Climate Change as a Risk Multiplier in a World of Complex Crises

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1. Introduction

Although much is known about the effects of climate change on components of the Earth system, the interaction of the subsystems is still poorly understood. Since changes in one system can have direct or indirect effects on other systems, local events can propagate through complex causal chains and feedbacks on various spatial and temporal scales. Accordingly, climate change was called a risk amplifier and threat multiplier (EU 2008, WBGU 2007).

Some critical questions are relevant in this context. What happens if climate impacts exceed the adaptive capacity of natural and social systems? Are there ranges of tolerance where systems remain stable, or outside of which turmoil, destabilization and tipping points to qualitatively different states of the Earth system are likely? Is it possible that climate change triggers regional or global risk cascades? Will critical infrastructures which are essential for the economy and society, become dysfunctional? How does the risk multiplying effect of climate change connect various problem areas? Will the stressor climate change lead to a destabilization of human-environment interaction or set reactions into motion which strengthen or weaken the effects of the disturbance?

Some aspects are highlighted in the following, based on general considerations about the complexity and stability of human-environment interaction, in particular the interaction between climate change and society (Scheffran 2015). The complex relationships in highly networked systems are illustrated by various types of risk, including instabilities in the climate system; hot spots of climate change and human insecurity; vulnerable infrastructures and networks; economic and financial crises; social and political instability; environmental migration; climate change and violent conflict. As became clear during the Arab Spring, such processes have primary and secondary consequences for Europe which are mediated through mechanisms at global, regional and local levels.

2. Instabilities in the climate system

Weather and climate are considered primary examples of complex systems, and the Lorenz equations in atmospheric dynamics became one of the roots of chaos theory. Complex dynamic processes are characteristical for the climate system and are difficult to predict from knowledge of the individual factors and equations. Compared with previous abrupt climatic changes, such as the transition between the ice ages, the climatic conditions in recent periods of human history were relatively stable. Little is known about how stable the current world climate is in face of the massive interference from anthropogenic greenhouse gas emissions. Furthermore, there are significant uncertainties regarding the climate sensitivity and the estimation of critical stability limits where the climate could experience a “tipping” to a qualitatively different state.

One focus of climate change research are weather extremes such as hurricanes, droughts, forest fires, floods and heat waves which can be described through processes of nonlinear dynamics, e.g. phase transitions, critical thresholds, chaos, which became paradigms in complex systems theory and many application areas (Scheffran 1983, Bunde/Kropp/Schellnhuber 2002, Kurths et al. 2009). Regarding their frequency or intensity extreme events represent phenomena on the boundaries of the climate system. They are outside of the "normal" range and are associated with extreme circumstances that can burden the functionality and stability of affected natural and social systems and overwhelm their resilience and viability. An increased number and intensity of extreme weather events is likely to occur in the future (IPCC 2012, Rahmstorf/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 sliding of ice shelfs in Greenland and West Antarctica, the release of greenhouse gases such as methane from frozen soils in Siberia or Canada, or 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. A massive and abrupt climate change could also overwhelm the ability of the strongest states and societies to deal with the problems. Less time-critical, although globally more hazardous in the long-term is the rise in sea level that poses stress to many coastal regions and threatened islands. Given the large 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 a global destabilization.

An integrative framework can help to analyze the complex interactions in the Earth system and their stability (Scheffran et al. 2012ab) (Figure 1). The couplings in this network can be characterized by sensitivities, which represent the impact of one variable on another variable. According to the IPCC (2007: 881) sensitivity is "the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change”. Changes in the climate system affect the functioning of ecological systems and natural resources (e.g. soil, forests, biodiversity). Depending on the degree of vulnerability this can have an impact on human security, for instance, by affecting the supply of water, energy, food and economic goods. Even for uncertain sensitivities the sign of effects can provide valuable information to classify relevant patterns or syndromes using qualitative analysis (Eisenack et al. 2007).

Human reactions to environmental change can affect the stability of societal structures, which can cause conflicts and social destabilization in regional climate hot spots that propagate in a networked world via transfer mechanisms like a cascading domino effect. On the other hand, cooperative and sustainable response strategies for mitigation and adaptation can be initiated, weakening and mitigating the causes and consequences of climate change. The question is to develop practical strategies that are adequate to the level of complexity and address the challenges of climate change to prevent dangerous instabilities and facilitate necessary system changes. In order to achieve the goals agreed in the UN Framework Convention on Climate Change to stabilize the climate system to a non-dangerous level, a better scientific understanding of the underlying interactions and an anticipatory-adaptive policy framework is needed that avoids or circumvents risky pathways and allows for timely qualitative system transformation in the sense of self-organized stabilization. In the following some types of complex interactions are discussed in which climate change may act as a risk multiplier and trigger social destabilization in complex crises.

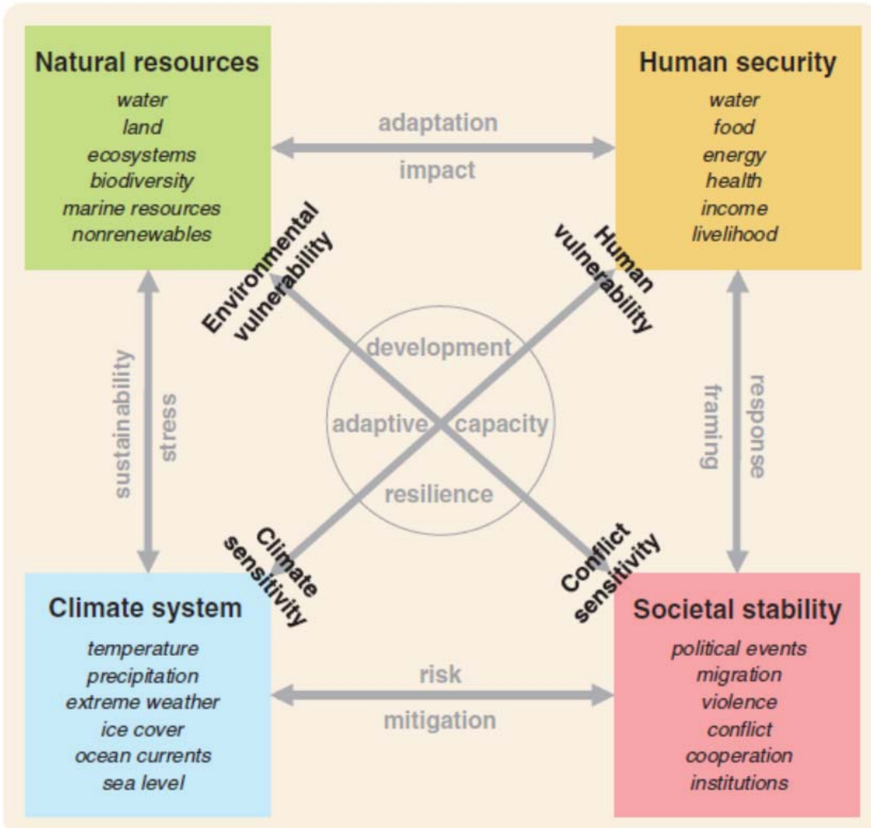


Figure 1: Impact chains and feedbacks in climate-society interaction (Source: Scheffran et al. 2012a)

3. Hot spots of climate change and human insecurity

In areas strongly affected by climate change (hot spots) there are multiple stresses on human security (Figure 2). Hydro-meteorological disasters (storms, floods and droughts) are an immediate danger to life and health of the most affected people (Germanwatch 2014) in developing countries (e.g. Indus flood in Pakistan 2010, drought in China 2010/11, typhoon in the Philippines 2013) and industrialized countries (e.g. European heat wave of 2003; Elbe floods in Germany in 2002 and 2013; hurricanes in the USA in 2005 and 2012; wild fires in Russia 2010). The consequences can be so severe that in the regions of concern adequate assistance is not possible and social systems become overloaded. For instance, Hurricane Katrina in 2005 caused enormous damage to the south coast of the USA, including more than 1,300 deaths, displaced hundreds of thousands of citizens and overwhelmed disaster management. The heat wave of 2003 in Europe left behind tens of thousands of casualties and tens of billions of Euros damage to agriculture. The Indus flood in 2010, the worst since more than 80 years, flooded a fifth of the land area of Pakistan and had consequences for 20 million people, with about 2,000 deaths, 1.7 million homes and a large part of the infrastructure destroyed (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 freshwater, forests and farmlands, lack 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 vulnerability and adaptive capacity, which is influenced by the access to resources, information and technologies, as well as the stability and effectiveness of institutions (Adger/Lorenzoni/O'Brien 2009).

In the hot spots, climate stress causes great human suffering and significant economic and social losses which undermine human security. A large part of the risks is not only or primarily related to climate change, but often is also due to pre-existing local problems in the affected areas, such as the destruction of ecosystems, high poverty, political instability, overuse of land, or lack of early warning and disaster protection. Most vulnerable to climate stress are vulnerable regions whose economies are dependent on climate-sensitive resources and are particularly exposed to climate change. These include developing countries with high dependence on agriculture, coastal areas and river basins and hot and dry regions. If in such hot spots natural resources are depleted or degraded which are of fundamental importance for the existence of people and the satisfaction of their needs, human security is at stake.

In many cases, the primary consequences are confined to the affected areas but may be connected to remote regions through humanitarian aid, civil protection or other direct interventions (including military operations). In many cases, however, indirect and secondary effects are relevant, which go beyond the hot spot region. Some reactions may further aggravate the situation, e.g. when people in need enforce the over-exploitation of resources, move to other risk areas or use violence against competitors, to ensure their own survival. An example are rising land prices that induce the search for cheaper land that is often found in developing countries where it leads to environmental and supply risks and displaces local users. Another example is the impact of land scarcity on water availability and related crop losses, e.g. due to droughts in parts of Asia, Africa and America, which through global food markets lead to price drops elsewhere. In this context, various exchange processes between different resources are to be taken into account, which is expressed in the nexus of water, energy and food (see following sections).

4. Vulnerability of infrastructure, technical systems and supply networks

Climate change may affect the viability of critical economic and social infrastructures and supply networks. These include systems for the supply of water, food and energy, goods and services, systems for the provision of communication, health, transportation and security, and human settlements and political institutions. It is not only the failure of important subsystems that matters, but also the possibility that selective disruption of certain system components spreads across couplings and destabilizes the entire system so that a collapse of parts or the whole system are the result. This is true for developing countries which depend directly on ecosystem services and agriculture, to a different degree also for developed countries which rely on highly networked technical systems but have more sophisticated protection and response mechanisms. The stronger the impacts are and the more sub-systems are affected, the harder it is for societies to absorb the consequences.

Corresponding relationships are examined in risk research for the failure of complex technical systems in which the combination of different events results in the loss of the control mechanisms.

This was initiated by the debate on various spectacular accidents in high-risk technologies (Bhopal, Challenger, Chernobyl), which demonstrated that large-scale technology (chemical and nuclear engineering, biotechnology and genetic engineering, aerospace, defense technology) are not completely manageable and contain a "residual risk", comparable to natural disasters. Since not all contingencies are predictable in complex systems, it is often enough that a minor event can initiate a chain of events, which appears as a "normal catastrophe" in tightly coupled human-machine systems (Perrow 1984). In a globalized world these tight couplings cannot only happen in technical systems but in other fields as well.

A spectacular example for a risk cascade of natural and technological disasters was the earthquake in Japan on March 11, 2011 which triggered a chain of events with a global effect. The tsunami wave flooded parts of the Japanese coast, cost many human lives, and triggered the accident at Fukushima that destroyed several reactors, spreading the radioactive inventory 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 affected. Automakers and electronics companies worldwide cut back production because important components were no longer delivered from Japan. The shock waves of the nuclear disaster triggered the energy transition in Germany. This disaster impressively shows how a single event can set into motion different process chains and can change the political environment (Kominek/Scheffran 2012).

In addition to earthquakes or technological accidents, weather extremes can also hit critical nodes in the networks of business, technology and society. For industrialized countries such as Germany, whose economy and society depend on a functioning infrastructure, the stability of a sustainable supply system to extreme weather events is of great importance. Weather extremes, such as the 2003 heat wave, the storm surge in 2013 or the Elbe flood in 2013 led to temporary impairments of transport or energy supply systems. From the perspective of climate research, it is important to assess whether extreme weather events may occur within a given period that exceed the limits of the carrying capacity of supply networks. It is important to identify the critical nodes and links in the global supply network and to understand how local failures of infrastructure components affect the global supply. Network research analyzes what happens in case of failure of network elements, how shocks propagate into the power grid and whether chain reactions and cascading effects can occur which can cause a collapse of the network.

As an example we discuss here the failure of power grids. Since virtually all other supply networks depend on a well functioning power grid, its failure affects all parts of society. Most hydro-meteorological disasters affect parts of the national electricity grid only temporarily which is then restored. However, there have also been cases in which the power supply fell victim to a large area blackout caused by minor events. In the biggest blackout in history in July 2012, over 600 million people in North and East India were affected due to an overloading of the power grid. In November 1965, about 30 million people in the northeastern United States and in many parts of Canada stayed for about six days without electricity. In California, there were regular power outages due to insufficient generation capacity and market manipulation (Brand/Scheffran 2005). During a large power blackout in Europe in November 2006 parts of Germany, France, Belgium, Italy, Austria and Spain were temporarily disconnected from the power supply. While in these cases there were various underlying causes, in other cases weather events were the trigger. In November 2005, after heavy snowfall in North Rhine-Westphalia and Lower Saxony, one of the largest power outages in German history occured, in which some 250,000 people were without power for several days, resulting in a financial loss of about 100 million Euros. More recently, the snow storm in North America at the turn of 2013/2014 caused major power cuts for hundreds of thousands of people, leading to partial failure of the communication and transport system.

If a supply system for a particular resource is hit, this often has effects on other resources, which has been increasingly highlighted in the nexus of water, energy and food (Beisheim 2013, IEA 2012). Energy is needed for irrigation and production of food, water, and energy supply, in particular for the extraction, transportation and processing of fossil and nuclear energy. The promotion of unconventional gas and oil reserves (fracking, oil sands and oil shales) has a growing need for water and land. Also renewable energy such as hydropower, biofuels and geothermal power need large amounts of water. Regions with low rainfall are dependent on artificial irrigation for the cultivation of plants for food and energy. Even with large solar power plants in desert areas, water supply is a critical issue. Overall, the water demand for energy generation will rise twice as fast 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. A warming of the waters, long periods of drought or floods affect power generation in developed countries such as Germany, leading to critical situations when cooling water is no longer available or water in power plants is below the critical level (Beisheim 2013: 24). Through the tropical Hurricane Katrina in 2005 in the Gulf region, more than a quarter of offshore oil production, almost a fifth of natural gas production and almost half of the refining capacity were temporarily disabled, as well as important oil pipelines, thousands of oil rigs, a large part of the train and ship transportation. The Typhoon Haiyan in the Philippines 2013 destroyed part of the country's supply of renewable energies (Bradsher 2013). Renewable energy (bio, hydro, wind, solar) depends on certain meteorological conditions, which are affected by climate change. The forced cultivation of bioenergy plants as part of a climate change strategy intensified a global resource competition as large amounts of water and land areas are needed that are no longer available for food production (Scheffran 2010). With a shortage of resources due to climate change market prices increase, making the expansion of agricultural production more attractive. This may lead to a rise of production factors such as water, energy, pesticides and fertilizers, which in turn are associated with increasing environmental pollution and a growing demand for land (Beisheim 2013). On the other hand increasing food prices have adverse effects on poor populations (see below). To some extent competition can be mitigated by synergistic effects, e.g. when water power 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 or 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 and with multiple effects which hit a system simultaneously, with short time delays or in a narrow geographic area. With increasing intensity and frequency of climate-related events, the question arises as to when the limits of capacity and resilience of infrastructure are reached and whether existing safeguards and adaptation measures are sufficient.

5. Economic and financial crises

Exposed to climate change are also assets and economic processes such as global freight, trade and financial markets that regulate the exchange between supply and demand. Financial transactions and pricing information represent virtual transfer mechanisms which link the events with each other globally and within a very short period of time. If there is a disturbance in one place as a result of climate-related events, such as production losses, bankruptcies of companies or declines in the stock market, it is propagated across the global networks and markets.

The economic crisis of 2008 showed the instability of the complex interconnected global economy. Powered by reckless lending practices of financial institutions and short-sighted human behavior, local events and individual responses have 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 Euros worldwide. Public investment and regulatory policies were initially unable to compensate for the short-term fluctuations. The interaction between rating agencies and government response led to an explosive situation. In Europe, the global economic crisis was followed by a crisis in southern Europe, most dramatically in Greece.

Although other factors were at work here, climate and economic crisis may increase and lead to a downward spiral. According to the Stern review, abrupt and extensive changes in the climate system could wreak havoc global trade and financial markets (Stern 2006). Given diverse links between climate change and financial markets, risk cascades can be analyzed and classified (Haas 2010, Onischka 2009). In addition to the risk of direct economic damage, global impacts are possible due to loss of production, supply shortages and price increases. Thus, extreme events in one country can induce production losses in another country which can spread through global supply chains (Levermann 2014). While direct damages and costs by weather extremes have been recognized since several years, indirect economic consequences are still poorly understood. Some issues have been raised in the context of the indirect effects of bioenergy, particularly as in other parts of the world the price and cultivation of cereals was changed or displaced due to bioenergy production (Scheffran 2010).

In the energy sector various risks (natural disasters, infrastructure problems, strikes, riots, wars, political interventions) may lead to supply constraints and strong market variations. High oil prices like in 2008, are a driver for recession, social risks and the willingness to accept high environmental risks (Beisheim 2013). Relevant questions can be raised if production losses can be observed through extreme events in a supplier country of food. These included the heat waves and related fires lasting over several weeks in Russia in the summer of 2010 which resulted in an export ban on wheat (FAZ 2010). The drought in the US in 2011 and 2012 and China 2010/11 were associated with price increases in the food market. For poorer countries the consequences of integration in the globalized economy can be as momentous as the direct effect of domestic local events. Even in developed countries such as Germany, the impacts of extreme events to the consumer are noticeable. Europe is not immune to the consequences 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 lower adaptation potentials. Here 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.

1. Floods in Australia 2010/2011: In the wake of tropical cyclone Tasha, Queensland and New South Wales were affected by heavy rainfall around 2010/2011. The worst flooding in 50 years inundated an area the size of Germany and France together, including 70 cities; 35 people lost lives and 200,000 people were evacuated, including parts of the metropolitan area of Brisbane. According to media reports the damage was on the order of 1 billion AUD and the GDP loss stood at 13 billion AUD, which had a significant impact on the economic performance of Australia. Furthermore, due to flooding about 40 coal mines were temporarily closed or operated at reduced power, whereby the production capacity of the largest coal exporter in the world was severely impaired. Coal mining in Queensland fell by 30%, coal production fell from 471 million tonnes in the previous year to 405 million tonnes. At times, the domestic coal industry lost more than 70 million Euros per day (Oldag/Walterlin 2011). Since the raw material cost is more than 80% of the production cost of steel, this triggered rising prices and supply bottlenecks in the steel industry. The outgoing Australian chain reaction was also felt in Germany and had an impact on the automotive industry, on mechanical engineering and other industries (Spiegel 2011).

2. Flood in Thailand 2011: As a result of a violent and unusually long-lasting monsoon Thailand was hit in October and November 2011 by the worst floods in 50 years, which affected nearly 12 percent of the country. Consequences of the flood were almost 400 victims, property damage of more than 11 billion Euros, substantial loss of economic growth, temporary drops in tourism and massive crop losses (a quarter below the previous year). 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 of electronic components led to bottlenecks in the international electronics and computer industry and a strong increase in hard drive prices in Germany (Feddern/Schnurer 2011). German companies like Volkswagen had problems with the delivery of important parts. Japan's auto companies suffered repeated losses in production shortly after the Fukushima disaster. Although the Thai electrical and electronics industry was thrown back by the flooding, the industry has recovered faster than expected after the flood. Given the stronger shift of production to Asia, plagued by earthquakes and floods, the consultant AT Kearney noticed that 80 percent of the companies were adversely affected (Gärtner 2011).

3. Drought in China 2010/2011: In November 2010, a century drought in China's eastern wheat belt threatened the winter wheat crop, which accounted for 22% of the harvest of the world's largest producer and consumer of wheat. Affected were 4 million acres and more than 300 million people. 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 the drying up of water resources and reduced hydropower generation. In early 2011 nationwide more than 2.2 million people and 2.73 million units of livestock animals suffered from a lack of water. Based on the experience from past famines (1958-1961), the Chinese government has taken measures to reduce the risk of crop failure. They invested in new hydro projects and bought wheat on the international market to compensate for the losses of the drought (Sternberg 2013). As a relevant part (6-18%) of the 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 import-dependent countries of North Africa and the Middle East (Sternberg 2013) (see following section).

6. Social and political destabilization

Directly or indirectly through the integration of physical, economic and geopolitical risks in a globally networked world, the impact of climate-related events could also undermine social and political stability in the regions concerned and possibly causes global turmoil. Due to globalization, combined with rapid developments in computer technology, in communication and 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. It is possible that small groups and individuals can set into motion global chains of events that have an influence on international relations. In a spectacular way, this became clear with the end of the Cold War, in the terrorist attacks of September 11, 2001, in the Arab spring in 2011 and in the recent refugee crisis, each having a large impact on Europe. It is also possible that individuals put solution processes in motion, as in the cases of whistleblowers, from Daniel Ellsberg to Edward Snowden, who brought sensitive information to the public in order to draw attention to deficits and problems.

The spirals of hate, terror and violence have their own dynamics across different levels. Environmental destruction, poverty and hunger affect the social conditions in many parts of the world. Particularly unstable are fragile and weak states with social fragmentation, poor governance and management capacity that cannot guarantee 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 (WBGU 2007).

Climate change may enhance destabilization, especially where 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 agriculture 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, family or friends provokes opposition and unrest that threaten the social contract and undermine the political order. Some of these processes act slowly and contribute to the erosion of social and political stability, others run quickly and overwhelm the problem-solving and adaptive capacity of communities. Various destabilizing processes may increase 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 into domains opened by the power vacuum. Particularly at risk are countries with low income and adaptive capacity, while richer societies have more potential capacities for adaptation. However, in view of the global interdependence, they cannot simply ignore the destabilization in other parts of the world which through complex chains may affect them as well.

Various natural disasters were associated with a temporary collapse of law and order. Looting and criminal acts occurred after heavy storms over and over again, for instance after the typhoon in the Philippines in 2013 or after Hurricane Katrina in the US in 2005. After a few storms and floods in South Asia and Central America, the distribution of aid and relief goods was subject to disputes that were partly fought violently (WBGU 2007). In addition to storms and floods that usually had temporary and local impacts on the food supply, droughts have a direct and lasting impact on global food markets due to their large spatial and temporal scale. Affected are many people who are highly dependent on agricultural production and the local availability of water resources. In contrast, it is usually the indirect influence of climate events and disasters on water, food and population that give such type of disasters an international dimension.

The most significant consequences include shortages of food and an associated increase in food prices, which can be life-threatening for poor social groups. Throughout history so-called “bread protests” and food riots have contributed time and again to political and social changes, as in the French and the Russian Revolution. This includes recent global supply crises such as in 2008 and 2011, when food prices quickly multiplied and the number of hungry people increased by 100 million to 1 billion (Beisheim 2013). In 2008 uprisings related to food crises provoked a change of government in Haiti, while in Cameroon 24 people were killed during protests and about 1,500 were arrested (Sternberg 2012).

A spectacular example are the social and political upheavals in North Africa and the Middle East (MENA) since 2011. The series of protests and uprisings in the Arab world led to a conflagration that affected the entire region and provoked a change of regimes in several countries (Johnstone/Mazo 2011). Starting with the unrest in Tunisia in early 2011, which forced the President to flee, the revolutionary impulse spread to Libya, Egypt, Syria and other MENA countries. This was accelerated and multiplied by electronic media and social networks (Kominek/Scheffran 2012), which enabled the rapid spread of protest and motivated others to join the protest movement. An example were the demonstrations on the Tahrir Square in Cairo and in other countries. Although supporters of the regime responded with force against the demonstrators, the self-organized resistance remained largely peaceful, reaching the resignation of President Mubarak. 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 proportion climate change and extreme weather events might have affected these processes, is still subject of scientific debates. At the beginning of the revolt some media reports constructed a link to the sharp rise in food prices at the turn of the year 2010/2011. 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/Femia 2013). It is not so much the argument that climate change was a primary cause, but rather that in an explosive political crisis climate change can act as an additional stressor that can exceed a tipping point. One of the factors that occurred before the crisis was the drought described above in China 2010/2011, which exerted a 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.

The consequences affected much of the MENA region in which the world’s nine largest importers of food are located, seven of which experienced political protests. Many households consume, on average, more than a third of their income on food (Sternberg 2013), while people in Western countries spend less than 10%. The dependence of Arab States on imported food makes them vulnerable to fluctuations in global commodity markets. High resource imports, low income and high spending for food together affect food security. Reinforced with the sharp rise in bread prices, the existing public discontent with the government was multiplied. In Egypt, the largest wheat importer in the world with rapidly growing populations, three percent of the national income was spent on wheat subsidies (Sternberg 2013). As early as 1977 there was the "bread intifada" in Egypt in which 77 people died, and in 2008 the bread riots happened. However, no protests took place, in Israel and the United Arab Emirates which are characterised by a high per capita income, a small food share of income and better adaptive capacities.

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

7. Environmental migration

Already the 1st IPCC Assessment Report of 1990 has warned that changes in temperature and precipitation “could initiate large migrations of people, leading over a number of years to severe disruptions of settlement pattems and social instability in some areas.” (IPCC 1990, pp. 55) The IPCC Special Report of 2012 stated that in the future climate extremes will have a larger impact on migration (IPCC 2012). And the most recent 5th Assessment Report found in 17 cases evidence for increased mobility or displacement while decreased mobility was found in 6 cases and socially differentiated mobility outcomes in 5 cases (IPCC 2014: 769).

According to the position paper of the European Commission, Europe must be prepared to substantially increased migratory pressure (EU 2008). In regions where poverty, violence, injustice and social insecurity prevail, climate-induced stress could increase the migration pressure. The International Organization for Migration (IOM) cites as reasons for environmental migration sudden or progressive changes in the environment that affect life or living conditions so that people are forced or choose to leave their homes temporarily or permanently (IOM 2008). In a narrow sense, Biermann/Boas (2008) denote "climate refugees" as people who leave their habitat as a result of rising sea levels, droughts and water shortages. By contrast, the UNHCR (2011) argues against the terms "environmental refugee" and "climate refugee", as they were imprecise and the term refugee is limited to political persecution and threats. As long as there are no international agreements, the legal status of climate migration remains unregulated.

According to the Internal Displacement Monitoring Centre (IDMC), 32.4 million people have been displaced in 2012 by natural disasters (mostly weather-related), more than twice as many as in 2011. In two flooding disasters in 2012 alone, 6.9 million people in Nigeria and 6.1 million people in India were displaced (IDMC 2013). The numbers declined to 22.3 million in 2013 and to 19.3 million in 2014 (IDMC 2015). In contrast, the number of internal displaced people (resp. refugees) showed the opposite trend, from 22.8 (15.4) million in 2012, to 33.3 (16.7) million in 2013 and 38 (19.5) million in 2014. Estimates of the numbers of future climate migrants in the literature vary widely, from 50 million to a billion people, which is disputed (Jakobeit/ Methmann 2012, Black et al. 2011).

Climate change is one among several other possible drivers for human migration. Given a large number of possible reasons for flight and complex relationships, the climate impact on migration is difficult to determine. Changes in the environment cannot only promote but also impede migration by increasing the poverty of the rural population and thereby limiting the opportunities to escape (trapped populations). Environmental impacts and vulnerabilities can increase if people migrate to ecologically fragile and conflict-affected regions, including coastal cities, which are affected by storms and sea level rise. In Europe and the United States climate migration often is seen as a security problem and conflict factor, leading to ethnic, religious and political tensions between the local population and immigrants. One contributing factor is the competition for scarce resources, such as arable and pasture land, housing, water, jobs and social services. Media coverage of events, such as the drought in Somalia, boat people in the Mediterranean or 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 is to be expanded – including environmental and climate migrants.

So far climate or environmental factors have not yet been identified as major contributions to international South-North migration. The majority of people affected by precarious environmental conditions remains in the home region or migrates 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 for privileged classes. How far migration can be proven to trigger political instability and conflict, is debated (Barnett/Adger 2007; Reuveny 2007). Response patterns in security policy narrow the scope of action to combat symptoms, with the risk of an "arms race" between migration and countermeasures. Adaptation strategies and international cooperation can help to avoid the risks preventively and even to develop migration into an important measure of adaptation to climate change (Black et al. 2011), which strengthens resistance and resilience of the affected communities. Migration networks can contribute to resilience and stable structures between source and destination countries, such as transfer of payments, knowledge and technology (Adger et al.2002; Scheffran/Marmer/Sow 2012).

Industrialized countries are not spared from environmental migration. The debate became more important when Hurricane Katrina in 2005 forced hundreds of thousands to flee New Orleans, some of which did never return. 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 are not expected in the foreseeable future. In contrast, the debate on the immigration of refugees from conflict areas can provoke massive internal social conflicts which became an issue in Europe, particularly in Germany, in the summer of 2015.

A large number of immigrants comes from the MENA region and the Sahel. In addition to the destabilizing remote impacts that have been mentioned in the previous section, both regions are directly affected by climate change, which increases the migration pressure (BW 2012). By progressing climate change, population growth and resource depletion in large parts of Africa, a declining availability of drinking water, arable and pasture land is expected that affects hundreds of millions of people (IPCC 2007, Schilling et al. 2012). Environmental variations increase the pressure on agriculture, fisheries and pastoralism (Werz/Hoffman 2013). Water availability in some countries is already below the threshold for water scarcity of 1,000 cubic meters per person per year. In Libya in 2009 this was only about 95.8 cubic meters and in Syria 356 cubic meters per capita which is significantly lower than the figures for 2002 and well below the world average (World Bank 2013).

In the years before the rebellion Syria suffered devastating droughts (Kelley et al. 2015) that hardest hit the main growing areas of the country, and many people were driven from the countryside to the cities, in 2010 alone 50,000 Syrian families. In 2002 more than 30% of Syrians have been working in agriculture, and this share fell by 2010 to less than 15% (Werz/ Hoffman 2013). Syria suffered from the presence of more than 1 million Iraqi refugees who had fled after the US invasion in 2003. In Tunisia, the country's population is declining despite the growth of the total population. In Algeria there have been repeated violent protests in cities, especially of unemployed immigrants. Yemen suffers from the competition over dwindling water resources and illegal water sources. Due to its growing population, the capital Sanaa could use up its groundwater in a few years. The agriculture in Morocco is particularly vulnerable to climate change (Schilling et al. 2012). Water and food supply in Egypt depends heavily on the Nile, which is increasingly being used by upper riparian States (Link et al. 2012).

Due to the growth in population and the flow of people into the cities, ethnic, religious and social tensions are increasing. Health and social services are under pressure, infrastructure and utility networks are overloaded. The frustration sparks protests, especially among the young population, and increases the willingness to leave the country to the north. The problems of North Africa are linked in complex ways with those in the Sahel, which is also affected by climate change. Libya has been a goal of many migration routes from the south because of oil revenues and related jobs. Nearly 700,000 immigrants were more than 10 percent of the total population. After the government was overthrown, the tensions with the immigrants increased, and many of those who were expelled were suspected of collaborating with Gaddafi. Since the border became more permeable, some armed mercenaries who went to Mali and other countries of the Sahel contributed there to destabilization. In Sub-Saharan Africa, climate change, desertification and scarcity of resources became connected with economic and social marginalization, political instability and violent conflicts that undermined the livelihoods of farmers and herders and increased the migration pressure (Gemenne et al. 2013).

8. Climate change and violent conflict

By altering the natural and social livelihoods in many regions of the world, 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 various negative consequences such as famine, economic crises, flight, resource exploitation and environmental degradation (WBGU 2007). The joint vulnerability to environmental change and violent conflict in hot spots may multiply and lead to an escalation spiral that is difficult to control and can spread to other regions (see Figure 2).

Different fields of conflict are relevant in the context of climate change. There is a widely held assumption that the growing consequences of global warming will increase the likelihood of conflicts aggravated by the destruction of human livelihoods and resources. In addition, there are potential differences over strategies to avoid climate change and their financing, which can induce damages, costs or resistance of other actors. Examples include the controversy over 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/Cannaday 2013). The same applies to differences on adaptation to climate change and its security implications, such as military operations in disaster management and mitigation. Particularly prone to conflict are technical interventions into the climate system (geoengineering or climate engineering) to remove CO2 from the atmosphere or to influence the radiation budget. Such measures raise critical issues regarding technical and economic feasibility, risks and responsibilities across global, national and local levels (Brzoska et al. 2012). In all these consequences and responses there are concerns about justice regarding the distribution of costs, benefits and risks of climate change which can complicate cooperative solutions.

The potential contribution of environmental change and resource use to violent conflict has been subject of a controversial scientific debate 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 causality for historical events that is detectable by statistical methods and emphasize the ability of human societies to deal with resource issues through collaboration and innovation (Brauch 2009). So far, most environmental conflicts were limited to a regional scope and presented no threat to international security (Carius et al. 2006). The connections are regionally quite different and depend on the resource type. While for renewable resources (water, food, biodiversity) scarcity more likely is a conflict factor, for non-renewable resources (fossil fuels, uranium, diamonds, coltan) abundance largely is more prone to conflict. In both cases, violent conflicts consume resources, which can drive or restrain a spiral of violence (Scheffran/Ide/Schilling 2014).

The debate has continued more recently on the links between climate change and violent conflict which became an issue in the 5th IPCC Assessment Report (IPCC 2014; Gleditsch/Nordas 2013). While some studies for long historical periods found significant correlations between climate variability and violent conflicts, particularly in the Little Ice Age in Europe, studies for more recent periods come to mixed results, which depend in a complex way on regional contexts and conflict situations (Scheffran et al. 2012ab). Selecting data and studies to prove the relationship between climate change and violence over all historical periods, regions of the world, forms of violence and causal mechanisms (Burke et al. 2009; Hsiang et al. 2013), has exacerbated the controversy (Buhaug 2010; Buhaug et al. 2014).

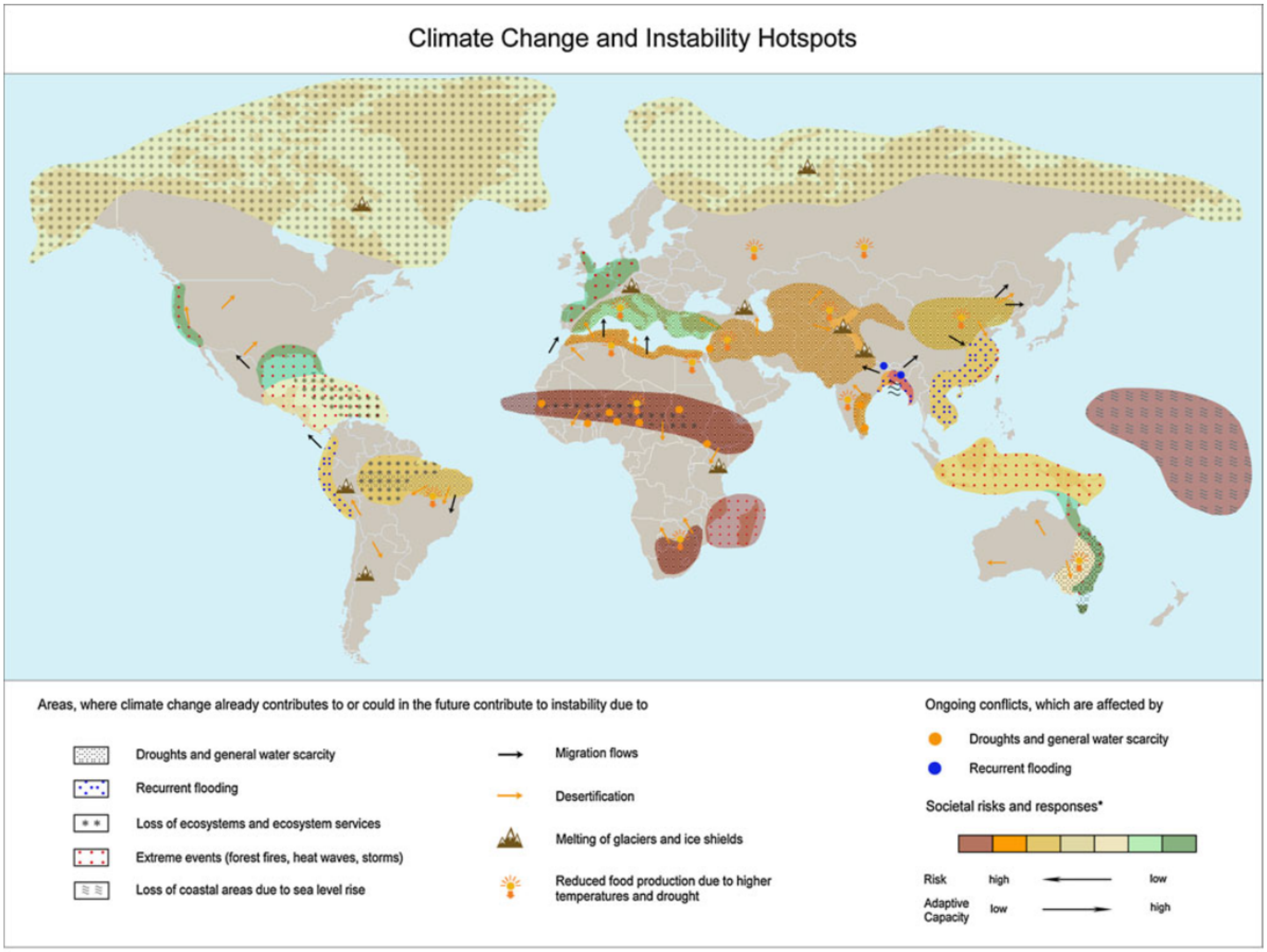
Regardless of the interpretation of historical data the impact of future climate change goes beyond previous experiences which leaves space for scenarios, plausibility considerations and speculations. It is well possible that societies were able to adapt to moderate climate change over historical periods of time but may be overwhelmed by rapid and strong climatic changes in the future that exceed their adaptive capacities. There is a wide range of possible conflict constellations 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, vegetation and biodiversity, which can become conflict factors individually or in conjunction. In addition, the effects of climate change on infrastructure and social destabilization (see Section 6) may become crucial factors that trigger societal tipping points, leading to social unrest, riots, violence, crime and armed conflict.

Particularly pronounced is the vulnerability in agrarian societies that have a strong population growth and a low level of development or are already suffering from violent conflicts (Raleigh/Urdal 2007). Whether climate change acts as a "threat multiplier" and creates a "climate of violence", depends largely on how people and societies respond to climate change and whether their adaptive capacities and institutional structures are adequate to maintain stability and support viable solutions. While the rich industrialized countries are not spared by climate change, they may benefit from more advanced economic and institutional conditions for problem solving and conflict management. Potential conflicting issues in Europe include tensions over territorial claims and natural resources in the Arctic region and the Mediterranean (Figure 2). A melting of the polar ice sheets affects the strategic interests of Europe, Russia and North America. Efforts to build a power grid based on renewable energy between Europe, the Middle East and Northern Africa open up the possibility of converting the Mediterranean from a region coined by oil interests towards a region of cooperative security, provided that the utilization of energy is sustainable, and promotes development, peace and justice.

As an example we discuss the importance of climate change for conflict in North and East Africa. In the wake of the Arab spring, Syria and Libya experienced bloody unrest that led to a coup in the case of Libya, and in the case of Syria to a bloody civil war which continues to this day. In both countries, climate change plays a dual role. With a rise in temperature and decreased precipitation water supply and agriculture are hit, affecting the lives of people. Indirect consequences of conflict are mediated by the political unrest in which international food markets play a role. Like in 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 been characterized by political instability and violent conflicts, reinforced by national power games, regional struggles and global geopolitics. Peripheral regions like Darfur are characterized by marginalization and exclusion that contribute 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, affecting water shortages and deterioration of pasture land in the northern Sahel following drought and desertification, which exacerbate resource competition between herders and sedentary farmers. The expansion of mechanized agriculture continues to deprive nomadic peoples of their traditional migration routes and to dispossess peasants, which results in serious tensions.

Attempts by the Sudanese government to set up new administrative structures has weakened traditional mechanisms of conflict resolution and resource allocation between tribal groups, which became intermingled with the conflict between the government and rebels. Resulting expulsions, killings and destructions, as well as the inflow of weapons increased the uncertainty and fueled the spiral of violence in Darfur. In the vicinity of crowded refugee camps more environmental and health problems were caused by firewood collection and infectious diseases (Scheffran/Ide/Schilling 2014). 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), others are concerned about the oversimplification of the Darfur conflict (Butler 2007), and criticize the fact that the Government of Sudan has exploited the climate argument to distract from its own responsibility (Verhoeven 2011). Overall, climate change is one of many conflict factors that reinforce each other in a complex way (for other regional case studies see Scheffran et al. 2012c).



* Risk of conflict and adaptive capacity are correlated. The higher the adaptive capacity, the lower the societal risk. The risk of conflict increases from the green to the red end of the scale, while the adaptive capacity decreases.

Figure 2: Hot spots regions where climate change impacts are critical for human security and social stability in different regions of the world (Source: Scheffran/Battaglini 2011)

9. Conclusions

Climate change is considered a threat multiplier which affects the balance between natural and social systems and amplifies the consequences through complex impact chains in interconnected systems. Previous sections highlighted several cases of complex crises where interconnected systems and cascading events magnify individual events to the degree that affects the stability of large systems. Through multiple pathways, climate change can affect the functioning of critical infrastructures and supply networks; intensify the nexus of water, energy and food; lead to production losses, price increases and financial crises in other regions through global markets; undermine human security, social living conditions and political stability; trigger or aggravate migration movements and conflict situations. Whether these linkages will materialize, ultimately depends on the strengths and sensitivities of each coupling. Some effects could act over long distances, for instance through interventions or humanitarian aid in remote regions affected by violent conflict or large migration movements.

In an increasingly interconnected world where systems are tightly coupled across different scales, stabilization of human-environment interactions under climate change is a major challenge in international relations that requires the integration of complexity science with global governance. An integrative framework of human-environment interaction can help to to analyze destabilizing developments, tipping elements and cascading risks. To survive destabilizing consequences, affected systems need to adapt to the changing circumstances to ensure their viability which refers to the ability of a system to live, grow, and develop within environmental boundaries and constraints (Aubin/Saint-Pierre 2007; Eisenack et al. 2007). Concepts of anticipative and adaptive governance influence critical decision points and adjust the actions along multiple causal chains to protect human security, develop social livelihood and strengthen societal resilience. The goal is to avoid risky pathways and facilitate a qualitative and self-organized system transformation towards sustainability. Nevertheless, given the complexity and interconnectedness of affected systems large uncertainties exist regarding the consequences and related damages, which underscores the need for new approaches of decision-making under uncertainty and novel concepts to address the nexus of multiple problem areas that lead to complex crises.

To some degree, social systems have the ability to cope with the magnitude of climate change, and develop possible alternative pathways of human responses and actions. To succeed responses need to be timely and adequate compared to the speed and intensity of climate change. Some responses could help to diminish harm and develop new opportunities; others may cause additional problems (maladaptation). A key question is to which degree of climate change societies can adapt and how effective and creative they are in developing coping strategies that are complex enough to deal with the challenges. One task is to translate environmental change into new social and political structures and institutions that avoid or minimize social instability. Rules and regulations that guarantee a peaceful coexistence are characteristic of a viable society which in turn is important to satisfy human needs.

Concepts of resilience, viability and sustainable peace can strengthen the social capability of people in their effective, creative and collective efforts to handle the problems of climate change. In a resilient social environment, actors are able to cope with and withstand the disturbances caused by climate change in a dynamic way that preserves, rebuilds, or transforms their livelihood. Key viability strategies, supporting a “new climate for peace” (Rüttinger et al. 2015), include climate mitigation and adaptation; the building of networks, the cultivation of diversity and the maintenance of flexibility; migrant networks that facilitate the exchange of knowledge, income and other resources; new capabilities to manage disasters; arms control, non-proliferation and disarmament;. regional security concepts, crisis prevention, conflict resolution and confidence building; innovative institutional frameworks and legal mechanisms.

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