[8], Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification schemes (PEFC), Fairtrade Labelling Organizations International (FLO), International

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[6] In this paper we consider all vegetation including logging slash, limbs, tops, small-diameter trees, and any tree not sold as saw timber, poles or higher value products as woody biomass. These can come from trees and woody plants in forests, rangelands or woodlands.

[7] Forest biomass harvesting includes processes required to deliver tree tops, small diameter trees, slash, limbs and cull logs product to roadside. This includes cutting, felling, piling, chipping, and transporting from the site to the roadside landing (i.e., skidding or forwarding), and in some cases merchandizing and transporting to biomass processors.

[8] SFI, ATFS are regional schemes endorsed by the Programme for the Endorsement of Forest certification (PEFC) that currently supports more than two dozen independent certification schemes

federation of organic agriculture movements (IFOAM), Roundtable on Sustainable Palm Oil (RSPO), have not come out with standards for wood based bioenergy till date.[9] Specific bioenergy labels such as Green Gold Label (GGL) and Eugene have also been developed during last few years.

Sustainability criteria and indicators have also been suggested in works such as Moret et al. (2006) for Brazialian forum of NGOs, Fritsche et al (2006), for World Wildlife Federation Germany, Lewandowski and Faiij (2006), and Van Dam et al. (2008), on sustainable bioenergy trade, and Roundtable on Sustainable Biofuels (RSB) principles and criteria (RSB, 2008). However, existing and suggested certification systems do not have specific standards for woody biomass harvest for bioenergy. The present paper attempts to come out with some sustainability indicators that can be used as starting point for ensuring that forest biomass harvesting is undertaken in a sustainable manner.

Sustainability of Woody Biomass Production and Harvesting

A set of forest biomass sustainability indicators (See Table 1.1.) has been developed based on the review and analysis of existing and suggested certification systems, states biomass harvest guidelines and current scientific literature that discuss concerns regarding forest management practices in general and forest biomass based energy in particular. The indicators have been developed for three sets of criteria namely: ecological, social and economic.[10]

Table 1.1 Suggested Sustainability criteria and indicators for woody biomass harvest

Criteria	Attributes	Indicators
Ecological	***I. Silviculture operation and management***	1. Biomass harvest should not damage forest health 2. Harvest undertaken in season that minimizes ecosystem damage 3. Minimal harvesting in riparian zone 4. Effective road and infrastructure developed for biomass harvest 5. Biomass harvesting is not frequently undertaken (longer rotation period for biomass harvest is preferred) 6. Rate of harvest does not exceed level that can be sustained 7. Improvement in conditions for reforestation 8. No overharvesting takes place 9. Vehicles and machinery used in harvest should cause minimal damage to ecosystem 10. Vehicle re-entry at site during harvesting is minimized 11. Continuous supply of woody biomass is emphasized in harvest plans 12. Supply security for the biomass consumer (processor)
	II. Land use change and green house	13. Natural forests older than 1995 have not been converted to energy plantations Old growth or native multi-cropped forests are not converted to mono-cropped ones

[9] FSC is currently revising its guidelines to suit bioenergy harvesting and use.

[10] Other aspects such as transparency, chain of custody tracking, monitoring and inspection, compliance with law and treaties have not been discussed in this paper.

	gas reduction	14. Old growth or native multi-cropped forests are not converted to mono-cropped ones 15. Forest biomass is sourced from forests that meet set of sustainability indicators (such as the one suggested here) 16. Carbon accounting should calculate net change in above ground carbon, in soil carbon stocks as well as carbon sequestered in wood products made from harvested wood 17. LCA of forest biomass based energy production and use should reduce GHG emission by at least by 60 percent as compared to fossil fuels. The baseline for comparison used for GHG reduction should be 2005 level. 18. Indirect land use change effects are included in LCA 19. Written records for harvesting activity undertaken is maintained 20. Chain of custody trace of the product is possible
	III. Biodiversity conservation	21. One third of harvest residue are left at site 22. Snags and den trees should be left at site (in case den trees are not present one large tree and 1/5 acre of tree surrounding it are left at site) 23. Critical wildlife breeding season are avoided in harvesting 24. Gradual transition from heavy harvest areas to light harvest areas. 25. Careful/no use of exotic species 26. Preservation of genetic and ecosystem diversity 27. No logging activities in protected or critical wildlife areas 28. Preserve high conservation value forests
	IV. Soil quality and erosion	29. Minimize soil compaction 30. No harvesting in area having steep slope (>35 degree) 31. Minimize nutrient loss from soils 32. Apply agrochemicals only when necessary 33. Apply management plans that consider integrated pest management 34. Minimize top soil damage during harvesting, road construction and mechanical disturbances 35. Limit permanent road and landings area (3%) and total area under harvesting infrastructure (such as access roads and skid trails) to 10% to minimize soil damage. 36. Restrict biomass harvest in shallow soils (where bedrock is within 20 inch to surface) 37. Minimize biomass harvest in nutrient poor soils 38. Having post harvest conditions that are conducive to maintaining site productivity 39. Do not undertake below ground biomass removal 40. Restrict forest floor, litter layer and root systems removal during biomass harvest.
	V. Water quality and supply	41. Minimize fertilizer or sediment increase 42. Water table is improved or maintained 43. Hydrological cycle of the area is not disturbed 44. No depletion of ground water resources 45. Protectof quality and supply of freshwater resources

		46. No pesticide or chemical residues in the water 47. Compliance with state BMP guidelines 48. Avoid harvest of additional biomass from within riparian management zones over and above the tops and limbs of trees.
Economic	***VI. Profitability***	49. The bioenergy venture is profitable for landowners, contractors as well as processors. 50. Profits is not completely dependent on government support 51. There is sustained funding for running the operation, i.e. there is no liquidity (cash) crunch 52. A long term profitability plan is put in place
	VII. Community benefits	53. Community benefits are prioritized 54. More than half the money generated remains in the local economy 55. Energy supply in the biomass production region does not suffer from biomass trading 56. Biomass harvesting activities contributes to strengthening and diversifying the local economy 57. Lowers income inequality 58. Local people are employed rather than outsiders 59. Skill development of local workforce is emphasized 60. Ratio of skilled to unskilled local people employed increases with time
Social	***VIII. Participatory democracy***	61. All stakeholder have access to critical information 62. Continuous stakeholder engagement through discussions and meeting 63. Establishment of a communication systems that facilitates the exchange of information
	IX. Conserve community and human rights	64. Community traditions are respected 65. Local community rights are not violated 66. Indigenous people rights are respected 67. No discrimination on basis of age, ethnicity, sex or color; 68. Protection and promotion of human health; 69. Safe and healthy work environment, with sufficient machine and body protection; 70. Availability of document routines and instructions to prevent and handle possible near-accidents; 71. Human rights are respected; 72. Elimination of child labor and no violation of child rights.

The indicators by definition tend to provide concrete and measurable information. However, no "*one size fit all*" indicators can be suggested for forests having diversity in terms of sites, species, and ownership objectives. The intent of these indicators is to prioritize the operations in terms of what issues are of foremost importance and where care needs to be taken to ensure sustainability. For example, complying with indicators like "*absolutely no impact on forest soils during biomass harvesting operations*", will be quite difficult to meet rather than the one saying "*minimal impact on soil nutrient level during biomass*

harvesting." However, interpretation about what this "minimal impact" should be is difficult to standardize and there are hardly any indicators that quantify deviations in terms of percentage nutrient loss. Indicators for many issues such as those for indirect land use change effects need much more research, consequently indicators developed for these are suggestive in nature. The indicators suggested here can be adapted based on the feedbacks gathered through field based evidence. Subsequent subsections briefly discuss the reason behind indicators so developed.

Ecological Criteria

Silviculture operations and management

In light of surge in bioenergy production from forestry feedstocks many states acknowledge that current standards or guidelines are inadequate, and are in the process of creating new guidelines (or improving on existing ones) for biomass harvesting. One of the reasons for this inadequacy is that most of harvesting guidelines are geared towards regulating timber harvests for wood products, rather than woody biomass production (Abbas, 2007). The woody biomass harvest generally involves removal of more woody material under typical timber harvest as biomass harvesting can be done along with timber harvests. States like Minnesota, Missouri, and Pennsylvania have already come out with guidelines for sustainable biomass harvesting, while some other states like Wisconsin, Maine and Michigan are currently working towards developing such guidelines. Most of the southern states of U.S., having more than 214 million acres of forest land (Wear and Greis, 2002) and meeting 60% of forest products needs in the country, are currently relying just on Best Management Practice (BMP) guidelines for forestry.

Existing state forestry best management practices (BMP) and guidelines argue for silvicultural interventions according to commonly accepted practices relating to timber harvest and their sustained yield. But, there are hardly any standards in existing certification systems categorically set to reflect how, when or where woody biomass removals should take place. Some of the issues that need to be considered during biomass harvest include: rotation length, regeneration potential, natural or artificial nature of stand, thinning, harvesting frequency, pruning, salvage, sustained yield and harvest, removal of lops and tops, and use of vehicle and machinery for undertaking these operations. The season of biomass harvest is also important as this can potentially affect soils, water quality, biodiversity, and forest regeneration. For example in Minnesota, it is suggested that all biomass harvest should be undertaken before June. This helps in maintaining forest health as harvesting during late spring or summer, and removing slash and logs from abandoned piles helps in controlling bark beetle populations (MFRC, 2007).

Though, the biomass indicators can be used in conjunction with existing forest guidelines/indicators, there are cases where existing ones need to be modified. For example, unlike timber harvest, 100 percent biomass harvest removal can severely impact regeneration and biodiversity. The machinery use and creation of roads and infrastructure might also be different than those for traditional timber harvest as biomass harvest can take place in forest areas where timber harvest is traditionally not undertaken resulting in new roads or pathways. Frequency of harvest is also much more than traditional harvest, and second operation or harvest residues collection exercise during biomass harvest generally results in vehicle re-entry at site.

Another aspect that gains significance is the "localized" nature of bioenergy industry, as high transportation cost limits the feedstock movement beyond certain distance. Process of increasing the

energy density of woody biomass close to harvesting site through process of reducing residues to small pieces with a chipper, grinder or a flail, or by compacting into bundles can slightly increase this transportation distance. But, there remains a chance of overharvesting or unsustainable harvesting to meet the processing demands due to localized nature. During biomass harvesting care must be taken that seed sources of species needed for long-term management objectives are retained during intermediate silvilcultural operations. The high grading of stands generally observed during timber harvesting can also be done away with during biomass harvest. For maintaining health and vitality of forests longer rotation length for biomass harvest is preferred as young trees have higher proportions of nutrient-rich biomass compared to older ones.

It is also imperative that silvicultural criteria should be formulated based on the understanding that local (site) level resource management priorities are based on a plethora of intertwining factors related to management priorities, forest resource needs, site potential, existing regulation and policies, species being harvested for biomass, and financial returns at any given period of time. Thus, we need to have some overarching silvicultural standards but flexibility should be there to accommodate local conditions. Suggested silvicultural standards for this criterion are outlined as indicator 1 to 12 in table 1.1.

Land use change and Green house gas reduction

It is increasingly being recognized that environmental effects of bioenergy production are linked to land use and land cover change. If one assumes that energy crops do not cause land use changes, the life cycle analysis(LCA)[11] of different biofuel options (including woody biomass) leads to potentially substantial Green House Gas (GHG) reduction benefits (Von Blottnitz and Curran, 2006). Wang et al. (2007), through LCA, outline that corn ethanol reduces emissions by 19-52%, while cellulosic ethanol can decrease emissions by as much as 86%. Many authors argue that using wood instead of fossil fuel for energy can potentially reduce GHG emissions (Eriksson et al. 2007; Gustavsson et al. 2007; Birdsey et al. 2006). However, Searchinger et al. (2008), argue that life cycle studies have failed to factor in indirect land use change effect, such as carbon storage and sequestration sacrificed by diverting land from its existing uses and found that using U.S. croplands or forestlands for biofuels results in adverse land use effects elsewhere and thus harms the environment rather than helping it. The question for overall GHG balance of different bioenergy pathways thus, need to be evaluated in terms of whether these can lead to indirect land use change from carbon rich land cover types (e.g. virgin grasslands or forests) to energy crops (Petersen, 2008).

Direct land use change effect is incorporated by some European certifiers of green electricity such as Eugene (Europe); Bra Miljoval (Sweden); Ok-Power (Germany); and Naturemade Star (Switzerland), who emphasize that biomass used for energy must come from FSC certified forests. Some other certifiers have come out with their own indicators to incorporate land use change issues. Milieukeur (Netherlands) and Green Power (Australia) insist that biomass should not be sourced from plantations that clear, or have cleared after 1990 existing old growth or native forests. However, certifiers from North America such as

[11] Lifecycle analysis measures the emissions and energy consumption of the entire production process fin term of inputs and machinery used for the production of biomass to industrial conversion processes to final combustion of the fuel

Green-e (U.S.) and Environmental choice (Canada) do not consider even land use change issue in their electricity certification initiative.

Almost all the listed certification systems (except RSPO) lack GHG specific indicators. The RSPO indicator as well as recent suggestions on bioenergy certification (Lewandowski and Faaij, 2006; Van Dam et al. 2008; Richardson et al. 2005) suggest indicators which insist on net GHG emission reduction but do not elaborate "how much this reduction" should be. EISA specifies that 60 percent[12] reduction in GHG emissions from use of advanced biofuels (such as cellulosic biofuels) should take place as compared to gasoline or diesel sold or distributed as transportation fuel in 2005. It also insists that LCA should not only include direct emissions but also significant indirect emissions from processes such as land use changes. Fritsche et al. (2006) suggest that this reduction should be much higher, 67% reduction in GHG emissions from (unprocessed) crude oil combustion, and insist that bioenergy conversion should also demonstrate 67% conversion efficiency.

The LCA for emission include all stages from feedstock production till the use of finished fuel by the final consumer. The emission reduction from feedstock production and harvesting plays a significant part in this calculation and sustainability indicators should ensure that these processes, at the minimum, are able to reduce the emissions at the level outlined for the whole process. The amount of GHG emission reduction and how is this calculated is also a matter of much debate. Some of the issues that need to be resolved for developing implementable standards are : reference(baseline) to be used for GHG reduction; emission calculation based on consistent (standard) approach to LCA so that comparative analysis is possible; what GHG gases should be included in calculations (CO2, N2O and CH4 or other gases are also included); what should be the methodology that can be used measure the indirect impacts of biofuels production due to land use change; and what should be timescale of analysis for emission estimates related to land use change.

Direct land use change effects need to be minimized and a cut-off year (such as 1995) should be established, to ensure that if natural forest are cut to raise energy crops after this year, it should not be termed sustainable. Further, standards relating to direct land use effects which incorporates net changes in above ground carbon, in soil carbon stocks and in carbon sequestration in products (such as products made from harvested wood) should also be developed. The LCA and GHG accounting for each forest biomass producer site includes quite a bit of transaction costs and the challenge is to develop standards for the quality of acceptable default values and measurements, for typical forest biomass supply chains in different regions to help small producers comply with these standards (RSB, 2008).

In chain of custody tracking, it is difficult to keep track for forest residues and one of the way is that broader energy certification schemes can assess forest bioenergy sustainability at various points along the supply chain process, including feedstock harvesting, transportation, conversion and waste disposal (Mayfield et al. 2007). Thus, the supply chain trace of woody biomass feedstock is important as it helps in establishing whether the particular product originated from forests that are sustainably managed or not.

[12] If it is determined that that generally such reduction is not commercially feasible using a variety of feedstocks, technologies, and processes to meet the applicable reduction then the specified 60 percent reduction in greenhouse gas emissions from cellulosic biofuels may not be adjusted below 50 percent.

However, insisting on procuring biomass only from FSC certified forests is not deemed appropriate as FSC might not be the best certification system for U.S. industrial or family forests. FSC imposes stringent environmental standards (such as reserve area mandates) and social obligations than other certifiers such as SFI. For example, traditional clear-cut harvesting practices being followed in Oregon or Washington acts as bottleneck for FSC certification, while SFI can certify these forests if other standards are met. Further, the FSC seem more attuned towards public forest certification (FSC has certified ~25million hectare of forest in Canada where forests are largely under public ownership (FSC, 2008a)) and in U.S. where ~58% of forests are privately owned, FSC might impede the growth of forest biofuels industry.

FSC indicators are also being criticized for increasing the acceptance of large scale monocultures largely due to its principle 10 dealing with plantations. Apart from principle 10, the FSC criteria 6.10 which suggests that "*certification may be allowed in circumstances where sufficient evidence is submitted to the certification body that the manager/owner is not responsible directly or indirectly of such conversion*" is also being criticized. In light of such concerns FSC is currently undertaking a review of principle 10 dealing with plantations. Even the scale of FSC certification in U.S. does not favor the criteria of all biomass coming from FSC certified forests as currently 10.31 mha of forests in U.S. are FSC certified through 106 certificates (FSC, 2008b), ~50% of which are in just three states of Minnesota, Michigan and Wisconsin (Herrick et al. 2008).

Sourcing biomass from forests certified by existing certification system will fail to address biomass specific issues and concerns as they are. A better approach should be insisting on biomass from forests that meet a set of biomass sustainability standards. The forest management plan of biomass supplier and its implementation can help assess whether the feedstock supplier meets these sustainability standards or not. The indicators developed under this criterion are listed in Table 1.1 (indicators 13 to 20) . Here it needs to be clarified that these indicators need further work to achieve more specific quantitative (and measurable) indicators.

Biodiversity conservation

The impact of biomass removal on biodiversity is difficult to generalize as it depends on particular specie requirements (Evans, 2008). Many researchers argue that it adversely affects wildlife through processes such as litter and deadwood removal (Amacher et al. 2008; Butts and Mccomb, 2000; Gunnarsson et al. 2004), while some others like Bies (2006), argue that if biomass removal is made part of restoration projects it can potentially benefit wildlife rather than harming them. Biomass removals from managed forests in some Scandinavian countries has already been identified as one of the main reasons for decline in many forest species (Berg et al. 1994; Essen et al. 1997).

Biodiversity might be threatened in different ways due to biomass harvest. One is habitat fragmentation and adverse impact on wildlife corridors due to increased access and intensity of harvest. Another is loss of habitat, i.e. dead wood removal or conversion of natural or mixed forests into energy plantations. There is also chance of insects or other species that colonize wood getting trapped in wood burnt for fuel. Further effect can be seen in term of the removal of logging residues, which change nutrient availability and cause loss of organic matter (Gunarsson et al. 2004; Astrom, 2005). Currently in U.S., only local assessments of potential biofuel production impact on wildlife have been evaluated (e.g., Christain et al. 1997; Murray et al. 2003). While these assessments have been useful in quantifying potential effects of

biofuels at local scales, regional and national assessments are needed for interpreting potential tradeoffs. Even though, studies to establish bioenergy-biodiversity linkage are limited, the existing certification schemes or forest management guidelines of different U.S. States have biodiversity criteria embedded in them. These deal largely with issues such as maintenance and enhancement of species, wildlife habitats, breeding seasons, preservation of rare and threatened species, control of exotic species, genetic diversity, sensitive sites disturbances, ecological corridors and unique habitats.

Along with existing criteria and indicators outlined in existing certification systems, some additional indicators are required for biomass harvests. One of them should emphasize that some harvest residues should be left at site to maintain habitat for small mammals, insects, reptiles, and amphibians. How much of these should be left will depend on the site specific conditions, though general guidelines can be formulated at the national level such as the one in Finland, where biomass removals have occurred for a longer time, recommendations are to retain 30% of harvest residue in stands to help maintain soil nutrient status and biodiversity (MFRC, 2007). Some states in U.S. in their biomass harvest guidelines insist on retaining different amount of residues at site, ranging from 10% (in Pennsylvania) to 33% (like Missouri and Minnesota).

For biodiversity conservation, one should also leave some snags and den trees at site. Provisions of how much of these should be left depend on site specific conditions and factors such as whether harvest is undertaken in heavily forested areas, riparian corridors, bottomlands, and tree species being harvested. In case den trees are not present, one might follow Missouri BMP manual suggestion of leaving at least 1/5 acre of trees in a group surrounding at least one large tree that could become a den tree for every 5 acres harvested.

Another indicator for conserving biodiversity should insist on having gradual transition from areas that are to be heavily harvested to areas that are to be lightly harvested to avoid hard-edge effect. The hard-edge might result in heavy concentration of wildlife in narrow areas and make them more vulnerable to predatory attacks. Developing special management regimes for sites from where biomass harvest is planned should also be considered. These special management regimes can aim for maintaining forest health and vitality, particularly conserving ecosystem functions and biodiversity Some of the indicators that focus on biodiversity during biomass harvesting are outlined in table 1.1(indicators 21 to 28).

Soil quality and erosion

Site clearing, bedding, burning, soil tillage, pruning, fertilizer application and weed control along with the machinery or vehicle movement during harvesting might affect forest soils in one way or other. Some of the major concerns of woody biomass harvest are soil compaction and rutting (Reijnders 2006; Burger, 2002); decreasing the amount of decaying wood on forest landscapes; changes in chemical and physical environment of soils (Astrom et al. 2005); increased use of agrochemicals (Fritsche et al. 2006; Raison and Rab, 2001; Van Dam et al. 2008); increased soil erosion (Raison and Rab, 2001; Burger, 2002; Fritsche et al. 2006; Raison et al. 2001: Mead et al. 2006);and nutrient loss by biomass removal (Evans, 2008; USFS, 2005; Johnon and Curtis, 2001; Mahendrappa et al. 2006; McIver and McNeil, 2006; Raison et al. 2001; and Burger, 2002).

Existing certification systems and forest harvesting guidelines of various states have indicators regarding soil conservation and maintenance These indicators suggest having forest practices that maintain or enhance environment including soils and focus on issues such as soil erosion and compaction, nutrient loss, agrochemicals, integrated pest management, minimize soil damage during harvesting, prohibiting exotic species and species that adversely impact soil nutrients or general site quality, and maintain post harvest conditions that are conducive to regeneration . These soil indicators need to be retained and should be supplemented with few indicators specific to biomass harvesting.

The biomass specific indicators should consider slope limits, infrastructure construction, and erosion reduction. Recent work by Fritsche et al. (2006), suggests having indicators that define maximum slope limit for bioenergy harvest. Missouri biomass harvesting manual also suggests limiting biomass harvesting in steep sloped areas to prevent erosion. Minnesota biomass guidelines specifically mention that no biomass harvest should take place from land having slope more than 35 degrees. The creation of harvesting infrastructure such as roads and damage caused by machinery to soils and existing vegetation adversely affects ecological conditions at the site. Specific indicators related to these activities need to be developed. One of the indicators that can be developed is the harvest area that can be occupied by harvesting infrastructure such as roads, skid trails and landings. Cue can be taken from Minnesota and Wisconsin biomass guidelines which insist that no more than 3% of the harvest area should be occupied by permanent roads and landings. Based on Missouri state manual recommendations, even if one includes temporary structures such as temporary access roads and skid trails, the total area under harvesting infrastructure should not exceed 10 percent of the total area. Apart from limiting the area, care must be taken that design of infrastructure such as skid trails and skid roads minimize damage by avoiding residual trees and take benefit of natural contours.

What is also required is that erosion preventing indicators should consider specific soil conditions such as depth of soils, nutrient conditions and regeneration potential. Biomass harvesting should be restricted in shallow and nutrient poor soils. Indicators that restrict harvesting in nutrient-poor soils or shallow soils are required. The shallow soil definition can be borrowed from Wisconsin draft BMP which considers shallow soils as soils where bedrock is within 20 inches of the surface. Apart from retaining some residues at the site, below ground biomass removal should be prohibited. Indicator restricting forest floor, litter layer and/or root systems removal as forest biomass is also required. Overall soil related safeguards should consider local level site specific management for soil. Suggested soil related indicators are outlined in table 1.1 (indicator 29 to 40).[13]

Hydrologic processes, water quality and supply

Bioenergy feedstocks should be produced and used in ways that maintain or improve the quality of environmental resources, including water resources. The balance between water and air can affect root respiration as well as nutrient and water uptake (McKee and Shoulders 1970, in Burger, 2002). Listed certification agencies call for efficient and productive water use for bioenergy systems and have indicators for reducing impact on surface and ground water quality and quantity, conservation of water bodies or drainage patterns. The forest guidelines and BMP in many U.S. states emphasize water quality

[13] Some indicators impacting soil sustainability such as use and re-entry of vehicles; leaving forest residue to replenish soil nutrients; related to forest roads and infrastructure have also been included under silvicultural operations indicators or biodiversity indicators.

and conservation of riparian zones (Sheppard, 2006). For example, Georgia BMP guidelines focus on practices that minimize wetland disturbance through avoiding direct damage to wetlands due to trafficking, drainage or filling. However, only few certification systems (like SFI) link the state BMP guidelines to their sustainability indicators.

The existing water related guideline/standard should be retained for biomass harvesting and few more added as activities like building roads and structures and tillage activities such as those for disking, bedding, and sub-soiling might impact water quality more in case of biomass harvest than conventional timber harvest. Increased machinery use might also impact water table as soil compaction might lead to impermeable soils. Removal of not only stems but also younger trees and lops and tops during biomass harvests decrease leaf surface resulting in decreased transpiration and interception. The re-entry at harvest sites also increases chances of sediment movement into wetlands through damaging erosion control features and rehabilitated infrastructure. Integrating BMPs in the existing standards and minimizing damage to the existing hydrological systems largely due to infrastructure and machinery use, thus, need to be emphasized for ensuring sustainability for biomass harvest. Indicators that can be used to safeguard surface and ground water quality and quantity during forest biomass harvesting are outlined in table 1.1 (indicators 41-48).

Economic Criteria

Profitability

One of the major challenges to energy production from woody biomass is its economics. Under current market conditions forest biomass is economically not feasible as compared to coal or oil. However, accounting non-market benefits in term of reducing the amount of GHG emitted; reducing site preparation cost in term of logging residues removal; stand improvement through trees left over by diameter-limited cutting; local employment and income creation can significantly enhance its viability.

Evans (2008), through review of 45 case studies of biomass projects in the country demonstrated that biomass removal projects are hardly an income source. Though, some managers have generated profits through strategies such as: combining multiple forest products in the removal; responding to fluctuating biomass markets; and developing supply chain through selling to established outlets. Since woody biomass is a high volume low value product, harvesting and transporting these is costly. Furthermore, harvesting technology is geared towards large diameter trees rather than small diameter woody crops. The profits are usually low in forest biomass sector (Stupak et al. 2007).

Currently, all certification schemes applied to individual, private or industrial ownerships assume that financial survival or failure can act as adequate indicator of the economic sustainability (Richardson et al. 2005). Some form of government support is necessary for forest biomass energy in the short run (Sims and Richards, 2006), and many policy supports like consumption incentives (fuel tax reductions), production incentives (tax incentives, direct subsidy, and loan guarantees), and mandatory consumption requirements are already in place (Childs and Gradley, 2007; World Bank, 2007). However, longer term profitability plans and cash flow requirements for long term sustainability are required (Lewandowski and Faaij, 2006; and Van Dam et al. 2008). RSB (2008,) criteria also emphasizes on implementing a business plan to achieve economic viability without government support (such as tariffs and production subsidies) in order to minimize long term risks.

The profitability indicators thus should have both short run and longer term outlook. The indicators should reflect pure economic profit with (or without) government incentives as well as bottom-line under scenarios accounting for non-market benefits of woody biomass based energy. The viability of the operations in terms of availability of short term liquidity and a longer term profitability plan need to be ensured. Some of the indicators that can be used to assess profitability are listed in table 1.1 (indicators 49 to 52).

Community benefits

Bioenergy development is expected to benefit the community through job creation, infusing income to local households and accruing tax revenues to local communities (Domac et al. 2005). Wood based bioenergy systems are also expected to contribute towards diversification of local economies and rural communities, in particular those traditionally depending on timber production (Bliss and Bailey, 2005). However, ownership of bioenergy plants by large agribusiness corporations has raised questions about who is gaining most from the growing bioenergy industry (Mazza, 2007). The large scale operation is also thought to be inconsistent with community capacity to participate, and regional power market dynamics (Temple, 2007).

Some certification systems (such as FSC and FLO) argue for enhancing economic well being of forest workers and local communities. FSC argues for giving opportunities for employment training and other services to community adjacent to forest area and suggest having forest management regime that strives to strengthen and diversify local economy. SFI standards on the other hand are more attuned towards industrial forests and completely lack community benefit standards. Recent work on certification by Moret et al. (2006), and Lewandowski and Faaij (2006), suggest that sharing of project benefits with local population is necessary. Fritsche et al. (2006), call for having income distribution standards while RSB (2008) emphasizes on following best practices that amongst other things aims for increases opportunities for local employment and livelihood, opportunities for the labor force in the off-season to ensure stable local communities, training of local communities and suggests undertaking social impact assessment of bioenergy projects.

Community benefit indicators should be ingrained in any bioenergy certification system. In situation where there is no or limited community interface (such as industrial forests), these indicators can be relaxed, however not having such indicators needs to be discouraged. Community benefits also ensure societal support and increases consumer acceptability of bioenergy which might enhance economic feasibility of the venture. Sustainability standards that dealing with poverty reduction, income distribution, and money flow in the local economy also need to emphasized. Some indicators that can possibly be used to assess community benefits are listed table 1.1 (indicators 53 to 60)

Social Criteria

Participatory democracy

Participation of stakeholders in decision making is essential for efficient functioning of woody biomass projects. People participation should not be just presence of effected parties in meetings, public hearings, seminars or other events, rather these should be undertaken through a process of engagement and consultation with the interested parties where early dissemination of information is undertaken by forest

feedstock supplier or biomass producer (Moret et al. 2006). All the existing certification systems are weak in terms of community involvement and participation and some such as SFI do not have such criteria at all. FSC calls for maintaining consultations with people and groups directly affected by management operations. However, this might not be of critical importance in case of private forests. The PEFC route of making best use of forest related experience of communities might be more applicable in case of private forests. Suggested indicators for participatory democracy are listed in table 1.1 (indicator 61 to 63).

Conserve community and human rights
Woody biomass project should respect community custom and traditions. Appreciation of community rights and local culture will not only help in garnering community support and goodwill but also help avoid potential conflicts. Existing certification systems such as FSC, PEFC and recent work by Moret et al. (2006), and Lewandowski and Faiij (2006), emphasize need for encouraging communication with local community to promote an awareness and understanding of biomass production and use and preserve their impact on local amenity and aesthetics. These also become important in light of FAO (2008) report, which points those socioeconomic conditions in large-scale biofuel plantations tend to be substandard. The guideline framed by International Labor Organization (ILO) on worker safety, child rights, human rights, wage, working hour and FSC standards on community rights can very well suffice for woody biomass based energy systems. Suggested indicators under this head are listed in table 1.1 (indicators 64 to 72).

Strategies to Operationalize Sustainability Indicators

Apart from voluntary certification system, there are other strategies that can be applied to enforce/operationalize sustainability criteria and indicator in U.S. These range from regulatory policy of government led action to voluntary enforcement by private parties.

Government led woody biomass standards: In order to ensure sustainable bioenergy production and utilization, government can come out with technical regulations and standards for bioenergy and other new energy products. These standards can vary from defining what constitutes biomass to the enforceable standards that can be set for GHG reduction. Cramer Commission (2007) suggests that this approach of government regulation for biomass minimum standards should generally be combined with incentives. Countries such as the United Kingdom and the Netherlands have already included certification into their policy mandates (Van Dam et al. 2008). Canada has an Environmental Choice Program (ECP) to recognize manufacturers and suppliers that produce environmentally preferable products and services which can potentially be extended for labeling forest based bioenergy products as well. Along with level federal EISA 2007 standards (such as the one related to emission reduction for different feedstocks), many states are also coming out with guidelines and road-maps to ensure bioenergy sustainability. For example California Energy Commission has a chapter on standards and best practices for sustainable feedstock supply (Tiangco et al. 2006). Here, it should be recognized that standards should be based on a market-based mechanism to reward sustainable forest management rather than increasing compliance cost of bioenergy certification.

Voluntary certification: Many private entities with an objective of earning goodwill from the society, or in order to reach out to environmentally conscious consumers, can opt for voluntary biomass certification. It is possible to have a voluntary certification scheme, in terms of an eco-label for biomass-related

products that meet higher standards than those mandated by law (WWI, 2006). This approach can give rise to private certifications such as GGL or Eugene in Europe. These voluntary systems emphasize the policy of product differentiation which assumes that consumers have higher value for certified products than non-certified ones

International partnership and commitments: At international level, group of governments, companies, and other interested parties are coming together at several Roundtables. One of the significant collaboration is the Global Bioenergy Partnership, (GBEP), an alliance of private sector associations, countries and international agencies[14] GBEP amongst others, promotes global policy dialogue and cooperation, aids policy making, facilitates information exchange and collaboration on field projects, promotes market development and works with other relevant stakeholders to develop science-based benchmarks and indicators for biofuel production and use. Another multi-stakeholder collaboration is the Roundtable on Sustainable Biofuels (RSB) which brings together farmers, companies, NGOs, experts, governments, and inter-governmental agencies working towards ensuring the sustainability of biofuels production and processing. RSB is striving for achieving global, multi-stakeholder consensus around the principles and criteria of sustainable biofuels production. Existing governments or organizations, through these collaborations can voluntarily move towards establishing schemes that ensure sustainability. International agreements between major bioenergy players for developing global bioenergy markets can accelerate acceptance of international standards, however, these processes tend to be quite time consuming. Many countries have domestic bioenergy constituency to safeguard which makes these international negotiations tedious. However, once agreement is reached these have overarching implications. In case of woody biomass standards, however, no one approach can be termed correct or sufficient. Rather, a multi-pronged strategy comprising of all the three approaches is suggested.

Conclusion and Way Ahead

Harvesting woody biomass resources for energy production has inherent benefits such as contributing towards climate change, energy security, creating jobs and helping local economy. However, some authors suggest that removal biomass residues might result in negative ecological impacts, increased emissions, changing land use, or have adverse impact on local businesses or society. The jury is still out in the research community regarding the benefits and threats posed by wood based energy. However, there is a general consensus towards having criteria and indicators to safeguard ecological, social, economic conditions within the bioenergy system.

Many states in the U.S. have accepted that current harvesting guidelines and BMPs need to be revised, and states like Wisconsin and Minnesota have already done it. In many other states revision process is not complete yet. Setting up good practice codes and integrating sustainability safeguards in forest harvesting guidelines are suggested for all states where woody biomass removal is taking place or is expected to take place in near future. A bioenergy monitoring/certification system supported by government standards and international agreements might allay sustainability concerns. A framework comprising of ecological, economic, and social indicators for the same are proposed herewith.

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[14] Canada, China, France, Germany, Italy (Chair), Japan, Mexico (Co-Chair), Russia, UK, USA, FAO, IEA, UNCTAD, UNDESA, UNDP, UNEP, UNIDO, UN Foundation, WCRE and EUBIA

The approach of having governmental regulation combined with a set of private standards can start out as collaborative sustainability schemes, setting minimum standards for cultivation and harvesting practices for producers, transportation and trade practices for suppliers, and production practices for processing units. The ideal approach would be having broad based roundtables with the stakeholder representatives and reaching a broad based agreement on sustainability criteria that can be suggested for policy formulations. Feedback from stakeholders such as local community representatives and NGOs is required based on the belief that communities can help in developing innovative, lasting partnerships and ecosystem stewardship.

Currently, RSB is in the process of developing global principles and criteria for sustainable biofuels production and has already come out with version zero. It is hosting a series of meetings, teleconferences, and online discussions to generate consensus around the same. In the next level they will be working on specific measurable indicators. GBEP also is working to develop a set of global science-based criteria and indicators coupled with field examples and best practices (including benchmarks) for bioenergy sustainability. It is also developing a methodological framework to assess GHG impacts by which the results of GHG lifecycle assessments could be compared on an equivalent and consistent basis across projects. It will be useful to capitalize on the efforts of RSB and GBEP for biomass harvesting as well.

Rather than having multitude of standards, existing certification systems such as FSC can be appropriately revised to incorporate woody biomass issues. Strictness, extent and level of detail of the indicators so developed, can be adapted to local conditions and priorities. The benchmarks can also be revisited to arrive at measurable quantitative indicators. These revisions should be based on feedback gathered through field evidence and stakeholder responses. It should also be emphasized that design of specific criteria and indicators as of now are not final or operational rather they should be treated as work in progress. Gathering evidence from the field as well as from the stakeholders regarding various concerns such as GHG balance, energy balance, sustainable forestry, biodiversity impact, job creation, equity issue, social impacts, transactions costs, transparency and fair trade is necessary. These evidences can act as policy inputs for the government and guiding principles for other stakeholders such as industry, landowners, foresters, biomass buyers, loggers and site preparation and reforestation contractors.

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