Climate Change Management

Walter Leal Filho · Jelena Barbir
Richard Preziosi *Editors*

Handbook of Climate Change and Biodiversity

Springer

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Preface

Climate change as a whole, and global warming in particular, are known to have a negative impact on biodiversity in three main ways. Firstly, increases in temperatures are known to be detrimental to a number of organisms, especially those in sensitive habitats such as coral reefs and rainforests. Secondly, the pressures posed by a changing climate may lead to sets of responses in areas as varied as phenology, range and physiology of living organisms, often leading to changes in life cycles (especially but not only in reproduction), losses in productivity, or even death. On occasions, the survival of some very sensitive species (e.g. corals) may be endangered. Thirdly, the impacts of climate change to biodiversity are estimated to be felt in the short term in respect of some species and ecosystems, but also in the medium and long term in many biomes. Indeed, if left unattended, some of these impacts may be irreversible.

Many individual governments, NGOs, financial institutions and international donors are currently spending billions of dollars in projects around climate change and biodiversity, but with little coordination. Quite often, the emphasis is on adaptation efforts, with little emphasis on the connections between physio-ecological changes and the life cycles and metabolisms of fauna and flora, or the influence of poor governance on biodiversity. There is therefore a perceived need to not only better understand the impacts of climate change on biodiversity, but to also identify, test and implement measures aimed at managing the many risks climate change poses to fauna, flora and micro organisms. In particular, the question as to how better restore and protect ecosystems from the impact of climate change, also has to be urgently addressed.

This book has been produced to address this need. Papers here compiled look at matters related to the use of an ecosystem-based approach to increase local adaptation capacity, consider the significance of protected areas network in preserving biodiversity in a changing northern European climate, and the impact of climate change on specific species, and wild terrestrial animals. It also presents a variety of case studies such as the Yellowstone to Yukon Conservation Initiative, the effects of climate change on the biodiversity of Aleppo pine forest of Senalba (Algeria), climate change and biodiversity response in the Niger delta region of Nigeria, and the impact of forest fires on the biodiversity and the soil characteristics of tropical peatlands in Indonesia. Moreover the book also entails contributions on how to promote the climate agenda and biodiversity conservation at the local level.

It is a truly interdisciplinary publication, and we hope it will be useful to scholars, social movements, practitioners and members of governmental agencies, undertaking research and/or executing projects on climate change and biodiversity across the world.

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Water Management and Climate Change in the Focus of International Master Programs in Latin America and the Carribian

Frido Reinstorf, Petra Schneider, Raymundo Rodriguez Tejeda, Leslie Santos Roque, Henrietta Hampel and Raul F. Vazquez

Abstract Water is regional priority around the world but synthesis of water resource management aspects from local-to-global scales is currently not included in not currently included higher education curriculua of Latin American and the Caribbean (LAC) universities. This leaves local populations vulnerable to future shifts in climate at global scales and changes in land usage at regional scales. To close this gap, the project "WATERMAS—Water Management and Climate Change in the Focus of International Master Programs", is financed by the European Union. The project will develop and establish a new standard of higher educational and scientific knowledge exchange between Europe and Latin America as well as the Caribbean. This will be done leveraging existing Master's courses/programs of Water Management at the various partner universities in Latin America (LA), respectively in Cuba and in Ecuador. The scope of the project is to enable the development of strategies

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for the adaptation of local water management facilities and the biodiversity with regard to future challenges in the partner countries targeting a Society-Education-Research Nexus. The project addresses sustainability under the Teaching-Research-Practice Nexus, particularly the UN Sustainability Development Goals (SDG) 4 (Quality Education), 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), and 13 (Climate Action). Besides the water management aspects the biodiversity guaranties the functionality of eco system services, which plays an important role by considering the value of the nature for the mankind.

Introduction

Water is fundamental for the economy and quality of life in every country of the world; however, this renewable resource is increasingly threatened by human activities (i.e. pollution, overexploitation). Further, due to this human influence on earth processes, the global climate is changing, affecting the availability and frequency of natural rainfall. In Latin America (LA) long term prediction foresees more or less the same amount of rain in the future but its distribution will change causing longer periods of drought and increased intensity and frequency of rainfall resulting in severe flooding and devastating consequences (IPCC-AR5 2014). Moreover, the hydrological cycle is influenced by complex meteorological phenomena such as “El Niño” and “La Niña”, which produce extensive damage with regard to the local-to-global economy and can bring also significant human losses in the affected countries. In Europe, especially in the southern countries like Spain and Italy, water crisis is more and more severe each summer, e.g. summer water crisis in 2008 when water needed to be imported to Spain. Only the retention of water in reservoirs, and even the re-use of heavily salty wells, e.g. in Cataluña, can fairly satisfy the water demand (Maracchi et al. 2005).

Such climate change is exacerbated by coupled impacts of land use changes associated with, for instance, agricultural frontier expansion and related water use to feed growing populations and satisfy other urban needs. Moreover, in LA, especially in Ecuador, in the last few years, aiming at securing and diversifying energy sources, several hydroelectric power stations started to function and many more are under construction, e.g. Paute Dam and Mazar Dam (WEC 2017). The lack of control on environmental flow results in strong impact on the river system functioning and its capacity of recovery. Contamination due to the lack of control of industrial and agricultural activities and lack of water treatment plants prior river disposal (e.g. only three cities in Ecuador have adequate sewage treatment systems, in Cuba there are no norms for the design of waste water treatment plans) further aggravates the water related problems. In addition, as the result of the last few years of strong economic development, water consumption increased dramatically reaching in average 200 L per day in LA cities. Due to the above mentioned issues all countries globally will have to face water related problems in the future. But these problems will be especially severe in LA where countries are highly vulnerable due to the lack of mitigation and adaptation strategies (WWDR 2015). In the most affected regions the economic development growth will be hindered promoting further growth of poverty and desperation among inhabitants, with potential consequences on the rise of criminality and other social issues.

In the European Union (EU), the Water Framework Directive (WFD 2000) aims to achieve good qualitative and quantitative status of all water bodies. Also, the new status of ecosystems, which considers not only the conservation of biodiversity but also the new aspect of improving the ability of ecosystems to deliver eco system services, plays an important role in the strategy of the EU (COM 2011, 244). However, in LA, where the proposed project will be executed, the focus is different. For instance, in Ecuador exists the "Law of the use and exploitation of water resources" but this does not mention at all anything on the protection of water bodies but only guarantees "good" and enough water for the population. Strikingly, despite water's recognition as a very important regional priority, water conservation, protection, environmental flow definition, and relation to good ecosystem functioning are very rarely considered in legal regulations and decision-making. Even more significant as we look to future generations of managers, these integral aspects of water resources are not included in the vast majority of curricula development for higher education across LA. Further, these curricula need to implement up-to-date scientific and technological knowledge, aiming at increasing the local skills and expertise of young students and professionals as multiplier on key water resources (WR) aspects such as optimisation of use, conservation and management; promoting at the same time, common values, social integration, intercultural understanding and language/communication skills, as a way of overcoming current educational deficiencies that constrain professionals to a narrow working environment. This is what the WATERMAS project targets.

The Project: "WATERMAS—Water Management and Climate Change in the Focus of International Master Programs"

General Aspects

WATERMAS is a project financed by the European Union under the ERASMUS + program in the period 2017–2019. Partners are the University of Applied Sciences Magdeburg-Stendal (UAM, Germany), the Universities of Holguin (UHo, Cuba), Gent (UG, Belgium), Cuenca (UC, Ecuador), Stockholm (SU, Sweden) and the Polytechnical School of Litoral Guayaquil (ESPOL, Ecuador). As such, WATERMAS focuses in the regional priority for boosting academic curricula in the field of water resources (WR) with the innovative goal of including perspectives of conservation and protection of WR leveraging management aspects from local-to-global scales especially in the view of climate change.

Hence, the participating institutions have very high level teaching and/or research expertise in a broad range of WR issues. Nevertheless, particularly the LA institutions have the necessity of connecting to more modern knowledge, especially on water conservation and management issues, as well as, language skills. In this respect, the exchange of students and teachers targeting an ability to share knowledge and transfer research among universities in the LA and EU contexts will further provide support to current and future decision makers and civil society in general. This will guarantee not only the successful execution of the project objectives but also the future sustainability of its outcomes.

The general approach is to include several important and unique aspects, such as (1) the transference of the EU view on WR management on the basis of the Water Framework Directive (WFD) application; (2) the wide range of WR related expertise of the partners (e.g. hydrology, hydrogeology, hydraulics, water quality, water management, river/lake monitoring/restoration, climate change, landscape/aquatic ecology, ecosystem functioning, environmental flow) will provide a complete overview on water issues in the view of climate change; (3) the long teaching/research trajectory of the participants will ensure effective knowledge transference; and (4) different WRes problems from the participating countries (e.g. Belgium: severe reduction of intertidal areas of rivers and related flood events; Germany: pollution vs. water use from transboundary rivers; Ecuador: lack of proper legislation for environmental flow, severely increased water consumption) will be analysed and presented as case studies, profiting from the significant expertise of the partners.

Currently, there exists already a student exchange program between University of Applied Sciences Magdeburg-Stendal (UAM, Germany) and University of Holguin (UHo, Cuba), through which lecturers/scientists from both universities worked together to create a jointly taught course given at the UHo and initiated common research on WR applied on Cuba. Further, the universities of Gent (UG, Belgium), Cuenca (UC, Ecuador) and the Polytechnical School of Litoral in Guayaquil (ESPOL, Ecuador) have a long term collaboration (20 years) through the VLIR (Flemish Council of Universities) program, which promoted mobility actions, technology transference and development of research projects and an interuniversity M.Sc. program in WR (while a related Ph.D. program is currently being planned). Hence, the integration of these well stablished and fruitful networks gave birth to the current proposal that in addition involves the collaboration of the University of Stockholm (SU) due to its relevant complementary experience on WR and expertise on well-aligned curriculum development connecting research and application.

Climate Change in Latin America with Focus on Cuba and Ecudador

The climate of the Central and South American continent is extraordinarily complex. On the one hand, the long continent reaches from the tropics of the northern to the tundra climate of the southern hemisphere. On the other hand, the Andes and the

Fig. 1 Location of the countries in the focus of WATERMAS

mountains of Central America cause great differences on the west and east sides of the continent. Cuba and Ecuador, the countries in the focus of the project, are located in the Latin American and Carribbean (LAC) LAC region, see Fig. 1.

The LAC countries are considered particularly vulnerable to climate change, on the one hand by a possible increase in hurricane activity and on the other hand by the rise in sea levels (IPCC 2007, 2013; UNEP 2010). While sea-level rise is more a global phenomenon, but particularly prone to Caribbean islands, the frequency and intensity of Caribbean hurricanes are heavily controlled by the climate of the tropical Atlantic and the Caribbean itself (Pielke et al. 2013). The Caribbean climate is initially determined by the subtropical high above the Atlantic. It lies far to the south in winter and brings drought to the region. In the summer, it shifts to the north and makes room for east winds, causing rain from May to November. From June to November, when sea surface temperatures are above 26.5 °C, these easterly winds may develop into tropical storms and hurricanes, bringing the bulk of precipitation. The whole system is under the influence of the El Niño Phenomenon in the South Pacific and the North Atlantic Oscillation (NAO). El Niño years provide more dryness and less hurricane activity across the Caribbean, La Niña years for wetter conditions. A positive NAO phase intensifies the subtropical high pressure area and thus also causes a reduction in rainfall (IPCC 2007, 2013).

The devastating effects of climate change are already evident in LA today. Expected impacts of climate change in 2050 can be seen in Fig. 2. Regions with increased vulnerability to weather extremes like storms, droughts and floods changes in biodiversity as well as the risk of desertification can be located. Crop failure, water

Fig. 2 Expected impacts of climate change in 2050 in Latin America (Landa et al. 2010)

scarcity and landslides are some of the consequences as well as a higher risk of diseases, impacts on agriculture and fisheries. This especially affects poorer people in the countryside. For many small farmers, for example, climate change is already an existential threat today. Overall, it leads in LAC societies to ever greater ecological and social upheavals. Added to this is the continued exploitation of natural resources for more and more economic growth, which accepts the social and environmental damage that goes along with it.

By the end of the 21st century, the LAC region is expected to see a temperature increase of about 2–3 °C, slightly less than the global average, which has to do with the dominance of the sea over land (IPCC 2007, 2013). Not less important than the air are the water temperatures, because they determine the evaporation and the precipitation. Till 2050, the sea surface temperature is expected to increase by 1 °C. This should result in higher precipitation, as predicted by a model calculation for August to

October (Angeles et al. 2007). However, the IPCC assumes drier conditions in Central America and the Caribbean at the end of the 21st century. The reason is that in the East Pacific, more El-Niño-like conditions are expected in the future, and an increase in the North Atlantic Oscillation (NAO). Both changes lead to less precipitation in the Caribbean (IPCC 2007). An exception is only the northern Caribbean in the winter months (IPCC 2013). A warming of the eastern tropical Pacific, from which an El Niño develops, intensifies the subtropical jet stream, which in turn amplifies vertical heavy winds across the Caribbean that obstruct the convection of humid air. A positive NAO phase increases the Atlantic subtropics high and the trade winds, causing the Caribbean Sea surface temperatures to cool (Angeles et al. 2007).

In addition, there are many problems and deficiencies that contribute to the vulnerability of the LA countries in terms of climate change (Leal Filho and Mannke 2014), as there are:

- poor or non-existing climate change governance systems,
- limited awareness on the causes and consequences of climate change,
- endemic poverty,
- limited access to capital and global markets,
- continuous ecosystem degradation,
- complex disasters and conflicts,
- unplanned urbanization,
- limited capacity (personal and institutional) to address the problem and its many ramifications.

Conflicts due to climate change and environmental degradation, resource exploitation and scarcity of resources are exacerbated by the fact that they are directly linked to the distribution problem—that is, the question of how benefits and risks are socially distributed. On the one hand, the LA example shows the connection of environmental and climate problems with social and economic issues; on the other, the global dimension of climate change and environmental conflicts becomes clear: the gap between the main causes of climate change and beneficiaries of the economic system in the Global North on the one hand and, on the other hand, people who are marginalized are continuing to open up, partly because others can protect themselves against the consequences of climate change. But looking at LA not only highlights the implications and inequalities surrounding the global climate change problem, it also opens up hopeful alternatives: In some LA countries, people are pioneering ways of reconciling human development, social justice and environmental sustainability.

Methodology

To increase the local expertise for optimising the management of WR, in LAC countries academic curricula needs to incorporate the perspective of protection and conservation of WR and their advantages, especially in the view of climate change, and up-to-date scientific and technological knowledge. EU partners have a very diverse research/teaching/technological/management expertise on these WR issues, which will help solving local WR problems by increasing local expertise and, in the mid-term, could be incorporated into local/regional decision making systems, which in turn would represent a huge contribution to regional WR management. Further, collaboration between EU and LAC countries will generate joint knowledge on WR issues, which will allow the establishment of thematic networks that will be sustainable through common research projects, scientific publications and mobility actions involving both students and researchers.

The main research questions of the project are:

- Which are the main contents to be included in curricula for teaching water management and climate change in the focus of international master programs for the LAC region?
- How can a continuing education program for teachers contribute to curriculum development in the sense of higher education for climate adaptation and sustainable development?
- Which competencies are developed individually?
- How can water management and climate change be integrated into the teaching routines in a transdisciplinary way? Which new and innovative pedagogical approaches are feasible to be implemented under LAC conditions?
- What contributions are there for the development of the university?
- How does the program contribute to the dissemination of climate mitigation and adaptation as a cross-cutting issue in the university and outside?

The general approach of the project to provide answers to the above questions is the knowledge value chain according to Weggeman (1996), which provides a structured approach on the base of knowledge management routines. The knowledge value chain represents a transfer of a technique to teaching, which has proven itself in practice. The knowledge value chain is starting from MVOS (mission—vision—objectives—strategy), followed by Developing knowledge—sharing knowledge—Applying knowledge—Evaluating knowledge, a process, which is under cyclical repetition (Weggeman 2000), as analogue to the Deming cycle (Deming 1982). The methodology in the WATERMAS project is based on the creation of a common knowledge base by cooperation, exchange and dissemination among the network participants to promote curriculum development with the following key activities:

- Identification of the main topics of the curricula regarding water resources conservation and management both from a regional and global perspective
- Collection of relevant information material (national standards, publications regarding regional and global water management aspects and land use impacts, examples of existing curricula, etc.) among the partners with subsequent assessment, summarization and distribution as presentations at workshops
- Assessing local and global scientific information relating to the project aims. Discussion of the information, producing outlines of articles and decisions regarding the implementation within the virtual data base

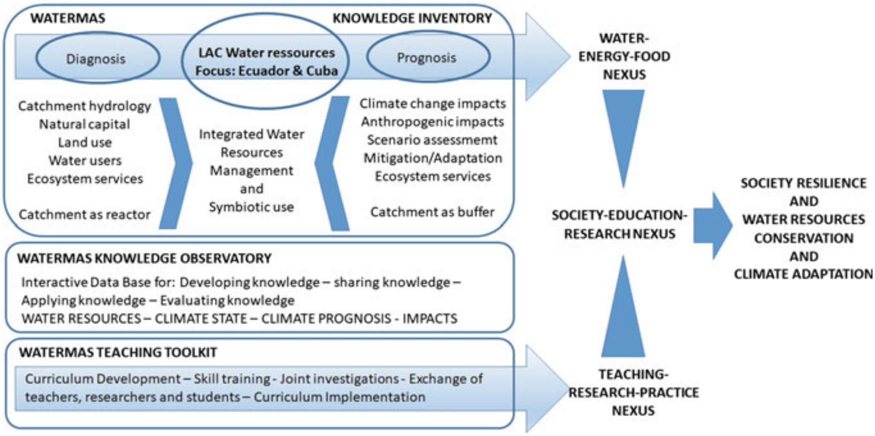

Fig. 3 Methodology for the implementation of the WATERMAS project

- Identification of the main local impacts of land use and climate change on the water resources
- Participation in joint investigations targeting the interests of the regions, e.g. erosion in landscape and riverbeds, hydrological extreme events, standard hydrological methods, high flood protection, biodiversity, European regulations and rules (water framework directive, groundwater directive etc.), dam construction, damage of dams and spillways, coast protection, International Water Management, which will be implemented through the exchange of M.Sc. students and project participants between universities.
- Exchange of teachers, researchers and students across different levels of higher education among the participating universities.
- Develop skills in technical (e.g. water sampling, water treatment and water supply technologies, numerical process modelling, using of Geographical Information Systems) and methodological (e.g. teaching methods, e-learning) training within the group of network participants and other involved persons in the different countries in order to strengthen their skills and abilities (i.e. How can we connect education and research directly for the benefit of not only students but also researchers?)
- Development of a list of relating aspects of conservation and management of water resources under European standards in consideration of local and regional characteristics to include them within the new curriculum.

The methodology for the implementation of the WATERMAS project will be structured in the following way (Fig. 3):

The three main basic working fields in WATERMAS, which are inventory, observatory and teaching lead to the three main impact nexus' for water-energy-food, teaching-research-practice and society-education-research and furthermore to the three social results society resilience, water resources conservation and climate adaptation.

Teaching and Learning Contents to Be Addressed

Fundamentals and Definitions

The exacerbating impacts resulting on the changes of the climate system on the water resources systems and the complexity based on interacting systems are issues that becoming increasingly importances. Damages and alterations in the atmosphere, global warming, impacts on the oceans, the cryosphere, changes in sea level, as well as differences in carbon concentrations and other biogeochemical magnitudes are inescapable. These affect the normal balance of ecosystems and force humans to seek alternatives to adapt to new conditions and find immediate solutions. In this context the understanding of the impacts requires the consideration of the interrelations between water resources—water scarcity—water risk—water stress—water security as well as water resources—water use—waste water discharge—waste water treatment. These fundamental interrelations within the Water Resource Management (WRM) are necessary to implement in learning and teaching contents, including the interrelations between WRM aspects and other natural resources like ecosystems.

Displaying the Scales of the Hydrological Cycle and the Impacts of Climate Change in the Curriculum

Scope of this part of the curriculum will be to get knowledge of the fundamentals of hydrology, as well as to get knowledge of hydrological processes and methods for the estimation of hydrological variables, which are relevant for the dimensioning of hydraulic structures and for the use of water resources on all levels and scales. The classification of the spatial scales relevant for hydrology ranges from "micro" (up to about 1 km^2) via "meso" (up to 1000 km^2) to "macro" (from 10,000 km^2). To show how the different scales of the hydrological cycle and the impacts of climate change can be considered in curricula an understanding of the processes and known facts at the different scales is required. For that, a differentiation into the global, regional, and local scales is needed. Using the concrete examples of Cuba and Ecuador, it will be demonstrated how this content can be displayed in a curriculum.

Dimensions of WR Management to Be Considered in the Curriculum

Water resources are sources of water that are potentially useful for uses like agricultural, industrial, household, recreational and environmental activities. Water availability, including the security of water supply and sanitation, is essential to achieving the United Nations Sustainable Development Goals (SDG; United Nations 2015). Water availability, which UNESCO refers to as available fresh water resources (UN-Water 2006), indicates the amount of fresh water that is available to one person per year. According to Gerlak and Mukhtarov (2015), water security has emerged as a new discourse in water governance challenging the more traditional dominant discourse of Integrated Water Resources Management (IWRM) in the past decade. The definition of IWRM that is most widely accepted and of relevance today was given by the Technical Committee (TEC, former Technical Advisory Committee, TAC), of the Global Water Partnership (GWP). It states that IWRM is "*A process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*" (GWP 2000).

IWRM is based on a management approach for balancing water demand and availability under a spatial planning approach, practically combining water management and water protection at catchment level (Grigg 2008). The formalised framework of IWRM was developed from the Dublin Principles that were ratified during the 1992 International Conference on Water and the Environment, through the following four guiding principles:

- Principle 1: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment
- Principle 2: Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels
- Principle 3: Women play a central part in the provision, management and safeguarding of water
- Principle 4: Water has an economic value in all its competing uses and should be recognized as an economic good.

The Human Right to Water and Sanitation (HRWS) was recognised by the United Nations (UN) General Assembly on 28 July 2010 (UNEP 2010). A revised UN resolution in 2015 highlighted that the two rights were separate but equal (United Nations 2015). Through its focus on water, IWRM often neglects the needs of users from agriculture and/or energy services. To consider a more holistic approach, the Water-Energy-Food Security Nexus (WEF) has been proposed, linking the decision-making processes of the competitive users and balancing the "trade-offs" between them (Hoff 2011).

In the last decades, the awareness has grown that water is a scarce resource which needs to be managed also under the principles of environmental economics, particularly the water value chain, which takes the aspect of water being food into account. The "Water Footprint" (WF) is an indicator that shows the direct and indirect water consumption of a consumer or a producer (Hoekstra and Chapagain 2008). In contrast to direct water consumption, the WF also includes indirectly used water. The amount of water hidden in products is often referred to as "Virtual Water". The WF describes the total amount of water that nations, businesses or consumers consume.

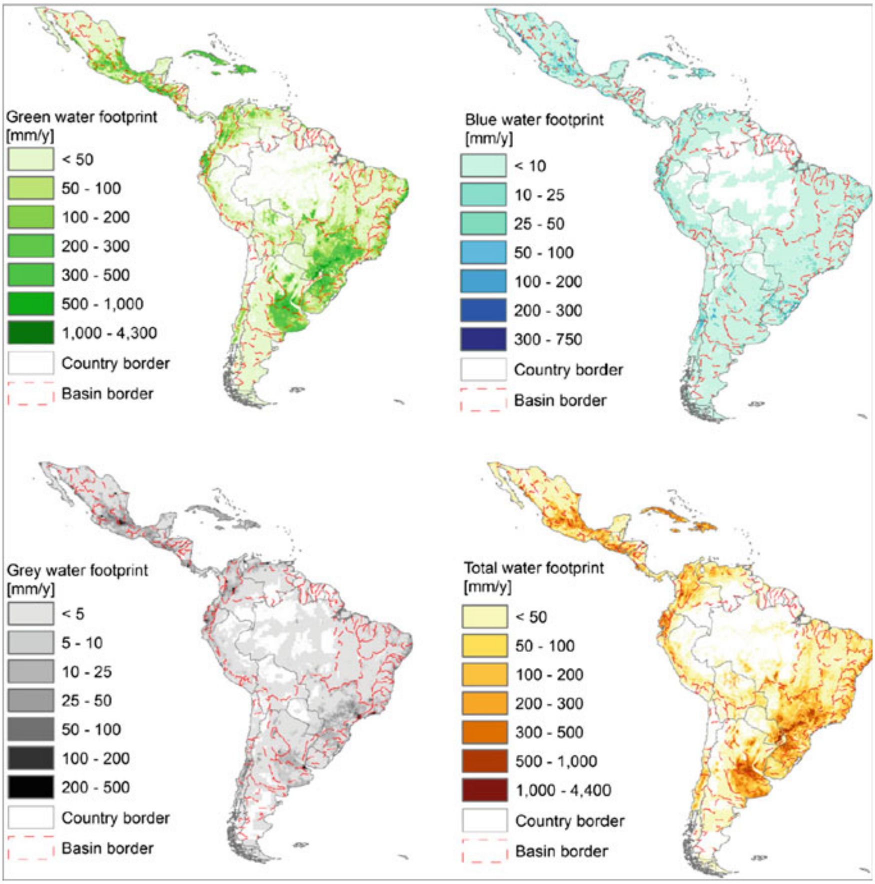

Fig. 4 The green, blue, grey and total water footprints in the LAC region (1996–2005) (Mekonnen and Hoekstra 2011)

The special feature of the concept is that it combines the amount of water that is used, evaporated and/or polluted for production, with information on both the consuming and the producing region of the product. Dividing the used water into categories is helpful for a later assessment of the WF. "Green water" is the naturally occurring soil and rainwater, which is absorbed and evaporated by plants. It is relevant to agricultural products. "Blue water" is ground or surface water that is used to make a product and is no longer returned to a body of water. In agriculture, it is the water for watering the plants. "Grey water" is the amount of water that is polluted during the manufacturing process. Figure 4 shows the green (GWF), blue (BWF), grey (YWF) and total water footprints (TWF) in the LAC region according to Mekonnen and Hoekstra (2011).

According to Mekonnen and Hoekstra (2011), the total WF of production in the LAC region in the period 1996–2005 was 1162 billion m^3/y (87% GWF, 5% BWF, 8%

YWF) (Mekonnen and Hoekstra 2011). About 21% of the WF within LAC is related to production for export. The gross virtual water export of the LAC region to the rest of the world was 277 billion m^3/y (Mekonnen et al. 2015). The LAC average WF of consumption was about 1769 m^3/y per capita. In LA does exist the Latin American Water Tribunal (Tribunal Latinoamericano del Agua, TLA), which is an autonomous, independent and international environmental justice organization created to help solve water related conflicts in LA and to support water management (Weaver 2011). The TLA work is based on the principles that the balanced coexistence with nature, respect for human dignity, and solidarity among peoples are are required for the preservation of the region's water systems. The TLA is committed to preserving the water commons for future generations and to guaranteeing access to water as a human right. Its legitimacy derives from the moral nature of its resolutions and the juridical fundamentals they are based on.

Climate Change—The Role of Biodiversity and Ecosystem Services

Biodiversity plays a significant role in the frame of the climate change mitigation strategy development and refers to the variability of living organisms and their ecological complexes. It includes (a) the diversity of ecosystems or communities, habitats and landscapes, (b) the biological diversity and (c) the genetic diversity within the different species. Various forms of the use of the natural capital, including biodiversity, have been grouped together under the term ecosystem services, without paying particular attention to the idea of nature conservation yet (Schröter 2017).

Ecosystem services (ES) are services produced by ecosystems through the function of the compartiments of the respective ecosystem, that provide essential benefits to human (Millennium Ecosystem Assessment 2005). The Millennium Ecosystem Assessment (2005) derived provisioning, regulating, cultural, and supporting services. Biodiversity is the prerequisite for a healthy and natural development of all living individuals and ecosystems. ES include e.g. purification of drinking water and air, climate regulation, pest and disease control, pollination and other mechanism of supporting food production, medicinal resources, flood regulation and the recreational value. ES are also provided by restored ecosystems, particularly forests under natural succession like secondary forests. According to a study of Lourens Poorter of Wageningen University in the Netherlands (Poorter 2016), secondary forests, unlike primeval forests, allow large amounts of water to circulate and renew soil fertility. Besides, they grow very fast. Covering 28% of LA's total land area, all industrial processes that emit CO_2 could be offset. Having in view the strong interrelation between WR and ES, the role of biodiversity and ES for the mitigation of climate change will be particularly outlined in the curriculum. Figure 5 shows the predicted value (per hectare) of ecosystem services and loss in ecosystem services due to habitat loss, 2000–2010 (Mekonnen et al. 2015).

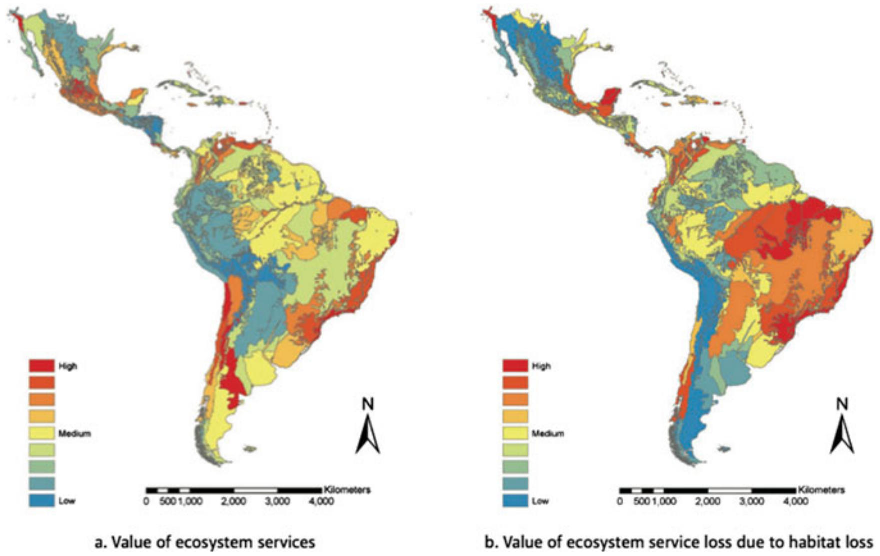

Fig. 5 Predicted value (per hectare) of ecosystem services and loss in ecosystem services due to habitat loss, 2000–2010 (Mekonnen et al. 2015)

Structure of the Curriculum

The curriculum will be structured in modules, based on the data collected for the WATERMAS inventory. The general approach to the structure of the curriculum is based on the following modules:

First semester (theoretical)

Module 1 Introduction to IWRM in the LAC region
Module 2 WR conservation and ecosystem services
Module 3 Circularity: Multifunctional land use and reuse
Module 4 Climate change, climate impact, climate adaptation
Module 5 Engineered and nature-based solutions for sustainable water and land management

Second semester (practical)

Workshop 1 Applying IWRM on catchment scale (project seminar)
Workshop 2 Development of a climate adaptation strategy on catchment scale (project seminar)
Workshop 3 Water-Energy-Food Nexus and Public Participation

Green Campus—The Living Lab

The universities campus should play a key role in the water management and climate change master programs as it is part of the student's real life system, and could be used as living lab for the development of the practical part of the curriculum. A living lab is a place-based research concept that utilizes the college campus as test-bed for innovation and knowledge generation, representing the campus as a pilot site for climate adaptation. A green campus is a challenge as it means using the built environment to revitalize college education as a form of experimental learning. A feasible guideline for such activity is the Greening Universities Toolkit of the United Nations Environment Programme (UNEP 2010).

Teaching and Learning Methodology

General Didactic Approach—Students Become Self-Directed Learners

Three main goals characterize the approach to curriculum development in the WATERMAS project (in analogy to Leat 1998):

- the development of flexible, adaptive learning methods and types of tasks that transform WR management into a challenging and exciting subject
- to help students to understand important key concepts of thinking in WR management and develop cognitive skills that they can apply in a different context,
- To support the intellectual development of students so that they can better handle diverse and complex information in the study and beyond.

In order to achieve these goals, the WATERMAS project will develop learning methods and exercises that will motivate students to reflect and think in a motivating systems thinking way. Decisive is always the thinking process, which leads to the solution of the tasks. That is why each task has a reflection in which the students themselves should become aware of this thought process (metacognitive learning; Ambrose et al. 2010; Barkley 2010). Working with learning methods also opens the way to a self-directed way of thinking that goes beyond the specialist content of WR lessons. The following thinking strategies play a central role in this context:

- *Compare:* Find similarities and differences
- *Link:* Search internal and external connections
- *Locate:* Map phenomena geographically and assign them
- *Change of scale:* Consider phenomena on different scale levels
- *Change of perspectives:* Analysis of phenomena in multiple perspectives
- *Deduce and induce:* Connect the general and the specific.

Water and Climate Cycles—Circular Thinking

Nature's systems are based on cycles, and water and climate are prominent examples for natural cycles. Sustainable systems are based on balanced cycles that do not produce waste. After the development of the cradle-to-cradle (circular) concept by Braungart and McDonough (2002), water management was one of the key implementation fields for circular economy principles. Circular economy in water management include waste water reuse and roof water harvesting. The learning methodology intends to develop students' insights into circular approaches as such and in analogy to natural ecosystem cycles. The teaching methodology is based on circularity: the knowledge value chain.

Climate Change and Climate Impact Mitigation—Systems Thinking

Main focus of the teaching and learning methodology is to overcome fragmentation in (a) WR management and climate adaptation approaches, and (b) teaching and learning approaches. To achieve that, the framework for the teaching and learning methodology is a Nexus approach, mediated through systems thinking.

In the last years increases the awareness of the complexity of environmental problems and led to the development of new management approaches. Pahl-Wostl (2007) proposed to focus on the transition to new management paradigms for systems to be managed that are complex and adaptive. Systems thinking refers to a holistic approach that recognises the tendency in nature to form 'wholes' that are more than the sum of the parts by ordered grouping. While IWRM as a reductionist approach tends towards breaking down complex systems into simple constituents (Dzwairo et al. 2010), a Nexus refers to a link or set of links that link two or more things or topics. At the 'International Kick-off Workshop: Advancing a Nexus Approach to the Sustainable Management of Water, Soil and Waste (WSW)' in 2013 the WSW Nexus was hence described: "*The Nexus Approach to environmental resources' management examines the inter-relatedness and interdependencies of environmental resources and their transitions and fluxes across spatial scales and between compartments. Instead of just looking at individual components, the functioning, productivity, and management of a complex system is taken into consideration*" (UNU FLORES 2015; Avellan et al. 2017).

The management of natural resources through a Nexus approach has gained significant importance in the last years. The main Nexus approaches are summarised below. They will form the didactic framework for the transfer of the systems thinking to the learners. The Nexus' perspectives below are referring particularly to WR, climate change and the teaching of these subjects in an LA context, and show the systems thinking dimensions.

***The WR dimension: Water-Energy-Food Nexus* (Hoff 2011; Huelsmann and Ardakanian 2014; UNU-FLORES 2015)**

The Water-Energy-Food (WEF) Nexus assesses the interdependencies between water, energy and food security for human well-being and intends to achieve all three of them in an equitable manner. The Nexus approach is based on the understanding of the synergies and the regulated negotiation of fair trade-offs between competing uses of water, land and energy-related resources (Schneider et al. 2018a). A particular WEF approach for transboundary river basins was developed under the UNECE Water Convention for the 2013–2015 program, that is the Transboundary River Basin Nexus Approach (TRBNA) (de Strasser et al. 2016).

***The land use dimension: Water-Soil-Waste Nexus* (Avellan et al. 2017)**

The Water-Soil-Waste (WSW) Nexus complements the WEF Nexus (UNU Flores 2015), and asks how resources should be managed to tackle sustainable management. The addition of waste as a resource dimension that often gets omitted in the sector based approaches shall arguably result in more effective and efficient solutions to problems (Avellan et al. 2017).

***The climate adaptation dimension: The Land—Climate—Energy Nexus* (Dale et al. 2011)**

The Land—Climate—Energy Nexus focuses explicitly on the intersectoral dependencies of competitive land use, energy production and the related climate change impacts, based on an integrated analysis of climate change, land-use, energy and water strategies for mitigation and for adaptation purposes.

***The resources dimension: The Minerals—Energy Nexus* (McLellan 2017)**

The Minerals-Energy Nexus according to McLellan (2017) describes the interlinkages between the extraction and use of mineral resources and the necessary energy supply, underlining energy as necessary resource for the minerals production, but also the necessary minerals to produce energy. The Minerals-Energy Nexus has also a WR dimension in the moment when minerals are extracted from catchments, and particularly from rivers. This interlinkage was recently illustrated by Schneider et al. (2018a) using the example of the sand extraction from rivers in South East Asia and the impact of water power stations as barriers for the sediment transport.

***The educational dimension: Teaching-Reserch-Practice Nexus* (Schneider et al. 2018b)**

Like three-bottom-line of sustainability includes social, ecological and environmental issues, the Teaching-Research-Practice Nexus (TRPN) describes the co-equal existence of teaching, research and practice in institutions of Higher Education. As a framework for the implementation of sustainability in Higher Education, the TRPN is intended to lead to the integration of an intensive reference to practice in teaching and research.

***The regional dimension: Spaces-Practices-Goods Nexus* (Schneider and Popovici 2018)**
The Spaces—Practises—Goods Nexus in the light of water resources refers to the sustainable consumption of locally produced goods representing the regional identity, which promotes the valorisation of regional value chains of sustainably produced goods.

The project intends to open up a complementing Nexus dimension, the ***Society-Education-Research Nexus***, which describes the socio-economic dimension of sustainability implementation approaches, particularly through educational activities. The Society-Education-Research Nexus describes the interlinkages between the conditions for the resilience and adaptive capacity of a society, promoted through formal and non-formal education for capacity building on water resources conservation and climate adaptation, based on state of the art research.

Integrated Water Resources Management—Practical Application

As mentioned above, the curriculum shall include teaching as well as a practical application on IWRM, based on particular regional data bases for river basins in Cuba and Ecuador. The pilot catchments for practical education shall serve as modelling site for water resources and conservation as well as for the stakeholder analysis to understand the real life problems of competing water uses. In the ideal case, the pilot catchments can be used for the stakeholder participation process under the Water-Energy-Food Nexus perspective.

Administrating Water Resources—The Institutional Dimension

The conservation and sustainable use of water resources is based on the provision that water resources are managed and administrated properly in order to avoid over-exploitation and pollution. For a sustainable administration is the establishment of reliable, transparent and functionable institutional settings, which includes a sufficient administrative structure acting under the requirements for good governance. WATERMAS will outline key aspects for the institutional dimension.

Protecting Water and Biodiversity Resources—The Social Dimension

The protection of water and biodiversity resources that are essential for the long term provision of water-related ecosystem services. Capacity building in terms of water and biodiversity resources conservation can support the awareness development for this problem. WATERMAS will outline key aspects for the social dimension and how to prepare capacity building to rase awareness for the protection of water and biodiversity resources.

Valorising Water and Biodiversity Resources—The Economic Dimension

Water is a good for nutrition, and the protection of water resources requires its valorisation in economic terms along the product value chain. Therefore, information on water extraction and distribution investments, water treatment methodologies and their operational cost as well as on resulting tariffs for the water consumer must be included. Relevant are also innovative water conservation strategies like payment for ecosystem services (PES). WATERMAS will outline key aspects for the economic dimension, under consideration of the environmental and institutional dimensions.

Engineered and Nature Based Solutions for the Mitigation of Climate Change Impacts and Disasters—The Engineering Perspective

By now, the majority of solutions for mitigation of climate change extremes and disasters are engineered solutions, like high tide reservoirs or dams. On the way to the implementation of sustainable development solutions, the International Union for Conservation of Nature and Natural Resources (IUCN) fosters nature-based solutions (NbS) to address global societal challenges (Cohen-Shacham et al. 2016). According to Cohen-Shacham et al. (2016), nature-based solutions use ecosystems and their services to address challenges like climate change, food security or natural disasters. IUCN defines NbS as: "*Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*."

Examples of nature-based solutions for climate protection and adaptation include the conservation of peatlands as important CO_2 storage, the renaturation of floodplains as retention areas to mitigate flood peaks, and the use of urban green to retent heavy rainfall events in cities. WATERMAS will provide key aspects for the implementation of the engineering perspective in the curriculum.

Internalisation of Externalities—The Environmental Perspective

Water disagreements can occur when opposing interests concern the fair distribution of water resources and especially, when they are superimposed by externalities, e.g. a situation that influences the welfare of individuals or a community (Young 2000). Typical externalities that lead to water disputes or conflicts are upstream-downstream problems (Kelsey 2009), like water pollution or missing flood risk management that impact the downstream user. The way to resolve externalities in a sustainable way is the internalisation of the externalitie's cost back to the causer of the externality, based on the polluter-pays-principle. In case of transboundary water resources, the resolving of water disputes through internalisation of externalities is supported by hydropolitics. WATERMAS will outline key aspects for the environmental dimension, under consideration of the economic and institutional dimensions.

Conclusions

Natural resources and biodiversity are essential to the economies of the LAC region, where the many threats of climate change to water and biodiversity conservation pose a serious risk to their socio-economic development. Scope of the WATERMAS project is to address these aspects through the development of international master programs on water management and climate change. The project will develop and establish a new standard of higher educational and scientific knowledge exchange between European and LAC countries. This will be done leveraging existing Master's courses/programs of Water Management at the partner universities.

The water-related challenges facing the LAC region have to do with variations in climate and hydrology and with the administrative level to which the management corresponds. Other factors with equal or greater importance are the differences in the nature and effectiveness of the institutional systems, the disparities in the distribution and demographic structure of the population and macroeconomic factors related to world trade. An increase in water abstraction due to increasing population and economic development is expected above all in the LAC region.

The WATERMAS project addresses these challenges under the Teaching-Research-Practice Nexus (TRPN), particularly the Sustainability Development Goals (SDG) 4 (Quality Education), 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), and 13 (Climate Action). The scope of WATERMAS is to implement sustainability approaches in the curricula of higher education institutions through the development of (key) competences that make it possible to act with a future-oriented and global perspective (Adomßent and Michelsen 2006; Mochizuki and Fadeeva 2010; Rieckmann 2012).