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Applied Hydrotechnics Multidisciplinary Research and Future Challenges

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Abstract

The purpose of this paper is to provide an actual view on the role of applied hydrotechnics in the context of current and future challenges based on a multidisciplinary research. This paper will debate only some hydrotechnical activities (like irrigation and drainage works, flooding protection structures etc.), activities which require multiple skills and knowledge. The principal results and the main conclusion are based on implementing a new conceptual approach linked to water – energy – food nexus and the use of ecosystem services, approach which will help stakeholders to better understand and systematically analyze the interactions between the natural environmental and resources across sectors and scales.

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1. Introduction

Hydrotechnics is an ancient branch of science and technology. All major ancient civilizations used different water techniques to develop and to increase their life standards. Hydrotechnical measures and activities known different change during centuries but permanently included knowledge from many other sciences and faced many challenges. Hydrotechnical measures represents the structural aspects of integrated water resources management and should be focused on coordinating basic resources management (land, water), recognizing water quantity and quality linkages, protecting and restoring natural systems, including consideration for the results and outputs of climate changes. In a broad approach, applied hydrotechnics is the science which should answer to European water challenges using an ecosystem-based approach and ensuring that there is enough water of sufficient water quality to support ecosystems

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and societies.

The main objective of this paper is to provide a review of the applied aspects for some hydrotechnical works considering the multidisciplinary features of related research activities as well as the current and future challenges at European level.

2. Applied hydrotechnics and sustainable land management

Applied hydrotechnics represents the science dealing with the theoretical and practical aspects of civil engineering structures (mainly water infrastructure) carried out for solving specific water utilization tasks [13]. Natural disasters like floods and droughts with great economic losses [1, 8], the increasing competition for water generated by the need to increase food production [4], the challenges created by water demands of energy, industry and urban systems [15] stress the importance and relevance of applied hydrotechnics today. In order to answer to all these challenges, hydrotechnical measures must respect 3 key principles: efficiency, effectiveness, eco-friendly. These principles are also governing the relations between land, energy, water and food, hydrotechnics representing the main binder in this nexus.

3. Multidisciplinary research and future challenges

Land reclamation and improvement works (irrigation, land drainage), flooding defense systems, water supply and water sewage systems, dams and dykes, hydro-power constructions etc. are facing the challenges generated by the transition from “water bankruptcy” policies to “green economy”. Water is a resource without substitutes and alternatives.

3.1. Land reclamation and improvement works

Global population is expected to increase from 7 to 9 billion until 2050, situation which will lead to an even significant increase of food demand and, consequently, of water needs [3, 5, 12]. Agricultural lands and agricultural production are threatened by climate changes especially due to the severe changes in rainfall and temperatures variability. The increasing pressure on lands and agricultural water management stemming from complex water-food-energy linkages requires an improved integrated land and water resources management [11]. Water scarcity and water excess (water logging) have a negative impact on agricultural productions and can be managed with the help of land reclamation and improvement arrangements (irrigation, surface drainage, deep drainage, soil erosion control etc.). Land reclamation and improvement works are a significant part of agricultural water management and have influences spread in all components of land-water-climate-energy nexus. They provide important ecosystems services including groundwater recharge, flood retention, carbon sequestration, erosion control, accumulation of soil organic matter, recycling of soil nutrients, supporting diversity by providing habitats for flora and fauna. Integrating these different benefits in the framework of agricultural water management requires breaking down disciplinary boundaries between engineers, ecologists, agronomists, economists, hydrologists and climate scientist and the appliance of some reliable climate-energy-economic models as well as land-use models. An improved understanding of ecosystem services provided by these works and of relations developed in the frame of land-water-climate-energy nexus and the implementation of climate adaptive land reclamation and improvement systems will decrease the pressures on basic resources.

At European level is a large quantity of knowledge on land reclamation systems and the degradations they address but this knowledge is dispersed, fragmented and sometimes incomplete especially regarding the complexity, functioning and services of land reclamation works and their interaction with food-climate-energy-ecosystem nexus. Land reclamation and improvement works should also be part of sustainable land management which is defined (according to the UN Earth Summit from 1992) as the use of land and water resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions. Understanding regional certainties is a key element for practitioners and policy makers involved in planning, designing and operating climate adaptive land reclamation and improvement systems but also in setting new relevant policies for this sector.

Sustainable irrigation and drainage management is and will continue to be a frontier field in the future. The efficiency and productivity of water use under the circumstance of increasing uncertainties of flooding and drought, reducing the nutrients output from agro-fields and reducing the pollution to groundwater and surface water, alleviating land degradation, increasing the soil carbon pool and soil fertility, reducing the greenhouse gas (methane, nitrous oxide and carbon dioxide) emission from soil and increasing the carbon stock in soil-plant system can be all achieved with a sustainable climate adaptive land reclamation system.

3.2. Flooding defense systems

Classical hydro-technical engineering solutions for flood management still focus in many places simply on runoff acceleration through river regulation, combined with water retention in reservoirs. Floods are part of the natural hydrological cycle and the natural development of ecosystems but this natural hydrological cycle has been disturbed. Climate change pressures over Europe are likely to increase the frequency of flood events generating a supplementary pressure by human activities in the form of construction works (such as dikes, dams, or large reservoirs). The environmental damage caused by floods is thus more a consequence of man‐made flood defense (hydrotechnical constructions) than it is of the water ecosystems themselves. A major challenge is to achieve a balance between the direct damage of floods to society and the economy and the value of ecosystems generated by allowing the necessary space for the appearance of natural flood events [9].

Applied hydrotechnical measures, including green infrastructure works, must be part of integrated flood management approaches considering nowadays challenges (climate changes, urbanization, population growing) which require a multidisciplinary integration of hydrology, flood routing, ecology, spatial planning, cost – benefit analysis, retention schemes etc. [14].

The future role of hydrotechnical works for flood defense will be to enhance the ecohydrological links between the conservation of ecological services and the enhancement of sustainable economic development and to provide the tools for a sustainable floodplain management in view of global climate change.

3.3. Water supply and water sewage systems

Around the world, water supply sector is facing tremendous challenges due to global warming and climate change, urbanization, increasing water stress and pollution of raw water sources. The efficiency of water supply can be increased by better water demand management, using water saving devices and by reducing the leakages in the network [2, 6, 7, 10].

Water sewage systems, as parts of hydrotechnical systems, should emphasize the links with ecosystems and thus to make a step forward from grey infrastructure sector to the green infrastructure. Water purification is one of the many services provided by ecosystems. Pollutants such as metals, viruses, oils, excess nutrients, and sediment are processed and filtered out as water moves through wetland areas, forests, and riparian zones.

3.4. Water and Energy

Energy and water are interdependent and thus the availability and predictability of water resources can directly affect energy systems. It is almost impossible to assume that the future is like the past in terms of climate, technology and the evolving decision landscape, these issues presenting important challenges to address. Across the water-energy system, there are a number of technical challenges and opportunities for solutions at multiple scales. These include technical solutions from both water-for-energy and energy-for-water perspectives, as well as analytical tools. The use of water and energy is based on the mutual interdependence between these two resources. A deep and accurate analysis of this link between water and energy will require multidisciplinary research on several directions like climate change, renewable energy and energy storage, smart grid, water treatment, water/energy nexus, carbon capture, sustainable built environment, materials in sustainable energy, natural gas production and storage, biofuels, energy for the next generation of vehicles, and energy efficiency. The future of the water-energy nexus will depend on energy and water needs, which will be shaped by climate change as well as population growth and migration patterns.

4. Results and Discussions

We already know that one of the most significant impacts of climate change is the modification of hydrological cycle especially by increasing the frequency of extreme events. In addition, quality of life and health in populated areas becomes more and more critical nowadays, due to increasing human and urban populations, aging of hydrotechnical works, decreasing fresh water resources and superimposing global changes. Most of the existing hydrotechnical structures were designed using a quantitative approach and disregarding the qualitative aspects. Moreover, the applied hydrotechnics was focused on grey infrastructure and less on the green infrastructure with less consideration for ecosystem services.

A future challenge for applied hydrotechnics is to provide adaptation measures to climate change using an ecosystem services based approach. A sustainable management of the ecosystem services is based on the assessment of the self-regulation and support capacity of the ecosystem and the use of goods and services within the limits of these capacities. A major role of applied hydrotechnics will be the ability to enhance, to strength and/ or to protect ecological and evolutionary responses of water-related ecosystem services and biodiversity to hydro-climatic and land use changes and to provide humanity the tools to deal with such ecological and evolutionary responses. The future hydrotechnical works will require cross-disciplinary approach, connected to a multidisciplinary strength of research at combined landscape and drainage-basin levels.

5. Conclusions

The water infrastructure needs technical improvements based on innovative aspects and respecting the trends in water policies by promoting water resource efficiency and further protecting water ecosystems and ensuring their resilience. Moreover, there is a strong need for harmonizing ecohydrological measures with necessary hydrotechnical infrastructure in order to respond to current and future challenges raised by several natural and human induced factors.

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