POLICIES AND INSTRUMENTS AFFECTING WATER USE FOR BIOENERGY PRODUCTION

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ABSTRACT

Bioenergy related water use intensifies existing water stress, increasing the importance of sustainable management of water resources for sustainable bioenergy production and use. This paper discusses policies and instruments of importance for water use for bioenergy production, considering both biomass production and the subsequent conversion to solid/liquid/gaseous fuels and electricity. Water policies on the biomass production side should focus on ensuring efficient water use. While environmental policy instruments such as command-and-control approaches support maintaining specific water quantities and quality standards for biofuel production, market-based tools can help users to identify least-cost options for biofuel operation. For the energy conversion side, water quality is the key issue that needs to be addressed with adequate policy instruments. Finally, the evaluation of water-use policies and instruments for bioenergy production should not only relate to their direct impacts on water use, but should take into account overall impacts on the economy.

Keywords: Sustainability, Policy Instruments, Bioenergy.

INTRODUCTION

Overview on Policies and Instruments that Affect Bioenergy Water Use

In the past, increasing the supply of water through new water development has been a common strategy to manage water resources. However, in maturing water economies, the focus is increasingly shifting to demand management to generate both physical savings of water and economic savings by increasing the output per unit of evaporative loss of water, by reducing water pollution, and by reducing non-beneficial water uses.

Four types of policy instruments for demand management can be distinguished(Bhatia et al, 1995): 1) Development of institutions, such as water rights and collective action mechanisms; 2)Market-based incentives; 3)Nonmarket instruments or command-and-control approaches; and 4) Direct interventions, such as investments in efficiency-enhancing water infrastructure, or conservation programs. All of these instruments are applicable to water management for bioenergy. In most situations, a mix of all four types of policy instruments is applied.
Implementation of water policies is highly complex, given the variety of water sources, ranging from precipitation to groundwater, and various surface water bodies, the fluidity of the resource, the many claimants on its uses, and the distinction between consumptive and non-consumptive uses. Moreover, water policies are implemented at different scales, ranging from the local level to the district, national, and regional levels up to the global level; policies for bioenergy water use can be implemented at all these scales. While most statutory-based water policies are generated at the national level, increased decentralization processes have often moved the actual implementation and applications to lower levels of authority, in particular the province or district level, providing both new opportunities and new challenges.(Peterson and Muzzini, 2005)

Simultaneously, some water and related policies have moved up to higher levels, such as global climate policy, which is being discussed by the United Nations Framework Convention on Climate Change (UNFCCC) and assessed by international working groups, such as the Intergovernmental Panel on Climate Change (IPCC). Moreover, water policies can also be implemented at the basin boundary or sub-catchment level, which tends to dissect various administrative scales. Furthermore, some water policies follow customary use rights, generally those on a small scale, while others are based on statutory laws and regulations. Thus multiple legal and normative frameworks coexist, and the dynamics between statutory and customary water policies are fluid and in constant motion (see also the literature on legal pluralism(Bruns and Meinzen-Dick, 2000).

The key basis of sustainable water policy for bioenergy and other uses are water rights. Although some legal or customary systems of water rights are found to operate in virtually any setting where water is scarce, systems that are not firmly grounded in formal or statutory law are likely to be more vulnerable to expropriation. On the other hand, if well-defined rights are established, water users can benefit from investing in water-saving technology. When property rights are difficult to define or enforce, as for example for common pool resources, such as small reservoirs, collective action is needed to achieve sustainable water management (Ostrom, 1990). While scarcity itself and access to markets may drive the emergence of collective action and/or property rights, appropriate institutions are needed to enable and administer property rights and to support collective action. If property rights to water or land have not been established by statutory means or if customary rights are not recognized by government authorities, local water users might lose out when biofuel plantations are established through government sales of concessions.

Also, many policies affect water use for bioenergy indirectly. Such policies include macroeconomic and trade policies, and input and output price support policies (subsidies), as well as investment strategies for infrastructure and agricultural research, to name a few. Other, global factors, such as the global trade and finance systems, climate change and climate policy, energy policy, demographic changes, including migration, and foreign direct investment also affect water policy and use for bioenergy (Ringler et al. 2010). Trade policies and agricultural and food security policies can also introduce or eliminate biofuels from national production statistics.

Energy policy and price developments as well as climate change have been major underlying causes for increased bioenergy production and therefore water use for bioenergy. Higher energy prices, in turn, have also impacted water use in biorefineries, generally increasing efficiency of use.

As a further complexity, in many countries, including both developed and those under development, water policies are developed and implemented by different agencies or ministries, including those focusing on the environment, agriculture, public health, construction, energy, fisheries, and water proper, such as ministries of water resources. For bioenergy, water policies in the agricultural, energy, industrial, environment and forestry sectors are of relevance. In several countries, bioenergy policy, research and development are housed with the Ministry of Energy, while the research capacity would rather be available at the Ministries of Agriculture, increasing the cost of coordination and potentially reducing efficiency of water-related policies.

METHODS

Policy instruments to address water use for bioenergy production can usefully be disaggregated following the bioenergy lifecycle into those related to feedstock production and those related to the bioenergy conversion side, which, in turn, have different impacts on both water availability and quality(UNEP/OEKO/IEA, 2011). Table 1 lists key components of the bioenergy lifecycle and examples of policy instruments that can be used to reduce the water footprint of bioenergy production.

Solutions are available for mitigating many of the environmental impacts resulting from the agricultural production phase as well as today's biorefineries. However, for farmers and refineries to adopt these solutions will require supporting policies and instruments that encourage adoption without reducing competitiveness or creating distortions for producers. It is also necessary to integrate new policies and instruments within the existing set of policies in order to create synergies amongst them rather than conflicts. A combination of policy instruments oriented towards incentives with command and control approaches seem to be an evolving trend(Thomas and Callan, 2010).

Table 1 - Water-and related policy instruments across the bioenergy lifecycle

Bioenergy lifecycle/Policy instrument	**Development of institutions**	**Market-based instruments**	**Nonmarket instruments**	**Direct interventions**
Feedstock choice	Intellectual property rights to support development of water-conserving feedstock; secure property rights to land and water to support pro-poor feedstock choice	Elimination of subsidies and distortions to support feedstock choice based on comparative advantage of water and other (natural) resources	Licenses for feedstock and plantations based on water-scarcity situation; taxes and quotas on less water-efficient feedstocks	R&D to develop water-saving bioenergy crops and new technologies for crop residue use; awareness campaign on water use for bioenergy production
Feedstock production	Secure property rights to land and water to support pro-poor biofuel plantations and production practices	Water pricing (irrigation); tradable water use rights and water markets to increase efficiency of water use for bioenergy crops; incentives for enhanced soil-water conservation measures; trade liberalization to ensure production based on comparative advantage	Taxes and quotas on less water-efficient feedstock production methods	R&D to develop water-saving production technologies; extension on water-saving production measures, such as low/zero tillage
Bioenergy lifecycle/Policy instrument	**Development of institutions**	**Market-based instruments**	**Nonmarket instruments**	**Direct interventions**

Feedstock conversion	Secure property rights to land and water to support pro-poor, efficient biofuel refineries	Water market to increase efficiency in refinery water use; water pricing/billing	Regulations on water use efficiency and effluent control	R&D (new technologies); Environmental Impact Assessment of new refineries
Nonpoint source pollution		Water trading / permits	Quotas/permits/penalties for fertirrigation practices; regulation of fertilizer and pesticide applications and zoning to avoid soil erosion	Awareness campaign of Best Management Practices; infrastructure investments
Point source pollution		Tradable water quality permits	Discharge permits; Strict regulations (prohibitions/standards)	Infrastructure investments

FINDINGS AND DISCUSSION

Policies and instruments affecting water quantity aspects

Impacts related to availability can be mitigated mainly by choosing appropriate bioenergy feedstocks that are suited to specific rainfall and other biophysical conditions in the production region as well as through adequate agricultural practices and technologies.

Policies and instruments that can support choosing appropriate bioenergy feedstocks and production methods

The cultivation phase of the bioenergy chain or the feedstock production side has considerable impacts on water resources, which are particularly due to the quantity of (green and blue) water used to grow the feedstocks. (Berndes, 2002; Pate et al, 2007). Planting crops that are less "thirsty" can save large amounts of water. The water efficiency of biofuel crops varies not only by crop, but also by location. Thus, the use of water, whether it is for corn, miscanthus, switchgrass, or soybeans, depends largely on the region they are to be planted in, as well as the irrigation technology chosen. Converting the current crop or grass land vegetation to land producing bioenergy feedstocks in general, changes the annual total ET and/or shift its seasonal distribution, which will subsequently change soil moisture and can affect the regional climate over a long-term period.

Given that most global crop water use is from precipitation, and that most investments have focused on blue water alone, both investments and policies affecting rainfed feedstock production will be important for many regions. Such policies include incentives for enhanced soil-water conservation measures, including rainfall capture, conservation tillage, and precision agriculture (Berndes 2002; Sulser et al. 2009). Such policies and investments can, if implemented appropriately, reduce pressure on generally more costly blue water developments.

Because of possibly excessive ET from crop or other vegetation, the National Water Act of South Africa (NWA) (DWA, 1998) has established the concept of a "stream flow reduction activity" (SFRA), which uses land use changes that can affect water availability as an instrument to manage water resources. (Jewitt et al, 2009)
In many areas lacking sufficient water for agricultural production, irrigation development supports production. However, many regions are already overusing irrigation and are thus draining water resources. For example, in India more than 60% of cereal crops grown for consumption are irrigated. This figure rises to nearly 70% in China(Rosegrant et al, 2002).

In countries where crops or feedstock are irrigated, it has been difficult to reduce water applications through water pricing, even if growing water shortages can be traced to irrigation (see, for example Perry 2001; Rosegrant et al., 2000 and Smeets et al., 2008).

Currently, around 20% of corn grown in the Midwestern United States is irrigated(USDA, 2011). However, due to the impact of climate change, it is likely that further area expansion will require irrigation, increasing blue water consumption(Cai et al, 2009). An alternative to irrigation would be to plant crops that would not require irrigation or simply to import biofuels from areas with abundant water resources (virtual water trade concept), rather than using scarce water supplies for domestic biofuel production (Schneider, 2010).

Water modeling tools which can support decision makers in their policy formulation - see for example, the Water Evaluation and Planning System (WEAP) used in the Chira-Piura System of Peru(FAO, 2010) – must incorporate aspects inherent to an integrated management such as water quality, ecosystem preservation, economic efficiency, direct and indirect economic impacts, reuse, among others.

An adequate design and evaluation of environmental policy instruments must help ensure sustainability of resource use while, at the same time, promoting economic development. It is fundamentally important, to achieve this goal, that the instruments be applied and continuously reviewed in an environment that:1)Maintains publicly available records on bioenergy production' water consumption.;2)Establishes water regulations and laws to support integrated water resource planning.;3)Ensures effective participation of all users/uses involved.;4)Establishes indicators and transparent criteria that are consensus-based and practical.;5)Applies models to simulate the behavior of the water users facing different environmental policies instruments to assess water allocation across users, considering regulatory and technical restrictions. ;6)Applies models that measure economic effects associated with different environmental policies instruments and water allocation outcomes, both on the economy as a whole and for various economic sectors (see section 3); 7)Use of scenarios for the evaluation of technological trends in the bioenergy production as well as to the demand for the final product.

Both market-based tools and command-and-control approaches can be effective in changing crop or feedstock varieties and types to crops more suitable for a specific region, but also in increasing the adoption of modern agricultural practices, such as precision agriculture, and advanced irrigation technologies. The use of the particular policy instrument will depend on a series of factors, especially: 1) legal environment and restrictions, 2) state of economic development, 3) characteristics of impact on water resources, and 4) market context.

Despite the fact that some command-and-control approaches also meet the technical efficiency criterion (least-cost criteria) market-based tools are more likely to reach cost-effective solutions. This is because market-based approaches allow producers to react according to their own interests to choose least-cost strategies.

Policies and instruments that can support water use efficiency during bioenergy conversion

The water consumption of biorefineries depends on the conversion process used and the biomass proper (Pate et al, 2007). The bioenergy conversion side is generally characterized by smaller impacts regarding the availability of water when compared to the feedstock production side. However, this relation may change depending on local characteristics.(Smeets et al, 2008). Moreover, if bioenergy conversion outputs are added back into feedstock production, then effects can be substantial at the local level.

For the bioenergy conversion side, the water use is generally a low share of total production costs, and because of this is unlikely that industries will increase efficiency unless regulations or other measures provide incentives for efficiency improvements. In this respect, environmental policy instruments can be useful, but their design and application must be supported by studies with reliable data and models in order to become effective.

Two of the world´s major ethanol producers, the United States and Brazil, show trends of declining water consumption in refineries. In the United States the reductions were due to technological improvements, regulatory measures triggered by water scarcity and cost-saving measures due to electrical power prices. Data from NRDC attest to the importance of energy use for water, (Pate et al, 2007) as well as theoretical economic models(Zilberman et al., 2008) suggest that rising energy prices alter water allocation and use for irrigated agriculture. However, without water allocation mechanisms that consider environmental costs, the adoption of such innovations can worsen over-extraction problems. Because of this, efficient water allocation mechanisms will become increasingly important.

In the case of Brazil, reduction in ethanol production plants´ water consumption in the state of São Paulo as well as the industrial water use in a whole, has been declining across the sector as a result of a greater awareness of the need to save water and the indications of future legal and regulatory action in this direction (Macedo et al., 2005) Water use legislation in São Paulo state has been enforcing water pricing and water standards - regulations on the volume and quality of water supply and return flows. Water prices have been introduced in some basins, where they are determined by committees that include representatives from all users. Meeting water use goals during bioenergy conversion in Brazil is viable due to technological advances. However, overall water depletion will depend on integrated water allocation strategies that include the feedstock production side, given projected increases in ethanol production and the consequent pressure on production areas that need irrigation (for instance, western São Paulo).

Likewise, water use can be reduced in the United States, where "the ethanol industry claims that net zero water consumption is achievable by water reuse and recycling using existing commercial technology and with capital investment." (Wu et al., 2009)

Policies addressing water quality aspects
In addition to policies affecting mainly water quantity, water quality aspects of bioenergy production require increased policy attention.

Policies that can help reducing water pollution on the feedstock production side (Nonpoint source pollution)
The main concerns on the feedstock production side relate to the possibility of additional nutrient and sediment loadings in water bodies as a result of the application of fertilizers/pesticides and soil erosion, respectively. The main concerns are the large increases of both Nitrogen (N) and Phosphorus (P), because they stimulate primary production in downstream riverine, lake, estuarine and coastal waters. (Simpson et al. ,2009) Agricultural policies to prevent the use of highly erosive lands and policies and investments targeted at increased nutrient use efficiency as well as incentives to change tilling practices have already been in use, but mainly in developed countries.

Moreover, developed and emerging countries have made considerable advances, over the last four decades, in controlling nonpoint source pollution through both nonmarket and market-based tools (e.g. standards, quotas, and subsidies).

In the United States, for example, farmers are receiving subsidies for specific agricultural practices, so-called Best Management Practices (BMPs) aiming at improving water quality by reducing nonpoint source pollution related to the use of fertilizers and soil erosion. However, "the suggestion that Best Management Practices be required to reduce nonpoint surface pollution does not allow for flexibility and cost-minimum abatement strategies unless applied on a site-specific basis, which is generally impractical." (Segerson, 1988) This means that BMP incentives do not necessarily favor the use of pollutant reduction strategies at minimum cost by the producers.

Attempts to complement efforts, such as BMP, with lower-cost approaches have been encouraged by the US EPA Office of Water in the form of trading of water quality permits. However, success has been limited to date as a result of a variety of economic and regulatory barriers and the lack of integration across instruments that are already in use. (US EPA, 2008).

Moreover**,** subsidies for bioenergy production as well as higher agricultural commodity prices in recent years, partially as a result of biofuel policies and subsidies, have outstripped support payments for aiming to encourage BMP(US EPA, 2008). As a result, enrollment in conservation programs has declined in the United States. (Dominguez-Faus et al., 2009)

Reduced tillage is another BMP, which reduces nonpoint source pollution related to the soil erosion Further advances in lignocellulosic bioenergy crops offer considerable potential to reduce the impact on feedstock production also in terms of water quality.
In the case of nonpoint agricultural pollution contributing to water quality deterioration, the focus must be given to mechanisms to control levels of pollutants in the environment (such as Total Maximum Daily Load (TMDL) approved in 1992 by the US EPA), as opposed to those aiming at controlling individual emissions. Regulations such as TMDL as well as the development and use of models to support the determination of these maximum amounts (for example, SWAT, MONERIS, etc) have been fundamental for the control of nonpoint source pollution.

In addition to the identification of ambient-based water quality standards, policies and instruments putting nonpoint source pollution control into practice would benefit from a series of characteristics, including: 1)Increase the probability that pollutant levels in the environment are below ambient-based water quality standards; 2)Minimum government interference in the polluters' day-to-day business, to achieve lowest-cost pollution reduction; 3)Focus on environmental quality, that is, monitoring of pollutants, not emissions; 4)Have defined parameter values in a way to ensure that emission reduction levels are socially optimal; 5)Eliminate free-riding in case of multiple pollutants; 6)Avoid excessive burden in the pollutant sector in the short term; and 7)Ensure long-term efficiency of the sector. (Segerson, 1988)

Policies that can help reducing water pollution on the energy conversion side (point and nonpoint source pollution)

The major challenge at the bioenergy conversion side is the potential chemical and thermal pollution through the discharge of effluents and the fate of waste or co-products from today´s refineries into aquatic systems (Berndes, 2008). These components (effluents, waste or co-products) are by-products of the conversion process, which require some form of disposal, which can result in adverse environmental impacts for water and other natural resources.

Regardless of biomass used for biofuels, distillery wastewater or stillage is currently the most substantial by-product of the biomass-to-fuel conversion process, and, therefore, loss minimization at the energy conversion side must necessarily focus on its economic reclamation (Wilkie et al., 2010). Stillage characteristics are variable and depend on the biomass as well as several aspects of the production process, but, in general, this residue presents high organic load values (BOD) and can result in major environmental impacts, especially if not adequately disposed and in contact with water resources..

The best utilization of these by-products and consequently lesser impact on water quality generally requires strict regulation as well as the existence of a market and return to stillage by-products or recoverable. The biorefinery industry keeps developing new research to better use by-products and to avoid over-supply. In the face of biofuel production growth projections and associated “losses,” policies and nonmarket and market-based instruments to address water implications of bioenergy production must focus on stillage handling options associated with adverse water quality impacts, basically from molasses and sugar-based fermentation(UNEP/OEKO/IEA, 2011) . because they are often used as fertilizer through land disposal with low to moderate water quality impacts.

As adverse water quality impacts from stillage through land disposal can also be considered nonpoint source pollution, policy instruments used for the feedstock production side are also valid to address the water quality implications of the bioenergy conversion side when stillage is disposed of on crop or other land.
If improperly developed policy instruments can turn away investors, especially in less developed regions, and therefore can affect the income of many people, infrastructure investments by the government as well as the country’s or region’s own bioenergy goals. Moreover, policies must be established to promote a balance between energy production and water quality maintenance and they need to be part of Integrated Water Resources Management (IWRM).

CONCLUSIONS

Approaches for Assessing Water-Use Policies and Instruments for Bioenergy

The evaluation of water-use policies and instruments for bioenergy should not only focus on their relative effectiveness and efficiency as far as the use and quality of water resources is concerned, but should also incorporate socioeconomic costs and benefits.

Ideally, water policies and institutions for bioenergy development must be part of an integrated intersectoral water allocation analysis to assess the full costs and benefits, including opportunity costs of using water.

Bioenergy production can offer opportunities to regions with economic indicators at risk and can benefit not only overall economic development and industrialization, but also job creation along the supply chain.

Because of that, it is very important that the evaluation of water policies, in terms of both water quality and water quantity, related to bioenergy production incorporates measures of their direct and indirect economic impacts.

The fact is that different water allocation values not only lead to differing economic impacts affecting all water users and uses, but also have backward and forward linkages related to both inputs and outputs of the bioenergy lifecycle.

Moreover, impacts also need to be differentiated by different social strata to assess consequences for the most vulnerable and poor people(Bhatia et al, 2006).The question of measurement of indirect and sector-based economic impacts of water policies (demand management-side) are of particular importance, given their large and growing importance. The proportion varies according to the characteristics and interlinkages of the various economic sectors in which the water planning unit is inserted. To measure these connections, the concept of multipliers(Bhatia et al, 2003) has generally been used and is added to a social accounting matrix (SAM) (Strzepek et al, 2008). Water policy impacts can also be compared in terms of impacts on job creation and welfare (Fullerton and Metcalf 2001). What has yet to be done is to link water quality models to modeling frameworks that allow to assess overall economy impacts.

Recommendations

Bioenergy production will undoubtedly increase pressures on water availability and use. To address growing water shortages, both quantity and quality, as a result of bioenergy production will require the implementation of judicious water policy instruments. In addition, it will be important to take into account the impact of policies affecting bioenergy water use indirectly, such as climate change, energy, and trade policies. Given the potentially large impacts from biofuel expansion in and on developing countries, it is important to ensure that the rural poor have secure property rights to land and water prior to biofuel development. Moreover, economic models that integrate water quantity, water quality, and overall socioeconomic consequences of biofuel use should be developed to support policy formulation for bioenergy development to avoid potentially long-term adverse consequences on the poor from large-scale development.

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