Contextual Instability: The Making and Unmaking of Environment

Irina Comardicea[a] & Achim Maas [a]
[a]Adelphi Research

Abstract – The environment and its resources are of fundamental importance for complex societies. Inadequate environmental governance may thereby lead to human suffering including armed conflict, while incapacity to adapt to environmental change has contributed throughout history to the collapse of complex societies. These threats exist in the anthropocene as well, where they are possibly even more pronounced. Environmental engineering technologies such as geo-engineering and synthetic biology add a new challenge by allowing modification of the environment from micro- to global scales in ways and at a scope unprecedented in history. "Making our environment" is truer now than ever before. However, risks of unintentional and cascading consequences can contribute to the unmaking of global society, if the defining characteristics of the new era are not appreciated.

1. Introduction and Background

"International control of weather modification will be as essential to the safety of the world as control of nuclear energy is now" – Henry Houghton, chair of the MIT meteorology department, 1957

Nobel-prize winner Paul Crutzen considered in 2000 the impact of human action on the environment so profound as to constitute a new geological era – an era, which has been referred to as "anthropocene" (Dalby 2009: 99). While there is a debate about when this era exactly started, its key defining quality is that there is no historical precedence regarding the amount of environmental change as a consequence of human action. Thus, the environment is no longer an independent background or simple context of human action: it has become a "matter of our own making" (Ibid.).

Modifying the environment according to some predefined specifications is not a new phenomenon, as Henry Houghton's quote above shows. Arguably, since agriculture has been invented, species bred and civilisation emerged, the environment has been constantly modified in pursuance of human agency (see Diamond 1999). However, the upsurge of the debate on geoengineering in the past decade as well as advances in synthetic biology promise to do so quicker and on far more radical scales – the environment would then truly become a matter of our own making, as everything from microscopic scale to global systems would be subjected to conscious human manipulation.

However, environment and security interface on multiple levels: the role of the environment in questions of peace and security has been repeatedly established (see e.g. UNEP 2009; WBGU 2007). Judging from past research, over 70 conflicts between 1980 and 2005 were related to renewable resources (Carius et al. 2006), while natural resources in general were implicated in approximately 40 percent of all armed conflicts since World War II (UNEP 2009). Multiple studies have outlined how climate change may lead to insecurity and instability in the future by altering productive landscapes and negatively impacting human habitats, such as due to sea-level rise (SLR) (see WBGU 2007, Halden 2007, Carius et al. 2008). Targeting the environment in times of war or enlisting it as a weapon of war has an ancient history (Lockwood 2009), while fears of terrorists harnessing biotechnology for attacks strongly surfaced after the anthrax attacks in the aftermath of the September 11 attacks (Monke 2004; Ratta et al. 2009).

Against this background, the paper provides a conceptual overview to the potential implications of environmental modification from a security perspective. In section 2, the interface of security and the environment will be elaborated in more detail against the backdrop of the anthropocene and times of global environmental change. In section 3, the emerging role of modification technologies will be highlighted, with a particular focus on geoengineering and synthetic biology. The conclusions of both sections will be discussed in section 4.

2. Security and the Environment

Connecting security and environment via the term “environmental security” may be misleading, as the reference object is unclear (Buzan et al. 1998) – is it security of the environment? Or is it security from the environment? Without a clear reference object, the term security is meaningless. Concurrently, it is an essentially contested concept, as it depends strongly on the perspective and the reference object (cf. Dalby 1997). As security is in addition a term used to justify exceptional measures, such as sanctioning violence or cessation of rights, labelling something a security issue may have significant consequences (Buzan et al. 1998). The term environmental security received much criticism, as it distracts attention from actual security concerns and/or may lead to securitization or militarization of environmental politics (cf. Brock 1997; Dalby 2002). Recently, the framing of climate change from a security perspective resulted in similar concerns (Brzoska 2008). From a terminological point of view, it is therefore more useful to keep security and environment apart.

At the beginning of the 21st century, the environment and security nexus can be discussed by studying two levels of interlinkages. The first is the interface level, where security and the environment are observed as two distinct subjects interfacing each other. The second level is the system level, where security and environment cannot be meaningfully separated. Each level will be reviewed below individually and in term of relating to each other.

The interface level is useful to understand how environmental issues and processes may lead to insecurity, which is here understood as violent conflict or related forms of human suffering. A number of approaches emerged to study how natural resources are implicated in violent conflict (see Carius et al. 2006, WBGU 2007), in particular how either scarcity or abundance of resources may contribute to the outbreak, continuation or cessation of violent conflict (see e.g. Ross 2004; Homer-Dixon 1999). It has been estimated that natural resources have been implicated in up to 40 percent of all violent conflicts in the past six decades (UNEP 2009). Indeed, in multiple conflicts control over profitable resources such as diamonds, gold or oil has been a key driving factor in the past decades. However, violent conflicts may also be related to environmental destruction (UNEP 2009). Conversely, violent conflicts also negatively impact the environment, such as destruction as a result of combat – which may be intentional, as in case of the use of Agent Orange during the Vietnam War – or unsustainable exploitation such as excessive logging to provide shelter to refugees (Ibid.).

Access to resources or environmental destruction is never the sole cause of conflict, but rather one aspect which may, to a lesser or greater degree, be implicated (WBGU 2007). Indeed, it can be argued that environmental and resource governance – the distribution of wealth from abundant resources or allocation of scarce resources – are the actual core conflictive issues, and not the environment or resource availability per se. By comparing multiple cases across different regions, it becomes apparent that despite similarities with regard to the respective environment/resource endowment, some tense situations may escalate into violence while others do not (see e.g. Kahl 2005).

Yet the interface level is insufficient to grasp the deeper relationship between environment and security. Without agriculture, domestication of animals and cultivation of plants, there would be no complex society (see e.g. Diamond 1999). Concurrently, security as a term would be difficult to apply. Conversely, humanity has continued to shape the environment – thus the contemporary environment is in large part also the product of human action and rarely "natural" in a strict sense (cf. Dalby 2002, 2009). Climate change is the most clearly observable part of this process, and will not leave any habitat or ecosystem untouched. It epitomises how societies and the environment are co-evolving. As a result, experts argue that our geological era should be called "anthropocene", as environmental change is largely driven by humanity (Dalby 2009).

The notion of anthropocene and the view that security and the environment are constituent parts of a larger complex system is important to understand how complex societies may collapse under environmental change: in contrast to the interface level mentioned above, security is not about issues such as human suffering or violent conflict, but about a form of "stability" – i.e. the continuation of the current socio-ecological patterns. Jared Diamond (2005) reviewed several historical examples where this pattern changed and societies ultimately collapsed, as their way of living was inadequate for their (changed) environment – the constituent parts mismatched and the pattern no longer stable. This may be the consequence of regional climate change or unsustainable development, as in case of the Easter Islands where ultimately no tree was left to sustain their cultures (Ibid.). Interestingly, in most cases such societies collapsed because they focused on security and stability in a static sense, i.e. observing and preserving their practices and lifestyle when they were no longer viable. Or as Simon Dalby said: keeping things as they are when they no longer could stay as they are (cf. Dalby 2009).

The contrast then between the interface and systems levels is that at the interface level the connection between security and environment is spatially and temporally limited to a specific case. It is furthermore relatively direct, observable and traceable, as security relates directly to individuals or groups of humans, be it through frustration of their physical needs or as a result of armed conflict. Concurrently, a calamity such as a violent conflict is quite avoidable, as it is a result of ineffective, inequitable or uncooperative resource governance. This can be changed and, consequently, terms such as "post-conflict reconstruction" apply and a positive, post-calamity situation can be created, all other things being equal.

On the complex systems level, however, insecurity may rather be seen as an existential challenge of a society, as it includes also challenging its political, social, economic and cultural practices on a fundamental level. Post-calamity reconstruction would be impossible, because it would be unviable. Whatever the outcome of an event is when a society breaks down, the new society has to look differently and adapt to the changed circumstances. Thomas Homer-Dixon (2005) coined the term "catagenesis" to describe this process: a combination of the terms catastrophe, which denotes the downfall of a society, and genesis, which denotes the creation of a new one after the downfall – which was the case on the Easter Islands, and is a process that has existed throughout history, with the rise and fall of civilisations.

The new quality of the anthropocene is that threats on the second, systems, level are thereby globalised as well: a global society has been created, which interconnects every part of the world. Its demands are equally staggering. Global population is likely to increase from seven to over nine billion by 2050. This, and currently further rising resource demands already create a series of interlocking resource challenges, where local events could have temporally and spatially dislocated impacts (cf. Lee 2009). A clear example for this is climate change, where activities by carbon-intensive societies will have disparate consequences around the world. The potential implications of such a change on a global scale have been outlined by multiple authors (see e.g. WBGU 2007; Halden 2007; Welzer 2008). The food crisis of 2008 exemplifies how loss of harvests and increased use of biofuels may affect food prices and lead to riots in distant countries (Maas et al. 2010). The global interconnectedness that comes with global society makes also more susceptible to turbulences (Homer-Dixon 2005).

This global change may have impacts on both levels, with risks of increased conflict related to natural resources – among others due to governance systems incapable of anticipating the changes – or whole societies no longer viable, as e.g. islanders may be forced to move and their collective identity[1] ceasing to exist (see Carius/Maas 2009). On a more global level, authors consider a "creeping social change" as adaptation to climate change inevitable (see Welzer 2008), while other authors already call democracy a failure and see a need for more authoritarian rule to cope with the challenges of climate change (see Shearmann/Smith 2007).

3. Changing Contexts: Making Environment

The aforementioned evolution of the environment is the sum of intentional and unintentional modification events – such as agriculture or climate change. They have in common the incremental modification of the environment within certain parameters, such as cattle breeding over several generations and climate change resulting from two centuries of emissions. These changes are likely to increase and accelerate further, not least because of globally ongoing, carbon-intensive economic development. However, a new quality is now added, as technology is becoming available to intentionally modify environment *outside* of contemporary parameters. Of these, geo-engineering (or climate engineering) and bio-engineering will be discussed in greater detail below, as they signify challenges to come.

Geo-engineering and bio-engineering are two extremes of environmental modification: large-scale, intentional manipulation (or engineering) of the non-living elements of the environment, in particular climate, and engineering of biological resources. A working definition for geo-engineering describes these technologies as focused on large-scale (continental or global) effects done with a particular intent on achieving a significant change (Keith, 2000). In the last decade in particular these techniques have been proposed primarily to address the global problem of climate change, therefore large-scale impacts or benefits are desired. However, many assessments concede that most techniques that are able to deliver a high enough impact also carry with them high uncertainties of risk (Matthews and Turner, 2009). Important techniques include among others managing solar radiation via increased reflections – e.g. via artificial clouds – or removal of carbon from the atmosphere, e.g. by ocean algae fertilisation (see Royal Society 2009).[2] Aside from being technologically feasible, geo-engineering is financially relatively 'cheap', compared with the scale of mitigation and adaptation costs: estimates for keeping global warming at <2°C has been estimated around US $6 billion per year (see Bickel/Lane 2009), while according to the UNFCCC costs for adaptation may be at least US $49 billion per year until 2030 (UNFCCC 2007).

Bio-engineering (or synthetic biology) on the other hand is applied in many different areas, from producing improved pharmaceuticals, food production, energy (biofuels) generation to new plastics and materials (OECD 2009; EU 2005). Bio-engineering emphasizes

[1] In the Pacific island states, for instance, land is customarily owned and very closely connected to socio-cultural identity. Giving land up means thus giving up this identity as well (Carius/Maas 2009).

[2] Methods that might provide most benefits in the short-run include the injection of aerosol materials (such as sulfur) into the stratosphere, and increasing the reflectivity of the ocean by injecting bubbles on a large scale (MacCracken, 2009).

using molecular elements and putting them together to develop and design new systems. The Synthetic Biology Community website defines their craft as “the design and construction of new biological parts, devices, and systems, and the re-design of existing, natural biological systems for useful purposes” (Syntheticbiology.org). What is most interesting however, is the scale of this genetic manipulation, which is unprecedented, and the scope of these endeavours: while parts of genes have so far been successfully introduced into organisms to encourage certain characteristics, scientists are now able to create an entire chromosome from scratch and endow it through computer programming with tailored behaviours (May, 2009).

Bio-engineering is increasingly seen as future economic growth area, with some seeing already an emerging bio-economy (OECD 2009) on the horizon. However, the increase in the use of synthetic biology and bio-engineering is not driven by individuals empowered by a creative use of these technologies. There is in fact a growing demand for synthetic DNA and synthetic genes, a boom visible after the human genome was decoded in full in 1991, and highlighted by the size of the synthetic biology market, which was over US $200 million in 2008 (May, 2009). Demand is driven by academic research institutions who use DNA parts, by companies who use synthetic biology to go beyond genetic engineering to increase the scope or efficiency of their work (i.e. creating designer enzymes), and by multinational biotech and pharmaceutical firms who are interested in these techniques for their own research and development work (May, 2009). In contrast to the genetically modified organisms (GMO) which are mostly associated with trans-national companies, synthetic biology has seen significant ‘democratization’ of its technologies and move towards ‘open source biology’ (Schmidt et al., 2008). Skills can now diffuse through ‘do-it-yourself’ (DIY) blogs or groups, between amateurs, and biohackers. The DIY groups[3] – still a rather small community mainly active in the United States – were inspired by the International Genetically Engineered Machine (iGEM) project at MIT, which showcases the ability of amateur scientists to create sophisticated biological project with very few resources.

There are several aspects that are common between geo-engineering and bio-engineering: first, they take an engineering approach to the environment, by dissecting their area of concern into components that can be produced and assembled according to pre-defined properties. Both are converging technologies, as they combine chemistry, engineering, biology, and information technology (see e.g de Vriend in Torgersen, 2009). Both are working on environmental fundamentals, from climate to genes. Together, they cover the environment from the entire globe down to cells and viruses. At the same time, both are still very new technologies and their potential consequences are not fully known (Royal Society 2009; ETC 2007). The impacts may be unevenly distributed and in case of geo-engineering, field testing may already have dramatic consequences (Royal Society 2009). In case of synthetic biology, while large-scale field tests are less of an issue, a community of so-called “bio-hackers” has emerged: People who conduct genetic engineering as hobby (Wall Stree Jounral 2009). Their impacts are potentially unevenly distributed, and for both, international regulation has been called insufficient or absent altogether (House of Commons 2010; ETC 2009). Concurrently, both received mixed or negative media attention, such as the possibility of creating ‘artificial’ life (Torgersen, 2009). Thus, the potential intentional and unintentional consequences of both technological areas require more scrutiny, which will be discussed below.

[3] Examples include a woman who used a PCR machine purchased on eBay to decode her own genome in order to see whether she carried the gene for a disease her father has; or a computer programmer created glow-in-the-dark yoghourt in her San Francisco apartment and then moved on to a biosensor for the toxic contaminant in Chinese infant formula (Alper, 2009).

4. Threats: Unmaking Environment

Bio- and geo-engineering both rely on the manipulation of elements that are part of a complex system (environment), whose properties are emerging through interaction and not as sum of its parts alone (cf. Gunderson/Holling 2002). As a result of interactions, a system develops equilibrium, i.e. fluctuations within certain parameters, which creates the stability of a system: it “behaves” along certain expectations, such as seasons or the Monsoon. Interactions are thereby networked, and changing one element has cascading impacts on all other parts of the system to varying degrees.

Geo-engineering and bio-engineering both have the potential to upset this interaction of factors, by either introducing new elements or changing interactions. As such, they may have cascading and unforeseeable impacts.

In the case of geo-engineering, solar radiation management may lead to significant changes in Monsoons in an unpredictable manner (Royal Society 2009). Ocean fertilization may also carry with it potential side effects such as a decrease in oxygen and a resulting increase in methane emissions, or significant changes in the microbiological composition and productivity (Keith, 2000). Thus, geo-engineering may fix one problem to create yet another problem, leading to a cascade of issues. Furthermore, with geo-engineering financially and technologically feasible even by single, less affluent countries, unilateral attempts may become possible – either to have a global solution to climate change or at least have regional protection (Ricke et al. 2009). However, climate is indivisible and global, thus unilateral attempts would have major repercussions and could be considered as hostile acts. Gwynne Dyer explored this possibility, that a country severely threatened by climate change may resort to desperate measures and even threaten countries with carbon-intensive economies to act or fear the consequences (Dyer 2008).

A particular concern regarding synthetically created organisms is that, even if created in the safety and security of laboratories, they may leak out into the environment. If they then undergo mutations and become established in resident natural populations, they may cause unknown harm (Kaebnick, 2009). For instance, when the cane toad was introduced to Queensland, Australia in 1929, the intended effect was that it would act as an insect control. While unsuccessful in this respect, the toad has instead become a major problem and threatens a number of native species (Matthews and Turner, 2009). The lessons learned could be that unknown and potentially unstable consequences are proportional to our knowledge of the system upon which we are acting: the less complete our understanding of the system the greater the potential for “undesirable or unforeseen environmental” impacts (Matthews and Turner, 2009). The democratisation of biotechnology thereby put such measures in the reach of a vast array of organisations, including small companies and individuals.

Another type of concern that is often cited by both supporters and sceptics of geo- and bio-engineering regards dual-use: it is conceivable that states, non-state groups, or even individuals, could apply a number of environmental modification techniques for hostile purposes. For example, the genetic makeup of the most dangerous agricultural pests have been decoded, which can help to gain insights into new strategies to prevent catastrophic outbreaks, but can also be used to put together new pathogens (Casagrande, 2000).[4] Additionally, nearly all of the materials and equipment used to cultivate biological warfare agents have commercial applications in the production of beer, wine, food products, animal feed supplements, bio-pesticides, vaccines, and pharmaceuticals (Tucker, 1996).

[4] Researchers in Brazil for example, have sequenced the genome of citrus variegated chlorosis (*X. fastidiosa*), whose strains cause disease in a variety of agricultural plants such as alfalfa, grapes, coffee, and stone fruit (2000 Casagrande_Biological Terrorism.pdf)

Indeed, if terrorists chose to target agriculture, a pathogen could easily be found and synthesized to suit the target crops, or an entirely new organism could be created from scratch (Kaebnik, 2009). Although most existing pathogens would need to go through a complex process of development, production, weaponization, and delivery in order to cause mass casualties (with the exception of the smallpox and 1918 influenza viruses) these processes would not necessarily be needed if agricultural crops were targeted (Vogel, 2006). However, taking into consideration past examples and the still-significant technical obstacles for using these techniques, many studies seem confident that they could become a threat only at the state level; non-state actors thus, even those considering a bioterrorist attack, may still prefer to use traditional biological warfare agents (Kelle, 2009). Perhaps, especially with bio-engineering, the security concerns are not so much directed at individuals and non-state groups, but rather toward the business industry. Several companies throughout the world are already working on producing synthetic DNA pieces (oligonucleotides), and as their size and complexity increases they will be theoretically able to manufacture any virus, including toxins and biological agents (Ibid.). These companies are already working together to create and check through databases before an order is placed, meaning they would receive an alarm if a potentially dangerous DNA sequence had been ordered. However, due to the increasing complexity of the genetic parts able to be manufactured, it is becoming very difficult to pick out the dangerous sequences, and to create a detailed enough definition of what is dangerous in this highly evolving field (May, 2009). Thus, the use of such sophisticated technologies may not be necessary: in the case of geo-engineering, global systems must be put in place and continuously maintained. If this system should be crippled it could lead to rapid global warming again, with disastrous associated consequences as little time would be left for adapting or building a new one (Brovkin et al. 2009). Similarly, releasing artificially created biological organisms by attacking manufacturing sites may also be more cost-effective and elicit greater psychological impact than producing them.

With environmental modification becoming pervasive politically, economically and even socially, it may also become a focus for military use and targeting – as did "cyberwar" before. A well-known example of environmental warfare using Agent Orange occurred during the Vietnam War, but a less well-known example of geo-engineering occurred at the same time: the United States carried out a campaign of cloud seeding during that war, with a budget of more than US $3 million per year. The negative public reaction to the war also extended to this effort, and lead to the international treaty of 1972, the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) (Keith, 2000). Still, both geo-engineering and bio-engineering are grey areas due to their dual-use purpose. Although the ENMOD treaty exists, it only has 75 ratifications and the past decade has seen deterioration and crises of several arms control treaties.

While protecting the environment and preventing climate change currently appears to be a globally agreed-upon goal, the introduction of large-scale geo-engineering, climate variability and instability, and similar impacts may lead to creeping changes of values and perspectives (see Welzer 2008) –thus making the environment a target and a weapon alike.

5. Discussion and Conclusions

The term anthropocene denotes a new era, in which direct human action is now a major driving force in global environmental change. Historically, complex societies could only thrive on a suitable environment and would collapse if they were unable to adapt to environmental change. On a local level, inequitable and ineffective environmental and resource governance along with unsustainable development may also lead to conflicts over resources and very direct human suffering. A major challenge is thereby the inflexibility, i.e. keeping things as they are even as they continue to change: the environment created by human action may not support its current social, political and economic practices – which will require change and adaptation.

Aside from a mismatch between environment and society, environmental modification becomes increasingly discussed, practiced and accepted, among others geo-engineering and bio-engineering. This pushes the term anthropocene to a new level, as it allows changes outside of conventional parameters and on unprecedented scales. A major mismatch of geo-engineering and bio-engineering are their underlying intentions: geo-engineering focuses on nullifying climate change impacts, trying to keep the climate as it is – while bio-engineering is attempting the opposite, creating new organisms never seen before, and thus changing things. A major challenge here is that the environment is seen as external issue to be engineered, and not an intimate co-evolving issue. As a result, there are significant threats of cascading, unexpected problems, which may destabilise environmental processes, and by extension societies.

Both ongoing environmental change as a result of human action as well as artificially conducted environmental manipulation, may lead to unpredictable environmental change for which current societies are no longer prepared to adapt. –This may also increase the risk of catagenesis: a calamity, which leads to the collapse of the current complex global society, and the potential creation of a new society thereafter. Such events tend to engender a significant reduction in the complexity of societies and be accompanied by a violent release of energy as well (see Homer-Dixon 2005; Diamond 2005).

Governance, legislation and regulation of these issues, such as via the ENMOD treaty, are currently insufficiently developed to accommodate the challenges. Furthermore, regulations have a tendency to be too rigid and inflexible: the Law of the Sea is a good example, as the issue of climate-induced sea-level rise is not covered and will raise serious legal questions in the future (Maas et al. 2010). Principles and codes of conduct guiding behaviour may be more appropriate, as flexibility will be needed to adapt continuously to ongoing environmental change. Of course, this course entails no guarantees: even if a kind of code of ethics would evolve within the community, similar to the computer hacking community, it is no guarantee that dangerous intentional or unintentional products (such as malware for the computer hacking industry) would not result (Schmidt, 2008).

Whatever the approach might be, it becomes clear that trying to let things stay as they are – an implicit key aspect of security – is not an option. Instead, it is likely that a transition will occur as a result of ongoing (and potentially accelerated) environmental change. The aim must be to identify where this transition may lead to frictions – where environment and security interfaces – and where it threatens to uproot societies. A set of social, political and economic practices are necessary, which are capable to sustain rapid change and to adapt accordingly.

References

Alper, Joe 2009: Biotech in the basement. Nature Biotechnology 27, no. 12: 1077-1078.

Baldwin, Daniel A. 1997: The Concept of Security. In: Review of International Studies 23:1, 5-26.

Bickel, J. Eric and Lee Lane 2009: An Analysis of Climate Engineering as Response to Climate Change. Frederiksberg: Copenhagen Consensus Center.

Brock, Lothar 1997: The Environment and Security: Conceptual and Theoretical Issues. In: Nils Petter Gleditsch (ed) 1997: Conflict and the Environment. Dordrecht et al: Kluwer, 17-35.

Brzoska, Michael 2008: Der konfliktträchtige Klimawandel – ein Sicherheitsproblem? In: Andreas Heinemann- Grüder, Jochen Hippler, Markus Weingardt, Reinhard Mutz und Bruno Schoch (eds) 2008: Friedensgutachten 2008. Münster: LIT, 195-206.

Buzan, Barry, Ole Wæver and Jaap de Wilde 1998: Security. A New Framework for Analysis. Boulder and London: Lynne Rienner.

Brovkin, Victor, Vladimir Petoukhov, Martin Claussen, Eva Bauer, David Archer and Carlo Jaeger 2008: Geoengineering climate by stratospheric sulphur injections: Earth system vulnerability to technological failure. In: Climate Change 92, 243-256.

Carius, Alexander and Achim Maas 2009: Climate Change and International Security. Technical Report. London: HTSPE.

Carius, Alexander, Dennis Tänzler and Achim Maas 2008: Climate Change and Security – Challenges for German Development Cooperation. Eschborn: GTZ.

Carius, Alexander, Dennis Tänzler und Judith Winterstein 2006: Weltkarte von Umweltkonflikten – Ansätze einer Typologisierung. Externe Expertise für das WBGU-Hauptgutachten: „Welt im Wandel: Sicherheitsrisiko Klimawandel“. http://www.wbgu.de/wbgu_jg2007_ex02.pdf (3. August 2007).

Casagrande, Rocco 2000: Biological Terrorism Targeted at Agriculture: The Threat to US National Security. The Nonproliferation Review.

Dalby, Simon 2009: Security and Environmental Change. Cambridge: Polity.

Dalby, Simon 2002: Environmental Security. Minneapolis: University of Minnesota Press.

Diamond, Jared 2005: Collapse. How societies choose to fail or survive. London: Penguin Books

Diamond, Jared 1999: Guns, Germs and Steel. New York: Norton.

Dyer, Gwynne 2008: Climate Wars, Toronto: Random House Canada.

ETC 2007: Extreme Genetic Engineering. An Introduction to Synthetic Biology. Available at http://www.etcgroup.org/upload/publication/602/01/synbioreportweb.pdf (22 April 2010).

European Commission 2005: Synthetic Biology. Applying Engineering to Biology. Report of the NEST High-Level Expert Group. European Commission: Brussels.

Gunderson, Lance H. and C.S. Holling (eds) 2002: Panarchy. Understanding Transformations in Human and Natural Systems. Washington et al.: Island Press.

Halden, Peter 2007: The Geopolitics of Climate Change. Challenges to the International System. Stockholm: FOI.

Homer-Dixon, Thomas 2005: The Upside of Down. Catastrophe, Creativity and the Renewal of Civilisation. Washington et al.: Island Press.

Homer-Dixon, Thomas F. 1999: Environment, Scarcity and Violence. Princeton: Princeton University Press.

House of Commons 2010: The Regulation of Geoengineering. London: The Stationary Office.

Kaebnick, Gregory, E. 2009: Should moral objections to systhetic biology affect public policy? Nature Biotechnology 27, no. 12: 1106-1108.

Kahl, Colin 2005: States, Scarcity and Civil Strife in the Developing World. Princeton: Princeton University Press.

Keith, David, W. 2000: Geoengineering the Climate: History and Prospect. Annual Reviews of Energy and Environment 25: 245-84.

Kelle, Alexander. 2009: Ensuring the security of synthetic biology - towards a 5P governance strategy. Systems and Synthetic Biology 3: 85-90.

Lee, Bernice 2009: Managing the interlocking climate and resource challenges. In: International Affairs 85:6, 1101-1116.

Lockwood, Jeffrey A. 2009: Six-legged Soldiers. Using Insects as Weapons of War. Oxford: Oxford University Press.

Maas, Achim, Chad Briggs, Vicken Cheterian, Kerstin Fritzsche, Bernice Lee, Cleo Paskal, Dennis Tänzler and Alexander Carius 2010: Shifting Bases, Shifting Perils. A Scoping Study on Security Implications of Climate Change for the OSCE Region. Berlin: Adelphi Research.

Matthews, H Damon, und Sarah, E. Turner 2009: Of mongooses and mitigation: ecological analogues to geoengineering. Environmental Research Letters 4.

May, Mike 2009: Engineering a new business. Nature Biotechnology 27, no. 12: 1112-1120.

Monke, Jim 2004: Agroterrorism: Threats and Preparedness. CRS Report for Congress. Washington: Library of Congress.

OECD 2009: The Bioeconomy to 2030. Designing a Policy Agenda. Paris: OECD.

Ratta, Raphael Della, Geral Epstein, David Fidler, Elisa Harris, Jo Husbands, Barry Kellman, Daryl Jimball, Ken Luongo, Michael Moodie, Randy Murch, Alan Pearson, Jonathan Tucker 2009: Reducing Biological Risks to Security. International Policy Recommendations to the Obama Administration. Available at http://www.armscontrolcenter.org/assets/pdfs/biothreats_initiatives.pdf (22 April 2010).

Ricke, Katherine, M. Graner Morgan, Jay Apt, David Vctor and John Steinbrunner 2008: Unilateral Geoengineering. Non-Technical Briefing Notes for a Workshop at the Council on Foreign Relations, Washington DC, May 05, 2008. Wahsington: Council on Foreign Relations.

Royal Society 2009: Geoengineering the Climate. Science, Governance and Uncertainty. Available at http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=10768 (17 December 2009).

Schmidt, Markus. 2008: Diffusion of synthetic biology: a challenge to biosafety. Systems and Synthetic Biology 2: 1-6.

Schmidt, Markus, Helge Torgersen, Agomoni Ganguli-Mitra, Alexander Kelle, Anna Deplazes, und Nikola Biller-Andorno 2008: SYNBIOSAFE e-conference: online community discussion on the societal aspects of synthetic biology. Systems and Synthetic Biology 2: 7-17.

Shearman, David and Joseph Smith 2007: The Climate Change Challenge and the Failure of Democracy. Westport: Praeger.

Torgersen, Helge 2009: Synthetic biology in society: learning from past experience? Systems and Synthetic Biology 3: 9-17.

Tucker, Jonathan, B. 1996: Chemical/Biological Terrorism: Coping with a New Threat. Politics and the Life Sciences 15, no. 2: 167-183.

UNEP 2009: From Conflict to Peacebuilding. The Role of Natural Resources and the Environment. Nairobi: UNEP.

UNFCCC 2007. Investment and Financial Flows to Address Climate Change. Bonn: UNFCCC.

UNPD 2008: World Population Prospects. The 2008 Revision. Available at http://esa.un.org/unpp/ (4 January 2010).

Vogel, Kathleen 2006: Bioweapons Proliferation: Where Science Studies and Public Policy Collide. Social Studies of Science 36, no. 5: 659-690.

Wall Street Journal 2009: In Attics and Closets, 'Biohackers' Disvoer Their Inner Frankenstein. 12 May 2009, available at http://online.wsj.com/article/SB124207326903607931.html (22 April 2010).

WBGU 2007: World in Transition – Climate Change as a Security Risk. Berlin and Heidelberg: Springer.

Welzer, Harald 2008: Klimakriege. Wofür im 21. Jahrhundert getötet wird. Berlin: Fischer.

Wheelis, Mark 2004: Will the New Biology Lead to New Weapons? Available at http://www.armscontrol.org/act/2004_07-08/Wheelis (16 April 2010).

Wolinsky, Howard 2009: Kitchen biology. European Molecular Biology Organization 10, no. 7: 683-685.