Water Policy 14 (2012) 89–105

The role of ethics in water and food security: balancing utilitarian and intangible values

Elena Lopez-Gunn*, Lucia De Stefano and M. Ramón Llamas

Water Observatory, Botín Foundation, Departamento de Geodinámica, Facultad de Ciencias Geológicas, Ciudad Universitaria, Universidad Complutense de Madrid, 28040 Madrid, Spain

**Corresponding author. E-mail: e.lopez_gunn@geo.ucm.es*

Abstract

In the past two decades, the world has experienced deep changes in terms of globalization of goods and people, the emergence of new economic powers, political turmoil, and a sustained growth of an increasingly urban global population. These and other factors have deep implications for global water and food security, and make discussion of ethical values – often implicit in global debates – more pertinent. An understanding of the ethical issues underlying water and food security is key to formulating solutions that truly contribute to their achievement. This is particularly true when considering that water and food security is strongly intertwined with human security and environmental security, and these cannot be addressed separately. This paper argues that solving water and food problems is not only a technical challenge but also a problem of fundamental ethical values and political will. It showcases three technological advances (desalination, information technology, and modern groundwater abstraction technology) and one concept (virtual water) that could contribute to secure water and food for a growing population, thus shedding light on the lack of concerted political will to face global and water food securities. In this context, trade has the potential to help countries manage water security in a globalized world, provided that global trade is revisited and undergoes a process of deep reform in the light of ethical considerations. Water and food are not isolated from general socio-economic and political trends. Therefore the drivers resulting in the present economic crisis also affect water and food, and add further complexity to the search for solutions.

Keywords: Desalination; Environmental security; Groundwater silent revolution; Human security; Virtual water trade; Water and food security

1. Introduction

According to FAO/OECD (2011), the rise in price commodities experienced in 2008 is predicted to continue and increase over the next decade by 20–30% compared to the period 2001–2010. The FAO/OECD attribute these predictions to several causes, such as a slower annual growth in agricultural stock

doi: 10.2166/wp.2012.008

levels and other compounding factors like climate variability, energy prices, exchange rates, growth in demand, and potential trade restrictions and speculation. Current drivers of change include globalization, the rise of new powers in the emergent economies, the erosion of international institutions, and the rising geopolitics of energy, increasingly tied up with water through the water/energy nexus. This new emerging global system is multi-polar, inherently more unstable, and with future rivalries predicted over trade, investments and technological innovation. The transfer of wealth from old economies to new economies is happening at a speed and size never witnessed before, in the so-called era of 'the anthropocene' (The Economist, 2011). All these changes in the world balance have deep implications for global water and food security. In this context, the analysis and discussion of ethical values implicit in many global debates are often missed. This paper will argue that an understanding of the ethical issues underlying water and food security is key to formulating solutions that truly contribute to achieving them.

The paper first reviews the concepts of water and food security then argues that these cannot be conceived without considering other equally impelling issues such as human security, and a rights-based approach to development framed by environmental security and ecosystem functioning. The paper highlights how solving water and food problems is not only a technical challenge, but rather a problem of deep ethical underpinnings. It then showcases some advances in key concepts, scientific knowledge, and technology that can open windows of opportunity to achieve water and food security in a globalized world, before concluding by highlighting the impending need to revisit world trade regulations in the light of ethical considerations. In addition, other global regulatory structures such as investment treaties are also under review, e.g. in cases where investment could override public interests related to water and food security (Solanes, pers. comm.). Trade and investment agreements, their conditionalities, and their purposes have to be analyzed as potential constraints to governments seeking the implementation of common good measures.

2. Framing water and food security in human and environmental security

The perfect storm announced by Bebbington (2010), in which population growth, climate change, closing basins, and increased food demand converge by 2050, means that global pro-active policy making is increasingly needed. In the words of Amartya Sen (1982), 'there is no such thing as an apolitical food problem'. The same statement could be made in relation to water. Thus, choices will have to be made in relation to securing food and water for a growing, and increasingly urban, global population. In this context a brief conceptual discussion of the meaning of water and food security could help identify some 'red lines', i.e. minimum requirements for all actors and stakeholders, in relation to water and food security.

Food security has been defined as 'when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life' (FAO, 2009). In contrast, the definition of water security is still mired by an unclear conceptual definition. In some cases it is understood as securing access to water, which in some contexts is linked to a lack of infrastructure in terms of water storage. In other contexts, it is related to institutional and governance aspects of access to water, rather than to the physical securing of water resources. This paper, however, argues that long-term food security and water security (in its physical and institutional aspects) are underpinned by environmental and human security (Figure 1).

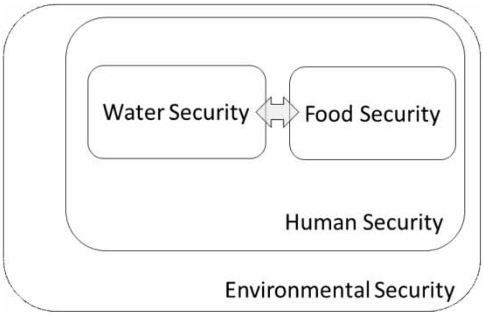

Fig. 1. The inter-linkage of food, water, human, and environmental security.

2.1. Human security and rights-based approaches to development

The concept of ‘human security’ was developed in the late 1990s whilst, at the beginning of the 21st century, attention turned away from conflicts between countries to increasingly frequent domestic conflicts e.g. in the case of failing and rogue states. Thus the concept of human security defined as ‘freedom from fear’ and ‘freedom from want’ has as a central tenet a rights-based approach to development (‘freedom from fear’) and a linkage with water and food security (‘freedom from want’).

A rights-based approach to development starts from the premise or ‘signal’ for all global actors of the need to secure the human right to water and sanitation, and the human right to food (UN, 2010a, b). Thus human security brings into the picture a series of normative frames for global policy making, a litmus test of minimum requirements. The implementation might be slow but these requirements demand their progressive realization and, therefore, road maps or signposts for their achievement, such as the Millennium Development Goals or more recent calls for universal access.

Human security and a rights-based approach to development are centered on individuals as the key referent to be secured and protected through the respect of human rights. In the literature we can see a series of waves in relation to human rights, the first concerned by political and civic rights, which demand immediate fulfillment; the second, focused on socio-economic rights, framed by the right to development and their progressive realization; and a final third wave, environmental rights, a right to a healthy environment that can support healthy lives and well-being.

At the institutional level, this evolution is reflected firstly in the development of the Human Rights Charter and in the automatic recognition of the human right to food, as well as the more contested recognition of the human right to water which was finally acknowledged by the UN in 2010 (UN, 2010a, b). Recently, in international water fora, the concepts of environmental rights and environmental justice are starting to be key discussion points in the development of global norms for a globalized planet.

2.2. Environmental security: searching for evidence and consensus

Environmental security, at the time of its origins after the fall of the Berlin Wall in 1989, referred to the possible rise of conflicts over natural resources (Mathews, 1989). More recently, however, and led by a number of environmental organizations and think tanks, it is now focused on guaranteeing the functioning of the biosphere as the basis for human wellbeing and existence.

In this context there are two new concepts on the scene, both a consequence of the difficulties of attaining sustainable development, which are opening new ways of thinking about the importance of securing win-win solutions and therefore of moving away from the intractable dichotomy of either socio-economic development or environmental conservation.

The first new concept is framed by current, rational choice, neo-classical economics, and is centered on the concept of green growth, based in turn on clearly differentiated criteria to mark a conceptual distance from sustainable development: an acceptance of growth, therefore a rejection of no growth or de-growth (which are included within the umbrella of sustainable development) and a need for clear metrics to evaluate green growth, based on the valuation of environmental services. This links up with the demand, under the new concepts, for a green economy to value green infrastructure, such as, for example, the value of floodplains and lowland wetlands to prevent flooding, the acknowledgment of aquifers as natural reservoirs, or the value of soil as a landscape reservoir.

The second concept is centered on the concept of planetary boundaries (Rockström *et al*., 2009), and the problem of finding ways of simultaneously meeting immediate social needs and long-term ecosystem needs, to secure social and economic development (Falkenmark & Rockström, 2004). In this context, there is increased evidence of how ecosystem degradation undermines food production and the availability of clean water, threatening human health, livelihoods and, ultimately, societal stability. Munang *et al*. (2011) argue that healthy ecosystems provide a diverse range of food sources that support entire agricultural systems but their value to food security and sustainable livelihoods is often undervalued or ignored. Llamas (2010) points out that it is crucial to improve research into ecosystem needs and values, while it is important to acknowledge that the available data are still scarce and not very concrete. The best-known case focuses on a valuation of environmental services as set out in the Millennium Ecosystems Assessment, which includes the evaluation of regulating, provisioning, supporting, and cultural services (MEA, 2005). This links with the conceptualization of complex socio-ecological systems and with new understandings of short- and long-term resilience and the maintenance of system functions that do not reduce natural capital value (Levin, 1999). This is framed – as compared with a green economy – by ecological economics where the limits to substitution and externalities are internalized, into national accounting systems. Demands are replaced by requirements, and supply is replaced by maintaining ecosystem productivity and regenerative capacity.

According to Falkenmark & Folke (2002), this new form of ethics centers on socio-eco-hydrological catchment management to secure the capacity of the life support system, and on a capacity to sustain the production of food and ecological services under conditions of change and uncertainty. In this context, change is assumed and stability is explained, avoiding the pathology of natural resource management which attempts to suppress disturbances, which in the context of socio-ecological systems is undesirable since it causes the accumulation of disturbances and means that change may be much more dramatic. The challenge, therefore, is how to develop food and water systems with a capacity to absorb continuous change, without losing stability. Nevertheless, in a globalized world, where food and (virtual water) increasingly move across boundaries through trade, this challenge acquires a global dimension, and analysis cannot be reduced to the river basin scale. In terms of ethical implications, this implies that that ecosystem management 'when applied at the global scale' is as much an ethos as a scientific concept. This links up with parallel debates in cultural, ethical, and religious values on the interaction of humans with nature (see Chuvieco, 2012; Galván 2012).

3. The ethics of water and food security

The world has partly emerged from the current financial and economic crisis with a shift in axis of economic power from West to East, with the growing importance of non-state actors (DNI, 2008). But with regard to this shift of power from West to East, it is important to note that, interestingly, a larger number of malnourished are also located in the East (Wojtkowski, 2008; Lobell *et al*., 2008). Some problems also remain, for example, failure to meet the Millennium Development Goals in the South, such as in Africa in relation to water and sanitation (Development Policy Forum, 2009; Mountford, 2011). Moreover, it is also important to note that, from a new global perspective, Latin America (and mainly Brazil), has plenty of blue and green water and could, once it has met the needs and rights of its own population (and under suitable economic and trading conditions), become a main supplier of food not only for these countries but also for other countries (see Allan, 2011).

All this means rethinking water and food security, and the ethics and values sustaining them. In 1988, UNESCO created the *World Commission on the Ethics of Science and Technology* (COMEST), which had several working groups including one on the 'Ethics of freshwater uses'. Its conclusions were published by the Botín Foundation (Llamas & Delli Priscoli, 2000), later adopted with minor changes by COMEST (Selborne, 2001) and generating a series of working papers by UNESCO (Delli Priscoli, *et al*., 2004).

According to Nash (1990) and James (2003) it is possible to distinguish two types of ethical problems:

- Type I ethical problems are those in which there is no consensus on what is ethical. An example of a (still unsolved) Type I dilemma is the use of animals in biomedical research (James, 2003), where arguments formulated from a utilitarian perspective clash with deontological arguments, and make the dilemma appear to be intractable. Type I ethical dilemmas are resolved when some kind of agreement is reached on what the solution ought to be or when the public at large is persuaded of the soundness or validity of the argument or evidence.
- Type II are ethical problems in which there is consensus on what is ethical but there are limited or misaligned incentives for individuals or groups to behave ethically. An example of this is water pollution (James, 2003). Despite the evidence and acknowledgment that polluting water resources is 'wrong', lack of accountability or the lack of follow-through on the 'polluter pays' principle disincentivize individuals to act ethically. Type II problems are resolved by challenging and changing the institutional environment and, consequently, modifying the incentives system that influences behavior. Thus institutional change therefore becomes an ethical issue of political will.

A key implication of this distinction is that Type I solutions will not be effective in solving Type II problems (James, 2003). What is also important in this context is that when a Type I ethical problem is 'resolved' it becomes a Type II ethical problem. An example in this case would be slavery and the debates ongoing at the end of the 19th century, and its remnants with current work conditions for some global migrants.

Nevertheless, sometimes the issue is more complex, as in the case of climate change negotiations and its nature as a global collective action problem, and the failure of the Copenhagen Conference of the Parties (COP 14) part of the UNFCC yearly conferences to reach an agreement. This failure had a range of reasons, ranging from the probably unrealistic expectation to reach agreements, to issues related to climate and environmental justice, or to the path of development.

While water and food security or a rights-based approach to development can increasingly be perceived as Type II ethical problems, i.e. where there is common agreement on the objective but few incentives to achieve them, the tension between food security and environmental security can increasingly be seen as a Type I problem. As Aiken (1984) stated: 'since agriculture causes environmental damage as a result of growing food to feed people, there seems to be a still to be resolved conflict between human needs and environmental integrity' (p. 258). This echoes the paper in this issue by Vaux (2012) on the ultimate trade-off between environmental and agricultural uses in the context of increased demand and diminishing supply – trade-offs that occur across multiple and economic scales.

The discussion of trade-offs is also analyzed in other papers in this special issue on evidence and arguments for the protection of the environment as essential for human survival. In this context, arguments beyond scientific evidence also refer to beliefs anchored, for example, on religious and ethical values. For example, as discussed by Chuvieco (2012), concepts like environmental stewardship emphasize the need to be accountable for the use of natural resources. Equally Galván (2012) refers to the symbolic value of water in Christianity as a nexus between the natural reality of creation and the divine realm of grace (see also Pontifical Council for Justice and Peace, 2004). Meanwhile Haddad (2012) comments on the key underpinning value of charity as a duty in Moslem behavior and beliefs in relation to food and sustenance, as ordered by Allah for the needy. Wolf (2012) argues that in more frequent conflicts over water use and allocation, focusing on a process of transformation (a physical state, an emotional state, an intuitive or knowing state, or a spiritual or connected level), can open venues for transformation across cultural and political boundaries beyond interests, looking for a universal set of needs. This links with the ongoing debate on environmental ethics to underpin human development in Maslow's (1954) hierarchy of needs in the four worlds (physiological, safety/love/belonging, esteem, and self-actualization).

Looking at environmental security as a Type I ethical problem helps us understand the difficulty of implementing sustainable development (a phrase first coined in 1987 by the Brundtland Commission). It goes to the heart of the difficult trade-off between socio-economic development and environmental protection. In some ways the arguments for a green economy and acknowledgment of planetary boundaries are complementary; however, as a Type I problem that is still unresolved, we can witness the evolution of both conceptual argumentation and accumulation of evidence, which could eventually lead to finding an agreement on how to solve the jigsaw of making socio-economic development compatible with a healthy environment.

4. Human ingenuity and water and food security: the implementation challenge

We now focus on some advances that could contribute in a relatively affordable and accessible way to secure water and food for a growing population. This and the following sections showcase three technological advances (desalination, water re-use, information technology, and modern water pumps) and one concept (virtual water) that provide evidence that water and food security is a type II ethical problem: the main stumbling block to solving it is not technical or due to a lack of knowledge but rather to a lack of political will.

4.1. Advances in information technology: solving information asymmetries

One of the most important problems in policy for all actors is the problem of lack of data, or inexact data, related (for example) to irrigated surface area for a type of crop, or related to inventories of groundwater uses, rights, and abstractions (Siebert *et al*., 2010). In this context remote sensing can often provide these data in a relatively fast and cheap way. Geographic Information Systems (GIS) and the internet (and increasingly cell phones and personal digital assistants (PDAs)) allow the dissemination of information to the general public with a relatively small upfront investment. Information and Communication Technology (ICT) can democratize the process of decision making, shedding light on these problems which could often be solved if there is political willingness. Thus the full use of modern technology through the internet, GIS and mobile technology, if backed by political will, can enable transparency of information. This is relevant because transparency is a core component of so-called second generation institutional reform, associated with better socio-economic development, as well as with higher competitiveness and lower corruption, which ultimately can improve policy outcomes (Bellver & Kaufmann, 2005). Transparency for example, can facilitate participation and collective action by stakeholders, and is at the heart of water governance and a fair allocation to all users – including the environment. It is also the basis of sound incentives for efficient water use (WEF, 2008) and is considered to be a powerful indirect means to fight corruption in the water sector (Transparency International, 2008). In some cases it may be useful to connect transparency and corruption, to illustrate the magnitude of some problems.

Technology can provide the means at a relatively affordable price to provide better monitoring and data collection, which can aid reform when change is inherently a political, negotiated process with potential winners and losers. For example, when water is subject to being re-allocated between e.g. agricultural and urban users, data transparency can be a catalyst against the inherent resistance or inertia in the system against change. Data transparency can shed light on false or inaccurate preconceptions on cost and benefits, identify knowledge gaps, and help a shift to other criteria such as cost effectiveness and full cost recovery, as demanded in Europe by the EU Water Framework Directive (EU, 2000). A necessary condition to getting all these benefits from technology, however, is the relevance and reliability of the data that are made accessible. Indeed, on a cautionary note, an oversupply of information or (even worse) the provision of biased data undermines the aims of transparency and shedding light on the issue at stake.

Science and innovation can help decision-making processes whilst encapsulating the complexity of the issues at hand. For example, techniques like participatory Bayesian networks, participatory modeling and participatory GIS have provided powerful new tools for decision support (Zorrilla *et al*., 2010). These advances in technology in effect open up decision making and can help policy implementation for Type II problems, i.e. when decisions are clear but incentives are giving the wrong behavior signals for the policy goals being pursued.

4.2. Advances in water technology: increasing ‘hot spot’ supply at real cost

In a world which is urbanizing, with more than half the world’s population already living in urban areas and a third located in coastal areas, a number of opportunities are now available related to the localized use of technologies such as desalination, water recycling, groundwater recharge, and rainwater harvesting. First, desalination is a technology that will become increasingly affordable, not necessarily as a standard source of water supply, but highly relevant to reduce risk in specific regions and cities, or as a standard supply for closed water systems such as islands. Desalination provides a reserve of guaranteed water, currently at a high cost but which can take the pressure off at specific times such as during drought events. For example, desalination offers the option that those who can pay more to use more expensive manufactured water such as desalinated water can leave other water resources available to meet ethical requirements on rights to water and sanitation, or ecosystem needs (see the discussion on different types of water in Feitelson, 2012). Ethical questions on equitable sharing, for example, still need to be resolved so that desalination is not used to delay difficult political decisions on such things as the necessary re-allocation of natural water resources. Second, water re-use offers a localized resource for urban populations, for instance in terms of agricultural use, or, in developed countries, for environmental flows, and is relevant for specific hot spots such as Arizona. Third, groundwater recharge offers the use of natural infrastructure like aquifers to store water in times of abundant supply for times of peak demand and drought. Finally, the importance of securing the beneficial use of green water for human consumption through rainwater harvesting, for example, is becoming increasingly important in countries as diverse as Brasil or India.

Decisions will be needed on whether, for example, to transfer water resources physically, to opt for desalination, or instead to re-allocate between existing uses. All these options have pros and cons and clear data are needed on prices paid per m^3, the economic value of a specific water use, and the willingness to pay by different economic sectors (e.g. agricultural *vs* urban users). This can inform scenarios on the potential for desalination plants to fulfill projections and time spans needed to operate at full capacity without hidden subsidies on energy costs. It is therefore important that more accurate data are collected from existing dispersed data at the global, national, and regional level on current uses, costs, and prices of desalinated sea water, desalinated brackish groundwater, and reused waste water; as well as on the potential costs savings from groundwater recharge and rainwater harvesting. The fact that discourses on water conflict continue despite available options highlights that water can become an excuse or smokescreen for other conflicts, or be used for political gain (Lopez-Gunn, 2009). Yet, as a Type II problem, the spotlight is on implementation of minimum rights to food and water as a problem for decision making, costs, and choices made, rather than looking at it as a technical problem.

4.3. Advances in water technology

As the world grows both in economic terms and in numbers of people inhabiting the planet, there is an increased search for water resources, from green water but also from rainfall harvesting and groundwater. In this context, both advances in technology (such as the development of modern drilling techniques and water pumps) and also the re-discovering of ancient traditions (such as maximization of soil moisture) are key. In the case of blue water, groundwater represents the largest freshwater resource in the planet in terms of storage. Equally, green water (and the realization of the need to manage water along the blue- to green-water spectrum) is coming to the fore in international discussions (Vidal *et al.*, 2009).

4.3.1. Groundwater's silent revolution. Groundwater represents the largest freshwater resource, in volume terms, on this planet, but largely remains out of sight and out of mind for most people including water planners. Yet, in the last half century, groundwater use has increased ten times, from $100 \times km^3/yr$

to more than $1{,}000 \times km^3/yr$ (Shah, 2009). This spectacular increase has been generally undertaken by millions of modest farmers, and little or no planning and control by conventional governmental water authorities, whilst the scale of this silent revolution is now becoming even more startling thanks to new technologies. Increased use of groundwater has produced large economic and social benefits (Llamas & Custodio, 2003; Giordano & Villholth, 2007; Mukherji *et al*., 2009; Shah, 2009) and has been at the center of the food security of countries like India and China. It is likely to also remain in the eye of the storm of water and food security questions worldwide.

However, it is less clear what the long-term consequences of this intensive groundwater use might be. What is clear, though, is that there can be, and have been, substantial environmental externalities to this groundwater growth model, which some authors think could follow the boom and bust model of mining and non-renewable resource use (the Hotelling rule; Hotelling, 1931), and even if renewable, the replenishment period may be the life of a generation, as in some cases in Mexico or Yemen (Solanes, pers. comm.). There is increased awareness of the scale of ecological impacts, such as the problems created by overdraft of aquifers in Southwest and Central USA, China, India, Australia, Spain, and Mexico (Shah *et al*., 2007), and this awareness is usually based on clear evidence, while the occurrence of socio-economic failures due to the intensive use of groundwater is still to be documented.

One of the most significant aspects of this silent revolution is the manner in which farmers, as they grow richer and more educated, move from low-value crops to cash crops. This is mainly due to the intrinsic reliability of groundwater and farmers who, encouraged by the expectation of enhanced revenues, decide to invest in better irrigation technology and, in turn, shift to higher-value crops. These efficiency gains (in both water use and increased productivity) can release water for other uses, such as for water needed by local wetlands. A problem might be the so-called 'efficiency paradox', or rebound effect, according to which water that is released in this way is then utilized for expanding irrigation, unless incentives and mechanisms are devised (subsidies, taxes, water markets, and regulations) so that this does not happen.

Llamas & Martínez-Santos (2005) described the evolution of a series of phases related to groundwater development in most arid and semi-arid countries. Figure 2 presents an idealized overview of the different water policy stages that many arid and semi-arid countries experience due to intensive groundwater use. Each of the stages is roughly equivalent to one generation (about 15–25 years). We revisit this analysis here to add a new 6th stage to groundwater intensive use (as suggested in Lopez-Gunn *et al*., 2011), which looks for win-win strategies for both farmers (and new users) and nature. This new stage can be summarized by the shift in developed countries from the motto 'more jobs and crops per drop' to 'more cash and care of nature per drop' (Llamas *et al*., 2009). It is important to note, however, that in some cases 'more cash per drop' or 'more cash per splash', may mean, in the context of developing countries, less staple crops.

Additional evidence and knowledge of groundwater are needed to understand how this resource can effectively contribute to water and food security whilst also ensuring human and environmental security. Obvious knowledge gaps are, first, in relation to water quality, and second in relation to groundwater governance. In relation to groundwater quality the 'more cash and care of nature per drop' may face a dilemma, due to the usually intense use of agrochemicals in cash crop production (e.g. in greenhouses) in arid and semi-arid areas. This is a topic that requires a more detailed analysis and evidence. It will also be important to assess how the motto can be applied to the industrialized humid countries where the use of agrochemicals is high in rain-fed agriculture, and the ecological impact is usually substantial because the water table is close to the land surface.

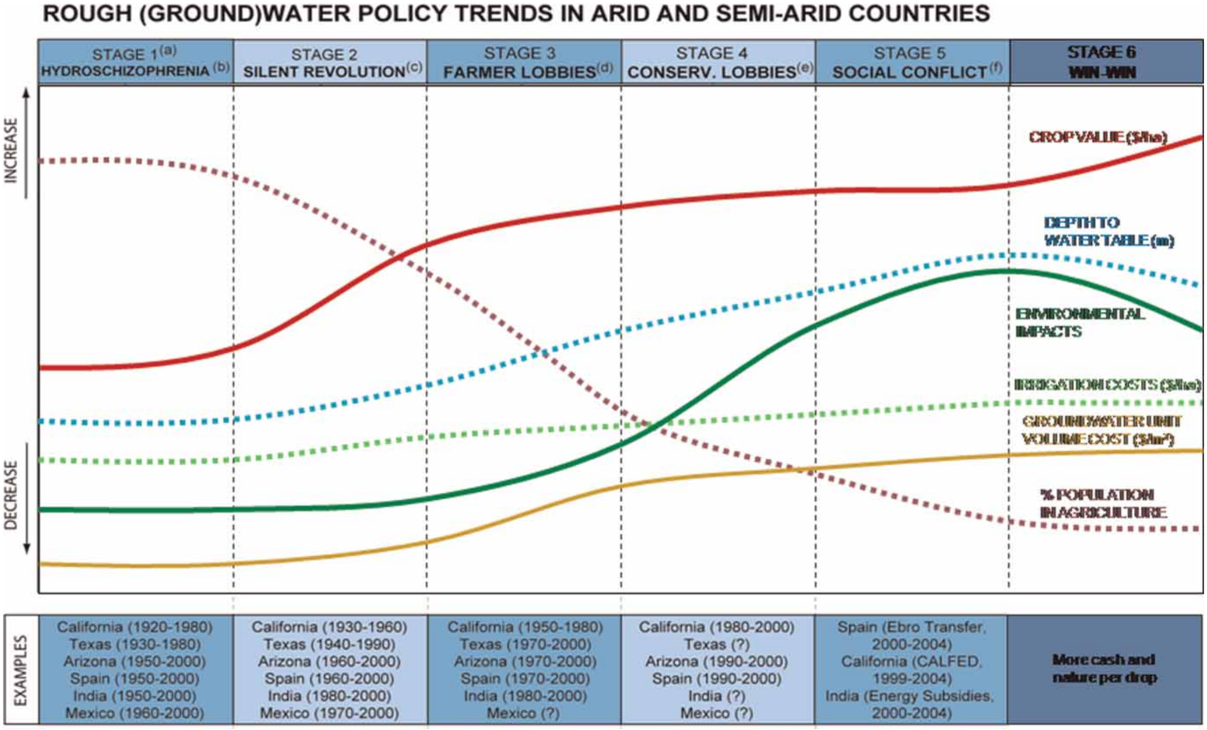

Fig. 2. Idealized stages in groundwater-related development in arid and semi-arid regions (after Lopez-Gunn *et al*., 2011; modified from Llamas & Martínez-Santos, 2005).

One pending issue is the extent to which groundwater governance is in its infancy. The approach must be very different to surface water irrigation governance (Rica *et al*., in press). In order to cope with the current groundwater development anarchy, it is increasingly important to analyze the 30-year experience of groundwater governance in depth, something which is now the focus of a new Global Environmental Facility project (GEF, 2011). Although there are commonalities between surface and groundwater irrigation governance, there remain significant differences (De Stefano & López-Gunn, 2012). In this context, a deeper understanding of groundwater governance and incentive structures is needed, as well as an appreciation of where the complementary use of other tools, like information technology and transparency principles, can help to guarantee that the potential benefits of groundwater for water and food security are realized in an equitable manner for both people and nature. At the moment, the dominant incentive structures drive the intensive use of groundwater in a highly individualistic manner, where there are few perceived benefits to be had from managing groundwater resources collectively. There are an increasing number of examples of groundwater governance, such as the case of groundwater user collectives or associations in Mexico, Spain, and India. Thus, how to generate the right incentives and institutions to favor collective action, how to avoid the potential boom and bust model of groundwater use, and how to prevent associated environmental negative externalities are all pressing questions to be addressed.

4.3.2. Green water and a greener revolution. A number of authors talk about the need for a greener revolution in the development model (Bebbington, 2010; De Schutter & Vanloqueren, 2011), i.e.

a green economy development model, and in this context the rediscovery of rain-fed agriculture should play a more important role in providing food for a growing world population (Falkenmark & Rockström, 2004). The importance of green water, however, falls into an area of type II ethical problems where more evidence and scientific knowledge is currently being developed to build a political momentum.

5. Political will in global food regulation: the elephant in the room

Concepts can sometimes be more important than facts, since concepts can determine what facts are considered relevant: this is the case, for example, with Gross National Product (GNP) and a new pressure to take into account natural accounting measures or happiness indicators. As George Paget Thompson said: 'All science depends on its concepts. These are the ideas which receive names. They determine the questions one asks and the answers one gets. They are more fundamental than the theories which are stated in terms of them' (Sir George Paget Thompson, Nobel Laureate in Physics, quoted in Falkenmark & Folke, 2002: 89).

Virtual water and the water footprint represent a new take on an old idea (embedded water and comparative advantage). They show that increasing the hydrological and economic productivity of water used for agriculture offers an entry point for relatively simple but high-impact changes in national and global water policy (WEF, 2008). However, the potential of virtual water to help address water and food security rests on the regulation of food trade. This is because of the need to address potential hidden monopolies and the threat of political embargo, to help protect countries that still need domestic social changes. In this section, we examine the role of virtual water in food and water security, and argue that understanding virtual water trade is a cornerstone in future water and food security, and that one of the most fundamental ethical questions centers on the regulation of food trade.

Agriculture is the key sector not only for food security but also for water security, since about 85–90% of all (blue and green) water consumed by humans is used for agricultural activities (Hoekstra & Chapagain, 2008; Mekkonnen & Hoekstra, 2011). The volume of water consumed by evapotranspiration in agriculture seems to be about 7,000 km^3/yr (Molden, 2007; Hoekstra, 2009). Out of this 7,000 km^3/yr, around 80% is used domestically (inside the country where the agricultural goods are produced) (Hoekstra & Chapagain, 2008), whilst 20% is food traded as virtual water trade. According to Yang & Zehnder (2008) about 15–16% is imported by arid and semi-arid countries. In other words, the virtual water traded to solve water and food security is less than 4% of the 7,000 km^3/yr consumed by agriculture globally, of the total amount of water currently consumed on the planet to feed the 7,000 million persons who inhabit it. (Liu *et al*. (2009) consider that the previous numbers are too high and that the real consumptive use is significantly smaller.) Nevertheless, this small percentage is very important to solve the problems in a good number of arid and semi-arid countries. One typical example is the Middle East and North Africa (MENA) region, where the volume of virtual water imported is greater than the Nile river average annual stream flow (Yang *et al*., 2007; Allan, 2011). Increasingly more water-poor countries will be looking outside their borders to secure access to virtual water or, in some cases, for land to grow their food, as is the case of Saudi Arabia buying land in Sudan, for example (Cotula *et al*., 2009).

Virtual water trade has advantages and disadvantages. It could be argued that the current land grab or food grabbing such as referred to by Via Campesina (2011) is an unintended consequence of the increased awareness of the key strategic role of virtual water. Equally, there are increased references to the potential blue water savings from international food trade for water-poor countries. Overall, the estimate of global water savings due to trade is around 300–500 km^3 (Hoekstra & Chapagain, 2008). This is between 4 and 8% of the total global agricultural footprint (around 7,000 km^3/yr). On the other hand, the cascade of errors in many estimations of evapotranspirative consumption (scale factor, discounting the type of soil, water storage in both reservoirs and aquifers, and others) is probably greater than 5%. Therefore, we have to be very cautious of the relevance or scale of global water savings due to virtual water trade.

The main advantage is that virtual water trade could represent a strategically significant outside option for intensively developed river basins or countries. It represents a way to secure access to additional (virtual) water resources, thus prioritizing real green and blue water for local uses such as public water supply, high added-value industrial uses like solar thermal energy and, increasingly, the environment. For instance, preliminary assessments indicate that, in Spain, the economic productivity of water in thermo solar is between 100 and 200 times greater than the economic productivity of water for irrigation of cereals or cotton (Garrido *et al*., 2010). It seems obvious that cereals and cotton can be imported from other water-rich countries and it would therefore be illogical to prioritize water uses for irrigation over thermo solar production. This preliminary analysis has now been developed for the whole Guadalquivir river basin (Salmoral *et al*., 2011).

However, the main ethical questions in relation to virtual water and to water and food security refer to key issues relating to regulatory structures on both national and global food trade, as well as national and global regional structures to adapt them and make them resilient to changes in trade and land ownership. Trade has the potential to help countries manage water security in a globalized world system. However, the global trade system is outdated and in need of deep reform (WEF, 2008). In the context of the current stall in World Trade Organization (WTO) negotiations, and the growth in bilateral negotiations, questions center on how food trade fits into inherently political decisions. Usually, global food trade is not driven by water scarcity, since international commodity trade mainly depends on factors such as availability of land, labor, technology, the costs of engaging in trade, national food policies, and international trade agreements. In this sense, only a small amount of international virtual water trade is due to water scarcity. However, some cash-rich, water-poor countries like Saudi Arabia have taken the policy decision to secure food and water from outside their border (see above). Land grabbing may be a problem for local farmers if land is a public, state-owned resource disposed of by governments anxious to make a quick return. Further complication results from the fact that these investments are protected by international investment treaties, their principles and courts, and local people may be unable to supply their food needs from these investments (Solanes, pers. comm.). Meanwhile, other water-poor countries will be unable to adopt this strategy because they are also cash-poor. This is the case for some countries of the MENA region (Yang *et al*., 2007) and in other countries (Yang & Zehnder, 2008; Liu *et al*., 2009). Clearly, preconditions for trade are a minimum of wealth (in terms of GNP) and a fair trading system.

The virtual water trade is fraught with diverse problems and possibly the most urgent of them is the lack of fair international trade regulations; attempts to solve this impasse by the WTO have so far failed. Another key associated topic is the issue of perverse incentives and, in particular, the current subsidy structure in agriculture by most Organisation for Economic Co-operation and Development (OECD) countries. In the context of recent large subsidies to other sectors (e.g. the bail-out of the financial system and banks), key questions need to be posed, such as what are the principles that define which subsidies are permissible? And which subsidies (for example, price supports) are detrimental to development? The WTO agreements on subsidies and countervailing measures have established a legal definition of subsidy. However, in reality there is no clear overarching consensus and analytical framework to help evaluate the use of public budgets in relation to subsidies for energy (electricity) and agricultural prices, or for cross subsidies (e.g. for public water supply or to water infrastructure). The analysis of the increase of the price of staple foods two years ago has already identified a number of drivers (biofuels, speculation by some international food corporations, oil price increase, lack of enough storage for staple foods, economic and financial crisis, and others) (Paarlberg, 2008a, b; FAO, 2011). One of the main potential reasons is the change in diets globally, particularly in the emergent BRIC countries (Brazil, Russia, India, and China), which could drive cereal prices up for the long run. Therefore, the issue of incentives (and subsidies) is, in the context of regulatory reform for trade liberalization, together with the criteria used to assess the *kindness*, or impacts, of subsidies. For example, do subsidies locking in inappropriate technologies lead to inefficient use of water, or remove incentives to invest in infrastructure? Important ethical questions center on where, how, and when to reduce perverse incentives (including subsidies), and on identifying when and where subsidies are in fact needed.

As Allan (2011) states, the production, processing, and marketing of the world's food is mainly in private hands. First, the production relies on millions of farmers, most of them small- or medium-size, usually organized as powerful lobbies in every country. Second, distribution to consumers and processing is in the hands of national or international corporations. Today, there are a number of large international corporations that play a dominant role in staple food trade. Sometimes, these may be real oligopolies with budgets greater than the national budget of medium-sized countries. This is a situation that may be prone to speculation and corruption. This situation may explain the recent increase in staple food prices (De Schutter, 2010). Given that world food trade, according to a recent model, is expected to increase every year, a 2–2.5% price hike would increase the number of hungry people. Therefore the most important pending issue to solve current problems would be to achieve a more efficient, just, and equitable international regulation of the food trade.

6. Conclusion

A planet focused on continued economic growth, coupled with 1.2×10^9 more people by 2025, will put pressure on energy, food, and water resources (Bebbington, 2010). This paper has argued that the pace of technological innovation and new conceptual innovations will be key to helping to address water and food security. It has also argued that the current problems in addressing water and food security are not technical but ethical; it is clearly not a question of technological fixes. A mix of instruments, grounded on ethical norms, can address water and food security where, for example, intensive groundwater use will have to be complemented by adequate access to information, or where the increased use of desalination is complemented by virtual water trade or strategic water reallocation. A complex world has complex problems; the evidence in this paper clearly demonstrates that there are no simple solutions to complex problems (Forrester, 2007). However even more important than technological innovations and human ingenuity are the underpinning ethical dilemmas faced by humanity. This paper has argued that the grounding of water and food security in a rights-based approach to development, combined with the push for its contextualization into environmental security and planetary boundaries, offers clear ethical guidelines for water and food security.

Rosenhead (2006) noted, 'Turbulence rather than stability has become the commonsense perspective on the future'. In a world marked by change, the fact–value dichotomy points to the importance of empirical relevance and normative values. According to Gerring & Yesnowitz (2006), the normative turn in policy means that justice, not science, should determine our civic and cosmopolitan obligations. 'True science does not preach, it proves and predicts … a normative argument without empirical support may be rhetorically persuasive or logically persuasive but it will not have demonstrated anything about the world … good social science must integrate both elements; it must be empirically sound and it must be relevant to human concerns' (Gerring & Yesnowitz, 2006: 117).

References

Aiken, W. (1984). Value conflict in agriculture. *Agriculture and Human Values 1*(1), 24–27.

Allan, J. A. (2011). *Virtual Water: Tackling the Threat to Our Planet's Most Previous Resource*. L. B. Tauris, London, 365 pp. ISBN 978-184511-984-3.

Bebbington, J. (2010). *Food, Energy, Water and the Climate: A Perfect Storm of Global Events*? Chief Scientific Adviser to HM Government, Government Office for Science, London. Available at: http://www.bis.gov.uk/assets/bispartners/goscience/docs/p/perfect-storm-paper.pdf (accessed 10 December 2011).

Bellver, A. & Kaufmann, D. (2005). *Transparenting Transparency: Initial Empirics and Policy Applications. Preliminary draft*. World Bank, Washington. Available at: http://siteresources.worldbank.org/INTWBIGOVANTCOR/Resources/Transparenting_Transparency171005.pdf (accessed 5 December 2011).

Chuvieco, E. (2012). Religious approaches to water management and environmental conservation. *Water Policy 14*(Supplement 1).

Cotula, L., Vermeulen, S., Leonard, R. & Keeley, J. (2009). *Land grab or development opportunity? Agricultural investment and international land deals in Africa*. IIED/FAO/IFAD, London/Rome.

De Schutter, O. (2010). *Food Commodities Speculation and Food Price Crises. United Nations (UN) Briefing Note, September 2010*. UN, New York.

De Schutter, O. & Vanloqueren, G. (2011) The new green revolution: how twenty-first-century science can feed the world. *Solutions 2*(4), 33–44.

De Stefano, L. & López-Gunn, E. (2012). Non-authorized groundwater use: institutional, social and ethical considerations. *Water Policy 14*(Supplement 1).

Delli Priscoli, J., Dooge, J. & Llamas, M. R. (2004). *Overview: Series on Water and Ethics*. UNESCO, Paris, France. ISBN 92-9220-016-X. Available at: http://unesdoc.unesco.org/images/0013/001363/136343e.pdf (accessed 10 December 2011).

Department of National Intelligence (DNI) (2008). *Global Trends 2025: A Transformed World*. US Government, Washington DC.

Development Policy Forum (2009). *Saving the MDGs from Global Recession: Report of the Fourth Development Policy Forum (DPF)*. Roundtable organised by Friends of Europe in partnership with UN, World Bank, AFD, DFID and GTZ. Friends of Europe, Brussels.

European Union (2000). Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. *Official Journal of the European Union, Official Journal* (OJ L 327), 22 December 2000, 0001-0073.

Falkenmark, M. & Folke, C. (2002) The ethics of socio-ecohydrological catchment management: towards hydrosolidarity. *Hydrology and Earth System Sciences 6*(1), 1–9.

Falkenmark, M. & Rockström, J. (2004). *Balancing Water for Humans and Nature: The New Approach in Ecohydrology*. Earthscan, London, UK.

FAO (2009). *Declaration of the World Summit on Food Security*. World Summit on Food Security, Rome, 16–18 November 2009. Available at: http://www.fao.org/fileadmin/templates/wsfs/Summit/Docs/Final_Declaration/WSFS09_Declaration.pdf (accessed 10 December 2011).

FAO (2011). *How does International Price Volatility Affect Domestic Economies and Food Security*? FAO, Rome. ISBN 978-92-5-106927-1.

FAO/OECD (2011). *FAO/OECD Agricultural Outlook 2011–2020*. FAO/OECD, Rome.

Feitelson, E. (2012). What is water? A normative perspective. *Water Policy 14*(Supplement 1).

Forrester, J. W. (2007). System dynamics—the next fifty years. *System Dynamics Review 23*, 359–370.

Galván, M. J. (2012). Insights of the Christian Anthropology for a water-related technoethics. *Water Policy 14*(Supplement 1).

Garrido, A., Llamas, M. R., Varela-Ortega, C., Novo, P., Rodríguez Casado, R. & Aldaya, M. M. (2010). *Water Footprint and Virtual Water Trade of Spain: Policy Implications*. Springer Publishers, London.

GEF (2011). *Groundwater Governance: A Global Framework for Action*. Available at: http://www.thegef.org/gef/node/3622.

Gerring, J. & Yesnowitz, J. (2006). A normative turn in political science? *Polity 38*(1), 101–133.

Giordano, M. & Villholth, K. G. (eds) (2007). *The Agricultural Groundwater Revolution: Opportunities and Threats to Development*. Volume 3. CABI Publications, Wallingford (UK) and Cambridge (MA, USA).

Haddad, M. (2012). An Islamic perspective of food security management. *Water Policy 14*(Supplement 1).

Hoekstra, A. Y. (2009). Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis. *Ecological Economics 68*(7), 1963–1974.

Hoekstra, A. Y. & Chapagain, A. K. (2008). *Globalization of Water: Sharing the Planet's Freshwater Resources*. Blackwell Publishing, Oxford, UK.

Hotelling, H. (1931) The economics of exhaustible resources. *Journal of Political Economy 39*(2), 137–175.

James, H. (2003). On finding solutions to ethical problems in agriculture. *Journal of Agricultural and Environmental Ethics 16*(5), 439–457.

Liu, J., Zehnder, J. B. & Yang, H. (2009). Global consumptive use for crop production: the importance of green and virtual water. *Water Resources Research 45*(W05428), 15.

Llamas, M. R. (2010). Foreword. In: *Re-Thinking Water and Food Security*. Martínez-Cortina, L., Garrido, A. & López-Gunn, E. (eds). Taylor & Francis, London.

Llamas, M. R. & Custodio, E. (eds) (2003). *Intensive use of Groundwater: Challenges and Opportunities*. Balkema Publishers, Lisse, The Netherlands. ISBN: 9058013905.

Llamas, M. R. & Delli Priscoli, J. (2000). Water and ethics. *Papeles del Proyecto Aguas Subterráneas, Serie A 1*(5), 99. Fundación Marcelino Botín, Santander. Available at: http://www.fundacionbotin.org/file/10456/ (accessed 10 December 2011).

Llamas, M. R. & Martínez-Santos, P. (2005). Intensive groundwater use: silent revolution and potential source of social conflicts. *Journal of Water Resources Planning and Management 2005*(September/October), 337–341.

Llamas, M. R., Martínez-Cortina, L. & Mukherji, A. (eds) (2009). *Water Ethics*. Taylor & Francis Group, London, UK. Available at: http://www.fundacionbotin.org/file/10345/ (accessed 10 December 2011).

Levin, S. (1999). *Fragile Dominion: Complexity and the Commons*. Perseus Books, Reading, MA.

Lobell, D. R., Burke, M., Tebaldi, C., Mastrandrea, M., Falcom, W. & Naylor, R. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science 319*, 607–610.

Lopez-Gunn, E. (2009). Agua para todos: the new regionalist hydraulic paradigm in Spain. *Water Alternatives 2*(3), 416–439.

Lopez-Gunn, E., Zorrilla, P. & Llamas, M.-R. (2011). The impossible dream? The Upper Guadiana system: aligning changes in ecological systems with changes in social systems. In: *On the Water Front: Selections From the 2010 World Water Week in Stockholm*. Lundqvist, J. (ed.). Stockholm International Water Institute (SIWI), Stockholm. ISBN: 978-91-975872-8-0.

Maslow, A. (1954). *Motivation and Personality*, 3rd edition. Harper & Row Publishers, London.

Mathews, J. (1989). Re-defining security. *Foreign Affairs 68*(2), 162–177.

Mekkonen, M. M. & Hoekstra, A. J. (2011). *National Water Footprint Accounts: The Green Blue and Gray Water Footprint of Production and Consumption; Volume I: Main report*. Value of Water Research Report Series no. 50. UNESCO-IHE, Delft, The Netherlands.

Millennium Ecosystem Assessment (MEA) (2005). *Synthesis Report*. United Nations, New York, NY.

Molden, D. (ed.) (2007). *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. Earthscan, London, UK and International Water Management Institute (Colombo, Sri Lanka).

Mountford, H. (2011). *Water: The Environmental Outlook to 2050*. Presentation by H. Mountford, Deputy Director, OECD Environment Directorate. OECD Global Forum on Environment: Making Water Reform Happen 25–26 October 2011, Paris.

Mukherji, A., Facon, T., Burke, J., de Fraiture, C., Faurès, J. M., Füleki, B., Giordano, M., Molden, D. & Shah, T. (2009). *Revitalizing Asia's Irrigation: To Sustainably Meet Tomorrow's Feed Needs*. International Water Management Institute, Colombo, Sri Lanka and FAO (Rome, Italy).

Munang, R., Thiaw, T. & Rivington, I. M. (2011). Ecosystem management: tomorrow's approach to enhancing food security under a changing climate. *Sustainability 3*(7), 937–954.

Nash, L. (1990). *Good Intentions Aside: A Manager's Guide to Resolving Ethical Problems*. Harvard Business School Press, Boston, MA.

Paarlberg, R. (2008a). Rises in world food prices may hurt city-dwellers, but they do not increase global hunger. *Prospect*, (147) (29 June 2008). Available at: http://www.prospectmagazine.co.uk/2008/06/thetruthaboutfood/ (accessed 10 December 2011).

Paarlberg, R. (2008b). It's not the price that causes hunger. *International Herald Tribune* (22 April 2008). Available at: http://www.nytimes.com/2008/04/22/opinion/22iht-edpaarlberg.1.12230340.html (accessed 10 December 2011).

Pontifical Council for Justice and Peace (2004). Compendium of social doctrine of the church. Chapter Ten: Safeguarding the environment. No. 451–487. Available at: http://www.vatican.va/roman_curia/pontifical_councils/justpeace/documents/rc_pc_justpeace_doc_20060526_compendio-dott-soc_en.html#CHAPTER%20TEN (accessed 10 December 2011).

Rica, M., López-Gun, E. & Llamas, R. (in press). Analysis of the emergence and evolution of collective action: an empirical case of Spanish Groundwater User Associations. *Journal of Irrigation and Drainage ICID, Special Issue*. Bouarfa, S. & Kuper, M. (eds). Constructing local governance of groundwater.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. & Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society 14*(2), 32.

Rosenhead, J. (2006). Past, present and future of problem structuring methods. *Journal of the Operational Research Society 57* (7), 759–765.

Salmoral, G., Dumont, A., Aldaya, M. M., Rodríguez-Casado, R., Garrido, A. & Llamas, M. R. (2011). *Análisis de la huella hídrica extendida de la cuenca del Guadalquivir. Papeles de Seguridad Hídrica y Alimentaria y Cuidado de la Naturaleza (SHAN), No. 1*. Fundación Botín, Observatorio del Agua, Santander. Available at: http://www.fundacionbotin.org/file/24171/ (accessed 10 December 2011).

Selborne, J. (2001). *UNESCO World Commission on the Ethics of Science and Technology*. UNESCO, Paris.

Sen, A. (1982). The food problem: theory and policy. *Third World Quarterly 4*(3), 447–459.

Shah, T., Burke, J., Villholth, K., Angelica, M., Custodio, E., Daibes, F., Hoogesteger, J., Giordano, M., Girman, J., Van Der Gun, J., Kendy, E., Kijne, J., Llamas, R., Masiyandima, M., Margat, J., Marin, L., Peck, J., Rozelle, S., Sharma, B., Vincent, L. & Wang, J. (2007). Groundwater: a global assessment of scale and significance. In: *Water for Food, Water for Life: Comprehensive Assessment of Water Management in Agriculture*. Molden, D. (ed.), Earthscan, London, pp. 395–423.

Shah, T. (2009). *Taming the Anarchy? Groundwater Governance in South Asia*. Resources for Future Press, Washington, D.C., USA.

Siebert, S., Burke, J. M., Faures, J. M., Frenken, K., Hoogeveen, J., Döll, P. & Portmann, F. T. (2010). *Groundwater Use for Irrigation: A Global Inventory. Hydrology and Earth System Sciences Discussions*. FAO, Rome.

Solanes, M. (pers. comm.) (15 October 2011). Personal communication. Senior Researcher, IMDEA (Instituto Madrileno de Estudios Avanzados), formerly at ECLAC (Economic Commission for Latin America).

The Economist (2011). Welcome to the anthropocene. *The Economist* 26 May 2011, 26.

Transparency International (2008). *Global Corruption Report: Corruption in the Water Sector*. Cambridge University Press, Cambridge, UK.

United Nations (UN) (2010a). *UN Resolution A/RES/64/292*. UN General Assembly, NY, USA.

United Nations (UN) (2010b). *Human rights council resolution A/HRC/RES/15/9*. UN, NY, USA.

Vaux, H. (2012). Water for agriculture and the environment: the ultimate trade off. *Water Policy 14*(Supplement 1).

Via Campesina (2011). G20 Agriculture: No to 'food grabbing' by the richest nations of the world! *Via Campesina (International Peasant Movement)*. Jakarta, Indonesia. Available at: http://www.viacampesina.org/en/index.php?option=com_content&view=article&id=1086:g20-agriculture-no-to-food-grabbing-by-the-richest-nations-of-the-world&catid=21:food-sovereignty-and-trade&Itemid=38 (accessed 10 December 2011).

Vidal, A., van Koppen, B. & Blake, D. (2009). The green-to-blue water continuum: an approach to improve agricultural systems' resilience to water scarcity. *On the Water Front 1*, 66–72. Available at: http://www.worldwaterweek.org/documents/Resources/Best/Vidal-Koppen-Blake.pdf (accessed 10 December 2011).

Wojtkowski, P. (2008). Letters 'ensuring food security'. *Science 320*(5863), 580–581. Available at: http://www.sciencemag.org/content/320/5876/611.full.pdf) (accessed 10 December 2011).

Wolf, A. T. (2012). Spiritual understandings of conflict and transformation and their contribution to water dialogue. *Water Policy*. Special Issue on the Role of Ethics in the Globalisation of Water and Food.

World Economic Forum (WEF) (2008). Managing our future water needs for agriculture, industry, human health and the environment. *Discussion Document for the World Economic Forum Annual Meeting*. WEF, Geneva. Available at: http://www3.weforum.org/docs/WEF_ManagingFutureWater%20Needs_DiscussionDocument_2008.pdf (accessed 10 December 2011).

Yang, H. & Zehnder, A. J. B. (2008). Globalization of water resources through virtual water trade. Manuscript presented at the *Sixth Biennial Rosenberg International Forum on Water Policy*, Zaragoza, Spain, 19 pp. (unpublished).

Yang, H., Wang, L. & Zehnder, A. J. B. (2007). Water scarcity and food trade in the Southern and Eastern Mediterranean countries. *Food Policy 32*, 585–605.

Zorrilla, P., Carmona, G., De la Hera, Á., Varela-Ortega, C., Martínez-Santos, P., Bromley, J. & Jorgen Henriksen, J. H. (2010). Evaluation of Bayesian networks in participatory water resources management, Upper Guadiana Basin, Spain. *Ecology and Society 15*(3), 12.