2 Climate change and weather extremes as risk multipliers

Tipping points, cascading events, and societal instability

Jürgen Scheffran

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Abstract

The role of global warming as a risk multiplier is discussed in an integrative framework connecting climate and societal stability, acting through complex and destabilizing impact chains beyond thresholds. These include complex social interactions and self-enforcing collective dynamics such as breakdown of vulnerable infrastructures and networks; tradeoffs in the water-food-energy nexus; economic and financial crashes; social protest and turmoil; mass migration and violent conflict. Adressing the challenges through adaptive and anticipative governance can induce societal transformation processes to protect human security, develop social livelihood, strengthen societal resilience and solve problems along cooperative and sustainable pathways. In this context, key questions considered are conditions when climate stress exceeds the adaptive capacity of natural and social systems; tolerance ranges of stability and instability; impacts of climate stress on critical infrastructures and human-environment-interaction; thresholds of negative and positive tipping points triggering cascading events; and conditions for sustainability transition and societal transformation processes.

KEYWORDS: *Anthropocene, cascades, conflict, hot spot, migration, tipping points.*

Introduction: Tipping points and risk cascades in complex systems

During the 1980s, complexity emerged as a new paradigm in science and politics, increasingly shaping international relations. In 1989, the Cold War ended in a domino effect that led to the fall of the Berlin Wall, the breakup of the Eastern Bloc and a chaotic breakdown of the East-West conflict, which became a tipping point to an era of ever-growing complexity[1] (Scheffran 2008). In the new world (dis)order cascading chains of events have emerged, including complex social interactions and self-reinforcing collective dynamics such as stock market crashes, social turmoil, mass migration, and violent conflicts that increasingly challenged international security and stability (Kominek and Scheffran 2012). A particular form of social instability is conflict, based in incompatible values, priorities, and actions of agents who undercut each other's values and provoke responses, thus leading to the waste of resources and an escalating interaction if the conflict is not resolved.

A crucial issue is whether growing complexity breeds instability, a question that has been extensively discussed for ecosystems (Scheffran 1983). While artificially constructed complex systems are dysfunctional if the components do not fit together, unstable modes tend to disappear in evolving complex systems while those with better fitness or control mechanisms survive. Systems are often robust and adaptive against the most likely disturbances in the core region of stability (Held and Schellnhuber 2004); however, close to critical thresholds between regions of stability and instability small and rapid variation can lead to a systemic break down. This is symbolized by the famous butterfly effect in chaos theory, which may occur when a system is already "on the edge", driven by other processes. A key term is the sensitivity of couplings between variables, which determines how changes spread through the network of interconnections (Scheffran, Link, and Schilling 2012). Beyond a given sensitivity, threshold changes may trigger instabilities, tipping points, and cascading sequences. To maintain stability, it is essential to understand the conditions under which small-scale micro-level events lead to qualitative changes at the macro level that propagate in space and time. New and unforeseen "disturbances" may endanger system stability and force it to adapt to changing conditions.

A key term is "tipping point", which is defined as the "point or threshold at which small quantitative changes in the system trigger a non-linear change process that is driven by system-internal feedback mechanisms and inevitably leads to a qualitatively different state of the system, which is often irreversible." (Milkoreit et al.

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[1] Complexity expresses the difficulty to describe, understand, or explain something. A critical issue is to find a description of a system that contains the essential features and components (Scheffran 2015a). Systems that initially appear complex can become simple once they are understood or controlled.

2018: 9). Tipping points often involve the three notions "that events and phenomena are contagious, that little causes can have big effects, and that changes can happen in a nonlinear way but dramatically at a moment when the system switches." (Urry 2002:8; Scheffran 2008:14).

The continued expansion of human activities has become a driving force that transforms the earth system into a new geological epoch, the "Anthropocene". Climate change, together with other environmental challenges such as land degradation, resource scarcity, and biodiversity loss, is interconnected with other problem areas such as globalization, poverty, and violent conflict through multiple linkages from local to global levels. Associated risks affect human living conditions and undermine the stability of natural and social systems, particularly in fragile and failing states (Starr 2008). Thus, global climate change has been called a risk multiplier that amplifies other risks through complex impact chains that possibly exceed thresholds to instability.

In this context, key questions are considered: What happens if climate impacts exceed the adaptive capacity of natural and social systems? Are there ranges of tolerance, in which systems remain stable, and beyond which destabilization to qualitatively different system states is likely? Will climate change trigger regional or global risk cascades? When will critical infrastructures that are essential for the economy and society become dysfunctional? Does the risk-multiplying effect of climate change connect various problem areas? How will human-environment interaction be influenced by climate stress?

In the following, the role of climate change as a risk multiplier is discussed in an integrative framework that connects climate and societal stability. The main processes include instabilities in the climate system; hot spots of climate change and human insecurity; vulnerable infrastructure and networks; economic and financial crises; social and political instability; environmental migration; and violent conflict.[2]

Instabilities in the climate system

Weather and climate are considered primary examples of complex systems, and the Lorenz equations (a simplified mathematical model for atmospheric convection dynamics) became one of the roots of chaos theory (Sparrow 1982). The climate system is characterized by complex dynamic processes that are difficult to predict from knowledge of individual factors and equations. Although much is known about the effects of climate change on the components of the earth system, the interaction between the subsystems is still poorly understood. Since changes in one system can

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[2] This chapter is based on several publications of the author that are adapted for this purpose (Scheffran 2015b, 2016a, b, c, and Scheffran 2017a, b).

have direct or indirect effects on other systems, local events can propagate through complex causal chains and feedbacks on various spatial and temporal scales.

One focus of climate change research is on weather extremes such as hurricanes, droughts, forest fires, floods, and heatwaves, often corresponding to processes of non-linear dynamics such as phase transitions, critical thresholds, and chaos, which are paradigms in complex systems theory (Bunde et al. 2002; Kurths et al. 2009). In terms of their intensity, extreme weather events are rare in a particular location and a given time of year within a probability density function estimated from observations (IPCC 2013: Glossary). They represent phenomena outside of a given range around the average, representing too much or too little of the respective variable (such as temperature, rainfall, wind intensity, etc.). They are associated with extreme consequences that can burden the functionality and stability of the natural and social systems affected and exceed their resilience and viability range. The number and intensity of extreme weather events are likely to increase in the future (IPCC 2012; Rahmstorf and Coumou 2011).

In addition to single local events, the climate system itself can become unstable if critical tipping points are reached, for example by exceeding certain thresholds in global mean temperature that trigger amplifying effects (Lenton et al. 2008). These include the weakening of the North Atlantic thermohaline circulation, the rapid melting of ice shelves in Greenland and west Antarctica, the release of greenhouse gases such as methane from frozen soils in Siberia or Canada, and the change in the Asian monsoon. These phenomena and related chains of events can lead to a global and lasting transformation of the earth system. Massive and abrupt climate change could also overwhelm the adaptive capacities of even the strongest states and societies. Less time-critical, although globally hazardous in the long term, is the rise in sea level putting many coastal regions and islands at risk, which in the end can exceed the local coping capacity and trigger instability. Given the large number of uncertainties, it is a risky experiment to move into unknown areas of the climate system, where amplification of impacts and tipping elements open up the possibility of global destabilization. A sequence of tipping elements could drive the world's climate system into a qualitatively new state of a "hothouse earth", posing one of the gravest dangers facing humanity (Steffen et al. 2018).

In a world of interconnected crises, climate change can act as a potential risk multiplier through interactions between climate stress, environmental change, human responses, and social conflicts. We discuss how climate change affects human security and basic human needs (such as the availability of water, food, energy, health, and wealth) and societal instability events (such as forced displacement, riots, insurgencies, urban violence, and war) as well as the role of responses for transformation, including stability, resilience, sustainable development, and peace.

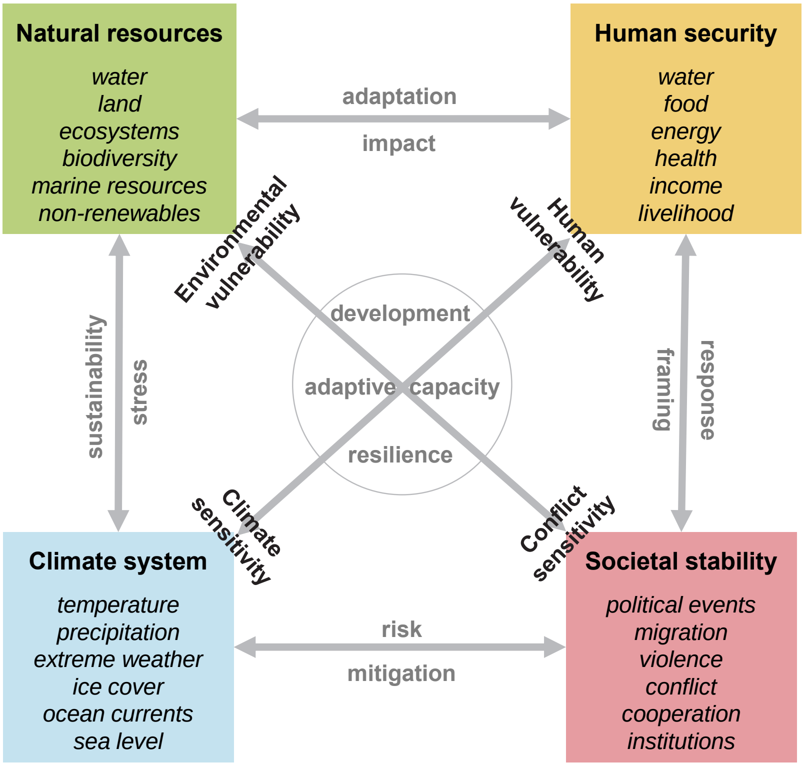

Figure 1: Impact chains and feedbacks in climate–society interaction. Source: adapted from Scheffran et al. 2012a.

Figure 1 presents an integrative framework describing the complex interactions in the earth system (Scheffran et al. 2012a, 2012b). The couplings in this network can be characterized by sensitivities that represent the impact that a change in one variable has on another variable. In particular, climate sensitivity is "the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change" (IPCC 2007: 881). Changes in the climate system affect the functioning of ecological systems and natural resources (e. g. soil, forests, and biodiversity). Depending on the vulnerability, this can have an impact on human security, e. g. by degrading the supply of water, energy, food, or economic goods. The sign of sensitivities can provide valuable information to classify qualitative patterns or "syndromes" (Eisenack et al. 2007a). Human reactions to environmental change can affect the stability of societal structures, driving conflicts and social destabilization in regional climate hot spots. The challenge is to develop practical strategies to address complexity, avoid dangerous instabilities of climate change, and maintain stability despite system changes. To meet the goal that was agreed on in the 1992 UN Framework Convention on Climate Change (UNFCCC) to prevent dangerous anthropogenic interference with the climate system and the temperature limits of the 2015 Paris agreement[3], an anticipatory-adaptive policy framework is needed that avoids risky pathways and allows for a timely and qualitative system transformation that takes the form of a self-organized stabilization. Some types of complex interactions are discussed below, with climate change acting as a "risk multiplier" and possibly triggering social destabilization in complex crises.

Hot spots of climate change and human insecurity

In hot spots strongly affected by climate change, compound effects lead to multiple stressors on human security. Hydro-meteorological disasters (storms, floods, and droughts) are an immediate danger to the life and health of the most affected people (Germanwatch 2018) in both developing countries (e. g. the Indus flood in Pakistan in 2010, a drought in China in 2010–11, or the typhoon in the Philippines in 2013) and industrialized countries (e. g. the European heatwave of 2003; the Elbe floods in Germany in 2002 and 2013; tropical storms in the US in recent years; wildfires in Russia in 2010; the European hot summer of 2018). For the most severe consequences, adequate assistance is hardly possible and social systems become overloaded in the regions of concern. For instance, in 2005 Hurricane Katrina caused enormous damage to the southern coast of the US and led to more than 1800 deaths; it displaced hundreds of thousands of citizens and overwhelmed disaster management. The heatwave of 2003 in Europe left behind tens of thousands of casualties and damage to agriculture worth tens of billions of euros. The Indus flood in 2010, the worst in more than eighty years, flooded a fifth of the land area of Pakistan with consequences for twenty million people; it led to approximately 2000 deaths and destroyed 1.7 million homes and a large part of the infrastructure (Gemenne et al. 2011).

On the other hand, climate change affects the long-term availability of natural resources, which can contribute to shortages and an unbalanced distribution of resources. Examples include the degradation of fresh water, forests and farmlands, shortage of nutrition, the threat to biodiversity, and overfishing. Whether people are able to cope with the consequences and to limit the risks depends on their vulnera-

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[3] The Paris Agreement of the 21st UNFCCC Conference of Parties (COP21) in 2015 aims to limit "the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels".

bility and adaptive capacity. These are influenced by their access to resources, information and technologies, as well as by the stability and effectiveness of institutions (Adger et al. 2009).

In hot spots, the stress from climate change can be associated with great human suffering and significant economic and social losses that undermine human security. A large share of the risks is neither exclusively nor primarily related to climate change, but often also affected by pre-existing local problems instead. These include the degradation of ecosystems, poverty, political instability, overuse of land, and the absence of early warning systems and disaster protection. Most vulnerable to climate stress are regions whose economies are dependent on climate-sensitive resources and where infrastructures are particularly exposed to climate change, particularly developing countries with a high level of dependence on agriculture; coastal areas and river basins; as well as hot and dry regions. Human security is at stake if natural resources that are of fundamental importance for the existence of people and the satisfaction of their needs are depleted or degraded.

While the primary consequences are often locally confined, it is possible that remote regions are affected through teleconnections as well as by humanitarian aid, civil protection or other direct interventions (including military operations). Some reactions may further aggravate the given situation, e. g. when people in need enforce the overexploitation of resources, move to other areas at risk, or use violence against competitors, in order to ensure their own survival. For instance, rising land prices may induce a search for cheaper land, a problem often found in developing countries, leading to environmental and supply risks and displacement of local users. Another example is the impact of land scarcity on the availability of water and on related crop losses. In case of droughts in major crop producing areas, global food markets can cause a fall in prices elsewhere. In this context, various trade-offs and exchange processes between different resources need to be taken into account. This is expressed in the nexus of water, energy, and food (see the following sections).

Vulnerability of infrastructure, technical systems, and supply networks

Critical economic and social infrastructure and supply networks are potentially vulnerable to climate change. This includes systems for the supply of water, food and energy, goods and services, systems for the provision of communication, health, transportation and security, as well as human settlements and political institutions. When important subsystems fail, the disruption may spread through couplings and lead to the collapse of the entire system. The consequences differ for developing countries, which depend directly on ecosystem services and agriculture, and developed countries that rely on interconnected technical systems but have more sophisticated protection and response mechanisms. The stronger the impacts are and the more subsystems are affected, the harder it is for societies to absorb the consequences. Corresponding relationships have been studied in risk research for the failure of complex technical systems, in which the combination of different events can result in the loss of control (e. g. Bhopal, Challenger, and Chernobyl). Since not all contingencies are predictable in complex systems, often a minor event can initiate a chain of events that initially appears to be a "normal accident" that triggers catastrophes in tightly coupled human-machine systems (Perrow 1984). In a globalized world, these tight couplings occur not only in technical systems but in other fields as well.

Although geophysical events are not related to weather disasters, they can provide insights with regard to their impact on social stability. A spectacular example of a disaster risk cascade was the earthquake in Japan on 11 March 2011, which triggered a chain of events with global effects. The subsequent tsunami flooded parts of the Japanese coast extinguishing thousands of human lives, and triggered the nuclear accident at Fukushima that destroyed several reactors and spread radioactivity globally through the atmosphere and the ocean. Because of the consequences of this large-scale accident, the Japanese power grid, the nuclear industry, stock markets, oil prices, and the global economy were all affected. Automobile manufacturers and electronics companies worldwide cut back production because important components were no longer being delivered from Japan. The shock waves from the nuclear disaster triggered a nuclear phase-out and renewable energy transition in Germany. This disaster impressively demonstrates how a single event can set in motion cascading events that overwhelm human coping and planning capacities (Kominek and Scheffran 2012; Scheffran et al. 2015; Scheffran 2016b).

In addition to earthquakes or technical accidents, weather extremes can also hit critical nodes in economic and social networks. For industrialized countries such as Germany, where both the economy and society depend on a functioning infrastructure, the stability of a sustainable supply system in response to extreme weather events is of great importance. Weather extremes such as the heatwave in 2003, the storm surge following storm Xaver in 2013, or the Elbe flood in 2013 lead to temporary impairments of transport or energy supply systems. From the perspective of climate research, it is important to assess whether extreme weather events can occur that exceed the adaptive capacities of supply networks. It is important to identify critical nodes and links in the global supply network and to understand how local failures of infrastructure components affect the global chain. Key research questions ask what happens in case of the failure of network elements, how shocks propagate in power grids, and whether a collapse of the network is possible.

An example is the failure of power grids, on which the functioning of other supply networks and socio-economic systems depends. Hydro-meteorological disasters can temporarily affect the supply of electricity before power is restored. There have been cases, in which minor events triggered a major blackout. In the biggest blackout in history in July 2012, more than 600 million people in northern and eastern India were affected due to an overload of the power grid. In November 1965, approximately thirty million people in the northeastern United States and in many parts of Canada remained without electricity for about six days. In California, there were regular power outages caused by insufficient generation capacity and market manipulation (Brand and Scheffran 2005). In November 2006, parts of Germany, France, Belgium, Italy, Austria, and Spain were temporarily disconnected from power supply. While there were various underlying causes in these instances, weather events were identified as trigger in other cases. In November 2005, after heavy snowfall in North Rhine-Westphalia and Lower Saxony, one of the largest power outages in German history occurred, and some 250 000 people were without power for several days, resulting in a financial loss of approximately €100 million (Deutschländer and Wichura 2005). A snowstorm in North America at the turn of 2013 and 2014 caused major power cuts for hundreds of thousands of people, leading to partial failure of the communication and transport systems[4].

If a particular resource supply system is hit, this often has effects on other resources, in particular the nexus of water, energy, and food (Beisheim 2013; IEA 2012). Energy is needed for irrigation and for the production of food or water, and to maintain the energy supply, in particular for the extraction, transportation and processing of fossil and nuclear energy. The development of unconventional gas and oil reserves (fracking, oil sands, and oil shales) has led to an increasing need for water and land. In addition, renewable energy sources such as hydropower and biofuels require large amounts of water as well. Regions with low rainfall are dependent on artificial irrigation for the cultivation of plants for food and energy. Even with large solar power plants, water supply in desert areas is a critical issue. Overall, the water demand for energy generation is estimated to rise twice as much as the demand for energy (Beisheim 2013).

Climate change affects this nexus in many ways and increases the competition between water, energy, and food. For instance, nuclear power plants are vulnerable because they are dependent on the flow of cooling water. Warming of the water or long periods of drought or floods affect power generation, leading to critical situations when cooling water is no longer available or water in power plants is below the critical level (Beisheim 2013: 24). If water levels in rivers and lakes are diminishing during

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[4] Ice storm blackouts frustrate tens of thousands; at: http://www.cbc.ca/news/canada/ice-storm-blackouts-frustrate-tens-of-thousands-1.2476866, last accessed 3 March 2020.

droughts, transportation of coal, oil, or biomass may become difficult or impossible, as was the case during the hot summer in Central Europe in 2018 (Olk and Witsch 2018). Storm surges and inundation place a substantial pressure on the entire transportation infrastructure. In 2005, Hurricane Katrina temporarily disabled more than a quarter of total offshore oil production in the Gulf of Mexico. This amounted to almost a fifth of total natural gas production and almost half of the available refining capacity, as well as important oil pipelines, thousands of oil rigs, and a large proportion of rail and sea transport (for an overview, see Kumins and Bamberger 2005). In 2013, Typhoon Haiyan destroyed part of the Philippines' supply of renewable energy (Bradsher 2013). Since renewable energy sources (bio-, hydro-, wind, and solar energy) depend on the given meteorological conditions, they are affected by climate change.

The cultivation of bioenergy plants as part of a climate change mitigation strategy has intensified global resource competition as large amounts of water and land are needed that are then no longer available for food production (Scheffran 2010). With a shortage of resources due to climate change, market prices tend to increase, making the expansion of agricultural production more attractive. The rising demand for production factors such as water, energy, pesticides, and fertilizers in turn increases environmental pollution and a growing demand for land (Beisheim 2013). On the other hand, rising food prices have adverse effects on poor populations (see below). To some extent, competition can be mitigated by synergistic effects, e. g. when hydropower plants achieve an optimal trade-off between water and energy use, solar energy is used for water desalination, organic waste is used in food production for energy purposes, and new jobs are created that contribute to development in rural areas.

It is difficult to make supply networks more resilient to climate change impacts if disruptive events occur in rapid succession that have multiple effects, which hit a system simultaneously, either with short time delays or in a narrow geographical area. With the increasing intensity and frequency of climate-related events, the question arises as to when the capacity limits and resilience of infrastructure are reached and whether existing safeguards and adaptation measures are sufficient.

Economic and financial crises

Assets and economic processes such as global freight and trading, financial markets and prices that regulate the exchange between supply and demand are also exposed to climate change. Financial transactions and pricing information represent virtual transfer mechanisms, which link different events with each other – both globally and within a very short period of time. If these processes are disturbed by climatic change, production losses, bankruptcies of companies, or a sharp decline of the stock market may propagate across global networks and markets.

The economic crisis of 2008 demonstrated the instability of the complex interconnected global economy. Driven by reckless speculation and lending practices of financial institutions and shortsighted human behavior, local events and individual responses escalated, pushing the global financial system to the brink of collapse. After a critical limit was exceeded, self-reinforcing mechanisms were triggered, leading to losses of hundreds of billions of Dollars and Euros worldwide. Public investment and regulatory policies were initially unable to compensate for the short-term fluctuations. The interaction between rating agencies and government responses led to a highly unstable situation. In Europe, the global economic crisis was followed by a crisis in Ireland, Iceland, and southern Europe, most dramatically in Greece.

Although other factors were at work here, weather extremes and economic crises may also interact and lead to a downward spiral. According to the Stern review, abrupt and extensive changes in the climate system could wreak havoc in global trade and financial markets (Stern 2006). Risk cascades are possible due to multiple linkages between disasters and financial markets (Haas 2010; Onischka 2009). In addition to direct economic damages, global impacts are possible through reduced production, supply shortages, and price increases for valuable goods, an overload of the insurance industry, flooding of major harbors, and the interruption of transportation networks and other components of the global supply chain. Through these connections, extreme events in one country can induce production losses in another country, and these can spread through global supply chains (Levermann 2014). While the direct damages and costs of weather extremes have been frequently studied, the indirect economic consequences are still poorly understood. Some issues have been raised in the context of the indirect effects of bioenergy, particularly as in some parts of the world prices and yields of cereals have been affected by bioenergy production (Scheffran 2010), e. g. in the so-called “tortilla crisis” in Mexico in 2007.

In the energy sector, various risks (natural disasters, infrastructure problems, strikes, riots, wars, political interventions) may lead to constraints on supply and market variation. High oil prices, as in 2008, are a driver for recession and social risks, or affect the willingness to accept a high level of environmental risk (Beisheim 2013). Relevant questions can be raised if production losses are observed after extreme events in a country that is a food supplier. Such events include the heatwave and related fires lasting several weeks in Russia in the summer of 2010, which resulted in an export ban on wheat (FAZ 2010). The droughts in the USA in 2011 and 2012 and in China in 2010–2011 were associated with price increases in food commodities as well. For poorer countries, the consequences of integration into the globalized economy can be as instantaneous as the direct effect of domestic local events. Even in developed countries such as Germany, the impacts of extreme events on consumers are noticeable. Europe is not immune to the adverse impacts if negative developments in the Mediterranean lead to a spiral of escalation. An economically weakened southern Europe is more vulnerable to climate-related risks and would have a lower potential for adaptation. In general, problems of water and food supply could hit tourism and agriculture, lead to conflict and migration, affect neighboring countries, and spread across continents. Some examples are discussed below.

Floods in Australia 2010–2011

In the wake of tropical cyclone Tasha, Queensland and New South Wales were affected by heavy rainfall in 2010 and 2011. The worst flooding in fifty years inundated an area equivalent to the size of Germany and France combined; it included seventy cities, thirty-five people lost their lives and 200 000 people were evacuated, including from parts of the metropolitan area of Brisbane. According to media reports, the damage was of the order of AUS$1 billion and the loss to GDP stood at AUS$13 billion, which had a significant impact on the economic performance of Australia. Furthermore, about forty coalmines were temporarily closed or operated at reduced power due to flooding, so that the production capacity of the largest coal exporter in the world was severely impaired. Coal mining in Queensland fell by thirty per cent; coal production fell from 471 million tons in the previous year to 405 million tons. At times, the domestic coal industry was losing more than €70 million per day (Oldag and Walterlin 2011). Since the cost of raw materials amounts to more than eighty per cent of the production cost of steel, this triggered price hikes and supply bottlenecks in the steel industry. The chain of events was also felt in Germany and had an impact on car production, mechanical engineering, and other industries (Spiegel 2011).

Flood in Thailand 2011

Thailand was hit by an unusually long-lasting monsoon in October and November 2011, resulting in the worst floods in fifty years, which affected nearly twelve per cent of the country. The consequences were almost 400 deaths, property damage of more than €11 billion, substantial loss of economic growth, temporary drops in tourist numbers, and massive crop losses. The neighboring countries of Cambodia and Laos were also affected. In addition to the regional consequences, the disaster had an impact on the world economy. Supply failures in electronic components led to bottlenecks in the international electronics and computer industry and an increase in prices of e. g. hard disk drives in Germany (Feddern and Schnurer 2011). German companies such as Volkswagen had problems with the delivery of important parts. Japan's automobile companies suffered repeated losses in production, shortly after the Fukushima disaster. Although the Thai electrical and electronics industry was severely impacted by the flooding, the industry has recovered faster than expected (Gärtner 2011).

Drought in China in 2010 and 2011

In November 2010, a once-in-a-century drought in China's eastern wheat belt threatened the winter wheat crop, which accounts for twenty-two per cent of the harvest of the world's largest producer and consumer of wheat. An area of 1.6 million hectares and more than 300 million people were affected. The severe drought hit the domestic and agricultural water supply and led to the closure of parts of the Yangtze River for navigation, as well as to the drying-up of water resources and to reduced hydropower generation. In early 2011, more than 2.2 million people and 2.73 million units of livestock nationwide suffered from lack of water. Utilizing experience from past famines (1958–1961), the Chinese government has taken measures to reduce the risk of crop failure. They have invested in the water infrastructure and bought wheat on the international market to compensate for the losses from the drought (Sternberg 2013). As a significant proportion (between six and eighteen per cent) of annual global wheat production is traded across borders (Lampietti et al. 2011), the decline in supply led to an increase in wheat prices and serious economic impacts in the import-dependent countries of North Africa and the Middle East (Sternberg 2013; see the following section).

Social and political destabilization

Directly or indirectly through the integration of physical, economic, and geopolitical risks in a globally interconnected world, the impact of climate-related events can also undermine social and political stability in regional and global contexts. Due to globalization, combined with rapid developments in computer technology, in communication, and in transportation systems, people are increasingly globally connected and able to respond collectively and rapidly to local changes. Accordingly, social and political changes in one region can have significant impacts in other regions, and determined groups can set in motion global chains of events that have an influence on international relations. This became apparent with the end of the cold war, the terrorist attacks of 11 September 2001, the Arab Spring in 2011, and the 2015 refugee crisis, each of which had a significant impact on Europe.

Environmental destruction, poverty, and hunger affect social conditions in many parts of the world. Fragile and weak states with social fragmentation and poor governance and management capacity are particularly sensitive, as the core functions of government, such as law and public policy, the state's monopoly on force, welfare, participation, and basic public services in infrastructure, health, and education cannot be guaranteed (WBGU 2008). Climate change may contribute to destabilization, especially if societies are in transition, for instance from authoritarian to democratic regimes. On the edge of instability, natural disasters can undermine the legitimacy and ability of states to protect their citizens from harm. If the agricultural sector of a developing country is severely damaged, the livelihood and existence of many people is at stake. The loss of life, income, wealth, jobs, health, or family or friends provokes opposition and unrest that threaten the social contract and undermine the political order. Some of these processes occur slowly and contribute to the erosion of social and political stability; others happen quickly and overwhelm the problem-solving and adaptive capacity of communities. Various destabilizing processes may intensify in climate hot spots and spread into neighboring regions. With the decay of the social and political order, non-state actors (private security companies, terrorist groups, warlords) penetrate the domains opened up by the power vacuum and trigger spirals of hate, terror, and violence. Countries with low average income and a weak adaptive capacity are particularly at risk, while richer societies have more potential capacity for adaptation. Due to global interdependence, however, destabilization in one part of the world may spread to other parts through complex chains.

Various natural disasters have been associated with a temporary collapse of law and order. Looting and criminal acts have occurred after heavy storms, for instance after Hurricane Katrina in the USA in 2005 and after the 2013 typhoon in the Philippines. After some storms and floods in southern Asia and Central America, the distribution of aid and relief goods was subject to disputes that were partly conducted violently (WBGU 2008; for a differentiated view see Brzoska 2018). In addition to storms and floods with usually temporary and local impacts on the food supply, droughts in major food exporting regions have a direct and lasting impact on global food markets because of their larger spatial and temporal scale. People who are highly dependent on agricultural production and the local availability of water resources are particularly affected. In contrast, the indirect influence of climate-related events and disasters on water, food, and population have an international dimension.

The most significant consequences include food shortages and a subsequent increase in food prices, which undermine the living conditions of poor social groups. This includes recent global food supply crises such as those of 2007–2008 and 2011 when food prices quickly multiplied and the number of hungry people increased by 100 million to 1 billion (Beisheim 2013). For instance, in 2008 uprisings related to food crises caused a change of government in Haiti, while in Cameroon twenty-four people were killed during protests and approximately 1500 were arrested (Sternberg 2012). A particularly noteworthy example is the social and political upheavals in the Middle East and North Africa (MENA) since 2011 (on the food crisis see Smith 2014; Bazzi and Blattman 2014; van Weezel 2016). The series of protests and uprisings in the Arab world affected the entire region and provoked a regime change in several countries (Johnstone and Mazo 2011). Starting with the unrest in Tunisia in early 2011 that forced the president to flee, the revolutionary impulse spread to Libya, Egypt, Syria, and other MENA countries, accelerated and multiplied by electronic media and social networks (Kominek and Scheffran 2012), which enabled the spread of the protest movement and motivated others to join. In the following years, the situation turned violent in some countries, especially in Libya and Syria.

Which role rising food prices played here and to what extent climate change and extreme weather events might have affected these processes is still subject of scholarly debate. At the beginning of the revolts, some media reports suggested a link with the sharp rise in food prices at the turn of 2010 to 2011. A collection of papers published by the Center for American Progress examined the impact of climate change on the upheavals in the Arab world (Werrell and Femia 2013). The argument was not so much that climate change was a primary cause, but rather that in a political crisis the effects of climate change can act as an additional stressor that exceeds a “tipping point”. One of the factors that occurred before the crisis was the drought in China in 2010 and 2011 (described above), which exerted pressure on the international market price of wheat and influenced the availability of food products. This coincided with other factors that further increased world food prices, including high oil prices, the development of bioenergy, and speculation on the global food markets (Johnson 2011).

The consequences affected much of the MENA region where the world’s nine largest importers of wheat in 2010 were located (based on per capita imports). Seven of these countries experienced political protests. In the MENA region, many households spend, on average, more than a third of their income on food (Sternberg 2013), while people in Western countries spend less than ten per cent. The dependence of Arab states on imported food makes them vulnerable to fluctuations in global commodity markets. Low incomes and high levels of resource imports and spending on food taken together affect food security. Reinforced by the sharp rise in bread prices, the existing public discontent with the government was magnified. In Egypt, the largest wheat importer in the world with a rapidly growing population, three per cent of the national income was spent on wheat subsidies (Sternberg 2013). As early as 1977 there was the so-called “bread intifada” in Egypt, in which seventy-seven people died, and in 2008 there were bread riots. However, no protests took place in Israel or the United Arab Emirates, which have a high per capita income, a smaller food share of income, and better adaptive capacities.

The chain of events before, during, and after the Arab Spring illustrates how extreme events can affect international relations in the interconnected world, mediated through economic, social, and political processes. In this complex pattern of overlapping stressors (Werz and Hoffman 2013), climate change was not the main cause but a contributing factor to triggering a complex chain of events. The political upheavals affected the stability of the Mediterranean region and coincided with the economic crisis in southern Europe. For Europe, these events were quite significant because of the civil wars in Libya and Syria and increasing migration from North Africa, the Middle East, and sub-Saharan Africa (see the following sections).

Environmental migration

According to the Internal Displacement Monitoring Centre (IDMC 2018), 18.8 million people have been displaced in 2017 by natural disasters (which were mostly weather-related), nearly half of the numbers of refugees counted in 2008. In contrast, 11.8 million were displaced by violent conflict in 2017 compared to 4.6 million in 2008. Between 2000 and 2016, floods were the most frequent weather-related disasters (followed by storms) and thus one of the biggest drivers of disaster displacement. For instance, as a result of the 2010 monsoon 15.2 million people in China and 11 million in Pakistan were displaced by floods. Every year millions of people escape from tropical cyclones, in particular in India, Bangladesh, China, the Philippines, Latin America, and the Caribbean. These countries often suffer from the consequences of severe cyclones. High-income OECD countries such as the USA, Australia, and Japan are also located in storm-prone areas. Particularly devastating catastrophes with extreme destructive power include Hurricane Mitch in 1998, Hurricane Katrina in 2005, Cyclone Nargis in 2008, Hurricane Sandy in 2012, Typhoon Haiyan in 2013, Hurricane Irma in 2017, and Hurricane Michael 2018, leaving millions of people homeless. Heat- and drought-related weather extremes reduce the adaptive capacity of social systems and lead to water, food, and health problems. Once traditional living conditions (agriculture and pastoralism) are suffering, long-term large-scale migration is one possible impact (Scheffran 2018).

Such problems are likely to become more important as a result of climate change, although its influence is currently difficult to determine. Thus, estimates of future climate migrants vary substantially in the literature, from fifty million to a billion people. All reported numbers are disputed (Jakobeit and Methmann 2012; Foresight 2011). The IPCC Special Report of 2012 on extreme events and disasters states that climate extremes will have a larger impact on migration in the future

(IPCC 2012). And the Fifth Assessment Report finds evidence for increased mobility in seventeen cases of observed or projected mobility associated with weather-related extremes or impacts of longer-term climate change while decreased mobility was found in six cases and socially differentiated changes in mobility patterns in five (IPCC 2014: 769).

Changes in the environment cannot only promote but also inhibit migration by increasing poverty in rural populations and thereby limiting their opportunities to escape (trapped populations). Environmental impacts and vulnerabilities can increase if people migrate to ecologically fragile and conflict-affected regions, including coastal cities that are affected by storms and sea level rise. In Europe and the United States, climate migration is often regarded as a security issue and conflict factor, possibly leading to ethnic, religious, and political tensions between the local population and immigrants. One contributing factor is competition for scarce resources such as arable farmland or pasture, housing, water, jobs, and social services. Media coverage of events such as the drought in Somalia, boat people in the Mediterranean, and refugee movements along the Balkan route reinforce threat perceptions in Europe. With the establishment of the European Agency for the Management of Operational Cooperation at the External Borders (FRONTEX), the "defense" of and against refugees – including environmental and climate migrants – has been expanded and continues to grow. One response to the refugee crisis of 2015 was to increase border controls.

So far, climate or environmental factors have not been identified as major contributions to international South-North migration. The majority of people affected by precarious environmental conditions remain in their home region or migrate to nearby urban areas. For weak and marginalized people, it is more difficult to overcome long distances or other barriers (e. g. language and cultural barriers) than it is for the privileged. It is subject of debate to what extent migration can be proven to trigger political instability and conflict (Barnett and Adger 2007; Reuveny 2007). Response patterns in security policy narrow the scope of action to the symptoms, with the risk of triggering a "chain reaction" between increasing migration pressure and countermeasures (such as enhanced border protection, as observed during the "refugee crisis" of 2015–16). Adaptation strategies and international cooperation can help to overcome risks and even develop migration into an important measure of adaptation to climate change (Foresight 2011), strengthening the resistance and resilience of the affected communities. Migration networks can contribute to resilience and stable structures between source and destination countries, such as the transfer of remittances, knowledge, and technology (Adger et al. 2002; Scheffran, Marmer, and Sow 2012).

Industrialized countries also experience environmental migration. The debate on this subject became more important when Hurricane Katrina forced hundreds of thousands of people to flee New Orleans in 2005, among them numerous refugees who never returned. Risk zones vulnerable to flooding in coastal or river areas can also become uninhabitable in Europe and lead to migration, even if a larger number of domestic environmental migrants is not expected in the foreseeable future. In contrast, the debate on the immigration of refugees from conflict areas can provoke internal social conflicts, an issue that become relevant in Europe since the summer of 2015.

A large number of immigrants to Europe originate in the MENA region (especially from Syria and Iraq), Afghanistan, and the Sahel. These regions are directly affected by climate change, which potentially increases the migration pressure there (Bundeswehr 2012). Because of high population growth rates, climate change and resource depletion in large parts of Africa, the availability of drinking water and arable farmland and pasture is expected to decline, potentially increasing dissatisfaction and tensions among millions of people (Schilling et al. 2012, Busby et al. 2013). Water availability in some countries is already below the threshold for water scarcity of 1000 cubic meters per person per year. In Libya, per capita water supply amounted to only approximately 95.8 cubic meters in 2009 and to 356 cubic meters per person in Syria, significantly lower than the figures for 2002 and well below the world average (World Bank 2013). In the years before the rebellion, Syria experienced devastating droughts (Kelley et al. 2015) that hit the main agricultural areas of the country and displaced many people from the countryside to the cities (Werz and Hoffman 2013; see the contribution by Christiane Fröhlich in this volume). Water and food supply in Egypt depends heavily on water from the Nile River, which is increasingly being utilized by upstream riparian states in recent years (Link et al. 2012).

Frustration sparks protests, especially among the young male population, and increases their willingness to leave the country to travel to the North. The problems of North Africa are linked in complex ways to those of the Sahel, which is also affected by climate change. Libya has been the destination of migration routes from the South because of oil revenues and related jobs. After the government was overthrown, tensions with immigrants increased. Some of the armed mercenaries in Libya went to Mali and other countries of the Sahel where they contributed to regional political destabilization. In sub-Saharan Africa, climate change, desertification and scarcity of resources have become connected with economic and social marginalization, political instability and violent conflict, which undermined the livelihoods of farmers and herders and increased the migration pressure (Ionesco et al. 2017).

Climate change and violent conflict

By altering natural and social livelihoods in many regions, climate change represents a potential driver for conflict and related acts of violence. These include civil wars and military interventions that in turn are associated with negative consequences such as famine, economic crises, refugees, resource exploitation, and environmental degradation (WBGU 2008).

There is a widely held assumption that the progressing consequences of global warming will increase the likelihood of conflicts that are associated with the destruction of human livelihoods and resources. In addition, there are potential disputes regarding the adequate strategies for avoiding climate change as well as their financing. Examples include the controversy about the use of nuclear power as a contribution to CO2 abatement or the debate about the consequences of bioenergy, which also determine the German discourse (Webersik 2010; Scheffran and Cannaday 2013). The same applies to differences on adaptation to climate change and its security implications, such as alternative farming practices, protection measures like the construction of dams, and military operations in disaster management. technical interventions into the climate system (climate geoengineering) to remove CO2 from the atmosphere or to influence the earth's radiation budget are also conflict-prone. Such measures raise critical issues of technical and economic feasibility, as well as on risks and responsibilities at global, national, and local levels (Brzoska et al. 2012). In all these consequences and responses there are concerns about justice when it comes to the distribution of the costs, benefits, and risks of climate change, which are likely to complicate cooperative solutions.

The potential contribution of environmental change and resource use to violent conflict has been the subject of scientific controversy for more than two decades. While some studies claim that natural disasters and resource scarcity put social systems under stress, threaten their stability, and make violent conflict more likely, others see no clear causal relationship for past events that is detectable by statistical methods. Those researchers emphasize the ability of human societies to deal with resource issues through collaboration and innovation (see reviews in Brauch 2002, 2009). So far, most environmental conflicts have been regional in scope and have presented no threat to international security (Carius et al. 2006). The connections vary substantially regionally and depend on the affected resource type. While scarcity is more likely to be a conflict factor for renewable resources (water, food, biodiversity), abundance is more likely to lead to conflict for non-renewable resources (fossil fuels, uranium, diamonds, coltan). In both cases, violent conflicts consume resources, which can drive or restrain a spiral of violence (Scheffran et al. 2014).

Debates that are more recent have addressed the links between climate change and violent conflict. This issue was raised in the fifth IPCC Assessment Report (IPCC 2014; Gleditsch and Nordas 2014). Some studies looking at long historical periods have found significant correlations between climate variability and violent conflicts, particularly in the Little Ice Age in Europe between the fifteenth and the nineteenth centuries. Research on more recent periods has produced mixed results, which depend in a complex way on the regional context and on the conflict situation (see reviews in Scheffran, Brzoska et al. 2012a, 2012b). Studies using selected data and studies on the relationship between climate change and violence over all historical periods, world regions, forms of violence, and causal mechanisms (Burke et al. 2009; Hsiang et al. 2013) have exacerbated the scientific controversy (Buhaug 2010; Buhaug et al. 2014).

Regardless of the interpretation of historical data, the impact of future climate change goes beyond previous experiences, leaving space for scenarios, plausibility considerations, and speculation. It is indeed possible that societies have been able to adapt to moderate climate change in history but they may be overwhelmed in the future by rapid and strong climate change that exceeds their adaptive capacities. There is a wide range of possible conflict constellations (WBGU 2008) associated with the effects of climate change on rainfall and water scarcity, land use and food security, migration and refugee movements, extreme weather events and natural disasters. These processes can become conflict factors individually or in conjunction. In addition, the effects of climate change on infrastructure and social destabilization may trigger societal "tipping points", leading to social unrest, riots, violence, crime, and armed conflict.

The vulnerability of agrarian societies with a high level of population growth and a low level of development is particularly pronounced (Raleigh and Urdal 2007). Pastoralists, for whom migration is part of their traditional way of life, suffer from long periods of drought that threaten the supply of water and grass to their cattle herds. Deviation from their usual routes can create tensions among herders or farmers, especially in regions with severe water shortages, such as West Africa and the Horn of Africa, the Middle East, and Central Asia.

Whether climate change acts as a "threat multiplier" and creates a "climate of violence" depends largely on how people and societies respond to change, and on whether their adaptive capacities and institutional structures are adequate for maintaining stability. While rich industrialized countries are not spared by climate change, they may benefit from advanced economic and institutional conditions for problem solving and conflict management. Potential issues of conflict in Europe include tensions over territorial claims and natural resources in the Arctic and the Mediterranean. The melting of polar ice sheets affects the strategic interests of Europe, Russia, and North America. Efforts between Europe, the Middle East, and Northern Africa to build a power grid based on renewable energy open up the possibility of converting the Mediterranean from a region dominated by oil interests towards a region of cooperative security (Scheffran and Brauch 2014), provided that the utilization of energy is sustainable and promotes development, peace, and justice.

As an example, the importance of climate change for conflict in North and East Africa is discussed. In the wake of the Arab Spring, Syria and Libya experienced bloody unrest that led to a coup in Libya, and in the case of Syria to a civil war, in which the contribution of climate change is disputed (Kelley et al. 2015; Selby et al. 2017; see chapter by Christiane Fröhlich). Similar to other MENA countries, both countries are facing water problems that compromise the supply of this elementary good (Schilling et al. 2012).

For several decades, Sudan has experienced political instability and violent conflicts, reinforced by national power games, regional struggles, and global geopolitics. Peripheral regions such as Darfur are characterized by marginalization and exclusion, and this leads to disintegration and secession. The complex nexus of problems includes population pressure, unsustainable exploitation of land and forests, declining agricultural productivity, food insecurity, and the spread of diseases such as malaria. Associated problems are environmental changes and resource degradation, which cause water shortages and the deterioration of pasture in the northern Sahel following drought and desertification (DeJuan 2005). This exacerbates competition for resources between herders and sedentary farmers. The expansion of mechanized agriculture continues to deprive nomadic people of their traditional migration routes, to dispossess peasants, and possibly lead to serious tensions.

The role of climate change as a conflict amplifier in Darfur is controversial. While some observers classify Darfur as a “tragic example of a social collapse as a result of an ecological collapse” (UNEP 2007: 12–13), others are concerned about the oversimplification of the Darfur conflict (Butler 2007). They criticize the government of Sudan for exploiting the climate argument to distract from its own responsibility (Verhoeven 2011). Overall, climate change is one of many conflict factors in Darfur that reinforce each other in a complex way (Scheffran et al. 2014). A recent expression of the climate-conflict nexus is the humanitarian crisis in the Lake Chad region. Environmental and climate stress from rainfall variability, droughts, and declining water and arable land in a shrinking Lake Chad aggravates multiple vulnerability conditions and contributes to livelihood risks and tensions between farmers, pastoralists, and fishermen who may become the target of recruitment by non-state armed groups such as Boko Haram. Resource conflicts contribute to destabilization and displacement, fueling the region’s fragility (Vivekananda and Born 2018).

Governing complex crises and climate risks

The “complexity turn” in international relations (Urry 2005) is characterized by multi-level crises constellations linked through global connectors such as globalized financial markets, infrastructure and supply chains, media and social networks,

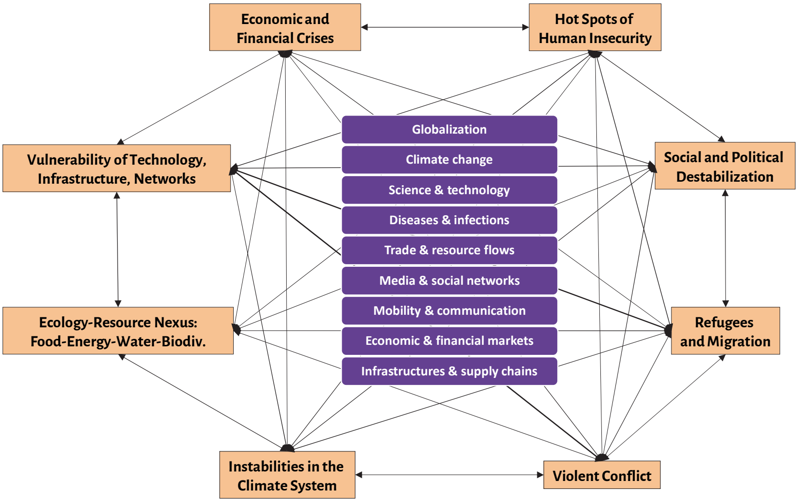

Figure 2: Compound events and global connectors in complex crises landscapes. Source: adapted from Scheffran 2017a.

communication and transportation systems, as well as resource flows and climate change (Figure 2). When everything is interconnected, changes in one part of the world can have significant impacts elsewhere and propagate through systemic networks like a domino effect or chain reaction (Scheffran 2017a). Growing complexity provokes opposing trends of over-simplification, populism, nationalism, religious fundamentalism, illiberalism, anti-globalization, and anti-science attitudes that fail to address the underlying mechanisms. Without adequate management or reduction of complexity, the world may continue on a slippery slope of destabilization. Instead, stability may be achieved by adapting the complexity of policies to the complexity of the systemic processes that they regulate. The challenge is whether humanity can anticipate and avoid hazardous pathways by counteracting forces that slow down and change course within the planetary boundaries of the Anthropocene (Rockström et al. 2009). Throughout history, Homo Sapiens was able to overcome constraints on resources in crises and to expand into new spaces by applying problem-solving capabilities and developing technical and social innovations that stretched the limits of growth, allowing more wealth to be generated on a shrinking base of natural resources. The question is whether humanity will succeed again facing today's complex world or whether disasters destroy any chances of success.

Operating in a multi-risk environment requires taking a whole-system approach to analyzing and measuring compounding risks (Mishra and Vivekananda 2015). Although risks from individual processes like climate change may be relevant,

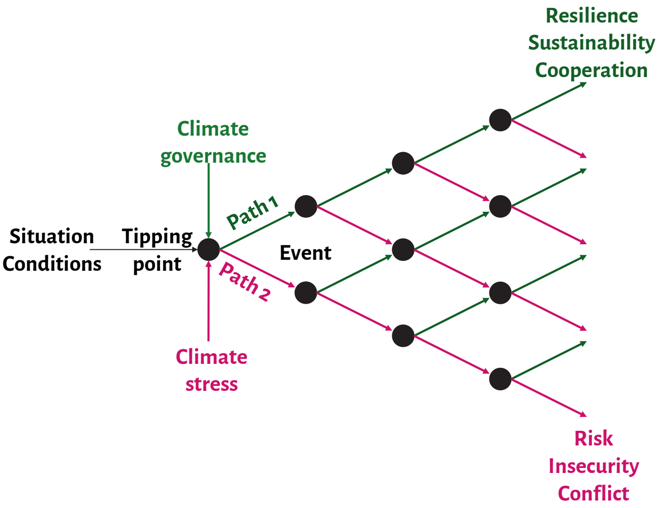

Figure 3: Pathways, tipping points, and cascades of transitions between conflict and cooperation. Source: adapted from Scheffran 2016c

their impacts may be hard to prove. It makes sense to identify criteria for stability, determine thresholds when transitions to instability occur and identify factors and mechanisms that facilitate the transition across thresholds. Regarding climate-conflict linkages, the question is how stable a certain level of conflict or cooperation is when an escalation between levels occurs and which role climate change can play in these transitions. This is not a single-stage process but a continued interaction between climate stressors and governance mechanisms driving the dynamics through a sequence of decisions and tipping points between conflict and cooperation. Whether climate stress fuels a cycle of violence or climate governance facilitates a cycle of cooperation and sustainable peace depends on the effectiveness of human and societal responses (Scheffran et al. 2014).

Strategies for sustainable and adaptive governance range from climate mitigation, adaptation, and the building of social networks to new capabilities of disaster management, crisis prevention, conflict resolution, and environmental peacebuilding to stabilize human interaction. Various measures can support the adaptive capacity of ecosystems and their human values, including the establishment of nature reserves, sustainable land use, preservation of endangered species, and the protection of terrestrial carbon stocks. Within limits, ecosystems can adapt to climate change. To be sustainable, consumption of natural resources should not exceed their carrying capacity, given by their limited regeneration and absorption abilities (Scheffran 2015a). Stabilizing human-environment interactions becomes a major challenge in international relations and global governance but there is little experience with integrative approaches in science and politics to understand and manage such level of complexity. Stabilization may be achieved by concepts of adaptive and anticipative governance that addresses and diminishes the complexity of the systemic processes. Integrative and interdisciplinary knowledge helps to avoid dangerous pathways, influence critical decision points and develop collective adaptive strategies and interventions towards a more sustainable, peaceful, and viable world (Scheffran 2016c).

References

Adger, W. N., P. M. Kelly, A. Winkels, L. Q. Huy, and C. Locke, 2002: Migration, Remittances, Livelihood Trajectories, and Social Resilience. Journal of the Human Environment, 31(4), 358–366.

Adger, W. N., I. Lorenzoni, and K. O'Brien, eds., 2009: Adapting to Climate Change: Thresholds, Values, Governance. Cambridge: Cambridge University Press.

Barnett, J. and W. N. Adger, 2007: Climate change, human security and violent conflict. Political Geography, 26, 639–655.

Bazzi, S and C. Blattman, 2014: Economic shocks and conflict: evidence from commodity prices. American Economic Journal: Macroeconomics, 6(4), 1–38.

Beisheim, M., ed., 2013: Der Nexus Wasser-Energie-Nahrung - Wie mit vernetzten Versorgungsrisiken umgehen? Berlin: Stiftung Wissenschaft und Politik, Deutsches Institut für Internationale Politik und Sicherheit.

Bradsher, K., 2013: Font of Natural Energy in the Philippines, Crippled by Nature, New York Times, 21 November.

Brand, R. and J. Scheffran, 2005: The price to pay for deregulation of electricity supply in California, Limits To Privatization - How to Avoid Too Much of a Good Thing. In: E. U. von Weizsäcker, E. Ulrich, O. R. Young, M. Finger, and M. Beisheim, eds., Report to the Club of Rome. London: Earthscan, 79–83.

Brauch, H. G., 2002: Climate Change, Environmental Stress and Conflict. Climate Change and Conflict. Can climate change impacts increase conflict potentials? What is the relevance of this issue for the international process on climate change? Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin.

Brauch, H. G., 2009: Securitizing Global Environmental Change. In: H. G. Brauch, Ú. Oswald Spring, J. Grin, C. P. Mesjasz, P. Kameri-Mbote, N. C. Behera, B. Chourou, and H. Krummenacher, eds., Facing Global Environmental Change: Environmental, Human, Energy, Food, Health and Water Security Concepts. Berlin – Heidelberg – New York: Springer, 65–102.

Brzoska, M., P. M. Link, A. Maas, and J. Scheffran, eds., 2012: Geoengineering: An Issue for Peace and Security Studies? Sicherheit und Frieden/Security and Peace (Special Issue), 30(4).

Brzoska, M. 2018: Weather Extremes, Disasters, and Collective Violence: Conditions, Mechanisms, and Disaster-Related Policies in Recent Research. Current Climate Change Reports, 4, 320–329.

Buhaug, H., 2010: Climate not to blame for African civil wars. Proceedings of the National Academy of Sciences, 107, 16477–16482.

Buhaug, H. and coauthors, 2014: One effect to rule them all? A comment on climate and conflict. Climatic Change, 127(3–4), 391–397.

Bunde, A., J. Kropp, and H. J. Schellnhuber, eds., 2002: The Science of Disasters—Climate Disruptions, Heart Attacks, and Market Crashes. Berlin-London: Springer.

Bundeswehr, 2012: Klimafolgen im Kontext—Implikationen für Sicherheit und Stabilität im Nahen Osten und Nordafrika. Teilstudie 2, Strausberg: Dezernat Zukunftsanalyse des Planungsamtes der Bundeswehr.

Burke, M. B., E. Miguel, S. Satyanath, J. A. Dykema, and D. B. Lobell, 2009: Warming increases the risk of civil war in Africa. Proceedings of the National Academy of Sciences, 106, 20670–20674.

Busby, J. W., C. Raleigh, and I. Salehyan, 2013: The Political Geography of Climate Vulnerability, Conflict and Aid in Africa. In: P. K. Huth, J. Wilkenfeld, and D. A. Backer, eds., Peace and Conflict 2014., Boulder, Co: Paradigm Publishers.

Butler, D., 2007: Darfur's climate roots challenged. Nature, 447: 1038.

Carius, A., D. Tänzler, and J. Winterstein, 2006: Weltkarte von Umweltkonflikten (Berlin: Adelphi); at: http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/hauptgutachten/jg2007/wbgu_jg2007_ex02.pdf, last accessed 26 January 2020.

CNA Corporation, 2007: National security and the threat of climate change. Alexandria, Va.: The CNA Corporation.

De Juan, A., 2015: Long-term environmental change and geographical patterns of violence in Darfur, 2003–2005. Political Geography 42, 22–33.

Deutschländer, T. and Wichura, B., 2005: Das Münsterländer Schneechaos am 1. Adventswochenende 2005. Klimastatusbericht 2005, 163–167; at: www.dwd.de/DE/leistungen/klimastatusbericht/publikationen/ksb2005_pdf/15_2005.pdf?__blob=publicationFile&v=1, last accessed 26 January 2020.

Eisenack, K., M. K. B. Lüdeke, G. Petschel-Held, J. Scheffran, and J. P. Kropp, 2007: Qualitative Modelling Techniques to Assess Patterns of Global Change. In: J. Kropp and J. Scheffran, eds., Advanced Methods for Decision Making and Risk Management in Sustainability Science. New York: Nova Science, 99–146.

FAZ, 2010: Russlands Exportverbot treibt den Weizenpreis. Frankfurter Allgemeine Zeitung, 6 August.

Feddern, B. and G. Schnurer, 2011: Teure Terabytes - Überschwemmung in Thailand führt zu Lieferengpässen bei Festplatten. c't magazin, 24 Nov., at: http://www.heise.de/ct/artikel/Teure-Terabytes-1370334.html, last accessed 26 January 2020.

Foresight, 2011: Migration and Global Environmental Change. Final Project Report, London: Government Office for Science.

Gärtner, M., 2011: Thailand: Flutdesaster bedroht globale Lieferketten, Manager Magazin, 14 November 2011; at: http://www.manager-magazin.de/politik/weltwirtschaft/a-797205.html, last accessed 26 January 2020.

Gemenne, F., P. Brücker, and J. Glasser, eds., 2011: The State of Environmental Migration 2010. Paris: Institute for Sustainable Development and International Relations, International Organization for Migration

Gleditsch, N. P. and R. Nordås, 2014: Conflicting messages? The IPCC on conflict and human security, Political Geography, 43 (November): 82–90.

Haas, Armin, 2010: Klimawandel und Finanzmärkte. UmweltWirtschaftsForum (uwf), 18(1), 3–9.

Held, H. and H. J. Schellnhuber, 2004: Evolution of Perturbations in Complex Systems. In: W. Steffen and coauthors, eds. Global Change and the Earth System. A Planet under Pressure. The IGBP Series. Berlin – Heidelberg –New York: Springer, 145–147.

Holling, C. S., 1973: Resilience and stability of ecological systems, Annual Review of Ecology and Systematics, 4, 1–23.

Hsiang, S. M., M. Burke, and E. Miguel, 2013: Quantifying the influence of climate on human conflict, Science, 341(6151), 1235367.

IDMC, 2018: Global Report on Internal Displacement. Internal Dispalacement Monitoring Centre, Geneva.

Ide, T., P. M. Link, J. Scheffran, and J. Schilling, 2016: The climate-conflict nexus: pathways, regional links, and case studies. In: H. G. Brauch, U. Oswald-Spring, J. Grin, and J. Scheffran, eds., Handbook on Sustainability Transition and Sustainable Peace., 285–304: Springer.

Ionescu, D., D. Mokhnacheva, and F., Gemenne 2017: The Atlas of Environmental Migration. London: Routledge, Earthscan, and International Organization of Migration.

IPCC, 2007: Climate Change 2007. Climate Change Impacts, Adaptation and Vulnerability. Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. SREX. Geneva: Intergovernmental Panel on Climate Change.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

IPCC, 2014: Climate Change 2014—Impacts, Adaptation, and Vulnerability—Part A: Global and Sectoral Aspects. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Jakobeit, C. M. and C. Methmann, 2012: Climate Refugees' as Dawning Catastrophe? A Critique of the Dominant Quest for Numbers. In: J. Scheffran, M. Brzoska, H. G. Brauch, P. M. Link, and J. Schilling, eds., Climate Change, Human Security and Violent Conflict: Challenges for Societal Stability. Heidelberg: Springer, 301–314.

Johnson, T., 2011: Food Price Volatility and Insecurity. Council on Foreign Relations, 24 June 2011. 1 May 2016.

Johnstone, S. and J. Mazo, 2011: Global warming and the Arab spring, Survival, 53(2), 11–17.

Kavalski, E., ed., 2015: World Politics at the Edge of Chaos. Albany, NY: State University of New York Press.

Kelley, C. P., S. Mohtadi, M. A. Cane, A. Mark, R. Seager, and Y. Kushnir, 2015: Climate change in the Fertile Crescent and implications of the recent Syrian drought. Proceedings of the National Academy of Science,112(11), 3241–3246.

Kominek, J. and J. Scheffran, 2012: Cascading Processes and Path Dependency in Social Networks. In: H.-G. Soeffner, ed., Transnationale Vergesellschaftungen. Wiesbaden: VS Springer.

Kumins, L. and R. Bamberger, 2005: Oil and Gas Disruption from Hurricanes Katrina and Rita. Congressional Research Service, 21 Oct. at: http://fpc.state.gov/documents/organization/55824.pdf, last accessed 26 January 2020.

Kurths, J., D. Maraun, C. S. Zhou, G. Zamora-Lopez, and Y. Zou, 2009: Dynamics in complex systems, European Review, 17(2), 357–370.

Lampietti, J. A., S. Michaels, N. Magnan, A. F. McCalla, M. Saade, and N. Khouri, 2011: A strategic framework for improving food security in Arab countries. Food Security, 3, S7–S22.

Lenton, T., H. Held, E. Kriegler, J. W. Hall, W. Lucht, S. Ramstorf, and H. J. Schellnhuber, 2008: Tipping elements in the Earth's climate system. Proceedings of the National Academy of Science, 105(6), 1786–1793.

Levermann, A., 2014: Make supply chains climate- smart. Nature 506: 27–29.

Link, P. M., F. Piontek, J. Scheffran, and J. Schilling, 2012: On Foes and Flows: Vulnerabilities, Adaptive Capacities and Transboundary Relations in the Nile River Basin in Times of Climate Change. L'Europe en Formation, 365(3), 99–138.

Milkoreit, M., et. al. 2018: Defining tipping points for social-ecological systems scholarship – an interdisciplinary literature review. Environmental Research Letters, 13, 1–12.

Mitra, S. and J. Vivekananda, 2015: Compounding risk - Disasters, fragility and conflict. London: International Alert Policy Brief.

Oldag, A. and U. Wälterlin, 2011: Kettenreaktion mit Kohle. Süddeutsche Zeitung, 6 Jan. 2011; at: http://www.sueddeutsche.de/wirtschaft/ueberschwemmung-in-australien-kettenreaktion-mit-kohle-1.1043437., last accessed 26 January 2020.

Olk J. and K. Witsch, 2018: Low water Dwindling Rhine paralyzes shipping transport. Handelsblatt Today, 27 November 2018.

Onischka, M., 2009: Definition von Klimarisiken und Systematisierung in Risikokaskaden. Diskussionspaper, Wuppertal Institut für Klima, Umwelt, Energie, Wuppertal, Germany.

Perrow, C., 1984: Normal Accidents: Living with High- Risk Technologies. Princeton: Princeton University Press.

Rahmstorf, S. and D. Coumou, 2011: Increase of extreme events in a warming world. Proceedings of the National Academy of Science, 108(44), 17905–17909.

Raleigh, C. and H. Urdal, 2007: Climate change, environmental degradation and armed conflict. Political Geography, 26(6), 674–694.

Reuveny, R., 2007: Climate change-induced migration and violent conflict. Political Geography, 26(6), 656–673.

Rockström, J. and coauthors, 2009: A safe operating space for humanity. Nature, 461, 472–475.

Rothe, D., 2015: Securitizing Global Warming: A Climate of Complexity. London: Routledge.

Scheffran, J., 1983: Komplexität und Stabilität von Makrosystemen mit Anwendungen. Department of Physics, Universität Marburg, Germany.

Scheffran, J., 1996: Leben bewahren gegen Wachstum, Macht, Gewalt—Zur Verknüpfung von Frieden und nachhaltiger Entwicklung. Wissenschaft und Frieden, 3/96, 5–9.

Scheffran, J., 2008: The Complexity of Security. Complexity, 14(1), 13–21.

Scheffran, J., 2010: Criteria for a Sustainable Bioenergy Infrastructure and Lifecycle. In: P. N. Mascia, J. Scheffran, and J. Widholm, eds., Plant Biotechnology for Sustainable Production of Energy and Co-products. Berlin: Springer, 409–443.

Scheffran, J., 2015a: Complexity and Stability in Human–Environment Interaction: The Transformation from Climate Risk Cascades to Viable Adaptive Networks. In: E. Kavalski, ed., World Politics at the Edge of Chaos. Albany, NY: State University of New York Press, 229–252.

Scheffran, J., 2015b: Climate Change as a Risk Multiplier in a World of Complex Crises. Planetary Security Conference, The Hague, Netherlands.

Scheffran, J., 2016a: Kettenreaktion außer Kontrolle: Vernetzte Technik und das Klima der Komplexität. Blätter für deutsche und internationale Politik, 3/16: 101– 110.

Scheffran, J., 2016b: Klimawandel als Risikoverstärker in komplexen Systemen. In: G. Brasseur, D. Jacob, S. Schuck-Zöller, eds., Klimawandel in Deutschland. Heidelberg: Springer, 287–294.

Scheffran, J., 2016c: From a Climate of Complexity to Sustainable Peace: Viability Transformations and Adaptive Governance in the Anthropocene. In: H. G. Brauch, U. Oswald-Spring, J. Grin, and J. Scheffran, eds., Handbook on Sustainability Transition and Sustainable Peace. Heidelberg: Springer, 305–347.

Scheffran, J., 2017a: Der Nexus aus Migration, Klimawandel und Konflikten. Migration und Flucht zwischen Klimawandel und Konflikten. In: J. Scheffran, ed., Hamburger Symposium Geographie, Vol. 9. Hamburg, Germany, 7–40.

Scheffran, J., 2017b: Complex Crisis Landscapes and Climate Risk Governance: Challenges for European Stability and Transformation. EU Paper Series, Vol. 1 (Special Issue), Urbana: University of Illinois.

Scheffran, J., 2018: Migration und soziale Probleme als Folge von Wetterextremen. In: J. L. Lozán, S.-W. Breckle, H. Graßl, D. Kasang, and R. Weisse, eds., Warnsignal Klima: Extremereignisse. Hamburg: Wissenschaftliche Auswertungen, 320–325.

Scheffran, J. and A. Battaglini, 2011: Climate and conflicts—The security risks of global warming. Regional Environmental Change, 11 (S 1), 27–39.

Scheffran, J. and H. G. Brauch, 2014: Conflicts and Security Risks of Climate Change in the Mediterranean Region. In: S. Goffredo and Z. Dubinsky, eds., The Mediterranean Sea. Dordrecht: Springer, 625–640.

Scheffran, J., M. Brzoska, H. G. Brauch, P. M. Link, and J. Schilling, eds., 2012: Climate Change, Human Security and Violent Conflict: Challenges for Societal Stability. Heidelberg: Springer.

Scheffran, J., M. Brzoska, J. Kominek, P. M. Link, and J. Schilling, 2012a: Climate change and violent conflict. Science, 336, 869–871.

Scheffran, J. and T. Cannaday, 2013: Resistance Against Climate Change Policies: The Conflict Potential of Non-fossil Energy Paths and Climate Engineering. In: A. Maas, B. Balazs, C. Burnley, I. Comardicea, and R. Roffey, eds., Global Environmental Change: New Drivers for Resistance, Crime and Terrorism? Baden-Baden: Nomos.

Scheffran, J., T. Ide, and J. Schilling, 2014: Violent Climate or Climate of Violence? Concepts and Relations with Focus on Kenya and Sudan. International Journal of Human Rights, 18(3), 369–390.

Scheffran, J., P. M. Link, and J. Schilling, 2012: Theories and Models of Climate-Security Interaction: Framework and Application to a Climate Hot Spot in North Africa. In: J. Scheffran, M. Brzoska, H. G. Brauch, P. M. Link, and J. Schilling, eds., Climate Change, Human Security and Violent Conflict: Challenges for Societal Stability. Heidelberg: Springer, 91–132.

Scheffran, J., E. Marmer, and P. Sow, 2012: Migration as a contribution to resilience and innovation in climate adaptation. Applied Geography, 33, 119–127.

Scheffran, J., Burroughs, J., Leidreiter, A., van Riet, and A. Ware, 2015: The Climate–Nuclear Nexus: Exploring the linkages between climate change and nuclear threats. Affiliation. Hamburg: World Future Council.

Schilling, J., K. P. Freier, E. Hertig, and J. Scheffran, 2012: Climate change, vulnerability and adaptation in North Africa with focus on Morocco. Agriculture, Ecosystems and Environment, 156, 12–26.

Selby, J., O. S. Dahi, C. Fröhlich, and M. Hulme, 2017: Climate change and the Syrian civil war revisited. Political Geography, 60, 251–252.

Smith, T. G ,2014: Feeding unrest: disentangling the causal relationship between food price shocks and sociopolitical conflict in urban Africa. Journal of Peace Research, 51(6), 679–695.

Sparrow, C., 1982: The Lorenz Equations: Bifurcations, Chaos, and Strange Attractors. Heidelberg: Springer.

Spiegel, 2011: Flut in Australien: Wichtige Kohleminen noch wochenlang unbrauchbar. Spiegel online 6 January 2011; at: http://www.spiegel.de/wirtschaft/flut-in-australien-wichtige-kohleminen-noch-wochenlang- unbrauchbar-a-738054.html, last accessed 26 January 2020.

Starr, H., ed., 2008: Failed States. Special Issue. Conflict Management and Peace Science, 25(4), 281–284.

Steffen, W. and coauthors, 2018: Trajectories of the Earth System in the Anthropocene. Proceedings of the National Academy of Science, 115(33), 8252–8259.

Stern, N., 2006: The Economics of Climate Change— The Stern Review. Cambridge: Cambridge University Press.

Sternberg, T., 2012: Chinese drought, bread and the Arab Spring. Applied Geography, 34, 519–524.

Sternberg, T., 2013: Chinese Drought, Wheat, and the Egyptian Uprising: How a Localized Hazard Became Globalized. In: C. E. Werrell, F. Femia, eds., The Arab Spring and Climate Change. A Climate and Security Correlations Series. Washington, D. C.: Center for American Progress, Stimson Center, 7–14.

UNEP, 2007: Sudan: post-conflict environmental assessment. Nairobi: United Nations Environment Programme.

Urry, J., 2005: The Complexity Turn. Theory, Culture & Society, 22(5), 1–14.

Verhoeven, H., 2011: Climate Change, Conflict and Development in Sudan: Global Neo-Malthusian Narratives and Local Power Struggles. Development and Change, 42, 679–707.

Vivekananda, J. and C. Born, 2018: Lake Chad Region climate-related security risk assessment. Report by Expert Working Group on climate-related security risks. Berlin: Adelphi.

WBGU (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen), 2008: Climate Change as a Security Risk. Berlin: German Advisory Council on Global Change.

Webersik, C., 2010: Climate Change and Security. New York: Prager.

van Weezel, S.; 2016: Food imports, international prices and violence in Africa. Oxford Economic Papers, 68(3), 758–181.

Werrell, C. E. and F. Femia, eds., 2013: The Arab Spring and Climate Change. A Climate and Security Correlations Series. Washington, D. C.: Center for American Progress, Stimson Center.

Werz, M. and M. Hoffman, 2013: Climate Change, Migration, and Conflict. In: C. E. Werrell, and F. Femia, eds., The Arab Spring and Climate Change. A Climate and Security Correlations Series. Washington, D. C.: Center for American Progress, Stimson Center, 33–40.

World Bank, 2013: Renewable internal freshwater resources per capita (cubic meters), at: http://data.worldbank.org/indicator/er.h2o.intr.pc/countries/tnLY-sY-1A- 1W?display= graph, last accessed 26 January 2020.