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A Review

Assessment of the Possible Effects of the Energy Crops Cultivation

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Abstract

Combining energy plants biomass conversion with developing carbon capture and storage could lead to long-term substantial removal of greenhouse gases from the atmosphere. Multiple drivers for bioenergy systems and their deployments in sustainable directions are emerging. The competitive feature of resources for plant biomass puts bioenergy under scrutiny before determining their real potential which is suitable. On the one hand, energy crops are an attractive substitute for fossil fuel sources, and on the other hand, its competing application of lands and water resources poses doubt on its potential. Energy crops are taken into many studies, because of the need to increase significantly the cultivated areas to meet the ambitious goals for renewable energies. The increase cultivation of energy crops can lead to severe negative impacts in ecosystem services. Therefore, there is a necessity for a better regulation of bioenergy production. In our paper, we analyze possible effects of energy crops production on soil, water, air, and habitat quality.

Keywords: air, habitat, quality, soil, water.

1. Introduction

A wide variety of energy crops is under development. These include short-rotation woody crops such as willow, hybrid poplars, silver maple, sweetgum, Jatropa and eucalyptus [21], and herbaceous perennials such as *Miscanthus*, switchgrass, cup plant and reed canary grass [5], [9], [12]. Energy crops can be considered to be a less intensive form of agriculture.

The energy crops considered here are perennials (herbaceous perennial grasses or short-rotation woody crops) and thus require less cultivation than conventional crops [15].

These energy crops also have the potential to be more efficient in the use of fertilizers. Overall, the inputs required by energy crops are generally less than for conventional agriculture for several reasons. They often have heavier and deeper rooting patterns [23], allowing the soil to be utilized to a greater depth for water and soil nutrients [16], and providing more time to intercept fertilizers or other agricultural chemicals as they migrate downward through the soil [11]. Heavier rooting puts more carbon into the soil [11] and so assists in creating more productive soil conditions such as enabling the slow continuous release of nutrients or the binding of chemicals so that they are not leached and also can improve soil biodiversity [10], [22]. Finally, energy crops are selected on the basis of their production of cellulosic biomass, which consumes less input energy per unit of energy stored than for many specialty plant components. Each of these

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crops will have different management regimens and differing impacts on soil, water, air, and habitat quality. These issues will be examined broadly here; detailed analysis of specific crop impacts are discussed in the literature. Much more research, development, and dedicated field trials are needed to understand the impacts of these energy crops. Experience gained in Europe and elsewhere in recent years may be useful in helping address these issues.

The U.S. Energy Information Adm. projected that by 2017, biomass is expected to be about twice as expensive as natural gas, slightly more expensive than nuclear power, and much less expensive than solar panels.

In another EIA study released, concerning the government's plan to implement a 25% renewable energy standard by 2025 [24], the agency assumed that 598 million tons of biomass would be available, accounting for 12% of the renewable energy in the plan [25].

The adoption of biomass-based of energy plants has been a slow but steady process. Between the years of 2002 and 2012 the production of these plants has increased 14% [14]. In the United States, alternative electricity-production sources on the whole generate about 13% of power; of this fraction, biomass contributes approximately 11% of the alternative production [19]. According to a study conducted in early 2012, of the 107 operating biomass plants in the United States, 85 have been cited by federal or state regulators for the violation of clean air or water standards laws over the past 5 years [14].

Despite harvesting, biomass crops may sequester carbon. For example, soil organic carbon has been observed to be greater in switchgrass stands than in cultivated cropland soil, especially at depths below 12 inches [26]. The grass sequesters the carbon in its increased root biomass. Typically, perennial crops sequester much more carbon than annual crops due to much greater non-harvested living biomass, both living and dead, built up over years, and much less soil disruption in cultivation.

The proposal that biomass is carbon-neutral put forward in the early 1990s has been superseded by more recent science that recognizes that mature, intact forests sequester carbon more effectively than cut-over areas. When a tree's carbon is released into the atmosphere in a single pulse, it contributes to climate change much more than woodland timber rotting slowly over decades. Current studies indicate that even after 50 years the forest has not recovered to its initial carbon storage and the optimal strategy is likely to be protection of the standing forest [13, 8, 17].

The environmental impacts of the energy crops are likely to be mixed, however, compared with continuing the land under arable with annual crops, it is considered to be a low environmental impact.

1. Energy Crops and Soil Quality

The impact of energy crops on soil quality depends on the energy crop, the soil, the climate, the land use it is replacing, and many other factors [21]. Extensive removal of biomass residues from energy cropland for use as biofuel or feedstock can reduce soil organic matter levels and associated soil quality. Some high-productivity energy crops such as certain herbaceous perennials can, however, provide a net increase to soil organic content relative to row cropping due to their heavy rooting alone [12, 18]. Energy crops with limited tillage and which return large quantities of organic matter (leaf litter) to the soil can improve soil quality compared with those that rely on frequent tillage or complete removal of crop residues. Such a protective layer of vegetative cover crops helps to provide shading, maintain soil moisture content, prevent erosion, and may offer other environmental services. Use of heavy equipment for preparing the soil, or for planting, maintaining, or harvesting the energy crop must be done cautiously to avoid the compaction of the soil or otherwise damaging the soil structure. For energy crops, this is primarily of concern during establishment [11] and harvesting on soils that are heavy and/or wet. Soil chemical properties as nutrient balance and acidity can be more easily managed than soil physical properties, but may nevertheless require a rigorous program of soil testing and specific additions of fertilizer, lime, and other inputs according to the selected energy crop. Preliminary results from studies elsewhere (India, Virginia, Minnesota) suggest that acidity or alkalinity is buffered and soil structure is improved where herbaceous perennials and short rotation woody crops are in production compared with conventional agricultural practices [11]. This is mainly due to increased organic matter content in the soil. A minimum data set of important soil properties physical, chemical, and biological should be developed for biomass production systems. This data set could then be used to follow changes in lands used for bioenergy crops. It is much more important to follow changes over time than to measure a particular parameter, such as organic matter content, a single time. Similar data sets could be developed for surface and groundwater resources and for habitat. This minimum data set could be developed in conjunction with extensive and carefully designed field trials.

2. Energy crops and water quality

Energy crops may affect water quality either positively or negatively, depending on the land use they displace, the specific impact examined, and the way they are managed. With good management they may significantly reduce surface waters from agricultural practices pollution, with attendant benefits for water quality and fish habitat [2]. With sustainable management, they could increase the runoff of sediment fertilizers, or pesticides into streams. Agricultural practices for perennial energy crops have an establishment phase; therefore they may help control the contamination of groundwater and offer a tool not previously available to help deal with some of the water quality issues.

Nitrogen in some form is needed for any crop, including energy crops. To attain high productivity, inputs like nitrogen, other agricultural chemicals and water supplies are needed to enter in many areas. Nitrogen (in the form of nitrate) and, in some cases, pesticides and herbicides are the most frequent contaminants of groundwater [1]. Nitrates move readily through the soil and can quickly reach groundwater unless first taken up by plant roots and incorporated in plant growth or by microbes feeding on plant residues. Energy crops can have significantly deeper and heavier rooting patterns than conventional agricultural crops, allowing greater uptake of nitrogen and other agricultural chemicals before they can run offsite. Root zones for many conventional agricultural crops are less than 0.3 meters. Effective rooting depths vary from about 0.3 to 1 m for some herbaceous perennials and 0.6 to 2 m for some woody crops [20]. The probability that chemicals can leach below these levels depends heavily on: the season because root uptake is low during the winter for many crops; the soil type and condition; the amount of rainfall; how heavily the chemicals are applied; the vigor and amount of energy crop. Newly planted or harvested crops have little ability to absorb large quantities of chemicals, however useful they might be; the extent of soil microbial activity; and other factors.

Energy crops may also require less nitrogen fertilizer than conventional agricultural crops. Extensive research on these and related issues for short-rotation woody crops are now in progress, but there is little data for most herbaceous perennials. Results to date indicate a high degree of nitrogen uptake and cycling except when high levels of nitrogen are added during the first year of crop growth [11, 16, 23]. Sediment, phosphorus, pesticides, and herbicides are the primary contaminants of runoff. Phosphorus is strongly bound to the soil and is readily taken up by soil microbes. Consequently, there is little migration of phosphorus to groundwater, but erosion can carry large amounts of phosphorus with it. Runoff of phosphorus to surface waters can cause eutrophication of these waters with all the attendant problems. Energy crops can potentially reduce the problem of soil and chemical runoff by lowering the requirements for these inputs compared with conventional crops [20], by controlling and 1imiting erosion and runoff, and/or by serving as filter strips to limit runoff from agricultural lands. The extent to which this potential is realized depends on the previous use of the land, how the energy crop is established and maintained, the soil type and slope, and other factors.

Nonfertilizer agricultural chemicals such as herbicides, fungicides, and insecticides can also move into groundwater or surface waters; energy crops are expected to use less of these chemicals than is conventional agriculture. The extent to which a chemical is lost depends on many factors, including: possible misapplication of the chemical, such as spray drift to surface waters during aerial application; runoff during heavy rainfall closely following application of the chemical during planting, when erosion and runoff are most likely; the type of chemical and the strength of its binding to the soil and plants; how much is applied; how quickly it decomposes; the topography; the type of crop and how it is managed (no-till versus conventional row crops); and other factors [3].

3. Energy crops and air quality

Energy crops can have an impact on air quality in a variety of ways, again depending on the particular energy crop, the land use it is replacing, and how it is managed. Compared with annual row crops, herbaceous perennials and short rotation woody crops are likely to reduce wind-blown dust and tillage dust (except during establishment). Besides the fact that the use of agricultural chemicals and diesel powered equipment for preparing the soil and for planting and maintaining the crop are reduced, in many cases may increase the tools for harvesting and transport. Herbaceous perennials and short rotation woody crops are likely to increase all of these emissions compared with pasture and Conservation Reserve Program lands. Energy crops may also affect the emission of hydrocarbons from growing plants. Finally, energy crops take up carbon dioxide from the atmosphere and can sequester the carbon in the plant biomass and in the soil [6]. The net cost and benefit of these changes in emissions in producing energy crops must be measured against the changes in emissions when they are used as a substitute for fossil fuels for transport, electricity, or direct combustion for heat applications considering the ambient air conditions in the locality affected by the emissions and total greenhouse gas emissions.

Dust generated during tillage nominally 6 kg/ha of PM-10 (particulates with a diameter of l0 microns or less) for each pass through a bare field should also be reduced, as most energy crops will be perennials, replanted every 15 to 20 years. This is in contrast to the annual planting and maintenance of many conventional agricultural crops [4].

One big problem nowadays is burning the crop residues on site for cleaning the arable lands of organic material or pests and diseases. These practices contribute to greenhouse gases [3]. In some cases, however, the creation of a market for bioenergy may make it sufficiently attractive for farmers to collect residues and take them to market rather than burn them on site. Burning these residues in a properly designed and operating boiler, furnace or for gas produces much fewer emissions than field burning. Use of agricultural chemicals and diesel fuel and their corresponding emissions will increase as idle or abandoned cropland is shifted over to energy crops. The intensity with which chemicals and fuels are used will, however, vary from conventional agricultural crops [6]. Use of fertilizers, pesticides, herbicides, and fungicides may be less than conventional crops, depending on the particular energy crop grown and what it is being compared with.

4. Energy crops and habitat

Wildlife has been broadly affected by agricultural activities. The most widespread problems are a result of expanding cropping and grazing into wildlife habitats, overgrazing riparian areas, and agricultural activities that contaminate aquatic habitats. Carefully designed and implemented, energy crops may moderate these impacts in some circumstances, depending on the particular energy crop, the previous land use, how the crop is managed, and which species are targeted. In other cases, energy crops may have mixed impacts. Energy crops cannot, however, substitute for natural habitats and are not intended to [11].

Although these efforts were partially successful, scientists and policy makers have gradually recognized that the species which gain publicity are just the tip of the iceberg, but are useful icons in helping to save the less telegenic species as well. Further, they have found that the more effective means of saving all these species is not through last-minute desperation efforts but rather through conserving critical habitat for all the species in the region. Thus, attention has shifted from species to habitats to regional landscape ecology [7]. The impact of agricultural, forestry and other land use practices on wildlife and habitat will first have to be examined.

5. Conclusion

1. Energy crops can be considered to be a less intensive form of agriculture.
2. Plants used as energy crops also have the potential to be more efficient in the use of fertilizers.
3. Energy crops with limited tillage and which return large quantities of organic matter to the soil can improve soil quality compared with those that rely on conventional tillage. Such a protective layer of vegetative cover crops helps to provide shading, maintain soil moisture content, prevent erosion, improve the functioning of soil biodiversity and may offer other environmental services.
4. With sustainable management, energy crops could increase the runoff of sediment fertilizers or pesticides into streams with attendant benefits for water quality.
5. Compared with annual row crops, herbaceous perennials and short rotation woody crops are likely to reduce wind-blown dust and tillage dust.
6. Carefully designed and implemented, energy crops may moderate the negative results of expanding cropping and grazing into wildlife habitats, overgrazing riparian areas, and agricultural activities that contaminate aquatic habitats in some circumstances, depending on the particular energy crop, the previous land use, how the crop is managed, and which species are targeted.

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