A Study of

The Impact on the UK of Climate Change Impact in Other Regions of the World

Book 2

World Stories and Wider Implications

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This document is not a statement of government policy

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Book 2 – World Stories and Wider Implications

Book 1 – Impact of Impact

Book 1 is the main study and summarisation of the results of which this is a companion. Book 1 has the following sections:

Introduction

The aim and basis of the study

1 Methodology

An account of the methodology developed to do the systems mapping based on the World System Model.

2 Assessing Climate Change Impacts and Vulnerabilities

The application of the methodology and its detailed analysis.

3 Climate Impact Mapping – Direct Impact Patterns

The World System Model 'fingerprints' of the seventeen countries or regions.

4 Anticipating Potential Impacts on the UK of Climate Change Impacts Elsewhere in the World

An analysis of eight different areas of potential impact on the UK

5 Conclusion

A distillation of the main findings of the study

6 References

An extensive bibliography of the range of sources drawn on and referred to in the report, both Book 1 and Book 2

1 World Stories – Background Scanning, Mapping and Critical Systemic Interactions

This section takes the analysis presented in Book1 Section 3 to a more detailed level. In Section 3, the first level, Direct Impact Patterns, give the reader a "snapshot" or "fingerprint" assessment of the reviewed literature of climate change impact on each country/region using the framework of the World System Model. These diagrams show the potential scale of impact on each of the nodes in isolation. The term 'direct' is used to indicate that these are the nodes which are most susceptible to physical and biological reaction to climate change. The nodes (see Figure 1 below) are *Health and Wellbeing, Food and Agriculture, Energy and Earth Resources, Ecosystem Services, Water Availability, Habitat and Infrastructure*, and *Community Resilience*).

In the World Stories (a short hand for a more complex account of climate impact) the impact of climate change on the nodes is no longer taken in isolation. Instead, a set of connections is made between each of the significant nodes, that is to say, the nodes which register a high, medium or lower impact. By mapping the pairs of connections a further pattern is made in the diagram, referred to as level 2 or 2nd order impacts. For example the literature may show critical interactions between water availability and food and agriculture. The literature has been scanned for evidence of such knock-on effects or reciprocal effects between different impacted nodes. This form of scanning does indeed highlight more fully the complexity of assessing climate impact and poses the challenge of avoiding simplistic and siloed definitions of problems and solutions.

The potential value of this use of the World System Model is to provide a heuristic framework for searching for likely interactions between impacted nodes. Each impacted node is potentially connected in varying degrees to all the other impacted nodes.. These cross connections (the red lines in *Figure 1)* are referred in the World Stories which follow in a sub-section headed *Systemic Relationships – Principal Paired Interactions.* Each country or region has its own unique impact pattern or 'finger print' represented by the size of the node circles and the red interconnecting lines. Once the paired interactions are identified, more complex patterns can be identified and reviewed for significance.

The number of connections is a function of the number of included nodes according to the simple formula n(n-1)/2. Each paired connection is supported from evidence in the reviewed literature. and references it accordingly.

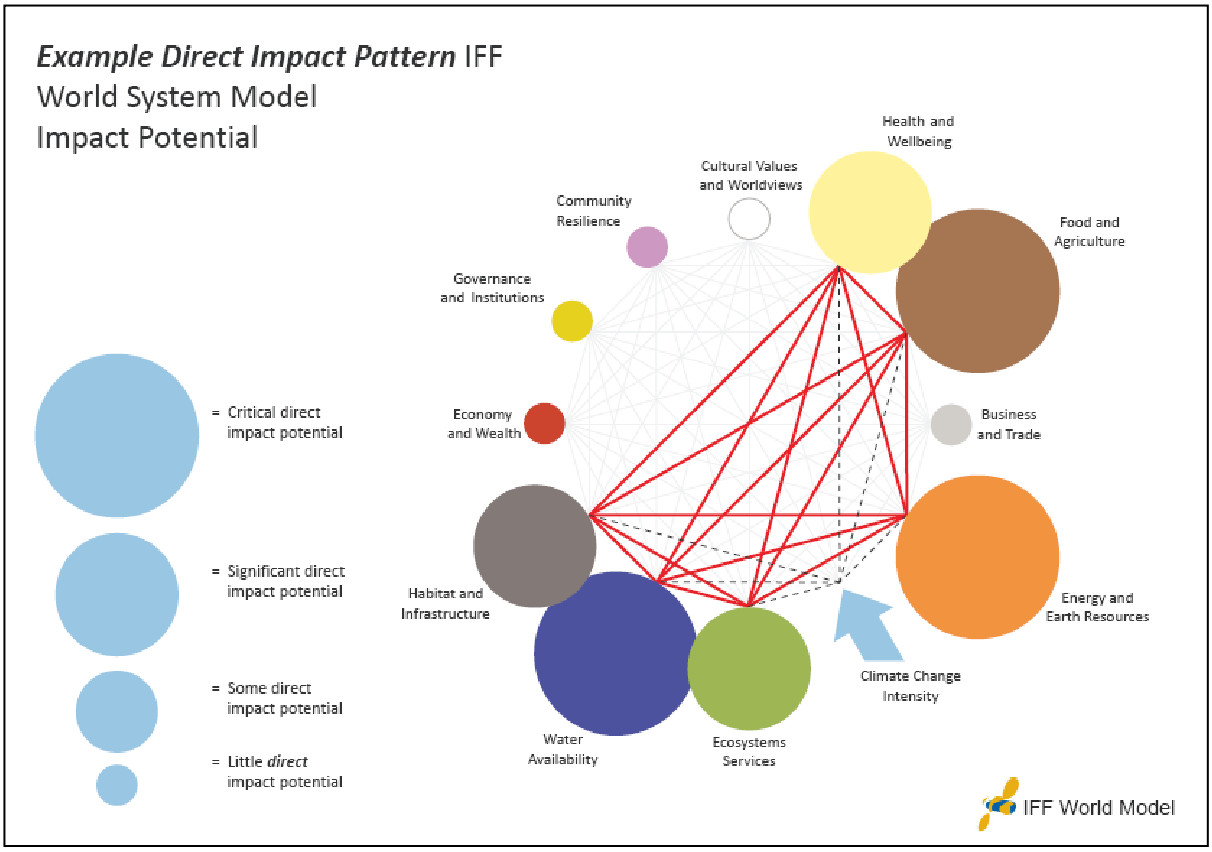


Figure 1 - An example of an interconnected direct impact pattern on the IFF World System model. The size of the circle indicates the scale of impact as indicated in the literature and these are joined by the red lines. The smallest circles are not part of the selected set of nodes for direct impact or have not been highlighted in the reviewed literature.

Due to the extensive nature of the world literature on impact of climate change it was decided that, within the scope of this project, the paired interactions could best be reviewed by direct block quotes from the literature. These block-quotes, mainly from synthesis literature often include references to other analysis. It was not considered relevant within the scope of this report to analyse the content of these "implicit" references. The authors cannot therefore verify the content or analysis of these implicit references which are in grey text in the document. Readers should refer to the original material for more information. They are listed in Book 1 Section 6 – References, under the synthesis reference within which they occur. They are indicated in the reference list by stars to differentiate them from primary material analysed for this report.

Each of the 17 Country/Region World Story is organised as follows:

1. An overview highlighting general considerations for that regions or country.
2. An account from the referenced literature (see Section 6) relating to each Principal Paired Interaction.

An index of Adaptive Capacity based on the proxy methodology described in Book1 Section 2.5. For convenience this method for assessing Adaptive Capacity through proxy indicators is reproduced here.

For each country/region in question adaptive capacity has been estimated in the following way: rankings from the Failed States Index, the World Bank Governance Indicators for political stability and government effectiveness, and the Human Development Index have been compiled. The grading in each category was assigned a number **n :** 1 – 5 for Failed States, 1 – 6 for Political Stability and Governance Effectiveness respectively, and 1 - 4 for the Human Development Index. Each figure was then normalized (as a fraction of 1) and the elements summed to give an index figure **x**. The framework is summarized in Table 1.

Proxy Indicator (selected for contribution to adaptive capacity)	Country or Region Grading Scale (as per that system)	
Failed States Index	Grading 1 to 5	n /5=x
Political Stability	Grading 1 to 6	n/6=x
Governance Effectiveness	Grading 1 to 6	n/6=x
Human Development Index	Grading 1 to 4	n/4=x

Table 1 – Proxy Indicators for Adaptive Capacity and Grading Scale

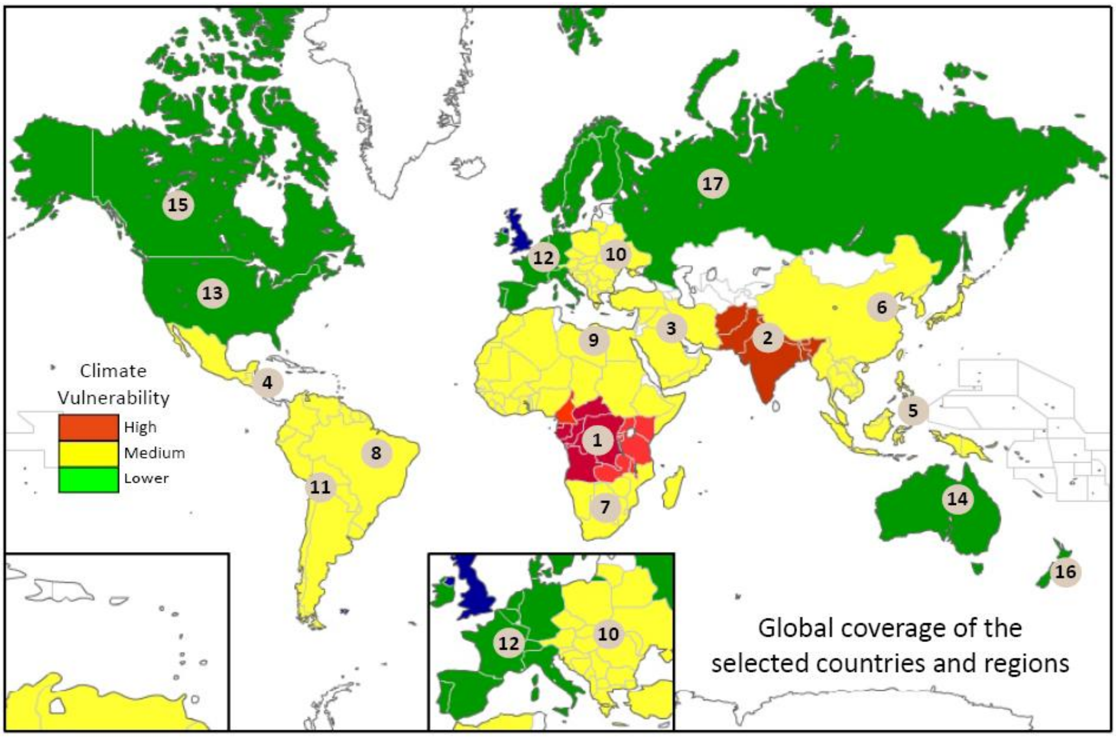
The sum of these measures (multiplied by 10 for ease of comparison) is taken as a single indicator of adaptive capacity for any country, and the average over the principal countries in a region provides a single indicator for that region. The country-level detail used to calculate the regional level indicator is also given and can usefully identify specific pockets of instability or resilience within a region. It should be noted that unforeseen geo-political changes could shift the indicators used below.

These assessment measures were divided into three bands indicating the adaptive capacity in an overall index of adaptive capacity, colour coded as in Table 2

1	Indicator values 0 to 18	Fragile adaptive capacity
2	Indicator values 19 to 30	Weak adaptive capacity
3	Indicator values 30 upwards	Reasonable adaptive capacity

Table 2 - Graded Classification of Adaptive Capacity for Assessing Vulnerability

Selected Regions and Countries According to Vulnerability



1 Mid-Africa 2 Indian Sub-Continent 3 Middle East 4 Central America and Caribbean 5 SE Asia 6 China 7 Southern Africa 8 Brazil 9 North Africa	10 Central and Eastern Europe 11 Andean South America 12 Western Europe 13 United States 14 Australia 15 Canada 16 New Zealand 17 Russia 18 UK Overseas Territories (UKOT) (♣)

(♣) The UKOT are not prioritised for vulnerability – see Book 1 Section 3.18

Figure 3.1 Map showing the distribution of countries and regions analysed in relation to the geography of climate impact vulnerability as calculated in Table 2.6 (p.35).The system maps of counties and regions that follow are arranged in a sequence from highest to lowest vulnerability.

1.1 Mid-Africa Direct Impact Pattern

Mid Africa is the region of Africa which runs approximately from Cameroon and Angola in the west to Kenya and Tanzania in the East. It excludes North Africa and the southern fringe of the Sahel and also excludes Southern Africa which are treated separately.

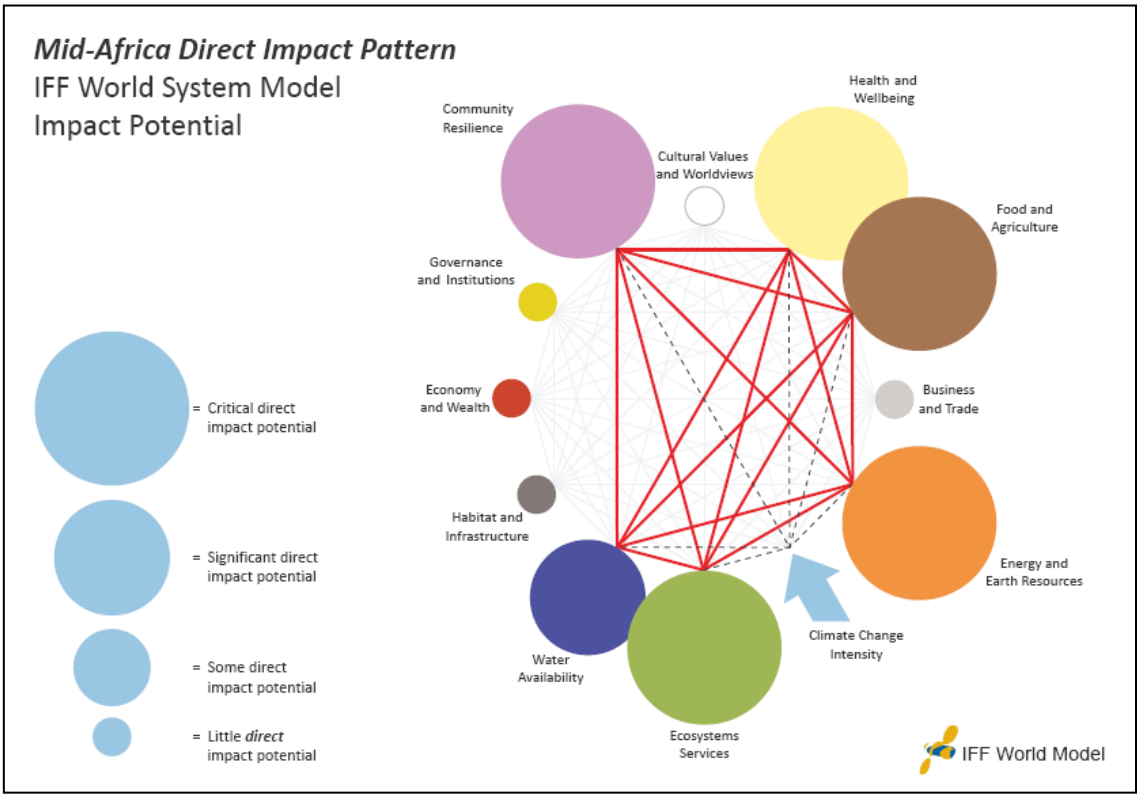


Figure 1.1.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects.

1.1.1 Overview

The German consultancy group 'Adelphi' and the German Ministry for the Environment have produced a comprehensive report on the security implications of climate change in Africa (Adelphi, 2009). The report highlights: "Climate change will negatively impact Africa and will likely stall or reverse development progress made towards achieving the Millennium Development Goals. The belt of fragility running along the Sahel zone from West to East Africa will likely be re-enforced and potentially widened by climate change. It will continue to require significant international resources for humanitarian aid and peacekeeping. Additionally, at present relatively stable states such as South Africa may experience instability if the pressures induced by climate change are not managed adequately" (Adelphi, 2009, p.4).

The Adelphi report emphasizes that events in Rwanda, Darfur and Sudan have strong land and environmental elements with degradation and scarcity key underlying factors that are likely to be exacerbated by further climate change, although as West African examples, such as Ghana and Burkina Faso show, scarcity does not necessarily lead to violence and adaptation strategies to a changing climate have long been a part of life in Africa.

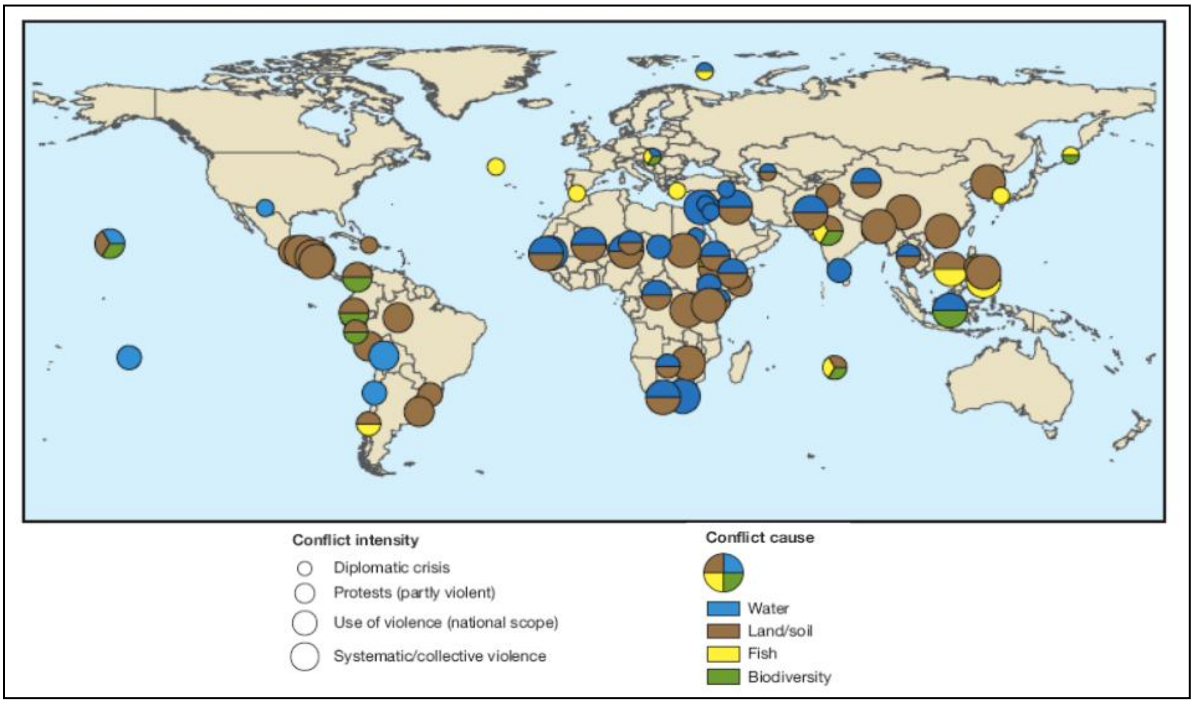


Figure 1.1.2 - World map of environmental conflicts showing intensity in mid-Africa

"Africa is the world's poorest continent. Almost half the population of sub-Saharan Africa lives on less than one dollar a day. The region has experienced only sporadic growth in the last 40 years and despite some improvements during this decade, Africa as a whole is not growing fast enough to keep up with the rest of the world, let alone to achieve eventual convergence with developed countries. There are many complex reasons for this: inadequate governance, crippling debt, limited infrastructure, disease and inadequate healthcare, reliance on natural resources and ongoing cycles of conflict. Life expectancy remains low at 49.6 years; no other region in the world is less than 60 years (UNDP, 2007). Together these factors inhibit the ability of many countries and communities to adapt to the impacts of climate change. Poorer countries are likely to have fewer resources and less stamina to deal with climate change, even in its early, modest manifestations (Campbell et al., 2007). Meanwhile, seventeen countries in Sub-Saharan Africa are included in lists of the world's most fragile states: Burundi, Chad, Central African Republic, Côte d'Ivoire, Democratic Republic of Congo, Liberia, Nigeria, Sudan, Angola, Ethiopia, Guinea, Sierra Leone, Somalia, Zimbabwe, Cameroon, Guinea-Bissau and Malawi (Smith and Vivekananda, 2007)" (Brown & Crawford, 2009, p.19).

1.1.2 Systemic Relationships – Principal Paired Interactions (15)

Health & Wellbeing – Community Resilience

Climate change will increase African populations' vulnerability to climate related disease, and is likely to increase numbers of internal migrants.

The African Partnership Forum 2007 warned: "The health effects of a rapidly changing climate are likely to be overwhelmingly negative. Africa is already vulnerable to a number of climate-sensitive diseases such as Rift valley fever, which afflicts both people and livestock; cholera, associated with both floods and droughts; and malaria, where warming climate has resulted in the extension of malaria to the highlands of Kenya, Rwanda and Tanzania. These factors are superimposed upon existing weak health systems" (APF, 2007, p.9).

The International Institute for Sustainable Development (IISD) emphasized: "Already more than 30 per cent of the world's refugees and internally displaced people are housed by African countries (Garcia 2008). North Africa is already a migration destination (for internal as well as cross-border migrants), and is a transit area for people from sub- Saharan Africa and Asia attempting to reach Europe. In certain locations, this has already given rise to problems of social unrest and attacks on migrants as well as human trafficking and an increasing number of fatalities from attempted sea crossings" (Brown & Crawford, 2009, p.18).

The IISD identified a number of climate impacts on community resilience in Africa: "Climate change and its impacts will affect a growing number of people, and migration hotspots around Africa are likely to increase. Climate change will cause population movements by making certain parts of the world much less viable places to live: by causing food and water supplies to become more unreliable; undermining livelihoods; through sea-level rise and flooding that reduces available land; and by increasing the frequency and destructive power of storms (Brown, 2008b). This in turn may force large numbers of people to leave their homes and communities. Migratory pressure can be expected to increase due to heightening stress and tensions in the rest of Africa, and in the Sahel in particular: by 2020 the population of the Sahelian countries will have quadrupled since 1960. Furthermore it is estimated that between 2025 and 2050 the population of North Africa will increase by around 50million (UN DESA, 2005)" (Brown & Crawford, 2009, p.18-19).

Health & Wellbeing – Energy & Earth Resources

Africa has considerable natural resources but there are real questions around the ongoing growth in demand both from Africa internal population and from international interests.

"The population of Africa is rapidly growing and urbanising for the foreseeable future. Its demand for resources will continue, and increase, as well. By and large, Africa is lagging behind Asian countries such as India and China regarding economic development. It is also significantly behind schedule regarding the Millennium Development Goals (MDGs) (see Martens 2007)"…"Most African states, however, already face difficulties or fail to deliver basic services, while economic development can hardly substitute by providing the necessary funds.

External food aid is likely to continue or increase for the foreseeable future. The richness of Africa's natural resources will continue to draw external attention. Thus, globally increasing resource demands could manifest themselves in a scramble for Africa as international powers and companies attempt to secure supplies." (Adelphi, 2009, p.7).

Access to energy is severely constrained in sub-Saharan Africa, with an estimated 51% of urban populations and only 8% of rural populations having access to electricity. This can be compared with the 99% of urban populations and 80% of rural populations that have access in northern Africa." (Bates *et al.* 2008, p.80).

Water Availability - Health & Wellbeing

One third of the population live in drought prone areas. Just under two thirds of the population have access to improved water supplies.

"About 25% of the contemporary African population experiences water stress, while 69% live under conditions of relative water abundance (Vörösmarty et al., 2005). However, this relative abundance does not take into account other factors such as the extent to which that water is potable and accessible, and the availability of sanitation. Despite considerable improvements in access in the 1990s, only about 62% of Africans had access to improved water supplies in the year 2000 (WHO/UNICEF, 2000). One-third of the people in Africa live in drought-prone areas and are vulnerable to the impacts of droughts (World Water Forum, 2000), which have contributed to migration, cultural separation, population dislocation and the collapse of ancient cultures. Droughts have mainly affected the Sahel, the Horn of Africa and southern Africa, particularly since the end of the 1960s, with severe impacts on food security and, ultimately, the occurrence of famine. In West Africa, a decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20–40% in the period 1968–1990 as compared with the 30 years between 1931 and 1960 (Nicholson et al., 2000; Chappell and Agnew, 2004; Dai et al., 2004a)" (Bates, *et al.*, 2008, p.80).

In addition to highlighting the shift in distribution and increase in range of malaria in Africa, the IPCC (2008) report on *Climate Change and Water* also addresses a number of other water-related diseases that may be affected by climate change:

"While infectious diseases such as cholera are being eradicated in other parts of the world, they are re-emerging in Africa. Child mortality due to diarrhoea in low-income countries, especially in sub-Saharan Africa, remains high despite improvements in care and the use of oral rehydration therapy (Kosek et al., 2003). Children may survive the acute illness but may later die due to persistent diarrhoea or malnutrition. Several studies have shown that transmission of enteric pathogens is higher during the rainy season (Nchito et al., 1998; Kang et al., 2001)" (Bates *et al.*, 2008, p.80-81).

Water Availability – Community Resilience

Even before factoring in climate change many African countries are heading towards a crisis in terms of their economically usable, land-based freshwater resources as a result of population growth and increased demand.

The African Partnership Forum (2007) emphasized: "Three-quarters of African countries are in zones where small reductions in rainfall could cause large declines in river water. Climate models show that 600,000 square kilometres classified as moderately water constrained will experience severe water limitations. By 2020, between 75 and 250 million people are projected to be exposed to an increase of water stress due to climate change. The problem of water scarcity is even more acute in North Africa in view of the very high population growth rates and already high rates of water resource use" (APF, 2007. p.9).

The International Institute for Sustainable Development (IISD) concurs: "Access to clean water is a major problem in many African countries. One-third of all people in Africa live in drought-prone regions. One-quarter (about 200 million people) currently experience significant water stress (IPCC, 2007). Drought accounted for 31 per cent of all natural disasters in Africa between 1975 and 2002. Floods accounted for another 26 per cent (ISDR, 2004). Ethiopia, Eritrea and Somalia have suffered more deaths through drought over the last century—600,000 by one estimate—than any other part of Africa. These countries have also experienced persistent conflict, internally and regionally. Drought and famine remain major underlying threats to security" (Brown & Crawford, 2009, p.13).

The IISD report continues: "In many places, the problem of water is both one of quantity and quality. Increasingly, the problem is not one simply of overuse but also pollution. …Two-thirds of the rural population and one-quarter of the urban population in Africa lack access to safe drinking water (Simms, 2005). Even before factoring in climate change many African countries are heading towards a crisis in terms of their economically usable, land-based freshwater resources as a result of population growth and increased demand. Agricultural use of freshwater is predicted to rise by 30 per cent between 2005 and 2025 (ISDR, 2004). The IPCC estimates several countries in Africa, particularly in North Africa, will exceed the limits of their economically usable land-based water resources by 2025 (IPCC, 2007).

The report concludes: "In some regions of Africa water interdependence is very high; for example, the 17 countries in West Africa share 25 transboundary rivers (Boko et al., 2007), the Nile Basin extends over 10 countries and the Nubian sandstone aquifer is shared by four countries. This means that economic progress is intimately tied to water management elsewhere—often a rationale for better cooperation, but also a cause for tension and conflict" (Brown & Crawford, 2009, p.14).

Community Resilience – Energy & Earth Resources

Globally increasing resource demands could manifest themselves in a scramble for Africa which may not contribute to overall social and economic development.

"From a global perspective, the continuing instability in areas such as the Horn of Africa can continue to impact trade and shipping routes. Furthermore, out-migration from Africa toward other areas may become a concern, especially for host communities and the routes used for transit. The chronic instability in the Sahel belt will continue requiring international humanitarian assistance. And, as mentioned above, the resource richness of Africa provides continuous incentives for external powers to become involved in local affairs, complicating the political situation further. Militant stands against environmental degradation have already begun in Africa. Armed insurgencies in Nigeria, for example, are fighting governmental forces and attacking oil installations, among other reasons due to the environmental havoc oil drilling produces in the Niger delta. On the other side of the continent pirates along the Horn of Africa are justifying their attacks in part with preserving Somalia's natural richness. While the extent to which this is truly a main driver behind their attacks is questionable, it has substance and justifies their actions at least partly in the eyes of their constituencies and sympathisers (see cf. Middleton 2008)" (Adelphi, 2009, p.8-9).

Energy & Earth Resources – Water Availability

Both fuel wood and hydroelectric power are central to African energy sources and likely to be adversely effected by climate change.

The IPCC (2008) reports: "The electricity supply in the majority of African States is derived from hydro-electric power. There are few available studies that examine the impacts of climate change on energy use in Africa (Warren et al., 2006). Nevertheless, the continent is characterised by a high dependency on fuelwood as a major source of energy in rural areas – representing about 70% of total energy consumption in the continent. Any impact of climate change on biomass production would, in turn, impact on the availability of wood-fuel energy. Access to energy is severely constrained in sub-Saharan Africa, with an estimated 51% of urban populations and only 8% of rural populations having access to electricity. This can be compared with the 99% of urban populations and 80% of rural populations that have access in northern Africa." (Bates *et al.* 2008, p.80).

The IPCC report highlights the link between climate change and hydro-electric power generating capacity. "Although not many energy studies have been undertaken for Africa, a study of hydro-electric power generation conducted in the Zambezi Basin, taken in conjunction with projections of future runoff, indicates that hydropower generation would be negatively affected by climate change, particularly in river basins that are situated in sub-humid regions (Riebsame et 1995; Salewicz, 1995)" (Bates *et al.*, 2008, p.82).

Water Availability - Ecosystems Services

Water catchments stressed by non-climate related activities are already impacting on ecosystems services. Climate change is highly likely to aggravate the situation.

“Forest ecosystems in tropical Africa are important repositories for vital livelihood resources and ecosystem services, and, at the same time, constitute major wildlife habitats including corridors that allow for migration facilitating coping with climate risks. The biodiversity of tropical forests in Africa is being threatened by a range of human activities such as mining, habitat loss due to conversion to agricultural land and logging, over-exploitation for fuel wood, food, medicinal plants, overgrazing, water catchment and river channel destructions some of which are in response to climate change pressures. Such activities have resulted in habitat modifications and the loss of endemic species and have also endangered other species. Several studies and predictive models have strongly emphasized the vulnerability of African tropical forest biodiversity to various climate change scenarios, and the resulting direct consequences on wildlife populations, and the livelihoods of humans. Such loss of biodiversity amplifies the vulnerability of the continent to the impacts of climate change. .. Climate change adaptation strategies in Africa should therefore simultaneously have an integrated plan for biodiversity conservation and livelihood adaptation strategies that match local resource use patterns without jeopardizing the resilience of the forest ecosystem to climate change impacts”(CIFOR, 2008, p.2-3).

Ecosystems Services - Community Resilience

Land degradation, population growth and urbanisation are challenging ecosystem services and the resilience of communities that depend on them.

“Africa is changing in a variety of profound ways, not just in terms of its climate. Its population is growing and moving, its economy is evolving and the health of its environmental resources is declining. Future climate change will take place against a backdrop of these powerful socio-economic challenges. How these are managed will determine the ability of African countries and communities to adapt to climate change. The scale of resource use and environmental stress in Africa will be sharply accentuated by population growth. Africa’s population is predicted to double by the middle of the century from 987 million people, or 15 per cent of the global population, to just under two billion (or 22per cent of the global total) by 2050 (UNFPA, 2008). Meanwhile, an increasing number of Africans are moving to urban areas—at a rate of three per cent per annum. Currently still predominantly rural, 50 per cent of Africans will live in urban areas by 2030, doubling Africa's urban population from 373.4 million to 759.4 million. By 2050 there will be more than 1.2 billion African city dwellers (UN-HABITAT, 2008)" (Brown & Crawford, 2009, p.13).

"Africa is likely to experience a continuing trend of land degradation. Already approximately 3,500 square kilometres of Nigerian land turns to desert each year, forcing both farms and herdsmen to abandon their lands (Campbell et al., 2007). The UN estimates that over 70per cent of Africa's agricultural drylands are degraded as a result of over-cultivation, mismanagement of irrigated croplands, overgrazing and deforestation (ISDR, 2004). Together with climate change these trends will affect the availability of and demand for water, food and agricultural land. These challenges will interact with external factors such as the health of international economy and the level of aid flows and internal factors such as the quality of governance to shape Africa's prospects" (Brown & Crawford, 2009, p.13).

The Centre for International Forestry Research (CIFOR) has argued: "Climate change, biodiversity and forest loss are issues inextricably interlinked and need to be addressed simultaneously. This is especially important with regard to climate change adaptation in Africa particularly with the emergence of contemporary global challenges such as the current food crisis. The same drivers of biodiversity loss in Africa are also largely responsible for increased vulnerability to climate change, most importantly drought, poverty, low institutional capacities that affect the adaptive capacity of communities, and inappropriate policies with preferences for short–term economic gains. The synergy between adaptation to climate change and biodiversity conservation requires a unifying strategy to enhance the sustainability of the forest resource pools on which poor communities directly depend for their livelihoods" (CIFOR, 2008, p.1).

Ecosystems Services - Energy & Earth Resources

Failure to protect forests contributes significant CO2 emissions

According to the African Partnership Forum (2007), "Africa has a legitimate need to increase its energy supply. It is in the wider global interest that Africa should be able to develop clean energy sources. There is enormous potential for this, including through the development of Africa's huge hydro-power potential" (APF, 2007, p.3). Their report also highlights that "deforestation is responsible for 20% of annual global CO2 emissions and constitutes the main source of GHG from many developing countries. According to the Food and Agriculture Organisation, around 130 thousand square kilometres - equivalent to four times the size of Belgium - of forest areas are lost each year. Brazil and Indonesia are the worst affected countries but six of the ten largest forest losses are in sub-Saharan Africa. Avoiding deforestation is currently not eligible either under the Clean Development Mechanism (CDM) or the multi-billion-Euro European carbon market. The past decade has also witnessed a sharp reduction in ODA [Overseas Development Aid] directed to the forestry sector that reached an all-time low in 2004 of only 0.3% of total ODA" (APF, 2007, p.11).

Ecosystems Services - Health & Wellbeing

Fragile ecosystems are stressed by climate and other changes impacting on human health and wellbeing.

The IPCC (2008) reports: "Ecosystems and their biodiversity contribute significantly to human well-being in Africa. … The rich biodiversity in Africa, which occurs principally outside formally conserved areas, is under threat from climate variability and change and other stresses... Africa's social and economic development is constrained by climate change, habitat loss, over-harvesting of selected species, the spread of alien species, and activities such as hunting and deforestation, which threaten to undermine the integrity of the continent's rich but fragile ecosystems (UNEP/GRID-Arendal, 2002)" (Bates *et al.*, 2008, p.81).

The report continues: "Approximately half of the sub-humid and semi-arid parts of the southern African region, for example, are at moderate to high risk of desertification. In West Africa, the long-term decline in rainfall from the 1970s to the 1990s has caused a 25–35 km shift southward in the Sahel, Sudan and Guinean ecological zones in the second half of the 20th century (Gonzalez, 2001). This has resulted in the loss of grassland and acacia, loss of flora/fauna, and shifting sand dunes in the Sahel; effects that are already being observed (ECF and Potsdam Institute, 2004)" (Bates *et al.*, 2008, p.81).

Ecosystems Services - Food & Agriculture

Agriculture which supports the livelihoods of many sectors of the population is particularly sensitive to climate change and already contends with other extreme natural resource challenges and constraints

The International Institute for Sustainable Development (IISD) investigated the impact of climate change on community resilience and food security. The report suggests: "Given Africa's high dependence on rain-fed agriculture, food production on the continent is intimately tied to rainfall. African farmers have developed many different ways to cope with existing climate variability… However such innovations may not be sufficient for future climate pressures. According to a study quoted in WBGU (2007) climate change will result in an increase in drylands and areas under water stress by 2080. As a result of climate change this arid and semi-arid area could expand by five to eight per cent, equalling a loss of productivity in another 50 to 90 million hectares of arable land. The IPCC notes that the causal contribution of climate to food insecurity in Africa is still not fully understood, particularly the role of other multiple stresses that enhance the impacts of droughts and floods and possible future climate change (IPCC, 2007). Nevertheless, they suggest that unabated climate change could, by 2080, mean an additional 30–170 million people suffer from malnutrition or under-nutrition, of whom three-quarters will live in sub-Saharan Africa. In countries that rely on agriculture in coastal zones such as Kenya (mangoes, cashew nuts and coconuts); Benin (coconuts and palm oil); Guinea (rice); and Nigeria, where coastal agricultural land accounts for about 75 per cent of the total arable land, rising sea levels will impact negatively on food supplies (ECOSOC, 2008)" (Brown & Crawford, 2009, p.16).

The IPCC (2008) reports: "The agricultural sector is a critical mainstay of local livelihoods and national GDP in some countries in Africa. Agriculture contributions to GDP vary across countries, but assessments suggest an average contribution of 21% (ranging from 10% to 70%) (Mendelsohn et al., 2000b). Even where the contribution of agriculture to GDP is low, the sector may still support the livelihoods of very large sections of the population, so that any reduction in output will have impacts on poverty and food security. This sector is particularly sensitive to climate, including periods of climate variability. In many parts of

Africa, farmers and pastoralists also have to contend with other extreme natural resource challenges and constraints such as poor soil fertility, pests, crop diseases and a lack of access to inputs and improved seeds. These challenges are usually aggravated by periods of prolonged droughts and floods (Mendelsohn et al., 2000a, b; Stige et al., 2006)" (Bates *et al.*, 2008, p.81).

Food & Agriculture – Community Resilience

Drops in food production could trigger regional food crises and further undermine the economic performance of weak and unstable states.

The UN Inter Agency Standing Committee Task Force on Climate Change (IASC, 2009) emphasized: "Climate change poses an unprecedented challenge to the aim of eradicating hunger and poverty. In order to meet the growing demand for food security and nutrition under increasingly difficult climatic conditions and in a situation of diminishing resources, the world must urgently move towards embracing a two-fold approach: first, we must invest in and support the development of more efficient, sustainable and resilient food production systems. Second, we must improve access to adequate food and nutrition by the most vulnerable and at risk populations and communities and enhance social protection systems and safety nets as part of the adaptation agenda. Protecting the most vulnerable also requires enhancing our capacities to manage weather-related disaster risks and accelerating community development. Only if we succeed in making significant advances on all fronts – increasing food availability, enhancing access to food, and strengthening resilience and development – we will reduce the risk of dramatic increases in the number of hungry people among the poorest countries in the most vulnerable regions of the world" (IASC, 2009, p.8).

"The German Advisory Council on Global Change (WBGU, 2007) argues that drops in food production could trigger regional food crises and further undermine the economic performance of weak and unstable states. Nyong and Fiki (2005) argue that conflict in sub-Saharan African countries has been associated with per capita annual declines in food production of over 12 per cent. If climate change leads to drops in agricultural production on a wide scale, prices of many agricultural commodities may rise, leaving individuals and countries financially overstretched. Food crises would be amplified in countries with existing inequality: if the majority of the population is hungry while a small minority is unaffected, outbreaks of violence are more likely than if the entire population is negatively affected .

However, whether a decline in food production leads to violent conflict will be determined by a complex range of other social, economic and demographic factors. In general the greater the part played by agriculture in employment and national food security as a whole, the more vulnerable a country is to the economic effects of a decline in agricultural production. Countries with higher incomes may be able to rely on food imports to offset domestic drops in production, but this option may not be open to poorer countries" (Brown & Crawford, 2009, p.16-18).

Food & Agriculture – Energy & Earth Resources

Relationships between climate change, fossil fuel use and potential scarcity, and nitrogen based fertilisers in African agriculture are complex.

Agriculture in Africa is extremely vulnerable to climate change. Africa is already struggling with poor soil fertility and low productivity. Some groups advocate more intensive use of nitrogen (Scientific American June 18, 2009) , but this could be problematic from various angles, not least of which is the potential future scarcity of fossil fuel based fertilizers "The food system is currently dependent on fossil fuels for powering irrigation pumps, petroleum based pesticides and herbicides, mechanization for both crop production and food processing, fertilizer production, maintenance of animal operations, crop storage and drying and for the transportation of farm inputs and outputs. Of these fossil fuel dependences, some are more easily overcome than others (Ruttan 1999). However, due to their current necessity, dependence on synthetic nitrogen fertilizer and the long distance transport of farm inputs and outputs are two outlying limiting factors that exemplify the vulnerability of the current food system and therefore require further analysis." (Smil 2000)

Food & Agriculture – Health & Wellbeing

Hunger and malnutrition are predicted to increase. Without urgent action it will not be possible to ensure the food security of a growing world population under a changing climate.

The International Food Policy Research Institute (IFPRI) investigated the impact of climate change on agriculture in Africa. The report concludes: “Agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines…Populations in the developing world, which are already vulnerable and food insecure, are likely to be the most seriously affected. The IFPRI emphasizes: “The negative effects of climate change on crop production are especially pronounced in Sub-Saharan Africa … [where] the rice, wheat, and maize yield declines with climate change are 15 percent, 34 percent, and 10 percent, respectively” (Nelson, *et al.*, 2009, p.4).

The UN Inter Agency Standing Committee (IASC) on climate change highlighted: “Climate change directly affects food security and nutrition. It undermines current efforts to protect the lives and livelihoods and end the suffering of the over 1 billion food insecure people and will increase the risk of hunger and malnutrition by an unprecedented scale within the next decades. Undernutrition is already the single largest contributor to the global burden of disease, killing 3.5 million people every year, almost all of them children in developing countries. Unless urgent action is taken, it will not be possible to ensure the food security of a growing world population under a changing climate.

“Recent modelling and analysis predicts additional price increases due to climate change for some of the most important agricultural crops – rice, wheat, maize, and soybeans. To the resulting increases in the number of people at risk of hunger, climate change is projected to add another 10 to 20 per cent by 2050. Calorie availability in 2050 is likely to have declined relative to 2000 levels throughout the developing world: 24 million additional malnourished children, 21 per cent more than today, are anticipated – almost half of them, 10 million, in sub-Saharan Africa” (IASC, 2009, p.4).

Water Availability – Food & Agriculture

Water stress will impact food security, with rain fed agriculture particularly vulnerable.

The African Partnership Forum warns: "Over 95% of Africa's agriculture is rain-fed. Agricultural production, including access to food, in many African countries and sub-regions is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020" (APF, 2007, p.9)

The IPCC (2008) special report on *Climate Change and Water* suggested: "Increased populations in Africa are expected to experience water stress before 2025…, mainly due to increased water demand. Climate change is expected to exacerbate this condition. In some assessments, the population at risk of increased water stress in Africa, for the full range of SRES scenarios, is projected to be 75–250 million and 350–600 million people by the 2020s and 2050s, respectively (Arnell, 2004). However, the impact of climate change on water resources across the continent is not uniform. An analysis of six climate models (Arnell, 2004) shows a *likely* increase in the number of people who could experience water stress by 2055 in northern and southern Africa …. In contrast, more people in eastern and western Africa will be *likely* to experience a reduction rather than an increase in water stress (Arnell, 2006a). … Groundwater is most commonly the primary source of drinking water in Africa, particularly in rural areas which rely on low-cost dug wells and boreholes. Its recharge is projected to decrease with decreased precipitation and runoff, resulting in increased water stress in those areas where groundwater supplements dry season water demands for agriculture and household use" (Bates *et al.*, 2008, p.81-82).

"Impacts of climate change on growing periods and on agricultural systems and possible livelihood implications have been examined (e.g., Thornton et al., 2006). A recent study based on three scenarios indicates that crop net revenues would be *likely* to fall by as much as 90% by 2100, with small-scale farms being the most affected. However, there is the possibility that adaptation could reduce these negative effects (Benhin, 2006). … Not all changes in climate and climate variability would, however, be negative for agriculture. The growing seasons in certain areas, such as around the Ethiopian highlands, may lengthen under climate change. A combination of increased temperatures and rainfall changes may lead to the extension of the growing season, for example in some of the highland areas (Thornton et al., 2006). As a result of a reduction in frost in the highland zones of Mt. Kenya and Mt. Kilimanjaro, for example, it may be possible to grow more temperate crops, e.g., apples, pears, barley, wheat, etc. (Parry et al., 2004). …

Fisheries are another important source of revenue, employment, and protein. In coastal regions that have major lagoons or lake systems, changes in freshwater flows, and more intrusion of saltwaters into the lagoons, would affect species that are the basis of inland fisheries or aquaculture (Cury and Shannon, 2004). … The impact of climate change on livestock in Africa has been examined (Seo and Mendelsohn, 2006). Decreased precipitation of 14% would be *likely* to reduce large farm livestock income by about 9% (−US$5 billion) due to a reduction in both the stock numbers and the net revenue per animal owned. …" (Bates *et al.*, 2008, p.83).

1.1.3 Adaptive Capacity

Mid Africa is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Mid-Africa					**LOW 11.92**
Sudan	0.20	0.17	0.17	0.50	
Somalia	0.20	0.17			
Ethiopia	0.40	0.17	0.50	0.25	
Eritrea	0.40	0.17	0.17	0.25	
Kenya	0.20	0.33	0.50	0.50	
Chad	0.20	0.17	0.17	0.25	
Congo	0.40	0.17	0.17	0.25	
Central African Republic	0.20	0.17	0.17	0.25	
Nigeria	0.40	0.17	0.33	0.50	
Cameroon	0.40	0.50	0.33	0.50	
Tanzania	0.40	0.50	0.50	0.50	
Uganda	0.40	0.33	0.50	0.50	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.2 Indian Subcontinent Direct Impact Pattern

The Indian Subcontinent includes India, Pakistan, Bangladesh, Nepal, Bhutan and Sri Lanka.

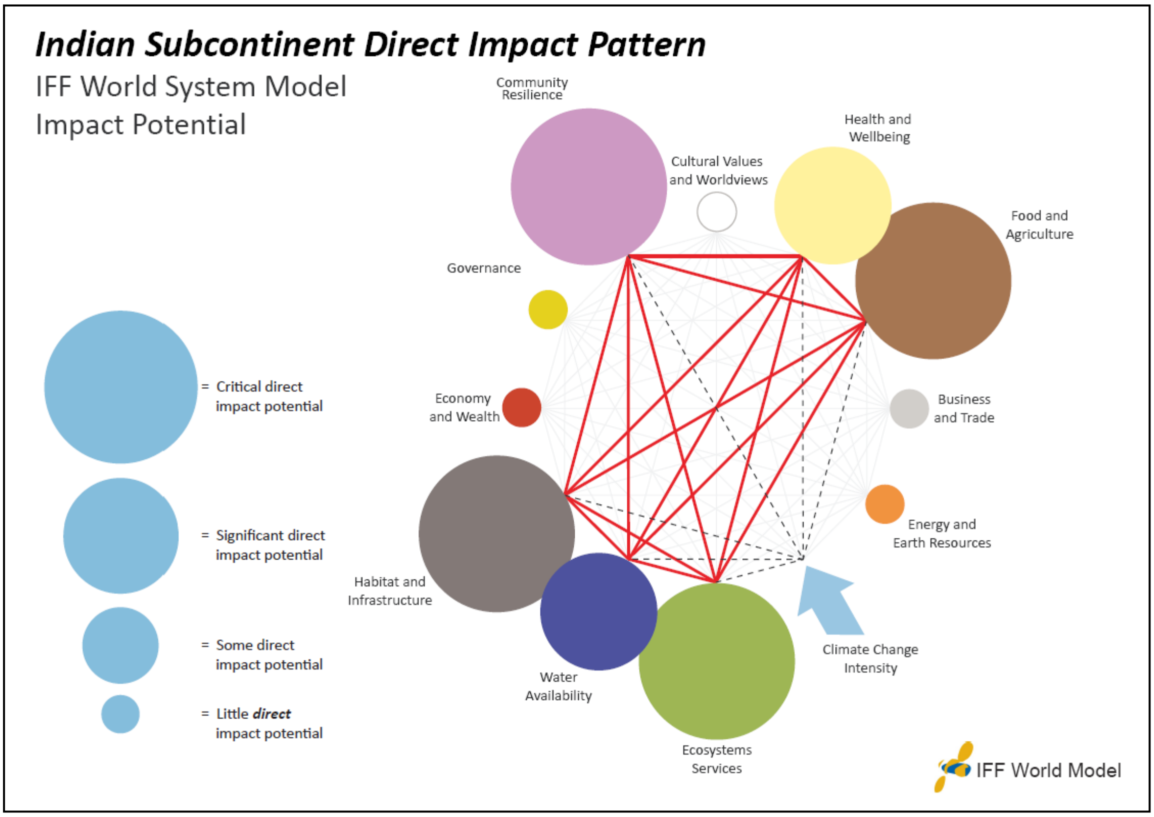


Figure 1.2.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects.

1.2.1 Overview

The Indian Subcontinent is a region of great contrasts in terms of vulnerability to climate change. In includes low lying river deltas and coastal regions, desert plains, tropical forest, mountainous regions and major river valleys. This a simple singular account of climate impact would be a massive simplification. However, viewed as a whole, the world system nodes reveal an overall pattern that makes this one of the most challenges regions in the world both in scale and in diversity of impact.

India and its neighbours are highly vulnerable to climate related events like floods, drought and cyclones. There are diverse publicly funded programmes to respond to and prevent climate risks, as well as, major rural development and anti-poverty programmes with the main intention of reducing the population's vulnerability to climate risk. For example, the Indian government's spending on these programmes exceeds the national defence budget and amounts to 2.63 percent of GDP, or 12 percent of the government's annual budget (Narain *et al.*, 2009).

A recent UNDP publication states that: "India's energy intensity shows a rapid decline and all modeling results show that it will continue to decline. This is the reason behind a GDP growth rate of 8% per annum being accomplished at no more than 3.7% increase in energy use" (Narain *et al.*, 2009, p.32). The report suggests that: "Floods and drought are …. projected to multiply as a consequence of climate change. This will lead to huge crop loss and leave large patches of arable land unfit for cultivation. To sum up it will threaten food security" (Narain *et al.*, 2009, p.40).

Dr. N. Chattopadhyay, the director the India Meteorological Department predicts a "decrease in yield of crops as temperature increases in different parts of India. For example at a 2°C increase in mean air temperature, rice yields could decrease by about 0.75 ton/hectare in the high yield areas and by about 0.06 ton/hectare in the low yield coastal regions." He points out that the "major impacts of climate change will be on rain fed crops (other than rice and wheat), which account for nearly 60% of cropland area. In India poorest farmers practice rain fed agriculture" (Chattopadhyay, 2008).

An Indian National Policy Brief on "Climate change and National Security (Pai, 2008) summarizes the main regional conflict potential that could be triggered by climate change related water scarcity, rising sea levels, and extreme weather events (see Table 2.2.1).

Conflict system/ Impact mechanism	Glacial recession	Rising sea levels	Extreme weather	Net assessment
Jammu & Kashmir	High	-	Medium	Risk of war, motivated in part by the quest for water resources
India-China border	High	-	Medium	Risk of natural disasters in India, worsening India-China relations
Bangladesh 'ethnic invasion'	High	High	High	Risk of mass migration into India
Pakistani separatism	High	Medium	Medium	Risk of existential crisis in Pakistan, and of ethnic conflict
Sri Lankan civil war	-	High	Medium	Risk of mass migration, and of ethnic conflict
Nepal civil war	High	-	High	Risk of natural disasters and mass migration into India due to social unrest

Table 1.2.1 Climate induces conflicts on the Indian Subcontinent (Pai 2008)

A recent report by the National Intelligence Council of the USA highlights that "Adaptive capacity in India varies by state, geographical region, and socioeconomic status. Studies point to influential factors such as water availability, food security, human and social capital, and the ability of government (state and national levels) to buffer its people during tough times. Where adaptive capacity is low, the potential is greater for impacts to result in displaced people; deaths and damage from heat, floods, and storms; and conflicts over natural resources and assets" (NIC, 2009, p.8).

Nearly two-thirds of the population of the region depend directly on climate-sensitive sectors such as agriculture, fisheries and forests. Climate change is likely to have implications on food production, water supply, biodiversity and livelihoods. As a result " India has a significant stake in scientific advancement as well as an international understanding to promote mitigation and adaptation. This requires improved scientific understanding, capacity building, networking and broad consultation processes" (Sathaye, *et al.* 2006, p.324).

Pakistan, with a predominantly arid climate with hot summers and cool or cold winters has wide extremes of temperature. Despite overall little rainfall, there is can be intense and cause flooding in some areas like the Indus valley. It is possible that “Enhanced CO_2 concentration in the atmosphere appeared to have a pronounced effect on the biomes’ area. Net primary productivity exhibited an increase in all biomes and scenarios. However, there is a possibility of forest dieback occurring and of time lag before the dominant plant types have enough time to adjust to changed climate and migrate to new sites. In the intervening period, they would be vulnerable to environmental and socio-economic disturbances (e.g. erosion, deforestation, and land-use changes). Thus, the overall impact of climate change on the forest ecosystems of Pakistan could be negative.” (Siddiqui, *et al*. 1999)

In Bangladesh between 30-70% of the country is normally flooded each year. Additionally, climate change poses significant risks. The huge sediment loads brought by three Himalayan rivers exacerbate the extent of flooding. Bangladesh’s very high population and population density increase such risks. “A subjective ranking of key climate change impacts and vulnerabilities for Bangladesh identifies water and coastal resources as being of the highest priority in terms of certainty, urgency, and severity of impact, as well as the importance of the resources being affected.” (Agrawala, *et al*. 2003)

In the Himalayan region, including Nepal and Bhutan, there is a contested view that the glaciers are receding. Satellite images lime that in Figure xx can be interpreted in different ways. The implications for down-river water supply dependent on glaciers are also contested. More important effects may be to do with the gradual change of tree lines and the dangers of glacier lake ‘outbursts’.

A recent report from UNEP summarises the current position. “The 2007 IPCC statement of glacial area is erroneous if one interprets them to apply to the Himalayas, and there appears to be no scientific foundation for the IPCC’s prediction for the year 2035. Does that mean that one should not pay attention to the IPCC’s statement? Indeed, no! There is ample evidence that glaciers are melting throughout the world and that global warming is the cause. The IPCC is correct in that regard.” (UNEP 2009)

1.2.2 Systemic Relationships – Principal Paired Interactions (15)

Water Availability – Food & Agriculture:

Food production will increasingly be dependent on effective water management,

According to IPCC predictions, gross per capita water availability in India will decline from 1820 m3/yr in 2001 to 1140 m3/yr in 2050 (IPCC, 2007, p.481). While glacier melt may yield more runoff in the short term but less in the medium and long term. "More severe storms (especially cyclones) will cause more damage to infrastructure and livelihoods and exacerbate salt water intrusion in storm surges. Changes in the timing and amount of monsoon rains will make the production of food and other agricultural products more uncertain, so that, even in good weather years, farmers will be more likely to make decisions leading to lower-productivity" (NIC, 2009, p8).

A recent report by the Lancet Commission on 'Managing the Health Effects of Climate Change highlights: "Water management will be crucial to future food security. Co-management of water for agriculture and ecosystems is a precondition for ecological sustainability, requiring ways to value water socially, economically, and ecologically" (Costello *et al.*, 2009, p.1714).

"Drought has two typical first-order impacts on Indian cities: drinking water shortages and increases in food and biomass fuel prices. It also has a number of important second-order impacts: depressed demand for urban-produced secondary goods and services because of depressed agricultural demand; and increasing seasonal and distress migration from rural areas. Continuing severe climate change-induced drought that makes subsistence agriculture uneconomical in large parts of semi-arid central, western and southern India could catalyze a sharp increase in migration." (Revi, 2008, p. 213).

Food & Agriculture – Community Resilience

A significant sector of the community are undernourished and this may trigger serious unrest.

The UNDP reports: "Despite fast economic growth and piling food stocks in the government godowns, India is home to the largest number of hungry and deprived people in the world - to be precise 360 million undernourished and 300 million poor people. Sustaining supply of food itself is emerging as a critical issue. Growth in food grain production is slow, rather decreasing over the last few decades" (Narain *et al.*, 2009, p.38). Indian wheat yields could decrease by 5-10% per 1°C rise in Temperature (Chattopadhyay, 2008).

The US National Intelligence Council predicts an exacerbation of inequality and suggests: "The welfare of those who are affected by climate change and who have limited means to adapt may act as a force that can change governments, strain public budgets, and foster unrest. About one-third of Indians are extremely poor, and 60 percent depend upon agriculture for their livelihoods" (NIC, 2009 p.8).

The Food and Agriculture Organization (FAO) points out that "global food production and global food security are not directly linked. Although there are 830 million people worldwide who are undernourished, there is enough food produced to supply the calorie needs of a growing global population. In this respect, food security concerns are mostly related to local, not global, production, as well as to a number of critical factors not linked to climate change. However, there is recent evidence that the global food production system is at an unprecedented level of risk from supply shocks, particularly with respect to cereals. This trend could be amplified by climate change, as trade is expected to increase as a result of shift in production patterns. Failures in rain fed production are not necessarily immediately buffered by irrigated production of food staples. The impact of these anticipated hydrological changes on food production will be felt primarily in terms of supply stability. Although food availability, access and utilization are less directly linked to water, income from irrigated cash crops related to water availability and safe utilization is intimately related to household hygiene and food preparation – which depend upon water supply" (FAO, 2008, p.11).

Food & Agriculture – Habitat & Infrastructure

Food production will increasingly depend on improved infrastructure.

Significant improvements of irrigation and agricultural infrastructure will be necessary in order to respond to the effects that climate change is predicted to have on food production and food security in India. Regulating the unrestrained exploitation of groundwater and aggressive pursuit of water conservation has been highlighted as a necessary Indian national priority by a recent UNDP report. It suggests that “a drip irrigation and water sprinkler approach, mulching and bed plantation, construction of tanks and check-dams should be promoted for water harvesting and conservation” and recommends an agroforestry based “programme for massive tree plantation and control on open grazing” to “help in the regeneration of forests and slow down the process of desertification” (Narain *et al.*, 2009, p.43)

Food & Agriculture – Health & Wellbeing

Climate change is likely to exacerbate malnutrition.

High-input, high-output agriculture will be negatively affected by climate change even as demands for food and other agricultural products rise because of an increasing population and expectations for an improved standard of living. “Millions of subsistence and smallholder farmers will experience hardship and hunger through being less able to predict climate conditions” (NIC, 2009 p.7).

“Malnutrition causes millions of deaths each year, from both a lack of sufficient nutrients to sustain life and a resulting vulnerability to infectious diseases such as malaria, diarrhea, and respiratory illnesses. In India, almost half of the children under age five and more than one-third of the adults are undernourished. In Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, and Orissa, more than two out of five women are undernourished. Anemia is another major nutritional health problem in India, especially among women and children. Among children between the ages of 6 and 59 months, the great majority (70%) are anemic. More than half of the women (55%) and one-fourth of the men are anemic in India. Anemia can result in maternal mortality, weakness, diminished physical and mental capacity, increased morbidity from infectious diseases, perinatal mortality, premature delivery, low birth weight, and (in children) impaired cognitive performance, motor development, and scholastic achievement” (Majar & Gur, 2009, p.14).

Health & Wellbeing – Community Resilience

Community health is likely to be stressed by climate change.

The US National Intelligence Council report on climate change impacts on India highlights: "The relationship between climate change and health outcomes is complex. If temperature rises in warmer parts of the country, heat waves may become more intense and longer lasting, resulting in increased incidence of heat stroke and related diseases. Warmer climate also worsens air pollution and increases the potency of airborne diseases." … "As climate change worsens the public health challenge, India will require renewed vigour in implementing major policy reforms in the health sector. India needs to accelerate medical education at all levels to ensure access to trained medical personnel. It also needs to improve access to medicine and implement public health measures to combat the spread of infectious diseases by ensuring proper drainage and supply of clean drinking water" (NIC, 2009, p.10). "While a general state failure in India is unlikely, India may accumulate a number of failed constituent states. The states most at risk are the densely-populated, underdeveloped, and politically unstable states of India's northeastern agricultural heartland" (NIC, 2009, p.3).

"Nearly 700 million of India's over one billion population living in rural areas directly depends on climate-sensitive sectors (agriculture, forests, and fisheries) and natural resources (such as water, biodiversity, mangroves, coastal zones, grasslands) for their subsistence and livelihoods. Heat waves, floods (land and coastal), and draughts occur commonly. Malaria, malnutrition, and diarrhea are major public health problems. Any further increase, as projected in weather-related disasters and related health effects, may cripple the already inadequate public health infrastructure in the country" (Majra & Gur, 2009, p11).

The UNDP highlights that the impact of climate change in India will hit women particularly hard. As climate change begins to exacerbate existing shortages of water, "women, largely responsible for water collection in their communities, are more sensitive to the changes in seasons and climatic conditions that affect water quantity and accessibility. This brings in more burdens for women." In addition, "climate change induced sea level rise affects the fishermen and fisherwomen not only in terms of fish-catch but also in term of water scarcity. Sea ingression turns local water bodies saline thus pushing women to search more for fresh water. Moreover, women face threat to their livelihoods as fishing may also be affected by sea level rise and intrusion of saline water into freshwater systems. Besides, large-scale migration from inundated areas is expected. Migration again leads to extra hardships for women. Due to extreme events and disasters, men migrate more often than women do. In dry land areas, the female-headed households left behind are often the poorest" (Narain *et al.*, 2009, p.49).

Health & Wellbeing – Habitat & Infrastructure

Public health in cities will come under increasing strain.

"India's cities will face increased challenges from climate change, although the direct effects on India's cities and towns may be less disruptive than those on rural areas. Overcrowding and poor air quality are already serious problems in India's cities, and these challenges will be worsened by climate change. Indian urban infrastructure is poorly developed and over-stressed in most cities. Floods and heavy rains are likely to collapse or sweep away shanties and makeshift urban dwellings where many of the urban poor live. Water scarcity due to glacial melting and shifts in rain patterns will reduce the supply of drinking water at the same time that migration into the cities increases the demand. Most significantly, the severe rural challenges will most likely be exported to the cities. A mass migration of displaced rural population into the cities could overwhelm critical urban systems such as health, transportation, housing, energy, and water. An influx of environmental refugees from the countryside also raises a serious challenge in terms of employment. Even if economic growth continues at a high rate, urban economies will have a difficult time accommodating large numbers of new workers, particularly if they arrive in surges due to climate change disruptions in rural areas. It is also unclear to what degree rural migrants will be absorbed into India's urban society. Conflicts between established urban populations and rural migrants could become a serious problem, particularly if employment is at issue" (NIC 2009, p.12).

Health & Wellbeing – Water Availability

There are increasing risks from water-borne diseases as water quality diminishes.

The principal regional challenges generated by climate change in South Asia will most likely be cross-border migration and water scarcity. The lack of effective regional institutions, longstanding political disputes, and India's preference for bilateral regional diplomacy will inhibit regional cooperation in confronting these issues. The region has a mixed record on resolving water disputes. As river flows decline, water disputes will intensify, leading to increased tension with Pakistan, Bangladesh, and China. Climate change may cause humanitarian crises or state failures in one or more of India's neighbors, including its nuclear-armed rival Pakistan" (NIC, 2009, p.3). "Floods and droughts may lead to water contamination and worsen unsanitary conditions, increasing incidence of diseases such as malaria or dysentery (NIC, 2009, p.10).

The main health effects of lack of access to clean water and sanitation are diarrhoeal and other diseases caused by biological or chemical contaminants. Poor drainage in human settlements increases exposure to contaminated water and provides habitat for mosquitoes, leading to increased incidence of water-borne and vector-borne diseases. In Delhi (India), for example, 15 million people face serious water shortages, with water being transported up to 300 km. The projected population of this municipality is more than 30 million by 2025 (Costello *et al.*, 2009, p.1705).

Huge gains have been made in meeting human needs through water resources development – the construction of dams and irrigation channels, the construction of river embankments to improve navigation, drainage of wetlands for flood control, and the establishment of inter-basin connections and water transfers. Between 1990 and 2000, 1.2 billion people have been supplied with both improved water and improved sanitation (WHO and UNICEF 2006). This is a massive achievement, although population growth has diminished its impact, but reaching the 'second billion' is proving a harder and slower task (Mayers *et al.*, 2009, p.17).

Water Availability – Community Resilience

River flow could be reduced putting stress on many dependent communities.

The flows of the Indus, Ganges, and Brahmaputra could be dramatically reduced and many other rivers could become seasonal. The Gangetic plain, home to nearly half of India's population, may face a decrease in the water table to levels close to those in arid Gujarat. Such a development would threaten the sustainability of the agrarian economy across the northern Indian plain. In the northwestern states of Punjab, Haryana, and western Uttar Pradesh, depleting water tables, increasing soil salinity, and micronutrient deficiencies have already made wheat and rice crops that use intensive irrigation and nitrogenous fertilizer unsustainable. In addition, India will face more frequent and severe droughts long before the transition to sustained water scarcity" (NIC 2009, p11).

Rising temperatures are also likely to result in earlier snow thawing and increased rain relative to snow precipitation, bringing peak river flows earlier in the year, potentially exacerbating dry season water scarcity. In August, 2008, when the Kosi river changed course, the Bihar flood (India) was probably partly caused by increased river flow from glacial melting. The flood affected 4·4 million people, destroyed 290 000 hectares of land, and cost an estimated US$6·5 billion. Reduced river flows and increased water temperature will lead to declining water quality as the dilution of contaminants is reduced, less oxygen is dissolved in water, and microbiological activity increases. These effects could lead to major health problems for vulnerable people, especially during drought, and might increase the risk of conflict and major population migration (Costello *et al.*, 2009, p.1705).

Community Resilience – Habitat & Infrastructure

Flooding in particular can destroy the whole infrastructure upon which communities depend.

Widespread climate stresses, such as major droughts or floods, could disrupt the village structure across entire regions of the country, putting tens of millions at risk. Flooding generated both by increases in runoff from melting Himalayan glaciers and more frequent severe storms will pose a major threat to India's heavily populated river plains. In low-lying coastal areas, sea level rise and storm surges will create similar challenges, with the added dimension of saltwater intrusion rendering soil infertile (NIC 2009, p.11).

A recent article in the *Indian Journal of Occupational and Environmental Medicine* summarizes the potential effects on health due to sea level rise: i) death and injury due to flooding; ii) reduced availability of fresh water due to saltwater intrusion; iii) contamination of water supply through pollutants from submerged waste dumps; iv) change in the distribution of disease-spreading insects; v) health effect on the nutrition due to a loss in agriculture land and changes in fish catch; and vi) health impacts associated with population displacement (Majra & Gur, 2009, p.13).

The same study emphasizes: "India has a 7500 km long densely populated coast line, which is vulnerable to coastal floods, hurricanes, cyclones, and tsunami. Any increase in frequency and severity of these extreme climate events or change in coastline as projected is likely to have serious effects and can cause population displacement. These displaced people are likely to face diverse health consequences - traumatic, infectious, nutritional, psychological, and other - that occur in demoralized and displaced populations in the wake of climate-induced economic dislocation, environmental decline, and conflict situations (Majra & Gur, 2009, p.14).

By 2025, an estimated 70 Indian cities are expected to have a population exceeding one million. Three mega-urban regions: Mumbai–Pune (50 million), the national capital region of Delhi (more than 30 million) and Kolkata (20 million) will be among the largest urban concentrations in the world. By mid-century, India could have both the largest urban and rural populations of the time. This will have an important bearing on global climate vulnerability and the potential for mitigation and adaptation (Revi, 2008, p.208).

Habitat & Infrastructure – Water Availability

Settlements have increasingly drained the aquifers beyond their replenishment rate,

Over the course of the last three decades groundwater as opposed to surface and sub-soil water from shallow wells has become the main source of irrigation. Surface irrigation systems already created are lying wasted because canals or other systems are hardly maintained. Because of inefficiency of large water irrigation systems, people have been forced to exploit groundwater. The bulk of

Indian agriculture not only remains rain-fed but also depends on groundwater, not surface water. This is worrisome in the current context of increasingly variable rainfall. Due to excessive withdrawal of groundwater, groundwater use exceeds the rate of groundwater recharge. As a result Government has classified nearly 30 percent of the development blocks in the country as semi-critical, critical or overexploited (mostly in 'green revolution' areas) in term of groundwater depletion (Narain *et al.*, 2009, p.39).

As agriculture is the largest user of water in India (using more than 80 percent of usable freshwater) and a large proportion of the population derives its livelihood directly or indirectly from it, we need to build efficient irrigation systems and adopt water conservation strategies. This we need to do more in semi- arid regions through conjunctive use of surface and groundwater in India. The main thrust of the programmes to combat the impact of climate change in the rain-fed areas should be on activities relating to rainwater harvesting, soil conservation, land shaping, pasture development, vegetative bonding and water resources conservation on the basis of the entire compact micro-watershed which would include both cultivated and uncultivated lands (Narain *et al.*, 2009, p.41).

Ecosystems Services - Food & Agriculture

Key ecological conditions for agricultural production are likely to come under greater strain.

Ecosystem services are defined as "the benefits provided by ecosystems to humans". Many key ecosystem services provided by biodiversity, such as nutrient cycling, pest regulation and pollination, sustain agricultural productivity. Promoting the healthy functioning of ecosystems ensures the resilience of agriculture as it intensifies to meet the stress of growing demands for food production. Climate change and other stresses have the potential to make major impacts on key functions, such as pollination and pest regulation services. Learning to strengthen the ecosystem linkages that promote resilience and to mitigate the forces that impede the ability of agro-ecosystems to deliver goods and services remains an important challenge (FAO, 2009). Ground and rain water availability, protection from erosion, and soil fertility are all key ecosystems services which have to be improved and maintained in order to safeguard India's agricultural production and food security in the face of climate change impacts.

Water Availability - Ecosystems Services

Increasing urbanisation is adding to the climate stress on ecosystems.

Freshwater ecosystem services – the benefits obtained by people from freshwater ecosystems like rivers, swamps, floodplains and groundwater systems – are central to human well-being. But ecosystems are in trouble and the Millennium Ecosystem Assessment, the Comprehensive Assessment of Water Management in Agriculture, and the Intergovernmental Panel on Climate Change have each shown that freshwater ecosystem services are particularly vulnerable. Water problems for poor people are exacerbated by the abuse of ecosystem services and global climate change looks certain to increase the stresses and variability they face (Mayers *et al.*, 2009, p.iii).

Drivers of change affecting water ecosystems include climate change, economic growth, population growth, urbanisation, energy use, land use change or trading systems. Drivers can work independently or in combination to alter the state of water ecosystems. Combined drivers might occur when economic growth leads to higher incomes, increased energy demands, urbanisation and changes in dietary requirements, such as from low water use (e.g. cereals) to high water use (e.g. meat) (Mayers *et al.*, 2009, p.12).

The state of water ecosystems will have water management implications in terms of availability of water for allocation to domestic, industrial, agricultural or energy uses. The timing, allocation and access to water have implications for development pathways across economic, energy, food systems and poverty sectors. In turn, these sectors may have direct impacts on water ecosystems in terms of abstraction, pollution or system modification (e.g. draining wetlands). Society has an array of responses at its disposal to alter drivers of change, subject to its political, economic, institutional and environmental situation. Responses available to global, national or local actors and institutions to mitigate, adapt or cope with climate-related changes to water ecosystems include improvements in governance, rights-based approaches, technological innovations, investment allocations, individual or collective decision-making, policy shifts or economic instruments, such as water pricing (Mayers *et al.*, 2009, p.13).

Ecosystems Services - Community Resilience

The condition of ecosystems is strongly bound up with the quality of water and atmosphere upon which communities depend.

Water as a basic human right, and water left in stream to sustain environmental flows, are both necessary guiding principles yet characterise the tension at the heart of this subject. The adaptive capacity and resilience needed in the face of climate change and other further stressors to livelihoods, and the ever-increasing demand for water for food, fuel and forests, must be better understood and tackled. Key knowledge gaps can be filled by well-targeted research on how to secure regulatory and supporting services of ecosystems while doing most for poverty reduction (Mayers *et al.*, 2009, p.iii).

Water availability introduces the temporal and spatial dimensions of water poverty. For example, a person can remain permanently below a stylised poverty line and be ‘chronically poor’. Alternatively, a person can be ‘transitorily poor’ and step out of poverty following a good harvest or reduced disease burden but fall back into poverty the following year. The transitorily poor may cause additional development policy concern to the enduring problems of ‘chronic poverty’ as this group may have increased exposure to climate change (Mayers *et al.*, 2009, p.12).

Rabganath (2008) describes an example in India. Before an Indo-German Watershed Development Program was launched in 1996, Darewadi village in the Indian state of Maharashtra relied on tanker trucks of water during periods of water scarcity. Technical training and leadership development enabled the village to adopt new ways to mitigate the effects of drought. The villagers chose efforts that included tree planting, grazing bans, and soil and water conservation measures. After five years, the village’s restoration efforts were self-sustaining. Once-bare hillsides surrounding the village are now replanted with trees. The area supports nine to ten months of agricultural employment a year (compared with three to four months before the restoration project); extensive new irrigation supports more crop varieties; and the value of cultivated land has increased four-fold. The village has not needed trucked-in water in recent drought years. The Indo-German Watershed Development Program has funded more than 145 similar projects in 24 districts, successfully mobilizing villagers to restore their watersheds (Ranganathan, 2008, p.6).

Ecosystems Services - Habitat & Infrastructure

Destruction of some ecosystems is rendering habitats vulnerable to increasingly intense weather events.

Projections of water demand in India indicate, according to the Ministry of Water Resources, that the nation's water requirements can be met until the year 2050 if integrated water management plans are properly implemented. Beyond 2050, demand will exceed supply even with such implemented plans. But two crucial factors have been absent in painting this relatively rosy picture: the impact of new interventions such as watershed management programmes, and the impact of climate change (Mayers *et al.*, 2009, p.31).

Climate impact assessments using BIOME-3 model and climate projections for the year 2085 show 77% and 68% of the forested grids in India are likely to experience shift in forest types under IPCC's A2 and B2 scenario, respectively. Indications show a shift towards wetter forest types in the northeastern region and drier forest types in the north- western region in the absence of human influence. Increasing atmospheric CO2 concentration and climate warming could also result in a doubling of net primary productivity under the A2 scenario and nearly 70% increase under the B2 scenario (Sathaye, *et al.* 2006, p.319).

Simulation models show an increase in frequencies of tropical cyclones in the Bay of Bengal; particularly intense events are projected during the post-monsoon period. Sea level rise is projected to displace populations in coastal zones, increase flooding in low-lying coastal areas, loss of crop yields from inundation and salinization (Sathaye, *et al.* 2006, p.319). "The ability to adapt to climate change is intertwined with sustainable development and poverty reduction in both a positive and negative sense. In the positive sense, enhancement of adaptive capacity entails a variety of similar actions to sustainable development and poverty reduction (e.g. improved access to resources and improved infrastructure) (Sathaye, *et al.* 2006, p.322).

Ecosystems Services - Health & Wellbeing

Changes in ecosystem health have a direct effect on human health.

The capacity of human communities to form stable societies, to generate formal economies, and to plan for the future is underpinned by environmental stability (predictable fluctuations, such as seasonal changes, are a form of stability), reliable supplies of natural materials, and the adequate functioning of the cleansing and recycling processes of nature. Thus all people and their societies are fundamentally dependent on ecosystem services, although in some contexts the source or importance of particular services is more apparent than in others. In general, the visibility of these linkages tends to vary inversely with the degree of modernization and urbanization" (McMichael *et al.*, 2005, p.57).

Ecosystem transformation may affect the spread of diseases with important impacts on human health. In the village of Koyyur in India, deforestation caused canopy gaps in the rainforest. This initiated growth of grasses and other fodder species, attracting cattle from the villages. These cattle carry ticks that transmit a monkey fever (Kyasanur Forest Disease), resulting in an increase in the disease in humans (McMichael *et al.*, 2005, p.54).

1.2.3 Adaptive Capacity

The Indian Subcontinent is rated as follows:

	Failed States Index	**Political Stability**	**Government Effectiveness**	**Human Development Index**	**Adaptive Capacity Rating (x 10)**
Indian Sub-continent					**LOW 16.00**
India	0.40	0.33	0.67	0.50	
Pakistan	0.20	0.17	0.50	0.50	
Sri Lanka	0.40	0.17	0.50	0.50	
Bangladesh	0.40	0.33	0.33	0.50	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.3 Middle East Direct Impact Pattern

The Middle East includes Saudi Arabia, Yemen, Oman, UAE, Iraq, Syria, Jordan, Iran, Qatar and Kuwait.

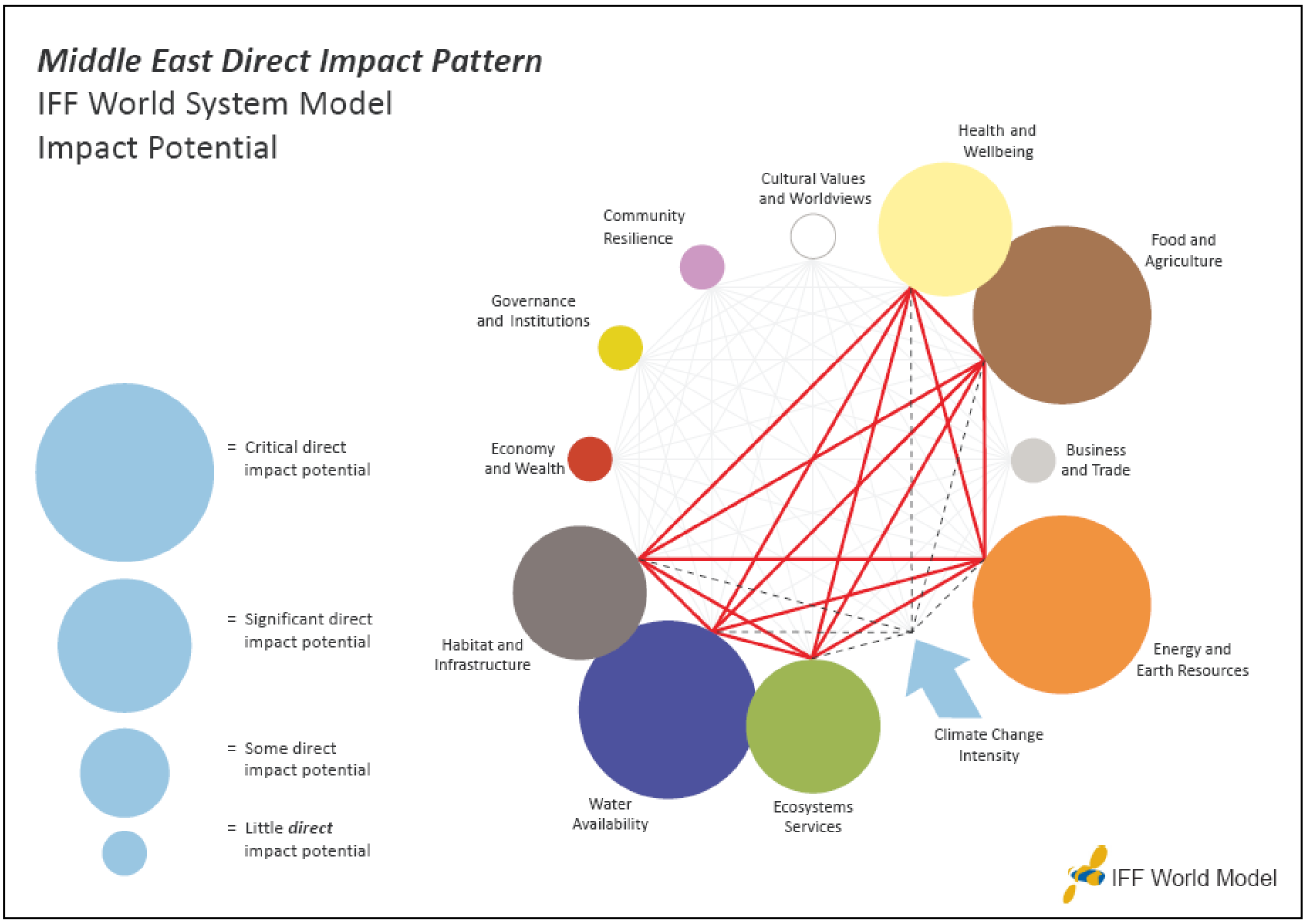


Figure 1.3.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.3.1 Overview

A 2007 report by Friends of the Earth, Middle East, (FoEME) highlighted the role of climate change as a risk multiplier in the region which could affect regional and global security. The report states: “With the Middle East being the world’s most water-stressed region, climate change, which is projected to cause sea level rise, more extreme weather events, such as droughts and floods, and less precipitation, will contribute to even greater water stress in the region. Governments, policy makers and the general public, through the media, must realize that the climate crisis is therefore a new and real threat to the Middle East with severe environmental, economic, political and security implications. When people lack adequate safe, clean drinking water, and water resources are shared across political boundaries, the risk of evoking political conflict increases. For a region that already possesses some of the greatest political tensions in the world, the climate crisis and its potential physical and socioeconomic impacts are likely to exacerbate this cross-border political instability” (FoEME, 2007, p.4).

The FoEME report emphasizes the climate crisis is already being witnessed today in the Middle East. And the situation is projected to become more severe. For the Eastern Mediterranean, for the 2080 timeframe, projected mean temperatures might increase between 3 and 5 degrees C. Additional projected climate change impacts for the region are as follows: i) A 20 percent decline in precipitation by the end of the century; ii) reduced stream flow and groundwater recharge might lead to a reduction in water supply by 10 percent or greater by 2050; iii) an increase of evapotranspiration by nearly 10 percent; iv) greater seasonal temperature variability; v) more severe weather events, such as droughts and floods; vi) significant sea level rise: the Mediterranean is predicted to rise between 30 cm and 1 meter by the end of the century – causing flooding to coastal areas along the Nile Delta; vii) Mediterranean biomes are expected to shift 300-500 km northward, if a 1.5 degree C warming were to occur, which could mean that Mediterranean ecosystems in Israel, the PA and Jordan would become more desert-like; and viii) an increase in vector-borne diseases and pests, mortality. Because of the effects climate change is having – and is predicted to have – on water resources, particularly in areas that already are arid or semi-arid, such as the Middle East, “climate change is transforming the nature of global water insecurity” (FoEME, 2007, p.13).

A recent report by the International Institute for Sustainable Development (Brown & Crawford, 2009) on “climate change and the risk of violence in the Middle East” identifies that “climate change change may present a real threat to security. The Levant already struggles with scarce water, food insecurity and erratic economic growth, each of which could be exacerbated by climate change. This report argues that climate change present a security threat in six distinct ways:

THREAT 1- Climate change may increase competition for scarce water resources, complicating peace agreements.

THREAT 2 – Climate change may intensify food insecurity, thereby raising the stakes for the return or retention of occupied land:

THREAT 3 – Climate change may hinder economic growth, thereby worsening poverty and social instability.

THREAT 4 – Climate change may lead to destabilizing forced migration and increased tensions over existing refugee populations:

THREAT 5 – Perceptions of resources shrinking as a result of climate change could increase the militarization of strategic natural resources.

THREAT 6 – Inaction on climate change may lead to growing resentment and distrust of the West (and Israel) by Arab nations.” (Brown & Crawford, 2009, p.2-3).

Note: The IPCC reports tend to include the Middle East within the geographically vast region of “Asia”, stretching from Northern Russia and the Middle East, all the way to SE Asia. This results in remarkably little detailed information on the region of the Middle East being highlighted in IPCC reports (see for example: IPCC, 2007).

1.3.2 Systemic Relationships – Principal Paired Interactions (15)

Health & Wellbeing – Habitat & Infrastructure

Unregulated urbanization may be accelerated by climate change leaving areas vulnerable to natural disasters and adding to urban poverty and social breakdown.

Shifting rainfall patterns, spreading desertification and falling agricultural productivity are likely to undermine rural livelihoods, worsen job prospects in rural areas and accelerate migration to urban areas. This could strain services in cities and lead to increased resentment of existing refugee populations. Although a relatively high proportion of the region's population already lives in urban areas, many cities in the region growing rapidly. The current population of Amman, for instance, is over 2.5 million, but the Mayor of Amman, Omar Al Maani, expects the population to hit 6.4 million by 2025. Higher rates of urbanization may, of course, help to offset some problems such as providing health and education services, but if unplanned and unregulated, such urbanization may leave areas more prone to natural disasters such as landslides and add to urban poverty, the fragmentation of urban areas, and an increased risk of social breakdown, crime and extremism. The 2007/8 drought caused significant hardship in rural areas of Syria. In the northeast of the country a reported 160 villages have been entirely abandoned and the inhabitants have had to move to urban areas. In addition, there may be pressure from migrants escaping the impacts of climate change elsewhere. It is estimated, for example, that between two and four million people could be displaced from the Nile delta as a result of a sea level rise of just 50 centimeters (Brown & Crawford, 2009, p.26).

Health & Wellbeing – Energy & Earth Resources

Resource constraints aggravate conflict between Israel and Palestine and impact upon health in multiple ways.

The International Institute for Sustainable Development (IISD) has highlighted the important relationship between the border conflicts between Israel and the Palestinian territories and the relative water and energy scarcity in that region of the Middle East.

The IISD report also highlights that "there are tremendous opportunity costs associated with high levels of military spending. Israel spends nearly 10 per cent of its GDP on the military each year, the highest rate among developed countries, and maintains a standing army of 168,000 soldiers. Syria's army is nearly double that size, at 308,000 soldiers. In each of the countries … military expenditures exceed those for health and education, and armed forces personnel make up more than five per cent of the total labour force. This represents a massive diversion of resources, effort and energy, a portion of which—in a context of a wider peace settlement—could be used otherwise (including adaptation projects)" (Brown & Crawford, 2009, p.15).

Energy & Earth Resources – Water Availability

Rainfall is likely to decline overall, while acquiring and distributing water is energy intensive, either through pumping ground water from diminishing aquifers or "manufacturing water" through desalination.

"Because of the region's diverse topography (ranging from the snow-capped mountains of Lebanon to the world's lowest point on the shores of the Dead Sea), the climate is not uniform: differing vegetative cover and extremes in altitude create a number of distinct microclimates in this relatively small area. The variations are stark: for example, 43 per cent more rain falls in Beirut in January than falls in Damascus in an average year. By the middle of the century, the region is expected to get hotter across all seasons: models predict an increase of between 2.5 to 3.7°C in summer, and 2.0 to 3.1°C in winter (see Map 2). Higher temperatures will change where rain falls, how much of it falls and how often it falls. It will also result in a global increase in sea levels, which are expected to rise between 0.1m and 0.3m by 2050. The region will get drier, with significant rainfall declines in the wet season outweighing slight increases during the drier summer months. Meanwhile, the distribution of rains will change (moving to the north). The weather is also likely to become more unpredictable, with the region experiencing an increase in extreme rainfall events" (Brown & Crawford, 2009, p.7).

Acquiring and distributing water is energy intensive: in the West Bank town of Nablus, an estimated 80 per cent of the cost of water is associated with pumping water from an aquifer 700–900 metres underground. Wealthy and oil-rich countries can—to some degree—defer their water shortages with desalination ('manufacturing' water) or importing food (buying 'virtual' water). These options are less available in much of the Levant. They are very expensive and can swap a dependence on transboundary water for a dependence on transboundary energy supplies—unpalatable options for the regions' strategists" (Brown & Crawford, 2009, p.13).

Water Availability – Habitat & Infrastructure

Sea level will displace populations and salinate crucial aquifers.

"Scenarios conducted by the United Nations Environment Programme (UNEP) and other organizations indicate that a 0.5 meter (approximately 19 inches) rise in sea level, for example, could displace nearly 2-4 million Egyptians by 2050. The drinking water of 1.5 million Palestinians in Gaza would be further contaminated by rising sea levels leading to sea water intrusion of their only water source, the Coastal Aquifer" (FoEME, 2007, p.4)

Habitat & Infrastructure – Energy & Earth Resources

Energy Infrastructure could be at risk from sea level rises and extreme weather.

The region is almost entirely dependent on oil and natural gas for its energy needs, and some countries derive substantial economic benefits from these industries. Sea level rises and possible shifts in the reach of tropical cyclones (or other extreme weather events) could potentially put key export and refinery infrastructures at risk (Met Office, 2009)

Health & Wellbeing – Water Availability

Water stress is likely to become acute for some populations, exacerbating social and political tensions.

"Climate change is likely to act as a "threat multiplier" – exacerbating water scarcity and tensions over water within and between nations linked by hydrological resources, geography, and shared political boundaries. Poor and vulnerable populations, which exist in significant numbers throughout the region, will likely face the greatest risk. Water shortages and rising sea levels could lead to mass migration in the Region" (FoEME, 2007, p.4). "However, dealing with climate change and recognizing the looming crisis provides opportunities for local, cross-border and international cooperation to ameliorate the problems that are already occurring and that are projected to intensify. Improving local demand- and supply-side water and energy management policies is essential and will only become more critical as the needs increase due to climate change" (FoEME, 2007, p.4-5).

Water Availability - Ecosystems Services

Water quality is already compromised. Climate change and increasing scarcity will further compromise water related ecosystem services.

"The Coastal Aquifer, which follows the coastal plain of Israel and Gaza, is also shared, but is the only source of drinking water for the 1.5 million people of Gaza .... Water quality in the Coastal Aquifer is already abysmal; well samples in Gaza indicate that intensive agriculture and inadequate waste management have contaminated the groundwater supply with levels of chlorides, nitrates, pesticides, bacteria and raw sewage far above those considered safe by the World Health Organization (WHO). … [In addition,] the region is not only water scarce but also poor in energy, which constrains its ability to secure more water. (FoEME, 2007)

Ecosystems Services - Habitat & Infrastructure

Sea level rises could lead to flooding and salination of aquifers threatening the agricultural livelihoods of millions.

"For Palestinians in Gaza, the rising sea level could be the end of agricultural productivity, because of the likely loss of the Coastal Aquifer as a water supply for agricultural and domestic purposes. Rising sea levels will likely cause massive flooding of rural and urban areas. In the case of Egypt, the major city of Alexandria will likely be inundated, although several hundred million dollars are being spent to build protective walls. Flooded rural areas in the Nile Delta will lead to the loss of agricultural livelihood for millions of Egyptians. Governments will face increasing difficulties fulfilling the needs of their rapidly expanding populations. The anticipated growing resource shortages, due to the climate crisis, in turn, could lead to greater dissatisfaction with government authority and a rise, beyond what already exists, of extremist groups, and/or potential changes in – or overthrows of – government regimes or failed states" (FoEME, 2007, p.19).

Ecosystems Services - Energy & Earth Resources

If renewable energy sources become more valuable the political economy of energy could shift significantly, with impacts on global ecosystems.

The Middle East still holds just over half of the World's "proved oil reserves, a staggering 746 billion barrels of the total estimated global reserves of 1342 billion barrels" (EIA, 2009). Little of the fossil fuel resource wealth lies in Israel, Palestine, Jordan, and Syria. Just like with water, access to Earth resources is unevenly distributed across the Middle East, creating a resources based potential for conflict in addition to historical conflict based on religion and ideologies that has haunted the Middle East for decades, or even centuries and millennia. The impact of climate change on the region will affect the Middle East more or less equally across different countries and could offer opportunities for new forms of collaboration. "If renewable energy sources become more valuable as a result of an ambitious post-2012 climate agreement, then the political economy of energy and the geo-politics of the region could shift dramatically. It is conceivable, for example, that there could be a growing rift between the oil-producing and non-oil producing Arab states in the Middle East over collaborative action on reducing greenhouse gas emissions" (Brown & Crawford, 2009, p.34)

Ecosystems Services - Health & Wellbeing

Climate change will affect ecosystem services adversely impacting on food self-sufficiency and increasing destabilization.

Climate change will affect ecosystems services in the Middle East in a deteriorating way, with desertification, salinization, and increasing water scarcity leading to an even further reduction in food self-sufficiency in the region. Reduced water and food security could become major destabilizing influences in an already unstable region. Combined with the devastating effects of decades of armed conflict in the region these factors will have a immediate and long-term effect on human health and wellbeing. "Hans Günther Brauch of the Peace Research and European Security Studies Institute argues that it may be possible to "gradually overcome the cycle of violence in the Middle East by increasingly recognizing the common regional impacts of global environmental change by addressing them jointly through a network of coordinated functional cooperation of water, soil, food, energy and health specialists" of all countries" (Brown & Crawford, 2009, p.35)

Ecosystems Services - Food & Agriculture

Crop yields will be negatively impacted by climate change.

"Climate change will have a negative effect on crop yields in the Middle East and North Africa in 2050. The region will face yield declines of up to 30 percent for rice, about 47 percent for maize and 20 percent for wheat" (IFPRI, 2009).

"In the case of the Palestinians and Egyptians, agriculture is still a major component of peoples' economic livelihoods, particularly in the predominantly rural areas. Significantly, when one adds climate change and its potential physical – and socioeconomic – impacts into the already volatile political setting of the Middle East, one recognizes that political stability could be in even greater jeopardy" (FoEME, 2007, p.14).

Food & Agriculture – Habitat & Infrastructure

The loss of agricultural lands combined with growing population is likely to accelerate urbanization and increase competition for food and water resources.

The 'loss of productive agricultural lands in Egypt due to climate change could lead to a 20 percent drop in wheat and maize production by 2050. Such a decline, combined with growing populations and water demands, will increase competition for food and water resources, and could cause Egyptians to move from one area to another within Egypt (or beyond). An Organization for Cooperation and Economic Development (OECD) study points out that "any medium-term adverse trends regarding the reliability of water supplies . . . will have a critical impact" on densely-populated areas and could affect the welfare of the entire country. Taking migrants into account that already exist from Sudan and possibly from other areas in the future (also likely due to climate change) will lead to an exacerbation of these pressures and possibly to additional conflicts along the lines of what we have witnessed in Darfur" (FoEME, 2007, p.16).

Food & Agriculture – Energy & Earth Resources

The Middle East's dependency on food imports and oil exports provides an interesting focus for the world wide relationship between energy and earth resources, food and agriculture, and climate change.

"The food system is currently dependent on fossil fuels for powering irrigation pumps, petroleum based pesticides and herbicides, mechanization for both crop production and food processing, fertilizer production, maintenance of animal operations, crop storage and drying and for the transportation of farm inputs and outputs. Of these fossil fuel dependences, some are more easily overcome than others (Ruttan 1999). However, due to their current necessity, dependence on synthetic nitrogen fertilizer and the long distance transport of farm inputs and outputs are two outlying limiting factors that exemplify the vulnerability of the current food system and therefore require further analysis." (Smil 1991 2000).

Food & Agriculture – Health & Wellbeing

Decreased agricultural production is likely to increase the number on malnourished children as well as exacerbate unrest.

"Economic unrest across the region, due to a decline in agricultural production from climate impacts on water resources, also could lead to greater political unrest, which could threaten current regimes, thereby affecting internal and cross-border relations" (FoEME, 2007, p.4). As already mentioned above the effects of food and water scarcity, combined with the devastating effects of prolonged armed conflict in the region is likely to have negative effects on the health and wellbeing of more and more people in the region.

Models predict that these reductions in yield will impact negatively on the amount of calories available per person per day and will lead to about 2 million malnourished children in the region by 2050. (IFPRI, 2009).

Water Availability – Food & Agriculture

The Middle East currently feeds its population by importing virtual water in the form of agricultural products. Climate change is likely to increase international food prices making this option less viable.

“Food production in the region is largely determined by the availability of water—either from rain or from irrigation. Agriculture is by far the biggest consumer of water, accounting for 84 per cent of all demand. Complete food self-sufficiency is an unrealistic goal: one analyst estimates that the Middle East as a whole ran out of water resources to meet its full strategic needs (including producing all its own food) in1970. Currently the region sidesteps the problem of its inability to provide enough food for its population through imports of ‘virtual water’ in the form of agricultural goods. … Already the Middle East as a whole is the world’s most dependent region on wheat imports. So far, this has been (relatively) affordable as a side effect of the consistent subsidization of EU and U.S. agriculture, which has served to keep international food prices low for decades. All the countries in the region, with the occasional exception of Lebanon, import more food than they export. In 1998, for example, this net deficit in food trade was costing Jordan US$115 per person per year” (Brown & Crawford, 2009, p.22).

1.3.3 Adaptive Capacity

The Middle East is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Middle East					**MEDIUM 21.72**
Saudi Arabia	0.40	0.50	0.67	0.75	
Yemen	0.40	0.17	0.33	0.50	
Oman	0.80	0.83	0.67	0.75	
UAE	0.60	0.67	0.83	1.00	
Iraq	0.20	0.17	0.17		
Syria	0.40	0.50	0.50	0.50	
Jordan	0.40	0.50	0.50	0.50	
Iran	0.40	0.33	0.50	0.50	
Qatar	0.60	0.83	0.67	1.00	
Kuwait	0.60	0.67	0.67	1.00	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.4 Central America & Caribbean Direct Impact Pattern

Central America and Caribbean includes Mexico, Cuba, Haiti, Costa Rica, Nicaragua, Honduras, Panama, Guatemala. The Caribbean region also includes various British Overseas Territories, namely Anguilla, the British Virgin Islands, the Cayman Islands, Montserrat, and the Turks & Caicos Islands. This gives this section particular significance from a UK Overseas Territories perspective.

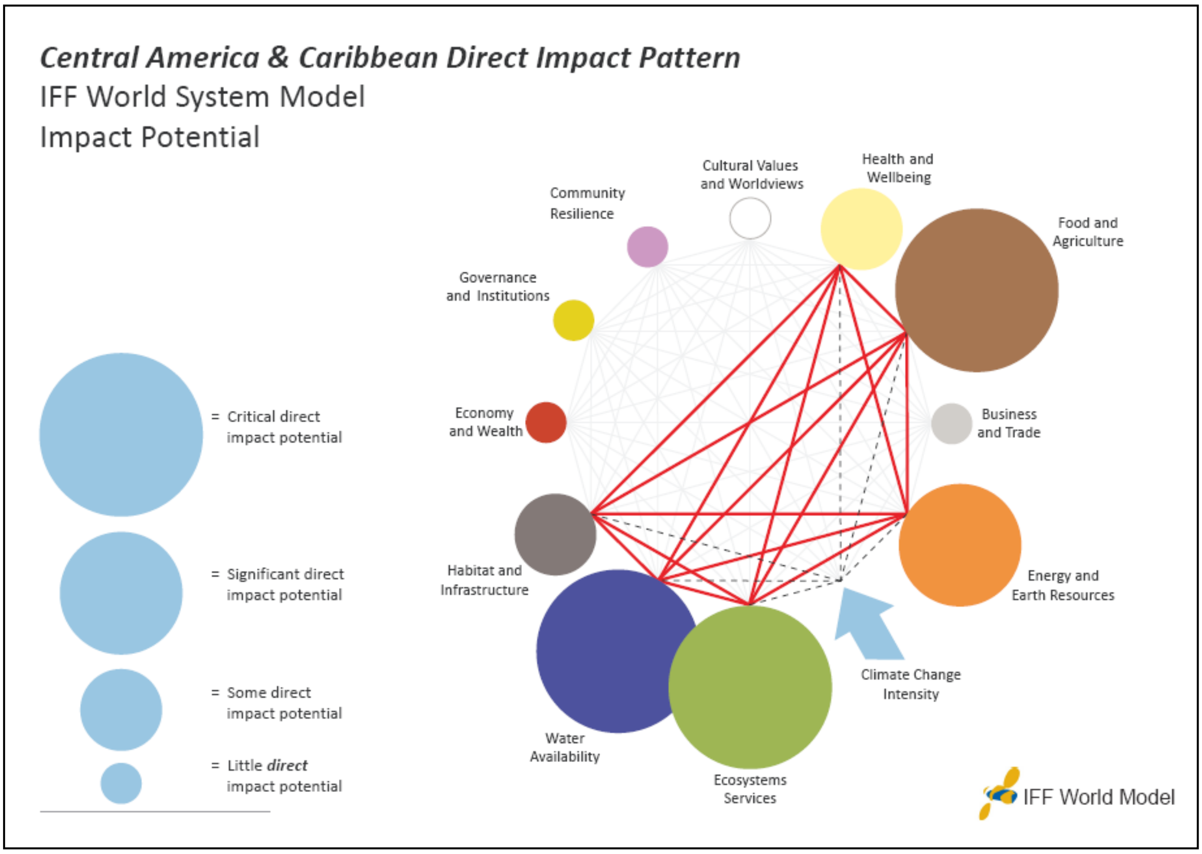


Figure 1.4.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.4.1 Overview

The National Intelligence Council report on *Mexico, The Caribbean, and Central America: The Impact of Climate Change to 2030: Geopolitical Implications* summarizes the potential effects of climate change on the region as follows: “Although the region does not contribute to significant global greenhouse gases, it is highly vulnerable to the effects generated by increasing climate variability. Rising temperatures, rising sea levels, increased rainfall in some places, drought in others, and a greater frequency of extreme weather events such as hurricanes, floods, and heat waves are expected from climate change” (NIC, 2009, p.3).

“Although the islands of the Caribbean are marked by nuanced differences which define the social, economic and political fabric of each individual country, there are broad similarities which make the islands, as a collective, all vulnerable to the risks and impacts of climate change. The fact that they all share similar economic and sustainable development challenges (consisting of low availability of resources, high debt, a small but rapidly growing population, remoteness, susceptibility to natural disasters, excessive dependence on imports and vulnerability to global developments) enhances their vulnerabilities and reduces their resilience to climate change, particularly via the associated sea-level rise and enhanced climate variability and occurrence of extreme natural events” (CCRIF, 2009, p.1).

“The implication and impact of climate change on these predominantly island nations is therefore not simply physical but inherently tied to their economic and social viability. The deterioration in coastal environments, for example through beach erosion and coral bleaching, will significantly affect local resources such as the fishing industry as well as directly impacting on the value of the tourism industry. Sea-level rise will result in an increase in storm surge inundation area, flood water height and wave damage, in turn resulting in enhanced levels of erosion and specific event impacts which threaten vital infrastructure, settlements and facilities that support the livelihood of most Caribbean communities” (CCRIF, 2009, p.1)

1.4.2 Systemic Relationships – Principal Paired Interactions (15)

Health & Wellbeing – Energy & Earth Resources

Climate change may increase social tensions and potential conflict in the region.

"Climate change may increase prospects for conflict in the region. Increased resource scarcity may combine synergistically with weak states and economic inequalities to promote organized insurrection. Civil conflicts are more likely than state-on-state violence, though some internal conflicts may spill across borders. Potential inter-state flashpoints include the Dominican Republic and Haiti, the Guatemala-Honduras-Nicaragua zone of instability, and the US-Mexican border. In Mexico, water scarcity may intensify community vulnerabilities to water-related diseases and exacerbate social tensions over access to water for agriculture and domestic uses" (NIC, 2009, p.3).

Health & Wellbeing – Habitat & Infrastructure

Water born disease and heat stress and natural disasters are likely to will impact human health.

"The regional assessments of health impacts due to climate change in the Americas show that the main concerns are heat stress, malaria, dengue, cholera and other water-borne diseases (Githeko and Woodward, 2003). Malaria continues to pose a serious health risk in Latin America, where 262 million people (31% of the population) live in tropical and sub-tropical regions with some potential risk of transmission, ranging from 9% in Argentina to 100% in El Salvador (PAHO, 2003). … Kovats et al. (2005) have estimated relative risks (the ratio of risk of disease/outcome or death among the exposed to the risk among the unexposed) of different health outcomes in the year 2030 in Central America and South America, with the highest relative risks being for coastal flood deaths (drowning) followed by diarrhoea, malaria and dengue" (IPCC, 2007a, p.599). Infrastructure improvements to improve health and wellbeing will have to occur directly through the improvement of health infrastructures (hospitals and wider spread availability of medical care) and indirectly, through the general improvement of coastal and river flood defences.

Energy & Earth Resources – Habitat & Infrastructure

Energy sector infrastructure is likely to be stressed by the demands of a changing climate.

"The energy sector is vulnerable to the effects of climate change in several ways, as many different aspects of the energy industry are directly affected by environmental and climatic conditions. Some of these interactions are described below (DOE/NETL, 2007):

- Seasonal and daily temperatures and precipitation changes affect the timing of peak electricity demands and the size of these peaks;
- Extended periods of drought lead to reduced water availability for hydropower generation;
- Changes in temperature and precipitation affect water availability for cooling power generators;
- Changes in cloud cover, temperature and pressure patterns directly affect wind and solar resources (affecting resource availability or productivity)
- Increased intensity and frequency of severe weather events impacts on energy infrastructure, for instance power plants, transmission lines, refineries, oil and gas drilling platforms, pipelines and power lines in and around the Caribbean. These weather-related supply disruptions result in higher energy prices;
- Increased intensity and frequency of severe weather events impact design and safety requirements of future energy infrastructure and other capital investments;
- Increased occurrence of blackouts may be observed as a result of higher electricity demand for cooling and refrigeration caused by higher temperatures" (Contreras-Lisperguer & de Cuba, 2008, p.4-5).

Water Availability - Habitat & Infrastructure

Climate change has affected freshwater resources of the region with significant consequences to ecosystems and societies.

“Despite the fact that Latin America and the Caribbean have the largest freshwater resources per capita, a third of the region’s population is cut off from sustained access to drinking water. Up until a few years ago, freshwater problems had been generally characterized as a result of inequitable natural distribution, lack of adequate financing for water infrastructure, poor freshwater governance, or a combination of the three. Nowadays, as nations try pave the way towards sealing a deal to put in place a multilateral regime that will stabilize the global climate, Latin America and the Caribbean countries have realized that global climate change has affected freshwater resources of the region with significant consequences to ecosystems and societies. (Sempris, 2009).

“In the past three decades, the region has witnessed the mightiness of extreme water-related weather events, resulting in human and material losses, particularly during the hurricane season. … Deforestation and climate change have combined to put biodiversity spots of global significance under significant stress. The consequences to societies in Latin America and the Caribbean from fluctuations in both quantity and quality of freshwater as a result of climate change will increase the likelihood of conflicts over land, as nearly one sixth of the population is settled in transboundary watersheds. Along with food security and climate-induced migrations, this is probably the most pressing water governance issue that will challenge the region in the years to come. Freshwater solidarity and policy transparency will be tested as nations and stakeholders struggle to fast track solutions that address the needs of their people, particularly the most vulnerable, to the adverse effects of climate change” (Sempris, 2009).

Water Availability - Energy & Earth Resources

Scarcity of fresh water may lead increased competition for shared water resources in different locations and for different purposes including energy.

“Changes in hydrological cycles, particularly in small island states, trigger serious issues related to water availability and use. Most small island states have limited fresh water resources because of the limited availability of surface for groundwater aquifer formation or regeneration and the intrusion of salt or brackish sea water. Scarcity of fresh water may lead increased competition for shared water resources in different locations and for different purposes including energy, commercial, residential and agricultural uses. This potential increase in competition may negatively affect the energy sector, especially when considering the existing conventional fossil fuel based power plants that are dependant on quality water for their cooling systems to function appropriately…" (Contreras-Lisperguer & de Cuba, 2008, p.6).

"Economic activities in the Caribbean primarily involve direct exploitation of natural resources such as coastal and marine ecosystems, forests, agricultural land, and mineral resources. Tourism is the major and most rapidly growing industry across the region. Mining and mineral extraction industries, located principally in the larger islands, are also important engines of economic growth and development. The major foreign exchange earning sectors and employers are mining, tourism, agriculture and offshore banking, all of which are very likely to be disrupted by extreme meteorological events of which hurricanes are the most common" (UNEP, 2008, p.12).

"Mining is an important sector in some Caribbean countries, especially in Guyana, Jamaica, and Trinidad and Tobago accounting for, respectively, 19.3 per cent, 7.9 per cent and 10.6 per cent of GDP (UNEP 2005). In Jamaica the bauxite-alumina industry is one of the most important economic earners. (Goverment of Jamaica 2000). Gold, diamond, and bauxite mining is important in Guyana (gold, diamond, bauxite) (Goverment of Guyana 2002). Dominican Republic is also an exporter of ferro nickel and gold. In many countries of the region sand mining is reported as being a problem for coastal zone conservation" (UNEP, 2008, p.12). As water availability decreases overall and the regional variability in water availability increases, more intense competition over existing water resources is likely and in some cases that may lead to social unrest and political instability.

Water Availability - Health & Wellbeing

Heavily populated coastal areas, and costal aquifers, are vulnerable to the effects of climate change.

"The majority of the population in most of the countries in the review [Mexico, Central America and the Caribbean] lives in coastal areas, which are highly vulnerable to severe climate changes. As populations continue to grow in the same areas, increasing water extraction and rising sea levels are expected to have severe impacts on the quantity and quality of water available. Many of these countries' aquifers are open to ocean waters and are already experiencing increased salinity. Rising sea levels will accelerate the deterioration of aquifers and available water resources" (NIC, 2009).

A recent review of the situation by Emilio Semoris, the director of the Water Centre for the Humid Tropics of Latin America and the Caribbean, in the *The UN Chronicle* highlights: "Regarding human health, vector-borne diseases such as dengue and malaria, as well as transmission of pathogens from rodents to humans, seem to be increasing due to freshwater fluctuations in Central America and the Caribbean. Food security has become an issue every time there are flood or drought events affecting transboundary watersheds, prompting international humanitarian assistance. As of September 2009, several Central American Governments have declared a state of emergency and are implementing contingency measures in response to the prevailing drought conditions. Projects like the RedHum (http://www.redhum.org) and the Mesoamerican Regional Visualization and Monitoring System (http://www.servir.net), coordinated and facilitated by the United Nations Office for the Coordination of Humanitarian Affairs, are providing continuous information support to the region with respect to the erratic availability of freshwater" (Sempris, 2009).

Water Availability - Ecosystems Services

Increased water stress will impact on water related ecosystem services and the habitats that provide them.

"Many islands in the Caribbean are likely to experience increased water stress as a result of climate change. Under all 'Special Report on Emissions Scenarios' (SRES) scenarios, reduced rainfall in summer is projected for this region, so that it is unlikely that demand would be met during low rainfall periods. Increased rainfall in winter is unlikely to compensate, due to lack of storage and high runoff during storms" (IPCC, 2007b, p.689).

"Available freshwater in the Caribbean SIDS [small islands developing states] is considerably less than in oceanic islands. In 2002 freshwater resources (that is, internal renewable water resources) in the Caribbean … were 2532 m3 per capita, compared to 17607 m3 in the Western Indian Ocean and 127066 m3 in the South Pacific. At current population levels, the available water supply in some of the Caribbean SIDS is significantly lower than the international limit of 1000 m3 per capita per year below which a country is classified as 'water scarce'. This limit places Antigua and Barbuda (800 m3 per capita), Barbados (301 m3 per capita), and St. Kitts and Nevis (621 m3 per capita) in the category of water-scarce countries (UNEP 2005).

Many Caribbean islands rely almost entirely on a single source of water such as groundwater, imports, rainwater, surface reservoirs, rivers and other surface flows. The situation is critical in the low limestone islands of the Eastern Caribbean, where seasonal rainfall is very pronounced. In islands such as Anguilla, Antigua and Barbuda, Grenada, and Barbados, more than 65 per cent of total annual rainfall may be recorded in the wet season from June to December. Recent modelling of current and future water resources on several small islands in the Caribbean, using a macro-scale hydrological model and the SRES scenarios, found that any of these islands would be exposed to severe water stress under all SRES scenarios" (UNEP, 2008, p.9).

Water Availability - Food & Agriculture

Agriculture will be competing with other sectors for diminishing water supplies.

Around 35 per cent of the world's freshwater is found in Latin America. Regardless of climate change, stress on water resources is set to increase because of rising human demand from growing populations and economic activity. Estimates of freshwater availability and the impacts of climate change in Mexico and South America over the next quarter of a century indicate that by 2025 about 70 per cent of the population will live in regions with low water supply (WWF, 2006, p.6).

Despite the importance of agriculture in countries like Belize, Cuba, Dominica, and Jamaica, where agriculture is one of the key economic sectors, in the region the scale of this sector cannot be compared to that in larger countries. Dominican Republic is the main producer of rice in the Caribbean. Rice is also an important income source in Guyana and Belize (Government of Guyana 2002, Government of Belize 2002). In Jamaica, agriculture produces 7.3 percent of gross domestic product (GDP), representing approximately 12 percent of foreign earnings, and employs approximately 25 percent of the population (Government of Jamaica 2000). Methane emissions are far lower than CO 2 emissions and NO2 emissions are even smaller. Livestock farming in the region is also mainly subsistent (UNEP, 2008, p.13).

Habitat & Infrastructure - Ecosystems Services

Tourism is the major contributor to GDP and employment on many small islands. Sea-level rise and increased sea water temperature will cause accelerated beach erosion, degradation of coral reefs, and bleaching.

“Sea level rise will affect many of the Caribbean islands, leading to saline intrusion into freshwater aquifers and increased coastal flooding and erosion. This will particularly affect many of the low-lying population centres and tourism reports. Increased temperatures will lead to heat stress for the population, drive coral bleaching (along with the acidification of the ocean), resulting in rapid loss of biodiversity across Central America and the Caribbean, and allow the increased emergence and spread of vector borne diseases. Changes in rainfall pattern and increased variability will lead to both droughts and flood and decreased freshwater availability on some Caribbean islands. Most immediately, the increased frequency and intensity of tropical storms will cause direct damage to infrastructure and result in loss of lives. The costs of direct impact of climate change on the Caribbean by 2050 have been estimated to reach between 1.5 billion and 9 billion $US, for low and high impact scenarios respectively” (King, 2007)

“Although almost 70 per cent of the Caribbean Region population lives in coastal cities, towns and villages, there is only limited investment in waste management systems. Coastal areas are being contaminated with solid waste, sewage, industrial effluents, chemical run-off from agriculture, and wastes from the transportation sector (lubricants, coolants, battery acid, tires). It has recently been estimated that 70% of Caribbean beaches are eroding at rates of between 0.25 and nine metres per year” (UNEP, 2008, p.9).

“Tourism is the major contributor to GDP and employment on many small islands. Sea-level rise and increased sea water temperature will cause accelerated beach erosion, degradation of coral reefs, and bleaching. In addition, a loss of cultural heritage from inundation and flooding reduces the amenity value for coastal users. Whereas a warmer climate could reduce the number of people visiting small islands in low latitudes, it could have the reverse effect in mid- and high-latitude islands. However, water shortages and increased incidence of vector-borne diseases may also deter tourists" (IPCC, 2007b, 689).

Ecosystems Services - Energy & Earth Resources

Reef ecosystems, which support tourism, are degrading at alarming rates. Hydropower is likely to be effected.

"Approximately 20% of the freshwater used in the Latin American and Caribbean countries runs through hydroelectric and thermal electric plants (IPCC 2001). In the Caribbean, approximately 13,872 TJ of hydropower energy is consumed (de Cuba, et. al., 2008), with Jamaica, Haiti, the Dominican Republic and Suriname representing the bulk of this primary energy use. Extended periods of intense droughts may result in severe water availability reduction for hydropower generation and cooling of thermal electric power plants. Conversely, it is precisely in periods of draught that thermal plants are expected to increase their generation output in order to make up for the loss of generation from hydropower plants. Drought also causes increased electricity demand for cooling or refrigeration and ground water pumping activities, thus augmenting the pressure on thermal electric power plants, affecting energy and water supplies, and leading to increases in CO emissions" (Contreras-Lisperguer & de Cuba, 2008, p.6).

The natural beauty of the reef ecosystems around the Caribbean is among the major attractions that support the regions tourism industry and hence among the region's most priced earth resources. "Recent studies suggest that some 80% of living coral in the reefs of the Caribbean has been lost in the past 20 years (Figure 1b). Absolute percent coral cover of the reefs investigated is the average difference between the estimated percent live coral at the start and end of each year of the study period. This unprecedented rate of degradation has seen some reefs change from 50% cover with live coral organisms, to just 10%. It has been estimated that the continued decline of coral reefs could cost the region between US$350m and US$870m per year by 2050" (UNEP, 2008, p.7).

Ecosystems Services - Health & Wellbeing

Climate change will affect wellbeing through changing patterns of disease, and transform many ecosystems. Coral reefs and mangrove are seriously threatened.

As already mentioned, climate change will result in the transformation of many ecosystems in the region and such changes are always associated with loss in biodiversity and shifts in the range and abundance of certain species. The IPCC predict: “Coral reefs and mangroves are expected to be threatened, with consequences for a number of endangered species: e.g., the green, hawksbill and loggerhead turtles, the West Indian manatee, and the American and Motelet’s species of crocodile” (IPCC, 2007a, p.600).

Beyond the loss of biodiversity and its often drastic effect on ecosystems viability and resilience, and hence ecosystems services, these will also be affected by a number of other climate change related factors. A recent review of climate change impacts on the region by the US National Intelligence Council suggests:

Steady increases within the region in the number of extreme weather events—hurricanes, storms, and droughts—and their effect on infrastructure, public health, loss of human life and agriculture may be attributable to climate change. The countries reviewed do not yet have a full understanding of the potential impacts of future climatic changes and are not prepared to prevent or reduce those impacts (NIC, 2009, p.7).

Human health and wellbeing can be significantly affected by such extreme weather events both through the immediate damage and through their long-term effects on people’s livelihoods. In addition, climate change will affect wellbeing through changing patterns of disease. “Threats to health posed by extreme weather events in the Caribbean include insect- and rodent-borne diseases, such as dengue, leptospirosis, malaria and yellow fever; water-borne diseases, including schistosomiasis, cryptosporidium and cholera; food-borne diseases, including diarrhoea, food poisoning, salmonellosis and typhoid; respiratory diseases, including asthma, bronchitis and respiratory allergies and infections; and malnutrition resulting from food production or distribution disruptions. (UNEP, 2008, p.19).

Ecosystems Services - Food & Agriculture

Crop yields are likely to decline fishing industries to be impacted.

The International Food and Policy Research Institute (IFPRI) reports: "The crop modeling results indicate that climate change will have a negative effect on crop yields in Latin America and the Caribbean in 2050. The region will face average yield declines of up to 6.4 percent for rice, 3 percent for maize, 3 percent for soybean, and up to 6 percent for wheat" (IFPRI, 2009).

According to the US National Intelligence Council: "Projections for productivity losses in Cuba range from 10 to 15 percent for rice, cassava, and corn; five to 10 percent for sugar cane; and 40 to 45 percent for potatoes. Coffee production in Veracruz, Mexico is likely to drop over 30 percent by 2020, degrading its economic value to the region. Projections for other states in the region are similar, though they vary by state and study. Further, the rise in CO2 levels could result in a fertilizing effect with crops having shorter growing cycles. The salinization of ground water supplies due to climate change and sea-level rise may also threaten agricultural productivity. Many Central American and Caribbean states have major fishing industries. Climate change is likely to lead to changes in migration patterns and depth of fish stocks with possible negative effects on the fishing industry." (NIC, 2009, p.11).

Food & Agriculture – Energy & Earth Resources

Loss of soil fertility may be addressed by higher uses of synthetic nitrogen fertilizers derived from fossil fuels.

"Mexico, Central American, and Caribbean states have economies with significant agricultural sectors. In many of the states selected for this review, the agricultural land use vis-à-vis total land area varies widely. In 2005, Belize agricultural land was 6 percent of the total land area, reflecting the fact that over 50 percent of GDP comes from the services industry, particularly tourism, compared to Dominican Republic where agricultural land was 70 percent, Costa Rica and Haiti 57 percent, Cuba 60 percent and Mexico 55 percent of total land area. In the past 27 years, all of the states reviewed have maintained relatively stable ratios of agricultural land use to total land area. The conversion of forests to agricultural use is likely to continue; however, the general projected drying trend in the area is likely to limit the types of viable agricultural crops. Although projected temperature changes may not differ much by season, changes in rainfall will likely lead to extended periods of drought and possible loss of soil fertility during the peak growing season in June, July, and August" (NIC, 2009, p.11)

Food & Agriculture – Health & Wellbeing

Variations in crop yields, food crops, and cash crops could present major challenges to health and wellbeing.

"Mexico, Central America, and the Caribbean states all continue to experience population growth, albeit at somewhat different rates, leading to an increase in food demand. Most of the states in these regions depend greatly on agricultural production. Variations in crop yields, food crops, and cash crops present major challenges. Increased rainfall, sea level rise, drought, and extreme weather events may provoke populations to migrate to more suitable habitats. The arrival of environmental migrants to existing settlements may provoke tensions with local populations and competition over scarce resources. Migration may also lead to the separation of families, with males leaving home to seek income-generating opportunities, placing the burden of household maintenance on women and older children" (NIC, 2009, p.13).

Rising temperatures, increased rainfall, and the movement of populations into new areas may exacerbate or contribute to the emergence (or re-emergence) of infectious diseases, including diarrheal disease and acute respiratory disease, as well as vector-borne diseases such as dengue fever, malaria, leptospirosis, and Chagas disease. Since 1990 the region has experienced a series of re-emerging diseases following severe climatic events such as floods, hurricanes, and droughts. There is evidence of increases in several communicable diseases, such as dengue, malaria, and Hantavirus pulmonary syndrome; and the reemergence of a large host of infectious diseases following years in which there were El Niño/Southern Oscillation (ENSO) events" (NIC, 2009, p.13).

Habitat & Infrastructure – Food & Agriculture

The impact of climate related catastrophic events on habitat and infrastructure could impact on food distribution.

The IPCC's (2007) assessment of the impact of climate change on small island states highlighted: "In the Caribbean and Pacific islands, more than 50% of the population live within 1.5 km of the shore. Almost without exception, international airports, roads and capital cities in the small islands of the Indian and Pacific Oceans and the Caribbean are sited along the coast, or on tiny coral islands. Sea-level rise will exacerbate inundation, erosion and other coastal hazards, threaten vital infrastructure, settlements and facilities, and thus compromise the socio-economic well-being of island communities and states" (IPCC, 2007b, p.689). Where agricultural and food producing infrastructure is not directly affected by increased catastrophic climate change weather events, their indirect impact on the general transport, energy and housing infrastructure will impact the food distribution, processing, and markets.

1.4.3 Adaptive Capacity

Central America and the Caribbean are rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Central America & Caribbean					**MEDIUM 20.12**
Mexico	0.60	0.33	0.67	0.75	
Cuba	0.40	0.50	0.50	0.75	
Haiti	0.20	0.17	0.17	0.50	
Costa Rica	0.60	0.67	0.67	0.75	
Nicaragua	0.40	0.50	0.33	0.50	
Honduras	0.40	0.50	0.50	0.50	
Panama	0.60	0.50	0.67	0.75	
Guatemala	0.40	0.33	0.50	0.50	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.5 South East Asia Direct Impact Pattern

South East Asia includes Thailand, Cambodia, Vietnam, Laos, Myanmar, Malaysia, Indonesia, Japan, S Korea, N Korea, Philippines.

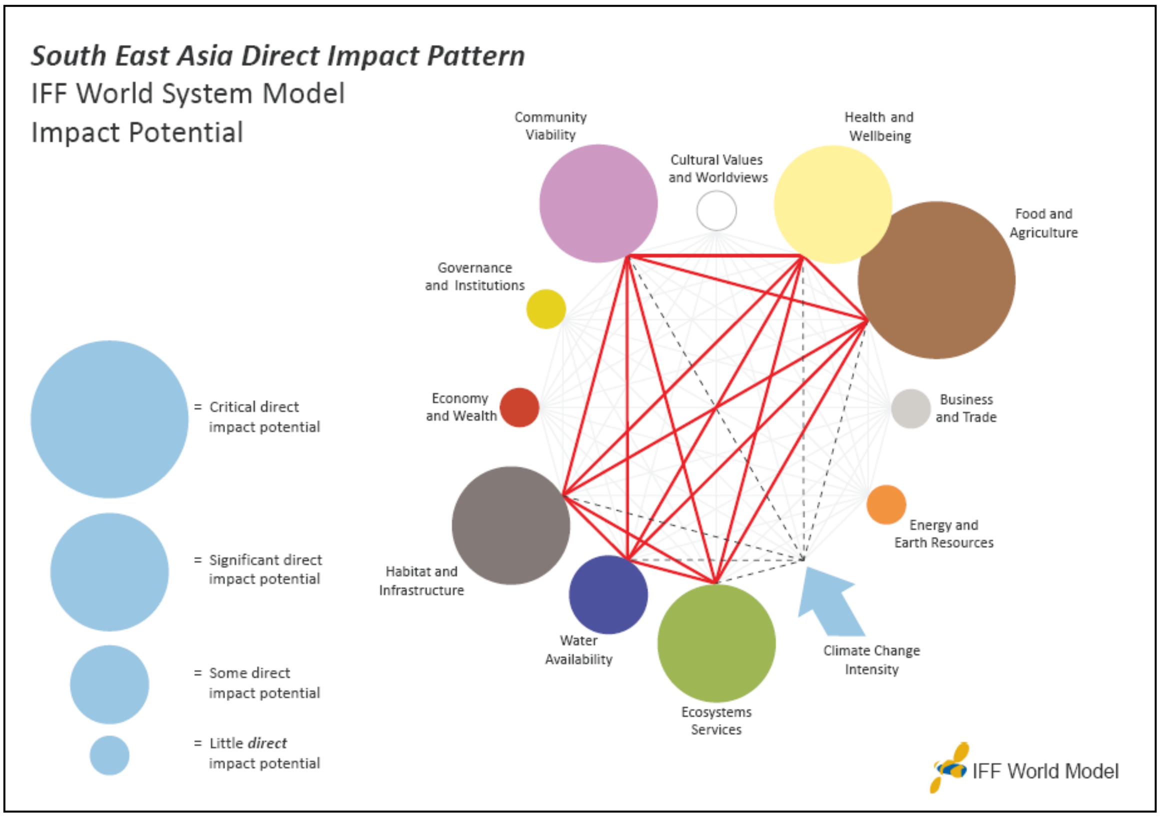


Figure 1.5.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.5.1 Overview

"Southeast Asia and Pacific Islands are at risk from the impact of climate change in the next 20 years due to the region's large and growing population, long coastlines, abundant low-lying areas, reliance on the agricultural sector, and dependence upon natural resources. [For example]… Thailand, Cambodia, Laos, Vietnam, the Philippines, Malaysia, Singapore, and Indonesia … have a diverse range of governments, populations, religions, economic growth, development, and allocation of natural resources, but they all have a similar tropical maritime climate and face similar threats from climate change" (NIC, 2009, p.3).

"There is a great deal of natural climate variability in Southeast Asia. The regular pattern of seasonal monsoons can cause extreme weather events, such as floods and droughts. Overlaid on the monsoon variability is the periodic shift in global climate caused by ENSO [El Niño Southern Oscillation], which can create or intensify existing floods and droughts. Drought in El Niño years can have wide-reaching impacts on countries in Southeast Asia. (NIC, 2009, p.14)

1.5.2 Systemic Relationships – Principal Paired Interactions (15)

Water Availability – Community Resilience

The management of water issues is one of the most challenging climate related issues as it is central to health and sustainable development.

"Future changes in regional water resources are closely tied to changes in precipitation. Individual areas under severe water stress in the region are projected to increase dramatically in the next few decades, although model results suggest that the region as a whole will not be at risk for water shortages. Fresh water resources on all island nations in the region are especially vulnerable to any variability in precipitation because many rely on rainwater collection for their supply of fresh water. The management of water issues is one of the most challenging climate-related issues in the region, as it is central to health and sustainable development. The impacts of climate change on water resources are interrelated with impacts on agriculture, river deltas, forests, coastal ecosystems, diseases and human health, and national security" (NIC, 2009, p.4).

For example, during the 1992 El Niño episode, total inflow to the Angat Reservoir in the Philippines, a major source of domestic and irrigation water supplies, was 69 percent less than average for the first six months of the year. As a result, there was a 20 percent reduction in the domestic water supply for the Manila metropolitan region, which necessitated water rationing in many areas. (NIC, 2009, p.14).

Water Availability – Food & Agriculture

Fresh water availability has far reaching impacts on agriculture. Climate change will impact on rainfall and sea level with knock on effects in agriculture.

"Climate change is expected to impact the supply and quality of fresh water in Southeast Asia, which in turn will have far-reaching impacts on agriculture, coastal ecosystems, and population growth. Heavy seasonal monsoon rainfall in Southeast Asia provides abundant fresh water, but increases in agricultural use, inadequate planning and misuse, and deforestation have led to water shortages in recent years, particularly in dry seasons. Climate change will likely exacerbate these effects. (NIC, 2009, p.29)

For Example during the 1992 El Niño episode the cropping season was delayed due to water shortages in June and July, and there were negative impacts on the national rice yield due to lack of irrigation water" (NIC, 2009, p.14).

"Assessment of the specific impacts of climate change on agriculture is challenging because it is difficult to reliably simulate the complicated effects of future variations in temperatures, precipitation, and atmospheric CO2 concentrations on crop growth. Temperature increases associated with climate change could result in a northward expansion of growing areas and a lengthening of the growing season. Rising atmospheric CO2 levels are expected to stimulate plant photosynthesis, which would result in higher crop yields. Studies show that the beneficial effects of CO2 on plants may be offset by average temperature increases of more than 2°C, however. Overall, it is likely that future crop yields will vary by region and by crop, with yield increases in some locations but decreases in others. Management of the agricultural sector by regional nations is critical to their economic growth and national security. The impacts of climate change on agriculture are interrelated with impacts on sea level, river deltas, natural disasters, water resources, and national security" (NIC, 2009, p.4).

Water Availability – Habitat & Infrastructure

Increases in sea level associated with climate change are particularly problematic for Southeast Asia, which is comprised of low-lying coastal and island nations.

Recent observed increases in temperature have already contributed to increased evapotranspiration in water bodies, which results in decreased fresh water availability. Much of Southeast Asia's water supply and water quality are sensitive to small changes in the frequency and distribution of precipitation. Recent changes in precipitation patterns have already been linked with increases in runoff, erosion, flooding, and associated impacts on surface water and groundwater in Southeast Asia" (NIC, 2009, p.29).

"As documented in the Model Projections section, sea level rose in the Southeast Asia region at rates of up to 3 cm per year for the period 1993-2001, and sea level is projected to rise up to 40 cm in the 21st century. … Increases in sea level associated with climate change are particularly problematic for Southeast Asia, which is comprised of low-lying coastal and island nations. In fact, approximately 20 percent of the world's population of low-lying coastal regions is in Southeast Asia. The effects of rising sea level on island nations, including the Philippines, Malaysia, Singapore, and Indonesia, whose borders are mostly or entirely coastline, will be most pronounced. (NIC 2009, p.28)

Water Availability – Ecosystems Services

Sea level rises will inundate coastal ecosystems

Although limited studies exist, recent estimates indicate that Indonesia could lose 2,000 small islands to sea level rise by 2030. … The primary impacts of sea level rise are saltwater intrusion into estuaries and aquifers, coastal erosion, displacement of wetlands and lowlands, degradation of coastal agricultural areas, and increased susceptibility to coastal storms. (NIC 2009, p.28)

Water Availability – Health & Wellbeing

Increased floods and droughts will particularly effect the urban poor of fast growing mega cities

Water availability and quality are crucial factors affecting the overall health and wellbeing of populations. This is true everywhere, but particularly so in tropical regions like South East Asia. Droughts cause temporary regional food shortages which lead to malnutrition with its multiple effects on reducing resistance to tropical diseases and people's ability to take care of their own needs. Floods can cause major problems with the quality of the available water and lead to the spread of water borne diseases as well as the spread of diseases transmitted by insect vectors. Particularly the increasing number of urban poor around the fast growing mega-cities of South East Asia will be at risk as climate change will increase the frequency and severity of periodic droughts and floods. (NIC 2009)

Habitat and Infrastructure – Community Resilience

Industry, infrastructure, and urban populations are concentrated in low lying coastal areas vulnerable to sea level rises and storm surges.

The megadeltas of Asia are vulnerable to climate change and sea level rise that could increase the frequency and level of inundation due to storm surges and floods from river drainage putting communities, biodiversity and infrastructure at risk of being damaged. This impact could be more pronounced in megacities located in megadeltas where natural ground subsidence is enhanced by human activities. In Bangkok land subsidence, coupled with rising sea levels due to climate change, puts the city at risk of disappearing into the sea within 15 or 20 years. Indonesia will suffer significantly from even very small rises in mean sea level. Industry, infrastructure, and urban populations are concentrated in low lying coastal areas. Of a total population of 179.4 million people, approximately 110 million live in coastal areas. Sea level rise is of particular concern in Jakarta because parts of the city are already subsiding rapidly, apparently because of excessive exploitation of ground water, soil compression due to heavy construction and tectonic subsidence of northern Java. (see WWF, 2009).

Climate change-induced sea level rise in Southeast Asia will likely have significant economic effects as well. A recent study estimates that rising ocean waters could cause the loss of 40,000 km2 of land in Vietnam, particularly rice paddies, and necessitate re-engineering of port facilities and transportation systems. Taken together, these impacts could result in economic losses of up to 80 percent of the yearly Vietnamese GDP. … In addition, coastal inundation of Indonesian cities associated with potential sea level rise in the 21st century is estimated to cause total economic losses of 1.8-2.3 billion… Sea level rise is expected to inundate 38 km2 of the total land area of Jakarta, Indonesia, by 2030, resulting in economic losses of US$1 billion" (NIC 2009, p.28)

Food and Agriculture – Ecosystem Services

The region is the largest producer of fish and climate change is likely to exacerbate other stresses on marine fisheries.

Vietnam is among the world's top rice exporters, and 90 percent of the exported rice is harvested in the delta, which appropriately goes by the name, "Vietnam's rice bowl." With water rising approximately one meter above sea level, the whole of the Mekong Delta is at risk as global climate change has brought along severe storms and unpredictable weather.

"The Asia-Pacific region is the world's largest producer of fish, from both aquaculture and capture fishery sectors. Recent studies suggest a reduction of primary production in the tropical oceans because of changes in oceanic circulation in a warmer atmosphere. The tuna catch of East Asia and South-East Asia is nearly one-fourth of the world's total. A modeling study showed significant large-scale changes of skipjack tuna habitat in the equatorial Pacific under projected warming scenario (Loukos et al., 2003).

Marine fishery in China is facing threats from over fishing, pollution, red tide, and other climatic and environmental pressures. The migration route and migration pattern and, hence, regional catch of principal marine fishery species, such as ribbon fish, small and large yellow croakers, could be greatly affected by global climate change" (IPCC, 2007, p.482).

"Climate change is expected to affect the agriculture in South East Asia in several ways. For example, irrigation systems will be affected by changes in rainfall and runoff, and subsequently, water quality and supply. Yet the region already faces water stresses, and future climate change effects on regional rainfall will therefore have both direct and indirect effects on agriculture. [In scenarios assuming an increase of] 2-4 °C, studies suggest the potential for both gains and losses. (IFAD, 2008, p.1).

In particular, scientific studies document a high sensitivity of major cereal and tree crops to changes in temperature, moisture, and carbon dioxide concentration of the magnitudes projected for the region. For example, projected impacts on rice and wheat yields suggest that any increases in production associated with CO2 fertilization will be more than offset by reductions in yield resulting from temperature and/or moisture changes" (IFAD, 2008, p.1).

Food and Agriculture – Community Resilience

Decreasing rice yields could have huge impacts on rural communities.

Floods droughts and rising sea levels could push Thailand's rice yields down significantly—with a huge impact on rural communities. Thailand is the home to 65 million people, the majority of whom live in rural, agricultural areas. The country is the world's largest exporter of rice, and is often called "the rice bowl of Asia." Agriculture employs 49% of the population and contributes 10% of GDP. Farmers who depend on rice yields for their livelihood may be forced to migrate from rural to urban areas.

Salt water intrusion caused by climate change has prompted thousands of small scale farmers around the Mekong Delta to produce shrimps instead of rice. Despite the fears that the country's food security might be at risk, shrimp is a valuable export crop and has brought greater wealth to these communities.

"Some recent studies (PAGASA, 2001; Sukumar et al., 2003; Batima et al., 2005b) confirm TAR findings that grasslands, livestock and water resources in marginal areas of Central Asia and South-East Asia are likely to be vulnerable to climate change. Food insecurity and loss of livelihood are likely to be further exacerbated by the loss of cultivated land and nursery areas for fisheries by inundation and coastal erosion in low-lying areas of the tropical Asia. Management options, such as better stock management and more integrated agro-ecosystems could likely improve land conditions and reduce pressures arising from climate change" IPCC, 2007, p.483).

Community Resilience – Ecosystem Service

Communities struggling to adapt to the pressures created by climate change can often put greater stress on local ecosystems

For example in the quest to breed shrimp as rice yields fall, some farmers have undermined dikes and cut down clusters of mangrove to place shrimp ponds near the coast. Mangrove has for decades been recognised as the single most important safety measure against storms wreaking havoc on the coastline.

Climate change could cause the collapse of essential industries - coastal tourism, mangrove products and fisheries - along Malaysia's extended shoreline which is now devoted either to agriculture or dense cities. (IPCC, 2007)

Food and Agriculture – Health and Wellbeing

With continued population growth in South East Asia, climate impacts on rice yields could have very serious consequences.

Rice production determines food security for many countries, as it is the only major grain grown exclusively for food and provides over one fifth of the calories consumed worldwide. In 2008 shortages created a surge in rice prices which posed a threat to regional governments worried about the prospect of hoarding and social unrest. With continued population growth in South East Asia, climate impacts on rice yields could have very serious consequences. "As land for agriculture becomes limited, the need for more food in South Asia could likely be met by increasing yields per unit of land, water, energy and time, such as through precision farming. Enhanced variability in hydrological characteristics will likely continue to affect grain supplies and food security in many nations of Asia. Intensification of agriculture will be the most likely means to meet the food requirements of Asia, which is likely to be invariably affected by projected climate change" (IPCC, 2007, p.482).

Health & Wellbeing – Habitat & Infrastructure

Increasing population density and potential sea level rise could combine to bring serious challenges to health and wellbeing.

The population density is now 860 persons per square kilometre in the state of Penang, making it comparable to some of the most densely settled parts of The Netherlands, and the trend is likely to endure. As the population expands, the coastal zone deteriorates. "With a 1 m rise in sea level, 2,500 km2 of mangroves in Asia are likely to be lost; …15,000 – 20,000 km 2 of Mekong River delta are projected to be flooded" (IPCC, 2007, p.481).

Habitat and Infrastructure – Ecosystem Services

The coastlines of South East Asia are highly vulnerable to the effects of climate change due to the geology and geography of some of the region's coastal areas, the growing density population and infrastructure in the coastal zone.

" Stability of wetlands, mangroves and coral reefs around Asia is likely to be increasingly threatened (high confidence)... Recent risk analysis of coral reef suggests that between 24% and 30% of the reefs in Asia are likely to be lost during the next 10 years. Projected sea-level rise is very likely to result in significant losses of coastal ecosystems and a million or so people along the coasts of South and South-East Asia will likely be at risk from flooding (high confidence) ….Sea-water intrusion due to sea-level rise and declining river runoff is likely to increase the habitat of brackish water fisheries but coastal inundation is likely to seriously affect the aquaculture industry and infrastructure particularly in heavily-populated mega and 30 years, respectively" (IPCC, 2007, p.471).

"Moreover, large tidal variations, tropical cyclones, coupled with the potential increase in regional rainfall, suggest the potential for increased coastal hazard. Sea-level rise and increases in sea-surface temperature are the most probable major climate change-related stresses on coastal ecosystems. In particular, sea-level rise is the most obvious climate-related impact in coastal areas. Densely settled and intensively used low-lying coastal plains, islands, and deltas are especially vulnerable to coastal erosion and land loss, inundation and sea flooding, upstream movement of the saline/freshwater front, and seawater intrusion into freshwater lenses. Especially at risk are the large deltaic regions of Bangladesh, Myanmar, Viet Nam, and Thailand, and the low-lying areas of Indonesia, the Philippines, and Malaysia. International studies have projected the displacement of several million people from the region's coastal zone in the event of a 1-m rise in sea level. The costs of response measures to reduce the impact of sea-level rise (30-50 cm) in the region could amount to millions of dollars per year" (IFAD, 2008)

Ecosystems Services – Health and Wellbeing

Studies suggest that disease outbreaks in the region, including malaria, dengue, diarrhoea, and cholera, are linked with climate events.

“Climate-related health risks in Southeast Asia include increases in vector-borne disease, heat stress, food stress, and air pollution. Studies suggest that disease outbreaks in the region, including malaria, dengue, diarrhoea, and cholera, are linked with climate events such as droughts and floods, which are in turn strongly related to ENSO events. Changes in temperature and precipitation patterns have already been linked to increases in dengue fever and malaria in Indonesia, Thailand, and Vietnam. Mosquito populations will be affected by variations in temperature and precipitation associated with future climate change, and thus the incidence of mosquito-borne diseases such as dengue fever and malaria are likely to be affected as well. Environmental conditions strongly influence the growth and survival of mosquitoes. “(NIC, 2009, p.37).

“Projected increases in flooding due to changes in precipitation patterns and sea level rise are expected to increase the risk of water-borne disease such as dermatosis, amoebiasis, cholera, giardia, shigellosis, and typhoid. Residents of Southeast Asia already have higher risks of mortality and morbidity from water-borne diseases than in many other parts of the world, and climate change is expected to exacerbate these risks. Heat is also a public health threat, especially among the elderly and very young. Chronic exposure to excessive heat has been linked to increased incidence of cardiovascular and respiratory diseases…A recent study found that human health impacts from climate change in the Philippines include blooms of toxic marine micro-organisms which can lead to dietary constraints and even poisoning, increases in heat stroke and vector-borne diseases, and population dislocation. Although this study was focused on the Philippines, the impacts are applicable across the Southeast Asian region” (NIC 2009, p.38).

Community Resilience – Health and Wellbeing

Health and wellbeing will be challenged by climate related disease and displacement which will in turn impact on the resilience of communities.

Changes in temperature and precipitation patterns will and raise the incidence of water- and mosquito- borne diseases. “Increases in endemic morbidity and mortality due to diarrhoeal disease primarily associated with climate change are expected in South and South-East Asia (high confidence). Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in south Asia (high confidence). Natural habitats of vector-borne and water-borne diseases in north Asia are likely to expand in the future (medium confidence)" (IPCC, 2007, p.471).

1.5.3 Adaptive Capacity

SE Asia is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
S E Asia					**MEDIUM 19.65**
Thailand	0.40	0.33	0.67	0.50	
Cambodia	0.40	0.33	0.33	0.50	
Vietnam	0.40	0.67	0.50	0.50	
Laos	0.40	0.50	0.33	0.50	
Myanmar	0.20	0.17	0.17	0.50	
Malaysia	0.60	0.67	0.83	0.75	
Indonesia	0.40	0.33	0.50	0.50	
Japan	0.80	0.83	0.83	1.00	
S Korea	0.80	0.67	0.83	1.00	
N Korea	0.40	0.67			
Philippines	0.40	0.33	0.67	0.50	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.6 China Direct Impact Pattern

China is treated alone.

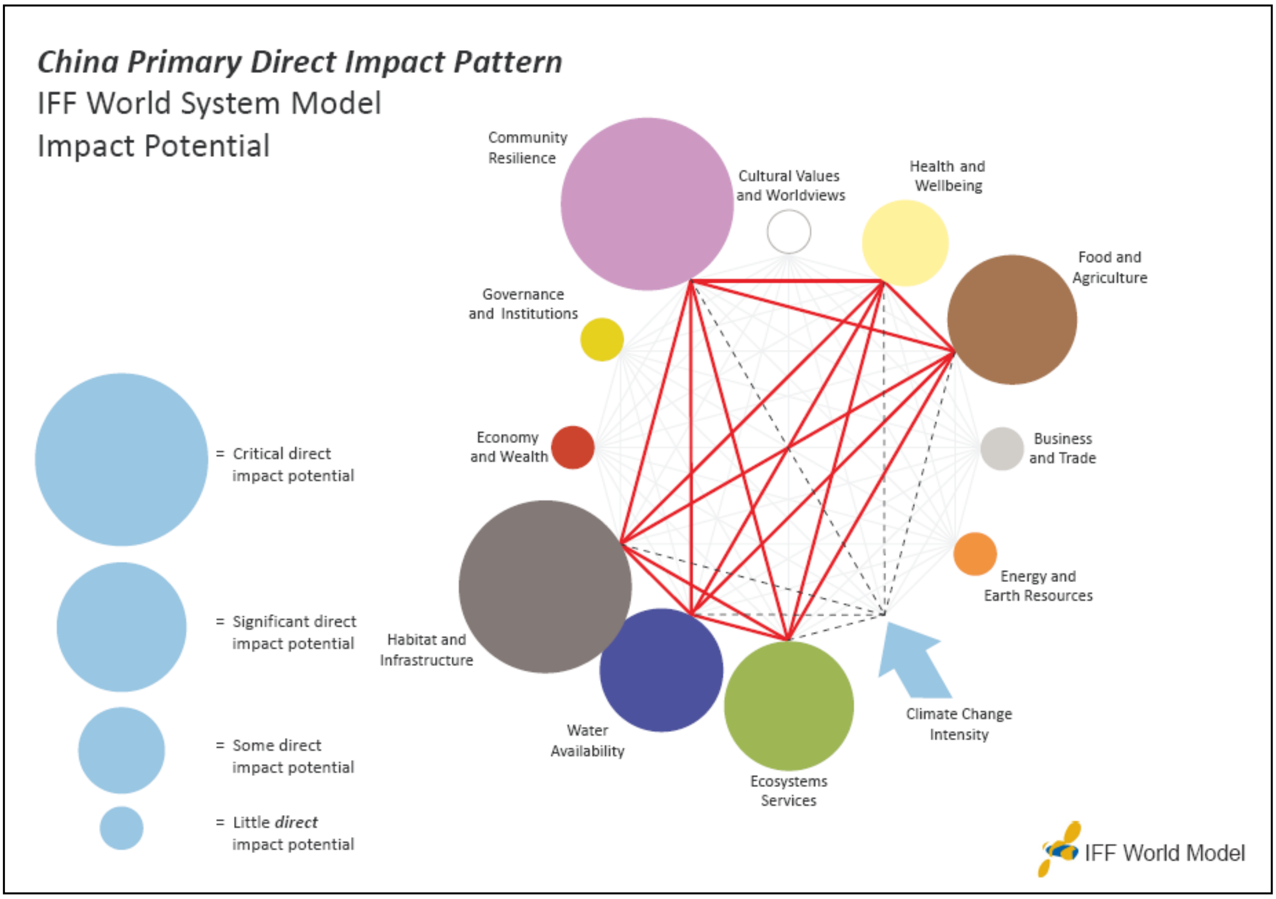


Figure 1.6.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.6.1 Overview

A recent report by the US National Intelligence Council emphasizes that "compared to other countries, China ranks lower in resilience to climate change than Brazil, Turkey, and Mexico, but higher than India. China ranks high in food security, human health, and human resources. Projections of resilience show China gaining capacity quickly and outranking Brazil, Turkey, and Mexico by 2020" (NIC, 2009, p.3). The report concludes: "There is little doubt that China has taken climate change issues seriously, although China's seriousness has often been overlooked due to its more-publicized, non-negotiable, "you-take-the-first-step" attitudes in international negotiations. Evidence of China's seriousness is apparent in its fast growing array of national laws, regulations, and policies that focus on mitigation, energy efficiency, resource protections, and adaptive capacities. The Chinese Government has successfully used its power to promote and implement some of its national programs and policies, such as energy efficiency standards for appliances, top 1,000 industrial energy conservation program, and an efficient light bulb subsidy program" (NIC, 2009, p.34).

Growth towards matching developed nation status implies that "with the current level of technology development, to reach the development level of the industrialized countries, it is inevitable that per capita energy consumption and CO2 emissions will reach a fairly high level. In the development history of human beings, there is no precedent where a high per capita GDP is achieved with low per capita energy consumption. With its ongoing economic development, China will inevitably be confronted with growing energy consumption and CO2 emissions. The issue of GHG mitigation will pose a challenge to China to create an innovative and sustainable development pattern" (CNCCP, 2007, p.19).

There are issues here deeply entangled with the relationship between China and developed nations including the UK. In June 2007, Chinese Foreign Ministry Spokesman Qin Gang made the following comment regarding the issue: "the developed countries moved a lot of manufacturing industry into China … A lot of the things you wear, you use, you eat are produced in China. On the one hand, you shall increase the production in China, on the other hand you criticize China on the emission reduction issue." … Indeed, developed countries have successfully exported their manufacturing activities to developing countries together with the carbon emission and other related pollution" (Wen, 2009, p.6).

1.6.2 Systemic Relationships – Principal Paired Interactions (15)

Health & Wellbeing – Community Resilience

China has no effective social protection system and climate change will add pressure to existing social and resource stresses.

The US National Intelligence Council (2009) reports: "Facing a large unemployed population, China's underdeveloped social protection system is less and less able to protect those who need it. Rising expenses in health care, education and housing have been financial burdens for the average Chinese family. The export-oriented economy is vulnerable to a global financial crisis. The increasing dependence on foreign oil exposes China to an unstable world oil market. The adverse impacts of climate change will add extra pressure to existing social and resource (such as energy) stresses. Establishing an effective social protection system should be ranked high on the Chinese Government's long to-do list" (NIC, 2009, p.4).

Health & Wellbeing – Habitat & Infrastructure

The urban heat island effect will increase the vulnerability of the poor, the elderly and labourers.

"As the climate changes, there will be significant impacts on human health. Temperature increases and a higher incidence of heatwaves will result in increased illness and death (Takahashi et al., 2007). This could be highest in cities where temperatures are exacerbated by the urban heat island effect, particularly affecting vulnerable groups such as the poor, elderly and labourers (Cruz et al., 2007). Deaths as a result of cold temperatures are likely to decrease in number, although the increases in the number of deaths from heat-related illnesses are expected to exceed this decline. Occurrences of diarrhoeal and other bacterial diseases are very likely to increase as temperatures rise and water quality issues increase. Malaria, dengue fever, tick-borne encephalitis and many other vector-borne and infectious diseases are also likely to change in geographical range and frequency. Cardio-vascular and respiratory diseases are projected to increase, particularly in urban areas where air quality is poor and heat stress high (Patz et al., 2007). Flooding, sea level rise and increasing sea surface temperatures could lead to increased incidences of toxic algal blooms, the spread of diseases such as cholera and also an increase in the physical and mental health problems that often follow flooding" (MET Office, 2009, p8)

Health & Wellbeing – Water Availability

China is facing a water crisis that is likely to have significant impacts to human wellbeing.

"China is facing one of the world's worst water shortages. Per capita, it only has 35 percent of the world's average fresh water resources. The water distribution is also highly uneven. The country is divided into two regions: the "dry North," referring to all areas north of Yangtze basin, and the "humid South," which includes the Yangtze River basin and everything south of it. The north has two-thirds of the country's cropland, and one-fifth of the water. The South has one-third of the cropland and four-fifths of the water. Climate change may further this imbalance. Climate models predict that global warming would cause less rainfall in northern China and more rainfall in southern China. This is consistent with observations in recent years" (Wen, 2009, p.10).

The US National Intelligence Council (2009) warns: "Scarcity of natural water resources, fast-growing urbanization and industrialization, severe water pollution, cheap water prices, and the adverse impacts of climate change on water sources may lead to a water crisis in China. The drought regions in northern China may be prone to social unrest caused by conflicts about water rights and distribution between social groups and between sectors. The expected South-to-North Water Diversion Project may alleviate the water stress of some northern regions, but it will not provide a full solution (and has in any case been delayed). The forthcoming water crisis may impact China's social, economic, and political stability to a great extent" (NIC 2009, p.4).

Higher water temperatures could mean that more waterbodies become toxic, meaning that harmful algae and other microscopic organisms would become common and form large blooms. When this happens the blooms absorb all the oxygen in the water, killing off most of the life. Such conditions have already developed in the Zhujiang and Changjiang estuaries, resulting in increasing frequency of algal blooms known as red tide events (Hu et al., 2001), the toxicity of which can then cause health problems to those eating fish and shellfish from such waters" (MET Office, 2009, p.6)

Water Availability – Community Resilience

Population growth and ongoing urbanisation are challenging water availability. Beijing is among one of the most effected cities.

The US National Intelligence Council offers the following analysis: "With 20 percent of the world's population but only 7 percent of global water resources, China is suffering an underrated water crisis. According to Chinese studies, China's water supply is likely to reach its limit by 2030 when its population hits 1.6 billion with an urbanization rate of 60 percent. China's water supply will fall 11 billion cubic meters annually in spite of the improved supply capacity. Beijing is among the most affected cities. (NIC, 2009, p.33).

The Chinese government's national climate change program states: "There are two objectives for development and conservation of water resources in adapting to climate change in China: to promote sustainable development and utilization of water resources; and to enhance adaptive capacity of water resource system to reduce its vulnerability to climate change. How to enhance water resources management, optimize water resources allocation, strengthen infrastructure construction, ensure the anti-flood safety of large rivers, key cities and regions, promote nationwide water-saving program, guarantee safe drinking water and sound social and economic development, and make a good use of river functions while protecting aquatic ecosystem are the long-term challenges on water resources development and conservation in terms of enhancing climate change adaptation capability" (CNCCP, 2007, p.22)

Community Resilience – Habitat & Infrastructure

Pressures on agriculture are likely to cause an influx of immigrants to urban areas, transferring resource and social stress to Chinese cities. Coastal regions are vulnerable to storm flood and sea level rise.

"Due to their flat and low landscape, China's coastal regions, the engine of China's economic achievement, are highly vulnerable to storm, flood, and sea-level rise. The increasing frequency and intensity of extreme weather events such as typhoons has threatened economic development at local, regional, and national levels. China has been actively developing early warning systems and related monitoring systems and improving the design standards of sea dikes and port docks. These efforts may help buffer some risk of natural weather extreme events" (NIC, 2009, p.4).

"Frequent and prolonged droughts and floods will not only affect livelihoods, but also damage the local, regional, and national economy. With 300 million workers, agriculture, which is highly water-dependent, may be at greater risk than all other sectors. The negative impacts on agriculture will bring high risk for China's food security but also lead to an influx of immigrants to urban areas for jobs, transferring resource and social stress to Chinese cities"(NIC, 2009, p.33).

A 2009 MET Office report adds: "In most cities around the world, the temperatures recorded in the urban environment can be significantly greater than the surrounding countryside. However, in most Chinese cities this 'urban heat island effect' is offset by the severe pollution which blocks much of the incoming solar radiation. As climate change raises temperatures, and if emissions are restricted, this influence could be overcome and temperatures in Chinese cities could increase significantly, possibly affecting the productivity of industry and workers. Industries could also be affected in other ways by climate change. China relies heavily on manufacturing goods for export and metal/ore extraction and processing. Such industries could see declines in productivity if the environmental effects of a changing climate, such as water shortages or flood, impact upon them more regularly" (MET Office, 2009, p.7-8).

Habitat & Infrastructure – Water Availability

North China is likely to have severe problems meeting water needs while the coastal areas of the south are vulnerable to sea level rise.

"Climate change has brought certain impacts on the coastal environment and ecosystems of China in some extent, mainly represented by the accelerating trend of sea level rise along the Chinese coast in the past 50 years, which resulted in coastal erosion and seawater intrusion, as well as mangrove and coral reef degradation. The future climate change will have even greater impact on the sea level and coastal ecosystems of China. Firstly, the sea level along the

Chinese coast will continue to rise. Secondly, the frequency of typhoon and storm surge will increase, aggravating the hazards induced by coastal erosion. Thirdly, some typical marine ecosystems, including coastal wetlands, mangroves and coral reefs, will be further damaged" (CNCCP, 2007, p.18).

"It is estimated that in North China only 70% of the future water requirement from surface and groundwater sources for agricultural production will be met due to the combined effects of climate change and increased demand (Liu et al., 2001). River flows are expected to change, with the risk of flooding increasing during the wet season and the possibility of drought and unsustainable use (over-abstraction) of river and groundwater aquifers during the dry season. The retreat of glaciers and reduction in snow cover and its early melting may temporarily increase the spring flows, but as temperatures rise and the snow and ice disappear, stresses could arise in West and North China where lots of the population depend on meltwater for consumption, irrigation and livestock (Cruz et al., 2007; Stern, 2007). Rapid melting of glaciers and snow melt could also lead to increased flooding and land- and mud-slides" (MET Office, 2009, p.4-5).

Water Availability - Ecosystems Services

Desertification is advancing at alarming rates, while salt water intrusion along the coastline is affecting ecosystems. Dams are also creating environmental problems.

The National Climate Change Program of the Chinese government reported in 2007: "China's total area of desertification for 2005 is 2.63 million square kilometres, accounting for 27.4% of the country's territory. China has a continental coastline extending over 18,000 kilometres and an adjacent sea area of 4.73 million square kilometres, as well as more than 6,500 islands over 500 square meters. As such, China is vulnerable to the impacts of sea level rise" (CNCCP. 2007, p15).

"Desert expansion has accelerated with each successive decade since 1950. China's Environmental Protection Agency reports that the Gobi Desert expanded by 52,400 square kilometres (20,240 square miles) from 1994 to 1999, an area half the size of Pennsylvania. With the advancing Gobi now within 150 miles of Beijing, China's leaders are beginning to sense the gravity of the situation. The dust bowl currently forming in China is much larger than the one that formed in the Great Plains of the United States during the 1930s when the US population was only 150 million—compared with 1.3 billion in China today. The increase of dust storms may also lead to severe air pollution episodes, destruction of vegetation, erosion of surfaces, and change in soil pH values, affecting agricultural production, downwind of their source" (NIC, 2009, p.21).

"Over-abstraction, rising sea levels and increasing frequency of droughts have lead to progressive saltwater intrusion along the coastline of China (Cruz et al., 2007)… Additionally, poor design of dams can significantly reduce the volume of sediment transported downstream into deltas, thereby starving the delta of sediment supply and allowing further saline intrusion into aquifers (Cruz et al., 2007)" (MET Office, 2009, p.5).

Ecosystems Services - Community Resilience

Climate related disruption Ecosystem services – such as storage and filtering of water –can have a significant impact on local communities.

The potential reduction in the quality and quantity of key ecosystems services due to climate change will have significant impact on community Resilience in China, in particular in Chinese cities. The WWF's 2009 report on the impact of climate change on megacities in Asia offers the following example for Shanghai: "Climate change is a major threat to Shanghai and is best illustrated by the substantial damage that occurred in 2006. The combined effects of sea-level rise, storm-surge, coastal erosion, and salt water intrusion significantly impacted Chinese coastal economies, including Shanghai. For example, in 2006, salt water intrusion and coastal erosion impacted a large portion of the Yangtze Delta region. Specifically, salt water intruded into Shanghai's water supply and greatly reduced the quality of groundwater…Unfortunately, this salt water intrusion also impacted local ecosystems, such as wetlands, which can greatly improve water quality by naturally filtering pollution and debris. These coastal areas also provide habitat for aquatic species like fish, which also support a significant portion of food and livelihoods for Shanghai's poorest residents. The events in 2006 also illustrate how damaging tropical storms and typhoons can be. One such storm, tropical storm Bilis, affected nearly 32 million people, and around 3.4 million were relocated. This one tropical storm damaged over 1.3 million hectares of crops and caused an additional 250,000 hectares to go unharvested. Additionally, nearly 900,000 houses either collapsed or were damaged" (WWF, 2009, p.23-24).

"The IPCC suggests that the frequency and intensity of storms in this region will likely increase with climate change and as in 2006, damages will rise. Unfortunately, the Yangtze delta is particularly vulnerable to typhoons, and resulting storm surges as high as 5.2 m have been measured in the past. Sea-level rise is being compounded by subsidence throughout the Yangtze River Delta (also referred to as the Changjiang Delta). The current subsidence is estimated at 2.0 to 2.6 m, and as more and more people are being drawn to Shanghai, the increased use of groundwater is resulting in accelerated subsidence. Further, projections of sea-level rise range from 50 to 70 cm by 2050. Models indicate that with 0.3 m sea-level rise, the area inundated will be 54,500 km2. Flooding is another significant climate change threat in the Yangtze River Delta. …Shanghai is vulnerable to climate change, and the events of 2006 show how the combination of tropical storms, sea-level rise, coastal erosion and salt-water intrusion will impact China's megadelta metropolitan areas" (WWF, 2009, p.24). The WWF report give a similar assessment for the city of Hong Kong (see WWF, 2009, p.27-28).

Ecosystems Services - Habitat & Infrastructure

A significant impact of climate change will be sea level rise impacting ecosystems like mangrove. The heavily populated lowland and mega deltas will find their infrastructures significantly challenged.

"Climate change will have a considerable impact on the ecosystems and biodiversity of China. One of the most significant impacts will be sea level rise leading to a decrease in the extent of current coastal environments, such as mangroves, although new areas could form over time if low-lying land becomes flooded. (MET Office, 2009, p.6)

The MET Office (2009) warns: "The increasing incidences of extreme weather events and other environmental stresses could lead to more rapid declines in the condition of infrastructure across the country. It is likely that the weather events that different types of infrastructure are built to withstand will occur more regularly, and that more intense events will also increase in frequency, putting many types of infrastructure at significant risk by the middle of the 21st century. Sea level rise and coastal erosion will exacerbate any deterioration due to rising temperatures" (MET Office, 2009. P.8).

The lowlands and mega deltas of East China, including those that are home to millions of people, are particularly vulnerable even to relatively small rises in sea level. Modelled scenarios suggest that current protection in the form of sea defences may not be adequate with moderate to high sea level rises. Many of these settlements are also at risk from storm surges. As sea levels and storm intensities rise with climate change, the degree of risk to these settlements from storm surges is also likely to increase" (MET Office, 2009, p.5).

Ecosystems Services - Health & Wellbeing

The long term effect of large scale environmental degradation will impact on human health and well being.

Increasingly the World Health Organization is recognizing the direct link between the quality of ecosystems services and human health and wellbeing (Waltner-Toews, 2004, p.90). The long term effect of large scale environmental degradation will have significant impact on people's health and on therefore the Chinese economy.

China's National Climate Change Programme identified the main ways in which ecosystems services will be affected by climate change. It predicts: "Firstly, the geographical distribution of major forest types will shift northward and the vertical spectrum of mountain forest belts will move upward… Secondly, forest productivity and output will increase to different extents…Thirdly, the frequency and intensity of forest fires and insect and disease outbreaks are likely to increase. Fourthly, the drying of inland lakes and wetlands will accelerate…The area of coastal wetlands will reduce and the structure and function of coastal ecosystems will be affected. Fifthly, the area of glaciers and frozen earth is expected to decrease more rapidly…Sixthly, snow cover is subjected to reduce largely with significantly larger inter-annual variation. Seventhly, biodiversity will be threatened. The giant panda, Yunnan snub-nose monkey, Tibet antelope and

Taiwania flousiana Gaussen are likely to be greatly affected" (CNCCP, 2007, p.17).

Ecosystems Services - Food & Agriculture

Climate change will cause increased instability in agricultural production, where the yields of three main crops, i.e. wheat, rice and maize, are likely to decline if no proper adaptation measures are taken.

As temperature and precipitation patterns have changed over recent decades, the suitability and demands of agricultural land in China have changed, with over 30% of agricultural land requiring irrigation (Thomas, 2008)...It is likely that the large year-on-year variability of seasonal rainfall, caused mainly by the timing and intensity of the summer monsoon, coupled with irrigation demands, will have a greater impact on crop production, at least during the first few decades of the 21st century, than the projected northward-drift of agricultural areas (Thomas, 2008). Increased temperatures could also influence the growth and mortality patterns of crop diseases and pests, with some species not being killed off in the winter and others able to reproduce more and spread further during the growing season (Cruz et al., 2007). Crop yield could be affected by climate change. A study conducted by the International Rice Research Institute showed that rice yield decreased by 10% for every 1°C increase in growing-season minimum temperature (Peng et al., 2004), and further studies looking specifically at rain-fed rice varieties in China estimate drops in rice yield between 5 and 12% with a 2°C increase in mean air temperature (Lin et al., 2004)" (MET Office, 2009, p.6).

The Chinese government's own assessment of future climate change impacts is similar: "Climate change has already had certain impacts on agriculture and livestock industry in China, primarily shown by the 2-to-4-day advancement of spring phenophase since 1980's. Future climate change can affect agriculture and livestock industry in the following ways: increased instability in agricultural production, where the yields of three main crops, i.e. wheat, rice and maize, are likely to decline if no proper adaptation measures are taken; changes in distribution and structure of agricultural production as well as in cropping systems and varieties of the crops; changes in agricultural production conditions that may cause drastic increase in production cost and investment need; increased potential in aggravation of desertification, shrinking grassland area and reduced productivity that result from increased frequency and duration of drought occurrence due to climate warming; and potentially increased rate in disease breakout for domestic animals" (CNCCP, 2007, p.16).

The MET Office (2009) reports: "As sea surface temperatures increase and ocean circulation patterns change, overall primary production is projected to decrease in the seas of China and fish larvae become less common in coastal waters. This could have an impact on the fishery sector of East Asia, with declining stocks or changes in the types of fish available for farming or capture (Cruz et al., 2007). This could have further impacts on worldwide fish supply, with nearly one quarter of the tuna caught around the world coming from East and South-East Asia oceans. (Cruz et al., 2007)" (MET Office, 2009, p5-6).

Food & Agriculture – Community Resilience

Climate change may threaten China's food security.

"Besides water crisis, climate change may threaten China's food security. Global warming could — if the worst predictions of scientists come true — lead to a drop of between 20 and 37 percent in China's yield of rice, wheat and maize over the next 20 to 80 years, according to a report published in September 2004 by the Chinese and British governments. In a more recent report commissioned by Greenpeace, scientists from the Chinese Academy of Agricultural Sciences have warned that temperature rise, water scarcity and loss of arable land could cut China's overall food production by 14 to 23 percent by 2050. In 2008, a series of winter storm events affected large portions of southern and central China. Heavy snows, ice and cold temperatures caused extensive damage. It was China's worst winter in half a century. In early 2009, a severe drought in northern China – considered the country's breadbasket – has hit almost 43% of the country's winter wheat crop. The expectation of withered harvest has already driven up world wheat price. All these events are consistent with the trend of global warming: more extreme weather conditions, more droughts in the dry north. They foreshadow a turbulent climate future" (Wen, 2009, p.11).

Food & Agriculture – Health & Wellbeing

Climate change may threaten China's food security.

"Recent studies show that climate change is likely to significantly influence China's agricultural output. By 2030, overall crop productivity in China could decrease by as much as 5- 10 percent if no action is taken. By the second half of the 21st century, climate change could cause reductions in yields of rice, maize and wheat of up to 37 percent. In the next 20-50 years, agricultural production may be seriously affected, compromising long-term food security in China. The North China Plain is the largest agricultural production area in China. NIC 2009, p.21-22)

A 2008 World Bank report on how climate change may affect food security in China concludes: "Several studies addressing the supply and demand for food in China suggest that the nation can largely meet its needs in the coming decades. However, these studies do not consider the effects of climate change. This paper examines whether near future expected changes in climate are likely to alter this picture..[Our] analysis demonstrate that global warming is likely to be harmful to China but the impacts are likely to be very different in each region… Although we were able to measure the direct effect of precipitation and temperature, we could not capture the effects of change in water flow which will be very important in China." (World Bank, 2008,p.i).

Water Availability – Food & Agriculture:

Effects of climate change on food production affect the availability of water.

"Can China continue feeding itself if climate changes? Based on the empirical results, the likely gains realized by some farmers will nearly offset the losses that will occur to other farmers in China. If future climate scenarios lead to significant reductions in water, there may be large damages not addressed in this study" (World Bank, 2008,p.i).

The extensive use of groundwater for irrigation agriculture under variable climatic conditions has resulted in the rapid decline of the groundwater table, especially in areas north of the Yellow River, leading to hydrological imbalance and unsustainable agricultural production. Future climate change is likely to exacerbate the problem. If the negative impacts of climate change are not effectively controlled, Chinese experts warn that the production of wheat, rice, and corn will be reduced by 37 percent in the late 21st century" NIC 2009, p.21-22). "It should be also noted that the global warming could induce an increase in evapotranspiration, which may result in a water deficit in the rice area, particularly in the North and Northeast China where the annual precipitation is generally less than 700 mm. [But] We conclude that rice production in China is likely to benefit from global warming due to the extended length of rice growing season that allows earlier planting and later harvesting, the reduction of low-temperature injury, and the northward expansion of rice-planting area, while the increasing plant diseases and insect pests and water demand must be recognized." (Huang *et al.*, 2009).

Food & Agriculture – Habitat & Infrastructure

China has a limited capacity for agricultural production with a low per capita area of cultivated land and an underdeveloped agricultural economy.

"China not only encounters frequent agricultural meteorological disasters that cause long time instability in agricultural production, but also features low per capita cultivated land, a less developed agricultural economy and a very limited capacity for adaptation. In coping with the climate change, how to rationally adjust agricultural production distribution and structure, improve agricultural production conditions, control the prevalence of plant diseases and pests/insects and spread of weeds, reduce production cost, prevent the potential desertification expansion, and ensure sustainable development of China's agricultural production are some of the aspects that pose long-term challenges for China agricultural sector in terms of improving its capacity of adapting to climate change and resisting climatic disasters" (CNCCP, 2007, p.21).

However, as many studies reveal, climate change may bring some positive impacts on China's forestry productivity and output. Data show that the growing season has been extended by 1.4 to 3.6 days per year in the northern regions and by 1.4 day per year across the country between 1982 and 1993. According to a Chinese study published in 2007, net primary productivity grew by 11.5 percent between 1982 and 1999 due to climate change" (NIC, 2009, p.20).

1.6.3 Adaptive Capacity

China is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
China	0.40	0.50	0.67	0.50	**MEDIUM 20.67**

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.7 Southern Africa Direct Impact Pattern

Southern Africa includes South Africa, Namibia, Botswana, Zimbabwe and Mozambique.

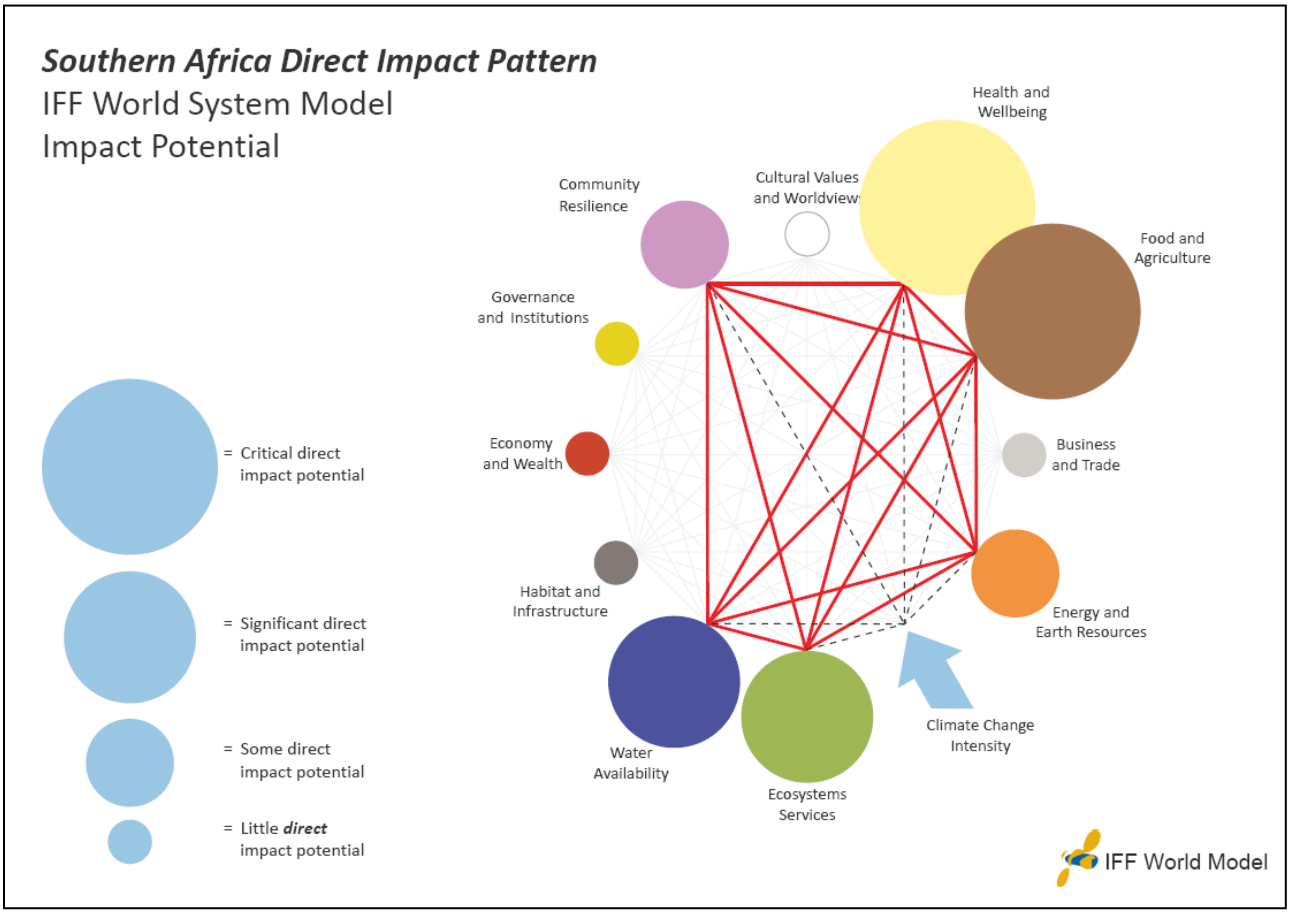


Figure 1.7.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects.

1.7.1 Overview

The International Institute for Sustainable Development (IISD) summarizes the main effects of climate change in Africa as follows: "There are three factors that make Africa particularly vulnerable to the impacts of climate change (Garcia, 2008). The first is Africa's position on the globe; Africa already has a warm climate and is exposed to inconsistent rains with large areas characterized by poor soils or floodplains. Already the Sahelian climate is described as “perhaps the most dramatic example of climatic variability that we have quantitatively measured anywhere in the world”. Second is the fact that many of Africa’s economies are dependent on sectors that are susceptible to climate fluctuations, such as agriculture, fisheries, forestry and tourism. Agriculture represents on average between 20 to 30 per cent of GDP in sub-Saharan Africa and makes up 55 per cent of the total value of African exports. Meanwhile, depending on the country, between 60 and 90 per cent of the total labour force in sub-Saharan Africa is employed in agriculture.

Third is the socio-economic context: the lack of good governance; persistent and widespread poverty; poor economic and social infrastructure; conflicts; and limited human, institutional and financial capacities means that as a continent, Africa is least able to adapt to the effects of climate change” (Brown & Crawford, 2009, p.12).

The South African department for Environmental Affairs and Tourism (DEAT) is responsible for the national monitoring and research on climate change impact. DEAT predicts: “Changes in our climate may have significant effects on various sectors of South African society and the economy. The South African Country Studies Programme identified the health sector, maize production, plant and animal biodiversity, water resources, and rangelands as areas most vulnerable to climate change” (DEAT, 2009).

Dependence on coal for electricity means South Africa emits more greenhouse gases per person than many industrialized countries, with Carbon dioxide from the energy sector as the main source of our greenhouse gas emissions. Poverty and inequality levels and still extremely high in South Africa and are increasing. The DEAT report continues: “When the Government of South Africa used internationally agreed scientific computer models to explore the potential impacts of climate change on South Africa over the next 50 years, it predicted: A continental warming of between 1 and 3 deg C; Broad reductions of approximately 5 – 10 % of current rainfall, but with higher rainfall in the east and drier conditions in the west of South Africa; Increased summer rainfall in the northeast and the southwest, but a reduction of the duration of the summer rains in the northeast, and an overall reduction of rainfall in the southwest of South Africa; Increased rainfall in the northeast of the country during the winter season; Increased daily maximum temperatures in summer and autumn in the western half of the country. Wetter conditions with a reduction in frost, which could see malaria mosquitoes expand their range onto the Highveld" (Oxfam, 2009, p.1).

1.7.2 Systemic Relationships – Principal Paired Interactions (15)

Health & Wellbeing – Community Resilience

Climate Change will worsen the vulnerabilities of South Africa's poor, who make up the majority of the population.

The South African Department of Environmental Affairs and Tourism (DEAT, 2009) emphasizes: "The potential impact of climate change on the health of the South African population has not been modelled (as it has been in other countries, for example in the United States of America). Indirect health effects anticipated to occur locally include the following: i) mortalities and increased incidence of infectious diseases and respiratory diseases due to increased surface temperatures. The likely occurrence of epidemics of infectious diseases are related to changes in the distribution of disease carriers and to reduced cellular immunity in humans as a result of ultraviolet exposure; ii) increases in respiratory diseases due to ambient air pollution. Higher ambient temperatures are likely to result in increased ozone levels, with longer lasting peaks predicted in urban areas early in the day; iii) Increased incidence of skin cancer, eye diseases, and immune suppression due to exposures to higher ultraviolet radiation levels."

"Indirect effects of global climate change on human welfare are related to the potential impacts on biodiversity and ecosystems and on the availability of agricultural land and water for irrigation. The potential for crowding, malnutrition and starvation, allergic diseases, and suffering due to weather extremes has also been noted. … It is predicted that the area of the country prone to malaria could more than double in the next 50 years, and that 7.8 million people could be at risk, of whom 5.2 million did not previously live in areas at risk from malaria" (DEAT, 2009).

Oxfam (2009) warns: "As the climate changes, it is South Africa's poor, the majority of the population, who will be the hardest hit. Climate change worsens existing vulnerabilities and adds to the pressures on the environment and natural resources on which so many South Africans directly rely. Climate change could increase the prevalence and distribution of vector-borne diseases such as malaria and dengue fever and water-borne diseases such as cholera and dysentery. Such things mean that people living with HIV and AIDS in particular would experience increased risks" (Oxfam, 2009, p.1).

Health & Wellbeing – Energy & Earth Resources

Mining industries may be adversely affected as workers contend with the health impacts of climate change and mining infrastructures have to be adapted to higher temperatures.

A recent report on climate change and the global mining industry points out: "In parts of Sub- Saharan Africa companies are facing soaring costs from employee health care and training, as well as elevated rates of absenteeism from diseases. In South Africa an estimated 30% of all gold mining employees are HIV- positive. Mining companies have calculated that HIV adds between $4 and $10 an ounce to production costs from South African mines. Whilst there is no direct impact between climate change and HIV, there are potential indirect impacts, arising from increasing stress on social and economic systems. Climate change will affect the health of the human capital upon which businesses rely, including staff, labour pools, sub-contractors and commercial partners. This will create additional costs for mining companies through lower productivity, compensation claims and disputes, and business interruption" (Acclimatise, 2010, p.6).

"Under a changing climate, risk of death, disease or injury from heat waves, floods, storms, fires and droughts for mining operatives will increase. These occupational risks will affect both indoor and outdoor workers. The safety and performance of buildings, structures and other assets that may not be climate-resilient could also translate into increased costs to ensure worker safety, comfort and productivity. For example, warmer working conditions are a concern for health, safety and levels of performance. They can lead to diminished mental task ability, increased accident risk and, if prolonged, heat exhaustion or heat strokes. These can significantly affect the productivity of outdoor, production line and factory workers. In order to reduce impacts, it is likely that we will see regulations on maximum workplace temperatures with significant compliance cost implications for mining companies" (Acclimatise. 2010, p.7). "In South Africa gold mining companies' production fell by almost 20% on a year-on-year basis in the first quarter of 2008 due to electricity shortages" (Acclimatise, 2010, p.11).

Health & Wellbeing – Water Availability

Water scarcity and poor quality will impact on human health, while water borne diseases may spread as the result of floods.

The IPCC (2007) reports: "Assessments of water availability, including water stress and water drainage, show that parts of southern Africa are highly vulnerable to climate variability and change. [Models predict] possible heightened water stress in some river basins" (IPCC, 2007, p.451).

The South African Department for Environmental Affairs and Tourism (DEAT) suggests: "Even without climate change, it is predicted that, within a few decades, South Africa will be using up most of its surface water resources. The most significant impacts of climate change on water resources are the potential changes in the intensity and seasonality of rainfall. While some regions may receive more surface water flow, future problems are likely to include water scarcity, increased demand for water, and water quality deterioration. Climate change may also alter the magnitude, timing, and distribution of storms that produce flood events. Arid and semi-arid regions, which cover nearly half of South Africa, are particularly sensitive to changes in precipitation, and desertification, which is already a problem in South Africa, could intensify" (DEAT, 2009).

Various diseases may spread as an effect of climate change. "In 1996, 3 to 4 million people were infected with one or more species of schistosomoa in South Africa. Modeling suggests that, as temperatures rise, larger areas of South Africa could be favourable to the survival of schistosomoa, and, consequently, a greater portion of the population will be at risk of infection. With increases in unexpected weather phenomena such as flooding, the distribution of the snail host may extend further, bringing with it the potential for urinary schistosomiasis in areas that are currently free of the disease. Community Water Supply and Sanitation projects currently being undertaken by the Department of Water Affairs and Forestry are designed to contribute to the prevention of infection" (DEAT, 2009).

Water Availability – Community Resilience

Already vulnerable communities/households will need to adapt to unexpected climate effects, which could be very costly.

A case study of the International Food Policy Research Institute (IFPRI) in South Africa's Limpopo River Basin focused on the vulnerability of communities to climate change related impacts. It concluded:

"While the impact of droughts on income was found to be statistically insignificant, and the majority of households said they "did nothing" in response to droughts, this does not necessarily mean that farming households in South Africa's Limpopo River Basin are prepared for future changes in climate patterns. Climate change is expected to bring a number of unexpected climate-related shocks requiring new adaptive behaviour to mitigate their impacts. As a result, adaptation could be very costly, especially for those least able to bear that cost. The vulnerability break-downs can help policymakers identify households that are not currently poor but are at risk of becoming poor in the future. Given that climate change will involve a redistribution and intensification of risk, attention to vulnerability is important. Given that predicting the actual effects of climate change is fraught with difficulties due to high levels of uncertainty, identifying households that are vulnerable to climate stresses will help to reduce future poverty" (IFPRI, 2008, p.2)

The Met Office's 2008 report on climate impacts on South Africa suggested: "Food supplies and water quality issues could also be affected by increases in temperatures and heatwaves, further straining the health of the population. Occurrences of diarrhoeal and other bacterial diseases are very likely to increase as temperatures and water quality issues rise. Changes in occurrence of *Salmonella*, *E. coli* and other food poisoning bacteria are known to be associated with rises in ambient air temperature (Fleury et al., 2006). Bacterial infection from contaminated water will possibly increase in the future as heavy rainfall and rising temperatures, as well as increased incidences of toxic algal blooms, lead to pollution of recreational waters and increased need for treatment of drinkable water (Christensen et al., 2007)" (Met Office, 2008, p.5).

"Air pollution is very likely to increase as surface ozone concentrations rise with increased temperatures, inducing increased incidence of asthma and other cardio-vascular and respiratory diseases. Pollen and other particulate matter may also increase in concentrations, especially if there is increased growth of plants and there are more wildfires. Occurrences of a number of those diseases which can be transferred from animal to human such as malaria, are often related to climatic factors, therefore are likely to change in geographical range and frequency of occurrence. Malaria epidemics have been linked to both temperature and rainfall in South Africa, and appear to show a steady increase overall since 1993 (State of the Environment Report – South Africa, 2008). With warming and changing rainfall patterns, changes in malaria distribution are likely to continue, although further investigations are required" (Met Office, 2008, p.5).

Community Resilience – Energy & Earth Resources

South Africa is faced with a difficult challenge in trying to juggle three imperatives – development (conventionally based on fossil fuels), poverty eradication and climate change. Its energy production is depended on coal, and emissions are very high.

"South Africa is the world's largest producer of gold, chromium and platinum, with the extractions of many other minerals, such as diamonds, playing an important part of the economy. Little work has been conducted into how these heavy industries might be affected by climate change, but some general observations can be made. The infrastructure surrounding mineral extraction, processing and transportation could be significantly affected by an increase in the number of extreme events.

Flooding, storms and heatwaves can all damage infrastructure and could lead to increased stability, access and transport problems around industry. Mining and processing of ores is a highly water intensive activity and the decreases in rainfall projected for South Africa could limit the operation of these industries" (Met Office, 2008, p.6).

Oxfam points out that "South Africa has been playing an influential role as a developing country in the international negotiations even though it is not yet obliged to make commitments to reduce emissions. But South Africa is also part of the problem - the largest emitter of green house gases on the African continent and home to the world's biggest single emitter of CO2. Although it is not (yet) under any legal obligation, South Africa has a moral obligation to reduce its emissions, which would also send a powerful political message to the world and increase the strength of its negotiating position in global climate change talks and its leverage in demanding emissions cuts from rich countries. South Africa is faced with a difficult challenge in trying to juggle three imperatives – development (conventionally based on fossil fuels), poverty eradication and climate change. On the one hand, the country has to fast track provision of adequate transport, power, communication networks, water, sanitation and other infrastructure services. Much of this development implies that South Africa's GHG emissions will increase. The provision of these services is essential to improving people's well being and to reducing poverty" (Oxfam, 2009, p.1).

"Energy production is a particular concern. South Africa's dependency on coal-fired power stations has already resulted in a yearly per capita emission rate of about 10 tons of carbon dioxide, 43 percent higher than the global average. At the same time, this extremely high per capita energy use has not meant that everyone in South Africa has access to energy; 30% of South African citizens do not have access to electricity. South Africa has benefited from an abundant and cheap supply of electricity since the founding of the monopoly public utility, the Electricity Supply Commission (later renamed Eskom) in 1928. Eskom in effect subsidized South Africa's industrial development and is responsible for supplying 95% of the country's electricity – 90% of which comes from coal-fired power stations. Eskom accounts for about half of South Africa's total emissions. Eskom predicts that with electricity supply growing at a potential 4.4% per annum CO 2 emissions from electricity generation would more than double over the next 20 years" (Oxfam, 2009, p.2).

Energy & Earth Resources – Water Availability

Energy production and water availability are inextricably linked and both face challenges from the impacts of climate change.

The Met Office (2008) report on South Africa suggests: "It is possible that thermal power stations will decrease in efficiency in the future as water for cooling becomes warmer or its availability reduces as a result of climate change. It is likely that as precipitation patterns and river volumes change, the management of such sites will need to be carefully monitored. The increased temperatures could also lead to drops in efficiency in generation and supply, particularly in the electricity sector" (Met Office, 2008, p.3).

The World Business Council on Sustainable Development recently highlighted: "Water, energy and climate change are inextricably linked. If we truly want to find sustainable solutions, we must ensure that we address all three in a holistic way. They are pieces of the same puzzle and therefore it is not practical to look at them in isolation. … The search for solutions is complicated because water, energy and climate change are each complex. Examining their interrelationship further complicates the discussion but we must if we are to take the next step toward a sustainable society. They also touch all parts of our culture and are interconnected with other issues, such as our values, ecosystems and livelihoods. To make meaningful progress, we must acknowledge this complexity and use it to our advantage. When you have an energy problem, you most certainly have a water problem. It works the other way, too. And if you are concerned about climate change, you are actually concerned about both energy and water – whether you know it or not. Just as the issues are interconnected, so too are the solutions" (WBCSD, 2009, p.i).

"Eskom uses about 1.5% of South Africa's total freshwater consumption annually while supplying more than 95% of the country's electrical energy and over half of the electricity used on the African continent. Innovative technologies (e.g., dry cooling, desalination of polluted mine water for use at the power stations) means that 200 million litres of water are saved every day compared to other, more common practices. Eskom also influences customers to get them to use electricity in the best way – for every kilowatt-hour of electricity that is saved, approximately 1.26 litres of water is also saved on average. Eskom continued to increase its energy production between 1993 and 2004 (by 43%), but with less water consumption (by 27%)" (WBCSD, 2009, p.11).

Water Availability - Ecosystems Services

Ecosystem services of flood control, improvement in water quality, water storage, and maintaining biodiversity are already seriously threatened, with half South Africa's wetlands destroyed or converted.

"South Africa's water supply is largely dependent on managed surface water resources, with most of the country's rivers dammed to provide regular supply. However, the rainfall recharging supplies is highly unevenly distributed, with the eastern seaboard receiving over 80% of the runoff (State of the Environment Report – South Africa, 2008). With the projected decreases in precipitation, runoff and potential changes in circulation, the slowly improving water and sanitation sectors in South Africa could see security issues and significant declines in quantity and quality (Boko et al., 2007). Lower river flows combined with higher temperatures are likely to lead to less dispersal of pollutants in watercourses and aquifers, while intense rainfall events could result in more diffuse pollution and sediment entering rivers. The higher that is harmful algal blooms are common and low oxygen amounts kill off most of the life in the water body" (Met Office, 2008, p.4).

The IPCC (2007) predicts: "Some biomes, for example the Fynbos and Succulent Karoo in southern Africa, are likely to be the most vulnerable ecosystems to projected climate changes, whilst the savanna is argued to be more resilient" (IPCC, 2007, p.451). Studies published by the South African government (DEAT) show that of South Africa's ecosystems], "aquatic ecosystems are in the worst shape, and are experiencing a rapid loss of functioning. Wetlands are essential in a water-scarce country like South Africa, yet an estimated 50% of South Africa's wetlands have been destroyed or converted. This means they can no longer provide the ecosystem services of flood control, improvement in water quality, water storage, and maintaining biodiversity. The health of river ecosystems is declining on the whole, with effluent pollution continuing to grow. Over-exploitation and degradation of our water resources are incurring high opportunity costs; which refer to the costs associated with giving up an opportunity such as access to healthy water resources" (DEAT, 2006, p.11).

"Freshwater environments near the coast could be at risk from increased saline intrusion as sea levels rise and saltwater infiltrates the aquifers, as well as intrusion as a result of groundwater aquifers being over-abstracted to provide water for irrigation and consumption. Coastal communities and reefs are likely to see increasing surface water temperatures and sea water acidity, both of which could lead to significant drops in the primary production of ocean and the health of the reefs, also leading to coral bleaching" (Met Office, 2008, p.5).

Ecosystems Services - Community Resilience

Biodiversity is important for South Africa because of its role in maintaining ecosystem functioning, its economic value for tourism, and its support of subsistence lifestyles. Climate change could jeopardize all of these.

"South Africa has one of the highest levels of biodiversity in the world. Due to the rich diversity of our plants, animals, and ecosystems, the country contains three globally recognized biodiversity hotspots: the Cape Floristic Region, the Succulent Karoo, and the Maputaland–Pondoland–Albany hotspot. Biodiversity is important for South Africa because of its role in maintaining ecosystem functioning, its economic value for tourism, and its support of subsistence lifestyles. Our ecosystems are the basis of our society and our economy. Healthy ecosystems provide vital services to people: wetlands purify water and control floods, plants remove pollutants from the air and absorb greenhouse gases, and soil supports agriculture. Ecosystem services are of great value to society, in economic, cultural, and spiritual terms. Tourism, which is the fastest growing economic sector in South Africa, is based largely on our natural and cultural heritage, which in turn is based on healthy ecosystems" (DEAT, 2006, p.10).

Ecosystems services and South Africa's biodiversity is one of the major attractions that make it one of the primary destination for wild-life tourism in the World. Climate Change could jeopardize this important national income stream. "South Africa is one of the most ecologically diverse countries in the world. A number of studies conducted have found that South Africa's flora and fauna, many of which are endemic to the region, could be severely affected by climate change. The Fynbos and Karoo biomes, situated predominantly on the Western Cape, are projected to lose between 51 and 61% of species by 2050 (Midgley et al., 2002). The Kruger National Park could see declines in nyala and zebra species of up to 66% also by 2050 (Erasmus et al., 2002) and bird species across South Africa could lose over 50% of their range in the same time due to climate change (Simmons et al., 2004). Areas of grassland and the small amounts of forested areas may move higher in altitude to combat the increasing temperatures, although the topography of South Africa will restrict this somewhat" (Met Office, 2008, p.4-5).

Ecosystems Services - Energy & Earth Resources

The Forestry industry is highly sensitive to climate change.

"The South African forestry industry is highly sensitive to climate change. Currently, only 1.5% of the country is suitable for tree crops and the forestry sector is affected by factors such as land availability, water demand, and socio-economic conditions. General aridification in some areas, due to lower rainfall and higher air temperatures, could affect the optimal areas for the country's major tree crop species, and raise the marginal costs associated with planting in sub-optimal areas. Shifts in the optimum tree growing areas could affect the profitability of fixed capital investments such as sawmills and pulp mills. Lower production would also reduce the planting of trees, which serve as carbon sinks. More temperature tolerant cultivars among the current tree species being planted could be selected for cultivation, but it is probable that more lucrative uses for the land, such as sub-tropical fruits, will compete for the land currently taken up by tree plantations" (DEAT, 2009).

"Following rapid population growth and industrialisation, South Africa is in the process of modernising its energy production and distribution networks. Much of South Africa's energy is from fossil fuels, particularly coal and oil (EIA, 2008). Nuclear power is also used, with plans to build more power stations over the next few decades. However, following the signing of the Kyoto Protocol and committing to reduce its significant greenhouse gas contribution, South Africa is also looking to expand its use of renewable energy (South Africa Info, 2008). It is likely that with increasing temperatures, the demand for heating energy will decrease across South Africa, particularly during the winter, whereas the demand for air conditioning in homes and businesses will increase during the summer months. Summer peaks in energy demand could equal winter peaks over time" (Met Office, 2008, p.3)

Ecosystems Services - Health & Wellbeing

Degraded and degrading ecosystems are less able to provide the services that support human wellbeing, and more likely to create challenges such as an expansion in insect pest and algal blooms.

"Biodiversity is important for South Africa because it maintains ecosystem functioning, has proven economic value for tourism, and supports subsistence lifestyles. The combined effect of climate change, rising human population, and increasing per capita consumption will result in major changes to biodiversity. Climate change scenario modelling indicates that the area covered by the current biomes will decrease by 38–55% by the year 2050 (see this map). Of the 179 species of animals examined, 143 indicated range contractions and 4 are predicted to become extinct. A concern is the predicted expansion of insect pests, such as the brown locust, to areas that were previously cooler" (DEAT, 2009).

"The predicted rise in temperature would raise sea surface temperature, resulting in the migration of species residing along the coast. Studies have also indicated that the occurrence of 'red tide' on the west coast would increase. Dense concentrations of red tide organisms can suffocate fish by clogging or irritating their gills, so that they cannot extract sufficient oxygen from the water. Red tides may also kill indirectly by depleting the oxygen dissolved in the water. Low oxygen levels following such blooms are believed to have caused rock lobsters to attempt to escape the sea on a number of occasions, by crawling on to sand and rocks. Other predicted results of climate change are changes in sand inundation on the eastern coast and a predicted increase in the intensity of storms. Climate change and the resulting loss of biodiversity has the potential to harm the tourism sector, which currently contributes R100 billion each year to our economy. It is estimated that if South Africans do not immediately act to adapt to the effects of climate change, it could cost the country about 1.5% of gross domestic product by 2050" (DEAT, 2009).

Ecosystems Services - Food & Agriculture

Climate change may make existing land degradation worse. speciality crops grown in specific environmentally favourable areas may also be at risk

"Predictions for climate change over the next 50 years are that there will be less rainfall, especially in the western parts of South Africa, and higher temperatures, particularly in the interior. Changes in the distribution and availability of water will cause changes in the patterns of agriculture. … It is likely that we will have more frequent floods and droughts. As rainfall decreases in the west, the habitats of plants and animals will shift to the eastern parts of the country. This could lead to more extinctions, as plants and animals move into areas where landscapes are more transformed by urban and industrial areas as well as by agriculture. Climate change may make existing land degradation worse. The areas that are predicted to dry the most – the Western Cape, Northern Cape, North West, and Limpopo provinces – may suffer increased land degradation. This would lead to reduced agricultural productivity, subsistence livelihoods, and biodiversity" (DEAT, 2006, p.5).

"About 70% of total grain production in South Africa consists of maize. Crop yield modelling predicts that, under a hotter drier climate, maize production will decrease by up to 20%, mostly in the drier western regions" and speciality crops grown in specific environmentally favourable areas may also be at risk…. "In addition, an increase in pests and diseases would also have a detrimental effect on the agricultural sector and invasive plants could become a greater problem" (DEAT, 2004, p.5).

Food & Agriculture – Community Resilience

There are large geographical differences in vulnerability. Policy makers need to target adaptation help appropriately. Rural urban migration is likely to increase.

The International Food Policy Research Institute (IFPRI, 2009) looked at the vulnerability of South Africa's farming sector to climate change and made the following recommendations: "In examining vulnerability at the province level, caution must be taken given enormous heterogeneity in household-level resource access, poverty levels, and adaptive capacity. The IFPRI report recommends: "In light of large spatial differences in vulnerability, policymakers should tailor policies to local conditions. In highly vulnerable regions, such as Limpopo, KwaZulu-Natal, and the Eastern Cape, policy- makers should enact measures (1) to support the effective management of environmental resources (for example, soil, vegetation, and water resources); (2) to promote increased market participation, especially within the large subsistence-farming sector; (3) to stimulate both agricultural intensification and livelihood diversification away from risky agriculture; and (4) to enact social programs and spending on health, education, and welfare to help maintain and augment both physical and intangible human capital." (IFPRI, 2009,p.2).

A reduction of reliance on industrialised mono-cropping and diversification of the range of crops cultivated will reduce vulnerability as well as creating jobs and potentially reducing irrigation needs. …Seed banks that maintain a variety of seed types that preserve biological diversity and provide farmers with an opportunity to make informed choices could be used to counteract the effects of climate change, maintain food security and establish possibilities for profitable specialisation." (DEAT, 2005, p.20).

The Met Office 2008 report on climate change impacts on South Africa suggests "as climate change continues, both external and internal migration is likely to become more important for South Africa. As rural areas experience water and food stresses and the health of the population deteriorates, movement from rural to urban areas could increase. South Africa could also be a recipient of many environmental migrants from surrounding countries potentially less able to adapt to climate change" (Met Office, 2008, p.4).

Food & Agriculture – Energy & Earth Resources

The side effects of biofuels schemes are likely to compromise food security in South Africa.

"Modelling suggests the country as a whole could be an average of 3.4°C warmer by 2100, relative to 1990 figures, and even drier than it already is, with potentially devastating effects on agriculture and other natural sources of food. Already, 34%

of its mostly rain-fed terrestrial ecosystems are threatened or critically endangered. The implications for regional food security are serious. South Africa grows 50% of the subcontinent's white maize, a staple food for much of Africa, and was, until recently, self-sufficient in virtually all major agricultural products. But with the impacts of climate change, the national maize harvest is expected to fall by as much as 10% – 20% over the next 50 years. Other crops such as wheat and sugar cane face similar slumps. Meanwhile, the number of people to feed is rising. But instead of focusing on large-scale adaptation strategies for food security, central Government's primary response to climate change in the agricultural sector has been to invest in biofuels. In 2007 the Industrial Development Corporation and the Central Energy Fund invested R3.2 billion ($413 million) in a scheme to produce a billion litres of biofuels... as with biofuel schemes the world over, it has not been well thought through, and is beset with side effects. It risks depleting water supplies, reducing the land available for food production and (ironically) increasing greenhouse emissions." (Graaff & Joubert, 2009)

Food & Agriculture – Health & Wellbeing

Maize production, a staple crop, needs to increase yearly to meet the needs of a growing population. Climate change is likely to decrease production between 10 and 20%.

The IPCC 2007 reports: "Food security, already a humanitarian crisis in the region, is likely to be further aggravated by climate variability and change, aggravated by HIV/AIDs, poor governance and poor adaptation" (IPCC, 2007, p.451). The South African Department of Environmental Affairs and Tourism (DEAT) observes: "Maize production contributed to 71% of grain production during 1996. To meet the increasing food demand, agriculture has to expand by approximately 3% annually. If the climate becomes hotter and drier, however, maize production will decrease by approximately 10–20% over the next 50 years, and speciality crops grown in specific environmentally favourable areas may be at risk. An increase in pests and diseases would also have a detrimental effect on the agricultural sector, and invasive plants could become a greater problem" (DEAT, 2009).

An article in the *Lancet* by McMichael *et al.* (2007) makes a very interesting connection between climate change and livestock production: “Food provides energy and nutrients, but its acquisition requires energy expenditure. In post-hunter-gatherer societies, extra-somatic energy has greatly expanded and intensified the catching, gathering, and production of food. Modern relations between energy, food, and health are very complex, raising serious, high-level policy challenges. Together with persistent widespread under-nutrition, over-nutrition (and sedentarism) is causing obesity and associated serious health consequences” (McMichael, *et al.*, 2007, p.55).

Water Availability – Food & Agriculture

Range lands are likely to become significantly less productive, and a notable drop in maize production is predicted. The effects on Fruit growing, a major export, have not been studied.

“Previous climate change scenarios predict that rangelands will generally become drier, bringing both direct and indirect effects. With current predictions of wetting in the eastern parts of South Africa, rangelands here may not be affected directly. Nevertheless, lower rainfall and higher air temperatures will affect fodder production and affect the marginal costs of ranching. Over the savannah regions in the northeast of the country, forage production may decrease by about one-fifth, and this would affect the cattle ranching industry by reducing the national herd by about 10%. (Beef production would, however, be less affected, as much of the beef herd is fattened in feedlots before slaughter). In addition, climate change could affect the frequency and spatial extent of livestock disease outbreaks, such as foot and mouth disease. Increased grass fuel load is predicted to increase fire intensities by about 20% by the year 2050” (DEAT, 2009).

“Few specific studies have been conducted into how climate change might affect South African agriculture, which is surprising given the economic gain from the industry. South Africa is one of the world’s largest exporters of avocados, maize and other fruits. Wine is also exported around the world.

Some estimates suggest that with climate change, notable reductions in maize production will occur (Boko et al., 2007). Without good management practices, land degradation and desertification (severe drying out of the soil) is increasingly likely. Output could drop in the agricultural sector by up to 90% by 2100, with small subsistence farmers most severely affected (Benhin, 2006). Although if adaptation measures are implemented in the near future some negative impacts might be alleviated. Fish stocks could be affected by climate change with some estimates showing declines in productivity along the South African coastline of up to 60% during the 21st century (Clark et al., 2003)" (Met Office, 2008, p.4).

1.7.3 Adaptive Capacity

Southern Africa is graded as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Southern Africa					**MEDIUM 19.87**
South Africa	0.60	0.50	0.83	0.50	
Namibia	0.60	0.83	0.67	0.50	
Botswana	0.60	0.83	0.67	0.50	
Zimbabwe	0.20	0.17	0.17	0.50	
Mozambique	0.60	0.67	0.50	0.25	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.8 Brazil Direct Impact Pattern

Brazil is treated alone.

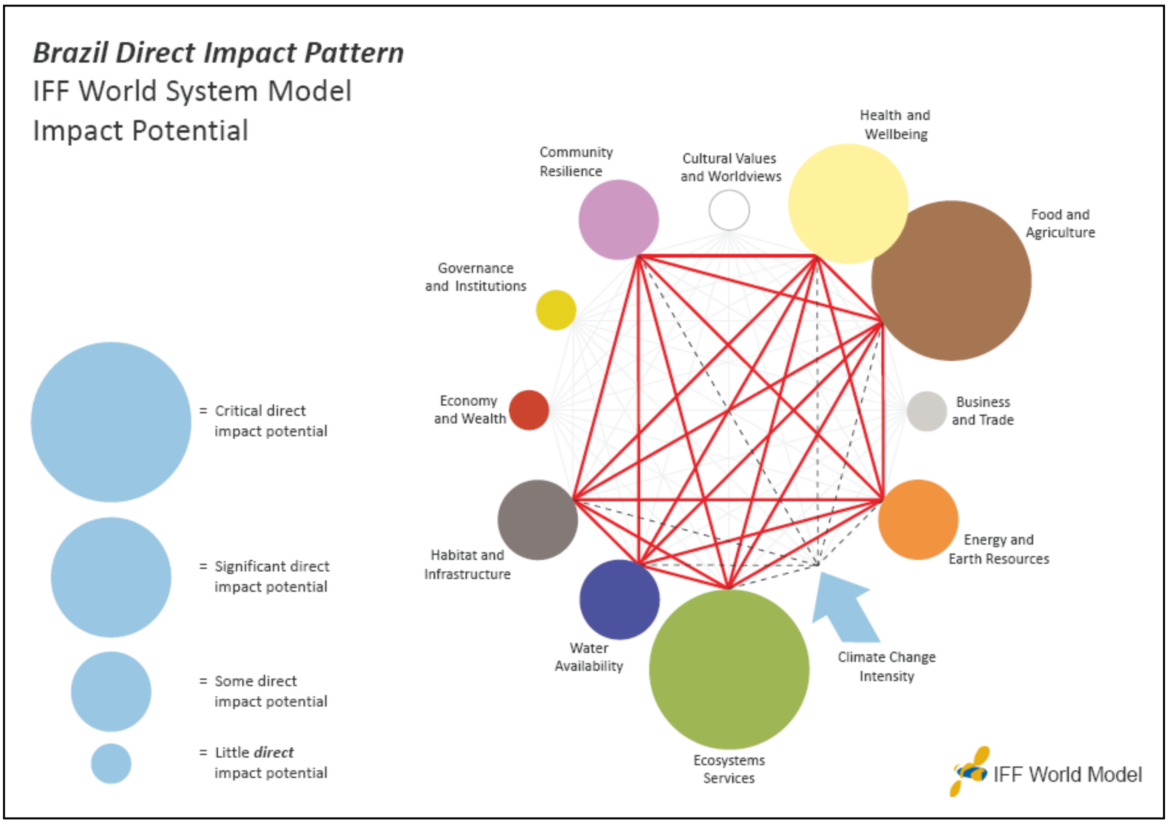


Figure 1.8.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.8.1 Overview

The Met Office (2008) summarizes: "Brazil is one of the few South American countries not to include the Andes and hence has no permanent snowfields. The country is split into four distinct climatic regions: the Amazon Basin, the Brazilian plateau, the coastlands within the tropics and the southern states. The Amazon Basin is the largest area with a typical equatorial climate in the world. Rainfall in some places can exceed 2,000 mm and there is no real dry season.

Temperatures of 27-32°C are typical and night temperatures never reach below zero. South of the Amazon Basin, the Brazilian Plateau has quite a different climate. There is a very distinct wet season with almost all the rainfall, about 1,500 mm, falling between October and April. The dry northeast of the region has a much lower average rainfall (in some places less than 750 mm), but it is also very irregular from year to year, causing prolonged droughts. The tropical east coast has a typically hot tropical climate, although there are significant differences in the season of greatest rainfall from north to south. Near the Amazon mouth all months are wet, but the greatest precipitation amounts occur from December to May (in excess of 300 mm per month). Moving southward the wettest seasons change, being May to August around Receife, and November to April near Rio de Janeiro. Winter in the Southern regions is often affected by cold air from the Antarctic. During summer, temperatures can rise to levels similar to the tropical regions" (Met Office, 2008, p.2-3).

The Met Office report describes how the risks posed by deforestation and climate change are intimately linked. Forests provide water transfer from the soil into the atmosphere and recycle significant amounts of rainfall in some areas of the Amazon, which aid the development of larger circulation patterns. It is more widely understood that forests absorb and store huge amounts of carbon but in addition the Amazon is so huge that it not only modifies the local climate but also helps drive global circulation. It continues "Not all models agree on how the climate over Amazonia is going to change over the 21st century. Most agree that there will be a warming, and some, such as the projections made by the Hadley Centre's models, suggest a drying over this region. These changes could have profound consequences on the health of the forest, practices undertaken therein, and the climate on a much larger scale. … The Amazon Rainforest is regarded as relatively resilient to some climatic drying but… as the climate warms, rainfall declines and water stress increases, some projections show the vegetation of the Amazon starting to die-back, despite the increasing atmospheric CO2 concentrations (Betts et al., 2008a). This releases large volumes of carbon back into the atmosphere, providing a feedback process, accelerating climate change."

Loss of the vegetation then causes less recycling of rainfall into the atmosphere creating further drying of the regional climate. "Deforestation can cause other environmental impacts. Soil becomes degraded, with increasing desertification and salinisation; erosion of the top-soil can occur, polluting rivers with sediment and chemicals; and natural habitats are destroyed. Recent studies combining all these issues have shown that climate change is likely to increase the impacts of deforestation (Betts et al., 2008b)" (Met Office, 2008, p.7).

1.8.2 Systemic Relationships – Principle Paired Interactions (21)

Ecosystem Services – Habitat & Infrastructure

As specialist ecosystems such as mangrove are lost, infrastructure could be at increased risk.

The IPCC (2007) report predicts a severe loss of biodiversity all over Brazil as the impact of droughts, extreme weather events, shifting vegetation patterns, and spread of plant pests take their toll (IPCC, 2007, p.582). Coastal ecosystems are at significant risk from climate change. In particular the mangroves and the species, which are dependent on them along Brazil's Northern and Northeastern coasts, are highly susceptible to rising sea levels and changes to sedimentation. Estimates suggest that in marginal areas, mangrove systems could disappear completely (Met Office, 2008, p.11). Biodiversity loss, impact on fisheries, and increased coastal erosion are among the results of loosing the protective barrier and hatchery function of these important ecosystems.

Energy & Earth Resources – Water Availability

Brazil generates a high proportion of it's electricity through hydro-power. It is not clear how drought years in the Amazon might reduce this capacity.

At present 45.8% of the Brazilian energy supply derives from renewable energy (as compared with 12.9% being the global average). This is due mainly to the large proportion of hydro-electric power in Brazil's energy generation portfolio (Gov. of Brazil, 2008). The challenge will be to maintain and improve on this high percentage of renewable energy generation as Brazil's energy demand rises. It is unclear to what extent drought years in the Amazon caused by changes of the El Nino and La Nina patterns might reduce the hydro-power generating capacity periodically. The energy and mining industry are likely to increase their considerable water demands as climate change continues.

Water Availability - Ecosystems Services

Increased frequency in droughts and changing rainfall patterns could turn parts of the Amazon into savannah, which can in turn have wider impacts on regional climate: Deforestation and climate change are intimately linked (see overview).

In north-eastern Brazil the increased frequency of droughts will lead to increased salinisation and desertification. Towards the end of the 21st century eastern parts of the Amazon could have turned into savannah (IPCC, 2007, p.600).

Ecosystems Services - Community Resilience

Coffee growing may be severely impacted effecting many livelihoods.

"Areas suitable for coffee growing are projected to decreases by anything up to 97% in Brazil (Pinto et al., 2002), and the leaf-miner pest which can affect coffee crops may increase in range and number" (Met Office, 2008, p.8). The resulting reorientation of the agricultural sector will have a significant economic impact. As international financial mechanisms are put in place to promote the preservation and restoration of damaged forest ecosystems (eg REDD) other significant income streams could become available to Brazil (see UN-REDD, 2010, p.1).

Ecosystems Services - Energy & Earth Resources

Biofuel production could result in the collapse of deforested areas into vast degraded pastures.

Another major driver of deforestation is the globally growing demand for biofuels which has driven rapid growth of sugar cane plantations in Brazil, the world leaders in the use of domestically produced bioethanol. "The agro-energy stage now beginning involves rapid frontier expansion and offers various environmental and economic opportunities, but also generates a series of negative ecosystemic and socio-economic impacts, which are both direct and indirect, for tropical regions. The Amazon and the Cerrado are particularly vulnerable. Interacting with climate change and land use, the upcoming stage of cellulosic energy could result in a collapse of the new frontier into vast degraded pasture. The present and future impacts can be mitigated through crafting of appropriate policies, not limited to the Amazon, stressing intensified and more sustainable use of areas already cleared, minimizing new clearing and consolidation of alternatives for sustainable use of natural resources by local communities. Coping with these scenarios requires knowledge of complex causal relationships" (Sawyer, 2008, p.1747).

Ecosystems Services - Health & Wellbeing

A reduction in biodiversity decreases the resilience of an ecosystem to environmental change, and degrades the services they provide that support human health.

The climate variability and temperature rise associated with climate change will lead to a significant loss of biodiversity in the Amazon. The IPCC (2007) A2 scenario predicts extinction of 24% of the 138 tree species of the central Brazil savannah by 2050 (IPCC, 2007, p.596). In Amazonia a loss of 43% of th3 69 tree species is predicted by the end of 21C, along with savannisation of the eastern part (IPCC, 2007, p.606). The direct link between ecosystem health, community health and individual health is increasingly being demonstrated, so we can expect significant effects on human health due to the reduction in biodiversity. A reduction in biodiversity decreases the resilience of an ecosystem to environmental change. Ecosystems become in danger of collapsing or transforming into a new, radically impoverished, stable state if biodiversity is reduced too much. This in turn has drastic effects on ecosystems services and affects human health and wellbeing.

Ecosystems Services - Food & Agriculture

Climate change is likely to lead to salinisation and desertification of agricultural land. The introduction of non-timber forest products into the agricultural industry may help to decrease deforestation.

In the dryer part of the country, such as north-eastern Brazil, climate change is likely to lead to salinisation and desertification of agricultural land, affecting as much as 50% of the agricultural land in those regions by 2050. Climate change is also going to create the conditions for plant pests (particularly in coffee) to spread more widely (IPCC, 2007, p.597).

The government of Brazil is committed to a drastic reduction in the speed of deforestation of the Amazon and a crack-down on illegal logging. The introduction of non-timber forest products into the food & agriculture industry is beginning to create incentives for sustainable management of the native forest (Gov. of Brazil, 2008). The extent to which increased climate variability will increase the bio-productivity of the Amazon is hard to estimate.

A recent publication on the eco-social impacts of biofuel production in Brazil came to the following conclusion: "The apparent biodiesel and alcohol boom in Brazil could collapse into an empty frontier, not unlike the collapse of the rubber economy, except for the dimensions of its devastation… Induced both directly and indirectly by climate change, dieback could result in economic bust, social unrest and political instability. " (Sawyer, 2008, p.1750).

Food & Agriculture – Community Resilience

Communities that grow coffee may be threatened by climate change.

An end of the Brazilian coffee industry would result in a reorganization of agricultural production and might lead to a migration out of coffee-growing areas into the already over-stretched mega-cities. Yet again, it has to emphasized that it is very difficult to make any kind of reliable predictions about the exact impact of climate change. A recent report by the International Trade Centre on the impact of climate change on the coffee industry made the following predictions for Brazil: "Rising temperatures suggest coffee production will become viable in areas formerly considered too prone to frosts. Meteorological agencies report temperatures consistently above the historical average since the 1990's. However, too high temperatures will reduce the overall acreage with climatic potential for coffee production" (ITC, 2010,p.6).

Food & Agriculture – Energy & Earth Resources

Brazil is the world's second largest Biofuel producer. Biofuel production risks global food security in the longer term.

A recent study by the International Institute for Applied Systems Analysis on the relationship between biofuels and world food security came to the following conclusion: “The target of achieving a ten percent biofuels share in transport fuel at the global level can be met but this causes about a fifteen percent increase in the number of people at risk of hunger (i.e., and increase 140-150 million people at risk of hunger as compared to 2008 numbers). In particular the poor urban population, subsistence farmers and the landless in developing countries will bear the brunt. Moreover anticipated greenhouse gas savings from biofuels use can only be expected after 30 to 50 years and that is about the time when climate change impacts will result in increased agricultural vulnerability, particularly in a number of developing countries.

Brazil is the world’s second largest producer of ethanol (after the United States) and the largest producer of sugarcane ethanol (US ethanol is made primarily from corn). Brazil is the world’s largest exporter of the fuel, although most of the ethanol produced in Brazil is consumed domestically. ” (AS & COA, 2009, p.5-6).

To avoid negative impacts of biofuels on food security, any use of first-generation biofuels would need to be preceded by concerted research efforts to increase agricultural productivity.” (IASA, 2009, p.38).

Habitat & Infrastructure – Health & Wellbeing

Inadequate urban infrastructures, particularly in the growing favella, will leave populations vulnerable to changing disease vectors.

“Dengue, a significant health issue in Brazil, particularly in urban areas, could also change in distribution (Hales et al., 2002; Pongsumpun et al., 2008). The disease is spread by mosquitoes which use standing water as breeding sites. In those areas projected to see increases in rainfall, more incidences of dengue could occur. However, there could also be increases during times of drought as water is stored in artificial containers, which may provide suitable mosquito breeding locations …” (Met Office, 2008, p.12).

In addition to health and climate stress, many of the urban poor suffer from the effect of stark inequality and overcrowding. The urban infrastructure, particularly in the favelas is unable to adequately respond to these challenges. This might lead to increasing social tension.

Habitat & Infrastructure – Food & Agriculture

Land degradation increases the pressure to move to urban areas.

Slash and burn agricultural practices, combined with the poor soil quality of the land left behind by the deforestation of the Amazon leads to displacement of people, and continuing relocation of farming operations. In the north-east of Brazil there is an need for significant investment in irrigation infrastructure in order to avoid salinisation and desertification of agricultural land. All the changes in land use patterns drive people off their land and increase the pressure to move to cities

Habitat & Infrastructure – Energy & Earth Resources

The increasing incidences of extreme weather events and other environmental stresses could lead to more rapid declines in the condition of infrastructure across the country.

"It is likely that the weather events that different types of infrastructure are built to withstand will occur more regularly, and that more intense events will also increase in frequency, putting many types of infrastructure at significant risk by the middle of the 21st century. Sea level rise deterioration due to rising temperatures" (Met Office, 2008, p11)

Habitat & Infrastructure - Water Availability

Climate change is likely to exacerbate "water rich" and "water poor" neighbourhoods in Brazil's mega-cities.

The sharp divide between the urban rich and the urban poor is reflected in the quality of infrastructure supplying different parts of Brazil's mega-cities, creating water-rich and water poor neighbourhoods. "Accelerated urban growth, increasing poverty and low investment in water supply will contribute to: water shortages in many cities, high percentages of the urban population without access to sanitation services, an absence of treatment plants, high groundwater pollution, lack of urban drainage systems, storm sewers used for domestic waste disposal, the occupation of flood valleys during drought seasons, and high impacts during flood seasons …" (IPCC, 2007, p.599).

Habitat & Infrastructure – Community Resilience

Major cities located on the coast are at risk. Brazil has a high risk of political instability from the knock on effects of climate change.

"Many South American countries have low-lying coastal areas, and some of the continent's major cities, e.g. Buenos Aires, Rio De Janeiro and Recife, are situated on the coast, with populations of 13 million, 12 million and 1.5 million respectively. These areas are vulnerable to a number of different events, such as tropical and sub-tropical cyclones and coastal flooding, as well as sea level rise (Magrin et al., 2007)" (Met Office, 2008, p.10). As mentioned above, these effects will act as risk multipliers in regions where the inequality gap is already resulting in social tension. Brazil is listed as a country facing high risk of political instability as a knock-on consequence of climate change (Smith & Vivekanada, 2007, p.18)

Food & Agriculture – Health & Wellbeing

The north-east is very vulnerable to the health effects of changing climate.

The agricultural regions of Brazil's North-East are among the country's areas that will be hit hardest by climate change, along with the potentially devastating effect on Brazil's coffee growing areas. "A national assessment of Brazilian regions demonstrated that the north-east is the most vulnerable to the health effects of changing climate due to its poor social indicators, the high level of endemic infectious diseases, and the periodic droughts that affect this semi-arid region (Confalonieri et al., 2005)" (IPCC, 2007, p.601).

Water Availability – Food & Agriculture:

Increase fluctuations in the water supply from year to year are likely to lead to regional droughts and may even cause temporary regional disruption in food supplies.

The water requirements for sugar-cane plantations in support of Brazil's booming biofuel industry, and the water-hungry meat production from cattle ranches are likely to put a strain on local ecosystem and water-supply and quality. In the state of Ceara there could be a significant reduction in stored surface water leading to a sever supply and demand imbalance in the agriculture sector by around 2025 (IPCC, 2007, 597). The IPCC (2007) predicts a long-term decrease in wheat-yields of -30% and in maize-yield of -15%, where as the yield in soya bean is projected to rise by 21% (IPCC, 2007, p.598).

Health & Wellbeing – Community Resilience

Heat stress and water borne diseases will impact on community resilience.

Among the primary impact of climate change on community resilience and health will be changing occurrences of heat stress, malaria, dengue, cholera and other water-borne diseases. The overall temperature increases and a higher incidence of heatwaves is likely to cause increased death and illness, particularly in the very old and the very young, and in other vulnerable groups such as the poor and labourers exposed to these conditions. The heatwaves will have most impact on the cities where the increasing temperatures exacerbate the 'urban heat island effect' (Met Office, 2008, p.11).

Health & Wellbeing – Energy & Earth Resources

Air quality is effected by the burning of biomass, conditions in the Brazilian mining industry could become worse.

The burning of biomass, and slash and burn agricultural practices can have significant impacts on regional air quality and severe health effects in people with prolonged exposure. The conditions in the Brazilian mining industry could worsen due to climate change and affect workers. The UNDP initiated REDD (Reducing Emissions from Deforestation and Forrest Degradation) programme could provide a new framework to protect the health of the forest and help protect its generation of valuable ecosystems services. Yet so far Brazil has not joined this process.

Health & Wellbeing – Water Availability

Water quality as well as drought and floods and water borne disease will impact on human health.

There is likely to be an increase in diarrheal and other diseases due to increasing temperatures and a degradation of water quality. Increased *Salmonella*, *E. coli* outbreaks are known to be associated with a rise in ambient air temperature. "Bacterial infection from contaminated water will possibly increase in the as heavy rainfall and rising temperatures, as well as increased incidences of toxic algal blooms, lead to pollution of recreational waters and increased need for treatment of potable water …" (Met Office, 2008, p.12).

Water Availability – Community Resilience

Community resilience, especially in more vulnerable populations, could be badly if there is inadequate investment in water resource management.

While Brazil is a water-rich country overall, there are regions of relative water scarcity which will require investment in water resource management. Increase climate variability will lead to intense events, which often go on to cause flooding, controlling such volumes of water may be difficult. "Over those areas projected to see decreases in rainfall and/or declines in glacier melt-water, hydropower generation potential could drop… This could be a particular problem for many countries, including Brazil, Bolivia and Peru" (Met Office, 2008, p.8).

Community Resilience – Energy & Earth Resources

Brazil's inequality gap could be improved or exacerbated through development of it's resource base

Brazil is not only the country with the highest proportion of renewable-energy use in it energy portfolio, it is also very resource rich in ecosystems services, fossil fuel reserves, and other raw materials. The sharply rising national revenue from its recent oil discoveries can either exacerbate Brazil's drastic inequality gap, or it can be used to improve conditions for the poorer communities. The latter strategy would help to reduce societal tension as the effects of climate change put a further strain on the poorer members of society.

1.8.3 Adaptive Capacity

Brazil is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Brazil	0.60	0.50	0.67	0.75	**MEDIUM 25.17**

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.9 North Africa Direct Impact Pattern

North Africa includes Egypt, Libya, Tunisia, Morocco, Algeria, Niger, Mali and Mauritania.

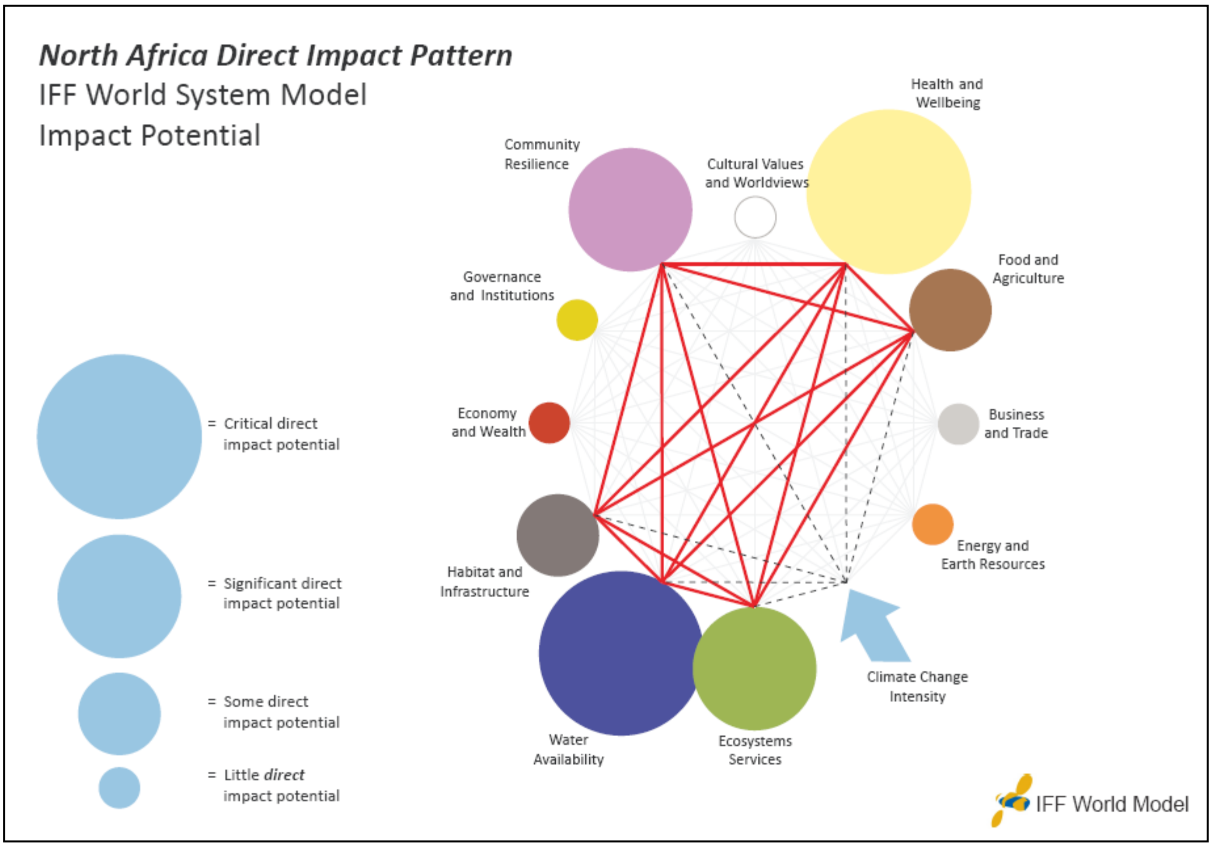


Figure 1.9.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.9.1 Overview

The International Institute for Sustainable Development's 2003 report on *Vulnerability of North African Countries to Climatic Changes* summarizes: "The North African countries are in an arid to semi-arid region with a Saharan climate in the south, an oceanic climate in the west, and a Mediterranean climate in the north. The central part of North Africa, composed of Morocco, Algeria and Tunisia, had 65 million inhabitants in 2000 and is projected to have more than 72 million in 2010. More than two-thirds of the population is predominantly concentrated on the Mediterranean and Atlantic coasts in the north of the region. In these countries, the life of the population is very much linked to the climate and its fluctuations. The economy is very dependent on water, agriculture, tourism and coastlines. This is particularly striking in Morocco and Tunisia. Climate data gathered in the region during the 20th century indicate heating, estimated at more than 1°C, with a pronounced trend in the past 30 years. The data also show a marked increase in the frequency of droughts and floods. The region experienced one drought every 10 years at the beginning of the century, to a current state of five or six years of drought per ten years. The general circulation models, even though they are not accurate enough for the region, since there is no mesh model, converge to estimate probable warming in the region in the order of two to four degrees in the 21st century. Climate change in this part of North Africa (Algeria, Morocco and Tunisia), which emits low levels of greenhouse gases (between 1.5 and 3.5 emission tonnes of CO2/inhabitant/year), represent a veritable threat to the region's socio-economic development and to its population. The extreme vulnerability of the region, coupled with the possible impacts climate change represents, stresses the need for adaptive strategies in key sectors in the region for the long term sustainable development of these countries" (IISD, 2003, p.1).

1.9.2 Systemic Relationships – Principle Paired Interactions (15)

Health & Wellbeing – Community Resilience

The knock on effects of climate change are likely to contribute to political and social tensions that will impact health and well-being.

The International Alert report "A Climate of Conflict" lists Morocco, Mauritania Libya, Egypt, Mali, Nigeria and Saudi Arabia as "states facing a high risk of political instability as a knock-on consequence of climate change" and Algeria, the Chad, Sudan, Jordan, Israel, Syria, and Iraq as "states facing a high risk of armed conflict as a knock-on consequence of climate change" (Smith & Vivekanada, 2007, p.18-19). This shows that North Africa is facing turbulent times among neighbouring states in potential conflicts. The effects of such political and social tensions, or outright armed conflict on community resilience and wellbeing are devastating, particular as over-crowding in cities faced with infrastructure overload and poor water quality, along with increasing streams of migrants amplify the effects and likelihood of such conflicts.

Health & Wellbeing – Infrastructure & Habitat

Stressed urban infrastructures that may well see more rapid expansion due to the effects of climate change are unable to support human health needs such as sanitation.

There has been rapid expansion of slum-like dwellings around the large cities. In most large cities of Algeria and Morocco sewerage infrastructure is lacking. The air quality is critical in cities at certain times of the year, particularly in Algiers, Casablanca, and Tunis (IISD, 2003, p.4). These dwellings are home to migrant streams from sub-Saharan Africa along with rural population that has moved to the city in response to degrading agricultural land. In North Africa "two-thirds of the population live along the coastline and various waste products are dumped into the sea without any treatment. Important tourist activities, particularly along the Mediterranean coast, are degrading the quality of the coastal waters, with noticeable consequences for water-based activities and marine life" (IISD, 2003, p.4). The overuse of water and the dumping of waste are affecting community health and will degrade fisheries.

Health & Wellbeing – Water Availability

Increasing water stress will ensure water becomes a scare resource, which may have a particular impact on health and wellbeing in expanding urban areas.

Water scarcity will be a limiting factor for the creation of other industries. The plans of the Dessert Tech consortium to create vast solar-thermal power stations along the northern border of the Sahara will increase water demand in a region that is already experiencing water scarcity. On the other hand, the revenues from this project could potentially provide the investment into new urban infrastructure and health care provision. “Decreasing water availability and agricultural yields will likely cause a sharp acceleration of the process of urbanization, and add to the pressure that cities are already exerting on natural resources” (Bigio, 2009, p.3).

Water Availability – Community Resilience

Water stress is likely to become much more acute, affecting significantly more people. Vulnerable communities in both agricultural and rapidly urbanizing areas will be at risk.

“Water is primarily used for agriculture (80 per cent), drinking water (13 per cent), and industry (seven per cent). Morocco, Algeria and Tunisia are considered water-stressed (less than 1,000 m3/inhabitant/year), with Algeria and Tunisia being closer to a shortage (less than 500 m3/inhabitant/year). Water quality is sometimes at the lower limit of the standards. The water table is decreasing strongly in recent years, with salinization of some coastal groundwater” (IISD, 2003, p.4). Like in Saudi Arabia, North Africa may see an increasing use of desalinated sea-water for the supply of its coastal and urban population. The considerable energy demand of desalination technology will require large-scale investment in solar-thermal technology.

By 2020, between 75 and 250 million people are projected to be exposed to an increase of water stress due to climate change. The problem of water scarcity is even more acute in North Africa in view of the very high population growth rates and already high rates of water resource use” (APF, 2007, p.9).

Community Resilience – Infrastructure & Habitat

Migration pressures that are likely to be exacerbated by climate change can stress both infrastructure and social cohesion. Natural disasters may be more likely to challenge many communities.

The US National Intelligence Council reports: “In recent years, North Africa has experienced vast migration pressures from both migrants that settle in the region from the south or that use North African countries as a transit area to reach Europe. Thus far, experts have not cited climate change as a driving force for migration in the region; nevertheless, a warmer climate and changing precipitation patterns, which will likely reduce viable cropland and reduce access to water, will increase urbanization and make accommodating the needs of a growing population more difficult. Besides food and water necessities, climate change-related migration may also imply greater demands on infrastructure along the coasts as well as ethnic, racial, or religious clashes" (NIC, 2009. P4).

In addition World Bank senior analyst Antony Bigio (2009) suggests that "the frequency and intensity of natural disasters directly correlated to climate change, and their impact and economic costs will also grow, also on account of the increase of population and physical investments in the urban areas. Natural disasters have significantly increased in frequency and intensity in the region during the last decade. Urban flooding episodes have taken place in many cities, causing huge damages, loss of life and of economic activities. Earthquakes of the past decade have been particularly violent in Algeria and in Morocco" (Bigio, 2009, p.3).

Infrastructure & Habitat – Water Availability

Population growth as well as demands from agriculture, industry and tourism will place ever greater demands on water supply.

"The population of the region is large and continues to experience significant growth. The combined population of Algeria, Morocco, and Tunisia went from less than 60 million in 1994 to nearly 65 million in the year 2000, and should reach more than 72 million in 2010. This population growth was accompanied by rapid and sometimes anarchic urbanization, with the appearance of large cities whose infrastructures were barely adequate to the needs of the population base, particularly in areas affecting the hygiene and quality of life of the citizens: drinking water, sewerage, urban waste and air quality" (IISD, 2003, p.3).

Agriculture, tourism and industry will put increasing pressure on water supplies at the same time as urban populations continue to rise rapidly. "Tourism is an important source of income for most countries of North Africa. Of concern, however, are the large quantities of water this sector demands and the little attention that governments of this region have given to water provision in the past. Thus, increased water scarcity, sea level rise, and increasing temperatures will likely have a negative impact on this sector and consequently the economy of most North African countries” (NIC, 2009, p.4).

Water Availability - Ecosystems Services

Even small reductions in rainfall could have dramatic effects on river flow, threatening ecosystems and accelerating desertification.

The African Partnership Forum reports: “Three-quarters of African countries are in zones where small reductions in rainfall could cause large declines in river water. Climate models show that 600,000 square kilometers classified as moderately water constrained will experience severe water limitations. By 2020, between 75 and 250 million people are projected to be exposed to an increase of water stress due to climate change. The problem of water scarcity is even more acute in North Africa in view of the very high population growth rates and already high rates of water resource use” (APF, 2007, p.9). Falling water quality and increased salinity from seawater incursion along the coast and unsustainable irrigation methods inland are threatening the already fragile ecosystems of North Africa and accelerating desertification.

Ecosystems Services - Community Resilience

Climate change is a risk multiplier of environmental and other types of migration.

The World Bank reports: “The five countries of North Africa (Morocco, Algeria, Tunisia, Libya and Egypt) had in 2005 a total population of 152m, of which 80m or 53% was urban. These numbers are projected to grow by 2030 to a total population of 209m, of which 128m, or 61%, will be urban. This increase of the urban population by 48m, or 60% in 25 years is a major challenge for the countries of North Africa, one that will require extensive planning, investments, and urban governance capabilities. … The cities of the region are the heart of all social, cultural and political life, and the hub of all economic activities. However, they are being increasingly impacted by climate change and its overall consequences on livability and productivity, and coastal cities are the most vulnerable cluster of urban agglomerations.” (Bigio, 2009, p.1-2).

Desertification, water stress, food shortages, spread of disease and armed conflicts are some of the drivers of migration from sub-Saharan Africa. These migrants combine with rural North Africans moving into the coastal cities in response to degrading agricultural land and ecosystems services. Environmentally driven migration, accelerated by the risk-multiplier effect of climate change is likely to be one of the major concerns for North Africa in the coming decades.

Ecosystems Services - Infrastructure & Habitat

If the trend toward soil salinisation persists, vegetation in the region will be compromised and desertification, where land is completely lost for agricultural use, is likely to expand

According to the US National Intelligence council report, "in North Africa, salinisation is widespread and at risk of increasing. The impact on North African economies, compared to the impact on the region's European neighbors, is greater. Countries such as Morocco and Egypt have a considerably larger portion of their population employed in agriculture (44 percent and 28 percent respectively). In addition, the contribution of agriculture to GDP in 2007 is also higher in North Africa—at 16, 14 and 11 percent in Morocco, Egypt and Tunisia, compared to 3 and 2 percent in Spain and Italy, respectively. Additional anthropogenic disturbances such as deforestation, overgrazing in rangelands, non-sustainable irrigation practices, and extractive farming practices, which produce fertility reductions and depletion of carbon stored in the soil, may be contributing to desertification in North Africa. … If the trend toward soil salination persists, vegetation in the region will be compromised and desertification, where land is completely lost for agricultural use, is likely to expand. Desertification, would in turn imply increased emissions of carbon dioxide (as vegetation is lost) and other greenhouse gases, reductions in agronomic productivity, contamination of water resources, and reductions in biodiversity." (NIC, 2009, p.29-30). The maintenance and restoration of North Africa's ecosystems services will be a key strategy in alleviating the considerable pressure on urban infrastructure caused by environmentally and economically induced migration.

Ecosystems Services - Health & Wellbeing

It is probable however that the combined pressures of rising population, migration, environmental degradation, water scarcity, and environmental disasters will have a drastic effect on health and wellbeing, particularly in the fast growing urban populations.

"The southern Mediterranean (Turkey-Algeria) is one of the regions with the largest risk of increased flooding in absolute terms for the 21st century … Coastal cities will be especially vulnerable due to the concentration of poor populations in potentially hazardous areas, such as Alexandria—the second largest city in Egypt. Specifically, studies on the vulnerability of several sectors of Alexandria suggest that with a 30cm sea level rise by 2025, Alexandria will incur land and property losses of tens of billions of dollars, more than half a million inhabitants may be displaced, and 70,000 jobs will be lost. … Low-lying coastal areas in Tunisia, Libya, and particularly Egypt, were identified as having the greatest risk in North Africa. … However, given the lack of tide gauge observational data in the region, the wide range of future estimates in sea level, and the paucity of regional climate model projections for the Mediterranean Sea, a definitive estimate of sea level rise along the coastline of North Africa in the next 20 years is not possible" (NIC, 2009, p.33).

Ecosystems Services - Food & Agriculture

Climate change will impact on agricultural production in complex ways. Capacity to adapt crop types to changing ecoystems will be important.

"Model results are inconsistent regarding future changes in crop yields and agricultural growing seasons in North Africa, and we do not know whether variations in temperature, precipitation, or atmospheric CO2 will be the dominant factor. One modeling study suggests that future increases in atmospheric CO2 concentrations will increase maize yields in Morocco, while other modeling studies suggest that future increases in air temperature will have a negative effect on growing seasons and crop yields in Egypt. Relatively heat-tolerant species, such as maize, are expected to suffer the smallest losses in yield and growing area, while heat-intolerant crops, such as wheat, are expected to suffer the largest losses. In addition, intensive irrigation practices in the region may result in further salinity, which may lead to desertification. Adaptation strategies, including modifications in sowing dates to match climate changes and development of heat-tolerant crop varieties, will likely mitigate some of the expected negative effects on North African agriculture. Development of regional and local climate models in the coming years that include projections of Mediterranean Sea level rise and decreases in the Nile River flow are expected to provide more accurate estimates of future changes in North African agricultural regions" (NIC, 2009, p.3-4).

Food & Agriculture – Community Resilience

Small scale subsistence farming which is crucial for community resilience in some areas is likely to come under pressure.

In the North of the North African countries there are some fertile, well-watered agricultural zones and some forests. The middle of the countries has a steppe-type vegetation, and the South is mainly dessert with some oases planted with date palms. Agriculture is mainly rain-based and thus subject to climatic hazards. Desertification is accelerated, particularly in the south of the region (IISD, 2003, p.4). The potential decrease in agricultural productivity, pressure on scarce resources due to the migrants from Sub-Saharan Africa, and increasing water scarcity is likely to make small scale subsistence farming more difficult, which will impact on community resilience in rural areas.

Food & Agriculture – Infrastructure & Habitat

Better irrigation infrastructure will be needed to support agriculture in drier conditions.

Strong soil erosion with extensive soil degradation is resulting in decreasing yields in rain-based agricultural yields "with grain yields reduced by up to 50 percent in periods of drought. There is an increased water need for irrigation and decreased agricultural production due to lack of water in recent years" (IISD, 2003.p.4). There will be continued economic pressure to export agricultural product to Northern Europe at the same time as the local demand will continue to rise. The increased revenue from energy exports, particularly from the vast solar-thermal plants planned by the European Dessert Tech consortium will possibly help to address this imbalance and help North African countries to invest in a better irrigation infrastructure to safeguard their food supply for the local population.

Health & Wellbeing – Food & Agriculture

Food imports, which may become more expensive, are likely to have to increase as climate change alters agricultural conditions

"Reduced annual rainfall and increased persistence and frequency of droughts related to climate change may have negative consequences on the region. Morocco and Tunisia's agricultural sector has already been largely impacted by increasingly frequent droughts. Egypt, where agriculture is impossible without irrigation, is at risk of being largely impacted. However, model results are inconsistent regarding future changes in crop yields and agricultural growing seasons in North Africa. One modeling study suggests that future increases in atmospheric CO2 concentrations will increase maize yields in Morocco. Nevertheless, as the price of water becomes apparent, North African countries will likely rely more on food imports" (NIC, 2009, p.42).

"Algeria is expected to face serious climate change in the form of increased and faster desertification, as well as increasing water and food insecurity. Only three per cent of Algeria's land is arable: not nearly enough to provide food for its population. This means that Algeria has to import 45 per cent of its local food needs and more than half of its grain. The little viable farmland that exists is at risk of desertification, a process that is expected to accelerate under climate change. Algeria's dependence on food imports is likely to increase and its food security may be extremely vulnerable to international grain shortages. Armed insurgent groups are still active and the country is in a state of socio-economic turmoil. It has been in an official State of Emergency since 1992, with wide-ranging powers for the state and limits on freedoms for political parties. Its continuation today is justified by the government on the basis of the War on Terror. However, many of the issues that led to war in the 1990s have not been resolved and there are militant Islamist groups that are committed to violently overthrowing the state" (Brown & Crawford, 2009, p.21).

Water Availability – Food & Agriculture

Most of North Africa will be under permanent water stress, with rain fed agricultural production falling and irrigation demands – which if poorly managed often have negative effects on overall water quality – increasing.

Intensive irrigation requires lots of water and reduces water quality for direct human consumption. Most of North Africa will be under permanent water stress as the effect of climate change. The IPCC (2007) reports: “Mixed rain-fed and semi-arid agriculture systems will decrease in productivity as the length of the growing season decreases (IPCC. 2007, p.451). One example: “Egypt … could be vulnerable to water stress under climate change. The water used in 2000 was estimated at about 70 km3 which is already far in excess of the available resources… A major challenge is to close the rapidly increasing gap between the limited water availability and the escalating demand for water from various economic sectors. The rate of water utilization has already reached its maximum for Egypt, and climate change will exacerbate this vulnerability. Agriculture consumes about 85% of the annual total water resource and plays a significant role in the Egyptian national economy, contributing about 20% of GDP. More than 70% of the cultivated area depends on low-efficiency surface irrigation systems, which cause high water losses, a decline in land productivity, water-logging and salinity problems... Moreover, unsustainable agricultural practices and improper irrigation management affect the quality of the country’s water resources. Reductions in irrigation water quality have, in their turn, harmful effects on irrigated soils and crops” (IPCC, 2007, p.445).

1.9.3 Adaptive Capacity

North Africa is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
North Africa					**MEDIUM 18.35**
Egypt	0.40	0.33	0.50	0.50	
Libya	0.60	0.67	0.33	0.75	
Tunisia	0.60	0.67	0.67	0.50	
Morocco	0.40	0.50	0.67	0.50	
Algeria	0.40	0.33	0.50	0.50	
Niger	0.40	0.33	0.33	0.25	
Mali	0.40	0.50	0.33	0.25	
Mauritania	0.40	0.33	0.33	0.50	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.10 Central & Eastern Europe Direct Impact Pattern

Central and Eastern Europe includes Romania, Hungary, Czech Republic, Slovakia, Poland, Bosnia, Serbia, Croatia and Bulgaria.

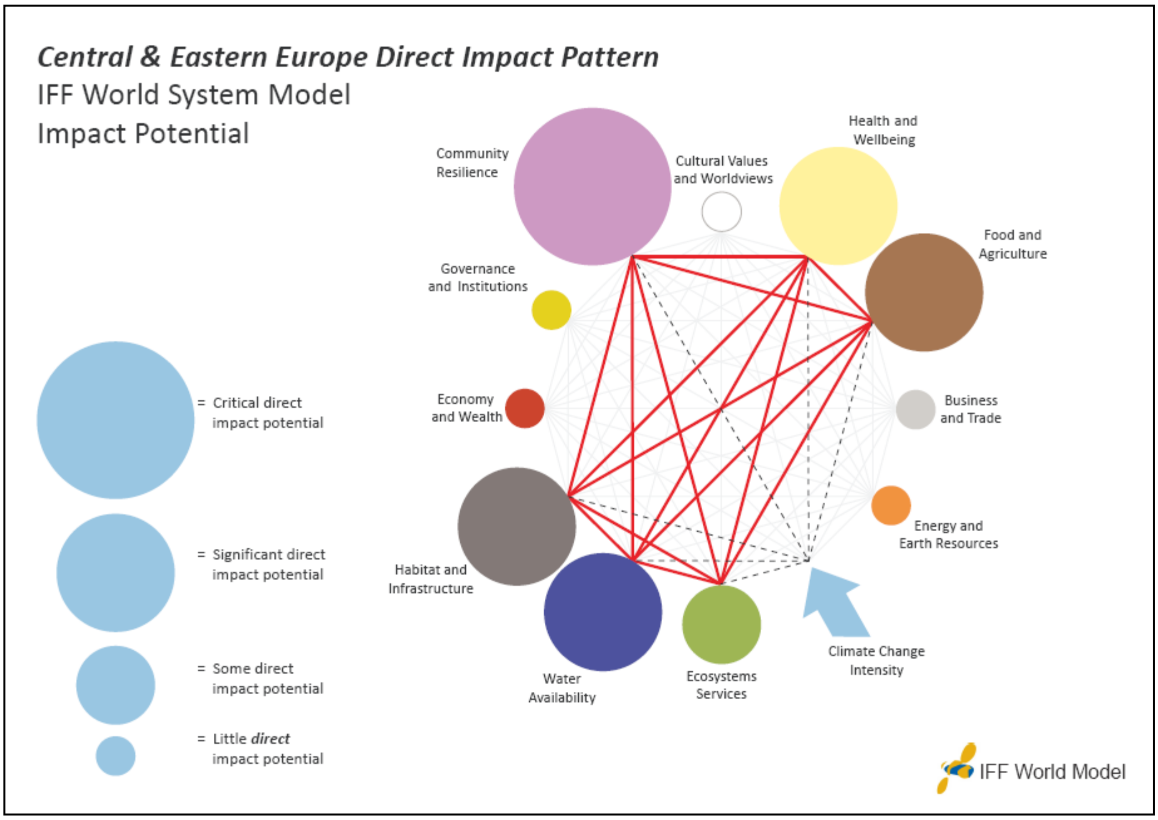


Figure 1.10.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.10.1 Overview

The impact of climate change will differ significantly from region to region across Europe and some areas – particularly Europe's poorer regions, will be affected more negatively than others. The Centre for European Policy Studies, in its 2010 report on *The Impact of Climate Change Across Europe* suggests that "…even at currently high levels of uncertainty, it is clear that the repercussions will vary considerably across regions. Some effects could even benefit certain regions. Most of the positive impacts will be in northern Europe." Central and Eastern Europe will have a likelihood of river flood disasters.

The report concludes: "Similar to the global context, where poorer developing countries are expected to suffer most, it is the poor regions in Europe that will be affected most. Hence, climate change further compounds the difficulties of these countries in achieving a level of welfare equivalent to the EU average." (CEPS, 2010, p.15).

The IPCC's 2007 report suggests a number of major climate change related impacts which will affect Europe over the course of the 21st Century. In Central and Eastern Europe, winter floods of increasing magnitude are to be expected, along with increased variability in crop yields, increased fires in drained peatlands, and increased health effects of heatwaves. South Eastern Europe will experience a decrease in crop yields accompanied with an increase in soil erosion and salination. (IPCC, 2007, p.558)

1.10.2 Systemic Relationships – Principal Paired Interactions (10)

Health & Wellbeing – Community Resilience

Most urgent health issues arising from climate change will effect already vulnerable populations.

"Modelling and assessing the impacts of climate change on human health are characterized by a high degree of uncertainty. Nonetheless, most studies indicate an increase in the heat-related mortality rate while the number of deaths attributable to cold weather could decrease. Similarly, vector-borne diseases such as malaria or dengue fever could spread in European regions, and at higher altitudes. Like most other effects, those on health are unevenly distributed across Europe, with Central and Eastern Europe likely to experience the highest rise in heat-related deaths (in absolute terms)." (CEPS, 2010, p.14).

In Eastern European countries, where per-capita health expenditure is relatively low, health services are less efficient in detecting and treating malaria cases, and the environmental measures to control mosquito distribution are poorly implemented. This could eventually contribute to the uncontrolled spread of the disease in these countries (WHO, 2005)" (CEPS, 2010, p.14).

The World Bank's report of climate change impact and adaptation for Europe and Central Asia (ECA) points out that "the most urgent health issues arising from climate change relate to already vulnerable populations: the elderly, the ill, the very young, the displaced, and the marginalized. When extreme weather combines with political instability and civil strife, the numbers of people facing serious health emergencies can multiply, as experienced in post independence Georgia in the 1990s. (World Bank, 2009, p.28)

Water Availability – Community Resilience

Flood and water stress are likely to increase with lowering of groundwater tables and poor land use. This may be exacerbated by climate change.

Without the implementation of adaptive measure Eastern Europe will see an increase in floods and water stress due to periodic droughts, along with a decrease in overall water availability (IPCC, 2007, p. 265).

"Water stress will increase, as well as the number of people living in river basins under high water stress (high confidence). Water stress will increase over central and southern Europe. The percentage area under high water stress is likely to increase from 19% today to 35% by the 2070s, and the additional number of people affected by the 2070s is expected to be between 16 millions and 44 millions. The most affected regions are southern Europe and some parts of central and eastern Europe, where summer flows may be reduced by up to 80%" (IPCC, 2007, p.543).

A number of non climactic factors already threaten the sustainability of water resources, including urban growth, changing land use, and unsustainable agricultural and industrial water use (Arnell and Delaney 2006; Holman et al. 2005).

One study (Vörösmarty et al. 2000) shows that for the early part of this century water stress in Europe and Asia will be almost entirely driven by increased water demand linked to socio-economic developments. Similarly, there is evidence that floods are often linked to poor land use and river basin management. Generally, climate related changes to freshwater systems have been small, compared with such non climatic drivers as pollution, regulation of river flows, wetland drainage, reduction in streamflow and lowering of the ground watertable (mainly due to extraction for irrigation). This mosaic of stresses calls for a shift towards more sustainable practices before the impacts of climate change are more strongly felt over the next 20 years" (World Bank, 2009, p.41).

Community Resilience – Infrastructure & Habitat

Heatwaves could affect electricity supplies.

The increase heat stress during extended periods will not only affect human health, agricultural production, and vegetation patterns in Central and Eastern Europe, it will also have significant impact on infrastructure and community resilience. "The cooling systems of thermal power plants (i.e. almost all coal, nuclear, geothermal, solar thermal electric and waste incineration plants, as well as many natural gas power plants) will be affected by the increasing temperatures of the atmosphere and rivers. Extreme heat waves can pose a serious threat to uninterrupted electricity supplies, mainly because cooling air may be too warm and cooling water may be both scarce and too warm. This can result in reduced capacities and reduced efficiency rates. Extreme heat waves can pose a serious threat to uninterrupted electricity supplies, mainly because cooling air may be too warm and cooling water may be both scarce and too warm. This can result in reduced capacities and reduced efficiency rates. (European Commission, 2009e; Eskeland et al., 2008). ..As regards other sources of energy, Eskeland et al.

(2008) note that higher temperatures and atmospheric CO2 concentrations in moderate climates north of the Alps may benefit the growth of biomass and thus the electricity generation from agricultural crops, manure and wood chips" (CEPS, 2010, p.12).

"Similarly, accelerating average wind velocities could improve the electricity output of wind converters. On the other hand, the efficiency of photovoltaic plants could be slightly reduced by higher temperatures, especially during heat waves. Finally, brownouts and blackouts stemming from storms, floods and heat waves may lead to more decentralised electricity generation in order to avoid the impacts of interruptions in supply for certain electricity users" (CEPS, 2010, p.12).

Health & Wellbeing – Infrastructure & Habitat

Much infrastructure in former Eastern Bloc countries is in poor condition and acutely vulnerable to climate variability and extremes.

A recent World Bank report argues that "the built environment of the former East Bloc is acutely vulnerable to physical changes from climate variability and extremes. Floods are an obvious threat in many cities. Storm surges in the Black Sea and elsewhere are affecting coastal infrastructure. Projected warming trends and changes in precipitation Patterns have the potential to impact the entire energy chain from production, through transmission and distribution, to end use. With the likelihood of many more extreme events - floods and droughts - water quality could be profoundly affected. This vulnerability is driven mainly by the poor condition of infrastructure. Old, badly maintained or constructed installations take fewer stresses to overwhelm them. Consider housing from the mid-1950s through the late 1980s, state enterprises built multi story, multi family housing blocks from prefabricated concrete panels, most of them designed for a life of 30 years. In Poland, for example, there are more than 5 million Soviet era flats, many in desperate need of refurbishment. Add the stresses of higher winds, more intense precipitation, summer heat waves, or melting permafrost in some regions and some of the buildings could become less livable still. Transport systems, energy infrastructure and water utilities are similarly vulnerable" (World Bank, 2009, p 75).

A 2008 study on the impact of climate change on the Czech Republic highlighted the link between climate change and infrastructure quality. ‘the increasing incidences of extreme weather events and other environmental stresses could lead to more rapid declines in the condition of infrastructure across the [Czech Republic]. It is likely that the weather events that different types of infrastructure are built to withstand will occur more regularly. More intense events will also increase in frequency, putting many types of infrastructure at significant risk by the middle of the 21s century” (Met Once, 2008b, p.8).

Health & Wellbeing – Water Availability

Waterborne disease exacerbated by more frequent floods could jeopardize the health of many.

“In Central and Eastern Europe, flash and urban floods are likely to take place more often, especially because of a large surge in rainfalls, predominantly during winter (Aaheim et al., 2008; AEA, 2007). By contrast, in summer a decrease in rainfalls is expected, leading to the opposite consequence: drought. The AEA predicts a substantial rise in annual rainfall and precipitation mainly in Austria, the Czech Republic, Eastern Germany, Poland and Slovakia. This will lead to a greater risk of flooding from rivers. Hungary and Romania will also have the same problem during winter, which will negatively affect various parts of the economy, particularly the agricultural sector” (CEPS, 2010, p.6).

The World Bank reports that “the following flood related illnesses are already present in [Europe and Central Asia], and are projected to become more frequent threats: Dysentery. In Tajikistan in 1992, flooding combined with displacement from civil unrest to put hundreds of people at risk, resulting in higher childhood mortality in two villages; Typhoid fever… In May 1996, following heavy rains and flooding in Tajikistan, a poorly maintained sewage system came under additional stress and contaminated the water supplies. In the ensuing typhoid fever outbreak, 7,516 cases were reported in a month’s time, a third of them in children under the age of 14. As in Georgia, simultaneous stresses on institutions and infrastructure, from the flooding and prior weaknesses, combined to worsen the health crisis. West Nile Virus, which is highly dangerous for the elderly, is spread primarily by mosquitoes, whose larvae thrive in the pools of standing water normally left by flooding. An outbreak of the disease followed 1999 floods in the Czech Republic when Aedes mosquitoes proliferated in affected areas. Europe's largest recorded outbreak occurred in Bucharest, Romania in 1996 and showed that urban areas also were vulnerable, with larvae multiplying in flooded basements of buildings.

Tahyna, a virus that breeds in flooded areas, was detected in the Czech Republic following separate episodes of flooding.. Leptospirosis, a once rare infectious disease carried rodents and other animals, spreads through contact with moist soil, mud, vegetation, or contaminated water. Russia, Ukraine, and the Czech Republic have experiences outbreaks following floods. Other water – borne diseases, including cholera, hepatitis A salmonella, have sufficed In the Legion following flooding episodes' NVorld Bank, 2009, p.30).

Water Availability – Food & Agriculture

Impacts on Agriculture will generally be negative, although the picture is far from clear.

A recent report by the Centre for European Policy Studies (2010) concludes: "The effects of climate change on agriculture and water will be quite different in the northern, southern and eastern regions of Europe, thus intensifying regional disparities. Impacts on Central and Eastern European agriculture…will generally be negative, although there are differences between and even within countries of that region. Initially, owing to warmer temperatures, the decrease in precipitation and the longer growing seasons, there may be an improvement in crop productivity (cereals, oilseeds and sugar beet) in countries such as Bulgaria, the Czech Republic, Hungary, Poland and Romania, (European Commission, 2009d; Stuzczynksi et al., 2000). Recent analysis for 2050 under the CLAVIER project predicts a positive climate-change effect on yields for the case study region in

Bulgaria and a negative effect on the case study region in Romania (CLAVIER, 2009). The ADAM project predicts an overall negative effect on crop yields for Central and Eastern Europe in the period 2030–60 as a result of +2°C of global warming (Mechler et al., 2009). Results from the PESETA study (Ciscar et al., 2009) indicate higher losses in the northern parts of Central and Eastern Europe than in its southern parts, which can reach up to 8% in the 2080s compared with the 1961–90 period" (CEPS, 2010, p.8).

Water Availability - Infrastructure & Habitat

Population growth plus increased agricultural and industrial demands may coincide with diminishing water resources. Permafrost is likely to retreat.

The fallout from climate change for water systems is overwhelmingly negative. Water professionals are confronted with an expanded set of possibilities and extremes and face more complex choices. Where water is less a available communities will have to change their water consumption patterns, or bring in water from farther away. Hydro-power output could be affected by varied or lower flows in some regions, straining energy supplies. Storm water drains may prove inadequate. In general, water structures such as pipelines, reservoirs, and dikes have been designed based on historic climate trends – but new patterns may call for structural shifts. Simple calculations of supply and demand raise other concerns. Population growth plus increased agricultural and industrial demands may coincide with diminishing warer resources, particularly in Central Asia. (World Bank, 2009, p79).

Increasing average temperatures will lead to drastic changes in the cryosphere across Europe. Such changes in the quantity and distribution of ice will also affect water availability and impact on existing infrastructure. There will be a retreat of glaciers all over Europe and North Eastern Europe will see a rapid retreat of the permafrost area over the course of the 21st Century. The duration of the snow cover will decrease and the tree-line in the mountains is likely to move upwards. Wetlands will dry up in Eastern Europe. The winter energy demand in

Eastern Europe is likely to go down and the summer energy demand may rise. (IPCC, 2007, p.565).

Food & Agriculture – Community Resilience

Even if climate change has only a small impact on the overall economy, it could have a profound effect on the proportion of the population living below the poverty line through it's impact on small scale agriculture.

Without large scale adaptation, agriculture in Eastern Europe will be negatively impacted by climate change over the 21st Century. The area suitable for agriculture is going to decline, along with the yields of summer crops like maize and sunflower seeds. In some areas, yields for winter crops like winter wheat may rise. There will be an increase need for irrigation and the impact of climate change on the livestock industry is also going to be negative (IPCC, 2007, p.565).

The World Bank suggests "agriculture is uniquely effective in reducing poverty in all country types. The inverse, of course, is that setbacks in agriculture – whether losses or missed opportunities – will be disproportionately damaging to the rural poor. Moreover, at the local or household level, the Impact could go beyond income to affect human health and nutrition (Randolph et al. 2007). Livestock activities are important to many vulnerable groups in [Europe and Central Asia] and may be undergoing structural shifts as the demand for meat, eggs and dairy products increases In Asia's' fast growing economies. The delicate balance of grain allocation as a staple food or as animal feed may become more difficult to maintain in the context of changing global demand. Shocks from climate change could add to an already uncertain mix of factors, potentially exacerbating the current global food and feed crisis. Untangling the interplay of shifting global demand, climate change, and patterns in livestock related land use – and teasing out the policy implications – is a continuing endeavor worldwide (World Bank, 2009, p.55).

Food & Agriculture – Infrastructure & Habitat

Agricultural sectors have fundamental weaknesses that suggest they will struggle to adapt to the demands of climate change.

World Bank argues “productivity depends not only on the climate conditions, but also on technology, investment, sup port services, and crop management. Analysis has shown that the current gap between potential and actual yields in Central and Eastern Europe and the European parts of the former Soviet Union are significantly higher than any potential gains from climate change. In particular, the current yield gap for the former Soviet countries in Europe (including Ukraine and European Russia) is 4.5 times higher than the potential Increase In production from climate change by 2050 (Olesen and Bindi 2002). While world grain yields have been rising on average by about 1.5 percent per year since 1991, yields in Ukraine and Kazakhstan have fallen, and Russia’s have increased only slightly. Yields in all three countries are far lower than those in Western Europe or the US. The fact that the Kazakhstan, Russia, Ukraine and other European and Central Asian countries have not been able to take advantage of this potential for productivity gains suggests fundamental weaknesses in the agricultural sectors of these countries, which does not bode well for their capacity to adapt to and benefit from climate change. Indeed, the key challenge would be to close the existing productivity gap rather than expecting to ride the climate change trends to a new era of prosperity” (World Bank, 2005, p.68).

Food & Agriculture – Infrastructure & Habitat

Agricultural sectors have fundamental weaknesses that suggest they will struggle to adapt to the demands of climate change.

A more stressed agriculture sector will translate into higher rates of malnutrition and increased susceptibility to disease. Families that depend on rainfed agriculture will be affected by shifts in precipitation and may migrate to seek improved livelihoods, thereby increasing the numbers of people underserved by local health systems. Water degradation from a variety of sources will expose more people to dengue fever and diarrheal diseases’ (World Bank, 2009, p.28).

“It is projected that with climate change, coupled with the benefits from new crop varieties and better technology, crop yields in Europe could increase throughout the 21st century, particularly across northern Europe. (Olesen et al., 2007). Poland’s agricultural sector could benefit from some of these changes, although the relatively low technology-methods employed on the majority of small Polish farms could limit this" (Met Office, 2008a, p.4)

"The Czech Republic's agricultural sector could benefit from some of these changes. However, agriculture may benefit in the short term from climate change, but as rainfall patterns change and temperatures rise, it is possible that some of the Czech Republic's agricultural land will become unsuitable for current crop schemes. Some areas could see greater crop damage from increased floods. Abandonment of land may lead to more areas becoming suitable for growing biofuel crops which can grow on poorer grade land, but the extent to which the Czech Republic could benefit from this is unknown" (Met Office, 2008b, p.4).

The 2007 IPCC report suggests that climate change will impact on forestry in Europe. The stability of the forest ecosystems of Eastern Europe will be drastically decrease as an effect of climate change during the 21st century. Diversity loss will go hand in hand with the Northward and inland shift of tree species, and the increase of natural disturbances like fires, pests, and wind-storms will result in further damage to Eastern European forests (IPCC, 2007, p.565).

1.10.3 Adaptive Capacity

Central and Eastern Europe are rated as follows:

	Failed States Index	**Political Stability**	**Government Effectiveness**	**Human Development Index**	**Adaptive Capacity Rating (x 10)**
Central and Eastern Europe					**MEDIUM 27.55**
Romania	0.60	0.67	0.67	0.75	
Hungary	0.80	0.67	0.67	0.75	
Czech Republic	0.80	0.83	0.83	1.00	
Slovakia	0.80	0.83	0.83	0.75	
Poland	0.80	0.67	0.67	0.75	
Bosnia	0.40	0.50	0.50	0.75	
Serbia	0.40	0.50	0.50	0.75	
Croatia	0.60	0.67	0.67	0.75	
Bulgaria	0.60	0.67	0.67	0.75	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.11 Andean South America Direct Impact Pattern

Andean South America includes Peru, Bolivia, Ecuador, Venezuela, Argentina, Chile and Colombia.

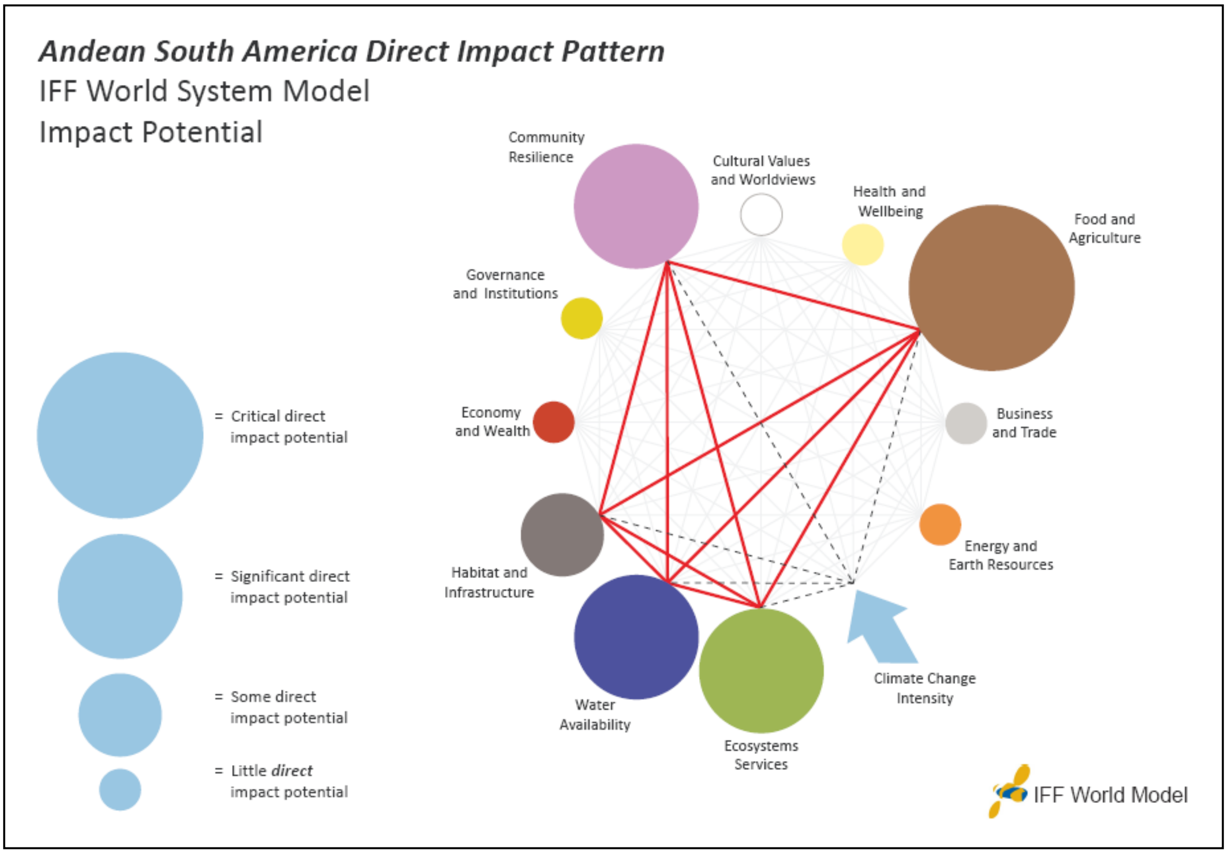


Figure 1.11.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.11.1 Overview

The IPCC (2007) reports: "Climatic variability and extreme events have been severely affecting the Latin America region over recent years (high confidence). Highly unusual extreme weather events were reported, such as intense Venezuelan rainfall (1999, 2005), flooding in the Argentinean Pampas (2000-

2002), Amazon drought (2005), hail storms in Bolivia (2002) and the Great Buenos Aires area (2006), the unprecedented Hurricane Catarina in the South Atlantic (2004) and the record hurricane season of 2005 in the Caribbean Basin. Historically, climate variability and extremes have had negative impacts on population; increasing mortality and morbidity in affected areas" (IPCC, 2007, p.583).

As a consequence of temperature increases, the trend in glacier retreat reported in the Third Assessment Report is accelerating (very high confidence). This issue is critical in Bolivia, Peru, Colombia and Ecuador, where water availability has already been compromised either for consumption or for hydropower generation. These problems with supply are expected to increase in the future, becoming chronic if no appropriate adaptation measures are planned and implemented. Over the next decades Andean inter-tropical glaciers are very likely to disappear, affecting water availability and hydropower generation (high confidence)" (IPCC, 2007, p.583).

A UNDP publication on the effects of climate change related deglaciation in the Andes (Painter, 2007) highlighted how sensitive the region is to the impacts of climate change: "The tropical Andes are often declared as one of the most vulnerable regions to climate change worldwide (IPCC, 2007), and the countries there are already facing major challenges in coping with climate variability (Bradley et al., 2006). The adverse effects of climate change are expected to affect in particular the poorest people because of their high vulnerability and low adaptive capacity. Furthermore, climate change impacts are manifold and multidimensional, and thus developing and implementing adequate adaptation measures is complex. (Painter, 2007, p.3).

1.11.2 Systemic Relationships – Principal Paired Interactions (10)

Ecosystems Services – Water Availability

Under future climate change scenarios ecosystems such as tropical forest are threatened,, while desertification of agricultural lands is likely. Glacier melting is increasing.

“During the last decades important changes in precipitation and increases in temperature have been observed (high confidence). Increases in rainfall in south-east Brazil, Paraguay, Uruguay, the Argentinean Pampas and some parts of Bolivia have had impacts on land use and crop yields, and have increased flood frequency and intensity. On the other hand, a declining trend in precipitation has been observed in southern Chile, south-west Argentina, southern Peru and western Central America. Increases in temperature of approximately 1°C in Mesoamerica and South America, and of 0.5°C in Brazil, were observed. “ (IPCC, 2007, p.583).

“Under future climate change, there is a risk of significant species extinctions in many areas of tropical Latin America (high confidence). Replacement of tropical forest by savannas is expected in eastern Amazonia and the tropical forests of central and southern Mexico, along with replacement of semi-arid vegetation by arid vegetation in parts of north-east Brazil and most of central and northern Mexico due to synergistic effects of both land-use and climate changes (medium confidence). By the 2050s, 50% of agricultural lands are very likely to be subjected to desertification and salinisation in some areas (high confidence). (IPCC,2007)

“Much of the research on how glacial melt is affecting current water availability and the modelling for the future has been carried out in Peru, using data taken from the vast Cordillera Blanca…The research suggests that in the Cordillera Blanca there has been a net annual increase in hydrological runoff, particularly in watersheds or valleys beneath glaciers. In one area, glacial melt now accounts for 58 per cent of the annual mean discharge, a 23 per cent increase since 1998-9 (Mark et al., 2005). Researchers predict this is a temporary effect due to current rates of ablation. In the longer-term, some models suggest a dramatic decline in water availability some time this century as the glaciers disappear and precipitation becomes the only source of water.(CONAM, 2005)” (Painter, 2007, p.3).

Ecosystems Services – Infrastructure & Habitat

Seven out of the 25 most critical places with high endemic species concentrations are in Latin America and these areas are undergoing habitat loss.

“Even in scenarios with relatively low greenhouse gas emissions, regions like Central America and the Andes will experience a more than 90 percent rotation of species. Thus, these areas’ plant and animal life will be radically different from what they are today. Among recent significant climate anomalies [in Latin America are] the intense rainfall that affected northern and eastern Brazil in April 2009, causing floods and landslides that forced over 186,000 people to abandon their homes. In 2008, certain areas of Argentina, Paraguay, Uruguay and Chile suffered their worst drought in more than 50 years. Ecuador, for its part, experienced extreme floods” (Canoura, 2009, p.17).

Seven out of the 25 most critical places with high endemic species concentrations are in Latin America and these areas are undergoing habitat loss. Biological reserves and ecological corridors have been either implemented or planned for the maintenance of biodiversity in natural ecosystems, and these can serve as adaptation measures to help protect ecosystems in the face of climate change” (IPCC,2007, 583).

Community Resilience – Infrastructure & Habitat

Some of the regions key sectors such as agriculture, mining and fisheries are already being affected by climate change, and tourism is also likely to suffer.

A recent report supported by the Department for International Development’s (DFID) UK Aid programme on *A Latin American Perspective on Climate Change* highlighted that “climate change is also having major consequences on economic development in Latin America, particularly as a result of increases in the intensity and frequency of disasters. Some of the region’s key sectors such as agriculture, mining and fisheries are being affected, with major job and investment losses in productive sectors such as tourism also predicted. The Andean Community of Nations (CAN) has suggested losses worth four and a half per cent of gross domestic product (GDP) by 2025, roughly equivalent to Andean countries’ annual spending on health. According to the Intergovernmental Panel on Climate Change (IPCC), the number of additional people at risk of hunger in Latin America is likely to reach five, twenty six and eighty five million in 2020, 2050 and 2080 respectively. Seventy-seven million people are predicted to be under water stress by 2020. Children and youth are particularly vulnerable to the impacts of climate change and its effects on their rights to education, health, protection and wellbeing. Climate change is affecting the poorest and most socially excluded population groups in Latin America the most, as they are least able to cope with the impacts of extreme weather conditions" (DFID, 2009, p.3).

Community Resilience – Water Availability

The rural poor are also likely to bear a disproportionate share of the cost of glacial retreat and water shortages, when compared to other sectors.

"In the past, poor communities in Peru and Bolivia have been prejudiced by inequitable water access, pricing policies and quality, and scant protection or legal rights over water usage. Large economic concerns have usually enjoyed de facto priority, or have been given it by regional and national authorities. This historical situation is unlikely to change in a context of reduced water availability. For the urban poor in Peru, there are few signs that the government is considering policies of targeted subsidies or prices which could distribute future water stress more equitably. The rural poor are also likely to bear a disproportionate share of the cost of glacial retreat and water shortages, when compared to other sectors. This is for three reasons: hundreds of thousands of poor people will be in the front-line of increased exposure to the possibility of natural disasters in high-altitude glacial-fed areas. Small producers in the agro-export sector will be less able to adapt to less water availability compared to larger agro-industrial concerns. And political decisions over priorities for water usage are unlikely to favour small-scale upstream farmers over demands from the mining, agro-export, and hydroelectricity sectors, and from downstream cities needing a regular supply of drinking water" (Painter, 2007, p.2)

"If the models are correct, growing conflict over the distribution of water resources is very likely, particularly during the dry season. Peru is widely considered as the South American country most vulnerable to water shortages, while in Bolivia the issues of universal access to water and the price low-income urban consumers should pay have provoked serious political confrontation since 2000. In both countries there are already competing demands: inter- and intra-departmental; urban versus rural consumers; and competition between commercial export agriculture, small-scale rural producers, hydroelectric power and mining companies. Conflicts between sectors will become more intense as water becomes less available" (Painter, 2007, p.2).

Water Availability – Food & Agriculture

Peru's boom in agro-exports has meant a huge increase in demand for irrigation in the desert coastal strip, which already had a precarious water supply.

It is also important to consider that "the boom sectors of the Peruvian economy in recent years have been water-intensive. The value of non-traditional agro-exports has risen three-fold from US$302m in 1998 to US$1,008 million in 2005. In the same year asparagus exports for example were worth US$263m, compared to US$396m for Peru's traditional coffee exports. But unlike coffee, asparagus requires constant irrigation. Artichokes too require more watering than non-export crops such as potatoes. Production of sugar cane, another thirsty crop, is also set to increase because of international demand for bio-fuels. Indeed, in general the boom in agro-exports has meant a huge increase in demand for irrigation in the desert coastal strip, which already had a precarious water supply. An estimated US$5bn has been invested in irrigation in recent years, of which US$3.5bn was invested in coastal areas. More than 1.2 million hectares have been planted with crops that need irrigation, significant parts of which currently come from glacial melt" (Painter, 2007, p.7).

Large-scale concerns have benefited from the opening of new areas for cultivation. For example, agro-industrial companies on the coast took advantage of large irrigation projects such as the Chavimochic project in the Rio Santa valley mentioned above. They had the capital to buy newly irrigated areas that were unavailable to small producers. Moreover, in many areas, companies have the capital to invest in their own wells, whereas smaller producers have to pay for their surface water or pay high charges to well owners. (Painter, 2007, p.11).

Extreme droughts (most recently in 2008-2009) affected summer crops, like soybean, corn, sunflower, sorghum and pastures, which are used as feed for beef and dairy cattle. Excess water has also affected winter crops, such as wheat and barley. (Canoura, 2009, p.12-13).

Water Availability - Infrastructure & Habitat

The increase in seasonal variation and decrease in overall water availability will require more investment in infrastructure and will particularly affect the cities in the Andean region.

The 2007 IPCC report also highlighted that water scarcity issues in the Andes region may be underestimated: “In global terms, Latin America is recognised as a region with large freshwater resources. However, the irregular temporal and spatial distribution of these resources affects their availability and quality in different regions. Stress on water availability and quality has been documented where lower precipitation and/or higher temperatures occur…The vulnerability to flooding events is high in almost 70% of the area represented by Latin American countries (UNEP, 2003c). Hydropower is the main electrical energy source for most countries in Latin America, and is vulnerable to large-scale and persistent rainfall anomalies due to El Niño and La Niña, e.g., in Colombia (Poveda et al., 2003), Venezuela (IDEAM, 2004), Peru (UNMSM, 2004), Chile (NC-Chile, 1999), Brazil, Uruguay and Argentina (Kane, 2002)” (IPCC, 2007, 586).

James Painter’s (2007) UNDP briefing paper on the potential effects of deglaciation in the Andes highlights a number of examples how the increase in seasonal variation and decrease in overall water availability requires more investment in infrastructure and will particularly affect the cities of that region. “There will be a pressing need for more dams, tunnels or reservoirs (be they small- or large-scale) to collect and store more of the precipitation during the wet seasons. Short-term water supply deficits produced by increased demand from growing urban populations will be exacerbated by a long-term decline in seasonal water availability” (Painter, 2007, p.2)

“Even now La Paz and El Alto, with a combined population of nearly 2 million people, face a pressing need for more water. The arrival of several thousand migrants from rural areas to El Alto every year means demand for water increases. One detailed study carried out in 2007 predicts that as early as 2009 there will be more demand than water available in the reservoirs feeding the two cities assuming the supply remains the same (Ramírez, 2007). (Painter, 2007, p.9).

Food & Agriculture – Infrastructure & Habitat

Deforestation is a continuing issue while the sectors that depend on agricultural are being affected by increased meteorological phenomena.

"An estimated 300,000 hectares are deforested every year in Bolivia -75 percent of them in Santa Cruz- to make room for industrial crops, such as soybean. The rising temperatures are shortening crop cycles, cutting the time from sowing to harvesting. This phenomenon affects yield and productivity, because less time to grow means less biomass accumulation. Crops are also being displaced to higher lands (Canoura, 2009, p.12-13).

The frequency of adverse meteorological phenomena, such as floods, hurricanes or droughts, is being altered. Agricultural systems are thus gradually losing their resilience and the sectors that depend on agriculture are becoming increasingly impoverished. But the more intense rains have not always had an adverse impact on agriculture. In recent years temperate regions - which include areas of Argentina, Uruguay and southern Brazil- have seen an increase in yields, particularly in summer crops. " (Canoura, 2009, p.12-13).

Ecosystems Services – Community Resilience

Latin America includes much of the world's biological diversity, as well as a wide variety of ecosystems, climatic regions, topographies and land-use patterns. Many sectors and ecosystems are particularly vulnerable to climate change.

"Few studies have been carried out on the impact of glacial melt, even though Peru and Bolivia are very vulnerable. While there is an abundance of articles on glacial retreat, there are only a few studies on the possible impact on the social and economic development of the South American countries most likely to be affected by predicted seasonal water shortages, and in particular on the rural and urban poor. For example, Peru and Bolivia have more than 90 per cent of the world's tropical glaciers within their territories, and are also two of the poorest countries in Latin America (with 49 per cent and 63 per cent respectively of their populations living below the national poverty line). From the early 1970s to 2006, the surface area of glaciers in Peru and Bolivia decreased by 30 per cent. A long-term decline in water availability during the dry season would have very significant consequences for millions of poor people in both countries” (Painter, 2007, p.2).

“Latin America includes much of the world’s biological diversity, as well as a wide variety of ecosystems, climatic regions, topographies and land-use patterns. Particularly vulnerable to climate change are the water, agriculture and health sectors, the Andean glaciers, the Amazon region and regions vulnerable to extreme climatic events (UNFCCC 2006d). … The region has already been experiencing climate-related changes with the frequency and intensity of extreme events, particularly those associated with the ENSO phenomenon [El Niño Southern Oscillation]. Torrential rains and resulting floods, including those associated with tropical cyclones, have result in tens of deaths and sever economic losses and social disruption in the region in recent years… Under climate change, as Andean glaciers disappear this century, there is likely to be serious effects on peoples lives and livelihoods and on ecosystems…Higher rates of economic recession correspond with greater flows of water, which cause erosion, flooding and mudslides in lowland areas. However, as the glaciers disappear – such as the Chacaltaya Glacier in Bolivia, predicted to disappear within the next 15 years – flows will tail off dramatically leading to serious water shortages, reduced hydropower, greater risks of drought, as well as flooding, and serious environmental degradation (nef 2006, Magrin et al. 2007, UNEP 2007)” (UNFCCC, 2007,p.22).

The IPCC (2007) highlighted the alarming rate of climate change related biodiversity loss in Latin America: “Changes in land use have led to habitat fragmentation and biodiversity loss. Climate change will increase the actual extinction rate, which is documented in the Red List of Endangered Species (IUCN, 2001). The majority of the endangered eco-regions are located in the northern and mid-Andes valleys and plateaux, the tropical Andes, in areas of cloud forest (e.g., in Central America), in the South American steppes, and in the Cerrado and other dry forests located in the southern Amazon Basin (Dinerstein et al., 1995; UNEP, 2003a)… Deforestation and forest degradation through forest fires, selective logging, hunting, edge effects and forest fragmentation are the dominant transformations that threaten biodiversity in South America. (Fearnside, 2001; Peresand Lake, 2003; Asner et al., 2005)” (IPCC, 2007, p.590).

Food & Agriculture – Community Resilience

Small-scale producers that are currently involved in growing crops for export are likely to be less able to continue in a future when less water is available

"It is likely that in the context of reduced water availability, small-scale agricultural producers in Peru will come lower in the pecking order than urban consumers, hydroelectric projects, commercial agriculture and mining companies. The last two sectors have in the recent past enjoyed favourable investment legislation, tax breaks, credit facilities and cheap water availability to foster their growth. This order of priorities is unlikely to be reversed.

In the agro-export sector, most of the new crops are produced by large-scale farmers or industrial concerns. For example, there are around 2,000 producers of asparagus in the country, and about 60,000 people employed directly by the industry. 56 per cent of the land cultivated with asparagus belongs to 200 producers owning more than 50 hectares of land. There are some smaller coastal producers, but they have a relatively high level of education and resources. The asparagus sector is markedly different to the coffee sector where around 85 per cent of the 150,000 coffee producers have less than five hectares (Frazer and Rojas 2007).

Large-scale concerns have benefited from the opening of new areas for cultivation. For example, agro-industrial companies on the coast took advantage of large irrigation projects such as the Chavimochic project in the Rio Santa valley mentioned above. They had the capital to buy newly irrigated areas that were unavailable to small producers. Moreover, in many areas, companies have the capital to invest in their own wells, whereas smaller producers have to pay for their surface water or pay high charges to well owners. Small-scale producers that are currently involved in growing crops for export are likely to be less able to continue in a future when less water is available. For example, one recent study found that in the Mantaro valley, which is partly glacial-fed, water shortages are already restricting farmers to growing only 1-2 hectares of artichokes each.(Frazer and Rojas 2007) Many do not own their own land so there is less incentive for them to invest in better irrigation. Moreover, the current government's laudable efforts to promote agricultural export production in the sierra (the 'Sierra Exportadora' programme) may also be affected by reduced water availability" (Painter, 2007, p.11).

Food & Agriculture – Ecosystems Services

Increased climate variability, interacting with other factors of environmental change can have drastic effects on fisheries, and hence on economies and peoples' livelihood.

The IPCC (2007) predicts" "Generalised reductions in rice yields by the 2020s, as well as increases in soybean yields, are possible when CO2 effects are considered (medium confidence). For other crops (wheat, maize), the projected response to climate change is more erratic, depending on the chosen scenario. If CO2 effects are not considered, the number of additional people at risk of hunger under the A2 scenario is likely to reach 5, 26 and 85 million in 2020, 2050 and 2080, respectively (medium confidence). … cattle and dairy productivity is expected to decline in response to increasing temperatures" (IPCC, 2007, p.583).

A UNDP sponsored study on the effect of climate change on Ecuadorian fisheries (Cornejo, 2007) came to the following results: "The main problem of evaluating the impact of climate change upon Ecuadorian fisheries is that because of insufficient data and incomplete knowledge on the behaviour of the different fisheries, it is not possible to quantify them. This reduces our ability to be efficient in promoting adaptation policies at the proper channels" (Conejo, 2007, p.38). There are however alarming cases of precedence indicating that increased climate variability, interacting with other factors of environmental change can have drastic effects on fisheries, and hence on economies and peoples' livelihood. For example, "the 1999-2000 La Niña event followed the [El Niño Southern Oscillation] ENSO extraordinary 1997-1998 ENSO, along with an epidemic (White Spot Virus Syndrome) that almost whipped out the Ecuadorian Shrimp industry, which at that moment employed 8% of the economically active population of Ecuador" (Cornejo, 2007, p.2).

1.11.3 Adaptive Capacity

Andean South America is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Andean S America					**MEDIUM 21.09**
Peru	0.40	0.33	0.50	0.75	
Bolivia	0.40	0.33	0.33	0.50	
Ecuador	0.40	0.33	0.33	0.75	
Venezuela	0.40	0.33	0.33	0.75	
Argentina	0.80	0.50	0.50	0.75	
Chile	0.80	0.67	0.83	0.75	
Colombia	0.40	0.17	0.67	0.75	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.12 Western Europe Direct Impact Pattern

Western Europe includes Portugal, Spain, Italy, Greece, Bulgaria, France, Austria, Belgium, The Netherlands, Germany, Ireland (UK), Sweden, Finland, Estonia, Latvia, and Lithuania.

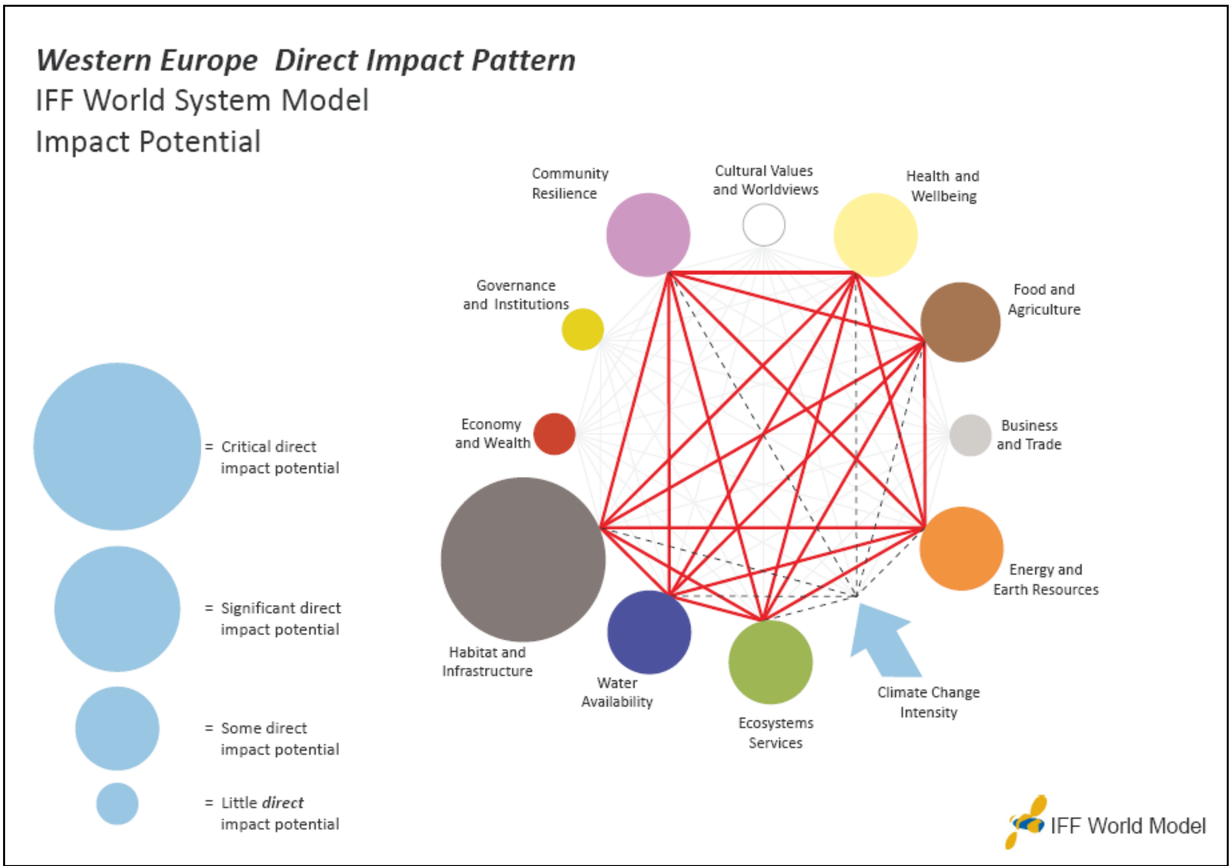


Figure 1.12.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.12.1 Overview

Climate change is likely to magnify regional differences of Europe's natural resources and assets (very high confidence). (EEA 2004) The consequences of climate change in the four market impact categories (*i.e.* agriculture, river floods, coastal systems and tourism) can be valued in monetary terms as they directly affect sectoral markets and – via the cross sector linkages – the overall economy. They also influence the consumption behaviour of households and therefore their welfare. The analysis of potential impacts of climate change, defined as impacts that might occur without considering public adaptation, can allow the identification of priorities in adaptation policies across impact categories and regional areas. If the climate of the 2080s occurred today, the annual damage of climate change to the EU economy in terms of GDP loss is estimated to be between 20 billion € for the 2.5°C scenario and 65 billion € for the 5.4°C scenario with high SLR. (Ciscar 2009)

Most of the positive impacts will be in northern Europe. This region could benefit from higher crop yields, an expansion of forest areas and enhanced forest-growth rates, an increasing number of tourist visits, and a net decrease in climate-related deaths. While northern Europe will also have to bear some severe negative consequences (e.g. in the form of more frequent extreme weather events or coastal and river flooding), it is mainly the countries in the south, which are already economically disadvantaged, that will suffer most. Some of the most severe negative impacts in the Mediterranean include prolonged periods with temperatures above the comfort zone and the accompanying effects on human health and tourism, increasing water scarcity, droughts, forest fires, desertification, decreasing agricultural productivity, coastal flooding and loss of biodiversity. One of the few positive outcomes will be the reduced likelihood of river flood disasters (which will be more frequent in Central and Eastern Europe). (Behrens *et al*, 2010).

Similar to the global context, where poorer developing countries are expected to suffer most, it is the poor regions in Europe that will be affected most. Hence, climate change further compounds the difficulties of these countries in achieving a level of welfare equivalent to the EU average. At the same time, the cumulative impacts of climate change on poorer countries will also affect northern European countries, as growing water scarcity and other repercussions in Mediterranean countries could pose social and security challenges through increasing risks of conflicts and migration pressures. Fighting climate change through domestic and international action is thus not only a matter of solidarity, but clearly in the self-interest of the EU and *all* of its member states (Beherens *et al*, 2010).

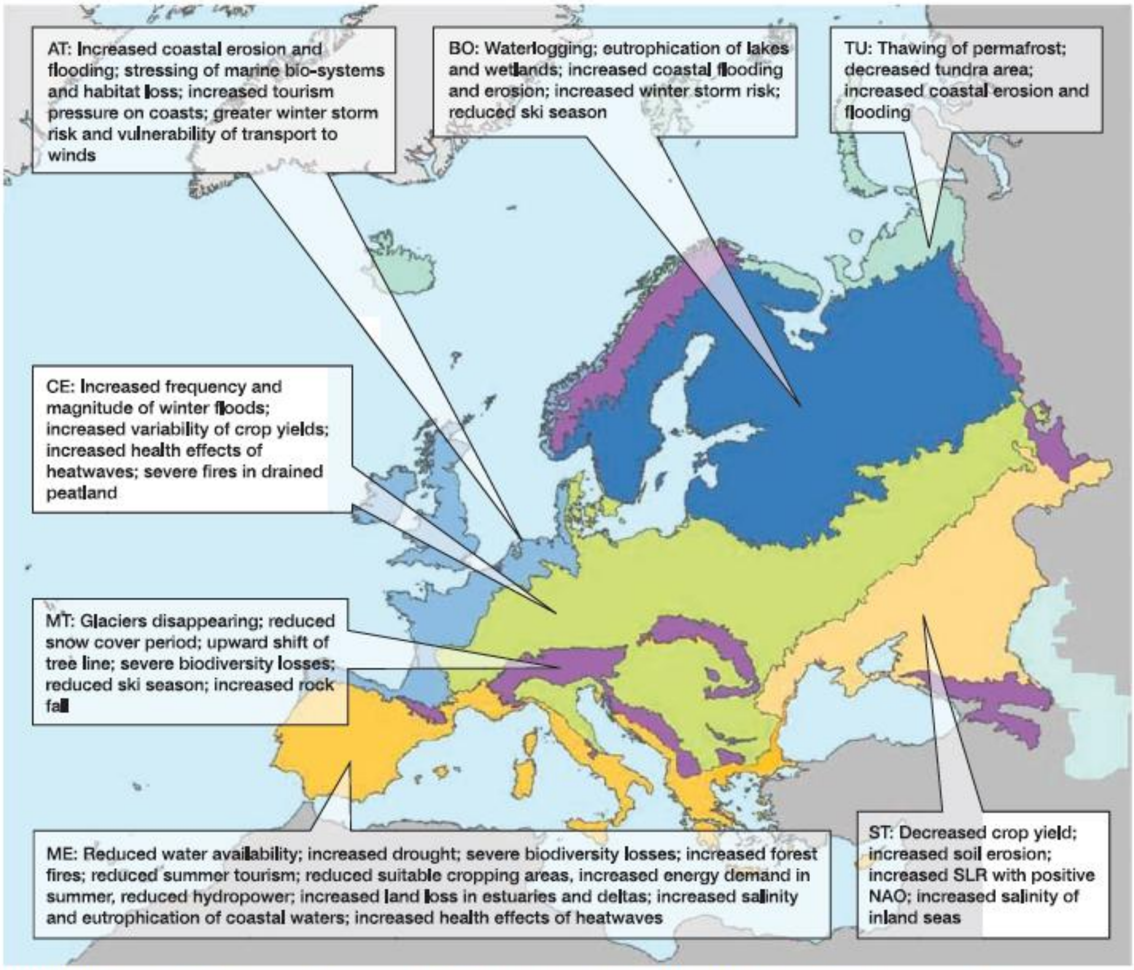


Figure 12.3. *Key vulnerabilities of European systems and sectors to climate change during the 21st century for the main biogeographic regions of Europe (EEA, 2004a): TU: Tundra, pale turquoise. BO: Boreal, dark blue. AT: Atlantic, light blue. CE: Central, green; includes the Pannonian Region. MT: Mountains, purple. ME: Mediterranean, orange; includes the Black Sea region. ST: Steppe, cream. SLR: sea-level rise. NAO: North Atlantic Oscillation. Copyright EEA, Copenhagen. http://www.eea.europa.eu*

Figure 2.12.2 Key European climate vulnerabilities (EEA 2004)

1.12.2 Systemic Relationships – Principal Paired Interactions (21)

Health & Wellbeing – Community Resilience

Heat waves are likely to increase heat related mortality- adaptation will play a significant part in how much. Cold related mortality is estimated to decrease.

In the 2020s, without adaptation measures and acclimatisation, the estimated increases in heat-related mortality are projected to be lower than the estimated decrease in cold related mortality. The potential increase in heat-related mortality in Europe could be over 25,000 extra deaths per year, with the rate of increase potentially higher in Central Europe South and Southern European regions. However, physiological and behavioural responses to the

warmer climate would have a very significant effect in reducing this mortality (acclimatisation), potentially reducing the estimates by a factor of five to ten. It is also possible that there may be a decline in the sensitivity of mortality to cold, though this is more uncertain. (Ciscar 2009)

By the 2080s, the effect of heat- and cold related mortality changes depends on the set of exposure-response and acclimatisation functions used. The range of estimates for the increase in mortality is between 60,000 and 165,000 (without acclimatisation), again decreasing by a factor of five or more if acclimatisation is included. The range of estimates for the decrease in cold-related mortality is between 60,000 and 250,000, though there may also be a decline in the sensitivity of mortality to cold. (Ciscar 2009) The likelihood of heat waves during summer month is going to increase, particularly in Southern Europe. The experience of heat waves in France in 2007 has shown that this can lead to increased death rates among the elderly, frail and very young. (Alcamo et al., 2007).

Health & Wellbeing – Energy & Earth Resources

Climate change is likely to increase the energy demand for regulating indoor temperatures.

Overall, there will be an increase in energy demand for cooling during the summer and a decrease in energy demand for heating in the winter Although strong climate fluctuations might also lead to occasions where this situation is reversed. (Alcamo *et al.*, 2007).

Health & Wellbeing – Water Availability

Water stress will increase, particularly in the Mediterranean, impacting on health and wellbeing.

Schröter et al. (2005), quoted in the IPCC's *Fourth Assessment Report*, maintain that by the 2070s the number of additional people living in water-stressed watersheds in the EU-15 (plus Switzerland and Norway) is likely to increase to between 16 and 44 million under the SRES A2 and B17 scenarios respectively, as projected by the HadCM38 model (+2.8°C and +3.1°C increase in Europe respectively by 2080) (Schröter et al., 2005 in IPCC, 2007b). Problems related to public water and drinking water will be exacerbated all over Europe with particular hotspots in the Mediterranean.

The Mediterranean will face problems of water scarcity more than any other region in Europe. Climate change may lead to an estimated decline in water availability, which will be greatest in the Mediterranean and southern Europe (European Commission, 2009a; MICE, 2005). Water availability may fall by 20-30% under a +2°C scenario and by 40-50% under a +4°C scenario. Summer water flows may be reduced by up to 80% and the annual average water runoff will decrease in Central and Eastern Europe and in the Mediterranean by 0-23% up to the 2020s and by 6-36% up to the 2070s (IPCC, 2007b). (Behrens et al 2009)

Water stress in Southern Europe will lead to increased competition for water between the agriculture sector and the tourism industry, particularly around the Mediterranean. (Alcamo *et al.*, 2007).

Water Availability – Community Resilience

Many communities will have to find ways to deal with increased droughts and water deficits.

Problems associated with water supply will affect the economy and the population, which will have to deal with increased droughts and water deficits on a daily basis. The agriculture and tourism sectors will be those affected most, above all on islands and in tourist resorts where problems of water supply are becoming ever more common. For example, Cyprus is exploring the possibilities of transporting water in tankers from Lebanon (EEA, 2008). Similar difficulties will be experienced in Central and Eastern Europe, where increased water stress and glacial retreat are projected.(Behrens et al 2010)

Water stress will increase, as well as the number of people living in river basins under high water stress (high confidence). Water stress will increase over central and southern Europe. The percentage area under high water stress is likely to increase from 19% today to 35% by the 2070s, and the additional number of people affected by the 2070s is expected to be between 16 millions and 44 millions. The most affected regions are southern Europe and some parts of central and eastern Europe, where summer flows may be reduced by up to 80% . (Alcamo *et al.*, 2007).

Community Resilience – Energy & Earth Resources

Energy supplies may be threatened by climate induced changes in energy infrastructure.

There is a danger that the melting of the permafrost may lead to problems with the pipelines supplying Russian natural gas to Western Europe. (Alcamo *et al.*, 2007).

Energy & Earth Resources – Water Availability

Decreased rainfall will impact on hydro-electric generation and water availability for nuclear cooling.

One of the major impacts of increased temperature will be a change in the relationship of Europe with water, whether rivers, rain, sea or glaciers. See the map from (Alcamo *et al.*, 2007).

Annual precipitation trends in Europe for the period 1900–2000 show a contrasting picture between northern Europe (10–40 % wetter) and southern Europe (up to 20 % drier). Changes have been greatest in winter in most parts of Europe. Projections for Europe show a 1–2 % increase per decade in annual precipitation in northern Europe and an up to 1 % per decade decrease in southern Europe (in summer, decreases of 5 % per decade may occur). The reduction in southern Europe is expected to have severe effects, e.g. more frequent droughts, with considerable impacts on agriculture and water resources. (EEA 2004)

Decreased rainfall in Southern Europe may lead to reduced potential for hydro-electric power generation. The IPCC report (2007) suggests that hydropower potential in Europe will decrease by 6% overall, but by 20-50% around the Mediterranean the 2070s. (Alcamo *et al.*, 2007).

Water Availability - Ecosystems Services

Biodiveristy will be adversely effected by droughts an floods.

Overall reduction of the cryospehere (permafrost and glaciers). The melting of the permafrost will lead to subsidence of buildings, transport infrastructure (roads, rail, pipelines). The melting of glaciers in the Alps my reduce the water supply and hydropower potential, as well as, increased erosion as forest types change and slopes become destabilized by the die-off of trees. The increase in both droughts and floods will reduce biodiversity in many European ecosystems. (Alcamo *et al.*, 2007).

Ecosystems Services - Community Resilience

In Europe, climate change will have severe effects on more than 830 million humans, who depend on ecosystem services and habitats primarily provided by managed landscapes.

Reduced provision of ecosystem services can be expected for all land uses: agriculture, forestry, fisheries, infrastructure, urban agglomerations and tourism. (EEA Cc 2010)

In Europe's mountain regions the shifts in vegetation patterns will destabilize the slopes and lead increased erosion, flash-floods, and water-retention. The effect of droughts and floods may make many remote mountain settlements uninhabitable. This will also have a significant impact on tourism in these areas. The rising temperatures in Southern Europe and central Europe will lead to an increased danger of fires and may further destroy the recreational value of ecosystems, thereby affecting community resilience. (Alcamo *et al.*, 2007).

Ecosystems Services - Energy & Earth Resources

Forrest may expand in Northern Europe while decreased rainfall will impact hydropower in Southern Europe.

Faster growing forest in Northern Europe will produce lower grade building timber, affecting the forestry industry. At the same time there will be an increase in biomass production in those areas, opening up new opportunities for biomass-based power generation and biofuel generation from cellulosic digestion (2^{nd} generation biofuels).

The IPCC (2007) predicts an expansion of forests in Northern Europe and a reduction in forest cover in Southern Europe. Reduced rainfall will lead to a decrease in hydropower potential, particularly in Southern Europe (Alcamo *et al.*, 2007).

Ecosystems Services - Health & Wellbeing

Climate change will alter the spread of vector born diseases, many of which will move northwards.

According to the cCASHh study, which investigates climate change and adaptation strategies for human health in Europe, not only heat waves and floods are detrimental for human health. Food- and vector-borne diseases can also pose a danger. These are indirect effects of climate change through alterations in the seasonal patterns of diseases. Milder temperatures in northern Europe in combination with higher rainfalls could indeed increase the possibility of food- and vector-borne diseases. For instance, it has been shown that the largely tick transmitted Lyme borreliosis and tick-borne encephalitis have spread into higher latitudes (e.g. in Sweden) and altitudes (e.g. in the Czech Republic) in recent decades, and that their transmission season will be extended and more intense in the future (WHO, 2005). Similarly, the risk of local malaria transmission could spread in northern Europe (e.g. by 8-15% in the UK, according to EEA, 2008). (Behrens et al 2010)

Heatwaves and forest fires will increase causing circulatory and respiratory illnesses to increase. The increasing temperatures and lack of prolonged periods of frost in the winter will lead to a Northwards-spread of vector borne disease in humans, livestock, and plants. (Alcamo *et al.*, 2007).

Ecosystems Services - Food & Agriculture

Climate change will impact on arable land and the biodiversity it can support.

The agriculture-biodiversity relationship is closely linked to other environmental pressures.
For example, climate change means that potential arable land area will decline in Europe
(Jones‐Walters and Nieto, 2007; EEA 2010a). Likewise, agriculture, public water supply and tourism in some locations pose a significant threat to freshwater ecosystems (EEA 2010b).

Change in vegetation pattern in the Alps as well as increased risk of floods and droughts will make agriculture in the Alps more difficult, leading to a potential change in the cultural landscape with possibly severe effects of community resilience and tourism, as well as food production in those regions. (EEA 2010)

Climate change over the past three decades has resulted in decreases in populations of plant species in southern and northern Europe. Globally a large number of species might become extinct under future climate change. Due to non-climate related factors, such as the fragmentation of habitats, extinction rates are likely to increase. These factors will limit the migration and adaptation capabilities needed by species to respond to climate change. (EEA 2004) The IPCC suggests that the North Atlantic fisheries are likely to increase in productivity (Alcamo *et al.*, 2007).

Food & Agriculture – Community Resilience

Some agricultural communities will need to adapt to as patterns of production change.

In the Alpine regions and around the Mediterranean the effects of climate change may lead to long-term changes in the patterns of agricultural production that will change regional identity and affect cultural identity and tourism. *(Alcamo et al., 2007).*

In the 2020s, most European regions would experience yield improvements, particularly in

Northern Europe, with the exception of some areas in Central Europe South and Southern

Europe. The EU overall yield gain would be around 15%. In the 2080s the scenarios of lower warming would lead to small changes in yields for the EU, while the 5.4°C scenario could mean a fall in crop yields by 10%. All 2080s scenarios share a similar pattern in the spatial distribution of effects. Southern Europe would experience yield losses, which would become relatively high under the 5.4°C scenario – about 25%. Central Europe regions

would have moderate yield changes. In all scenarios the Northern Europe region would

benefit from positive yield changes, and to a lesser extent the British Isles for the 4.1°C and 5.4°C scenarios. (Ciscar 2009)

Food & Agriculture – Energy & Earth Resources

Higher energy cost will increase fertilizer costs but mid and northern European agriculture may benefit from climate change.

The yields per hectare of all cash crops have continuously increased in Europe in the past 40 years due to technological progress, while climate change has had a minor influence.

Agriculture in most parts of Europe, particularly in mid and northern Europe, is expected to potentially benefit from increasing CO_2 concentrations and rising temperatures. (EEA 2004)

As the energy costs increase the price of nitrogenous fertilizers will increase which will lead to a decreased profit margin for large-scale industrial agriculture and a change in farming methods. (Alcamo *et al.*, 2007).

Food & Agriculture – Health & Wellbeing

Regional disparities are likely to increase, and this will have impacts on health and wellbeing.

The effects of climate change on agriculture and water will be quite different in the northern, southern and eastern regions of Europe, thus intensifying regional disparities. There may be some benefits and new opportunities, especially in northern Europe, but also many losses and additional difficulties for farmers in the south. Many studies give detailed information about the likely changes in agriculture. (Behrens et al 2010)

The IPCC (2007) predicts an overall yield reduction in Southern Europe and an increase in agricultural yields in the North of Europe. The Mediterranean countries might experience more frequent localized harvest failures due to increased floods (destroying crops and irrigation systems) and droughts (reducing yields or destroying crops). This may lead to changes in diet and related effects in health and well-being. (Alcamo *et al.*, 2007).

Water Availability – Food & Agriculture

Droughts and floods are likely to increase, as is the need for irrigation in some areas.

Seasonally, across Europe river discharges have decreased in summer and increased in winter. These changes in seasonal discharge have probably increased the risks of droughts in some periods and floods at other times, although floods are not just the result of climate change, they are also partly caused by mismanagement and inappropriate land use. (EEA 2007)

Water scarcity around the Mediterranean will effect agricultural productivity and change the cultural identity of certain regions. The irregularity of rainfall will lead to an increased need for water to irrigate crops. In the Alps reduced snowfall and the long-term reduction in glacier-fed water supplies will affect patterns of agricultural production negatively. (Alcamo *et al.*, 2007).

Current glacier retreat in the Alps is reaching levels exceeding those of the past 5 000 years. It is very likely that the glacier retreat will continue. By 2050, about 75 % of the glaciers in the Swiss Alps are likely to have disappeared. (EEA 2004)

Habitat & Infrastructure – Energy & Resources

Heat waves seriously effect energy infrastructure. Disruption in supply may lead to decentralised electricity systems. Biomass generation may improve in northern areas.

Extreme heat waves can pose a serious threat to uninterrupted electricity supplies, mainly because cooling air may be too warm and cooling water may be both scarce and too warm. This can result in reduced capacities and reduced efficiency rates. (European Commission, 2009e; Eskeland et al., 2008). ..As regards other sources of energy, Eskeland et al. (2008) note that higher temperatures and atmospheric CO2 concentrations in moderate climates north of the Alps may benefit the growth of biomass and thus the electricity generation from agricultural crops, manure and wood chips" (CEPS, 2010).

"Similarly, accelerating average wind velocities could improve the electricity output of wind converters. On the other hand, the efficiency of photovoltaic plants could be slightly reduced by higher temperatures, especially during heat waves. Finally, brownouts and blackouts stemming from storms, floods and heat waves may lead to more decentralised electricity generation in order to avoid the impacts of interruptions in supply for certain electricity users"

The import of key building materials becomes more expensive as energy prices rise and the water-footprint of these materials gets increasingly included in the price of construction resources. (Alcamo *et al.*, 2007).

Habitat & Infrastructure – Ecosystems Services

Infrastructure will be stressed by climate change effects in different ecosystems.

Heat waves in Southern and Central Europe make cities dysfunctional during the summer months (overstretched utilities infrastructure is not able to provide sufficient water, energy and waste-collection/processing). Winter floods will increase in maritime regions and flash floods in mountainous regions during spring and autumn.

As the risk of forest fires will increase, some road and rail infrastructure-link may be temporarily blocked. Increased erosion in mountain and costal zones may further disrupt important transport infrastructure. There is a need for increase investment in flood-defences in costal regions and along rivers. (Alcamo *et al.*, 2007).

Habitat & Infrastructure – Community Resilience

Climate change could seriously impact tourism and the communities that depend on it.

Changes in the frequency of extreme weather events, such as storms, hurricanes, floods and heat waves, can have direct and greatly negative socio-economic consequences for the EU and its member states. Weather-related disasters or extremes are projected to increase all over Europe but they will vary among regions in terms of the intensity, frequency and typology of the disaster. (Behrens et al 2010)

Tourism is a major economic sector in Europe, with the current annual flow of tourists from Northern to Southern Europe accounting for one in every six tourist arrivals in the world

(Mather *et al.*, 2005). Climate change has the potential to radically alter tourism patterns in

Europe by inducing changes in destinations and seasonal demand structure (Scott *et al.*, 2008). (Ciscar 2009)

Tourism around the Mediterranean is likely to decrease in the summer and increase in Autumn and Spring. Tourism in mountainous regions is likely to increase in the summer and may decrease in the winter if snow-fall patterns shift and decrease.

Disruption to transport and community infrastructure in remote costal and mountain regions due to mud-slides, floods, fires, and erosion may make certain communities uninhabitable. (Alcamo *et al.*, 2007).

Habitat & Infrastructure – Food & Agriculture

There is a clear need for improved irrigation systems in Southern Europe. At the same time over-use of groundwater will increasingly lead to salination and groundwater depletion in regions that saw a rapid rise in large scale production of vegetables for export (eg Almeria region of South Eastern Spain). (Alcamo *et al.*, 2007).

Habitat & Infrastructure – Water Availability

Flooding will affect more areas of Central Europe and the UK, while water stress will require a significant rainwater capture and storage infrastructure and more efficient water use.

River flooding would affect 250,000 to 400,000 additional people per year in Europe by the 2080s, more than doubling the number with respect to the 1961–1990 period. In general terms, the higher the mean temperature increase, the higher the projected increase in people exposed by floods. An increase in people affected by river floods would occur mainly in the Central Europe regions and the British Isles…The total additional damage from river floods in the 2080s ranges between 7.7 billion € and 15 billion €, more than doubling the annual average damages over the 1961–1990 period. The regional pattern of economic damages is similar to that of people affected. Thus, while Northern Europe would have fewer damages, the Central Europe area and the British Isles would undergo significant increases in expected damages. (Ciscar 2009)

The increased variability in rainfall patterns will require a significant investment of rainwater capture and storage infrastructure and a retrofitting of the built environment to incorporate more efficient water use and re-use (grey-water).

Up-grading of infrastructure to store and treat water will be of high priority, as well as, investment in more water-efficient (rainwater-fed) irrigation systems for agriculture. (Alcamo *et al.*, 2007).

‘Habitat & Infrastructure – Health & Wellbeing

Significant housing stock is not suitable for changing climate conditions

The housing stock in most of Southern Europe is poorly insulated and this will increasingly lead to heat stress for elderly people in the summer, as energy intensive air-conditioning becomes less affordable. (Alcamo *et al.*, 2007).

1.12.3 Adaptive Capacity

Western Europe is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Western Europe					**HIGH 35.26**
Portugal	0.80	0.83	0.83	1.00	
Spain	0.80	0.50	0.83	1.00	
Germany	0.80	0.83	1.00	1.00	
France	0.80	0.67	1.00	1.00	
Italy	0.80	0.67	0.67	1.00	
Switzerland	1.00	1.00	1.00	1.00	
Belgium	0.80	0.67	1.00	1.00	
Netherlands	0.80	0.83	1.00	1.00	
Austria	0.80	1.00	1.00	1.00	

See page 3 and Book 1 Section 2.5 for an explanation of the rating method

1.13 United States Direct Impact Pattern

The United States constitutes the contiguous states of the mainland US and the states of Alaska and Hawaii.

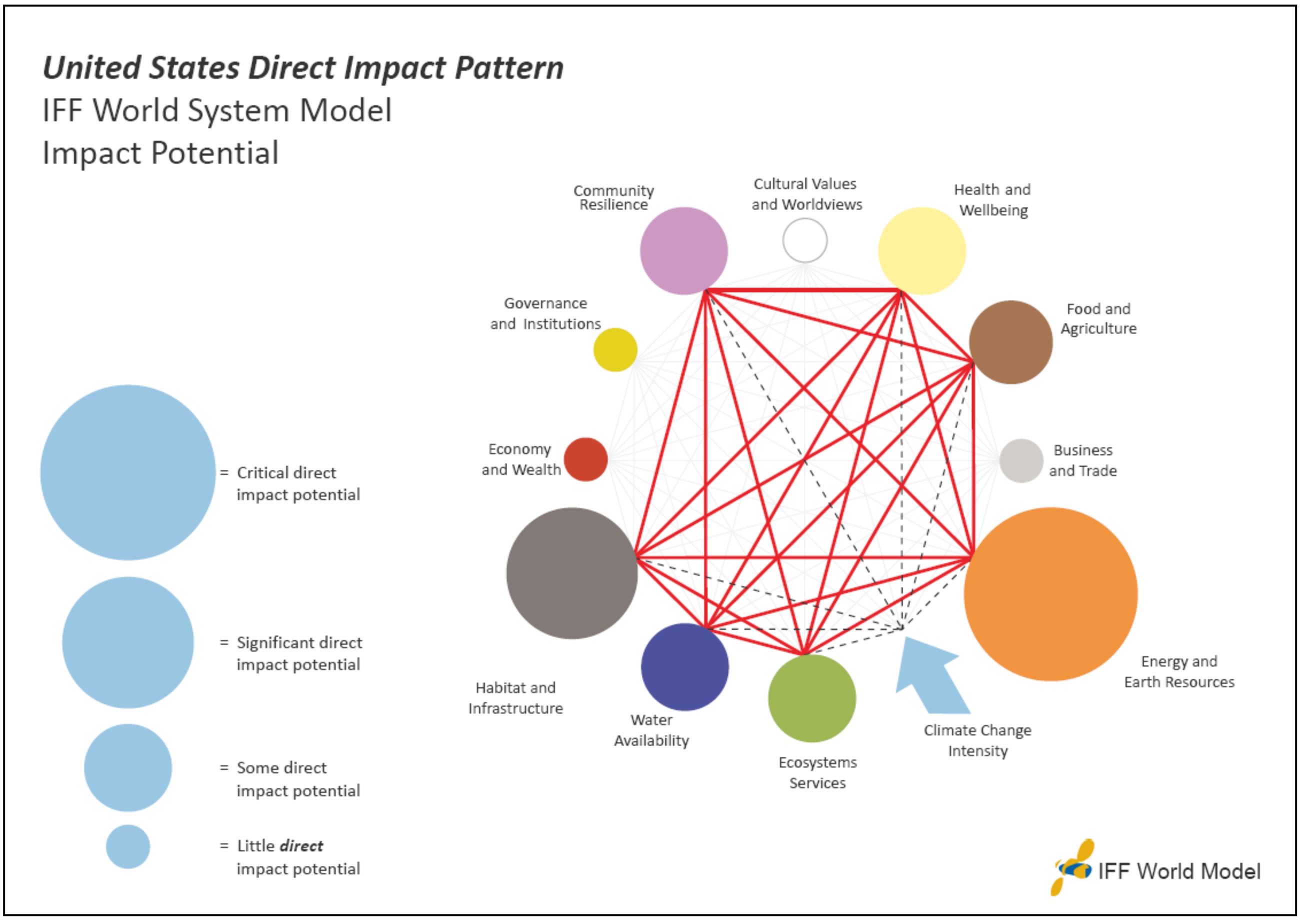


Figure 1.13.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.13.1 Overview

Climate-related changes have already been observed globally and in the United States. These include increases in air and water temperatures, reduced frost days, increased frequency and intensity of heavy downpours, a rise in sea level, and reduced snow cover, glaciers, permafrost, and sea ice. A longer ice-free period on lakes and rivers, lengthening of the growing season, and increased water vapor in the atmosphere have also been observed. Over the past 30 years, temperatures have risen faster in winter than in any other season, with average winter temperatures in the Midwest and northern Great Plains increasing more than 7ºF. Some of the changes have been faster than previous assessments had suggested. (Global Climate Change Impacts in the United States, 2009).

Between 1955 and 2005, the annual mean temperature across North America increased, with the greatest warming across Alaska (Field et al., 2007). As with many other regions, average night-time temperatures have seen a larger rise than daytime. Spring and autumn (fall) have experienced a greater warming than summer and winter. Snowmelt is occurring 1 to 4 weeks earlier across the mountainous areas of the continent, and ice break-up across North America has advanced by 0.2 to 12.9 days over the last 100 years (Magnuson et al., 2000). Across much of North America, precipitation (e.g. rain, hail, snow) has increased over the 20th century, particularly in northern Canada and Alaska. However, this is not the case in the south-western US. This area has seen a decrease in precipitation rates of 1 to 2% per decade as drought conditions prevail (Trenberth et al., 2007). Snowfall and snow cover has decreased across much of North America despite the increased precipitation, largely as a result of increasing temperatures. (Met Office 2008) See Table 2.13.1 for summary.

Region	Range of Projected Temperature Change (°C)	Range of Projected Precipitation Change (%)
Alaska & north-west Canada	+3.0 to +7.4	+6 to +32
North-east Canada & Greenland	+2.8 to +7.1	+8 to +31
Western North America	+2.1 to +5.7	-3 to +14
Central North America	+2.3 to +5.8	-16 to +15
Eastern North America	+2.3 to +5.6	-3 to +15

Table 1.13.1 Projected changes in North American temperature and precipitation for the period 20180 – 2099 relative to 1980 -1999 (Christensen et al, 2007)

1.13.2 Systemic Relationships – Principal Paired Interactions (21)

Health and Wellbeing – Habitat and Infrastructure

Higher temperatures are likely to lead to more deaths, particularly among vulnerable groups.

Another long-term challenge will be dealing with changing migration and immigration patterns in the United States. Climate change is likely to affect residents of coastal areas where rising sea-levels will force people inland. Public health and health care professionals must bereadу to address the added stress on the public health and health care infrastructure. (Trust for America's Health, 2009, p9)

Climate change is expected to lead to an increase in ambient (i.e., outdoor) average air temperature, with greater increases expected in summer than in winter months. Larger temperature increases are anticipated in inland communities as compared to the California coast. The potential health impacts from sustained and significantly higher than average temperatures include heat stroke, heat exhaustion, and the exacerbation of existing medical conditions such as cardiovascular and respiratory diseases, diabetes, nervous system disorders, emphysema, and epilepsy. Numerous studies have indicated that there are generally more deaths during periods of sustained higher temperatures, and these are due to cardiovascular causes and other chronic diseases. The elderly, infants, and socially-isolated people with pre-existing illnesses who lack access to air conditioning or cooling spaces are among the most at risk during heat waves. (California 2009)

Health and Wellbeing – Ecosystem Services

Climate change is likely to cause substantial ecosystem damage compromising ecosystem services.

Effects on ecosystems, and on species diversity in particular, are expected to be negative at all but perhaps the lowest magnitudes of climate change because of the limited ability of natural systems to adapt. Although biological systems have an inherent capacity to adapt to changes in environmental conditions, given the rapid rate of projected climate change, adaptive capacity is likely to be exceeded for many species. Furthermore, the ability of ecosystems to adapt to climate change is severely limited by the effects of urbanization, barriers to migration paths, and fragmentation of ecosystems, all of which have already critically stressed ecosystems independent of climate change itself. (Easterling 2004)

Health and Wellbeing – Energy and Earth Resources

Maintaining levels of health and wellbeing in hotter climates will require more energy, with greater impact on more vulnerable groups.

Some Americans are particularly vulnerable to the negative consequences of climate change on health, including increasing heat stress, air pollution, extreme weather events, and diseases carried by food, water, and insects. These vulnerable populations include: Infants and children; Pregnant women; The elderly; The poor; Racial and ethnic minorities; People with disabilities; and People with chronic medical conditions, including the obese. (Trust for America's Health, 2009, p4)

More African Americans will be "fuel-poor" as the demand for energy rises due to higher air-conditioning loads, population growth, and urbanization. African Americans already spend an estimated 25 percent greater share of their income on energy than the national average, and total spending is rising in the face of increasing gasoline and resource prices; (Trust for America's Health, 2009, p26)

Health and Wellbeing – Food and Agriculture

Climate change will increase pathogens transmitted by food, water and animals.

A number of important disease-causing agents (pathogens) commonly transmitted by food, water, or animals are susceptible to changes in replication, survival, persistence, habitat range, and transmission as a result of changing climatic conditions such as increasing temperature, precipitation, and extreme weather events. Cases of food poisoning due to *Salmonella* and other bacteria peak within one to six weeks of the highest reported ambient temperatures. Heavy rain and flooding can contaminate certain food crops with feces from nearby livestock or wild animals, increasing the likelihood of food-borne disease associated with fresh produce.163 *Vibrio* sp. (shellfish poisoning) accounts for 20 percent of the illnesses and 95 percent of the deaths associated with eating infected shellfish, although the overall incidence of illness from *Vibrio* infection remains low. There is a close association between temperature, *Vibrio* sp. abundance, and clinical illness. The U.S. infection rate increased 41 percent from 1996 to 2006,163 concurrent with rising temperatures. (Global Climate Change Impacts in US 2009)

Health and Wellbeing – Water Availability

Climate change is likely to increase the contamination of water bodies, as well as decrease fresh water resources.

Storm impacts, particularly hurricanes and tropical storms, are likely to be more severe. Heavy rainfall associated with these storms can increase the risk of flooding and lead to greater runoff and erosion, which can have adverse water quality effects. These can lead to an increase in the number of people at risk from disease and injury related to floods and storms. Other areas will be afflicted by declines in annual precipitation, leading to an increase in the number of people at risk from disease and injury related to droughts and wildfires. (Trust for America's Health, p5 2009)

Water quality has direct impacts on human health. The warmer temperatures associated with climate change are predicted to decrease dissolved oxygen levels, increase contaminant load to water bodies, reduce stream and river flows, foster algal blooms, and increase the likelihood of saltwater intrusion near coastal regions. All of these climate change impacts play a role in water quality and have implications for water, wastewater, and stormwater utilities. (Trust for America's Health, 2009)

Health and Wellbeing – Community Resilience

Climate change is likely to negatively impact community resilience in multiple ways.

Communities across the United States are at-risk for negative health effects associated with climate change. Urban communities face natural disasters, such as floods and heat waves. Rural communities may be threatened by food insecurity due to shifts in crop growing conditions, reduced water resources, heat, and storm damage. Coastal and low-lying areas could see an increase in floods, hurricanes, and tropical storms. Mountain regions are at risk of increasing heat and vector-borne diseases due to melting of mountain glaciers and changes in snow melt. And communities around the country could experience new insect-based infectious diseases that used to only be affiliated with high temperature regions. (Global Climate Change Impacts in US 2009)

Water Availability – Food and Agriculture

Agriculture will have to compete for diminishing water resources as aquifers and rivers become depleted.

A study by Rivera et al. (2004) examines how groundwater aquifers could see significant changes in character as more water is abstracted to meet irrigation and consumption needs, while recharge and transport or water into the aquifers are affected as precipitation patterns and temperatures change. Over-abstraction combined with sea level rise could then lead to increased incidences of saline intrusion into aquifers, polluting the water resource with saltwater for a period of time. (Met Office 2008)

Since five out of every six gallons of water used in the United States are consumed by agriculture, any changes in water supply will quickly ripple through the nation's farms. Growing demand has placed increasing stresses on the available supplies of water, especially – but not exclusively – in the driest parts of the country. The spread of population, industry, and irrigated agriculture throughout the arid West has consumed the region's limited sources of water. The huge Ogallala Aquifer, a primary source of water for irrigation and other uses in several of the Plains states, is being depleted, with withdrawals far in excess of the natural recharge rate. In the Southwest, battles over allocation and use of the Colorado River's water have raged for decades. (Global Climate Change Impacts in US 2009)

Water Availability - Ecosystem Services

Ecosystems services are threatened by over abstraction and drier climates.

In many rivers and streams in the US, there is not enough water to satisfy existing water rights and claims. Changing public values about preserving in-stream flows, protecting endangered species, and settling Indian water rights claims have made competition for water supplies increasingly intense. Climate change will very likely exacerbate competition in regions where fresh water availability is reduced by increased evaporation due to rising air temperatures and changes in precipitation. In some areas, however, an increase in precipitation could possibly outweigh these factors and increase available supplies.

Land health in the U.S. is already an ongoing and considerable ecological problem. Most models project that almost any amount of warming will cause much of the Southwest to become more arid over the course of the 21st century. Seventeen states in the Western U.S. can be categorized as arid, semi-arid or dry subhumid based on climate and soil type; and therefore vulnerable to desertification. Overgrazing, and poor irrigation, are the leading causes of desertification in the U.S. (Millenium Ecosystem Assessment, Desertification synthesis)

Water Availability - Habitat and Infrastructure

Rapidly diminishing snowpack will create greater supply challenges, while aging infrastructures will struggle to cope.

In older cities, some buried water mains are over 100 years old and breaks of these lines are a significant problem. Sewer overflows resulting in the discharge of untreated wastewater also occur frequently. Heavier downpours will exacerbate existing problems in many cities, especially where stormwater catchments and sewers are combined.

Drinking water and sewer infrastructure is very expensive to install and maintain. Climate change will present a new set of challenges for designing upgrades to the nation’s water delivery and sewage removal infrastructure. (Global Climate Change Impacts 2009)

Nearly 75 percent of California’s available water supply originates in the northern third of the state mainly from water stored in the rapidly diminishing Sierra Nevada snowpack. At the same time, 80 percent of the demand occurs in the southern two-thirds of the state. California has been able to bridge the geographic distance between water supply and demand by building one of the most complex water storage and transport systems in the world to convey large quantities of water throughout the state. Even without higher air temperatures and changing precipitation patterns over the next few decades, California's water supply problems would already be challenging. (California 2009)

Water Availability - Community Resilience

Climate change will create too much water in some places, too little in others and contribute to degraded water quality. Many communities will have to find ways to adapt.

For the future, marked regional differences are projected, with increases in annual precipitation, runoff, and soil moisture in much of the Midwest and Northeast, and declines in much of the West, especially the Southwest. The impacts of climate change include too little water in some places, too much water in other places, and degraded water quality. Some locations are expected to be subject to all of these conditions during different times of the year. Water cycle changes are expected to continue and to adversely affect energy production and use, human health, transportation, agriculture, and ecosystems. (Global Climate Change Impacts in US 2009)

Even if there were no large changes in precipitation, much of the country would face expensive problems of water supply in the course of this century. In Florida, one of the states with the highest annual rainfall, the rapid pace of residential and tourist development, and the continuing role of irrigated winter agriculture, have led to water shortages. In the dry southwest, shortages of water and the high energy costs involved in maintaining the water infrastructure may begin to threaten the resilience of many established communities. (Global Climate Change Impacts in US 2009)

Water Availability - Energy and Earth Resources

Much energy infrastructure requires significant water use, while water infrastructure requires significant energy use: both will be negatively effected by climate change.

Warming will result in significant increases in electricity use and peak demand in most regions while energy production is likely to be constrained by rising temperatures and limited water supplies in many regions. Coal, oil, nuclear, and many natural gas power plants rely on massive amounts of water. Extended droughts are increasingly jeopardizing nuclear power reliability. In the United States, many nuclear plants rely on river water for cooling, the category most vulnerable to heat waves. While Washington, Oregon, and Idaho – where dams account for a very significant percentage of generation,– are particularly vulnerable to drought, clearly reducing hydroelectric output.

While energy production is dependent on water, water infrastructure is dependent on energy. In California water-related energy use consumes 19 percent of the state's electricity, 30 percent of its natural gas, and 88 billion gallons of diesel fuel every year – and this demand is growing. (California Energy Commission, 2005)

Food and Agriculture - Energy and Earth Resources

Temperate agriculture will need to provide a higher proportion of the world's food, continuing the controversy of biofuel production.

The growing, or at least non-declining, crop yields in temperate agriculture over the next few decades will be a valuable, scarce global resource. The major producing regions of temperate agriculture – the United States, Canada, northern China, Russia, and northern Europe, along with Argentina, Chile, Australia, New Zealand, and South Africa – will have an expanded share of the world's capacity to grow food, while populations are increasing fastest in tropical countries where crop yields will be falling. The relationships between biofuel production and food growing in this global context will continue to be controversial. (Cassman, 2007)

Food and Agriculture - Ecosystem Services

Cattle production will become less efficient as the quality of forage diminishes and climate change is disrupting biological interactions such as pollination.

Agriculture in the United States is extremely diverse in the range of crops grown and animals raised, and produces over $200 billion a year in food commodities, with livestock accounting for more than half. With about 100 million cattle in the U.S., beef production takes place in every state in the United States. There are transformations now underway in many semi-arid rangelands as a result of increasing atmospheric carbon dioxide concentration and the associated climate change which are reducing the quality of the forage. More acreage is needed to provide animals with the same nutritional value, resulting in over grazing pressure and an overall decline in livestock productivity. (Global Climate Change Impacts in US 2009)

Forested areas will move northwards as temperatures rise and CO_2 levels increase, and the growing season could extend in length, increasing the primary productivity of North America (Berthelot et al., 2002). Such areas could then become carbon sinks, drawing CO_2 from the atmosphere. However, some areas, including those not currently water-stressed, might become drought-prone, particularly in the south-west where temperatures are expected to rise the most. (Met Office 2008)

The impact of warming has already affected the timing of biological events such as flowering, leafing out, breeding, and migration and will continue to do so. This change in composition can disrupt biological interactions and impact ecosystem dynamics by displacing existing biological interactions and replacing it with another. For example, an earlier occurrence of flowering may result in futile reproduction efforts for pollinators if they are unable to adjust quickly to the change in availability of resources. Changes in pollinator activity will affect dependent species throughout the natural and human food chain. (California 2009)

Food and Agriculture – Community Resilience

Extreme events may cause significant challenges to agricultural communities, while the adaptive capacity of agriculture to changing conditions will determine longer term resilience.

It appears likely, that under the business-as-usual scenario, the first half of this century will see either little change or a small climate-related increase in yields from non-irrigated agriculture; irrigated areas will be able to match this performance if sufficient water is available. By the second half of the century, as temperature increases further yields will drop everywhere. Assumptions about adaptation to changing climatic conditions are of great importance: the more rapid and skilful the adaptation, the smaller the losses will be.

Extreme events may be among the greatest challenges, as they can lead to large loss of crops, impose stress on livestock, and be most difficult to manage. (California 2009)

Food and Agriculture - Habitat and Infrastructure

There is a growing risk of declining yields from US arable and pasturelands which make up over 40% of land area.

Agriculture in the United States is extremely diverse in the range of crops grown and animals raised, and produces over $200 billion a year in food commodities, with livestock accounting for more than half. Climate change will increase productivity in certain crops and regions and reduce productivity in others (see for example *Midwest* and *Great Plains* regions). Increased pests, water stress, diseases, and weather extremes will pose adaptation challenges for crop and livestock production. (Global Climate Change Impacts in US 2009, p. 71)

Yields of some annual crops such as cotton, maize, sunflower, and wheat are expected to slightly decrease by mid-century, while rice and tomato yields remain more or less unchanged. By the end of the century there is a growing risk of declining yields of all examined crops except alfalfa; that risk is significantly higher under the higher emissions scenario. (California 2009)

Community Resilience - Habitat and Infrastructure

Tidewater and river based cities including NY and Washington are vulnerable to the effects of climate change.

Tourism is a very important part of the United State's economy. Increases in temperature could encourage more tourists to visit national and state parks throughout the year, although this could have negative impacts on the attractions themselves due to increased footfall and transport/infrastructure. Some attractions in the south-west of the country, which is expected to see the greatest increase in temperature, could see declines in visitor numbers as temperatures rise to uncomfortable levels throughout much of the year. (Met Office 2008)

Since most large North American cities are on tidewater or rivers, they will face a gradual increase in the probability of what are currently unusually large storm surges. New York City, for example, could experience what are now considered 100-year floods every three to four years by the end of the 21stcentury, while strong storm surges, could easily inundate much of the energy grids and other small-scale infrastructure in Washington D.C.

The most significant climate impacts to California's infrastructure are predicted to be from higher temperatures and extreme weather events across the state, reduced and shifting precipitation patterns in Northern California, and sea-level rise. Higher air temperatures are expected to increase the demand for electricity in the Central Valley and Southern California, especially during hotter summer months, reducing energy production and transmission efficiency while increasing the risk of outages. Potential reductions on precipitation levels could significantly reduce hydropower production which currently accounts for up to 20 percent of the state's electricity supply. The largest projected damages will come from sea-level rise threatening large portions of California's coastal transportation, housing, and energy-related infrastructure. (California 2009)

Community Resilience – Energy and Earth Resources

Climate change is likely to bring demands on energy resources that seriously challenge the viability of suburban lifestyles.

The United States of America is the world's largest energy producer, consumer, and net importer (EIA, 2009). Any disruption to supply can cost industry dearly. For example the hurricanes which crossed Florida during 2004 resulted in US$1.4 billion worth of damages to public utilities, and power outages regularly experienced across the US can cost the industry up to US$130 billion annually (Field et al., 2007). Hurricanes and other storms can also result in significant damage to extraction infrastructure, such as the oil and gas platforms and pipelines in the Gulf of Mexico, which were badly affected by Hurricane Katrina. (Met Office 2008)

American infrastructure is predicated the on the availability of cheap oil. Since World War II North Americans have invested much of their newfound wealth in car reliant suburbia. As the population of suburban sprawl has exploded in the past 50 years, so too has the suburban way of life become embedded in the American consciousness. Climate change (along with peak oil) is likely to bring demands on energy resources (including the development of low emission infrastructure) that will severely challenge the viability of this way of life. (http://www.endofsuburbia.com/)

Energy and Earth resources - Habitat and Infrastructure

Energy demands will rise with increased temperatures, which are likely to stress existing infrastructure. Domestic oil production is in vulnerable regions.

The recent natural disasters of Hurricanes Katrina, Rita and Wilma (all in 2005), highlighted just how susceptible the US's infrastructure can be. Increasing populations and further development on coastal areas will continue to put pressure on vulnerable infrastructure. Developing reliable projections on the changing frequency and intensity of hurricanes is notoriously difficult, although some studies do show an increase in both characteristics. If true, increase incidences of damage to infrastructure should be expected. Extra-tropical storms affecting the US are also expected to increase in intensity, although decrease in number (Meehl et al., 2007). (Met Office 2008)

The United States is the world largest energy consumer in terms of total use, with a high and growing dependency on imported oil. Domestic energy production and delivery systems are exposed to sea-level rise and extreme weather events in vulnerable regions. The U.S. Gulf Coast is home to many offshore and coastal energy facilities—more than a quarter of U.S. oil production and nearly 15 percent of natural gas production comes from the Gulf of Mexico, for instance. (Global Climate Change Impacts in US 2009)

Higher temperatures associated with climate change will place considerable strain on the U.S. power sector. Droughts and heat waves put most generators at risk, adding stress to transmission and generation systems and thereby reducing efficiency and raising the cost of electricity. (Global Climate Change Impacts in US 2009)

Infrastructure in Alaska is likely to become more vulnerable as areas of permafrost melt and the mobile, active layer of the ground becomes deeper and more susceptible to movement. This could result in infrastructure being more costly to build and maintain, although frost damage is likely to decrease. (Met Office 2008)

Energy and Earth Resources – Ecosystem Services

Several thousand offshore drilling platforms, dozens of refineries, and thousands of miles of pipelines are vulnerable to damage and disruption due to sea-level rise and the high winds and storm surge.

The Gulf Coast is home to the U.S. oil and gas industries, representing nearly 30 percent of the nation's crude oil production and approximately 20 percent of its natural gas production. One-third of the national refining and processing capacity lies on coastal plains adjacent to the Gulf of Mexico. Several thousand offshore drilling platforms, dozens of refineries, and thousands of miles of pipelines are vulnerable to damage and disruption due to sea-level rise and the high winds and storm surge associated with hurricanes and other tropical storms. For example, hurricanes Katrina and Rita halted all oil and gas production from the Gulf, disrupted nearly 20 percent of the nation's refinery capacity, and closed many oil and gas pipelines. Relative sea-level rise in parts of the Gulf Coast region is projected to be as high as 2 to 4 feet by 2050 to 2100, due to the combination of global sea-level rise caused by warming oceans and melting ice and local land sinking. Combined with onshore and offshore storm activity, this would represent an increased threat to this regional energy infrastructure. Offshore oil production is particularly susceptible to extreme weather events. Hurricanes Katrina and Rita in 2005 destroyed more than 100 platforms and damaged 558 pipelines. (Global Climate Change Impacts in US 2009)

Climate change in California forests may affect tree survival and growth, forest composition, forest health and productivity, and will likely increase the intensity of ecosystem disturbances from wildfire, insects and pathogens. Population growth and land use change may create additional stresses that increase vulnerability to impacts from climate change. The interaction of these forces may reduce or change the range of ecosystem goods and services available for wildlife and watersheds, citizens, communities, and businesses. (California 2009)

Community Resilience – Ecosystem Services

Rural economies and the natural environment and closely linked and likely to be impacted by climate change.

In many places, the rural economy is closely tied to its natural environment. Rural workers and communities are the stewards of most American forests, watersheds, rangelands, agricultural land, and fisheries. Each of these environments has already been affected by climate change, with both positive and negative results for rural economies. For example, scientists say warmer winters may be one reason pine-boring beetles have spread to new forest habitats in the American West, killing more than seven million acres of forest (Johnson 2009). Some logging companies in western forests have profited from using the dead trees in their operations, but public officials have also had to close roads and recreation areas due to dangers related to forest fires and falling trees (Cliff 2008). Scientists and policymakers predict that agricultural economies may also both benefit and suffer from climate changes, depending on their location. Some areas in the US will experience increased plant growth due to increasing levels of carbon dioxide in the atmosphere (GAO 2009). However, changes in precipitation patterns will mean more droughts, floods, and other water-related problems such as extreme storms (National Oceanic and Atmospheric Administration 2009) that will adversely affect some rural populations and agricultural economies. (Jensen 2009)

Habitat and Infrastructure – Ecosystem Services

Habitat and infrastructure is likely to be threatened in some areas with increased wild fires.

Due to changes in temperature and precipitation associated with climate change, researchers expect the frequency of wildfires to increase over and beyond the recently experienced trends. Depending on which emissions and population growth scenario is used, and what land use and vegetation assumptions are made, projections vary and uncertainty increases with time. The number of wildfires associated with the higher emissions pathway (A2) is substantial, with state-wide increases ranging from 37 to 94 percent by 2085. (California 2009)

Adaptive Capacity

The United States is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)	
United States	0.80	0.67	1.00	1.00	**HIGH**	**34.67**

See page 3 and Book 1 Section 2 .5 or an explanation of the rating method.

1.14 Australia Direct Impact Pattern

Australia is treated alone.

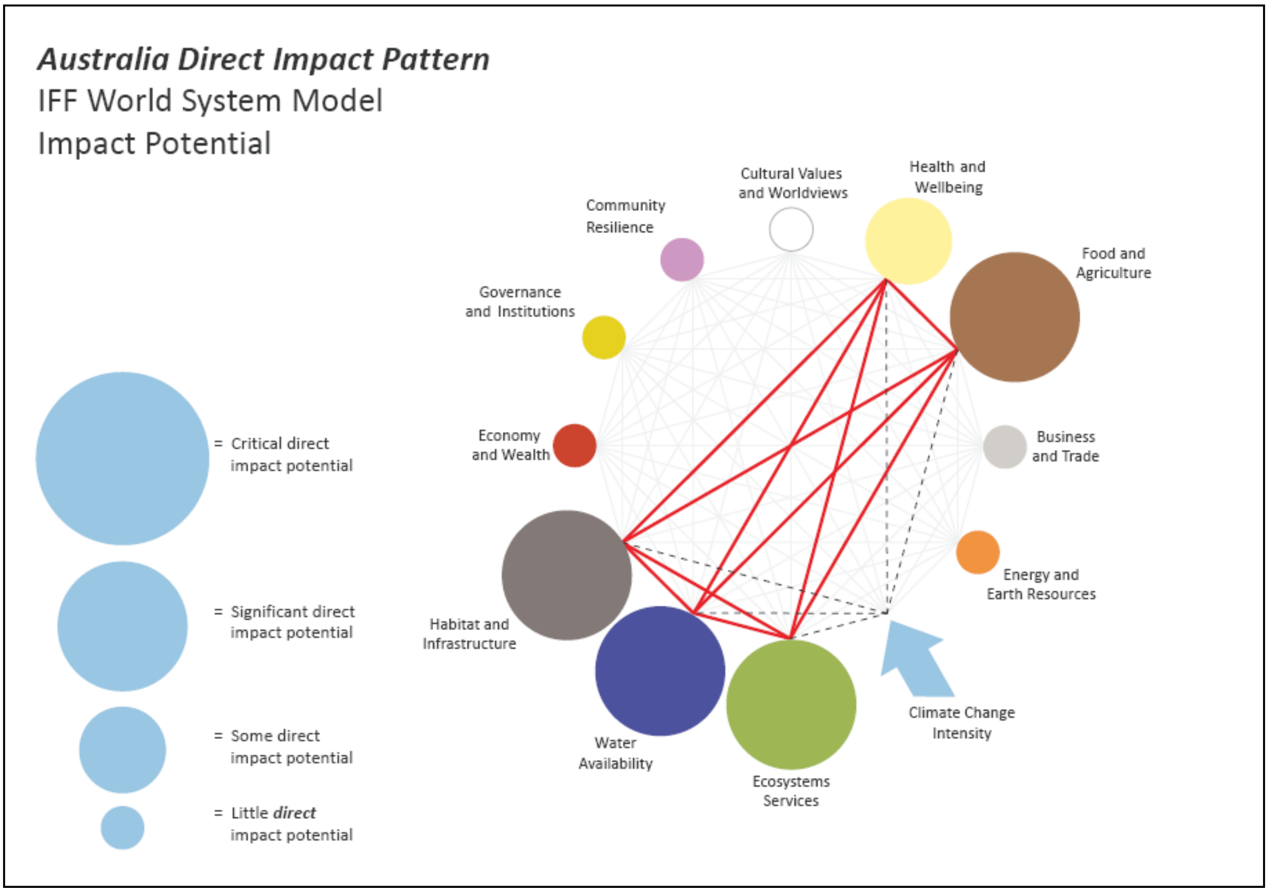


Figure 1.14.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.14.1 Overview

On Australia, the 2007 IPCC report predicted "the climate of the 21st century is virtually certain to be warmer, with changes in extreme events. Heat waves and fires are virtually certain to increase in intensity and frequency (high confidence).

Floods, landslides, droughts and storm surges are very likely to become more frequent and intense, and snow and frost are very likely to become less frequent (high confidence). Large areas of mainland Australia are likely to have less soil moisture. Vulnerability is likely to increase in many sectors, but this depends on adaptive capacity.

Most human systems have considerable adaptive capacity: The region has well-developed economies, extensive scientific and technical capabilities, disaster mitigation strategies, and biosecurity measures. However, there are likely to be considerable cost and institutional constraints to the implementation of adaptation options (high confidence). Some Indigenous communities have low adaptive capacity (medium confidence). Water security and coastal communities are the most vulnerable sectors (high confidence). *Natural systems have limited adaptive capacity:* Projected rates of climate change are very likely to exceed rates of evolutionary adaptation in many species (high confidence). Habitat loss and fragmentation are very likely to limit species migration in response to shifting climatic zones (high confidence). (IPCC, 2007, p.509) *Vulnerability is likely to rise due to an increase in extreme events:* Economic damage from extreme weather is very likely to increase and provide major challenges for adaptation (high confidence). *Vulnerability is likely to be high by 2050 in a few identified hotspots:* In Australia, these include the Great Barrier Reef, eastern Queensland, the South-West, Murray- Darling Basin, the Alps and Kakadu wetlands …(medium confidence)" (IPCC, 2007, p.509)

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) conducted a number of detailed studies on Australia's changing climate and future climate change scenarios for that region. "The average surface air temperature of Australia increased by 0.7°C over the past century – warming that has been accompanied by marked declines in regional precipitation, particularly along the east and west coasts of the continent. These seemingly small changes have already had widespread consequences for Australia…Analysis of future emissions trajectories indicates that, left unchecked, human GHG emissions will increase several fold over the 21st century. As a consequence, Australia's annual average temperatures are projected to increase 0.4–2.0°C above 1990 levels by the year 2030, and 1– 6°C by 2070. Average precipitation in southwest and southeast Australia is projected to decline further in future decades, while regions such as the northwest may experience increases in precipitation. Meanwhile, Australia's coastlines will experience erosion and inundation from an estimated 8–88 cm increase in global sea level" (CSIRO, 2005, p.5).

1.14.2 Systemic Relationships – Principal Paired Interactions (10)

Water Availability – Ecosystems Services

The impact of climate change on species composition and growth and the frequency of fires may profoundly effect Australia's most important forest water catchments areas.

"The current pressures placed on Australian water resources are indicative of their general high vulnerability to climatic change …. Many of Australia's most important catchments are covered by native forest. The impact of climate change on growth, species composition, and frequent/severity of fire and pest incursion may profoundly impact on water supply from these catchments, including the prospect of water losses due to further reforestation in cleared catchments. Climate change will also influence water demand for irrigation and other uses. If climate change increases demand and decreases water supply, then there is a need to supplement supply or reduce demand. " (CSIRO, 2005, p.25). The vital ecosystems services provided by native Australian forests include maintenance of the regional hydrological cycle, and a protection against soil erosion on salination.

"For the vast bulk of Australia's plantation forests the interaction between temperature and water availability is the key issue, with productivity being predominantly water limited, and "growing season" often being more influenced by water availability…However, knowledge of productive growth of a forest species beyond its core climatic envelope can provide valuable information on how species may acclimatise to changes. For higher magnitudes of warming, forestry in Northern Australia suffers lowered productivity, while in the cooler, less water limited areas of Southern Australia forest productivity increases" (CSIRO, 2005, p.23-24).

Ecosystems Services – Infrastructure & Habitat

Continued climate related deterioration of ecosystems services would have drastic impacts on Australia's infrastructure and economy. Climate change mitigation and adaptation will be an increasingly central component of Australia's political agenda.

"A number of Australia's ecosystems are vulnerable to changes in temperature and precipitation …, and thus significant adverse consequences from climate change are projected, even for relatively small shifts in climate conditions. The Great Barrier Reef, a UNESCO World Heritage area, is particularly vulnerable to climate change, given the narrow coping range and limited adaptive capacity of corals. Historically unprecedented rates of bleaching have occurred over the past two decades and considerable losses or contractions of species associated with coral communities are projected for a further warming of only 1°C …. Similarly, high altitude mountain ecosystems are sensitive to climate change-induced reductions in winter snow cover, and the highland rainforests of northern Australia are projected to decrease by 50% for just a 1°C increase in temperature. Given higher magnitudes of warming, adverse effects for certain groups of species are expected to become progressively worse" (CSIRO, 2005, p.23).

Observations of the changing climate and its impact over last 20 years have shown that Australia's already fragile ecosystems are particularly vulnerable to climate change. Since ecosystem diversity and adaptive capacity are directly linked, and a continued deterioration of ecosystems services would have drastic impact son Australia's infrastructure and economy, climate change mitigation and adaptation will be an increasingly central component of Australia's political agenda.

Health & Wellbeing – Infrastructure & Habitat

The concentration of Australia's population within 50 km of the coast this has exposed greater numbers of people, wealth and infrastructure to extreme weather events.

"Due to its relatively high adaptive capacity, the vulnerability of Australia's public health sector is relatively low …, although one can identify demographic groups, such as Australia's aboriginal population, with elevated vulnerability to health challenges due to limited access to financial and public health resources. The effects of climate change on heat- related mortality suggest that increases in temperature combined with population growth may result in an increase in heat-related deaths …. Climate change could cause large increases in flooding deaths and injuries, depending upon future changes in precipitation extremes. Climate change could cause the range of mosquito vectors for dengue and malaria to expand southward. However, public health interventions targeting malaria during the 1960s have largely eliminated the risk of transmission and reintroduction of the disease is unlikely. In contrast, the transmission of dengue continues in Australia, although cases are largely confined to northern Queensland. " (CSIRO, 2005, p.27).

Australia's population has been growing steadily combined with the concentration of Australia's population within 50 km of the coast this has exposed greater numbers of people, wealth and infrastructure to extreme weather events. Since these socioeconomic trends are projected to continue for the next 50 years, Australia's vulnerability to extreme events will continue to increase. To ensure the health and wellbeing of Australia's costal population major investments in costal infrastructure as part or the country's climate change adaptation strategy will be necessary.

Health & Wellbeing – Water Availability

Freshwater availability and quality are very likely to deteriorate, requiring adaptive management strategies to limit the consequences for human health.

Another critical influence on the health and wellbeing of Australia's population is the availability and quality of freshwater. The 2007 IPCC report states: "In Australia, there is a 50% chance by 2020 of the average salinity of the lower Murray River exceeding the 800 EC threshold set for desirable drinking and irrigation water (MDBMC, 1999)... Toxic algal blooms are likely to become more frequent and to last longer due to climate change. They can pose a threat to human health, for both recreation and consumptive water use, and can kill fish and livestock (Falconer, 1997). Simple, resource-neutral, adaptive management strategies, such as flushing flows, can substantially reduce their occurrence and duration in nutrient-rich, thermally stratified water bodies (Viney et al., 2003)" (IPCC, 2007, p.517).

"One of the most significant health impacts of climate change is likely to be an increase in heat-related deaths. Assuming no planned adaptation, the number of deaths is likely to rise from 1,115/yr at present in Adelaide, Melbourne, Perth, Sydney and Brisbane to 2,300 to 2,500/yr by 2020, and 4,300 to 6,300/yr by 2050, for all SRES scenarios, including demographic change (McMichael et al., 2003)… Australian temperate cities are likely to experience higher heat-related deaths than tropical cities, and the winter peak in deaths is likely to be overtaken by heat- related deaths in nearly all cities by 2050 (McMichael et al., 2003)" (IPCC, 2007, p.524).

Water Availability – Food & Agriculture

Changes in precipitation and subsequent water management are critical factors affecting the future productivity of the Australian landscape. Irrigated crops are likely to suffer, as are those requiring vernalisation, and pests may increase.

"Australian crop agriculture and forestry may experience transient benefits from longer growing seasons a warmer climate and increasing atmospheric CO2 concentrations, yet such benefits are unlikely to be sustained under the more extreme projections of global warming. Furthermore, changes in precipitation and subsequent water management are critical factors affecting the future productivity of the Australian landscape. The declines in precipitation projected over much of Australia will exacerbate existing challenges to water availability and quality for agriculture as well as for commercial and residential uses" (CSIRO, 2005, p.5).

According to the 2007 IPCC report: "Australian temperate fruits and nuts are all likely to be negatively affected by warmer conditions because they require winter chill or vernalisation. Crops reliant on irrigation are likely to be threatened where irrigation water availability is reduced. Climate change is likely to make a major horticultural pest, the Queensland fruit fly *Bactrocera tryoni*, a significant threat to southern Australia…(Sutherst et al., 2000). … a rise in CO2 concentration is likely to increase pasture growth [in Australia], particularly in water-limited environments (Ghannoum et al., 2000; Stokes and Ash, 2006). However, if rainfall is reduced by 10%, this CO2 benefit is likely to be offset (Howden et al., 1999d; Crimp et al., 2002). A 20% reduction in rainfall is likely to reduce pasture productivity by an average of 15% and liveweight gain in cattle by 12%, substantially increasing variability of farm income (Crimp et al., 2002)" (IPCC, 2007, p.519). Since the agricultural sector and livestock industries are significant contributors to the Australian economy, the pressure on scarce water resources is likely to increase as the population continues to rise.

Water Availability - Infrastructure & Habitat

Extreme weather events are likely to challenge coastal infrastructure and coastal areas which already experience decreased rainfall will need to adapt water infrastructures.

Since rainfall has already decreased significantly on the Australian East and West cost, and the majority of the Australian population lives in costal areas (see above) there will be a need to increase water efficiency along with other necessary infrastructure adaptations in response to climate change. "Future changes in climate extremes, such as tropical cyclones, heat waves, and extreme precipitation events, would degrade Australian infrastructure and public health; e.g. through increased energy demands, maintenance costs for transportation infrastructure, and coastal flooding" (CSIRO, 2005, p.5).

The IPCC predicts that "risks to major infrastructure are likely to increase. By 2030, design criteria for extreme events are very likely to be exceeded more frequently. Risks include failure of floodplain protection and urban drainage/sewerage, increased storm and fire damage, and more heatwaves, causing more deaths and more blackouts (high confidence)" (IPCC, 2007, p.509). Water efficiency will be one of many measures by which infrastructure upgrades in response to climate change will have to be measured.

Food & Agriculture – Ecosystems services

Several of Australia's ecosystems are close to tipping points that could change the basis of agricultural production.

Many of Australia's key industry sectors such as agriculture and tourism are also vulnerable to the high variability in temperature and rainfall patterns. If global greenhouse gas emissions continue to rise unchecked, Australia will experience further declines in agricultural production, as well as rising costs" (Australian Department of Climate Change, 2010, p.5).

According to the IPCC, the "production from agriculture and forestry is projected to decline by 2030 over much of southern and eastern Australia …" (IPCC, 2007, p.509). "Major changes are expected in all vegetation communities. In the Australian rangelands (75% of total continental land area), shifts in rainfall patterns are likely to favour establishment of woody vegetation and encroachment of unpalatable woody shrubs. Interactions between CO2, water supply, grazing practices and fire regimes are likely to be critical (Gifford and Howden, 2001; Hughes, 2003). … Saltwater intrusion as a result of sea- level rise, decreases in river flows and increased drought frequency, are very likely to alter species composition of freshwater habitats, with consequent impacts on estuarine and coastal fisheries (Bunn and Arthington, 2002; Hall and Burns, 2002; Herron et al., 2002; Schallenberg et al., 2003). In marine ecosystems, ocean acidification is likely to decrease productivity and diversity of plankton communities around Australia, while warmer oceans are likely to lead to further southward movement of fish and kelp communities (Poloczanska et al., 2007)" (IPCC, 2007, p.517).

The viability of Australia's fishing industry depends on a fragile ecological balance that could be permanently changed by unbridled climate change. The IPCC suggests "projected changes in Southern Ocean circulation … are likely to affect fisheries. Seasonal to inter-annual variability of westerly winds and strong wind events are associated with recruitment and catch rates in several species (Thresher et al., 1989, 1992; Thresher, 1994). (CSIRO, 2002) (IPCC, 2007, p.521).

Food & Agriculture – Infrastructure & Habitat

Climate change is likely to change land use, particularly in Southern Austrailia.

As already stated above the agricultural and livestock industry in Australia will have to face more or less fundamental changes depended on the amount of average warming that will actually take place. The 2008 Garnaut Review suggested that a 1 degree temperature change would already lead to decreased milk production due to increased heat stress in dairy animals. At 2-3 degrees there would be a 40% reduction of Australia"s livestock carrying capacity for the native pasture system, and the overall timber yield in the North of the country would increase by 25-50% (Garnaut, 2008, p.23).

The 2007 IPCC report summarizes: "In Australia, the potential impacts of climate change on wheat vary regionally, as shown by a study which used the full range of CO2 and climate change in the IPCC SRES scenarios (Howden and Jones, 2004), in conjunction with a crop model recently validated for its CO2 response for current wheat varieties (Reyenga et al., 2001; Asseng et al., 2004)…Nationally, median crop yields dropped slightly. There is a substantial risk to the industry as maximum potential increases in crop value are limited (to about 10% or US$0.3 billion/yr) but maximum potential losses are large (about 50% or US$1.4 billion/yr). However, adaptation through changing planting dates and varieties is likely to be highly effective… (Howden and Jones, 2004).

Climate change is likely to change land use in southern Australia, with cropping becoming non-viable at the dry margins if rainfall is reduced substantially, even though yield increases from elevated CO2 partly offset this effect (Sinclair et al., 2000; Luo et al., 2003). In contrast, cropping is likely to expand into the wet margins if rainfall declines. In the north of Australia, climate change and CO2 increases are likely to enable cropping to persist (Howden et al., 2001a). " (IPCC, 2007, p.518).

<u>Health & Wellbeing – Food & Agriculture</u>

Increasing food prices due to decreased productivity may particularly effect already marginalized communities.

Climate change could increase the risk of food and water-borne illnesses, yet again these can be addressed through appropriate infrastructure management and food handling. Decreased agricultural productivity and an associated increase in food prices could lead to an increase in malnutrition in a certain section of society and already marginalized communities. The majority of the health and wellbeing related climate impacts are not directly related to food and agriculture, but more associated with changes in average and peak temperatures, water availability and the spread of disease vectors.

Health & Wellbeing – Ecosystems Services

Protection of ecosystem services is essential to individual and community health.

"Australia's coastal zone is of particular concern, due to its thousands of kilometres of coastline and the concentration of much of Australia's population, commerce, and industry in the coastal zone. Climate modelling has suggested that storm winds, including those associated with tropical cyclones, may become more intense with a warming of 1–2°C …. This combined with sea-level rise would result in higher storm surge during storm events and a greater area flooded. In addition, higher wind speeds would increase storm damages as they tend to increase with the square of wind speed. Sea-level rise and storm events also contribute to coastal inundation and beach erosion, which may affect popular tourism and recreation areas. At higher levels of warming, coastal impacts become more severe with higher storm winds and sea levels" (CSIRO, 2005, p.28). The extent to which ecosystems services and general health and well being are intricately linked is difficult to quantify but the protection and restoration of ecosystems services has been recognized by the World Health Organization as an integral part maintaining individual and community health (Waltner-Toews, 2004, p.90).

1.14.3 Adaptive Capacity

Australia is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Australia	1.00	0.83	1.00	1.00	**HIGH 38.33**

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.15 Canada Direct Impact Pattern

Canada is treated alone.

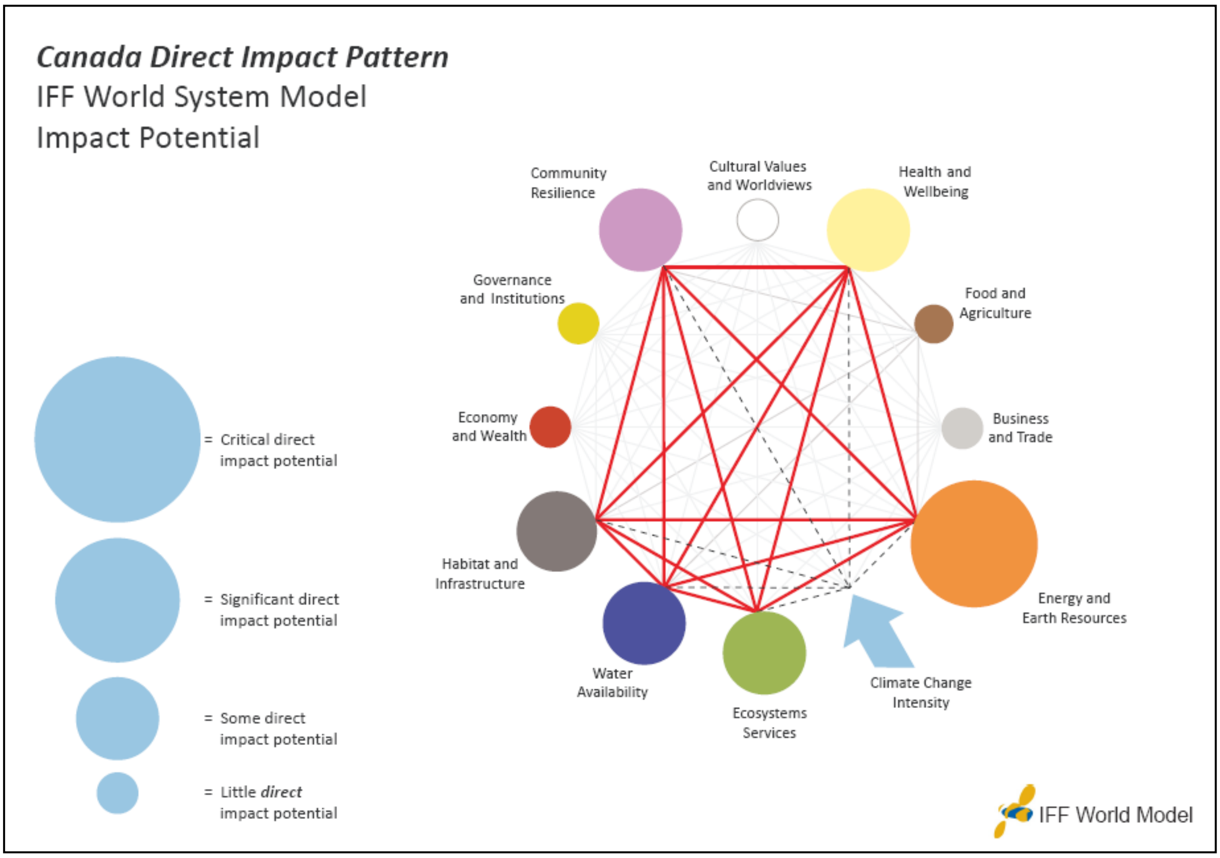


Figure 1.15.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

1.15.1 Overview

Canada's diverse landscapes fall into eight distinct regions called physiographic regions. Each region is associated with different natural resources, such as minerals, oil and gas, and forests. Canada's North includes six physiographic regions, three of which extend southward to the border with the United States.

For example, the Cordilleran Region, with its steep mountains and narrow valleys, includes most of Yukon and British Columbia, extending into western Northwest Territories. The Interior Plains, comprising low-lying plateaus and extensive wetlands, includes a portion of Yukon, much of the Northwest Territories, Alberta, and southern parts of Saskatchewan and Manitoba.

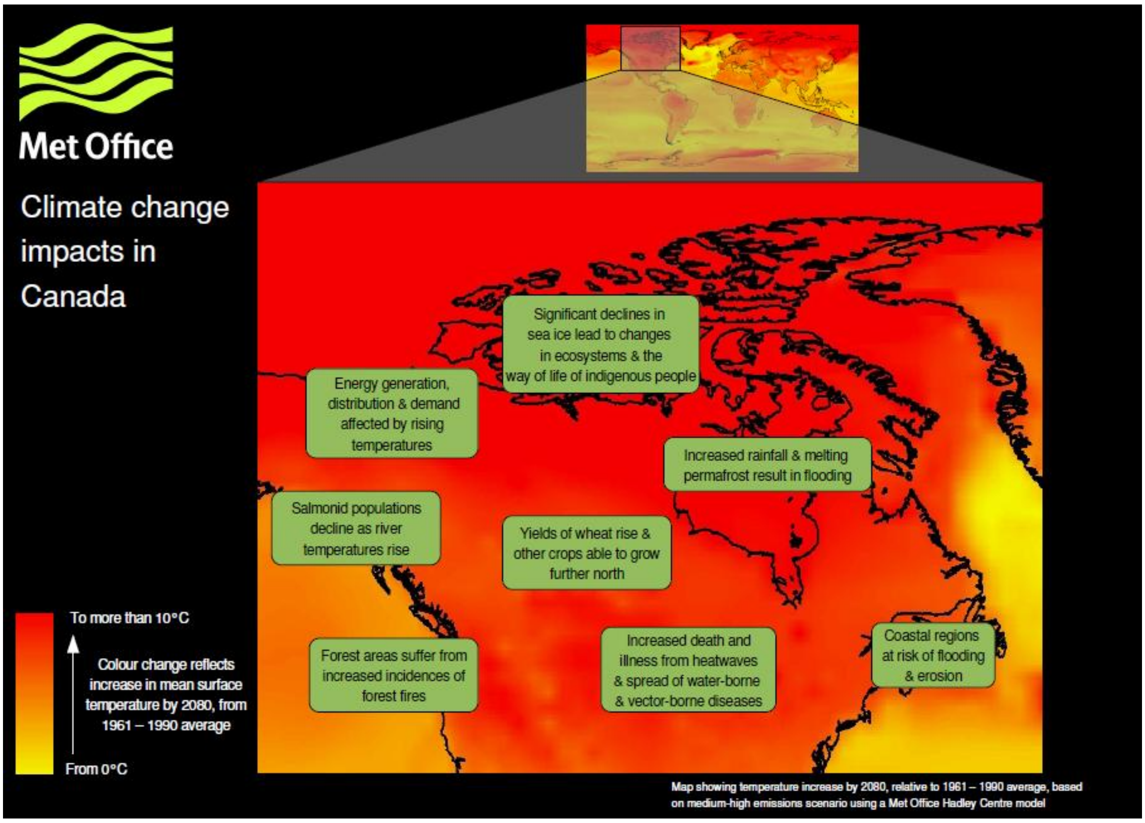


Figure 1.15.2 - Summary of climate impacts on Canada (Met Office 2008)

With its characteristic exposed bedrock, lakes and swamps, the Canadian Shield includes eastern parts of the Northwest Territories, southern parts of Nunavut, and much of Ontario, Quebec, and Newfoundland and Labrador. (NTEE 2009)

Canada will be spared several serious North American climate-related developments—intense hurricanes and withering heat waves—and climate change could open up millions of square miles to development. Access to the resource-rich Hudson Bay would be improved, and being a circumpolar power ringing a major portion of a warming. Arctic could be a geopolitical and economic bonus. (NIC 2008)

In Canada, the impacts of a changing climate are already apparent, and especially acute in Canada's North. The changing climate in northern Canada has unique environmental, social, and economic characteristics that that shape how it affects communities and people living there. Over the past fifty years, the region has been undergoing a rapid social, economic, political, and cultural evolution that a changing climate had historically little to do with, but is now accentuating. (NRTEE 2009)

1.15.2 Systemic Relationships – Principal Paired Interactions (15)

Ecosystem Services – Community Resilience

Many communities dependent on single industries such as fishing or forestry may have to adapt to significant changes.

In Canada, forests cover almost half of the landmass and make up 10 per cent of the world's forest cover. Canada's forests are expected to be among the most vulnerable in the world to climate change because temperatures are expected to increase more in the Arctic. Changes in temperature and precipitation could reduce the tundra and taiga/tundra ecosystems by as much as two thirds of their present size. More than one half of the discontinuous permafrost area could disappear. Wildlife would also be affected, with many species in fish and streams shifting northward 150 km for each degree increase in air temperature. (Met Office 2008)

Small communities scattered across the west and north of the country, many of whom are dependent on limited employment opportunities in single industries, such as forestry or fishing, may see significant changes in their industry. Indigenous settlements in the far north are very likely to experience declines in traditional industries and customs. (Met Office 2008)

Climate change, and rapid human exploitation of the boreal biome are rapidly eroding ecosystem services and natural capital. Among the foremost problems are decreasing water renewal in lakes and rivers, water pollution, increased insect outbreaks, continuing acid precipitation over large areas, decreased carbon sequestration resulting from melting permafrost and increasing forest fire, and increasing damage from hydroelectric development. (Schindler 2010)

Ecosystem Service – Energy and Earth Resources

Changing climate alters access to the regions oil and gas potential, with unanswered questions on the impact of resource development on ecosystems.

Canada's forest managers now face a new challenge: dealing with and preparing for the impacts of climate change on forested ecosystems. It is an influence that could have profound impacts on tree species and forests, particularly if corrective actions to reduce greenhouse gas emissions are not taken relatively soon. (Johnston et al 2009)

Canada's North is no longer an isolated region at the periphery of the global economy, but rather a region poised to assume greater geopolitical and economic importance. A changing climate alters accessibility to the region's oil and gas resource potential and to enhanced navigation options through increasingly open Arctic waters. For Canada, both prospects raise a series of challenges related to gaps in scientific knowledge on the potential consequences of enhanced traffic and resource development on ecosystems, human health, and culture. (NTEE 2009)

As sea ice formation declines in the Arctic Ocean and the transport routes and accessibility to energy reserves in the Arctic open up, further energy demands could be met by exploiting such reserves. However, territorial disputes and environmental concerns may affect the feasibility of such exploration. (Met Office 2008)

Ecosystem Services - Health and Wellbeing

Disease vectors are likely to alter with likely impacts on vulnerable groups.

Effects of heat are likely to be highest in the cities where the urban heat island effect is exacerbated by the increasing temperatures, and in other vulnerable groups such as the poor. Without adaptive measures, settlements in the northernmost regions of Canada may also suffer as populations here are unused to warmer temperatures and could succumb to increased incidences of food poisoning and other infectious diseases, previously killed off in the cold periods. Conversely, deaths related to cold spells should decline. Indigenous people suffer from diseases previously not experienced. Some diseases spread by animals, e.g. Lyme disease, change in distribution (Met Office 2008)

Air pollution is very likely to increase as surface ozone concentrations rise with increased temperatures, inducing increased incidence of asthma and other cardiovascular and respiratory diseases. Pollen and other particulate matter may also increase in concentrations, especially if there is increased growth of plants and there are more wildfires. (Met Office 2008)

Ecosystem Services – Water Availability

Reduced summer time river flows and reduced snowpack will impact ecosystem services.

In BC, large temperature increases have resulted in reduced snowpack (Stewart et al., 2004). Reductions in snowpack have changed streamflow volumes and timing. In particular, spring snowmelt now occurs much earlier in many BC rivers (Zhang et al., 2001) and alpine glaciers are melting rapidly (Moore et al., 2007). Increasing temperatures and precipitation will reduce snowpacks in the future, thus increasing winter runoff for most of BC (Mote and Hamlet, 2001). Groundwater recharge rates are also sensitive to changing climate conditions (Rivera et al., 2004). These factors, in combination with higher evapotranspiration, mean that there will be reduced summer-time flows in many BC rivers, a particular issue for the Okanagan region and, in terms of sectors, for energy and agriculture. (Ostry et al 2008)

Ecosystem Services - Habitat and Infrastructure

Changes in the Canadian Artic due to climate change are happening rapidly.

With the rapid warming of the northern Canadian climate comes a wide range of changes in physical conditions. Changes in the Arctic are happening much more rapidly than what was anticipated under even the most pessimistic scientific projections. The accelerated melting of Arctic sea ice is the most obvious example of how scientific projections have underestimated the rate and magnitude of changes taking place in the region. (NRTEE 2009)

Energy and Earth Resources - Community Resilience

Communities depending on a lengthy transport infrastructure may be vulnerable to permafrost melting and affecting roads and railways.

Evidence from communities in Canada's North indicates that rapid changes in climate conditions have resulted in permafrost melting at unprecedented rates, affecting nearly every type of built structure in the region. The variance between observed and expected changes suggests that either global climate models inadequately capture ice and snow processes or global changes are happening more rapidly than projected and this is most evident in the Arctic. (NRTEE 2009).

Energy and Earth Resources - Health and Wellbeing

Energy Demands for Heating and Cooling will alter with climate change.

It is likely that with increasing temperatures, the demand for heating energy will decrease across Canada, particularly during the winter. Conversely, demand for cooling and air conditioning in homes and businesses will increase, especially during the summer months. (Met Office 2008)

Energy and Earth Resources - Water Availability

Hydropower and nuclear cooling are vulnerable to water availability.

Hydropower generation plants on major rivers, such as the Fraser, have seen variations in output following changes in timing of rainfall and snowmelt in recent years. Spring flows are now higher than previously observed, but summer and early autumn flows are often significantly reduced. Hydropower plants situated on the Great Lakes saw decreases in output following the drought of the 1990s which significantly decreased levels in the lakes (Field et al., 2007). In the future, there may be increases in the winter and spring river flows and levels, but decreases in the summer flow, combined with environmental targets, may mean that the increases in generation needed for cooling are not met. (Met Office 2008)

Energy and Earth Resources - Habitat and Infrastructure

Climate related energy demands may challenge current energy infrastructure.

Demand for winter heating is likely to drop, demand for summer cooling to rise. Increased demand for water pumping and summer cooling and decreased winter demand due to higher temperatures, could push electrical utilities into a summer peak load position at the same time as hydropower production is reduced by decreased water flow. It is possible that thermal power stations, on which Canada relies for much of its energy needs alongside hydropower, will decrease in efficiency in the future as water for cooling becomes warmer or if its availability is reduced. (Met Office 2008))

Habitat and Infrastructure – Community Resilience

Atlantic Canada is particularly vulnerable to sea level rise while the diverse communities of Canada's north may need to adapt to much warmer conditions.

Strategies to address the impacts of climate change targeting Canada's North must be flexible enough to accommodate the incredible cultural, social, political, and economic diversity represented in the region. In some cases, pan-northern strategies may be less appropriate than efforts to leverage action across north-south borders. (NRTEE 2009)

The greater frequency and intensity of extreme weather events and related hazards, such as flooding and forest fires, will threaten key infrastructure (e.g., roads, ports) affecting communities and health and well-being. Atlantic Canada is particularly vulnerable to rising sea levels, whose impacts could include greater risk of floods; coastal erosion; coastal sedimentation; and reductions in sea and river ice. (NIC 2008)

Among other factors, reduced sea-ice extent and thickness could mean a seasonally icefree Arctic within this century, possibly as soon as the end of the next decade. Rapid sea-ice loss in summer months could also lead to pronounced overland warming and trigger rapid permafrost degradation. (NRTEE 2009)

Voyaging between Europe and Asia through Canada's Northwest Passage would trim some 4,000 nautical miles off of a trip using the Panama Canal. (NIC 2008)

Habitat and Infrastructure – Health and Wellbeing

Environmentally and socially stressed places are likely to suffer most.

Other indirect effects arising, for example, from secondary effects on agricultural and marine resources are difficult to assess, but it is likely that the most affected places will be those that are already environmentally and socially stressed (McMichael et al., 2003). However, there will be some regional winners in agriculture as the temperature increases in the province and these may lead to human health benefits. (Ostry et al 2008)

Habitat and Infrastructure – Water Availability

Many areas will experience growing water shortages and increased competition among water uses, including municipalities, irrigation, industry, power generation, fisheries, recreation and aquatic ecosystems.

With increasing demand for water to supply rising populations and demands for crop irrigation, any decline in freshwater supply could have significant impacts on water stress in Canada. The projected rise in precipitation may help to alleviate some water supply issues, although projections reveal that much of this increased precipitation could be in the form of extreme rainfall events, leading to flooding, difficulties in retaining the water for future supplies and a decline in water quality from the increased erosion. Melting permafrost will lead to more flooding. Rising sea level and over-abstraction leads to salt water intrusion of aquifers. (Met Office 2008)

Water Availability - Food and Agriculture

Warmer temperatures will increase the demand for irrigation putting pressure on groundwater supplies.

With increasing temperatures, demand for irrigation will rise and groundwater sources will be depleted, possibly leading to salt-water intrusion in coastal areas. Recharge of aquifers may not be as great, due to increased evaporation as a result of rising temperatures. Reservoirs and rivers may suffer more frequently from oxygen depletion and toxicity of supplies as temperatures increase. Water quality issues may become more common as sediment and chemical loads increase due to erosion during intense rainfall and higher temperatures. (Met Office 2008)

Water Availability – Community Resilience

Water related health issues could impact on vulnerable communities.

Food supplies and water quality issues could also be affected by these increases in temperatures and heatwaves, further straining the health of the population. Occurrences of diarrhoeal and other bacterial diseases are very likely to increase as temperatures rise and water quality issues increase. Changes in occurrence of *Salmonella*, *E. coli* and other food poisoning bacteria are known to be associated with rises in ambient air temperature (Fleury et al., 2006). More flooding is likely in winter and potential water stress in summer. (Met Office 2008)

Water Availability – Health and Wellbeing

Water quality could decline increasing the need for treatment of drinkable water.

Bacterial infection from contaminated water will possibly increase in the future as heavy rainfall and rising temperatures, as well as increased incidences of toxic algal blooms, lead to pollution of recreational waters and increased need for treatment of drinkable water (Christensen et al., 2007). (Met Office 2008)

Food and Agriculture - Ecosystem Services

There may be significant opportunities (dependent on water availability) for Canadian agriculture, although forestry is likely to be adversely effected.

Canada's tree species are vulnerable to climate change for a variety of complex, interacting reasons. For example… climatic envelopes will change faster than trees can adapt or migrate, site conditions will change, and the frequency, extent, and severity of disturbance will increase. Additionally, increased tree mortality and decreased forest health are expected, especially for sensitive species on poor sites. Commercially important tree species may lose their ability to compete and regenerate on some sites. Productivity gains are possible in areas that are not moisture limited (due to a longer growing season, warmer temperatures during the growing season, and CO2 fertilization), but productivity will decrease in areas that become drier. (Johnston et al 2009)

There may be significant new opportunities for Canadian agriculture in a warmer world, provided sufficient precipitation occurs in food-producing areas. Other regions are likely to be adversely affected. For example, already stressed fisheries will face further challenges, in particular the highly important Pacific salmon species, which are sensitive to stream and ocean surface warming. While agriculture may enjoy longer, warmer growing seasons, more frequent and prolonged droughts as well as increased pest infestations could erode any benefit from climate change and not all soil in Canada can take advantage of the change in growing season.

Food and Agriculture – Energy and Earth Resources

Canada may be a climate winner in terms of an increased share in the earths agricultural potential.

Many scientists predict that the area of arable land and the range of crops planted will increase, at least in nations situated in temperate regions, as the earth warms. Projections for BC indicate longer growing seasons in the future (Zebarth et al., 1997), which will increase the range of crops that can be grown in BC. With a moderate climate change scenario, by 2020, it may be possible to grow cereals, cabbage and potatoes, in the central interior, and corn and tomatoes along the Fraser River valley as far north as Prince George. By 2050 these latter crops may be growable in the Peace River region (Zebarth et al., 1997). There may also be greater potential for expansion of agriculture in the Peace River region. (Ostry *et al* 2008)

Food and Agriculture – Health and Wellbeing

There is a probability of that the risk of diseases that can impact on agricultural production will spread.

A rise in temperature may alter living conditions for animal and plant vectors of diseases (Patz et al., 1996). Climate change impacts vector-borne disease by increasing the range and abundance of animal or insect reservoirs, prolonging transmission cycles, and increasing the importation and range of new vectors. As noted by Wilkinson (2008), there is a risk of greater spread of a number of vector-borne diseases in many jurisdictions although more research is needed to obtain reliable predictions within the context of complex regional environmental co-factors. (Ostry 2008)

Food and Agriculture – Habitat and Infrastructure

Habitat and infrastructure will be effected by northward expansion of crop production.

Expansion to the north of crop production, including soft fruits, and higher yields of wheat is likely. Forest areas will suffer some dieback from increased ozone, pests & forest fires. Areas of peat dry out will suffer increased fire activity. (Met Office 2008)

Community Resilience – Health and Wellbeing

Canada's climate could become less challenging for much of the population.

In a study of a climate severity index (which is an aggregate indication of personal discomfort, safety and mobility arising form extremes of weather and climate) for Canada the authors conclude that the good news from this study is that the future climate of Canada will likely produce less personal discomfort for Canadians as a result of the warming associated with increasing green house gases in the atmosphere. The bad news is that although it has been speculated that the climate could become more hazardous as a result of an increasing frequency of severe weather events, this study provides no information on that score. In order to shed more light on that question we will need higher resolution climate models and the ability to output and archive more information, particularly information on the frequency of extreme events. (CICS 2001)

Community Resilience – Food and Agriculture

Communities will have to adapt to new opportunities, particularly in agricultural production.

Research suggests that most crops currently grown across Canada, including irrigated and rain-fed grain and maize, will increase in yield throughout the 21st century by anywhere between 5 and 20% (Trenberth et al., 2007). As temperatures rise, crops currently struggling to grow in Canada, such as some fruit, could become more common and more land, previously unsuitable for farming, may be able to be cultivated. Damage to crops from snow fall and frost events is also likely to decrease, whereas damage from intense rainfall events and flooding is expected to rise. More extreme weather could also lead to loss of crops with more irrigation needed in summer. (Met Office 2008)

Adaptive Capacity

Canada is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
Canada	0.80	0.83	1.00	1.00	**HIGH 36.33**

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.16 New Zealand Direct Impact Pattern

New Zealand is treated alone.

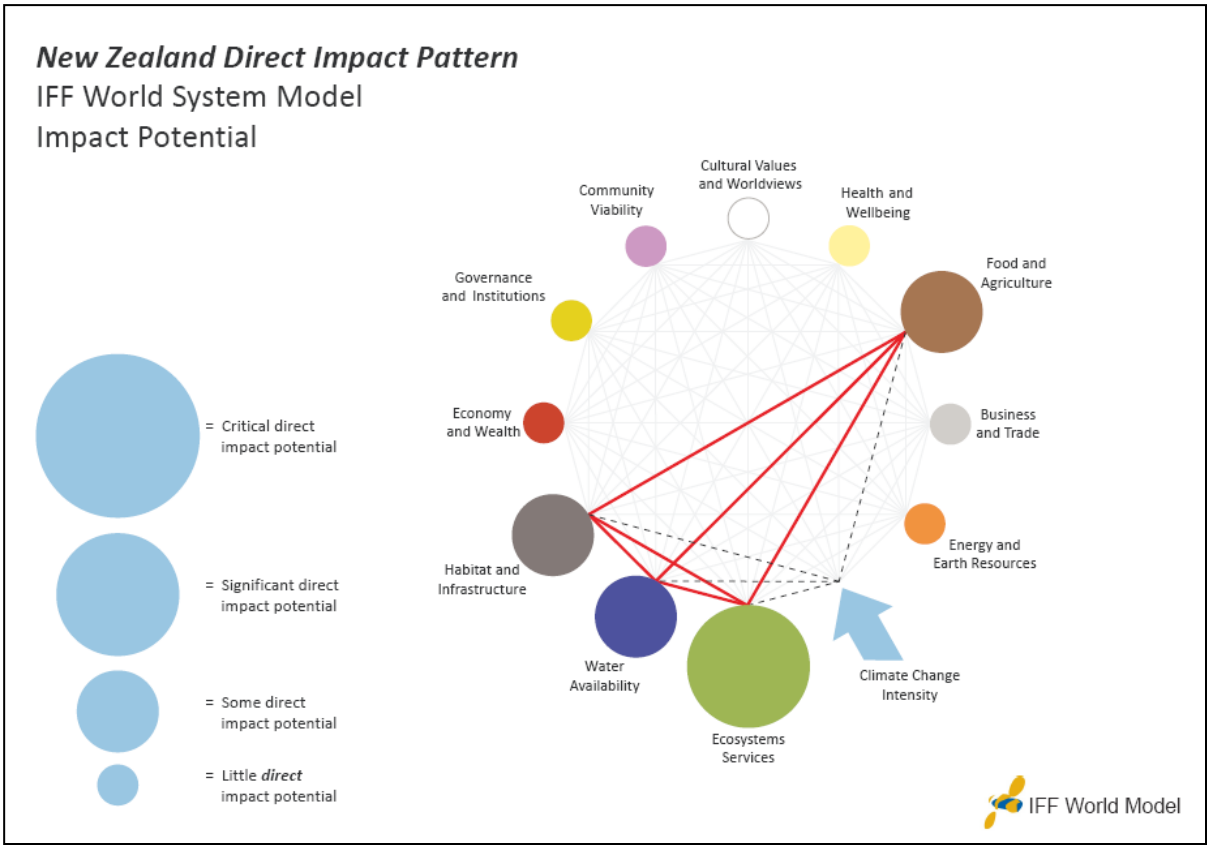


Figure 1.16.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects

2.16.1 Overview

New Zealand is among the least affected countries based on comparisons from the IPCC's and other predictions of future climate change. These are useful despite the substantial amount of scientific uncertainty associated with such prediction. Whether predictions of "positive" impacts of climate change will hold true in the mid and long term remains to be see, since it is impossible to predict the complex global interactions by which climate change impacts in one region of the planet will affect many other regions through economic and humanitarian repercussions.

The NIWA National Climate Centre of New Zealand (2008) reports conclusive evidence that "climate is warming and the cause cannot simply be natural variation. … nationally average temperatures have increased by about 0.9 degrees C over the past 100 years. [There are now] fewer frosts over most of the country, with Canterbury and Marlborough, for example, experiencing about 20 fewer frosts per year now than in the early 1970s. [In addition, glaciers are retreating and] the volume of ice in the Southern Alps reduced by almost 11% in the past 30 years. Twelve of the largest glaciers are unlikely to return to their earlier length without extraordinary cooling of the climate. … sea-level rise [has also been observed, with and increase of] 0.16m during the 20th century averaged over the four main ports" (NIWA NCC, 2008, p.1).

1.16.2 Systemic Relationships – Principal Paired Interactions (6)

Ecosystem Services – Food & Agriculture

Climate induced changes will impact on Agriculture in both positive and negative ways.

"The agriculture sector has substantial opportunities for productivity gains and diversification under climate change, but also faces some serious long-term risks. The most significant risks are associated with the potential increase in the number of extreme events such as droughts and floods, causing more damage and reducing recovery time for farmers. The generally drier conditions projected for the eastern areas of the country mean that water could become a more limited resource in some areas, and competition between agriculture and other water users could increase" (New Zealand Environment Ministry, 2004, p.23)

The IPCC (2007) reports: "Production of current kiwifruit varieties is likely to become uneconomic in Northland by 2050 because of a lack of winter chilling, and be dependent on dormancy-breaking agents and varieties bred for warmer winter temperatures in the Bay of Plenty (Kenny et al., 2000). In contrast, more areas in the South Island are likely to be suitable (MfE, 2001). Apples, another major crop, are very likely to flower and reach maturity earlier, with increased fruit size, especially after 2050 (Austin et al., 2000). New Zealand is likely to be more susceptible to the establishment of new horticultural pests. For example, under the current climate, only small areas in the north are suitable for the oriental fruit fly, but by the 2080s it is likely to expand to much of the North Island (Stephens et al., 2007)" (IPCC, 2007, p.519).

"The agriculture sector has opportunities for productivity gains and diversification under climate change, but also faces risks. The key benefit to agriculture is likely to be from elevated carbon dioxide concentrations which could lead to substantial improvement in growth rates and water-use efficiency. In addition, warmer conditions and lengthened growing seasons could allow the long-term southward shift of climate limited activities and new crops and related industries could be introduced. Currently resource poor areas could benefit from such shifts. (New Zealand Environment Ministry, 2004, p.3).

Food & Agriculture – Infrastructure & Habitat

High Agricultural adaptive capacity could make the sector well positioned to respond to climate challenges.

"Agriculture continues to be the backbone of the New Zealand economy. As an industry that relies heavily on environmental resources, it is particularly sensitive to changes in climate. The industry has undergone major adjustments over recent decades in response to non-climate changes, such as overseas market shifts and developments in production technology. These changing circumstances have made agriculture in New Zealand highly adaptive and could position it relatively well to respond to the effect of slow changes in climate" (New Zealand Environment Ministry, 2004, p.18)

Shifting land-use activities to adapt to altered climate conditions will incur costs, resulting in regional winners and losers. Pests and disease could spread in range and severity, and pasture composition is likely to change with uncertain outcomes to animal productivity and nutrient balances. The full range of the effect has not been quantified yet" (New Zealand Environment Ministry, 2004, p.3).

Ecosystems Services – Water Availability

Water security problems are likely to intensify. Tree growth changes will affect the forestry industry.

The IPCC report (2007) suggested "as a result of reduced precipitation and increased evaporation, water security problems are projected to intensify by 2030 in … in New Zealand, in Northland and some eastern regions (high confidence)" (IPCC, 2007, p.509). There could be potential benefits to the forestry industry. "In New Zealand, the growth rates for plantation forestry (mainly *P. radiata*) are likely to increase in response to elevated CO2 and wetter conditions in the south and west. Studies of pine seedlings confirm that the growth and wood density of *P. radiata* are enhanced during the first two years of artificial CO2 fertilisation (Atwell et al., 2003). Tree growth reductions are likely for the east of the North Island due to projected rainfall decreases and increased fire risk. However, uncertainties remain regarding increased water-use efficiency with elevated CO2 (MfE, 2001), and whether warmer and drier conditions could increase the frequency of upper mid-crown yellowing and winter fungal diseases (MfE, 2001)" (IPCC, 2007, p.520).

Ecosystems Services – Infrastructure & Habitat

No national-scale assessment of the impact of sea level rises is available.

"A quantitative assessment of the impact of rising sea levels on New Zealand coasts is difficult. Major earthquakes can lead to local changes in land elevation, which can override the effect of a gradual sea-level rise. In addition, circulation patterns of oceans and the atmosphere cause regional sea-level variations. On time scales of decades these changes have a larger influence on the sea level around New Zealand than global warming induced sea-level rise. In the long term, rising sea levels are expected to increase the erosion of vulnerable beaches and cause more frequent breaches of coastal protection structures. Quantitative predictions depend heavily on local variables, and only limited long-term data of sufficient quality exists. Hence no national-scale assessment of coastal risks under climate change is currently available" (New Zealand Environment Ministry, 2004, p.3).

Water Availability – Food & Agriculture

Possible climate gains may be limited by water availability.

It may be worth noting that the IPCC's assessment of climate change impact on New Zealand is more hesitant in making predictions suggesting climate change could have positive impacts than New Zealand's own scientific assessments seem to suggest. Considering the complexity and uncertainty involved with climate change predictions it seems reasonable to err on the side of caution rather than unfounded optimism. For example: "Production from agriculture and forestry is projected to decline by 2030 over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits to agriculture and forestry are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall (high confidence)" (IPCC, 2007, p.509)

"In New Zealand, annual flow from larger rivers with headwaters in the Southern Alps is likely to increase. Proportionately more runoff is very likely from South Island rivers in winter, and less in summer (Woods and Howard-Williams, 2004). This is very likely to provide more water for hydro-electric generation during the winter peak demand period, and reduce dependence on hydro-storage lakes to transfer generation into the next winter. However, industries dependent on irrigation are likely to experience negative effects due to lower water availability in spring and summer, their time of peak demand. Increased drought frequency is very likely in eastern areas, with potential losses in agricultural production" (IPCC, 2007, p.516).

The most significant risks are associated with the potential increase of drought and floods and water limitations in some areas. Warmer temperatures could also make the growing of some fruit crops in some northern areas uneconomical. (New Zealand Environment Ministry, 2004, p.3).

Water Availability - Infrastructure & Habitat

Climate variability will put more pressure on water storage and irrigation structures as well as flood protection.

In general, the increased climate variability that will lead to more periods of drought and heavy rainfall puts a higher demand on water storage and irrigation infrastructure as well as protection from floods, mud-slides and other forms of erosion. "Rain events are likely to become more intense, leading to greater storm runoff, but with lower river levels between events. This is likely to cause greater erosion of land surfaces, more landslides (Glade, 1998; Dymond et al., 2006), redistribution of river sediments (Griffiths, 1990) and a decrease in the protection afforded by levees. Increased demands for enhancement of flood protection works are likely, as evidenced by the response to large floods in 2004 (MCDEM, 2004; CAE, 2005)" (IPCC, 2007, p.517)

1.16.3 Adaptive Capacity

New Zealand is rated as follows:

	Failed States Index	Political Stability	Government Effectiveness	Human Development Index	Adaptive Capacity Rating (x 10)
New Zealand	1.00	0.83	1.00	1.00	**HIGH 38.33**

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

1.17 Russia Direct Impact Pattern

Russia is treated alone.

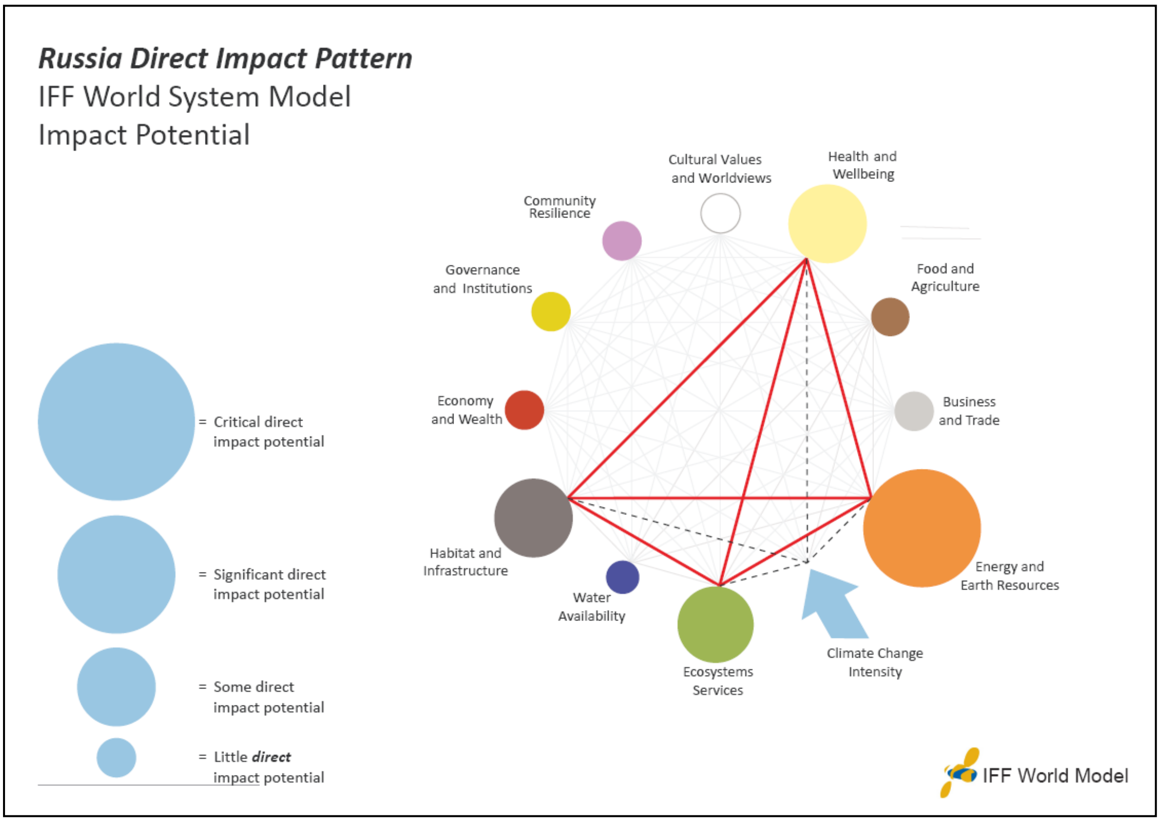


Figure 1.17.1 shows which nodes of the World System are most likely to be impacted by climate change. The size of the circles indicates the weight given to that impact in the literature surveyed. Those nodes with little direct impact will still be affected as the total system responds according to its adaptive capacity. The red lines show the possible complexity of connections where the results of impact may be amplified by systemic interaction and 'knock-on' effects.

1.17.1 Overview

Russia – the world's biggest country by geographical area - is already warming at one and a half times the rate of other parts of the world. However, together with Canada, this is one of the few areas which may get considerable positive impacts from climate change, providing the temperature rise is moderate.

Russia is already experiencing the impacts of climate change in the form of milder winters; melting permafrost; changing precipitation patterns; the spread of disease; and increased incidence of drought, flooding, and other extreme weather events. Many of these observed climate impacts are having concrete, negative effects on Russians' quality of life. According to a study by the US, "By 2030, Russia will start to feel the impacts of climate change in relation to both water and food supply. Nonetheless, a significant portion of the country's senior leaders continue to voice the view that a warming climate is a net benefit for Russia. Russia has a number of attributes that provide a greater capacity for resilience than some other industrialized countries and most developing countries. However, *as the impacts of climate change continue and intensify over the coming years, Russia's capacity to adapt and protect its people will be severely tested.* (NIC 2009)

The critical factor here is the higher resilience that Russia may show in adapting to the change. However, if global temperatures do go up by the 4C many scientists fear, the impact on Russia would be disastrous. Much of Russia's northern region would be turned into impenetrable swamp. Houses in several Arctic towns are already badly subsiding.

1.17.2 Systemic Relationships – Principal Paired Interactions (6)

Habitat and Infrastructure – Ecosystems Services

The Arctic is more vulnerable to major shifts caused by temperature rise that will radically affect its ecosystems,

Temperatures in the Arctic are rising at almost double the rate of the global average. In many inland Arctic regions, surface air temperatures have warmed 0.2°C per decade over the past 30 years. Sea ice in the Arctic has decreased by 3 percent per decade between 1978 and 1996, and summer sea ice thickness has decreased by 40 percent since the 1950s.v Precipitation at high latitudes has increased by 15 percent over the past decade, with most of this increase occurring over the past 40 years. Arctic summers are now warmer than at any time in at least the past 400 years. (NIC 2009)

The Arctic is extremely vulnerable to climate change. The region is warming much more rapidly than the global average. The IPCC report states that the winter warming of northern high latitude regions by the end of the century will be at least 40 percent greater than the global mean, based on a number of models and emissions scenarios. Temperature increases for the central Arctic are projected to be about 3-4°C during the next 50 years. Even an optimistic scenario for projecting future greenhouse gas emissions yields a result of a 4°C increase in autumn and winter average temperatures in the Arctic by the end of this century. Recent satellite data show that the area covered with perennial ice in the Arctic Ocean has receded significantly in recent years, falling to nearly half the area observed in 2005. (NIC 2009)

Most models project that summer ice will decline much more rapidly than winter ice. Arctic sea ice is projected to decrease more rapidly than other sea ice. Some scientists suggest that the Arctic Ocean could be ice free in summer in the next 10-20 years. (NIC 2009)

Habitat and Infrastructure – Energy and Earth Resources

Warming will affect the durability of the infrastructure with mainly negative consequences for the infrastructure of the energy industry.

A warming climate holds the possibility of milder and shorter heating seasons, which in turn may lead to reduced Russian energy demand. Increased water availability—particularly along those Siberian rivers that are used for hydroelectric power—should result in increased power production in certain parts of the country. However, existing and future energy infrastructure for the all-important petroleum industry will experience more pronounced challenges— structural subsidence, risks associated with river crossings, and construction difficulties as permafrost thaws earlier and deeper, impeding the construction of vital new production areas. These latter challenges have the potential for a material, negative impact on the single-greatest source of revenue to the Russian state—the oil and gas industry. (NIC 2009)

Rising temperatures will push the permafrost boundary further north and deepen the surface melt. This may have big implications for future oil, gas and other investment projects. De-stabilised, shifting permafrost conditions release greenhouse gases and could lead to flooding that will not only affect coastal and river bank human settlements, but will also require more expensive underpinning of buildings, refineries and other infrastructure such as the Baikal Amur railway and the planned East Siberia-Pacific export oil pipeline. This may increase the costs of pipeline construction because extensive trenching may be needed to combat the effects of coastal instability and erosion, especially that caused by permafrost melting.

The Arctic Ocean holds an estimated one quarter of the world's oil and natural gas. The resource is becoming increasingly available as the Arctic warms up, at a rate believed to be close to two times the global average. (Perelet 2008)

Russia's economy is highly vulnerable to climate change impacts that affect the current or future operations of the petroleum sector. Many areas that are currently the focus of exploration and production activity will be more difficult to exploit. Pipeline and rail transportation systems that cross major rivers and permafrost will be subjected to unprecedented stresses and strains, many of which were not anticipated when initial design parameters were established. (NIC 2009)

<u>Habitat and Infrastructure – Health and Wellbeing</u>

Russia is likely to become more vulnerable to the spread of disease, especially those associated with stress on water infrastructure.

Russia's current rodent population is ten times higher than historical norms. Worse yet, one-third of the rodent population is estimated to carry one of the viruses that cause hemorrhagic fever with renal syndrome (or HFRS), which is a deadly illness if not caught early in its course. Incidences of HFRS spike after each occurrence of an unusually mild Russian winter. (NIC 2009)

Many parts of Russia's massive territory will experience increases in the availability of water, including much of Siberia, the Far North, and northwestern Russia. This change will bring certain positive impacts—including for hydroelectric generation (above). However, managing the increased flows will pose other problems, especially when these increased flows coincide with extreme weather events such as downpours, or springtime ice-clogged floods. In addition, increasing water shortages are predicted for southern parts of European Russia, areas that already experience significant socioeconomic and sociopolitical stresses. Moreover, a number of densely populated Russian regions that are already subject to water shortages are expected to face even more pronounced difficulties in decades to come. (NIC 2009)

Health and Wellbeing – Energy and Earth Resources

Warming may have positive results on the domestic energy demand for many people.

Warming climate has some positive implications for the people's energy security and energy systems since they will be functioning at higher ambient temperatures. Housing construction may be more economic in that buildings could be less cold resistant and therefore lighter but sturdier and more robust to withstand storms and hurricanes. (Perelet 2009)

Health and Wellbeing – Ecosystems Services

There is a possibility of much increased spread of pestborne disease.

Climate change may present Russia with a host of new and unwelcome challenges by 2030—both in the form of dangers related directly to climate and in the form of pestborne disease. In the case of direct effects, the combination of more frequent droughts and heat waves has had an impact on vulnerable populations in Russia already. By 2030, as extreme weather events become more prevalent, this kind of increased risk to human health will rise further, particularly affecting the aged and infirm, especially for those unable to afford residential air conditioning. (NIC 2009)

Climate warming has negative influence on the people's health. The consequences are various. Typhoons, floods, hurricanes, anomalous high temperatures in the cities lead to the fatal outcomes. In case of perm frost territories deformation there is a break in the work of the water supply and sewage systems which leads to the increase of the infectious intestine diseases. The increase in the number of marshes, changes in the mosquito and tick biology can lead to the increase of malaria, Denge fever, tick encephalitis, tick ricketsiosis other diseases. (Revich 2006)

The level of the intestinal infectious diseases among population directly depends on the quality of the water (both in the water supply systems and natural ponds) and on the food staff quality. In Russia almost 1 million people per year suffer intestinal infectious diseases. Disruption of communication and transportation can exacerbate the risk of the infectious diseases taking hold before treatment. Climate change caused floods can trigger disease outbreaks. Early spring in Yakutia in 2002 caused floods followed by enteric fever outbreak. (Perelet 2008)

Ecosystem Services – Energy and Earth Resources

Increasing dangerous natural phenomena disrupting ecosystems are likely to frustrate important resource industries.

Russia's most important industry, petroleum, is core to its economy and its political power. The industry relies on pipelines built on permafrost that's rapidly melting due to climate change. Developing resilient energy infrastructure is vital for energy security in the context of climate change.

If Russia at the beginning of the 1900s annually experienced 150 to 200 dangerous natural phenomena causing damage to the economy, then within the last few years the number of such phenomena has grown to 300-400 annually. Climate change will manifest itself in the form of increased frequency and intensity of extreme meteorological phenomena such as floods, winter melts and earthquakes which in turn makes utilising energy and other resources more difficult.

Flooding could even impact underground formations such as natural oil reservoirs, which will raise the risk of the voiding of marshlands. Russia is estimated to have 70 billion tons of marshlands – a third of the marshlands in the world. (Kireeva 2009)

1.17.3 Adaptive Capacity

Russia is rated as follows:

	Failed States Index	**Political Stability**	**Government Effectiveness**	**Human Development Index**	**Adaptive Capacity Rating (x 10)**
Russia	0.40	0.33	0.50	0.75	**MEDIUM 19.83**

See page 3 and Book 1 Section 2.5 for an explanation of the rating method.

2 The Non-Linear Nature of Climate Impact

2.1 Runaway Change

There is increasing recognition that non-linear feedback is a major consideration in understanding the dynamics of climate change. Wasdell (2007) points out that most of the systems known to affect climate change are in net positive feedback. What this means is that each feedback mechanism accelerates its own specific process and, through coupling with other systems, contributes to their acceleration. The feedback mechanisms in question operate through some variable that, as well as increasing or decreasing, also has a second order affect of increasing the pace of that variation. The simple result is described as 'runaway change'. An graphical illustration is shown in Figure 2.1.

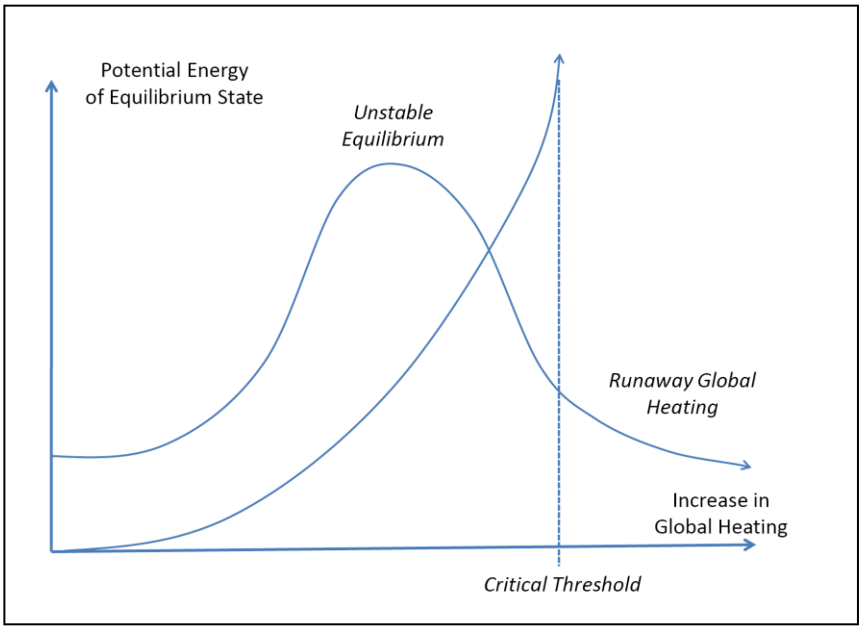


Figure 2.1 Graph showing how the erosion of power to intervene grows on an exponential curve as the climate system is moved through an unstable equilibrium to unstoppable global heating. At a certain critical threshold intervention no longer has any power to affect the situation. (after Wasdell 2007)

The implications of runaway change are not only in the objective situation as to what is really happening, they are also critical for the perception and action of people. There is an interaction between the mental assumptions of decision makers, their actions and the effectiveness or ineffectiveness of those actions in the system. If, for example, people assume that the growth of a variable is linear, a straight line, and they extrapolate this into the future, they will assume a certain position is reached after, say, ten time units. If the real world situation is actually behaving according to non-linear feedback, then that position will be reached much earlier than expected, say after three units of time. To put it simply, if people were preparing for a disruptive event, they would be caught out and ill-prepared because “things have happened sooner than we thought they would”. In climate change science, an example of this runaway change is the potential impact of methane escape from arctic tundra. As global warming releases the gas, a twenty time more potent greenhouse gas than carbon dioxide, it rapidly increases the greenhouse effect which in turn augments the release of further methane in a runaway cycle.

In a recent study from the Neils Bohr Institute Centre for Ice and Climate, Ditlevsen (2010) points out, using the analogy of a ball balanced on a see-saw, “we have already started tilting the seesaw and at the same time the ball is perhaps getting kicked more and could jump over into the other trench. This could mean that the climate might not just slowly gets warmer over the next 1000 years, but that major climate changes theoretically could happen within a few decades," [Note that ‘trench’ in the above quotation refers to the concept that the system migrates to a different normal state, the runaway state.]

These conceptions of sudden change also need to be considered seriously in the further complexity of social ecological systems. There are also feedback dynamics in the behaviour in social systems. Umpelby (2007) points out that reflexivity “can be thought of as positive feedback between cognition and participation”. The implications for impact of climate change lie in the area of how impact relates with adaptive capacity. How people see and experience the impact of climate change itself affects their behaviour which in turn will modify the impact. This could range from runaway panic and despair, through indifference and unchanged policies and behaviour, to radical changes in low carbon life style.

Just like climate change itself, these interactive systems between people and biosphere are complex and unpredictable.

The following section aims to show a basis for applying causal loop thinking, derived from system dynamics, to think about the structure that climate change impacts upon and how they might suddenly change behaviour in ways that will not be anticipated by conventional linear or statistical thinking. Although it has not been possible to apply such non-linear dynamics directly in this report, it is hoped this section with serve as a cautionary note to making over simplistic and linear assumptions about impact, vulnerability and adaptive capacity.

2.2 Complex Systems With Emergent Behaviour

In attempting to anticipate the impact of climate change on a country, region or territory we are concerned not simply with events (such as super-storms) that might impair its functioning but the dynamics of change that climate change overall might impose on the area. Any such area is itself a complex system with emergent behaviour as well as partially predicable ones. It is this local system that itself is subject to the consequences of the impact from climate changes. Overlaid on this is the way those consequences have repercussions for the UK. In security circles this 2nd order dependency is incorporated into the principle of treating climate change as a threat or risk multiplier.

Out of the many complications that this situation presents we have attempted to home in on a core dynamic system that has significant implications for considering the impacts on the UK. Fortunately there are some principles arising from system dynamics that give us a way of simplifying this task without losing the requisite structural rigour. In system science an overarching principle is that the behaviour of a system derives from its structure. This structure can be represented by combinations of non-linearities (represented as feedback loops, or stocks and flows) created by the interaction of the physical, biological and social aspects of aspects of the system as a whole. This will include the decision making processes of the human agencies in the system. The basic behaviour in the system is derived from feedback structures embedded in and of the system.

The behaviour of interest is more complex than the typical modes of behaviour such as growth, goal seeking, and oscillations. It includes S-curves and overshoot and collapse as shown in Figure 2.2.

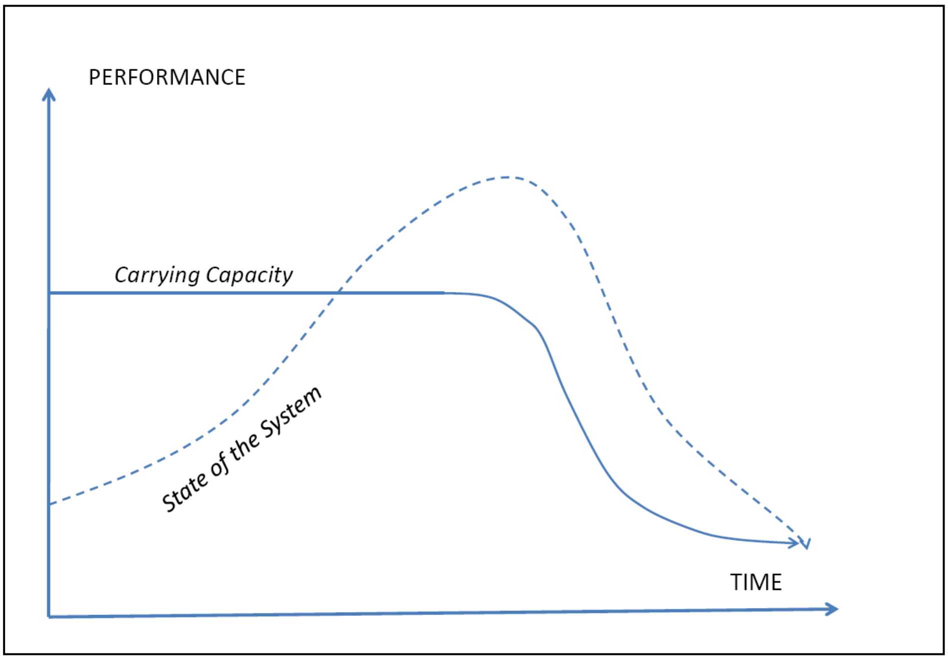


Figure 2.2. The state of a system can seem to improve whilst it is still able to absorb change within its carrying capacity. This abruption obscures and delays any feedback that a crisis is impending. This prevents effective planned intervention. Reaction to the crisis is unable catch up with the rapidly declining situation. Many examples of infrastructure breakdown illustrate this system dynamic.

Of particular interest in this context is the behaviour where a system appears to be coping with change but is actually eroding its capacity to cope. Extreme cases of this are civilization or biome collapse.

2.3 The Underlying Systemic Structure

The importance in studying this dynamic is not simple trying to see if the conditions for collapse are present but to recognise, as in any non-linear system, that the there are behaviours of the system that do not indicate, from a normal linear, perspective, that it is at risk from internal disruption. This is especially the case in human intervention in large scale natural systems. (One illustration of this is the way flood control efforts in one place have often led to more severe floods in other places by preventing natural dissipation of excess water in flood plains.)

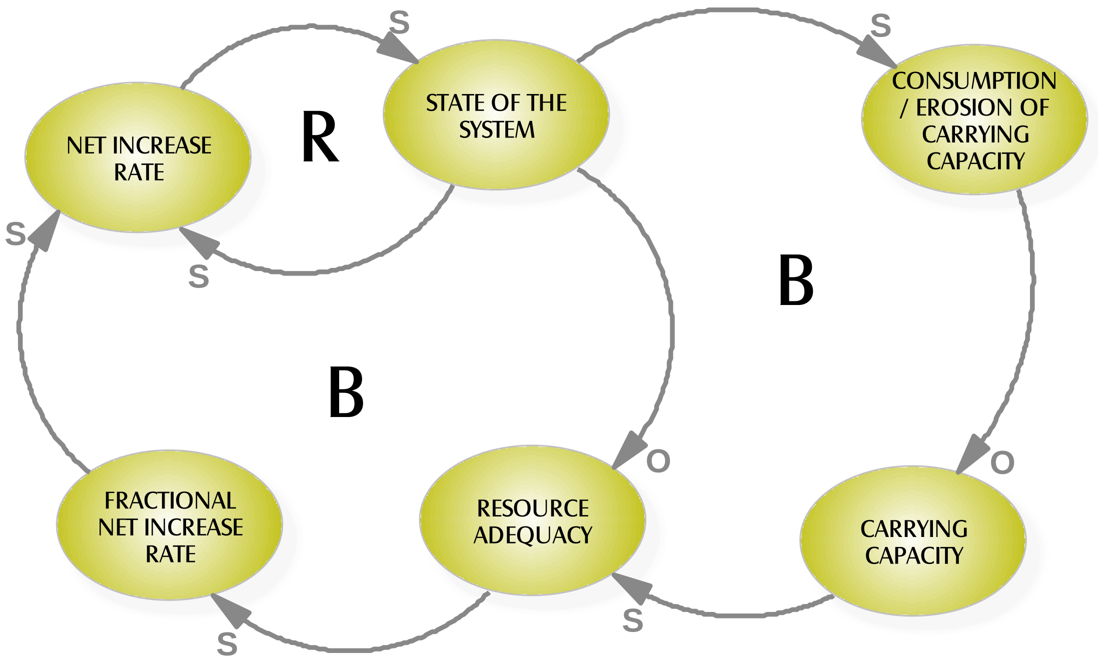


*Figure 2.3 Causal loop diagram showing the coupling of variables that typically drive and overshoot and collapse scenario. The **s** arrows change the variable in the same way; the **o** arrows change the variable in the opposite way. **B** stands for a balancing or restraining loop; **R** stands for a reinforcing or accelerating loop. (Sterman 2000)*

The causal loop diagram in Figure 2.3 shows a generic systems map for investigating how increasing intensity of climate heating may outpace adaptive capacity and lead to a scenarios of seeming to cope for a while and then suddenly collapsing. Policies which neglect to examine the question of non-linear change or the emerging of crisis points are likely to be caught out.

The major factors that need to be considered in order to arrive at some estimate of the vulnerability of a region are shown in Figure 2.4

In this system model the overall of climate change is considered as the exposure. The second element that responds to exposure is sensitivity which is treated here as the susceptibility of the social ecological system to climate change influences and event. This is also related to the carrying capacity of the system. The third component is adaptive capacity which may mitigate the direct impact in various ways.

Before describing this generic system it is necessary to define the basic symbols and conventions used in the diagram.

The fundamental unit is that of the *causal loop*. The simplest causal loop comprises two *variables* between which there are drawn feedback arrows such that a change in one variable influences a change in the other. The loop is represented by a verbal statement of a variable (e.g. carrying capacity) which can go up or down on some notional scale and by arrows (causal links) which imply some function that transmits influence form one to the other.

If the arrow head is labelled with an ***s*** *(= same)* then a rise in the tail variable will cause a rise in the head variable. If the arrow head is labelled with an ***o*** *(= opposite)* then a rise in the tail variable will cause a lowering in the head variable. If a causal loop drives some value to grow geometrically (such as an unpredated species with abundant resources) then it is called a *reinforcing loop* **R**. If a causal loop drives some value keep reducing (such a predator) after an increase it is called a *balancing loop* **B.**

Considering this system analysis in relation to the focus of this report, a given region in the world has a critical capacity upon which the UK depends or which is of significant interest to the UK. Examples are energy, food, raw materials and manufactured goods. If that capacity is growing then it will tend to follow an exponential curve. If there are increasing constraints then it will modify and follow an S-curve. Constraints could include limitations imposed by climate change effects or related policies. The trajectory will then be an S-curve. This will be a system with negative feedback control around a limit. If the control function has a delay factor then it will lead to overshoot and oscillation. However, the ability of an environment to support growth, for example in economy or population, is eroded or consumed by the society itself. It may be consuming biological material essential for ecosystem services. Its performance will be cut in two ways: by reducing the resources available per capita and by reducing total resources.

The behaviour over time (which is portrayed graphically in Figure 2.2) of the system is as follows. When the resource base is ample a positive growth dominates and the system grows exponentially. This is represented in the diagram as the **R** loop. But as it grows it reduces the resource adequacy and the negative loops **B** increasingly gain in strength. At some point the net increase rate falls to zero and a peak is reached.

Unlike an S-shaped curve case the system does not reach equilibrium. The carrying capacity continues to drop, resources per capita fall further, and the state of the system declines. If the remaining carrying capacity continues then the system collapses completely.

2.4 The Erosion and Collapse System Archetype

We can augment this core system dynamic with two moderating factors, one positive and one negative. The positive factor is investment in the development of adaptive capacity which can slow or reverse the decline. The negative factor is scale of climate change effects.

This augmented system gives a structural basis for examining the likely impact of climate change on any region and making judgements about the possible reverse impacts onto the UK.

We will call this system, represented in the diagram Figure 2.4, the *Erosion and Collapse System Archetype.*

It must be stressed that there are variants of the structure that can modify the outcome. In a social system the structure itself is open to modification over time by the additional feedback policy interventions.

Some examples of variability in the condition of the system are:

- the condition of the basic variables
- the strength/weakness of the linkages
- the speed or delay built into the linkages
- the relative strength of the dynamics of each loop
- the emergent properties of the complex adaptive system
- the extent to which there are other system couplings outside this system in question.

However, the factors that drive a system towards collapse are:-

- Fast growth
- Carrying capacity erosion
- Rapid drive through of feedback
- Weak adaptive capacity

The critical variable of concern to the UK is the ***capacity of the socio-economic system*** to deliver whatever the relationship or dependency requires. For example, this would be zero in a failed state. The higher the capacity the more it will provide ***maintenance of productive relationship with the UK.*** Where this capacity is growing it increases the ***differential rate of change*** (exponential growth) which in turn increases capacity. This is *reinforcing loop* R1.

However, the growing capacity places increasing demand on ***support by the overall environment*** and erodes the match of that support to demand. The overall environment as various sub components in interaction summarised as (a) ***state of ecosystem services***, (b) ***adequacy of food and water supply*** and (c) ***adequacy of infrastructure***.

These three are key variable directly affected by climate change from outside the system and which drive it faster towards erosion and collapse if it

(a) is impacted by **chronic climate change degradation**, often driven by slow and therefore harder to detect variables

(b) is affected by **acute critical climate impact** like drought and flooding

(c) is affected by **disruptive climate event impact** which is powerful enough to destroy life and trade supporting infrastructure

Reducing support by the overall environment increases the rate of change the system has to cope with and stretches its capacity further. This is the balancing loop **B1.** In parallel, reducing health of the environment reduces the ***level of well being***, which, with delay, tends to increase the ***pressure from population growth***. This further erodes the capacity of the socio-economic system to cope. This is the *balancing loop* **B4**.

Growth of the capacity of the socio-economic system, once beyond the peak, erodes and consumes the **societal carrying capacity** based on a variety of resources. This amplifies the effect of the growth impact on the environmental support. This is *balancing loop* **B3**.

As societal carrying capacity is erodes it reduces the **adaptive capacity** of the society (unless there is additional input here) and thus growth of capacity is overtaken by the resource deficits.

2.5 Applying the Erosion and Collapse System Archetype.

This core dynamic, which links the impact footprint (World System Model Map) with the review of adaptive capacity for each region, clearly varies by region. Some of the main variations to take into account are covered in the following questions.

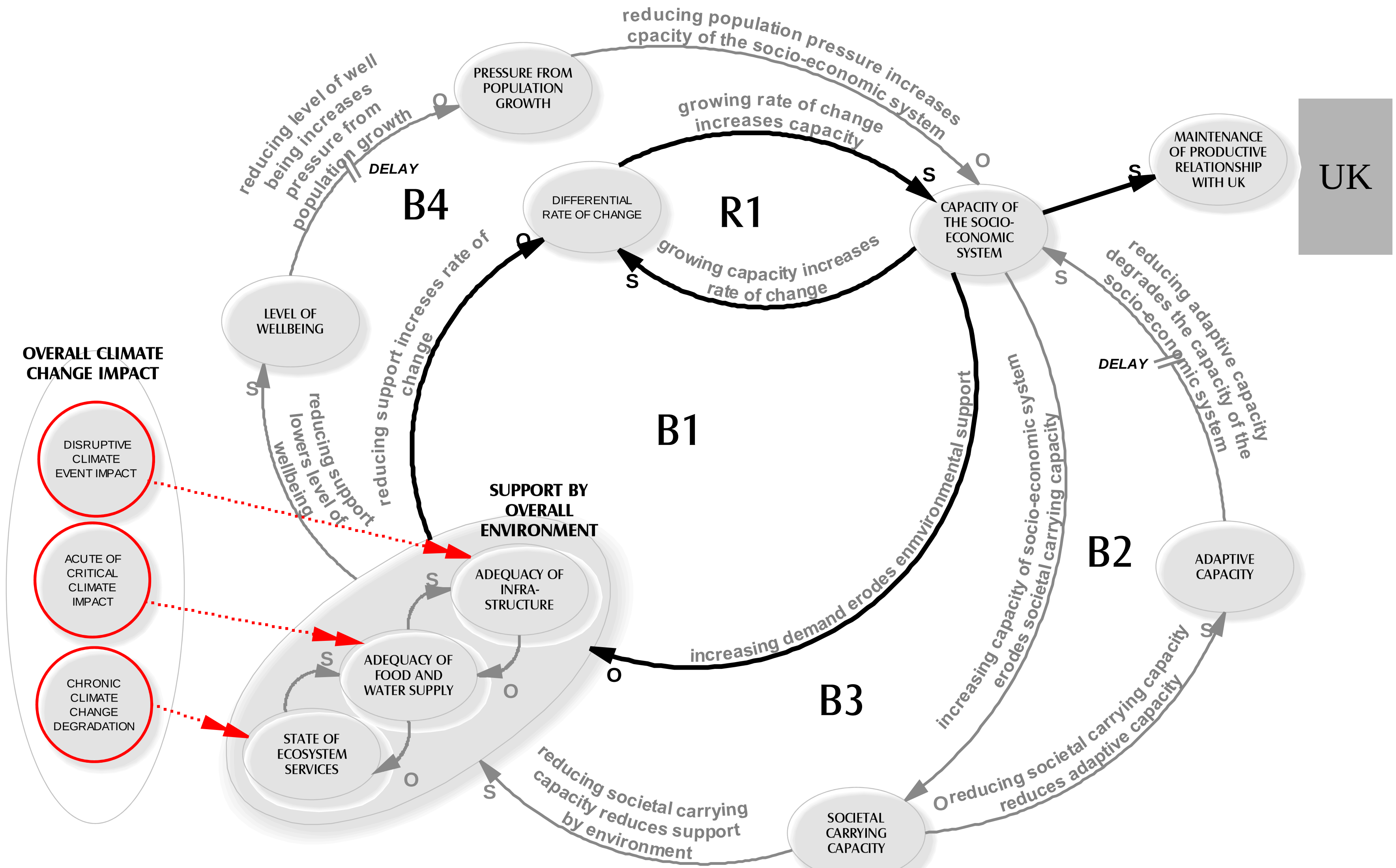
- What is the most significant dependency, exchange or interest for the UK in this region?
- How does this relate to the capacity of the local socio-economic system?

- What is the gap, if any, between the expected future performance and the known carrying capacity of the society?
- What is the condition of the supportive (or unsupportive_ overall environment?
- Which aspects of this supportive system is most vulnerable to climate change impacts?
- What might the local adaptive capacity be?
- What might the overall effect of all the loops be on the present and future ability to maintain a productive relationship with the UK?

These questions could provide the basis for further work in this newly opening field of considering the non-linear dynamics of climate change impact. Such considerations can then provide a more realistic basis for moving on to considering the impact on the UK of those non-linear impacts elsewhere.

Figure 2.4 A generic systems model for investigating non-linear potentials in the impact of climate change.

(see following page)


UK
MAINTENANCE OF PRODUCTIVE RELATIONSHIP WITH UK
CAPACITY OF THE SOCIO-ECONOMIC SYSTEM
DIFFERENTIAL RATE OF CHANGE
PRESSURE FROM POPULATION GROWTH
LEVEL OF WELLBEING
ADAPTIVE CAPACITY
SOCIETAL CARRYING CAPACITY
SUPPORT BY OVERALL ENVIRONMENT
ADEQUACY OF INFRA-STRUCTURE
ADEQUACY OF FOOD AND WATER SUPPLY
STATE OF ECOSYSTEM SERVICES
OVERALL CLIMATE CHANGE IMPACT
DISRUPTIVE CLIMATE EVENT IMPACT
ACUTE OF CRITICAL CLIMATE IMPACT
CHRONIC CLIMATE CHANGE DEGRADATION
R1
B1
B2
B3
B4
reducing population pressure increases cpacity of the socio-economic system
growing rate of change increases capacity
growing capacity increases rate of change
reducing adaptive capacity degrades the capacity of the socio-economic system
DELAY
increasing capacity of socio-economic system erodes societal carrying capacity
increasing demand erodes enmvironmental support
reducing societal carrying capacity reduces adaptive capacity
reducing societal carrying capacity reduces support by environment
reducing support increases rate of change
reducing support lowers level of wellbeing
reducing level of well being increases pressure from population growth
DELAY
S
O

3 High Impact Low Probability Events

3.1 Beyond Conventional Views

Part of the brief for this study included holding a special one-off workshop with participants from around Whitehall and invited others to consider ‘hard to imagine’ potential impacts of climate change.

The purpose of the workshop was to challenge some of the conventional assumptions on the impact of climate change and stretch the envelope of foresight possibilities a little. The purpose included anticipating which might be ‘black swans’, high impact events that are very difficult to predict and which might be overlooked from within the conventional mindset. The workshop aimed to encourage policy maker’s and analyst’s thinking further than the reasonable or ‘practical’ in the normal course of events and imagine some non-normal events. A further benefit of the workshop was to reveal underlying assumptions which have become received wisdom.

One of the techniques used to stimulate imagination was the challenge of putting two highly disruptive events together and making a conjecture about what that might lead to. Each event was based on existing evidence and was on the margin of plausibility in its own right. The mental challenge was to imagine what might occur if two such events happened simultaneously, or sparked off each other.

Perhaps the most difficult challenge that arose in the course of the workshop – and therefore most difficult to imagine within current policy assumptions – was that the targeting of carbon as the critical element in tackling climate change and sustaining the future economy might turn out to be false. Might it be that other nodes or elements in the world system are actually more pivotal?

The workshop also revealed the enormous range of the nature of the challenges that can plausibly be imagined as impacts of climate change. This emphasised the very high risk, therefore – forcefully expressed by one participant at the end of the workshop – of assuming that an item by item, risk by risk approach to 'managing' the range of threats stands any chance of being comprehensive enough to be useful.

3.2 The Workshop Approach

The workshop was designed and facilitated to guide the participants through several exercises to stretch their usual thinking and consider some more unthinkable possibilities in the arena of global climate change impacts. Here, unthinkable means any of hard to identify, contradicting received wisdom or recognition of new patterns. It does not mean the same as 'wild cards'. It is also important to note that the orientation was more on the impact on the social and political aspects of life. This was not a technical scientific workshop. Those attending were chosen primarily for their interest and experience in "thinking outside the box" as well as their expertise and experience.

The workshop was divided into stages beginning with a warm up on some creative thinking methods. This already generated some interesting thoughts. This was followed by using the IFF World System Model to identify potential discontinuities or tipping points in twelve interconnected areas of the global system. These were then used to generate new combinatorial of impacts. The emphasis here was on potential for synchronous failure (Homer-Dixon, 2006).

A different approach followed drawing on the recently published Vision 2050 report of the World Business Council for Sustainable Development (WBCDS 2010). We were fortunate to have Robert Horn (Horn 201) present who worked with the project to create an extensive information mural depicting the development of ten major themes to 2050 that could lead to a sustainable world. He introduced the mural after which the whole group engaged in responding with observations and questions again under the general orientation of 'hard to imagine'.

The workshop concluded with a mapping of ideas on to framework known as the three horizons (Sharpe and Hodgson 2006, Curry and Hodgson 2008) which brought in ideas of a shift of paradigm and a period of turbulent transition.

The report which follows captures the main ideas generated in all these sessions. Since the intention of the workshop was to generate a divergent range of provocative ideas which might stimulate people working in this field to expand their horizons of consideration, every point made needs to be treated with a large question mark, treating it as the germ of some interesting questions for further thinking and investigation.

3.3 Thought Starters

There follow some ideas generated during the warm up session on creative thinking techniques.

Consideration of unexpected accelerating frequency:

- ♦ Weather events impacting the mega-cities where over half the global population live coupled with incapacity to fund and administer that incommensurate scale of needed help – a major failure under stress of international aid
- ♦ Emergence of new alliance between commonly stressed regions, for example, deltas – this leading to friction with political boundaries that do no coincide with bioregional boundaries
- ♦ More and more major disruptions invalidate the current privatisation of profit and socialisation of debt – leads to the demise of private insurance.

Consideration of unexpected chain reactions:

- ♦ Exceptional hot season in China -> heat stress -> water crisis -> disruption of manufacturing -> collapse of retailing in the West
- ♦ Massive solar flare -> disruption of telecoms and broadband -> communications black out -> exploitation by organised crime and terrorists

Consideration of potential discontinuities or tipping points:

- ♦ Shut down of EU electricity connector spurs transformation of UK electricity local and micro-grid systems
- ♦ Unexpected incident triggers catastrophic loss of trust in government science leading to 'abolishing of climate change' and reversion to accepting behaviour of natural systems.

3.4 Synchronous Disruptions

This used the IFF World System Model (which is being used in the Foresight Impact on the UK of Global Climate Change project) as a framework to identify twelve areas of potential discontinuity or abrupt change. Pairs of these were brought together with their allocated advocates were challenged to conceive of some event or future condition that might arise from their combination or clash. The thinking technique is simply codified as 1+1=3. Hexagons were used as a visual pattern to stimulate and capture the thinking as shown in Figure 3.1. The various generated ideas and their origins are represented in the following set of examples.

The IFF World System Model comprises twelve nodes or factors which each indicate a wealth of complexity. However, the emphasis is on the overall holistic view where all the nodes are potentially linked together, making 66 in all. A sample of twelve of these, selected at random, was used as the stimulus in this exercise.

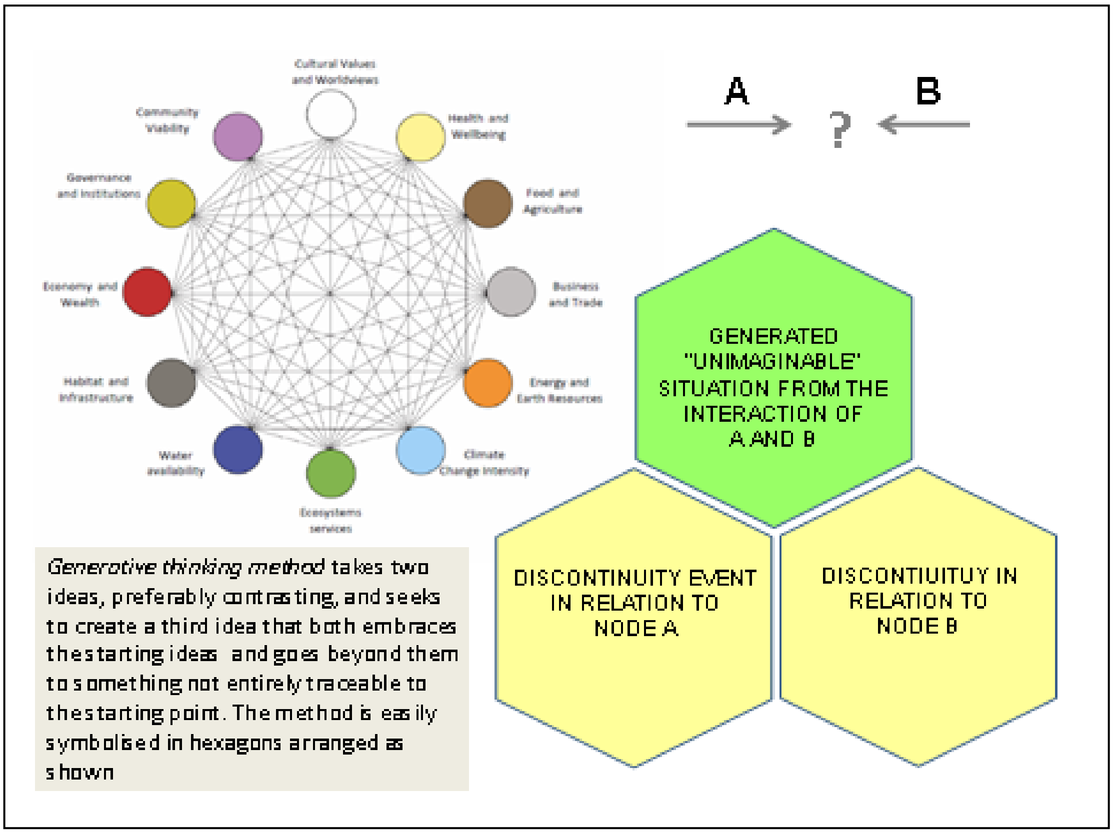


Figure 3.1 The visual *thinking technique used to stimulate generative ideas on possible outcomes of climate impacts in different parts of the social ecological system.*

Example 1

Node Pair	Step change	Generated Idea
Climate Change	Melting arctic ice opens new shipping lane in summer	Eurasian land of plenty with a new diet
Food and Agriculture	City based agriculture becomes common	

The combination of the opening up of the Arctic in both Canada and Russia leads to a new frontier of development in which the populations grow through the development of new well designed cities able to support themselves, especially in food, with a small local footprint.

Example 2

Node Pair	Step Change	Generated Idea
Governance and Institutions	Sudden scarcity leads to breakdown of public order abroad	Chronic global governance problems
Health and Wellbeing	World wide collapse of human fertility	

Various aspects of the global system are dislocated by climate conditions (no doubt exacerbated by volcanic activity). At the same time biological stress leads to sudden decline in human fertility leaving a progressively aging population. There is no effective global governance to deal with this situation.

Example 3

Node Pair	Step Change	Generated Idea
Water Availability	Commoditisation of water	OWEC – Organisation of Water Exporting Countries
Community Resilience	Inward protection and tribalism	

Water is taken over by private interests as globalising governments privatise water into a commodity. At the same time water scarcity leads to intense competition for water supply. To both exploit and moderate the situation there is formed the *Organisation of Water Exporting Countries* analogous to OPEC.

Example 4

Node Pair	Step Change	Generated Idea
Cultural Values and Worldviews	Food is seen as a local, indigenous and part of regional identity	Rationing of global food supply and distribution
Food and Agriculture	Stem rust and bee pollination failure triggers extreme scarcity	

A variety of food supply disruptions due to climate and volcanic activity lead to local food being increasingly seen as a necessity. However, the climate conditions exacerbate the biohazard to food production. The resulting scarcity leads to global negotiation of food rationing.

Example 5

Node Pair	Step Change	Generated Idea
Climate Change	Melting Arctic ice opens new shipping lanes in summer	New ungovernable trade route facilitates trade that doesn't want to be governed
Business and Trade	'Digitised' trade creates links to nations with weak governance that undermines global governance	

The opening of new northern shipping lanes leads to a more 'wild west' frontier approach to the movement of goods and trade. The ability to bypass conventional governance is amplified by digital networks of traders leading to a new ungovernable North Polar trade system.

Example 6

Node Pair	Step Change	Generated Idea
Ecosystems Services	Ecosystem collapse – loss of biodiversity and productivity	Loss of societal resilience (no more solutions)
Health and Wellbeing	Mental health pandemic "we can't cope"	

The collapse of areas of the ecosystem through the continuing massive species extinction combines with a widespread mental health pandemic, partly brought on by fear and stress. Instead of becoming more resilient to deal with the challenges, society becomes more brittle and at risk.

Example 7

Node Pair	Step Change	Generated Idea
Economy and Wealth	Collapse of trust paralysing capital investment	New 'cheap oil' confounds long term strategic investments in renewable electricity
Energy and Earth Resources	Non-conventional fossil energy becomes cheap and plentiful	

Various incidents of fraud and corruption on a global scale lead to a paralysis of trust. This slows down investment in renewable electricity. However, the increasing discovery and technical exploitation of shale gas deposits creates an economy that can still function of cheap energy and smaller capital commitments.

Example 8

Node Pair	Step Change	Generated Idea
Habitat and Infrastructure	Civil unrest in mega-cities as supply lines are affected by transport cost and environmental disruption	Re-tribalisation and breakdown of nation states (global crime able to adapt)
Water Availability	Upsurge of epidemics especially waterborne diseases	

Disruption of supply lines by escalating transport costs and environmental disruption leads to large scale civil unrest. Climate conditions trigger upsurge of water borne diseases which, combined with supply issues, lead to a tribalisation of local societies often dominated by criminal 'warlords'.

Example 9

Node Pair	Step Change	Generated Idea
Community Resilience	Power of 'ning-unities' – social virtual networks	Climate-Gate "nailin Pailin" Political/personal 'smart bombing'
Cultural Values and Worldviews	Climate denial power grab achieves dominance	

Virtual social networks grow and undermine conventional power. At the same time the climate change deniers achieve propaganda dominance. This is achieved by well placed and effective 'smart media bombing' of oppositional views.

Example 10

Node Pair	Step Change	Generated Idea
Economy and Wealth	Climate change driving to global governance with resilience as a priority	Global power and resource redistribution following ecosystem failure
Business and Trade	Growth revealed to be unsustainable and redirected towards transforming trade patterns	

Ecosystem failure means there is genuinely not enough for all (we consume 1.3 planet's worth). Is it too uncomfortable to think power rests with the rich world? Will any redistribution be unacceptable in governance terms (rich electorates will not accept). Can developing world compel a rebalancing? Where will Russia stand?

Example 11

Node Pair	Step Change	Generated Idea
Economy and Wealth	Change of GDP measurement disrupts 'business as usual'	Price of babies distorts global trade and provoked moral turmoil
Ecosystem Services	Biosphere backlash as collapse in human fertility	

The foundations of the business economy get disrupted by a complete change of the measures and rules. At the same time there is a collapse in human fertility. The sustainability of humans becomes highly valued and 'trade in babies' provokes huge social ethical issues.

Example 12

Node Pair	Step Change	Generated Idea
Habitat and Infrastructure	Water and food scarcity leads to rapid redesign and retrofit of city infra-structure	Militant regionalisation as centralisation is relaxed in face of drive for self-sufficiency
Energy and Earth Resources	Energy systems become very local and jealously defended	

The redesign and retrofit of cities becomes a dominant global agenda as a bid for greater sustainability. At the same time the localisation of energy systems, especially from renewables, lead to a re-emergence of the 'city state'.

In the unlikely future that all of these discontinuities happen simultaneously then the description of the future world reads as follows.

- Eurasian land of plenty with a new diet
- Chronic global governance problems
- OWEC – Organisation of Water Exporting Countries
- Rationing of global food supply and distribution
- New ungovernable trade route facilitates trade that doesn’t want to be governed
- Loss of societal resilience (no more solutions)
- New ‘cheap oil’ confounds long term strategic investments in renewable electricity
- Re-tribalisation and breakdown of nation states (global crime able to adapt)
- Climate-Gate style political/personal ‘smart info-bombing’
- Global power and resource redistribution following ecosystem failure
- Price of babies distorts global trade and provoked moral turmoil
- Militant regionalisation as centralisation is relaxed in face of drive for self-sufficiency

The value of such a ‘hard to imagine’ set of possible future conditions is that they provide alerts for policy and decision makers as to what far sighted actions might be needed now in the present to avoid or mitigate the undesirable aspects of passivity and inaction on many of these issues.

3.5 VISION 2050 – World Business Council for Sustainable Development

As part of their 50 year vision project the WBCSD commissioned Robert Horn to develop an information mural. The mural is a complex display of close to 500 different factors. They are laid out in ten parallel themes:

1. Energy and power
2. Buildings and energy efficiency
3. Mobility – low carbon
4. Materials – closed loops
5. Global ecology – finance and business models
6. Governance – enabling transformation
7. People – values, behaviour and development
8. Agriculture – feed 9 billion people by 2050
9. Forest – timber and fuel
10. Ecosystems and biodiversity – maintain and restore

Each theme is developed over five decades and is populated with

- Things that must happen
- Things that must not happen
- Some key statistics
- Illustrative icons and symbols

This report will not go into the structure of the mural any further. This can be accessed through (reference). The mural was produced for the workshop in a version 4ft high and 14ft long. After Bob Horn had walked us through the structure and main messages of the mural the workshop participants studied, discussed, walked up and down and then added sticky notes with ideas, observations and questions that occurred to them. These were stuck on appropriate places on the mural.

The scale is far too large to reproduce this as such in this document. What is laid out below is the set of ideas organised roughly into the time frame that triggered them. They are offered as relatively random thoughts provoked by the mural and which add in varying degrees to the hard to imagine collection. A 'postage stamp' impression is reproduced below to illustrate the range and complexity of the mural.

Figure 3.2 - The Robert Horn Mural of the Vision 2050 of the WBCSD

The following table captures the main thoughts which were provoked through discussions taking place around the mural.

Approximate Decade	*Thoughts Provoked*
2010s	♦ Needed accounting standards for internalising carbon costs seems unlikely ♦ Needed international agreements on climate energy seems unlikely ♦ Still leaves three quarter of illiterate population as women – long way from Millennium Development Goals ♦ Food rationing will surely have to be introduced ♦ It will be impossible to avoid an escalation of international terrorist and criminal organisations ♦ There are big unaddressed issues around who decides who gets scarce resources – likely that wealth + connection = access ♦ We are more likely to need a benign dictatorship to resolve the dilemma between growing food and growing biofuels ♦ We are likely to be trapped in fake metrics of sustainable economic growth and thus delay a proper response ♦ Vested energy interests likely to prevail with high use of coal ♦ The 'realpolitik' of self-interest is likely to lead to increasingly aggressive foreign policies (possibly resource wars) ♦ Countries like Kenya exporting more and more cash crops will find themselves highly vulnerable to environmental impacts

2020s	♦ UK will have to make a strategic choice between global policeman or focus on local protection ♦ We could see the end of the private insurance industry as the incidence of mental ill-health leads to crisis ♦ Will we have a chance to choose accepting or avoiding 'augmented humans'? ♦ Carbon capture and storage, even if successful, will come far too late ♦ Glocalism will develop to a further stage ♦ The assumed free market will be questioned as will 'democratic government' This will emerge through the growth of the networked society ♦ To implement the needed changes it is likely that a much stronger government will be needed than is being assumed – a weakening of democracy may be necessary? ♦ In this world there will be a constantly shifting view of allies and their values and systems – more transnational threats ♦ How will we distinguish between WE and THEY? ♦ Question that we will achieve the millennium development goals in this time – already off target ♦ Who captures the dominant concept of 'fair' –governance and market processes for the commons and essential commodities ♦ The idea that the accelerating gap between rich and poor will be reversed is pretty unimaginable! ♦ Linking shareholder value to social value will be a much bigger struggle ♦ The rich will survive by force: the poor will die by exclusion ♦ Is it likely that renewable energy production will take precedence over NIMBYism in communities? ♦ There will be a need for a much stronger central control over urban development and infrastructure – eg China
2030s	♦ On agriculture - by this time we will know whether green revolution 2 was best or actually permaculture was the answer ♦ There is likely to be considerable 're-regionalisation' as nations move from self-sufficiency to *selfish*-sufficiency through power politics ♦ It is perhaps already too late to think that the tropical rainforests will be stabilised by then. They are already in many cases past the point of sustainability. ♦ We can expect here a re-tribalisation across the globe with a layered society and much crime in cities ♦ There is a strategic choice whether we take on a new financial infrastructure or return to the old (WB,UN,IMF etc). We can't have both.
2040s	♦ We are at risk from 'silver bullets' that kill rather than save – call them 'black bullets' ♦ The whole approach seems to assume the continuing prevalence of the economic growth model – is this really likely to continue working on a limited planet? ♦ In terms of the three horizon model, this feels like an heroic effort to sustain Horizon 1 model with corporate ingenuity!

Some overall reflections on the mural and the conversations it provoked were:

- "There are several 'elephants in the room' that are not pointed to or discussed. It would be interesting to take a look at them"

- "There are many things in this chart that are difficult to see how free riders will be left to exploit the new situation in the old ways. What is the basis of enforceability of reaching a sustainable world? No penalties were mentioned."

3.6 Three Horizons into the Future

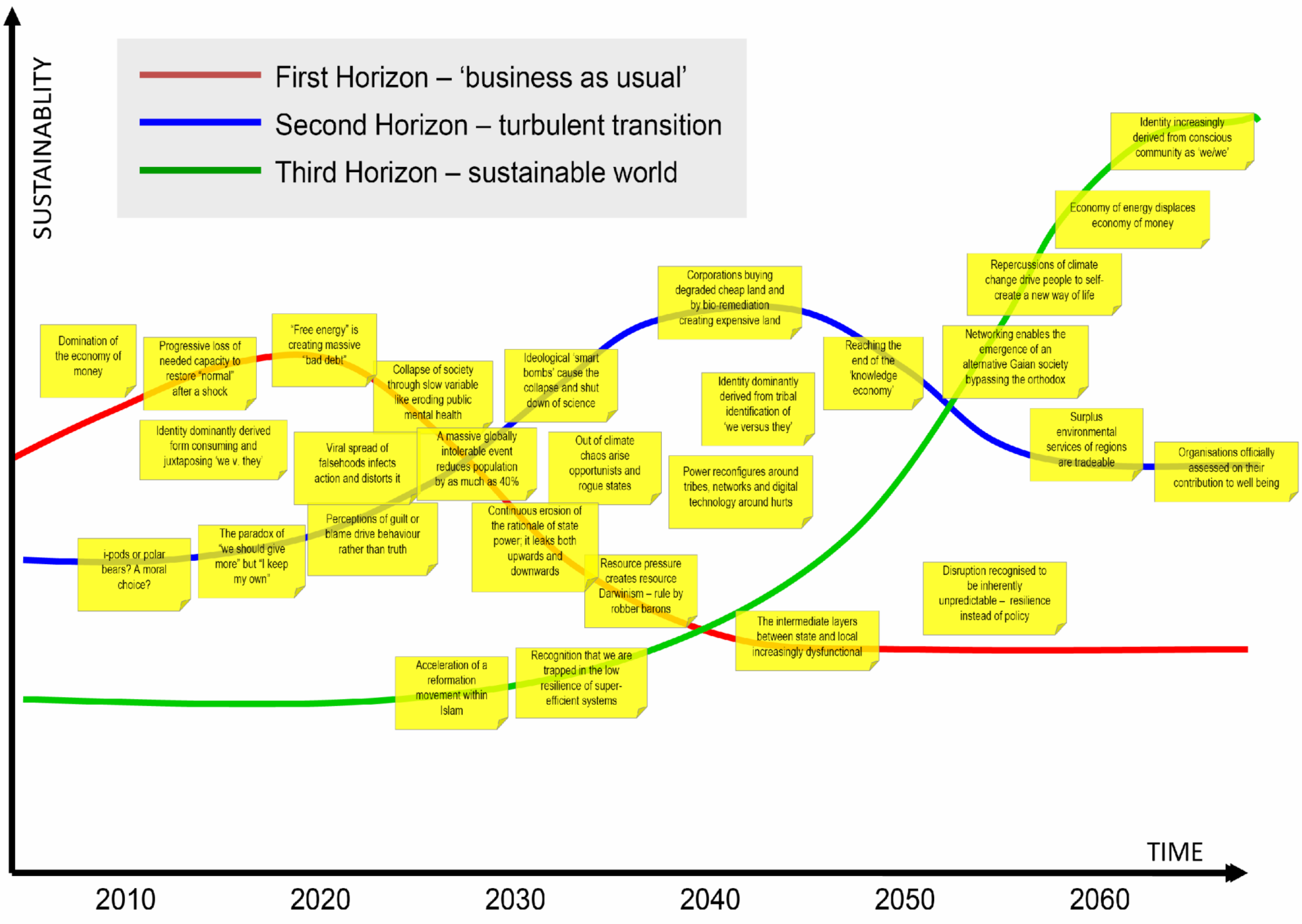
Building on the review of the next fifty years mural, a session was held to record further thoughts on the successful transition to a sustainable society by 2050 including some of the hard to imagine alternatives to the status quo. This is summarised in the diagram Figure 3.3.

In this diagram the status quo or 'business as usual' is *Horizon 1 (red)* which diminishes in effectiveness as a quite different operating environment comes about. *Horizon 3 (green)* represents a new paradigm that can be successful in the new operating environment. *Horizon 2 (blue)* is the transition period which is messy, full of dilemmas and wicked problems, but also innovative and promising.

Figure 3.3 - Three Horizons of a Possible Transition to a Sustainable Society

(see next page)

Three Horizons of a Possible Transition to a Sustainable World



3.7 Some Priority Challenge Areas

At the conclusion of the workshop the group shared some reflections as to what the overarching themes might be for deeper investigation of ‘hard to imagine factors’. These themes are not particularly difficult to imagine as fiction but challenging if considered to be a real possibility. Their generality is helpful as an heuristic device to look out for lateral or anomalous information in horizon scanning that might unearth missing factors and considerations. Psychologically this is known as cognitive priming – through the entertainment of an idea we tune up the mind to be sensitive to actual information that we might otherwise miss. If this turns out to be a trend or event actual happening then we are that much better prepared and have more lead time to consider policies and actions.

Five things worthy of hard-to-imagine thinking are:

Supposing:

1. Climate impacts on energy and the economy bring about an end to markets
2. Ecosystems are destroyed by the economy living off and exhausting the $25 trillion of eco capital
3. We are in denial of the equation :

   [(water, food, energy) X population] X climate
4. with dire consequences
5. Reduction in carbon emissions is NOT the problem to solve
6. The transition to a one planet global life style may pass through an “energy desert” disrupting people and economy

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