Chapter 9
Adaptation to Climate Change: Green Development

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Abstract Mitigation and adaptation are both responses to climate change. This chapter provides the reader with information related to various policy measures for climate change, in water management. A theoretical part introduces issues concerning water resources management and sustainable water use. The chapter is mainly devoted to green development as a new development model for the twenty-first century that can provide adaptation to climate change and can guarantee economic prosperity, environmental protection of natural resources, and social equity. The main characteristics of green development are analyzed. Methods and applications of green development in water management are discussed as a solution to the impact of climate change on water. EU adaptation policies, in the context of green development, are discussed, and a case study from Greece demonstrates nonstructural measures and combined methodologies used to promote sustainable water management.

Keywords Adaptation policy • Green development • Water resources management • Climate change • EU adaptation

9.1 Introduction

Water is the most indispensable resource significantly affected by climate changes. Water, as an essential environmental resource, but also as a vital element of life that supports a variety of ecosystem services, plays an equally significant role in almost every economic activity and needs to be properly sustained. Natural climate variability and human-induced climate change have posed severe threats to natural resources. Extensive research has brought to light that the impacts of unrelenting climate change are both on the water cycle (T. Huntington 2006;

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Trenberth 1999; Held and Soden 2000; Arnell et al. 2001) and on the water supply (Bates et al. 2008). There is a broad scientific consensus that immediate action must be taken. Other effects of climate change in water resources include air and water temperature increases, intensification of extreme events, sea level rise, and changes in coastal/ocean characteristics. The complexity of the different events creates nonlinear behavior in the entire system (Schneider and Lane 2006; Hansen et al. 2008) in ways that are unexpected and potentially irrevocable and need new knowledge and approaches to tackle.

Climatic drivers and, specifically, the uneven spatial and temporal distribution of precipitation and the extent of the rainfall (extreme events) are leading to a remarkable temporal and spatial variability in water resources worldwide. Periods of intense rainfall characterized by more runoff and less infiltration combined with increased evapotranspiration are expected to lead to groundwater depletion.

Temperature increases may have an effect on water quality and freshwater ecosystems in the form of changes in the aquatic species composition. Reduction in soil moisture, changes in land management, alterations in vegetation cover, all, are results of changes in temperature and precipitation which put the availability of water supplies in peril. The amount of freshwater availability is a function of multiple physical variables such as runoff, water quality, groundwater recharge, but also technical interventions such as water infrastructure. Changes in hydrology may not always have negative effects. Runoff, for example, may provoke erosion and severe quality problems as contaminants may be carried out by increased runoff, but at the same time, it may increase water resources availability. Water availability is likely to be further hampered by poor management, inefficient infrastructure, and overuse.

Other, non-climatic drivers, such as massive population growth of last century and also its tendency to rise near nine billion by 2050, have resulted in excessive water use. Technological innovations and consumption habits particularly in the developed countries will further increase water demand. The major increases, though, in water demand, will be in the emerging economies and developing countries (OECD 2012).

All the factors mentioned above are liable to affect key economic activities and development with a significant contribution to the quality of life, such as agricultural production and productivity, urban development, industry, tourism, and energy sector. The anticipated impact of these factors, on the food production and access to clean water together with the every so often occurrence of extremes events, could prompt uncontrolled population migrations, putting additional pressure on receiving countries. *"The number of refugees worldwide from environmental causes reached in 2014 its highest level since World War II,"* according to the official Global Risk website. In the Global Risk Report of 2015, issues such as water crises and extreme events related to water are ranked third regarding importance among global risks (Global risks 2015).

9.1.1 Water Resources Management and Climate Change

Sustainable management of water resources is currently challenging water managers throughout the world. Many of the issues related to water management today stem from the following factors:

- Changing priorities of water and environmental management goals over time
- The need for multidisciplinary inputs
- Uncertainties regarding future demand and supply
- Lack of adequate understanding of procedures that affect and are affected by the management of water and the environment
- The way institutions work
- Contemporary lifestyles and how water uses are perceived, especially in the "affluent West"

Engineering design and practice involves predicting and depicting future conditions with sufficient accuracy that the consequences of design choices can be evaluated. Hydrologists use frequency and regression analysis for the planning and operations of almost all water resources projects. The implicit assumption in all such analyses "is that the hydrologic record of the past is the best guide for the future" (Hirsch 2010, http://www.cwi.colostate.edu/NonstationarityWorkshop/SpeakerInfo/Hirsch_Abstract)

In statistical terms, the system is stationary. Climate change due to human-driven changes in the global atmosphere may not be subject to this rule (Kundzewicz et al. 2007; Milly et al. 2008). Whether stationarity exists or not is still open to debate (Lins and Cohn 2011; Koutsoyiannis 2011). If stationarity is "dead," new theories and tools need to develop to assist water management to take decisions.

A prominent example is the operation of current dams that had been designed under certain hydrological conditions that cannot efficiently respond to the spatial and temporal oscillations in water flows due to climate change. Increasing uncertainties reduce the predictability of the boundary conditions under which water management has to carry out.

It is not yet possible to estimate accurately climate uncertainties based on current modeling status, since their evolution is almost "a black box" for water planning and management needs (Stakhiv and Stewart 2010). Thus redesign of new infrastructure, customizing and adapting to new hydrological conditions, is an imperative need.

Integrated water resources management (IWRM) traditionally addresses challenges by incorporating spatial, temporal, economic, political, environmental, as well as administrative aspects of sustainability. It is a comprehensive methodology which, by the implementation of policies, laws, regulations, applied science and engineering, as well as "best management practices" in a consistent manner, promotes efficiency, effectiveness, and equity for all types of resources and all sectors.

Efficient management of risks related to climate change calls for an integrated approach linking technological, social, and economic development with the protection of natural ecosystems and with realistic projections of future climatic conditions. It is true, though, that significant progress had been made in the technological and engineering field in this sense. The major problem in the policy-making is how to establish the enabling environment, how to provide the means and resources, and how to integrate them into different sectors that economic prosperity, environmental integrity, and social coherence can be accomplished. The fundamental concern is not the exact amount of critical parameters such as rainfall and evaporation but rather the variability of these parameters from year to year or their seasonal modifications that should be incorporated in the decision-making process of water management. The real decision rules are determined by what society needs. A variety of parameters, other than detailed hydrologic information, are also crucial for decision-making, among them, economic priorities, cost–benefit criteria, legislations, personal views, etc. The great difficulty is encountered mainly with the existing institutional and regulatory framework and especially in the implementation of policy aspects, and not so much with hydrologic uncertainty. The problem is particularly intense in developing countries (Stakhiv 2010).

9.1.2 Mitigation and Adaptation Measures

Two types of response to climate change, mitigation and adaptation, play an equally important role in the transformation toward sustainability: on the one hand, economically effective measures for the reduction of GHG emissions (mitigation) (i.e., replacement of conventional fossil fuels such as coal with low-carbon power such as natural gas or even better renewable energy sources) and, on the other, planned as well as proactive planning and prediction of the impacts of climate change on water resources among which, i.e., using water conservation devices, promoting redistribution of crops with emphasis to set aside water-intensive ones, (adaptation) constitute the set of measures toward climate change.

The more successful the mitigation efforts are in cutting emissions, the less extensive the need for adaptation will be since mitigation reduces the root cause of the climate change problem. However, even if mitigation measures applied succeeded to limit and then reduce GHG emissions, the impact of climate change will challenge the planet for at least the next 50 years which provides the imperative need for adaptation measures in any case. “Limiting temperature increases to 2 °C requires as much as a 50 % reduction in global gas emissions by 2050” (OECD 2011c).

The objective of adaptation is to reduce the risk posed by the impact of climate change. Different strategies of adaptation exist. Climate change adaptation strategies are divided into planned adaptation (Füssel 2007) and autonomous adaptation (Wilk and Wittgren 2009). Planned adaptation explicitly takes climate change and variability into account, while autonomous adaptation (Malik et al. 2010) refers to measures that are not specifically climate related but are used to improve resilience to climate change as an additional effect. Also, critical is the issue of adaptation decisions seen as private (farmer, business, etc.) or public (government, joint agency). A limit to adaptation is a significant discussion that apart from technical and economic constraints entails issues of ethics, culture, and perception of risk and of course the diversity of goals of adaptation that complicates attempts to define limits. How people perceive issues of "risk," "need," and "habit" heavily depends on personal values that are different for various stakeholders in the society.

Depending on the primary purpose of the measures, the range of these measures can become quite extensive. Measures vary depending on the cause they need to confront (e.g., dealing with water scarcity, flood management, etc.) and also depending on different types of intervention that can be used with reference to legislative, administrative, financial, and other policies (Nõges et al. 2010).

While there is no single recipe for a successful climate adaptation policy, the OECD Green Growth Strategy (OECD 2011e) and earlier OECD work (OECD 2009a, 2011a; Duval 2008) summarize the following combination of key elements:

- National climate change strategies, as roadmaps for adaptation.
- Price-based instruments, for example, taxes on CO_2 emissions and subsidies for emission-reducing activities.
- Command and control instruments and regulations, for example, the Resource Conservation and Recovery Act to reduce environmental pressure, the "polluter pays principle," etc.
- Technology-based policies, including R&D and public research. Three types of technological instruments exist and should better work complementarily, hardware, software, and org-ware. Hardware refers to physical tools (reservoirs, rainwater harvesting equipment, etc.). Software refers to the processes, knowledge, and skills required in using the technology (like water recycling techniques), and organizational technologies, or org-ware, apply to the ownership and institutional arrangements about a technology (i.e., water pricing specifications) (Christiansen et al. 2011; UNFCCC 2014).
- Public awareness campaigns and information tools. Well-designed information-based instruments, such as energy/water efficiency labels on household appliances, combined with market-based and regulatory tools, constitute an effective approach (OECD 2007a, b, 2011d).

All the above set of tools, however, could not be successful if applied without taken into account how people and society perceive adaptation and to what extent they are ready to adapt to changes that are in line with broad cultural and ethical values. To gain consensus to implement adaptation measures, social acceptability and education are essential. A significant constraint on adaptation is funding, especially for underdeveloped countries that lack financial resources for adaptation. Also political will is important to choose the right adaptation measures fit into the overall context.

9.1.3 Synergies Between Climate Change Adaptation and Mitigation (A + M)

Indeed, there exist complex linkages between adaptation and mitigation. Some potential water management adaptation measures (e.g., desalination, pumping of deep groundwater, or water treatment) are very energy intensive, and their implementation would increase greenhouse gas emissions (Mata and Budhooram 2007). Afforestation can also contribute to climate change mitigation through carbon sequestration, which may affect, in a positive or negative way, biodiversity and ecosystem services. In general mitigation policies may reduce the impacts and consequently the need for adaptation to climate change. However, there are examples of mitigation measures (bioenergy) which may constrain adaptation options. Interactions between mitigation actions and adaptation to climate change need to be carefully examined and incorporated in any final adopted plan. Many authors have suggested that a more holistic approach to mitigation and adaptation would be more effective and efficient (Ayers and Huq 2008; Klein et al. 2007) and reduce tradeoffs between the two (Kane and Shogren 2000). Moser (2012) advocated for such a holistic approach stating that "the overlap of M + A demands a long-term, life-cycle, and systems perspective." Integration in a collaborative way and balance between mitigation and adaptation measures would provide a safe path toward the alleviation of climate impacts.

Planning processes that take place at higher levels that may include national laws, policies, and strategies, as well as financial means and measures can constitute an acceptable framework for "active cooperation" on mitigation and adaptation measures. Moreover institutional arrangements together with operational programs, projects, and initiatives throughout the country can enhance this effort (Lalisa et al. 2014).

9.2 Adaptation Strategies in the Context of Development

International evidence demonstrates how water scarcity (too little water), floods (too much water), and the lack of basic water and sanitation services and infrastructures coupled with poor water quality can hamper economic growth, lead to environmental degradation, and sharpen social disparities (OECD 2011a, http://www.un.org/waterforlifedecade/green_economy_2011/pdf/). The increase of the global temperature above 2 °C may provoke irreversible changes to the planet. Therefore, it is crucial to maintain the level of increase in global temperature below 2 °C. The global cost of adapting to climate change to a level lower than 2 °C from 2010 to 2050 has been estimated to be $75–100 billion each year (Margulis et al. 2010).

The concept of economic development also entails the notion of "water security." The twofold nature of water as both being a catastrophic and productive power is critical to understanding how investments in water security can support economic development. Reducing the negative economic costs associated with scarcity, flooding, and pollution, and taking advantage of the economic benefits of using water productively, can shove long-term economic development (Quick and Winpenny 2014). In this sense, natural disasters (floods, fires, etc.) should be imported into national capital accounts as a loss, while the protection and restoration of natural disasters, as well as investments in the natural environment, should be introduced as gains in governmental accounting.

According to Shipper and Lisa (2007), there are two approaches linking development and adaptation. In the first, adaptation contributes to development as it promotes the reduction of vulnerability and associated risks and takes climate change into consideration for development planning by improving the resilience of the system. In the second approach, development leads to better adaptation. Bearing in mind that vulnerability is related not only to climatic drivers but to other reasons as well, the most appropriate way is to integrate vulnerability reduction into general development policy.

There are cases where adaptation concerns conservation of status quo while others where the current situation is undesirable and hence adaptation measures are about progress. One can easily understand what is said above, considering the differences that occur between developed and developing countries. Significant disparities can be seen concerning infrastructure, capacity, economy, and sociopolitical implications in both cases.

In developed countries, high level of infrastructure combined with well-coordinated high-quality data and information bases can decrease vulnerability to natural disasters and reduce the adaptation measures, whereas in developing countries, inadequate or fragile infrastructure, low ethos of infrastructure maintenance, and lack of data and databases lead to the need for primary measures (most of them mitigation rather than adaptation measures) to deal with development and uncertainty of climate change impacts.

Speaking of capacity, limited administrative and scientific skills, and centralized systems, the absence of technological advances and lack of financial resources put a hindrance on developing countries in the implementation of adaptation measures. Moreover, high dependence on land and agricultural production and also external help and short term of planning perspective also intensify the already challenging environment in the developing countries.

Moreover, the different sociopolitical conditions, with high population growth, heavy environmental degradation, poorly informed public, centralized decision-making, and the imperative need for supervision in the underdeveloped countries, show the difficulties in adopting those measures.

The interdependency of water with other key domains (energy, food, and ecosystems) stipulates the “nexus” between them. It is important to stress that regional and sectoral conditions determine, at a significant level, the policy options.

9.2.1 Green Economy

Sustainable development is the alternative path between two fundamentally different models that had prevailed in the twentieth century: the "technocratic" one, according to which economic development is the major objective, while social and environmental aspects of development are of secondary importance having, consequently, a complementary role. Natural resources are the means for economic development, and science and technology can restore any apparent damage to the environment. Thus, the protection and restoration of natural systems, according to this model, depends solely on cost and economic feasibility, leading in many cases to the abandonment of the damaged systems, as extremely costly. This "supply-oriented management" practice has led to overexploitation and depletion of natural resources. On the other part, the "deep" ecological approach stated that economic development, through the overexploitation of natural resources, was the main responsible for the ecological disaster of the planet. The contribution of science and technology in human progress was considered as part of the environmental problem of destruction and ecological imbalance and not at all a condition for halting it. Basic in ecological criticism was the ongoing systematic pursuit of economic profit as the driving force of the economy.

In between those two models, sustainable development, as a novel guiding principle, had introduced the notion of "carrying capacity." Sustainable development is a balanced development, among the three pillars, namely, the economy, the environment, and the society, acting in an integrated way and not on a separate basis as up today. Sustainable development supports development that is compatible with the limitations imposed by nature. It introduces the carrying capacity of ecosystems as the "red line" for the management of the environment and stimulates the adjustment of economic development into nature's adaptive capacity. Sustainable development exemplifies the reorientation of economic activities toward resource conservation and protection. This "limited" "under condition" development, however, is incapable to effectively respond to current conditions of economic crisis, poverty, unemployment, and recession, which ask for "more development."

As it is set, in the twenty-first century, a twofold crisis is witnessed based on just one reason: an economic crisis and in the same time an environmental one, both caused by the dominant aggressive economic development model. The current foremost development model, based on the unbounded use of resources to meet demands, has directly resulted in overexploitation and overconsumption. Neither has it solved the problem of poverty (social sustainability) nor the problem of healthy ecosystem services (ecological sustainability). In fact, the current development model born in the era of globalization of the economy is based on the abolition of borders for the circulation of goods, capital, and labor, on the inequality of wealth contribution – in the hands of "the few" strong lobbies – and on the immense socioeconomic differences. This new context of economy and development did not answer to the problem of poverty alleviation (MDG goal) nor to that of preserving and enhancing the environment. On the contrary, it has caused severe deterioration and exhaustion of the global ecosystem, undermining hence not only the ability of future generations to meet their needs but posing an immediate risk even to today's survival of the inhabitants of our global system. In fact, the well-being of the 25 % of the world's population costs the depletion of the 70 % of global natural capital. And this means that if we decide to continue the same economic development policy, three planets like earth would be needed to sustain this development.

Undeniably, all multiple crises, namely, financial, economic, climate, energy, ecosystems, and demography of the twenty-first century, compel us to think of a radical transformation of the economy. The transition to sustainability calls for the shift to green economy–green development. The green economy appears as the follow-up to sustainable development. Clearly the principles are the same. The way to achieve them may differ.

9.2.1.1 Selected Definitions of Green Economy and Green Growth

European Environment Agency: "A green economy is one in which policies and innovations enable society to use resources efficiently, enhancing human well–being in an inclusive manner, while maintaining the natural systems that sustain us" (http://www.eea.europa.eu/themes/economy/about-green-economy, EEA 2012).

OECD: "Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well–being relies. To do this, it must catalyze investment and innovation that will underpin sustained growth and give rise to new economic opportunities" (http://www.oecd.org/greengrowth/48012345.pdf, 2011).

UNDP: "[. . .] new growth poles that can potentially contribute to economic recovery, good job creation, and reduced threats of food, water, energy, ecosystem and climate crises, which have disproportionate impacts on the poor" (http://content.undp.org/go/newsroom/2009/june/green-economy-a-transformation-toaddress-multiple-crises.en).

UNEP: "[. . .] a green economy is one that results in improved human well–being and social equity while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low-carbon, resource efficient and socially inclusive. Critical to attaining such an objective is to create the conditions for public and private investments to incorporate broader environmental and social criteria. A green economy is one whose growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services" (www.unep.org/greeneconomy).

World Bank: "[. . .] green growth — that is, growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters. And this growth needs to be inclusive" (http://siteresources.worldbank.org/EXTSDNET/Resources/Inclusive_Green_Growth_May_2012.pdf).

Green economy can, indeed, introduce a sustainable economic development model, where environmental aspects are no longer constraints, but rather become incentives for development and, therefore, should be incorporated into the development goals and objectives.

Whatever the definition of green development is, three objectives underline the green economy approach: improving *resource efficiency*, ensuring *ecosystem resilience*, and enhancing *social equity.*

The transition toward a "new development model" requires investment in the sustainability of ecosystem services upon which the world depends on and actions so that the environment can continue to be used for the benefit of current and future generations. The environment is the fundamental bottom line, as without a safe and stable environment we can have no economy or society. The sustainable use of natural resources and the environment has to be the core concept of economic growth, while the perception of endless resource exploitation should be replaced by resource efficiency. Crisis can turn into an opportunity, regarding fostering a new development model on the environment and with the quest of also investing in cultural and moral values for the pursuit of prosperity and people's well-being.

The new development model should rely on economic activities based on the comparative advantages of each country. This happens because the only way to balance economic, environmental, and social aspects of the development would be to base the economy upon activities that are fully compatible with the carrying capacity of the ecosystem. Hence, development should rely on products and activities fully compatible with the local conditions, such as the climate, the environment, the tradition, and the human resources. Instead of promoting, in the case of Greece, for example, the construction of water-consuming golf courses in Greek islands, which face severe water scarcity problems, Greece should invest in its Mediterranean diet and local agricultural products, such as olive oil, wine, grapes, and fruits, in its cultural heritage, biodiversity, and natural beauty. This is after all the principal of demand management, according to which demand should be adjusted to the limits of the carrying capacity of the systems. According to the premise of water sustainability, water demand should be in line with the real potential of water resources.

Moreover, the environmental objectives can no longer be a barrier but an incentive for development. The new development model needs to incorporate the reduction of consumption regarding demands, especially in the developed West, redirecting consumption toward more efficient paths and redistributing resources to the "poor" nations.

The twin challenges of resource efficiency and ecological resilience lie at the heart of achieving a green economy (SOER2015).

A transition to sustainability demands serious changes in the way people perceive the boundaries of the earth. A critical change is needed in "habits," "wants," and "needs" in the face of a diverse world (W. Adams, and S. Jeanrenaud, 2008).

The green economy is a total conversion of the current socioeconomic paradigm into a new development model, accepting environmental and social values equal to economic values according to UNEP (2011a). In economic terms, it involves the integration of social and environmental "externalities" into the market system, with all its consequences. The green economy will need to be interpreted and applied by national governments as a suite of policy measures selected and designed by national priorities and circumstances (UNDESA 2012).

Social issues such as sustainable consumption, equitable access to natural resources and ecosystem services, green jobs, and fair distribution of taxes are predominant to achieving a green economy.

The main characteristics of green economy are:

(a) Decoupling natural resource use and environmental impacts from economic growth

Decoupling is about "shifting from debt-financed consumption as the primary economic driver of our economies which proved to be unsustainable, to sustainability-oriented investments in innovation as the leading economic driver of our economies" (UNEP 2011b). This process of decoupling requires concentration both on resource efficiency innovations and environmental sustainability boundaries, expressed by the concept of "environmental flow" for securing the ecosystems' good status (EEA 2012).

Tools for achieving decoupling:

The application of environmental policy such as environmental certificates of use, Life Cycle Assessment (LCA), and Environmental Impact Assessment (EIA)
The introduction of "clean" technologies for the production of environmentally friendly products, for the reduction of the gas emissions
Public environmental awareness by establishing responsibility for users in case of environmental damage (polluter not only pays principle but also restores)

(b) Conservation through resource efficiency technologies that can enable users in different sectors to reduce water use and/or promote sustainable water use

Tools in this direction:

The positioning of public opinion through education and information campaigns
The encouragement of reuse and recycle

Also thanks to the use of improved and more efficient technologies, lower inputs of material and energy result to lower output of pollutants and higher environmental protection. Examples of such technology are drip irrigation systems, bioclimatic buildings, electric cars, etc.

A major drawback, though, is the "rebound effect." Efficiency gains in resource use may lead to more use of other resources (indirect rebound) or more use of the same resource (direct rebound). Efficiency improvements might bring about outputs cheaper. Some illustrative examples of "rebound effect" are the use of energy-saving devices (for heating) which can be left open several hours because they consume small amounts of energy. In the case of water, the spread of drip irrigation and the consequent saving in water/unit may end up to the expansion of irrigated land, putting in danger the groundwater reserves.

(c) *Creation of employment* (green jobs) through projects and environmentally friendly activities. Green jobs also refer to implementing and evaluating sustainable business practices, to promote job opportunities for environmental services and also to provide education on how to turn "green" in business. Sectors, where green jobs are possible, are sustainable agriculture, ecotourism, water treatment and management, environmental law, and "clean" energy. Specifically, in the water sector, green jobs are those that save water and energy while alleviating pressure on water infrastructure. Some examples include plumbers, water auditors, and low-flush water equipment installation.
(d) *Interference of the state* to secure economic development, environmental protection, and social equity. Economic instruments, such as taxes, subsidies, and tax exemptions, are used together with legislative instruments, namely, environmental quality standards (min allowable limits), and financial penalties.

In addition to these policies are the combination of capacity, the dissemination of good policy practice, and general education and awareness to make sure that green measures are well designed, implemented, enforced, and understood, without causing unintended impacts or being prevented by practical or political challenges (UNEP 2011).

Opposing green growth, there is a growing interest in the idea of "degrowth" (décroissance). "Degrowth" is an ethical concept of how the world needs to change. "A society of infinite growth is impossible in a finite world" Latouche, S. (2004). The degrowth concept relates the social and ecological questions of distribution, with the reduction of consumption and production to secure social rights for everyone.

The degrowth movement refers mainly to the reduction of overconsumption of energy and materials and advocates that economic degrowth is a necessary step in the transition to a more sustainable society. It connects micro-practices with macroeconomic concepts and a solidarity-based economy of "commons." For degrowth economy, the fundamental criterion is of sharing resources and not their individual possession. The idea of a just degrowth economy invests in everlasting ethical values of equity, solidarity, and freedom beyond the dominance of the existing ruling economic system. The current lifestyle can provide bigger houses but smaller families, more conveniences but less time to enjoy, more degrees but less understanding, more knowledge but less judgment, and significant progress in new medications but less "health."

9.2.2 Sustainable Use of Water in a Green Economy

The transition to a green economy requires new thinking about water and its management. Water needs to be seen as an integral part of the ecosystem, and as such, solutions should revolve around maintenance of ecosystem services, reallocation among sectors, true cost price, and public engagement in all stages of decision-making. Using water efficiently, making it available to all at a reasonable cost, and ensuring environmental sustainability of ecosystems consist the “puzzle” of sustainable water management.

In fact, sustainable water use requires the management of the water balance, also known as water inventory, in a river basin. Water use should rely solely on the actual consumption of available renewable water resources to serve water needs for various purposes. Sustainable water management should integrate all sectors to guarantee that all relevant water uses are satisfied within the sustainability limits of the river basin. The application of the fundamental principles of sustainable water management guarantees the sustainability of the resource. IWRM can act as a tool for implementing sustainable water use by incorporating the various aspects of all uses in an integrated and not fragmented way, by implementing demand management and accurate pricing policies, and by enabling the active participation of all interested users (stakeholders). Most significant differences in IWRM goals between the developed and the developing countries are summarized in Table 9.1.

It should be put emphasis on these differences because they are critical for the stimulation of the green economy since there exist major priority differences between countries and even between river basins. The role of water in the green economy is implicitly argued in UNEP, GWP, WWC, UN-Water, and other international organizations and forums.

There are certain measures applied in the water sector to favor both ecological and social sustainability. The most common types of measures are (UN-Water 2011):

- Economic instruments such as green taxes, green accounts, water markets, and pollution rights
- Innovative technology such as drip irrigation in agriculture, waste reuse in water treatment, and conservation technologies for urban use and tourism such as low-water-pressure devices
- Financing of water infrastructure in the form of reform of charges for water-related services and public–private partnerships

Table 9.1 Differences in IWRM goals between the developed and the developing countries

Developed countries	Developing countries
Coherent planning	Poverty reduction
Resource use efficiency/bulk private sector investments	Access to clean water/water supply and sanitation basic infrastructure
Flood control/irrigation	Flood control/irrigation/drainage
Watershed protection and management	Waterborne diseases
Hazard risk reduction plans	Rural development plans
Participatory planning	Water user associations for operation and management
Advanced technologies	“Proper” technologies

- Improved water resources planning with the emphasis on water utilization and protection, policy integration and institutional and legal frameworks, and water governance across all economic sectors

There is also ample criticism on whether green economy truly enhances sustainable water use and management. Those opposing the idea of this development model argue that too much emphasis is given on the role of the private sector and too little on the responsibilities of the state to supervise the sustainable use of natural resources (Die 2012).

Three primary drivers are behind water investments: expanding the water supply, increasing water supply efficiency, and improving water quality. All entail innovative companies specializing in water technologies that could represent some of the world's biggest capital growth opportunities. "The global market for environmental services and products" *is expected to triple by 1.37 trillion $/year to 2.47 trillion $ until 2020.* Primary sectors involved are energy, water, transport, and wastewater (Allianz Global Investors 2013). Today the water industry is considered as the third most profitable business after oil and electricity (Global Water Intelligence 2013).

Another risk reported is that of imposed prices for water, which may threaten food security, obstruct access to water supply and sanitation, and increase poverty (Die 2012). Privatization of water for municipal use is one indicative example that has led to unbearable increases in the water prices (200 % up in Bolivia).

The critical interactions that concern the water-energy-food nexus should be carefully analyzed, conflict of objectives must be discussed, and priorities should be set. Many of the measures proposed are in question concerning their effectiveness. In arid regions, for example, freshwater is being produced by the desalination of seawater using fossil energy sources. The replacement of conventional sources by renewable ones, such as solar radiation, abundantly found in many dry countries, could convert this negative example into a positive one if renewable solar energy is used (Die 2011).

As water is central both to the quest for sustainability and to economy, it will also be central to innovative solutions for the "greening" of the economy. Organic farming and ecotourism are examples of economic activities that harmonize perfectly with the spirit of a "green" water policy. The application of any adaptation measures, however, will not be achieved with supply management options such as large structural projects, (dams and river diversions), but rather with the right combination of a series of nonstructural measures and policies that ensure the integration of environmental considerations into economic goals.

Sectors like agriculture, water supply/treatment infrastructure, tourism, energy, and industry are interrelated to water efficiency practices. The list of policy responses and the methodologies used are not exhaustive, but the objective is to get an idea of possible methods and applications in the water sector about green development and green growth.

Among the requirements for a successful policy reform are the acquisition of relevant data and meticulous study and analysis for evaluating policies. Methods may be quantitative (cost–benefit analysis, integrated assessment modeling, and multi-criteria analysis, DPSIR, LFA) or qualitative (surveys and participatory approaches) (IPCC2014).

New metrics is available, such as ecological, carbon, and water footprint (WF), which is easy to communicate and hand over the urgency of the global problem, raising public awareness. In the case of the water problem, the water footprint can successfully calculate the direct and indirect water use. However, no single best method but rather a combination of structural and nonstructural methods can provide a comprehensive decision policy. One should carefully consider the overall context, the boundary conditions, and different complexities to avoid poor policy decisions.

9.2.3 Applications

9.2.3.1 Organic Farming as a Form of "Green" Agriculture

Organic farming is the process of producing food naturally. This method excludes the use of synthetic chemical fertilizers and modified organisms to facilitate the growing of crops, being an environmentally friendly approach.

The accreditation of a product that comes from "organic farming" is provided on a certain label. When it comes to selecting food products, certification is needed, to prevent the incorrect usage of the term "organic." Certification procedures help to ensure that the relevant standards regarding production and processing have been met.

Advantages of this method are that the food produced in this manner is considered to:

- Be of higher quality.
- Have higher nutritional value as opposed to producing food using modern, industrial practices.
- Contain no chemicals, artificial fertilizers, or pesticides.
- Contain no genetically engineered or altered substances or organisms.
- Minimize soil erosion.

Organic farming uses less water than conventional farming and replenishes the soil with vital nutrients. Also, the reliance on natural pesticides allows an organic farm to use wasps arriving at certain seasons during the year to eliminate other pests.

A farm in Jordan performed a study, finding that the water in the underground aquifer beneath the farm could irrigate 400 dunums of land, but through the use of water saving techniques, the farm uses the same level of water for irrigating 2,500 dunums (Luck, T. 2010). Concurrent measures for supporting organic farming in Jordan from the Jordan River Foundation were:

The establishment of a legislative framework for organic farming, the examination of already existing organic farming sites, the increasing awareness and knowledge of organic farming through workshops, and the supporting organic farming in both the public sector and NGOs (JRF 2007)

Despite the growing world demand, organic farming has not taken off in Jordan and has remained a niche product mainly due to a lack of appropriate policy incentives and institutional support, training on innovative agricultural practices and awareness. More information can be found in UNEP (2011), "Towards a Green Economy in Jordan."

9.2.3.2 Trading of Water Rights

In Australia, in the Murray–Darling Basin, which is under severe scarcity conditions, an expanding market for the trading of water use rights has enabled water to be allocated efficiently among users, generating significant economic gains (http://www.un.org/waterforlifedecade/green_economy_2011/pdf/resume_day_1.pdf). The Australian government introduced the National Water Initiative, under which water trading allows scarce water resources to be transferred to their most productive uses. Over a decade, a progressive water reform has provided the framework for the country's market-based approach, illustrating the lengthy process of setting up the infrastructure necessary for a market. Two critical success factors were the decoupling of water rights from land rights and making water rights proportional shares of available resources rather than fixed volumes. Environmental sustainability is ensured through the purchasing of water rights for the environment (UN 2011).

9.2.3.3 Karnataka Watershed (Sujala) Project, India

This example is but one of the many programs financed by the World Bank, on watershed management and poverty alleviation in rain-fed areas of India. A system approach, with a focus on soil and water conservation and sustainable resource use, combined with participatory planning and participation to improve local livelihoods, gender equity, and community capacity, was performed in India. Monitoring and evaluation were an essential facet of the program. The Indian Space Research Organization (Antrix) conducted the work. A set of different technological tools, namely, remote-sensing data with on-the-ground monitoring techniques combined with a household survey with baseline and control group, participatory observations, regional studies, and other case studies, were used. Indicators to measure quantitative and qualitative issues, before, during, and at the end of the project, were studied. The work also included a complete database, with reliable data and timely information useful to monitor the progress of the project (financial and physical) all levels. In the end, a broad range of data together with a set of reports were given to program managers and beneficiaries (World Bank 2013).

9.3 Adaptation Policies

Adaptation needs to be structured across sectors, in multilevel and interregional activities bringing together stakeholders with different levels of expertise, interests, and values (Grothmann 2011; Lebel et al. 2010). Adaptation policies can be classified (Table 9.2) according to various types of services.

In defining adaptation policies, it is extremely useful to identify priority measures. In doing that, it is important to explore which adaptation measures are of the highest priority and which complementary actions should follow. Successful adaptation should take into account not only the impacts of climate change but also how other non-climatic (socioeconomic, political, etc.) stresses affect the system and take measures for both cases.

Local conditions and local stakeholders are the most relevant to choose the analytical tools and approaches of critical economic, environmental, and social drivers. The interactions between the different sectors, the scale, and speed of change required as well as the actions that need to be taken over time, along with uncertainties, should shape the process of adaptation. These measures will confront high vulnerability and uncertainty. Problems are encountered because most of the time the government decides the adaptation measures, but local stakeholders need to implement them.

The results of the vulnerability assessment are the basis of the measures chosen. Of great importance is the involvement of stakeholders because any ranking of adaptation measures will involve those that affect and are being affected by those actions. Active engagement of stakeholders will provide accurate feedback of needs and the level of acceptance.

Table 9.2 Adaptation policies according to various types of adaptation

Adaptation			
Purpose	Planned (refers to a deliberate action to respond to change)	Autonomous (by sectors, by regions)	
Time component	Proactive (before the change to minimize the effects)	Reactive (after the change to adjust to new conditions)	
Space component	Local	National	International
Motive/interest	Public (government and all relevant public agencies)	Private (individuals, business, corporations)	
Type of measures (responses)	Structural (infrastructure)	Legal (laws, regulations)	Financial (taxes, subsidies)
		Institutional (establishment of relevant bodies to guide response to climate change)	Technological
Temporal scope	Short term (direct effect)	Long term (future impacts)	

To achieve short-term "win–win" strategy and also to support long-term changes, the application of a combination of policy instruments is crucial. Short-term changes will increase the strength of existing water systems, while long-term changes will deal with plans of high uncertainty. Measures may include price signals for water conservation, regulations, and standards that sustain changes in various practices and information and education programs to build public awareness.

9.3.1 Stakeholder Process

Decisions in water resources management are uncertain, and rational arguments arise within interested parties because the members of each party understand a problem from different viewpoints, even when they have similar interests in achieving a goal. To gain consensus, the participation of stakeholders in the decision-making is central especially in the implementation stage (Gardner at al. 2009).

"The term "stakeholder" in climate change studies refers to policy makers, scientists, administrators, communities, and managers in the economic sectors most at risk" (Engaging Stakeholders in the Adaptation Process. http://www4.unfccc.int/nap/Country%20Documents/General*)*. In this context, stakeholders can be brought together from both public and private sectors to develop a shared understanding of the issues and to create adaptations.

Benefits of Participation

- Better informed decisions: Stakeholders can express and exchange different views and find common ground in discussions that may lead to better-informed decisions.
- Transparency and wide representation in a democratic way in decisions: By involving people who are affected by the decision, a broader agreement can be sought, which will potentially increase support for implementation.
- Cooperative action, the capacity to work together and to create mutual trust.

Stakeholder analysis improves the understanding of the economic, social, and political impact of adaptation measures on interested groups, namely, authorities from local and regional administrations and decision power links. The engagement of various stakeholders requires a uniform awareness of climate change impacts for attaining consensus for implementation of the chosen adaptation policy.

True participatory processes across sectors and scales are meaningful when stakeholders at different levels of action can express their opinions, share their knowledge, and elaborate in real decision-making. Top-down strategies are no more the solution to the problem. Adaptation strategies will only work if they fit local conditions. Stakeholder processes include questionnaires, small group discussions, roundtables, application of CVMs, etc.

Basic keywords for stakeholder and participatory processes:

Stakeholders – Who are they? Why are they essential for consultation? What is their status of influence in decision-making?
Priority issues – Of high risk, high vulnerability, high sensitivity to climate changes
Techniques – Which techniques and methods will be most effective in communicating with the different stakeholders?
Documentation – How will the results of the process be used?

9.3.2 Vulnerability Assessment

Several aspects related to water management compile the vulnerability issue. Environmental degradation, lack of ecosystem resilience, economic inequalities, insufficient funding, lack of civil resistance, inadequate social protection, lack of preparedness, and not enough training are among the most common reasons for the high vulnerability of water resources management in the era of climate change. Underdeveloped regions are traditionally more vulnerable to climate change since their level of adaptation is relatively low.

The vulnerability of a given system is related to its physical exposure to climate change effects and its adaptive capacity to these conditions (Allen 2005). Systems that have a lower potential impact from changes in climate and climate variability, and those that have a higher adaptive capacity, are considered less vulnerable to climate change and vice versa.

A common methodology to assess vulnerability is by using DPSIR framework. The main drivers lead to pressure parameters that determine the state of the system, the potential impact of changes, and, of course, the response in the sense of adaptation measures. Relevant indicators measure the sensitivity of the system and the exposure to rank the system regarding high or low vulnerability to complex risks.

9.3.3 Review of Institutional and Regulatory Framework

There are almost 804 laws and policies according to Global Legislative 2015 from 99 countries that represent the 93 % of GHG emissions.

"A framework law is defined as a law, or regulation with equivalent status, which serves as a comprehensive, unifying basis for climate change policy, addressing multiple aspects and issues of climate change mitigation or adaptation (or both) in a holistic, overarching manner" (Global Legislative 2015, http://www.lse.ac.uk/GranthamInstitute/legislation/the-global-climate-legislation).

To effectively implement adaptation policies, we need to have strong institutions (national ministries, regional management entities, local authorities, etc.) which can adjust to changes needed to reinforce their adaptive capacity. Institutions are responsible for a variety of actions that are related to climate change. They allocate water; control infrastructure, such as dams and networks; and apply laws and policies (for droughts, floods), so they should be resilient and adaptive. Institutions can orient behaviors and constrain policy-making since they also influence political decisions. Of course at the same time, they can promote policy implementation of adaptation measures in many ways.

A good idea would be to establish new independent sectoral bodies dedicated to work on adaptation to climate change. These bodies may consult institutions how to apply necessary adjustments in all levels efficiently.

Regulatory adaptation measures to cope with climate change mainly consist of reviewing existing legislation and regulations to address climate impacts. For example, to deal with water scarcity problems, abstraction limits or restrictions on water uses are imposed. Also updating regulations on land use and standards for urban planning may address flood risk.

9.4 EU Adaptation Policies

9.4.1 EU Policies to Confront Climate Change

The European Union has a long history of environmental policies and has produced a considerable number of legal and guidance documents, forming a robust integrated water resources management system. Although integration is a central notion in EU, "EU policy mitigation and adaptation policies are likely to remain separate endeavors" (Responses-Frans Berkhout et al. (2013)).

Specifically, The European Union's mitigation strategy, known as "20-20-20 Energy and Climate Package," adopted in January 2008, is an example of a comprehensive and legally binding climate strategy with three different objectives:

1. Reach a reduction of GHG emissions by at least 20 % compared to 1990 by 2020, with a commitment to increase it to 30 % with a satisfactory international agreement.
2. 20% of energy is coming from renewable sources by 2020, supplemented by 10% of renewable transport fuel.
3. Reduce the European Union's energy consumption by 20% compared to the baseline in 2020.

On 23 October 2014, the European Council (2014) endorsed a binding common target for the 28 member states of the European Union of "at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990."

By defining a clear, long-term goal to limit the increase of global temperature to 2°C or better to 1.5°C by the decrease of greenhouse gas emissions and zero overall global emissions in the second half of this century, representatives of 196 countries, in Paris, (COP21), have set a path to decouple the prosperity and development from fossil fuel use. Maybe the EU needs to redefine its mitigation goals, accordingly.

Sectoral policies were enhanced with complementary adaptation measures. Sectors that are mainly affected by climate change and discussed below are water, agriculture, and biodiversity.

A set of key policy documents, related to water, namely, the WFD, Floods Directive, EU Adaptation, White Paper, and adaptation to climate change in water management, followed by relevant regulatory and economic policy instruments, such as Nitrates Directive, CAP, Urban Waste Water Directive, Natura 2000, Integrated Coastal Zone Management, etc., work complementarily as a roadmap to adaptation. R&D programs (FP7, FP8, etc., Joint Research Center) and financial mechanisms for funding (LIFE, EU Cohesion Funds, etc.) also support this effort (OEDC 2013). In detail:

- The EU's Biodiversity Strategy (COM (2010) 244 final) aims at pausing the loss of biodiversity and the degradation of ecosystem services by 2020 and restoring them.
- The White Paper "Adapting to climate change: Towards a European framework for action" (COM (2009) 147 final) sets out the EU framework for adaptation to climate change, including objectives and actions.
- The Soil Thematic Strategy (COM(2006) 231) and the proposed Soil Framework Directive (COM(2006) 232 final) have as the main objective the protection and sustainable use of soil resources.

For successful adaptation, cross-sectoral coordination needs to be further developed.

9.4.2 The EU Water Framework Directive

The Water Framework Directive (WFD) is a legal act (Directive 2000/60/EC) based on the principles of IWRM. The overall system provided by the WFD is based on the central concept of integration. Integration is a fundamental notion for all water resources, environmental and ecological objectives, water uses, functions and values, interdisciplinary analyses and expertise, and different decision-making levels within a common policy framework. The ultimate goal is "the good ecological status" for water bodies. Physical rather than administrative boundaries in the sense of management at river basin level represent a significant innovation (Kolokytha E. 2011).

The EU WFD through the 3Ps signifies an important step toward the sustainable use of water resources in Europe:

- Planning and integrated management
- Pricing and actual cost recovery
- Participation and improved decision-making

It is a principal legislative instrument that indirectly promotes climate adaptation policies through its step-by-step procedure of the different planning periods of implementation. The analysis of identified environmental pressures (Art. 5) in conjunction with the climate impact sensitivity of the programs of measures incorporated in the river basin management plans is the first step. The program of measures refers to a set of operations, including legal, control, and administrative initiatives, contained in the river basin management plans, contributing to the implementation of the WFD. Each measure may include various actions or initiatives that can be used to mitigate the effect of pressures on water caused by the different sectors.

The set of measures should be effective, sustainable, and cost-efficient to respond to changing conditions. In the second planning cycle, climate change impacts should be directly taken into account. A variety of complementary directives, addressing sectoral differences (CAP for the agricultural sector, energy directive in energy, etc.) and also specific impacts of climate change (Flood & Drought Directive, Biodiversity Directive), are present to cover the issue of climate change.

Opportunities given to the WFD river basin management planning for developing climate change adaptation policies have provided the reasoning for a guidance document, under the Common Implementation Strategy (CIS) (EC 2009). This guidance document sets out a framework to reduce EU's vulnerability to the impact of climate change.

9.4.3 The Common Agricultural Policy (CAP)

Agriculture in Europe accounts for around 33 % of total water use and is the largest source of nutrient pollution in water" (EEA 2012).

The vital role water plays in agricultural activities and the need for water protection render the necessity to look for synergies in modern agriculture and water policies. CAP, an important financial instrument, has been through a history of 50 years of reforms, trying to incorporate all global challenges, to sustain agriculture in Europe (Fig. 9.1). "Green" agriculture requires physical capital assets, investments in research, and capacity building to enhance soil fertility to achieve sustainable water use, crop and livestock diversification, and appropriate farm level automatization.

9.4.3.1 Typology of Terms in CAP

GAEC standards: The obligation to maintain land in good agricultural and environmental condition refers to a range of standards related to soil protection, maintenance of soil organic matter and structure, avoiding the deterioration of habitats, and water management.

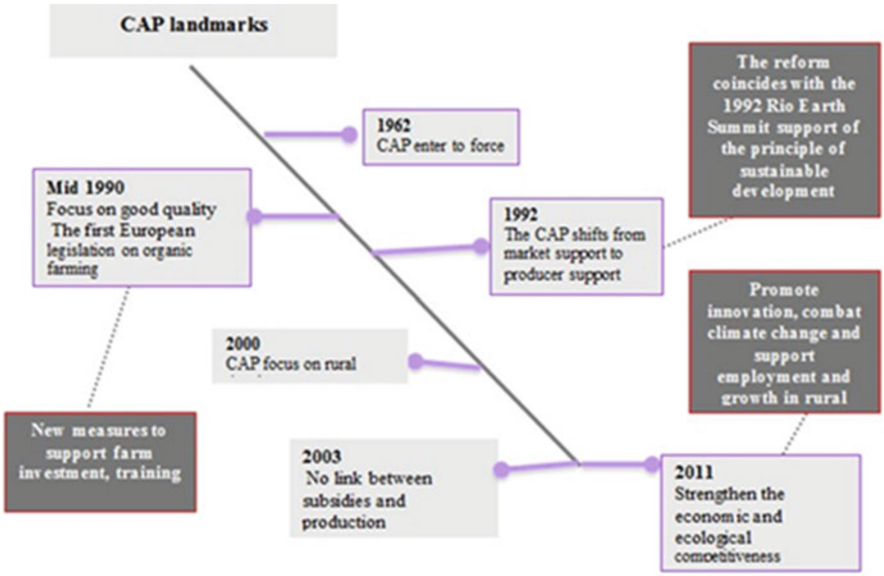


Fig. 9.1 CAP landmarks

Cross–compliance: A mechanism that ties direct payments to farmers and some rural development payments to compliance with a series of rules relating to the environment, food safety, etc., to maintain GAEC.

Direct payments: Payments granted directly to farmers under an income support scheme.

The need to address the challenges of climate change has been recognized, particularly in its rural development policy (the European Agricultural Fund for Rural Development – EAFRD). Currently, two CAP instruments (cross–compliance and the European Agricultural Fund for Rural Development) are used to encouraging good farming practices that are compatible with the protection of the environment and in line with related environmental legislation (EU Nitrate Directive http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0676).

In 2013, in fact, the CAP had introduced the main three objectives of viable food production, sustainable use of natural resources, and climate action. Territorial development challenges presented by climate change are signaled as an important priority for the CAP, in keeping with the priorities of the EU 2020 strategy (http://ec.europa.eu/agriculture/cap-overview/2012_en.pdf).

In the CAP, aid is provided at rural development measures promoting environmentally sustainable farming practices, like agri-environment schemes. Also a reduction in support payments is promoted for those farmers who don't respect environmental laws (http://ec.europa.eu/agriculture/envir/index_en.htm).

The most relevant EU policies to tackle extremes events (floods and droughts) are:

9.4.4 The EU Floods Directive (Directive 2007/60/EC)

The Floods Directive (2007/60/EC) is included in a larger "Flood Action Program" for the assessment and management of flood risks aimed at reducing the adverse consequences for human health, the environment, and cultural and economic activity associated with floods in Europe.

The Flood Directive's goal is to reduce and manage the risk from floods. The directive requires member states to perform a preliminary assessment by 2011 to detect the river/coastal basins which may have the risk of probable flooding. For such zones, flood risk maps should be developed by 2013, while by 2015, flood risk management plans should be made focused on prevention and preparedness. The directive is in line with the Water Framework Directive.

9.4.5 The EU Water Scarcity and Drought Strategy (COM (2007) 414)

The EU Water Scarcity and Drought Strategy (COM (2007) 414) aims at the identification of the extent of water scarcity and droughts in Europe and functions as a roadmap for the assessment of existing and potential selected measures for tackling water scarcity and droughts.

To confront the risk from extreme events, also CAP, through specific cross-compliance regulations (tillage practices to hold moisture in the soil), is indirectly linked.

9.4.6 The Biodiversity Strategy (COM (2011) 244)

In 2011, the EU adopted an ambitious strategy setting out measures and investments (six targets and twenty actions) to pause the loss of biodiversity and ecosystem services in the EU by 2020.

The synthesis of the review of the strategy for water scarcity and droughts, the analysis of the implementation of the Water Framework Directive, and the review of the vulnerability of environmental resources produced "The Blueprint to Safeguard Europe's Water Resources" (COM(2012)673 which is consistent with Europe 2020.

9.5 From Theory to Practice

9.5.1 A Case Study from Greece

An application of nonstructural adaptation measures to cope with climate change impacts in agriculture is performed. The water footprint is a new metrics that can easily communicate issues of water scarcity and water pollution to a broad audience (raising awareness) to stress these water problems. The new EU Common Agricultural Policy (2014–2020) is an important adaptation policy for the “greening” of agriculture. These two adaptation instruments are tested in Mygdonia river basin, Central Macedonia, Greece. The water balance of the Mygdonia basin is constantly negative, indicating that water management in the area is being unsustainably performed. The WF assessment can alter the change of behavior of the main stakeholders, the farmers, and urges the agricultural community to take appropriate measures to cope with water scarcity and water pollution problems in the area. Also by taking into consideration the provisions of the new CAP, the formulation of two possible scenarios provides viable solutions for the sustainable agriculture in the area.

9.5.1.1 The Area Under Study

The Mygdonia basin covers a total area of 2.026 km^2 and comprises two subbasins, namely, Koronia and Volvi lakes. The economic development of Mygdonia basin depends primarily on agricultural activity while cattle breeding is also well developed. The water-consuming crops, the excessive use of fertilizers, and the wasteful irrigation systems have led to the almost vanishing of Lake Koronia and significant widespread water pollution of Lake Volvi. The highly negative ($-20x10^6$ m^3/y) annual water balance of Mygdonia basin (Greek Ministry of Development 2008) reveals the unsustainable water management of the basin.

http://kyrcha.info/2013/04/18/tutorials-calculating-the-fractal-dimension-of-the-greek-coastline-1-25

The agricultural area covers a total of 406.000 acres scattered between 14 municipalities. The cultivation of wheat, sunflower, and maize is among the most encountered crops, occupying the area (Fig. 9.2). The calculation of the total water footprint (WF) of all crops in Mygdonia basin is presented, by analyzing its components (blue, green, gray). Data of farmland area and crop production were provided by the Agricultural Department of Central Macedonia, Greece, for the year 2011.

Blue Water Footprint refers to the volume of excess water from surface and groundwater resources being used during production,which is the irrigated water in the case of crops. Green water footprint expresses the amount of rainwater used during production. Gray water footprint reveals the amount of freshwater

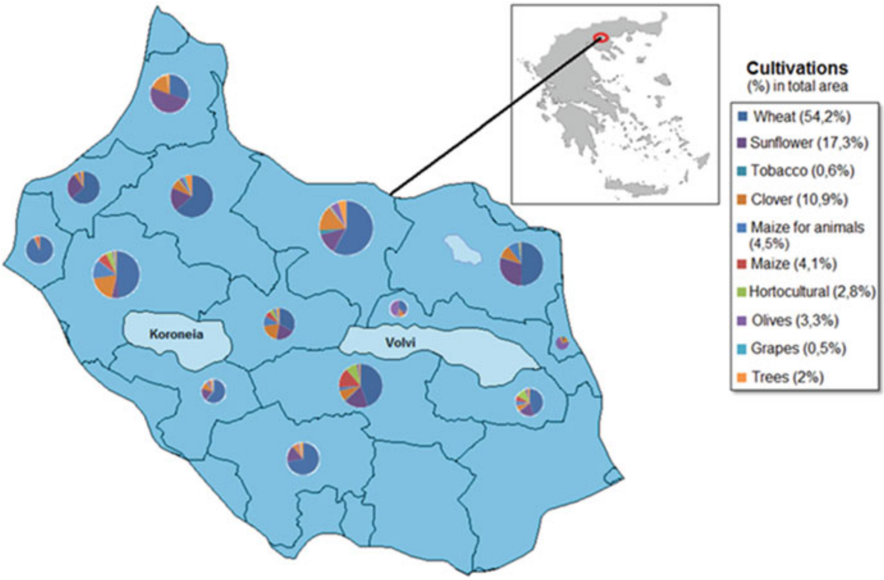


Fig. 9.2 Crop distribution in Mygdonia Basin

Table 9.3 Typology of methodology for the calculation of WF of crops

Water footprint		
$WF = WF\text{green} + WF\text{blue} + WF\text{gray}$ (m3/ton)		
WFgreen	WFblue	WFgray
$WF\text{green} = CWUg/Y$	$WF\text{blue} = CWUb/Y$	$WF\text{gray} = \left[\frac{a*AR}{C\max - C\text{nat}}\right]/Y$
where	where	
$CWUg = \Sigma Ug$	$CWUb = \Sigma Ub$	
$Ug = \min(ETc,\ Peff)$	$Ub = \max(0, ETc - Peff)$	
$ETc = Kc * ETo$		
$ETo = p\,(0.46 * T\text{mean} + 8)$		

that is required to dissolve a load of pollutants based on existing water quality standards (Mekonnen & Hoestra 2011, http://waterfootprint.org/media/downloads/Mekonnen-Hoekstra-2012-WaterFootprintF).

Total water footprint (WF) in m^3/tons of the major crops along with its components (green, blue, and gray water footprint) was calculated based on the methodology applied by Mekonnen et al. (2011). Critical parameters are crop evapotranspiration and yield, required for the estimation of the green and blue water footprint. Those parameters have been calculated following the method and assumptions provided by Allen et al. (1998) and also applied by FAO.

To calculate the total WF, one needs to calculate each one of the three WF components, expressed by the equations in Table 9.3 separately.

Where

CWU_g: green water use (m^3/acre)
CWU_b: blue water used by the crop (m^3/acre)
U_g: monthly green water demand (m^3/acre)
U_b: monthly blue water demand (m^3/acre)
Y: crop yield (ton/acre)
P_{eff}: effective rainfall (mm/month)
ET_o: reference crop evapotranspiration (mm/day) as an average for a period of 1 month
ET_c: potential evapotranspiration of the cultivation (mm/day)
T mean: daily mean temperature (°C)
p: mean daily percentage of annual daytime hours
K_c: crop coefficient that depends on climate, type of crop, and stage of development
C_{max}: maximum acceptable concentration of nitrogen (kg/m^3)
C_{nat}: the natural concentration of nitrogen in the receiving water body (kg/m^3)
a: nitrogen that leaches or runs off
AR: nitrogen application rate (kg/acre)

The total use of green water (CWU_g) for every crop is the sum of the monthly green water demand (U_g), yearly. Its value depends on the crop evapotranspiration and the total available amount of soil moisture.

Total blue water use (CWU_b) is calculated only for the irrigation period, and it is the sum of all monthly blue water used by the crop during that season. Blue water consumption of a crop refers to the amount of irrigated water that is used to fully fulfill crop water requirements.

The potential crop evapotranspiration (ET_c) is calculated based on the Blaney–Criddle method. The influence of the climate on crop water needs is given by the reference crop evapotranspiration (ET_o). Effective rainfall (P_{eff}) is calculated using the USDA-SCS method that takes into account the mean rainfall of the area, crop evapotranspiration, and the depth of moisturized soil (USDA 1993).

Crop coefficient values for basic crops are given by the Food and Agriculture Organization (FAO) (http://www.fao.org/docrep/x0490e/x0490e0b.htm#crop%20coefficients).

T mean and p values are taken from Lagada weather station (http://penteli.meteo.gr/stations/lagadas/).

The percentage of the contaminant, which penetrates the water system, varies, according to the bibliography, between 3% and 10%, mainly depending on water permeability of the soil. The reference area is taken equal to 5%, due to medium water permeability of the soil. According to 2/2600/2001 law in Greece, the C_{max} NO_3 is considered 50 mg/l for surface recipients. Due to lack of data, C_{nat} was considered 0 (Kolokytha E. 2014).

9.6 Results and Discussion

9.6.1 WF Analysis of All Cultivations

For each crop, the WF is calculated following the methodology explained in Tables 9.4a and 9.4b. The results for clover cultivation are presented in Fig. 9.3.

The most water-intensive crops (those with large blue WF) are sunflower, clover, and maize that cover around 37% of the total land (Fig. 9.4). Tobacco, although having large blue WF, occupies a tiny area of cultivation and hence has no special influence on the results. Concerning pollution, maize cultivation has the major impact on the environment due to the bulk use of fertilizers.

Table 9.4a WF calculation per crop cultivation

Month	Kc	T_{mean} (°C)	P	ET_o	Et_c (mm/day)	Etc (mm/month)	Peff (mm/month)	Ug (mm/month)	Ub (mm/month)
April	0,78	11,8	0,3	4,05	3,16	94,86	17,52	17,52	77,34
May	0,93	17	0,32	5,08	4,73	141,85	40,99	40,99	100,86
June	1,02	22,5	0,34	6,26	6,38	191,44	8,86	8,86	182,59
July	1,01	26,6	0,33	6,69	6,76	202,72	1,00	1	201,72
August	0,95	24,9	0,31	6,04	5,74	172,26	16,02	16,02	156,24
September	0,84	22,6	0,28	5,17	4,34	130,16	52,03	52,03	78,13
October	0,63	12,9	0,25	3,50	2,21	66,22	30,64	30,64	35,58

Irrigation period: April to October

Table 9.4b Components of WF calculation per crop cultivation

Y (ton/στρ.)
1,38
WFgreen (m^3/ton)
121,06
WFblue (m^3/ton)
603,23
WFgrey (m^3/ton)
196,56
WF (m^3/ton)
920,85

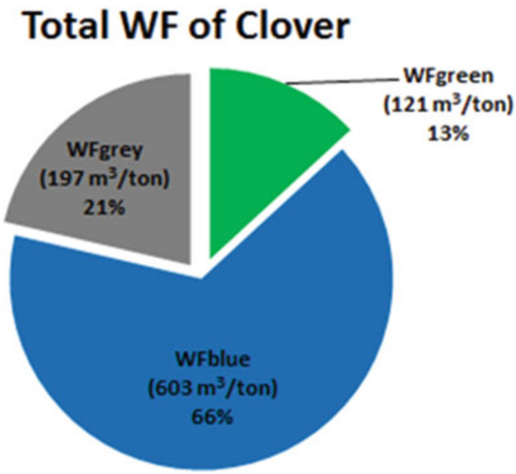


Fig. 9.3 Total WF of Clover

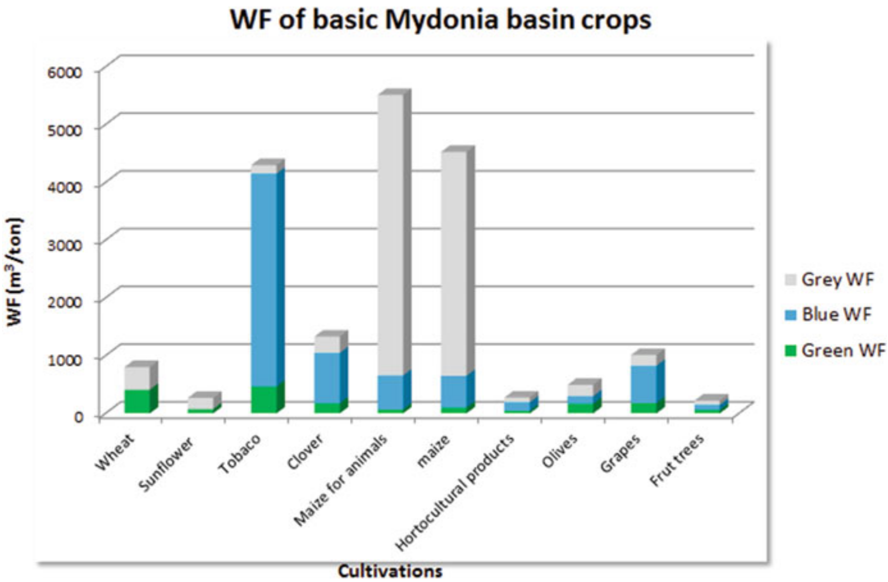


Fig. 9.4 Total WF, by component, of major crops in the area under study

9.6.2 Water Demand for Agriculture

To be able to assess data related to water demand, the water footprint was used as an indicator of water consumption, and the total water demand of the region was found. Crop performance is equal to Y = produced tons of crop/acres of the crop.

Table 9.5 Green, blue and grey water in Mygdonia basin

Municipality	Green Water (m^3)	Blue Water (m^3)	Grey Water(m^3)	Total (m^3)
Assiros	508.101,49	329.614,21	543.479,69	1.381.195,39
Evagelismos	281.999,56	642.563,81	367.930,04	1.292.493,41
Sxolari	2.354.962,15	5.526.408,44	37.098.223,38	44.979.593,97
St. Vasilios	1.908.209,71	1.928.375,68	5.569.187,89	9.405.773,28
Vasiloudi	589.736,24	554.258,17	2.432.714,91	3.576.709,33
Gerakarou	815.778,02	2.769.293,89	10.968.069,66	14.553.141,56
Lagadikia	813.206,12	2.279.922,31	12.766.019,52	15.859.147,96
Analipsi	461.118,29	1.294.182,01	6.088.943,40	7.844.243,70
Iraklio	682.081,71	3.138.931,77	16.209.832,44	20.030.845,91
Kavalari	2.826.445,04	12.384.752,45	51.174.697,36	66.385.894,86
Kolhiko	1.330.382,85	4.821.711,02	31.885.870,96	38.037.964,84
Lagada	507.777,22	1.640.524,38	4.457.100,49	6.605.402,09
Lagina	588.124,23	988.521,38	3.123.448,45	4.700.094,06
Perivolaki	706.443,52	3.188.584,28	10.964.434,68	14.859.462,48
Chrisavgi	280.304,19	959.770,36	6.942.674,34	8.182.748,89
Liti	623.428,50	857.956,52	2.526.481,22	4.007.866,24
Drimos	903.363,11	547.510,62	2.386.046,23	3.836.919,96
Melissohori	1.417.236,60	97.476,33	1.717.999,21	3.232.712,14
Total	**17.598.698,55**	**43.950.357,63**	**207.223.153,86**	**268.772.210,05**

In the baseline scenario, for the total of the arable acres and in order to achieve the performance measured in the year 2011, 48.000.000 + 128.000.000 = 176.000.000 cubic meters of water is required by all crops to satisfy this demand. Of these, 48 million is satisfied through precipitation and the remaining amount of 128 million is covered through the exploitation of surface and groundwater resources (irrigation water). In fact, the need for irrigation water per year is approximately 128 million cubic meters (almost 30% of total water), whereas of rainfall, we get 48 million cubic meters (11%) (Table 9.5). More than half the water used is polluted and corresponds to 252 million cubic meters of diluted water to dissolve pollution (59%). Knowing that, based on studies on climate change in the Mediterranean region, a further 20% reduction in rainfall is expected which means that water-intensive crops will need even more water to grow up, making the situation worse. The results in Table 9.3 form the baseline scenario.

Concerning the blue water, clover and maize are responsible for over 80% of the total blue water demand in the area, according to the % of crops cultivated. On the other hand, maize is the most polluting cultivation and the main cause for pollution of Lake Volvi, since its cultivation is mainly concentrated around Lake Volvi.

From the above analysis, it is clear that the systematic cultivation of water-intensive crops and the bulk use of fertilizers are responsible for the qualitative and quantitative degradation of the area.

There is a wide spectrum of provisions provided by the EU CAP 2014–2020 for the “greening” of agriculture in EU. The most suitable ones to be applied in Mygdonia basin are the following:

- Direct financial aid will be offered from the EU to farmers who cultivate in an environmentally friendly way by changing crops and reducing fertilizers.
- Also, the financial aid will focus on organic farming and creation of fallow areas. Crops that are preferred are nonirrigated crops and tree farming.

Taking into account those measures of the new CAP, two possible scenarios toward green growth were tested.

In the first scenario, water-intensive crops like clover, sunflower, tobacco, and maize are being replaced by grassland, while some of them are put into fallow. Concurrently, a reduction of 20% in fertilizers will be applied in the remaining crops as it is proposed by the new CAP provisions.

The second scenario has the following characteristics: All water-intensive crops will be replaced by 30% of grassland, 30% of trees, and 40% of rain-fed crops for animal food. Also, a reduction of 30% in fertilizer will be applied.

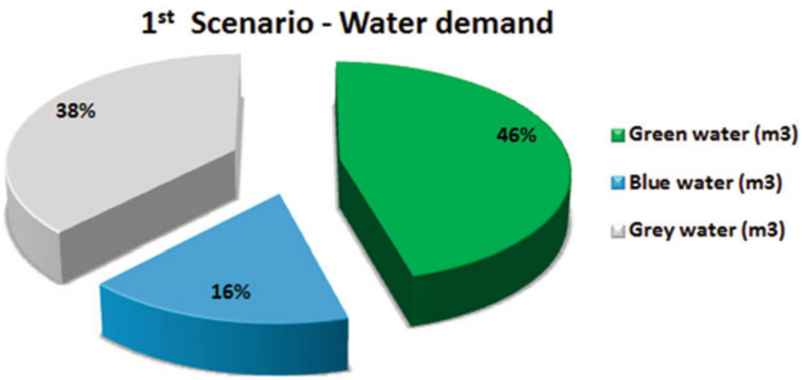
There is a significant increase in green water demand and a similar decrease in blue water demand due to the use of rain-fed crops. Also gray water demand is significantly reduced due to the reduction of the applied fertilizers. Protection of the environment and more sustainable water management and area development are the outcomes of this solution.

9.7 Conclusions-Discussion

WF analysis ends up with conclusions that are easy to be understood by the broad audience and hence providing the means to formulate a response strategy. By studying the WF, we can quantify total and actual water consumption and evaluate the sustainability of the water consumption spatially and at a particular time. The water footprint, or at least its blue and green component, measures resource use and not environmental impact.

The main advantage of this metric, as shown by the results, is that it quantifies pollution. Hence, it is easy to communicate to farmers appropriate changes, needed to reorient agriculture to a more sustainable and “green” direction and provide a true potential to use water in a more efficient way.

The results of the analysis of the WF of the major crops in Mygdonia basin have shown that there is an imperative need for crop redistribution. Increased water needs in combination with the extensive use of fertilizers are responsible for both the quantitative problem in Koronia basin and the qualitative one in Volvi basin. Organic farming is a viable solution to reduce the gray water footprint since it excludes or drastically limits the use of manufactured fertilizers, pesticides, and other chemicals that largely increase water pollution. It is important though to mention that maize



Green water (m^3)	Blue water (m^3)	Grey water (m^3)	Total
32.428.918,25	11.750.453,43	26.827.420,79	71.006.792,47

Fig. 9.5 Scenario 1

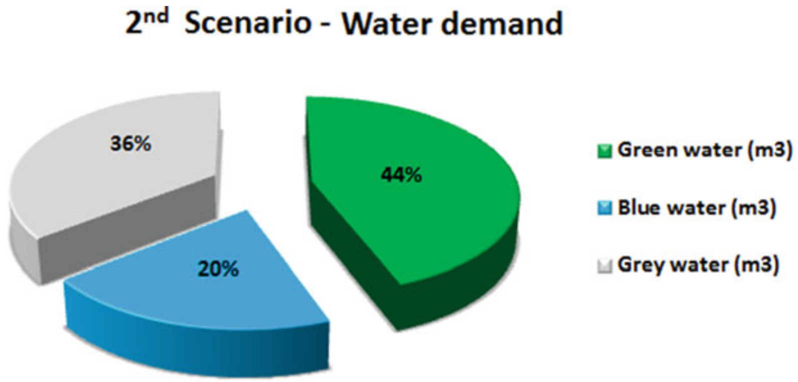
and maize for animals cannot be set aside and should remain in the area since it is the basic food for the livestock.

In scenario 1 (Fig. 9.5), the focus is on drastically reducing the cultivated area, through the conversion of much of the land into pastures and fallow lands. With the goal of achieving the same crop performance to that of 2011, only from the remaining crops, 44,000,000 cubic meters of water are required (32,000,000 + 12,000,000) in total. Green water consumption was not reduced as much as the blue, and this is because crops that were set aside were grounded substantially on irrigation water.

In the second scenario (Fig. 9.6), changes mainly concerned the redistribution of crops. In this case, the reduction in the arable area was not that great, but the emphasis was given on the replacement of crops, adding trees as well as dried leguminous crops suitable for animal feed. New water requirements were larger and specifically (47,000,000 + 21,000,000) reached 68,000,000 cubic meters. In this case, it was observed that green water consumption remained at the same level as in the baseline scenario, and this is because the new crops that were chosen utilize water from precipitation to achieve their given crop performance. By applying the two abovementioned scenarios, the abolition of sunflower and clover leads to significant water conservation of approximately 115.000.000 m^3 of irrigated water.

To achieve water conservation and provide “green” solutions in agriculture in the direction of “green development,” a two-step procedure may be adopted.

The more the crop performance increases, the more the WF decreases functioning as a tool for maximization of crop yield (ton/acre), which in turn may lead to excessive water use. Therefore, the best way is to achieve the maximization of crop efficiency (ton/m^3) instead of crop yield. The improvement of the efficiency of irrigation schemes and the control of water leakages will increase crop efficiency. Those technical interventions can contribute up to 10% water saving.



Green water (m^3)	Blue water (m^3)	Grey water (m^3)	Total
46.738.912,05	21.108.121,03	37.607.516,07	105.454.549,15

Fig. 9.6 Scenario 2

It is expected that climate change will decrease the current levels of precipitation in the area, and blue and green water will change dramatically. In the case of severe water deficits, radical changes regarding the selection of crops as well as the total decrease of cultivated land will be needed.

Of course, in times of economic crisis, such changes will, most probably, encounter the opposition of the farmers who are reluctant to new reforms that may differentiate or even risk their current income. In this case, we need the active involvement of all stakeholders using accurate and detailed information, as well as a suitable economic policy in the form of providing economic incentives to end up to consensus.

In parallel, more contemporary irrigation methods, regulations for borehole control, and restrictions on the fertilizer usage should be provided to improve the negative water balance in the basin.

It seems that the applied economic model should be changed. EU Common Agricultural Policy could be used to sustain the rural development in the area. By subsidizing activities such as agro-tourism that promote traditional local products that are compatible with the local climate, CAP could work as an effective viable tool toward the sustainable development of agriculture in the area, sustaining, hence, the farmers' income.

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