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Extreme hydrological events and security

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Abstract. Economic losses caused by hydrological extremes – floods and droughts – have been on the rise, worldwide. Hydrological extremes jeopardize human security and cause serious threats to human life and welfare and societal livelihood. Floods and droughts can undermine societies' security, understood as freedom from threat and the ability of societies to maintain their independent identity and their functional integrity against forces of change.

Several dimensions of security are reviewed in the context of hydrological extremes. Floods and droughts pose a burden and serious challenges to the state, responsible to sustain economic development, societal and environmental security – the maintenance of ecosystem services, on which a society depends. It is shown that reduction of risk of hydrological disasters improves human security.

1 Understanding security and hydrological extremes

Many notions of security are being commonly used, referring to a range of areas in physical, political, and financial realm, as well as the rapidly growing information technology realm. Many of these notions are beyond the scope of this study. The term security can be interpreted as the degree of resistance to, or protection from, harm and it can apply to any vulnerable and valuable asset (a person, family, household, community, nation, or organization). The Universal Declaration of Human Rights proclaimed by the United Nations in 1948 contains a reference to security in its Article 3 that provides for the right to "life, liberty and security of person".

The interpretation of the term "security" accepted in the present contribution follows Buzan (1991) and reads: freedom from threat and the ability of societies to maintain their independent identity and their functional integrity against forces of change.

The classical concept of security was focused on the military capabilities of the state, international relations, and state sovereignty. Yet, more recently, a wider understanding, embracing societal, economic, and environmental aspects of security has got increasing attention (Buzan, 1981). Societal insecurity appears if any of the substantial elements of a society's identity is threatened. Security in the economic area is related to the state's responsibility to sustain economic stability. Environmental security is related to the maintenance of ecosystem services, on which a society depends. The three areas of security are intertwined.

Water-related extremes can cause serious threats to human life and welfare and undermine societies' security. Floods and droughts can be regarded in the context of all three dimension of security, i.e. societal, economic, and environmental. Economic crises, societal disturbances, and environmental impacts caused by hydrological extremes can pose a serious danger to human security.

Water resources are a necessary element to sustain life and wellbeing and thus they are an important part of security of the society, playing a role in water security, food security, and energy security. Water security, i.e. providing uninterrupted access to safe drinking water in adequate quality and quantity, has become a major concern in international policy. The water-related target of the UN Millennium Development Goals (halving the proportion of the population without sustainable access to safe drinking freshwater by 2015) will not be met. The number of those without access to safe freshwater is still very high – perhaps 783 million people (http://www.unwater.org/water-cooperation-2013/water-cooperation/facts-and-figures/en/). Water security is jeopardized by both droughts (quantitative lack of water) and floods (destructive abundance of water of bad quality).

In this paper, significance of water-related extremes for security is discussed. The current knowledge on the changing risk of hydrological extremes, floods and droughts, in the security context, is summarized. Improving security via reduction of risk of hydrological extremes and implications for governance are also presented.

2 Security and the concept of risk

Since risk (the term being very frequently used in the context of hydrological extremes) is an antonym to security (the term being less commonly used), it makes sense to decompose the risk notion, depending on hazard, exposure, and vulnerability. Field et al. (2012) define disaster risk as the likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and to enhance recovery. This definition applies to both floods and droughts. Hazard can be defined as the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other adverse health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. Physical events become hazards where social components or environmental resources that support human welfare and security are exposed to potentially adverse impacts. Exposure refers to the presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by physical events. Physical and biological systems under the concept of "environmental services and resources" are fundamental for human welfare and security. Vulnerability is defined as the propensity or predisposition to be adversely affected.

The impacts of floods and droughts may threaten human security of local populations, through damage to health, wellbeing, food, water, or soil conditions. Rural communities in many world regions face risks of livelihood loss resulting from flooding, while droughts, especially in arid and semiarid areas, exacerbate water scarcity and cause decline in agricultural yields and fisheries, and loss of biological resources.

The metrics to quantify social and economic impacts (thus used to define extreme impacts) may include, among others, the impacts on psychological well-being and sense of security in those affected by floods (e.g. via post traumatic stress disorder).

Human security addresses the combined but related challenges of upholding human rights, meeting basic human needs, and reducing social and environmental vulnerability. Human security is realized through the capacity of individuals and communities to respond to threats to their environmental, social, and human rights. The linkages between hydrological extremes, climate change and human security are both complex and context-dependent (Field et al., 2012).

3 Risk of extreme hydrological events on the rise

Risk related to extreme hydrological events is the function of two factors: frequency and magnitude of events and potential of losses.

Frequency and intensity of heavy precipitation have grown in many, but not all, areas of the globe. However, no gauge-based evidence has been observed so far for a clear and ubiquitous climate-driven change in the magnitude and frequency of river floods.

Reported global flood damages (adjusted for inflation) have more than trebled since the 1980s. Flood losses are higher in developed countries, while fatality rates and economic losses expressed as a proportion of GDP are higher in developing countries. Current studies indicate that increasing exposure of population and assets and societal factors related to population and economic growth, rather than anthropogenic climate change are responsible for the past increase in flood losses (Handmer et al., 2012; Kundzewicz et al., 2014).

Projected changes indicate that heavy rains will likely get more frequent and stronger (Seneviratne et al., 2012), adversely affecting the risk of rain-generated floods (therein flash flooding and urban flooding), landslides, and soil erosion.

Recent global flood projections based on an ensemble of climate, hydrology and land surface models (Dankers et al., 2014; Hirabayashi et al., 2013) show that flood hazards increase over about half of the globe, but with great regional, and local, variability.

Droughts may have become more widespread, more intense and longer in many regions around the globe, due to reduced land precipitation and/or warming that enhances evapotranspiration and drying. Because drought is a complex variable, there are discrepancies in the interpretation of changes. Hartmann et al. (2013) review the contradictory results of change detection presented by different researchers, using different drought indices and different data periods. Since the 1950s some regions of the world (e.g. southern Europe and western Africa) have experienced more frequent meteorological and agricultural droughts. However, results of trend detection in hydrological drought do not support the general hypothesis of ubiquitous increasing severity or frequency of drought conditions. Dai (2011) found a general global increase in drought, although with substantial regional variation and individual events dominating trend signatures in some regions (e.g., the prolonged Sahel drought since the 1970s and the 1930s drought in the USA and Canadian Prairies).

More frequent droughts due to climate change together with an increase of population may challenge existing water management systems, placing even the domestic water supply at risk (Döll et al., 2015).

Bates et al. (2008) noted that the proportion of land surface in extreme drought at any one time will likely increase, in addition to a tendency for drying in continental interiors during summer, especially in the sub-tropics, low and mid-latitudes. This indicates a greater risk of droughts in these regions. However, confidence regarding quantitative changes in future drought hazards is not high because of uncertainty of model-based projections of extremes.

Many key risks constitute tough challenges for less developed countries and vulnerable communities, given their limited ability to cope. Climate-change impacts are projected to slow down economic growth, make poverty reduction more difficult, further erode food security, and prolong existing and create new poverty traps (Field et al., 2014).

Impacts from extreme droughts and floods are projected to adversely affect morbidity and mortality, mental health and human well-being. Climate change will increase demands for health care services and facilities.

There are a range of key risks related to floods and droughts. There is a risk of death, injury, ill-health, or disrupted livelihoods in low-lying zones and large urban populations due to inland flooding that may also lead to breakdown of infrastructure networks and critical services. Extreme floods and droughts exacerbate risk of food insecurity and the breakdown of food systems, particularly for poorer populations, as well as risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly in less developed semi-arid regions. There is also a risk of damage to ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for livelihoods (Field et al., 2014).

Several climate change impacts are of concern to water utilities (Jiménez et al., 2014). Increased storm runoff increases loads of pathogens, nutrients and suspended sediment. Heavier rainstorms imply the need to treat additional wastewater (increased amounts of water and wastewater in combined systems) for short periods. Droughts increase pollutant concentrations and bring other risks – soil shrinks as it dries, causing water mains and sewers to crack and making them vulnerable to contact with wastewater.

4 Security concerns related to floods

There is no such thing as absolute security from floods for people living in vicinity of river basins. Since the dawn of civilisation, destructive floods have jeopardised settlements located near rivers. Floods have devastated cultural landscapes and undermined sustainable development by breaking continuity (Kundzewicz, 1999).

About 800 million people worldwide are currently living in flood-prone areas and about 70 million of those people are, on average, exposed to floods each year. The highest relative share of national economy exposed to floods can be found in Cambodia, while Bangladesh is the country with the highest number of people exposed to floods, both in absolute and in relative terms (Kundzewicz et al., 2014). Since 1980, over 95 % of flood-related deaths have occurred in developing countries and 75 % in the Southern, Southeastern and Eastern Asia (Handmer et al., 2012).

There has been a huge population displacement associated with large disasters, e.g. floods in Pakistan in 2010 and in India in 2008 uprooted roughly 6 million people each. Effects of smaller, more frequent events can also contribute to displacement. Even if such events cause relatively low mortality, they destroy many houses and hence cause considerable displacement (Field et al., 2012).

Important security-relevant debate relates to structural flood defences, such as levees that provide excellent protection against more frequent (small to medium) floods, yet their existence may trigger development of flood plains. Development in flood prone areas may increase social welfare, enhancing economic gain in a short time, but increases flood risk. Hence, the distinction between adaptive and maladaptive actions depends on the time period over which risks are being assessed (Field et al., 2012). Dikes may reduce vulnerability in the short term, but increased security may generate more development and ultimately lead to increased exposure and vulnerability. If floods become more frequent, the time scale shrinks, i.e. a 100-year flood determined in the days of yore occurs, on average, more frequently than once in a hundred years.

Noting, already in the 1930s, that levees can provide a false sense of absolute security, Gilbert White advocated, among other adjustment measures, land use planning and environmental management schemes in river basins in order to face up to flooding hazards. This can be seen as a precursor of what is now called a nature-based solution. An important flood protection measure is the source control i.e. watershed management including land use and soil conservation to minimise surface runoff, erosion and sediment transport. The idea of catching water where it falls is implemented by such measures as enhancing infiltration: (e.g. pervious pavements and parking lots), local storages: ponds, building and groundwater storages (cf. Kundzewicz and Takeuchi, 1999). Enhancing retention counteracts the adverse effects of urbanisation (growth of flood peak, drop in time-to-peak of a hydrograph, drop in roughness coefficient and in storage potential) and of channelisation (faster flood conveyance through shortened and straightened rivers).

The flood risk contributes to the feeling of insecurity and vulnerability of informal settlements, surrounding many urban areas in developing countries, often placed on nobody's land adjacent to rivers. People living there suffer livelihood insecurity, poor health, and lack of access to service provision and basic needs (such as clean water, health care, education, and flood protection). The impacts of floods are often further exacerbated by health problems associated with water quality.

Economic dimension of security refers to two components: (i) the resource economy converting natural resources into productive assets and consumer goods and (ii) the money economy (Green and Kundzewicz, 2015). The two systems are interconnected and a flood impacts both. The obvious effect is the damage to physical assets that propagates through the resource economy. Both suppliers to and purchasers from a flooded factory are affected; the former potentially by a loss of orders, the latter by having to source an equivalent good from elsewhere, at additional costs. In the era of globalization, such impacts can spread globally. The effects of a flood also propagate through the money economy both from flooded households and productive assets. The economic impact depends upon what is sacrificed to enable recovery. Households can change the pattern of consumption, diverting expenditure away from normal uses to replacing what was lost or damaged, draw down on savings, or borrow. If governments directly compensate flood victims or act as the reinsurer of last resort to the insurers, the three options that a government has are: to increase taxes, to cut other areas of expenditure, or to borrow.

Environmental context of security related to floods has several aspects. Water availability in the root zone is critical to survival of plants but not all species can survive long if the root zone is saturated. Conversely, exploiting flooding before the growing season has been one of traditional means of increasing agricultural output (Green and Kundzewicz, 2015). The sediment left by receding flood waters can be beneficial if it is a thin layer of nutrient-rich silt (as in Nile floods) but this may lead to a change in species composition. Moreover, the deposited nutrient-rich silt was someone else's valuable topsoil that was eroded by runoff. Also sand deposition changes species composition. Important are water quality issues related to floods (e.g. fish kill by flood waters flushing residues of agricultural chemicals).

Different aspects of flood-related security are illustrated in Fig. 1.

Figure 1. In summer 1997, many cover stories of weekly magazines in Poland referred to the dramatic July floods and illustrated various aspects of human insecurity.

5 Security concerns related to droughts

The notion of drought should not be confused with aridity, where dryness is a normal condition and freshwater is always in short supply. The term drought (cf. Bates et al., 2008) may refer to a meteorological drought (precipitation deficit), agricultural drought (soil moisture deficit), and hydrological drought (surface water and groundwater deficit). The socioeconomic impacts of droughts may arise from the interaction between natural conditions and human factors such as changes in land use, land cover, and the demand for and use of water. Excessive water withdrawals can exacerbate the impact of drought.

Droughts affect rain-fed agricultural production as well as water supply for domestic, industrial and agricultural purposes. The number of people exposed to droughts, globally, extends to billions.

Droughts lead to scarcity of essential resources to support livelihoods (like water and food). They can affect water security and food security through reduction of agricultural production and can be a factor contributing to wildfires. Extreme droughts can give rise to conflicts resulting in the dislocation of large numbers of refugees and people within and across borders. Migration is a key coping mechanism for poor rural households, not only in extreme circumstances (e.g., during a prolonged drought, as with the 20th century US dust bowl period in 1930s and Sahelian droughts since the 1970s) but also as a means of diversifying and increasing income. The opportunities that population movement opens for risk reduction are seen in international remittance flows from richer to poorer countries. However, often migration takes place internally within a country, because people tend to return to re-establish their lives after a disaster; and more permanent migration is also internal. Forced land abandonment is stressful for migrants and can lead to a breakdown in traditional rural institutions and associated coping mechanisms. Local collective coping and adaptive capacity can also be limited by increases in the number of female-headed households as men migrate (Field et al., 2012).

The 2003 heat wave in much of Europe (cf. Bates et al., 2008), attributable to global warming, was accompanied by annual precipitation deficits of up to 300 mm. This drought had considerable environmental, economic, and social consequences, contributing to detectable reduction in gross primary production of terrestrial ecosystems in Europe. Record low levels of rivers resulted in disruption of inland navigation and irrigation. The consequences of water deficit for the energy sector were serious. After the cooling process, water was too warm to be fed back to surface waters. Hence, droughts jeopardized energy security.

6 Improving security via disaster risk reduction

Disaster risk management embraces processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, resilience, and sustainable development. Prospective risk management debates can involve security considerations decades ahead for production, infrastructure, hospitals, etc. Disaster risk reduction denotes both a policy goal and measures employed for anticipating future disaster risk; reducing existing exposure, hazard, or vulnerability; and improving resilience (Field et al., 2012). Smith (2013) indicates three main approaches to flood and drought risk reduction: protection, adaptation and mitigation.

Changes in hydrological extremes threaten human security, and both disaster risk management and climate change adaptation represent strategies that can improve human security. Because risks of hydrological extremes impacted by climate change often affect the basic functioning of society, it is increasingly recognized that climate change adaptation and disaster risk management should be integral components of development planning and implementation to increase sustainability. Scheffran (2011), summarizing the literature on climate change and security, noted simplifications in describing this relation and argued that systematic link between climate change and its security implications was missing. The negative impacts of climate change on human societies appear as a form of a social instability (demonstrations, migrations, riots, poverty, crime, civil unrest, armed rebellion, terrorism, ethnic conflict etc.). Moreover, some studies suggests coincidence between climate variability and armed conflict (Kuper and Kröpelin, 2006; Schubert et al., 2007; Hsiang et al., 2013). Although the definite evidence about increasing danger of conflicts along the predicted warmer climate and increasing variability of precipitation is missing, some support for this interpretation can be found.

National governments are charged with the provision of public goods, ensuring the economic and social wellbeing, safety, and security of their citizens from disasters, including the protection of the poorest and most vulnerable citizens. The demand for water, food, shelter, sanitation, health care, security, education, and employment is balanced against available resources (Field et al., 2012). Providing for basic human security after a flood and during a drought is essential. The international impacts of floods and droughts embrace financial consequences, international trade, migration, and security.

In terms of security, the role of public authorities is to manage emerging crisis situations. The assumption of an automatic link between disaster exposure and negative outcomes is not obvious (Paton et al., 2000), but the role of governments is to prepare adequate procedures and resources for a case of a crisis caused by a disaster. Crisis and emergency management structures react when a disaster actually happens. Boin et al. (2005) point out that the leadership is a crucial factor in dealing with disasters.

The option for anticipatory disaster risk reduction and adaptation exists precisely because risk is a latent condition, which announces potential future adverse effects. Disaster risk management shifts in focus from responding to the disaster event toward understanding of disaster risk and building preparedness. Although hazard is considered the cause of disaster risk, vulnerability and exposure are its key determining factors. Furthermore, contrary to the hazard, vulnerability and exposure can be influenced by policy and practice.

Dealing with risk and insecurity is a central part of how poor people develop their livelihood strategies. Underserved people require access to the social and economic security that comes from sharing risk, through financial risk transfer mechanisms such as insurance. Governments are increasingly using a range of instruments for transferring costs of disaster losses through risk-sharing mechanisms: financial insurance, micro-financing, investment in social capital, government disaster reserve funds, and intergovernmental risk sharing (Field et al., 2012).

Noble et al. (2014) distinguished categories and examples of adaptation options, therein structural/physical (engineered and built environment, technological ecosystem-based, services), social (educational, informational, behavioral) and institutional (economic laws and regulations, government policies, and programs). There exist a roster of strategies for reducing flood losses, falling in these categories. A category of strategies aimed at keeping water away from people includes flood defences, as well as flood flow improvement and retention. Another strategy – flood risk prevention – aims at keeping people and wealth away from water. However, we have to be aware that there is a possibility of coincidence of destructive abundance of water and a considerable damage potential in the same time and place. Hence, we have to consider the residual risk of the failure of attempts to keep water away from people and to keep people and wealth away from water. In other words, instead of striving to build a fail-safe system than never fails we should be aware that every system may fail. If the system fails, it should fail in a safe way (safe-fail) and recover after failure. This is the essence of the notion of resilience. Since a flood protection system guaranteeing absolute safety is an illusion, a change of paradigm is needed: it is necessary to live with the awareness of the possibility of floods (Kundzewicz and Takeuchi, 1999). Rather than trying, in vain, to eradicate floods, one could accommodate them in one's planning and learn to live with them. No matter how high a design flood for a structural defence is, there is always a possibility that a greater flood may come, inducing losses. It is necessary to be prepared what to do then – how to accommodate the residual risk in our planning.

Some international initiatives addressing the need to reduce the risk of floods and droughts, are already in place, such as the Hyogo Framework for Action – Building the resilience of nations and communities to disasters (a 10-year plan to make the world safer from natural hazards), Floods Directive and Solidarity Fund of the European Union, as well as international aid and technical assistance in the emergency situations.

Adaptation options designed to ensure water supply during drought conditions include both supply-side (providing more water) as well as demand-side strategies that improve water-use efficiency, e.g., by recycling water. Use of economic incentives, including metering and pricing, to encourage water conservation and development of water markets and implementation of virtual water trade, holds considerable promise for water savings. Supply-side strategies generally involve increases in storage capacity, conjunctive use of surface water and groundwater, and water transfers. Increase of storage of water and flow regulation is advantageous for floods and droughts – catching water when abundant and discharging it when in short supply. An important "soft" drought adaptation measure is drought forecasting that may trigger activities alleviating the adverse impacts.

7 Conclusions

The security context of the extreme hydrological events is a challenging issue. It is very important as providing security is one of the main tasks for governments. Growing risks increase the danger of social instability. Natural processes which are the sources of the risks are not separated from the human impact and interventions. Thus, providing security and dealing with risks requires taking into consideration the complex system.

On the top of this, the sustainable development principle as guidance for public policies assumes a built-in mechanism of maintenance of resilience against surprises and shocks, such as a large flood. A common interpretation of sustainable development is that civilisation, wealth (human and natural capital) and environment (built and natural) should be relayed to future generations in a non-depleted shape. Within the social pillar of sustainable development fairness or equity imply that flood protection, translating into a feeling of security, should be extended to all members of the society. Yet, difference in vulnerability to floods even between neighbouring households can be enormous, especially in less developed countries.

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