

The Water Futures and Solutions Initiative of IIASA

P. Burek¹, S. Langan¹, W. Cosgrove¹, G. Fischer¹, T. Kahil¹, P. Magnusziewski¹, Y. Satoh¹, S. Tramberend¹,
Y. Wada^{1,2,3,4}, D. Wiberg^{1,5}

1 International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. langan@iiasa.ac.at

2 Center for Climate Systems Research, Columbia University, New York, USA

3 NASA Goddard Institute for Space Studies, New York, USA

4 Department of Physical Geography, Utrecht University, Utrecht, the Netherlands

5 International Water Management Institute (IWMI), Colombo, Sri Lanka

ABSTRACT: The Water Futures and Solutions Initiative (WFaS) is a cross-sector, collaborative global project. Its objective is to developing scientific evidence and applying systems analysis to help identify water-related policies and management practices that work together consistently across scales and sectors to improve human well-being through water security. The Water Futures and Solutions (WFaS) initiative has produced a consistent and comprehensive projection for global possible water futures. Focusing on the near future until the 2050s, WFaS assessed how water future changes over time, employing a multi-model projection.

Keywords: Water Security, Water-Related Policies, Water Futures, Multi-Model, Cross-Sector

1. INTRODUCTION

The quest for water security has been a struggle throughout human history. Only in recent years has the scale of this quest moved beyond the local, to the national and regional scales and to the planet itself. Absent or unreliable water supply, sanitation, and irrigation services, unmitigated floods and droughts, and degraded water environments severely impact half of the planet's population. IIASA launched a new flagship program "Water Futures and Solutions" (WFaS) in 2013.

The WFaS Initiative is a cross-sector, collaborative global initiative which develops scientific evidence and applies systems analysis to help identify portfolios of water-related policies and management practices that work together consistently across scales and sectors to improve human well-being through water security. A stakeholder informed, scenario-based assessment of water resources and water demand, employing multi-model ensembles of state-of-the-art socio-economic and hydrological models, test the feasibility, sustainability and robustness of options that can be implemented today and can be sustainable and robust across a range of possible futures and associated uncertainties. Exploratory case studies zoom in on particular issues and regions to investigate values and goals, possible pathways, and effective options in those regions. These studies are also used to develop and enhance new methodologies for cross-scale and cross-sector analysis of particular processes. Knowledge sharing networks share policy, management, and technical solutions that have been effective in the bio-physical and socio-economic contexts to which they have been applied, so they can be assessed for application in similar conditions in other regions.

2. RESEARCH QUESTION

Knowledge Hub and Global Network for Systems Analytic Approaches to the Global Water Challenge. Broad participation of the water community, and the communities of related sectors, is essential for advancing knowledge and science, and for providing consistent analyses and messages to planners and decision makers across sectors and scales of management to foster consistent, comprehensive and more effective implementation of development projects in water, energy, and food. The Water Futures and Solutions Initiative is the main vehicle for establishing a water knowledge hub at IIASA, convening scientific and stakeholder coalitions across sectors and disciplines.

Water Futures – Comprehensive, Cross-sector, Stakeholder-informed Assessments of Present and Future Water Requirements and Availability. WFaS extends and develops new innovative methods for integrated analysis, while leading a global state-of-the-art, comprehensive and coordinated, stakeholder-informed assessment of water supply and demand balances, entailing future outlooks that are based on and consistent with scenarios developed within global assessments for other disciplines and sectors.

3. KEY RESULTS OF “FAST TRACK” WATER FUTURES AND SOLUTIONS

WFA has developed a set of scenarios of global water futures, which have been quantified and assessed with a multi-model approach. These water-relevant future scenarios (Magnuszewski et al. 2015) are based on water use narratives that extend the Shared Socio-economic Pathways (SSPs) (O’Neill et al. 2015) and Representative Concentration Pathways (RCPs) (van Vuuren et al. 2011); a set of pathways developed by a large global community over several years in the context of the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (Moss et al. 2010). The advantage of using these multi-disciplinary scenarios is to ensure the consistency among the different sectoral scenarios. The scenarios assume different paths of socioeconomic change and varying degrees of climatic change. These scenarios are: **Sustainability** scenario (resulting in low challenges with respect to sustainability, mitigation and adaptation), **Middle of the Road** scenario (intermediate challenges) and **Regional Rivalry** scenario (high challenges). In a quantitative analysis, based on the scenarios, WFA employs an ensemble of three state of the art Global Water Models (Wada et al. 2016) for which information about both climate and socioeconomic change is required to project future water supply and demand. Further description of the approach and the results are given in Burek et al. 2016. The main findings of this analysis are summarized as follows:

Population and GDP: Global total population is estimated at 6.7 billion in 2010. Future projections indicate that Global population is expected to undergo considerable changes in the coming decades. It will range between 8.4 and 9.8 billion in the 2050s and it will range between 7 and 12 billion in the 2100s depending on the scenario. Specifically, total population will continue to increase through 2100 under the *Middle of the Road* scenario, while it will peak at 2050 and 2070 in the *Sustainability* and the *Middle of the Road* scenarios, respectively. Global GDP levels at the end of this century are lowest in the ‘Rivalry’ scenario (with lowest levels of international co-operation and trade) amounting to around 280 trillion USD. In the ‘Sustainability’ and ‘Middle of the Road’ scenario this increases to 560 and 540 trillion USD. Owing to its large population Asia and Africa are the main drivers for differences across scenarios, especially in the second half of this century.

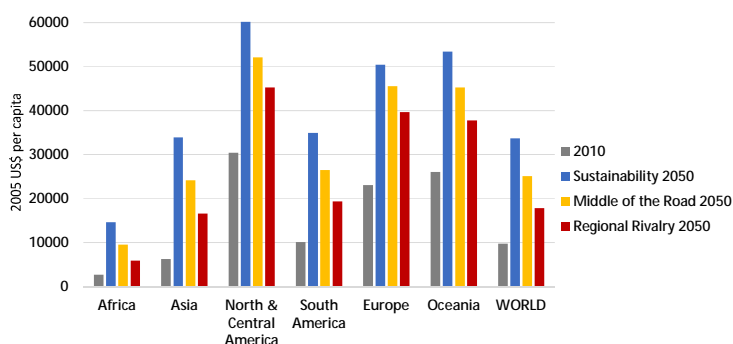


Fig. 1: Per capita GDP (PPP) in 2010 and 2050 under the three scenarios

Food: Globally, average food energy intake in the World Food System model is estimated at 2860 kCal/cap/day in 2010, with regions ranging from less than 2300 kCal/cap/day in Africa to more than 3500 kCal/cap/day in Northern America, Europe and Oceania. The projected per capita food energy intake in 2050 ranges levels between 2950 to 3360 kCal/cap/day depending on the scenario. The number of people at risk of hunger estimated for 2010 amounts to 920 Million, some 13.5% of global population. This number is rapidly decreasing in two development pathways and the share of people at risk of hunger is below 2% of global population by 2080. Only in the *Regional Rivalry* scenario the estimated number of people at risk of hunger stagnates at about 800 Million or some 8.5% of the global population in 2080.

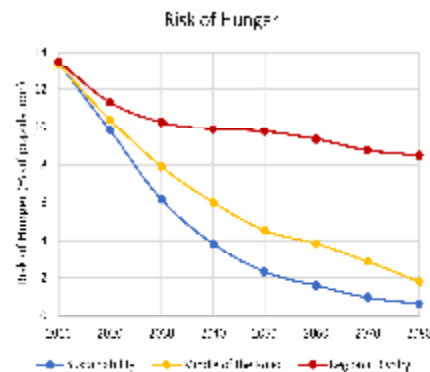


Fig. 2: Risk of hunger under the three scenarios

Energy: Global energy demand is expected to further increase in the next decades, from 13600 million tons of oil equivalent (Mtoe) in 2010 to 15200 - 19700 Mtoe in 2040 depending on the scenario of the 2015 World Energy Outlook. This increase will be driven mainly by demand growth in India, China, Africa, the Middle East, and Southeast Asia. The growing demand for power engenders global electricity generation to increase. Global electricity generation is expected to increase significantly from 23318 TWh in 2010 to between 33900 and 43100 TWh in 2040. The contribution of fossil fuels to total electricity generation will decrease from 77% in 2010 to between 29% and 64% in 2040. Generation from renewables grows the fastest, as their costs fall and government support continues, and it increases two to three and a half times, to reach between 11500 and 17800 TWh by 2040. Hydropower remains the largest source of renewables generation, while wind power and solar PV expand rapidly, but from a much lower base. Output from nuclear power plants increases up to 150%.

Available surface water resources per capita: Countries on the Arabic peninsula show the lowest water availability per capita in the 2010s followed by North African countries. Pakistan, China but also Belgium have low water availability per capita. Due to demographic changes, differences in water availability per capita among scenarios become evident by the 2050s. Water availability per capita is expected to decrease in a belt around 10° to 40° northern latitude from Morocco to India during the early half of the 21st century under all scenarios considered. Only a few countries show the opposite trend like Poland which goes from vulnerable in the 2010s to no stress in the 2050s and China which is under water stress now but will be in the category above 1700 m³/year/cap in two out of three scenarios in the 2050s.

Groundwater resource: Groundwater use globally amounts to 800 km³/year in the 2010s. The largest abstractions are taking place in India, USA, China, Iran and Pakistan. Abstractions these countries account for 67% of total abstractions worldwide. In

many countries, groundwater abstraction has already exceeded recharge, leading to the overexploitation and degradation of important aquifer systems. A worrying issue in the 2050s will be the expected large surge in groundwater abstractions, required to satisfy the increase of water demands, amounting to 1100 km³/year, a 39% increase compared to current level.

- Water demand:** It is estimated that global total water demand in the 2010s is about 4600 km³/year and projected that it will be between 5500 to 6000 km³/year under the three scenarios considered, with industrial and domestic demand growing much faster than agricultural demand. Under *Middle of the Road* scenario, the share of agricultural demand will decrease from 72% in the 2010s to 59% in the 2050s, while the share of industrial and domestic demand will increase from 18% in the 2010s to 24% in the 2050s. At continental scale, Asia remains the largest water user in the world in all sectors especially for agricultural water use. Significant rises in total water demand are expected to occur in Western, Eastern and Southern Africa, as well as in Southern and Eastern Asia.

At country level, India and China have the largest demand, followed by USA, Pakistan and Russia. Domestic demands are rapidly increasing in sub Saharan Countries, driven by their intense socio-economic growth. These changes in water use patterns come together with the potential increase of fertilizers utilization, due to the need to improve agricultural productivity. All of this will likely impair water quality and damage valuable water-dependent ecosystems, if no adequate abatement measures are designed and implemented.

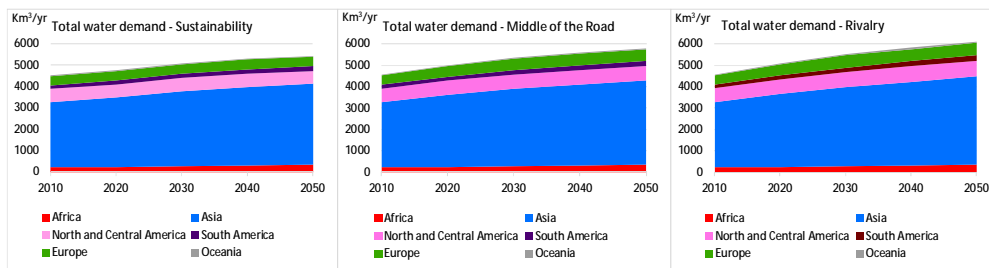


Fig. 3: Total water demand by continent until 2050 – Middle of the Road scenario

- Water scarcity:** Many countries including the countries on the Arabic peninsula, North Africa, Cyprus, Armenia, Uzbekistan, Afghanistan and Pakistan are already undergoing pervasive water scarcity conditions. At present almost all countries in belt around 10° to 40° northern latitude from Mexico to China and Western South America, South Africa, South Europe are affected by water scarcity. An increasing number of people will be exposed to conditions of severe water scarcity until 2050. In the 2010s on annual basis 1.9 billion people (27% of the total global population) live in potential severe water scarce areas and in 2050 it will be 2.7 to 3.2 billion depending on the scenario. If monthly variability is taken into account already now 3.6 billion people worldwide (51%) are living in potential severe water scarcity areas at least for one month per year and it will be 4.8 to 5.7 billion in 2050. 73% of the affected people live in Asia (69% in 2050).

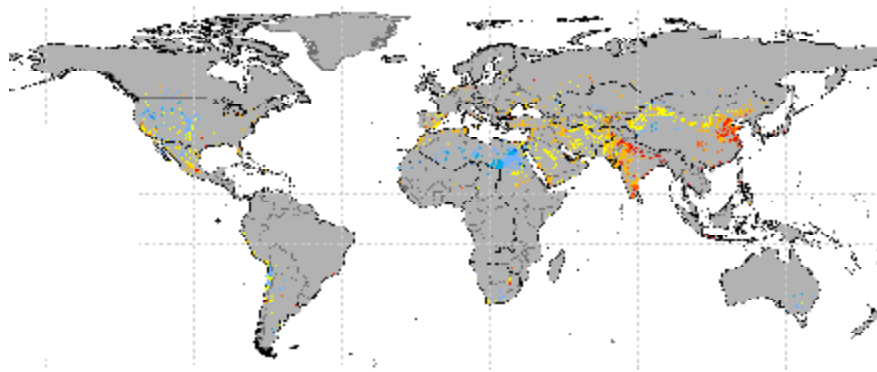


Fig. 4: Potential Population under severe water scarcity in 2010

- Hydro-Economic analysis:** 22 countries with combined population of 1.7 billion people are currently water stressed (rich and poor economies remaining water stressed) and 28 to 33 countries expected to be in the 2050s, depending on the scenario considered. Consequently, a population of 3.6 and 4.6 billion (43 to 47% of the World's total population) will be in the two water stress categories in the 2050s. 91 to 96% of the affected population will live in Asia (mainly Southern and Eastern Asia) and 4 to 9% in Africa (mainly Northern Africa). Our analysis reveals that Somalia, Eritrea, Niger, Burkina Faso, Senegal, Yemen, Afghanistan and Pakistan will be the most vulnerable countries globally, as they will be highly stressed with low adaptive capacity under most of the scenarios.

The results indicate that the World currently faces multiple and complex water challenges that are expected to intensify in the future. This will likely hinder economic development, threaten food and energy security, and damage valuable ecosystems. Improved water

policies and governance structures, and the adoption of a more innovative technological interventions will offer some solutions. However, managing the water sector alone is no longer sufficient, since water integrates across scales and sectors, which all use and influence increasingly scarce water resources. Consistent solution portfolios need to be identified to work across economic sectors and scales of management. Since we cannot manage what we cannot measure, information gathering, generation, and sharing must also be improved. This report provides essential information to inform and guide policymakers in the design and implementation of water solutions portfolios. The information provided includes estimates of water supply by source, water variability, water demand, and hydro-economic classification under various up-to-date socio-economic and climate scenarios. To improve water, energy, and food security, sustain human wellbeing, and ensure sustainable development, the identification of portfolios of options that work together synergistically in different regions will be the focus of continuing work

4. OUTLOOK

While the early focus of WFaS has been on establishing coalitions and building scenarios and assessing water futures, focus will shift in coming years to the assessment of options across the climate/energy/ environment/food/water nexus. This analysis will include: identifying and testing options and measures for improving water supply, elaborating demand side intervention options, and evaluating policy, institutional and behavioral changes for improving water management and enhancing water services and security; uncovering water solutions at multiple scales by applying a multi-disciplinary systems analytical framework and tools to identify and anticipate water gaps and risks and to assess and evaluate portfolios of water management and development options for their robustness, sustainability, coherence and synergies across all major sectors and management scales; and providing and maintaining water-related online decision support tools and knowledge-sharing networks.

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