Water Policy 10 Supplement 1 (2008) 1–10

Interactions between water, energy, food and environment: evolving perspectives and policy issues

Petra Hellegers[a,b,*], David Zilberman[c], Pasquale Steduto[d] and Peter McCornick[a]

[a]*International Water Management Institute, P.O. Box 2075, Colombo, Sri Lanka.*
[*]*Corresponding author. E-mail: p.hellegers@cgiar.org*

[b]*Current address: WUR, P.O. Box 35, 6700 AA Wageningen, The Netherlands. E-mail: petra.hellegers@wur.nl*

[c]*University of California, Berkeley, USA*

[d]*Food and Agriculture Organization of the United Nations (FAO), Rome, Italy*

Abstract

Major changes are occurring with far reaching implications for the existing equilibria or disequilibria in the water-energy-food-environment interface. The increased demand of energy worldwide will reflect directly and indirectly on water-dependent systems. *Direct* implications will come from higher energy prices, which make extraction and conveyance of water more costly. *Indirect* implications will be in the form of demand for alternative energy sources. It triggers demand for hydropower and remains a major driver—along with some environmental policies—for biofuel expansion. The key question is how these effects may alter water allocation and influence food security, rural poverty and environmental sustainability. This paper sets the background and context of this special issue by highlighting some of the major water-related policy issues related to the subject and provides an overview and synthesis of the papers in this special issue. Besides offering insight into how these papers address these questions in the practical context of few selected countries and basins, this paper also indicates some key areas for future research on the subject.

Keywords: Biodiversity; Biofuels; Energy prices; Environment; Food security; Hydropower; Water policies; Water prices

1. Introduction

The multifarious relationships that water has to energy, food and environment are continuously evolving across countries with their changing resource conditions, development priorities and technological advances. Water development for irrigation led to agricultural growth and power generation led to industrial expansion, thereby creating a tremendous impact on food production, income and

doi: 10.2166/wp.2008.048

livelihoods. While rising oil prices and the increasing focus on clean energy are raising the value of hydropower, water now also becomes critical in the development of another clean energy source, that is biofuels. In these evolving roles for water, there are not only positive synergies but also fundamental conflicts. Besides the irrigation-hydropower conflicts, there is also a divergence between the role of water in power generation and that of energy in groundwater pumping. Biofuels also present new conflicts as their development can reallocate water, reduce food production affect the environment and create distributional problems. Unless planned properly, biofuels are likely to divert land and water away from food crops, causing lower food production and higher food prices. In this changed scenario, existing water policies and management institutions are also likely to face new pressures. Food prices may increase because of land and water supplies diverted to biofuels. In addition, food production becomes more costly with rising energy prices. Finally, higher energy prices, resulting in higher water and food prices, may lead to changes in water management and institutions.

There is now an urgent need to assess the entire spectrum of the water–energy–food–environment interface as a basis for exploring options and strategies to minimize negative impacts while enhancing the synergy benefits. Such an assessment needs to provide an overview of the conceptual foundation, review the available mechanisms for managing properly the interaction between water, energy, food and the environment, assess the actual and potential synergies and trade-offs between these sectors and explore alternative policies for enhancing the synergies and minimizing the conflicts. Of particular interest here is the need for a special focus on the interactions between energy and water, including their implications for food security, rural poverty and environmental sustainability. It is this policy context that provides the main rationale and focus for this special issue on Water–Energy–Food–Environment Interface: Synergies and Conflicts.

This special issue aims not only to raise the tone and tenor of global debates on the water–energy–food–environment nexus but also to explore the practical experiences in and policy options for managing the synergies and conflicts within this nexus. To achieve this goal, the following questions are addressed. What are the implications of increased demand for hydropower on food and the environment? What is the impact of higher energy prices on the capacity to address water-related problems as well as on access of the poor to water? What are the consequences of biofuel production on water allocation, food security, farm income and the environment? The papers carefully selected for this special issue aim to address these and related questions both in a global as well as in the specific contexts of regions and basins in countries as different as China, Ethiopia, India, Jordan, Pakistan, Sri Lanka and the USA. The objective of this paper is to introduce the subject of the water–energy–food–environment interface and set the stage by providing a synthetic overview of the papers included in this volume, highlighting some of the most important water and related policy issues and research questions.

2. The special issue papers: overview and insights

Against a general overview of the water–energy–food–environment interface and an analytical review of the interconnections between the water and energy systems, this special issue will present a global and national review and assessment of three key facets. They are: (a) water–hydropower interactions and their effect on food and the environment, (b) energy–water interactions and their implications for groundwater depletions and rural livelihoods and (c) water–biofuel linkages and their consequences for water allocation, food security, farm income and the environment. Methodologically, the assessment will be based on a global and national overview and analysis of available data and country/basin/sub-regional level case studies. Apart from the global level review and analysis, there is regional coverage in country-specific case studies for China, Ethiopia, India, Jordan, Pakistan, Sri Lanka and the USA.

This special issue brings together 8 papers by 21 authors who examine the issue from a variety of disciplinary contexts and professional backgrounds. There is an introductory paper, an analytical paper on the linkages between water and energy systems, two papers presenting cases of synergy and conflict between water and hydropower, together with their implications for food and the environment, one paper on energy–water interactions in China and three papers on the water, food and environmental implications of biofuel. Of the three biofuel papers, two have a global overview and the remaining one presents a country case study from India. Together, these papers provide insight into the relationship that water has with energy, food and the environment, as highlighted in the following synthetic overview of the papers.

In the paper following this introduction, Zilberman *et al.* (2008) present an analytical framework to assess the effects of rising energy prices on inputs, outputs, allocation decisions and distributional impacts. They show that an increase in energy prices affects the capacity to address water problems, as many solutions are energy intensive. The higher cost of energy will substantially increase the cost of groundwater extraction and will make conveyance more costly, whereas increasing demand for hydroelectric power may reduce the price and increase supply of surface water. High energy prices and geopolitical considerations drive investment in land-and water-intensive biofuel technology, diverting land and water supplies to energy production at the expense of food production. Thus, rising energy prices will alter the allocation of water, increase the price of food and may have negative distributional effects. The impact of rising energy prices and the introduction of biofuels can be partly offset by the development and adoption of new technologies, including biotechnology.

Using an analytical framework and comparative case study approach, McCornick *et al.* (2008) present four contrasting examples of river basins from Ethiopia, Jordan, India and the USA to demonstrate the complex relationships that exist in different facets of the water–energy–food–environment interface. In the case of the Krishna Basin in India, since a growing economy is placing increasing stresses on water resources and energy, further energy needs have to take into account existing resource limitations and allocation conditions. But, in the case of the Awash Basin in Ethiopia, there is abundant water and land potential not only to improve the access to energy but also to enhance rural and urban livelihoods several fold. Since most energy in Ethiopia is based on biomass, any increase in the share of clean energy sources such as hydropower will also have major conservation and environmental benefits. The Snake River Basin in the USA presents a case of direct conflict between hydropower and the environment owing to the increasing pressure from environmentalists to protect salmon migration. On the other hand, the Jordan River Basin in Jordan illustrates the case of increasing energy use in lifting and moving water from the Jordan Valley to the areas where water is needed for irrigation and direct consumption.

Molle *et al.* (2008) discuss the sectoral water allocation conflict between hydropower and irrigated agriculture on the basis of the Walawe River Basin case in Sri Lanka. Although the generation of hydroelectric power has little impact on the quantity of water, it alters the timing of streamflows, both season-wise and hour-wise, as the timing of water releases is generally governed by the demand curve for electricity. This explains why conflicts between hydropower and downstream uses, including irrigation, in-stream uses and supporting ecosystems, often occur. The tradeoff between reducing releases from the dam for irrigation to the benefit of hydropower generation is analysed by Molle *et al.* (2008). Although the high level of current diversions for irrigation warrants the possibility of improvement in management, it is shown that finding ways to reduce supply leads to technical and socio-political constraints that make the realization of economic benefits costly and uneasy.

Kahrl & Roland-Holst (2008) describe the experience of China over the last decade, where energy and water constraints have indeed emerged as important sustainability issues for China's economy and have become the subject of greater scholarly, policy and media attention, both within China and abroad. Much less attention has focused on the linkages between energy and water use in China. In their paper, they attempt to begin to fill that gap from an economy-wide perspective, focusing on the energy implications of water use.

Fraiture *et al.* (2008) use the WATERSIM model to give a global overview of the land and water implications of increased biofuel production. They conclude that biofuel production will have a relatively minor impact on the global food system and water use. However, local and regional impacts could be substantial. China and India, the world's two largest producers and consumers of many agricultural commodities, already face severe water limitations in agricultural production, yet both have initiated programs to boost biofuel production. In fact, the strain on water resources would be such in China and India that it is unlikely that policy makers will pursue biofuel options, at least those based on traditional field crops.

Müller *et al.* (2008) come to a similar conclusion through different analytical procedures. Globally there is still land and water available to grow substantial amounts of biofuels, but regionally there can be significant shortages both with regard to land and water. Nevertheless, there are concerns for an expected increase in food price and for a decrease of capacity in food security by countries where appropriate food–security policies are not implemented. The authors also clearly indicate that China and India, being the two countries that will account for 30–40% of the global energy demand by 2030, will face serious resource limitations.

India's biofuel strategy is unique, according to Rajagopal (2008), in that it emphasizes the use of wastelands and drought-resistant crops, such as Jatropha, with a view to minimizing the competition with food production for scarce supplies of land and water. Although this strategy is usually considered promising, he argues that there are two main drawbacks. The first drawback is the sole emphasis on Jatropha, a crop with little track record (the economic viability under harsh conditions is unproven), whereas superior alternatives exist such as sweet sorghum (which has a higher yield of biofuel per unit of land and per unit of water than Jatropha). The second drawback is the emphasis on common lands, which are an important source of livelihood of the landless rural poor. Jatropha cultivation will worsen access to fuel wood and fodder by the landless poor. His main recommendation is therefore that biofuel policies should focus on short duration, multi-purpose and proven drought-tolerant crops, like sweest sorghum, which can be adopted by even small landholders, while wasteland rehabilitation policies should focus on a broader array of options, which can provide greater direct benefits to the rural poor.

Together, the papers in this volume describe in detail some of the relationships that water has with energy, food, and environment. They not only demonstrate how complex and sensitive are these relationships but also suggest that changes in these relationships are likely to present major challenges and tradeoffs for existing water policies and institutions. Some of these challenges and tradeoff are highlighted below.

3. Increased demand for hydropower: implications for agriculture

Rising energy prices and an increasing focus on clean energy will trigger demand for hydropower. The energy of flowing water is the most readily available, renewable and clean source of electricity there is in mountainous areas with high rainfall. It produces no carbon dioxide or any other air emissions, nor solid or liquid wastes, although it does increase methane emissions to the atmosphere. It is more reliable and efficient and less expensive than geothermal, biomass, wind and solar energy. Increased demand for hydropower may alter the allocation of water, especially under drought conditions.

A classic conflict is the one between those who want to use the water in the dam strictly for hydropower generation and those who want to divert some of it for industrial and agricultural needs. Although hydropower does not directly consume water (consumption is limited to the loss by evaporation in the dams), its generation frequently conflicts with other uses, especially irrigation, since its release schedule does not always correspond to the timing of other water needs (Molle *et al.*, 2008). Also, upstream agriculture development, both rainfed and irrigated, can have an impact downstream hydropower facilities (McCornick *et al.*, 2008).

But, as theory predicts (Zilberman *et al.*, 2008) there might also be positive synergies when water first generates hydropower and then provides agricultural benefits, as is the case in the lower Krishna Basin. In addition to other purposes, the revenues from the sale of hydropower can be used to cross subsidize users of irrigation water by covering a portion of irrigation costs. The Columbia River treaty, for instance, is a huge success story in trans-boundary benefit sharing. Large volumes of water are transferred each year as upstream flood control storage is traded for downstream hydropower benefits. Of course, the impact of hydropower development on the environment may be significant, for example, in the Snake River Basin, a major tributary of the Columbia (McCornick *et al.*, 2008).

4. Increased energy prices: implications for energy-intensive water practices

Many of the present solutions to water problems, such as physically relocating water, tackling water scarcity through desalinization and restoring water quality, are energy intensive. An increase in energy scarcity, therefore, clearly affects the capacity to address these problems. Historically, "protecting" the agricultural sector from increasing energy and water prices by means of substantial subsidies has induced a financially unsustainable situation and also encouraged misuse of resources with substantial consequences for future generations. An extreme example is the case of Jordan (McCornick *et al.*, 2008), a country which is both water and energy scarce.

In India, the linkage between energy prices and water use is most clearly manifested in the use of groundwater and the sale of pumping services by well owners. Energy prices for agriculture are highly subsidized, often with a zero marginal price. Higher energy prices may discourage groundwater irrigation, but may also reduce access to water by the poor. This is a serious issue in India, where 75% of farmers depend to some extent on groundwater—one third of these owning a well and two thirds buying water from a well owner. Groundwater markets in areas where energy is subsidized are more active than in areas where energy is not subsidized. On the other hand, many aquifers are in serious decline while electricity companies are in serious financial difficulties. Ironically, some of the power comes from hydropower, which in effect uses the surface water resource to subsidize the extraction of groundwater (McCornick *et al.*, 2008).

Agriculture has traditionally been characterized by government interventions in prices of both inputs and outputs and attempts to raise the prices of inputs (to recover costs, or, more ambitiously to limit overdraft of aquifers) have generally been resisted.

Interventions to avoid these difficulties include: revising tariff structures to a higher fixed payment (avoiding the complexities of meter reading and billing); providing separate power supplies to wells (to be run at given times for limited hours); focusing development on areas where groundwater is (still) plentiful; and introducing improved and appropriately targeted irrigation technologies (drip and sprinkler) with less power requirements. The introduction of biofuel products has already increased food prices and in some cases farmers income and may provide resources that will enable the price of inputs to be increased. On the other hand higher prices of food resulting from higher energy prices may raise new distributional challenges.

5. Increasing biofuel production: implications for food and the environment

In the context of rising energy prices and concerns about global warming, "carbon neutral" biofuels are currently seen as a way to limit dependency on oil and the countries that supply it, while contributing to reduced greenhouse gas emissions. However, the process of photosynthesis which turns the energy of the sun into biomass has very low energy gain ratios. Moreover, the amounts of land and water required to grow crops to satisfy a significant biofuel demand are huge. Second generation cellulosic technologies that derive energy from crop residues have the clear potential to augment biofuel production, but these technologies are probably 10–20 years away from commercial reality.

High oil prices are caused by human-induced factors like political instability and bottlenecks in refinement capacity, rather than by shortage of proven crude oil supply. These human-induced factors may change, causing the oil price to drop to low levels where biofuels cannot compete with fossil fuels (Fraiture *et al.*, 2008). The oil price per barrel at which biofuels currently become competitive varies from US$25–30 in Brazil, US$50–60 in the USA and US$70 in Europe, because of widely varying resource endowments and factor costs. Brazil, for instance, has ample land and water and can produce against low costs. Other areas with suitable agro-climatic conditions include sub-Saharan Africa (provided water is either available from rainfall or developed) and Latin America. Elsewhere the motivation for developing biofuels is either in reaction to climate control (in Europe) or, in India, as a means of increasing rural employment and incomes, based on wasteland and oil-producing crops (Jatropha and Pongamia). Sweet sorghum may provide a combination of grain and biofuel production, although may also displace food crops from the rainfed areas.

Production of bioethanol is currently dominated by Brazil (based on sugarcane) and the USA (based on maize and soya beans), accounting for 70% of the global supply of 37 billion litres. France, Germany and Italy account for 90% of the global biodiesel production (made of oilseeds) of 2 billion litres. The potential contribution of biofuels is probably limited to 20% of the petrol and diesel market, compared to 2–3% of the current global consumption of 1200 billion litres of petrol equivalent (Fraiture *et al.*, 2008). Key questions in the biofuel debate are related to the consequences for water use, food security, farm income and the environment, which are addressed below.

5.1. What is the impact on water?

Current biofuel production utilizes about 1% of crop water use. This will increase to about 3% in 2030, but locally this percentage may be much higher. Pursuing biofuel production in water-short areas will put pressure on an already stressed resource, especially if it is a crop requiring irrigation, such as sugarcane. The water consumed in the production of biofuel varies by crop and location. From a water perspective it makes a large difference whether biofuel is made from fully irrigated or rainfed crops. Sugarcane in Brazil evaporates 2,200 litres for every litre of ethanol, but this demand is met by abundant rainfall. In arid areas, irrigation must make up the shortfall. In India, for example, a litre of sugarcane ethanol requires 2,500 litres of irrigation water. Almost all of India's sugarcane—potentially the country's major ethanol crop—is irrigated, as is 45% of what is likely to be China's main biofuel crop, maize.

Growing sugarcane to produce the 9 billion litres of bioethanol needed to meet 10% of India's petrol demand by 2030 will increase current demand for irrigation water by 3.4%—equivalent to 22,000 billion litres. Growing maize to produce enough ethanol to meet 9% of China's predicted demand for gasoline by 2030 will increase current demand for irrigation water by 5%—equivalent to 26,000 billion litres (Fraiture, 2007). Water needed to process crops into biofuel is negligible compared with the amounts required to grow them.

5.2. Will there be a food–fuel dilemma and high food prices?

It is questionable whether biofuel production will push aside food production. According to Pimentel (2003) poor consumers will loose out against rich car owners. However, the most commonly used biofuel crops are sugarcane and maize. Sugar is a cash crop (not a staple) and may therefore provide additional income for poor farmers, while maize is primarily used to feed animals. So it is more likely that there will be increasing competition between feed and fuel. According to Fraiture *et al.* (2008) the conflict will not be between cars and the poor, but between cars and carnivores. So, the pattern of competition between fuel and food crops is not clear yet, and this will depend, among others, on whether food security policies are in place.

Whether food prices will rise owing to an increase in biofuel demand will depend, according to Fraiture *et al.* (2008) more on trade barriers, subsidies, policies and limitations of marketing infrastructure than on lack of physical capacity. They argue that at a global level, additional demand for biofuel will be small in comparison to projected food demand, while production may take place in land abundant regions. According to Schmidhuber (2007) the demand for biofuels has already resulted in a global rise in agricultural commodity prices. He argues that the potential demand from the overall energy market is so large that it could result in a change in the *overall paradigm* of rapidly rising supply, saturated demand and falling real prices that has governed international agricultural markets over the last 40 years.

So, biofuel production may exert upward pressure on food prices as a consequence of: (a) increasing energy prices, making food production more costly; (b) increasing demand for food, due to population growth; and (c) increasing demand for water-intensive foods. The latter is especially true for rapidly developing nations, like China and India, where improved standards of living will cause diets to shift towards more meat and dairy products, which require more water to produce.

5.3. What are the distributional implications?

Biofuels can provide new sources of income for farmers. While biofuels offers benefits for many of the poorer sections of society (especially rural farmers), the increasing numbers of poor urbanized consumers would face higher food prices. As 70% of the poor live in rural areas, the negative impact on (poor) consumers of higher food prices may outweigh the positive impact on (poor) producers of increased income for their food and biofuel crops. Biofuels are expected to create energy production *by* the poor, rather than energy production *for* the poor.

Schmidhuber (2007) emphasized that we have to ensure that the policy distortions in the agricultural markets of developed countries, which were slowly and painfully reduced in the 1990s, will not be reintroduced through the “biofuel backdoor”. Failure here would not only impede the development of the biofuel income potentials in developing countries, but also compound and prolong a possible bust period. A first step would be a noticeable reduction in tariffs for biofuels in developed countries.

5.4. What is the impact on the environment?

Current biofuel production utilizes about 1% of cropped land. This is expected to increase to 3% in 2030. There is wide spread concern that the production of biofuels will increase demand for new agricultural land at the expense of natural ecosystems. The big global issue will be the impact on biodiversity. If natural vegetation is cleared to produce biofuels, obviously it will have a negative impact on the environment. To ensure that biofuels are grown in appropriate places, careful analysis of land and other resource constraints will be required. But, the negative environmental implications from this resource perspective also need to be considered in the light of the potentially possible positive environmental benefits of biofuels from the perspective of pollution reduction. Understandably, the net environmental effects of biofuels depend on the relative magnitudes of their positive and negative effects, which can be reckoned appropriately only in local and regional contexts based on local resource endowments and energy compositions.

6. Implications for policy and research

The papers included in this special issue are few and they cover only selected issues involved in some of the facets of the water–energy–food–environment interface. Although their coverage is not exhaustive but only eclectic, these papers, taken together, are still very useful in terms of their role both in adding new insights into the water–energy–food–environment debate as well as in providing some important implications for present policies and future research on the subject.

First, the changing nature of water–energy–food–environment interactions has the potential to alter some of the conditions for institutional change. For instance, with higher energy, water, and food prices, the perceived costs of flawed water institutions are likely to increase, which will directly raise the social value of efficient water policies and institutions. Because the likelihood of reform will increase with the potential net economic gains from changes, it is more likely that increased energy and water prices and their associated economic and political consequences will create conditions for water policy reforms and institutional changes. Such changes are likely to target particularly the mechanisms for sectoral and regional water allocations, the regimes of pricing and subsidy.

Second, major policy changes are also likely in the development and promotion of new technologies. For instance, new technologies related to cheaper water extraction and conveyance and those needed to improve water use efficiency and land productivity will get higher policy attention and investment priority. While the former set of technologies can partly offset the effects of rising energy prices and the attendant expansion of biofuels, the later set will mitigate those effects through water conservation and farm productivity.

Third, although the land, water, and food implications of expanding biofuel production are of minor concern from a global perspective, they are of major concern from the local and regional perspective. As China and India—being the two countries that will account for 30–40% of the global energy demand by 2030—have very little land and water available to expand agriculture further, there are major issues of food production, food prices and farm income and livelihood. Moreover, there is also a trade-related question with far reaching consequences both for international cereal and energy prices and also for global food consumption and poverty. But, these consequences can be averted through proper policies for land use and crop pattern. For instance, the policy of promoting biofuel crops in rain-fed rather than in irrigated regions could improve the economic returns of farmers in rain-fed agriculture with no or minimum food consequences. The policy of promoting better use of farm by-products of biofuel crops (e.g. sorghum and sugarcane) can also have a similar effect.

Fourth, although higher prices of food may have a negative impact on food security for the urban poor, new stimuli in the agricultural sector can also offer new opportunities for rural communities. For countries with significant agricultural resources, there can also be new development opportunities at the national level, This will be the case particularly when import barriers for biofuels in developed countries are removed. Africa, with its sugarcane production potential, is often cited as a region that could profit from such opportunities as has already been experienced by Brazil, although the technical, policy and investment obstacles to realizing the potential should not be underestimated.

Fifth, another big issue will be the impact on the environment and biodiversity. The conflict between water development projects and the environment and forest is very old and well known in the context of the historical contributions of water projects for economic development, including food production, industrial expansion and poverty alleviation. However, the positive environmental benefits of hydropower as a clean energy are getting new attention in the present context of the climatic change debate. Obviously, biofuels are also becoming important in this context, although they have other serious effects, including those on food and the environment. Apart from its potential impact on land use changes and forest clearance, biofuel production can also alter biodiversity, depending on the nature and extent of its expansion. For instance, if the expansion of biofuel production leads to the destruction of biologically and hydrologically valuable ecosystems such as rainforests and wetlands and there can be major effects on biodiversity in terms of the loss of native vegetation and the disturbance of the ecosystem. But, these effects can clearly be avoided or reduced with proper land use policies and regulations.

To conclude, it is clear from this paper that there are serious conflicts as there are important synergies among the many goals of the water and energy systems. The papers included in this issue provide both a theoretical perspective as well as country and basin-based practical case studies to demonstrate some of them and to illustrate how they can be managed through proper policies and mechanisms. Some of these issues and policies obviously require further research. In this respect, it is hoped that this special issue will play an important role in contributing to the water–energy–food–environment debate and research.

Acknowledgements

The papers in this special issue build upon presentations or were triggered by discussions during the international conference on *Linkages between Energy and Water Management for Agriculture* held in Hyderabad, India on January 29-30, 2007. This conference was made possible through support from IWMI and FAO. The authors would like to thank R. Maria Saleth for his role in initiating this special issue and in shaping its contents and Jerome Delli Priscoli for encouragement and support.

References

de Fraiture, C. (2007). *Biofuel Crops Could Drain Developing World Dry: Biofuel production will increase demand for irrigation water*. SciDev.Net. Available at: http://www.scidev.net/Opinions/index.cfm?fuseaction = readOpinions&itemid=607&language=1

de Fraiture, C., Giordano, M. & Yongsong, L. (2008). Biofuels and implications for agricultural water use: blue impacts of green energy. *Water Policy*, *10*(Suppl.1), 67–81.

Kahrl, F. & Roland-Holst, D. (2008). China's water–energy nexus. *Water Policy*, *10*(Suppl.1), 51–65.

McCornick, P., Awulachew, S. & Abebe, M. (2008). Water–food–energy–environment synergies and tradeoffs: major issues and case studies. *Water Policy*, *10*(Suppl.1), 23–36.

Molle, F., Jayakody, P., Ariyaratne, R. & Somatilake, H. (2008). Irrigation vs. hydropower: sectoral conflicts in southern Sri Lanka. *Water Policy*, *10*(Suppl.1), 37–50.

Müller, A., Schmidhuber, J., Hoogeveen, J. & Steduto, P. (2008). Some insights into the effect of growing bio-energy demand on global food security and natural resources. *Water Policy*, *10*(Suppl.1), 83–94.

Pimentel, D. (2003). Ethanol fuels: energy balance, economics and environmental impacts are negative. *Natural Resources Research*, *12*(2), 127–134, June.

Rajagopal, D. (2008). Implications of India's biofuel policies for food, water and the poor. *Water Policy*, *10*(Suppl.1), 95–106.

Schmidhuber, F. (2007) Biofuels: An emerging threat to Europe's Food Security? Impact of an Increased biomass use on agricultural markets, prices and food security: a longer-term perspective. *Policy Paper 27*, Notre Europe.

Zilberman, D., Sproul, T., Rajagopal, D., Sexton, S. & Hellegers, P. (2008). Rising energy prices and the economics of water in agriculture. *Water Policy*, *10*(Suppl.1), 11–21.