Chapter 3
Risk, Resilience and Adaptation to Global Change

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Abstract *Background*: The significance and threat of global change is increasingly being acknowledged. Understanding and responding to it is of critical importance. Early action is more beneficial than delay. Responding to global change entails both adaptation and mitigation. This chapter focuses on the former. It sets out to contribute to the understanding of what global change is, and its implications for Africa in general and South Africa in particular. Understanding the risks that are present is vital for the formulation and implementation of appropriate responses to such risks. For South Africa, responding to global change is a priority and it is one of the grand challenges that have been identified in its policy documents. The chapter is based on extensive literature review. *Methodology:* An extensive literature review including policy documents and published scientific literature was conducted. *Application/Relevance to systems analysis:* Understanding and responding to global change requires the need to acknowledge that processes, risks and the impacts occur in multiple stressor and multiple scale contexts. The complexities associated with global change as well as the potential for maladaptation and unintended consequences motivate the need to apply systems thinking. *Policy implications:* South Africa as part of the global system, will also be impacted by global change and its associated risks. Hence, the need for the country to be proactive. Some of the factors that can promote resilience and adaptation to global change include: taking a "glocal" approach, promoting information generation and dissemination, enabling relevant and responsive institutions, promoting flexibility and learning, building the asset base of households and communities, promoting stakeholder buy-in and stewardship in programmes, enhancing ecological infrastructure, and forging partnerships and collaborations. The state and other stakeholders should strive to enable the creation of a favourable environment that can foster appropriate resilience and adaptation to global change. *Conclusion:* Strides are being made in terms of understanding and responding to global change. However, due to complexities involved, more effort is still needed to establish and further understand global change processes. There is need for more multi-disciplinary stakeholder partnerships in order to realise synergies. Continued effort should be directed at creating awareness and building positive perception of the

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need to adapt amongst various stakeholders. Proper assessment methodologies should be employed to evaluate various adaptation options before their implementation in order to avoid maladaptation. Global change should be embraced at the local level in the context of multiple stressors that tend to increase vulnerability.

3.1 Introduction

The Earth System is comprised of land, oceans, atmosphere and poles, plus the interacting physical, chemical, and biological processes, and the associated natural cycles (the carbon, water, nitrogen, phosphorus, sulphur and other cycles) (IGBP 2016). Significant changes have been observed in the Earth System, which has brought to the fore the term global change. Global change refers to planetary-scale changes in the Earth System. These changes include: atmospheric circulation, ocean circulation, climate, the carbon cycle, the nitrogen cycle, the water cycle and other cycles, sea-ice changes, sea-level changes, food webs, biological diversity, pollution, health, fish stocks, human society, amongst others (IGBP 2016; Muccione and Schaepman 2014).

Though the term global change is at times used to refer to global climate change, it is important to take note that it is much broader. Climate change is not the same as global change, but it is a component of global change; the Earth System has many other components and processes. Thus, global change includes changes in many aspects of the Earth System, including the climate (IGBP 2016; NAS 2000). Erisman et al. (2015) observes that current global-change risk assessments generally target single stressors, such as the climate, while paying less attention to wider impacts on land degradation, food and energy production, water supply and environmental hazards. In this regard, global change response efforts should not focus on the climate alone, rather should integrate many other components of the Earth System (NAS 2000). Much as this chapter takes cognisance of the fact that global change is not global climate change, it is important to highlight that many of the examples and the literature that is cited are mostly climate change related. This is so, mainly because a lot of research has been undertaken in the climate change field.

Although there are natural drivers of global change, it is noteworthy to point out that humans are increasingly contributing to global change. The Amsterdam Declaration on Global Change that was issued in 2001 highlights that the Earth System has already gone past the general natural variability (Moore et al. 2001). Humans are having profound impacts on the global environment, with detrimental effects on the climate, species, ecosystems, and human health (Camill 2010). This occurs as a result of population growth, pollution, energy and resource use, land use, agriculture, urbanization, transport and economic activities (Muccione and Schaepman 2014; Steffen et al. 2004). Two distinct aspects of human-induced global change are: first, humans are causing accelerated changes, and secondly, they are bringing new kinds of changes; which then interact to further compound the negative effects on the Earth System (NAS 2000).

3.2 The Interlinkages Between Risks, Vulnerability and Stressors

3.2.1 Risks

An important component of the discussion around global change is the notion of risk. Risk is defined as the probability of a negative event and its negative impacts (OECD 2014). Risk can be viewed as the likelihood of experiencing harm or loss (Mitchell and Harris 2012). Associated with risk are shocks and stresses. A shock is a sudden event that often has negative impact on the vulnerability of a system and its parts, while a stress is a long term trend, that worsens the vulnerability of the actors (OECD 2014).

Broadly, global change is associated with global risks. These risks do not have geographic boundaries, as their cascading effects stretch far and wide, with impacts that can affect several countries or industries (WEF 2016b). In other words, a global risk is not a threat to a particular region alone but covers many regions. The Global Risks Report 2016 ranks the failure of climate-change mitigation and adaptation as the most impactful global risk; it is also ranked as the third most likely to occur, while, water crises is ranked as the third most impactful and ninth most likely to occur (WEF 2016a, b).

In this context, individuals, households, and communities are battling with climate- and water-related challenges. The current and future projections paint a gloomy picture. The Global Climate Risk Index 2016 reports that between 1995 and 2014, greater than 525,000 people died worldwide and losses of more than US$ 2.97 trillion were experienced as a direct result of over 15,000 extreme weather events (WEF 2016b). In South Africa, it is estimated that about 5.8 million people will be affected by extreme rainfall events (Van Huyssteen et al. 2013). The year 2016 was recorded as the hottest year globally, with 43 °C being recorded in Pretoria (WWF-SA 2017). South Africa is a water scarce country, and projections point to further scarcity. Based on current usage trends, the country will likely face 17% water deficit by 2030, and the shortages will be worsened by climate change (WWF-SA 2017). Thus, delayed and inappropriate action on global change and its associated events will have significant detrimental effects on the socioeconomic development of the country.

3.2.2 Vulnerability

An important aspect in this discussion is the issue of vulnerability to global change and its associated risks. Vulnerability can be understood as the propensity or tendency to be negatively affected (Mitchell and Harris 2012). It is the manifestation of susceptibility to harm, and exposure to hazard (OECD 2014) or the propensity to suffer harm from exposure to external stresses and shocks (SRC 2015).

Vulnerability must be understood as a dynamic characteristic that is influenced by larger scale economic and environmental changes (Leichenko and O'brien 2002).

Some of the factors that influence vulnerability are location, access to information and resources, the quality of infrastructure, housing type, density of the built environment, economic wellbeing of a community, and socioeconomic and political status (van Donk and Gaidien 2014). Most of the factors that create potential for harm are inherent in social systems (Cutter et al. 2008), hence the strong and complex inter-linkages between local drivers of vulnerability and exposure (World Bank 2013).

The political and economic system affects the allocation and distribution of resources in a society, and can be a key source of vulnerability (Van Huyssteen et al. 2013). For South Africa, the historical socioeconomic and political marginalisation of many people in the country reinforces their vulnerability (GGLN 2014). Patterns of colonial development and apartheid legacies impact on urban resilience; Cape Town illustrates the continued high levels of social, spatial and structural inequalities (Rodina and Harris 2016). Van Huyssteen et al. (2013) also note that past and current urban planning as well as high levels of inequality in the country have seen people staying in unsafe and vulnerable locations such as floodplains, hillsides, and coastlines.

The negative effects of hazards tend to be both regressive and heterogeneous, thereby contributing to higher inequality (World Bank 2013). At the same time, the unequal distribution of vulnerability is worsened by pre-existing inequalities (Adger 2006). The negative effects of global change worsen the conditions of people who are already suffering. Hence, poverty underlies most of the vulnerability of communities and households. For instance, vulnerable low-income households and the unemployed are likely to face more severe climate related impacts (DEA 2011). Accordingly, tackling poverty will help to reduce vulnerability, and on the other hand reducing vulnerability helps to reduce poverty. Vulnerability does not only come from direct global change related impacts. In some cases, there are response measures that can have indirect negative impacts on the livelihoods of people. For example, South Africa may be economically vulnerable to commitments adopted at the international and national level to lower greenhouse gas (GHG) emissions as it is highly dependent on electricity generated from coal which is considered a dirty fuel (DEA 2011).

Population size, human settlements, and the availability of support resources are critical issues in the discussion on resilience and adaptation to global change. If the population in a particular area is not proportional to available resources, this reduces the ability of such a community to cope with and adapt to change. This seems to be the case with informal settlements or slums, which are increasingly being part of the urban landscape across the world. Areas such as these tend to be more vulnerable as they have inadequate access to the most important basic infrastructure and services. In this regard, South Africa is experiencing growing urbanisation and forecasts indicate further growth (Fig. 3.1). This urbanisation is also associated with expansion of informal settlements, which is partly driven by the high levels of inequality and marginalisation in the country.

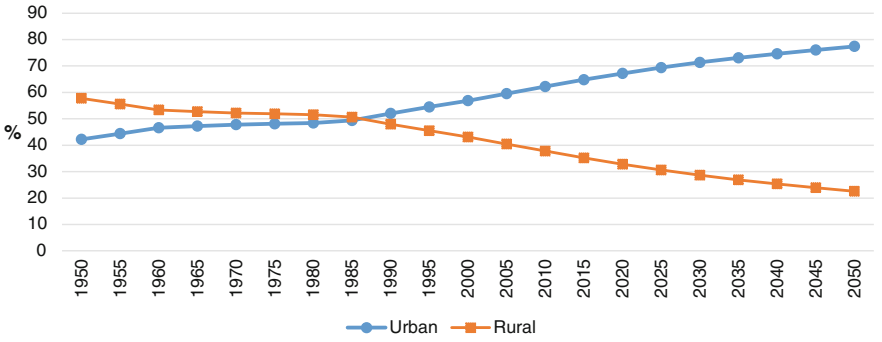

Fig. 3.1 Percentage of population residing in urban and rural areas for South Africa, 1950–2050. *Source* Author based on United Nations, Department of Economic and Social Affairs, Population Division (2014)

Informal settlements experience multiple pressures that combine with climate change impacts to worsen their pre-existing vulnerabilities and inequalities (Taylor and Peter 2014). In recent years, the vulnerability of many South African communities is becoming more evident. For example, Joubert and Martindale (2013) observed the vulnerability to flooding of informal settlements in Cape Town; the people living there generally had limited capacity to cope. This is also the case in Johannesburg. The Mail and Guardian (2014) reported that,

> *About 70 shacks in the Vusimuzi informal settlement near Tembisa, in Ekurhuleni, were flooded, and about 25 displaced families were moved to the community hall … About 90 shacks in Kliptown, Soweto, had also been flooded due to heavy rains in the area.*

3.2.3 Multiple Stressors

Most environmental challenges are likely to show combined action of several driving forces, acting at varying spatial and temporal scales (NAS 2000). This implies that many risks and shocks are closely related and interact with each other. Erisman et al. (2015) refer to them as networked risks—a sudden change in one can have a domino effect on others. In other words, a change in one has an effect on others, presenting a compounding effect. The interaction of such risks, shocks, and trends is sometimes referred to as multiple stressors. They act and impact differently but tend to have a reinforcing effect upon each other, thereby further worsening the situation. Casale et al. (2010) describes the situation as "entangled crises", whereby development efforts to disentangle one thread or another off the knot is difficult and generally fails.

The interconnectedness between stressors tends to blur the distinction between them, which in some cases lead to wrong diagnosis and action. Unfortunately, most

of the past studies did not take vulnerability as a pre-existing state generated by multiple factors and processes that influence the ability to respond to stress (Eriksen and Kelly 2007). Tackling the multiple stressors does not require a single lens that is specific to a particular stress, but a combination of complementary lenses that are able to diagnose multiple stressors. This calls for an integrative approach rather than focusing on a single type of hazard (Van Huyssteen et al. 2013). This is to say—all the key risks and stressors need to be considered collectively (World Bank 2013), as there are feedbacks between various processes.

In the same context, it is crucial to understand the effects of socioeconomic and biophysical processes on global change, and how global change impacts on the socioeconomic and biophysical processes (NAS 2000). The biophysical stress may further worsen existing socioeconomic and political stresses and vice versa (Vogel 2011). For example, Nel et al. (2014) observed that farmers in Eden District in Western Cape, South Africa were impacted by the continued occurrence of droughts, floods and wildfires; this had severe knock-on effects on their farming and the whole local economy, which further increased their vulnerability.

O'Brien et al. (2004) suggested that through the lens of vulnerability, in areas that face multiple stressors, climate change may be the stressor that pushes people or ecosystems "over the edge". This indicates that climate change compounds existing stressors and also brings with it new ones. For instance, climate change and water risks are closely related to food insecurity risks (WEF 2016b). Also, weather-related hazards, intensified by climate change, converge with local drivers of exposure and inherent vulnerability to amplify disaster risk (World Bank 2013). With a changing climate, it is important to understand both the potential 'big, extreme' events and also the regularly occurring 'smaller' events (Vogel 2011).

Fourie et al. (2015) identified a relationship between wave action, coastal erosion and shoreline retreat at Monwabisi Beach near the City of Cape Town. It was observed that the beach is experiencing extreme rates of coastline erosion which is damaging local infrastructure. Fourie et al. (2015) concluded that the vulnerability of the beach to erosion is due to many factors such as the number and height of big wave events, waves coming from a more southerly direction, the underlying geological substrate, and the impacts of local infrastructure on the geological substrate.

The additional risks for water security as a result of climate change, have knock-on effects on highly water dependent sectors such as agriculture, electricity production, mining and manufacturing (DEA 2011). Southern Africa has high dependence on the natural environment for livelihoods, which makes it more vulnerable to impacts (Davis 2011). Similarly, climate change can also have direct and indirect negative health impacts, for example, the reduced water availability associated with droughts can cause health hazards associated with poor water sanitation and the food insecurity can result in nutritional deficiencies (WHO 2014). The DEA (2011a) notes that South Africa has a notable proportion of people particularly the poor, who already face complex health challenges which are likely to be worsened by climate change-related health risks, for example the spread of vector-borne diseases such as malaria, rift valley fever and schistosomiasis.

The majority of natural biomes in South Africa are diverse and can be sensitive to changes in the climate (Midgley 2011). Moreover, the widespread presence of invasive alien plants (IAPs) can also undermine the resilience of ecosystems and communities to withstand risks and hazards. IAPs have been noted to draw more water compared to native plants which negatively impacts on the sustainability of such environments. This is a common challenge in South Africa. Estimates show that about 9000 plant species have been introduced in the country, of which about 161 species are deemed invasive, they tend to spread at a fast rate and consume more water (DEA 2012). IAPs also tend to increase the risk of fires, which becomes worse in drought conditions. In a study conducted in Eden District in Western Cape, South Africa, Nel et al. (2014) found that allowing the spread of IAPs into untransformed vegetation could halve monthly river flows experienced during drought as well as double fire-line intensities.

3.3 Resilience

The resilience concept has been gaining traction in both research and development practice. This increased attention to resilience is partly due to the current thinking about sustainable futures in the face of growing risk and uncertainty (Mitchell and Harris 2012). In this context, resilience-building is envisioned to expedite holistic, positive and lasting solutions in communities and nations who are most at risk of harm (Mitchell 2013). The Global Risks Report calls for a 'resilience imperative', which requires an urgent need to explore new avenues and more opportunities to mitigate, adapt to and build resilience against global risks and threats (WEF 2016a, b). The definition of resilience varies and in some cases there are contestations (Klein et al. 2004; Mitchell and Harris 2012; Adger 2000).

Resilience is the ability of a social system (household, community, nation, or region) to respond and recover from shocks, which includes those inherent characteristics that enable the system to absorb impacts and cope with an event, and post-event adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a threat (Cutter et al. 2008). In other words, resilience is the capacity of a system and its component parts to anticipate, absorb, accommodate, or recover timely and efficiently from the effects of a shock or stress (Mitchell and Harris 2012). That is, being able to deal with change and continuing to develop (SRC 2015).

Klein et al. (2004) state that while resilience has been defined in many different ways, it is important that it is used to define specific system attributes which are: the amount of disturbance a system can allow and remain within the same state; and the extent to which the system is capable of self-organisation. Resilience has two attributes, namely inherent and adaptive (Cutter et al. 2008). The inherent attribute means the system functions well during normal periods, i.e. non-disaster periods, while adaptive relates to the flexibility in response during disaster period, which allows the system to function well. Bahadur et al. (2010) identified ten

characteristics of resilient systems namely: high level of diversity; effective governance/institutions/control mechanisms; acceptance of uncertainty and change; community involvement and inclusion of local knowledge; preparedness, planning and readiness; high degree of equity; social values and structures; non-equilibrium system dynamics; learning; and adoption of a cross-scalar perspective of events and occurrences.

Resilience is a system-level concept; it avails a framework that integrates how multiple systems interact across temporal and spatial scales (Anderies et al. 2013). The use of 'system' in the context of resilience stems mainly from ecological theory (Bahadur et al. 2010). It considers multiple risks, shocks and stresses and their impacts on natural systems as well as people's livelihoods; also taking cognisance of the slow drivers of change that have impact and non-linearity (Mitchell and Harris 2012). It is important to point out that resilience is a dynamic process (Cutter et al. 2008; Mitchell and Harris 2012), meaning that it is not static but always evolving.

Adger (2000) distinguishes the resilience concept in ecology from social resilience, but also takes note that they are closely related. Ecological resilience relates to the application of the concept to ecological systems; this is where the concept was first used. Social resilience entails applying the concept to social systems, which considers how individuals and social groups respond and it has economic, spatial and social dimensions (ibid). The latter is the focus of this chapter.

Although resilience is generally perceived as having good purpose, some authors have suggested that there are cases in which it is undesirable. Resilience is generally associated with stability, however, this attribute might not always be desirable from an evolutionary perspective (Adger 2000). Mitchell and Harris (2012) assert that the 'dark side of resilience', occurs when it results in the persistence of a negative attribute, the system becomes fixed and less responsive to future threats. This means that in some cases, resilience might result in the system losing its ability to be flexible, or to adjust and be modified in response to harm or a disturbance.

3.4 Adaptation

Adaptation is an important response to global change. This is particularly so because some of the impacts associated with global change are already being experienced. Adaptation is a process, action or outcome in a system that helps the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity (Smit and Wandel 2006). It involves taking the right measures to reduce the negative effects or exploiting the positive ones, by making the appropriate adjustments and changes (UNFCCC 2007). Adaptation is generally meant to cushion against the negative effects of global change. However, it can be an opportunity to meet other developmental objectives. Davis (2011) states that proactive responses can harness opportunities for human development. For example, as noted by South Africa's Department of Environmental Affairs (DEA) that

well planned adaptation responses can be properly linked to sustainable development policies, whereby issues such as unemployment and poverty are addressed simultaneously (DEA 2011).

Adaptation involves cascading decisions across a landscape made up of various agents (Adger et al. 2005). The agents include individuals, households, communities, sectors, regions, and countries. Successful adaptation is dependent on three elements i.e. timely recognition of the need to adapt, an incentive to adapt, and the ability to adapt (Ikeme 2003; Fankhauser et al. 1999). There is a need to understand what types and forms of adaptation are feasible, the stakeholders involved, and what is required to facilitate or encourage their development or adoption (Smit and Skinner 2002). Adaptation involves a variety of measures. For instance, adaptation projects implemented across the world under the Global Environment Facility (GEF) were categorised into 10 categories namely: capacity building, management and planning, practice and behaviour, policy, information, physical infrastructure, warning or observing system, green infrastructure, financing, and technology (Biagini et al. 2014).

Resilience and adaptation are closely related and complementary concepts. However, there is lack of conceptual clarity on their relationship—"whether resilience pertains to an idealised form of adaptation or whether the terms can be used interchangeably" (Bahadur et al. 2010, 19). Similarly, adaptive capacity is an important concept as well. Engle (2011) highlights that adaptive capacity is a mutual thread between vulnerability and resilience frameworks. Adaptive capacity is defined as the ability to plan, prepare for, facilitate and implement adaptation options (Klein et al. 2004). The OECD (2014) defined adaptive capacity as "the ability of a system to adjust, modify or change its characteristics and actions to moderate potential future damage and to take advantage of opportunities, so that it can continue to function without major qualitative changes in function or structural identity". Increasing adaptive capacity helps a system to respond to varying ranges and magnitudes of impacts (Engle 2011). But, having adaptive capacity does not assure that it is used appropriately (Klein et al. 2004).

Despite the fact that many adaptation options have beneficial outcomes, some options may result in unintended consequences. The adoption and implementation of adaptation measures will have local (that is, specific to the project area) effects, as well as non-local or non-target group effects. This can be viewed as the external costs of adaptation measures, since such measures may impact negatively outside of the target area and/or group. This can happen by increasing the vulnerability of the target area/group or other areas/groups. This failed adaptation is termed maladaptation and has been defined by Barnett and O'Neill (2010) as 'action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups'. Due to complexity, it is generally not easy to predetermine whether a particular adaptation will be sustainable or maladaptive (Engle 2011). This is one of the motivations for applying systems thinking to global change, its management and policy planning.

It is not enough to discuss adaptation to global change without dwelling on potential barriers. Identifying such barriers can help to understand the process and

assist in decision-making (Moser and Ekstrom 2010). There are many barriers to adaptation to global change which include the inability of natural systems to adapt; systemic constraints (technological, financial, cognitive and behavioural, and social and cultural); knowledge gaps for adaptation, and impediments to flows of information and knowledge that are critical for appropriate decision making (IPCC 2007).

Perceptions and socio-cognitive factors influence adaptation as they influence the willingness and ability of an individual to take action. How people perceive global change and the associated risks determine how they respond (Steffen et al. 2004). An individual may be aware or unaware of the risk/s posed by global change. In the same vein, an individual might be aware or unaware of the appropriate adaptation action/s required for that risk or those risks. Risk awareness informs risk perception, which if positive can act as a motivation to take action. Béné et al. (2016) found that how people perceived their own ability to deal with risky events influenced the type of response(s) they adopted. Grothman and Patt (2005) stressed[1] that focusing on socio-cognitive indicators (for example, perceived adaptive capacity) helps to make better predictions about future adaptation and vulnerability, and the overall adaptive capacity can be increased by improving the communication of risk and information on possible, efficient and cost-effective adaptation options.

Adaptation can be limited by the values, perceptions, processes and power structures within society (Adger et al. 2009). In that context, gender norms, roles and relations can either enable or constrain adaptive capacities (WHO 2014). Poor and marginalised groups (disabled, elderly, orphans, widows) are generally less resilient and have difficulties in absorbing and recovering from disaster impacts (World Bank 2013). In addition, compared to men, women might have lower mobility and cultural limitations that hinder them from moving away from risk-prone areas or to utilise shelters during extreme events, which is likely to increase their exposure and vulnerability to hazards (ibid).

An important aspect relating to power dynamics is the issue of powerful actors whose interest take precedence over all other important development objectives. The World Bank noted that vested interests prioritise short-term responses over long-term prevention (World Bank 2013). For example, political leaders might be interested in implementing projects that give them huge support from the electorate in the short-term, e.g. distributing food parcels, rather than implementing long-term projects that empower such people to be self-sufficient. In the same context, Mitchell (2013) observed that the politicisation of initiatives can have a negative impact on the execution of projects, especially long-term large infrastructure initiatives that require sustained effort and resources across multiple election cycles. Such initiatives may be discontinued when a new government comes into power.

[1]Models such as the Protection Motivation Theory and Model of Proactive Private Adaptation to Climate change are critical in describing and predicting the process of adaptation.

3.5 Enabling Responses to Global Change

The DEA (2011) asserts that South Africa will adopt the resilience approach to climate change-related extreme events, because resilience enables a holistic approach to disaster management. This view is supported by Erisman et al. (2015) who state that rather than managing many individual risks, resilience should be promoted in responding to adverse events, because it focuses on the whole system and targets long-term security. A resilience systems analysis provides actors with a shared view of the risk landscape; it enables people to have an understanding of the broader system, the key components, attributes, impacts; power dynamics; and it enables the creation of a shared vision of the need to build resilience (OECD 2014). Such a holistic approach is important as it considers various risks and their interaction. It is acknowledged that in certain cases, having an in-depth understanding of a particular risk is essential; nonetheless as greater attention is paid to that particular risk, its relationship with other risks/factors should not be forgotten.

The World Bank (2013) identified three major ways to deal with risks associated with disasters, *viz.* 'retreating' to reduce exposure to the hazard that is, relocating to safer locations, 'protecting' (people and assets) by reducing the hazard risk (for example, through resilient infrastructure), and 'accommodating' that is, active decision to live with the hazard but reducing the vulnerability to it. The option to retreat to safer locations seems to be applicable to hazards that are specific to small areas, however, in the context of global change this might not be appropriate as the associated risks and hazards impact on larger areas making it impossible for the relocation of a large number of people or assets. More relevant options for global risks are protecting the people and assets from the hazard risk, as well as accommodating the risks and hazards and working on reducing vulnerability through adaptation, while reducing future risk through mitigation. In this context, a number of important issues were identified which can help to reduce the risks and impacts from global change, and also enhance adaptation responses to it.

3.5.1 Taking a "Glocal" Approach

Global change implies that the change occurs at the global level, with the effects or impacts manifesting at various levels. While looking at the global, it is vital to also view such impacts at the local level. In other words, zooming in and focusing on the local level will help to reveal the detailed picture that might be obscured by looking at global change as a global phenomenon in the strictest sense. Of importance is to consider local level impacts on communities and marginalised populations. Resilience building entails proactively understanding the risk landscape in each context and for different layers of society (Mitchell 2013), including the perspective of specific stakeholders (WEF 2016b). For instance, using a gender-disaggregated approach might help to understand the impacts of global change on different

groups. This can help in the designing and implementation of appropriate adaptation measures that are inclusive.

Understanding local level impacts of global change requires the use of the 'glocal' approach.[2] This approach helps to understand how the impacts of global change are experienced at the local level, and how these interact with other factors on the ground (Eriksen 2004). There is need to understand the physical projections, as well as, assessing the levels of vulnerability generated by social, economic, and political processes interacting across geographic scales (Eriksen and Kelly 2007). The glocal approach is important as it presents the picture of global change at the global level and within it, inserting a zoomed picture of local level impacts. Erisman et al. (2015) seem to also support the glocal approach by suggesting that in delivering the global risk-network model there should be two shifts. On one hand, the risk narrative has to be reframed by putting the individual at the centre. On the other hand, risk modelling must take a wide focus, which includes both environmental and socioeconomic risks on the whole Earth system. Thus, incorporating risks at the local to the global level and understanding their linkages can help people adopt effective actions that enhance resilience (Erisman et al. 2015).

3.5.2 Information Generation and Dissemination

Information is an important basis for risk management, resilience building and adaptation to global change. Mudombi (2014) observed two serious constraints. First, there can be lack of access to the necessary and complementary information and knowledge on what is happening, what to do, and how to do it. Second, in cases when such information and knowledge are available, action is limited by lack of resources to do what is supposed to be done. The World Bank (2013) suggested that the first step should be to improve the understanding of the risks, and the second step is to develop adaptation options based on that information. Having relevant information and disseminating it in an appropriate way can help to build a positive perception of the risks which is likely to improve people's motivation to adapt.

Effective adaptation planning requires improved observations; improved regional, national and global data, as well as denser networks; the recovery of historical data; building of support among the user communities; and promoting greater collaboration between the providers and users of the information (UNFCCC 2007). Early warning systems are also important sources of the much needed information to respond to various types of global change related risks and hazards. The early warning information should be accurate and timely, and based on relevant data and robust analysis. It is necessary to complement that information by availing

[2]Eriksen (2004) noted that the term 'glocal' has been used particularly in relation to cities (for example, by Brenner 1998); it represents the idea that globalisation takes place through local manifestations and forces on the ground.

supporting tools, technologies and resources needed to undertake the recommended actions.

When stakeholders have a better understanding of the challenges and are equipped with appropriate technical skills, their collaboration can result in optimal sustainable win-win solutions (Mudombi et al. 2017). Taking a multidisciplinary approach that involves natural, social and human disciplines is crucial (Muccione and Schaepman 2014). Therefore, there is need to intensify efforts to transfer the growing knowledge base to various stakeholders, while at the same time empowering the next generation of scientists with the essential skills to undertake Earth System science (Steffen et al. 2004).

A good research base will generate the much needed information to improve people's understanding. The information should be packaged and disseminated in an appropriate format and manner. Research can enhance adaptation by providing more reliable information about the risks and its impacts, as well as developing and testing improved adaptation options and technologies (Fankhauser et al. 1999). Thus, innovation is an important enabler that can facilitate global change adaptation because of the need to formulate as well as adopt new and appropriate technologies and strategies (Mudombi 2014).

Moore et al. (2001) suggested the need for a new system of global environmental science in order to understand global change. This new system should enable greater integration across disciplines, and collaboration within and across national boundaries. There are some examples that have been or are being undertaken in the country. For example, a lot of work is being undertaken by the South African Environmental Observation Network (SAEON), whose responsibilities focus on three mandates namely observation, information and education (SAEON 2009). In addition, the DST has supported a number of programmes, such as the development of the South African Risk and Vulnerability Atlas (SARVA), to bridge the gap between science and policy by improving access to information on impacts and risks associated with global environmental change (Davis 2011).

3.5.3 Relevant and Responsive Institutions

Institutions, institutional arrangements, and institutional capacity are critical in facilitating adaptation. Institutions are the norms and rules that shape human interactions; they can be formal or informal (SRC 2015). Eriksen (2004) highlighted that institutional factors can limit or enhance local capacity to carry out appropriate adaptation measures. The resilience of a social system depends on the institutional rules which govern that system (Adger 2000). Effective institutions and institutional structures can strengthen resilience in a system as well as enhance community cohesion. Ideally, the institutions should be decentralised, flexible, locally appropriate, and facilitate system-wide learning (Bahadur et al. 2010).

Responding to global change requires a new set of institutions or institutional arrangements that are capable of embracing risks in a holistic manner. The impacts

of global change will affect multiple sectors in multiple ways and the current institutional and governance systems are largely sector-based thus limiting how they are able to respond (World Bank 2013). Proper coordination between actors at various levels in the global change space is critical. This should be present at all levels (international, national, regional, community, and household level). Thereby helping to reduce conflicts and duplication of roles, while at the same time building synergies and complementarities as well as ensuring efficient allocation and usage of limited resources. Institutions should be flexible enough to proactively respond to global change, as well as being firm enough to take concrete steps towards building resilience.

Related to the broad institutional framework, is the social capital within a particular community

Social capital relates to social relations among individuals and the norms and social trust they generate which enhances coordination and cooperation for their mutual benefit (SRC 2015). Adger et al. (2007) state that human and social capital are key determinants of adaptive capacity at all levels. Social capital related aspects that can contribute to resilience building include: social cohesion, mechanisms of reciprocity, 'positive' social norms, strong social fabric, local 'good' governance, and the local capacity for collective action (Béné et al. 2016). However, it is not always the case that social capital is beneficial, in some cases it can be a constraint. Hence, the need to understand the various forms of social capital and the conditions under which they enhance people's resilience at different levels (Béné et al. 2016).

3.5.4 Flexibility and Learning

Resilience seeks to enable systems to be capable of learning, self-organising, and adapting to change (Anderies et al. 2013; Folke 2006). Ability to adjust (flexibility) to changing circumstances and timeframes is necessary for adaptation (DEA 2011). Flexibility ensures that the system can adjust appropriately in the face of risk or disturbance. In this regard, the uncertainty, change, non-linearity, randomness of events in a system should be embraced, with the policy shifting from seeking to control change and creating stability, to enabling the capacity of systems to respond to change (Bahadur et al. 2010). The important ingredients for resilience entail "learning to live with change and uncertainty, nurturing diversity, combining different knowledge systems for learning and renewal, and creating opportunities for self-organisation and cross-scale linkages" (GGLN 2014). Learning and experimentation through adaptive and collaborative management allows different types and sources of knowledge to be valued and included in developing solutions (SRC, n.d.).

Learning is critical in terms of ensuring that a system can adopt the good aspects from past experience, while avoiding the bad ones. This also entails learning from the experience of other areas or systems, what can have good results or bad results. While formal learning is necessary, this should be complemented by other forms of learning. This includes promoting conditions that nurture social learning, which is

an essential ingredient in enhancing the adaptive capacity of communities (Mudombi et al. 2017). Social learning can facilitate a shared understanding of the challenge and the recognition of the need and motivation to work together in tackling the challenge (Mudombi et al. 2017).

3.5.5 *Building the Asset Base of Households and Communities*

Assets are an important factor in determining how people respond. Assets include different forms of capital namely human, social, physical, financial, and natural capital. However, it is important to acknowledge that assets by themselves are not sufficient in ensuring resilience. Béné et al. (2016) found that the importance of assets should be understood by making a distinction between response and recovery. In their study, assets appeared to be more important in the recovery process of households affected by shocks and stressors, rather than in the response process. Assets can enable people to have a wider set of livelihood options, which is an important basis of livelihood diversification. Regrettably, in many developing countries, the local population has limited livelihood options which makes it difficult for them to transition to a sustainable future when they have to first meet pressing survival needs (Schlesinger 2006).

3.5.6 *Ownership, Participation, and Stewardship*

Wider participation of various stakeholders is required in order to have their buy-in and support. Broad and well-functioning participation creates trust among stakeholders (SRC, n.d.). Strengthening resilience in vulnerable communities should be bottom-up, taking into cognisance the important role that the affected people can play in strengthening their own resilience and adapting to change. Ziervogel et al. (2017) warn that building resilience in African urban settings should not be based on externally defined pathways and approaches, rather the primary focus should consider the physical and social complexities, as well as the development of critical infrastructure and governance systems necessary and appropriate to the local settings. This brings to the fore the concept of 'negotiated resilience', which is a process of building resilience through considering the interests and needs of diverse groups, including the marginalised (Ziervogel et al. 2017).

Participation, inclusion, and stewardship go hand in hand. Adaptation and sustainability should be prioritised in different aspects of life, in order to ensure good management of the Earth's environment, as well as meeting socioeconomic development objectives. The state can play a crucial role in creating an enabling environment that allows community resilience to flourish (van Donk and Gaidien

2014). At the global level, Moore et al. (2001) highlighted the need for an ethical framework for stewardship and strategies for the management of the Earth system. In order to meet this objective, the stewardship thinking should be entrenched amongst the public, and various stakeholders including both private and public sector leaders.

3.5.7 Enhancing Ecological Infrastructure

Investing in infrastructure, both physical 'hard' infrastructure and other softer forms of infrastructure is necessary for building resilience and supporting adaptation. In this context, ecological infrastructure is very important and in recent times increasing attention is being paid to building and restoring it. Ecological infrastructure can be understood as an interconnected network of natural areas and open spaces that holds valuable natural and biodiversity assets that are necessary for sustainable livelihoods (DEA 2012). This form of infrastructure is important to buffer and minimise the impacts of hazards associated with global change. The ecological infrastructure helps in the provision of various ecosystem services. An example of a programme to strengthen ecological infrastructure is the uMngeni Ecological Infrastructure Partnership (UEIP) in KwaZulu-Natal. The UEIP involves collaboration and partnership between various organisations with the aim of enhancing greater water security through improving and maintaining ecological infrastructure (Colvin et al. 2015).

The World Bank (2013) asserts that ecosystem-based solutions tend to be cost effective and enable flexibility in adapting to changing hazard patterns over time. The benefits go beyond better livelihoods but also entail the maintenance of flora and fauna. In reference to a community in Eden District in Western Cape, South Africa, Nel et al. (2014) noted that the multiple co-benefits of ecosystem management and restoration are significant, for instance, clearing invasive alien trees could reduce the effects of drought, wildfire and flood hazards, while at the same time creating employment.

3.5.8 Forging Partnerships and Collaborations

There is a need to further leverage the participation of a wide range of stakeholders to mutually address global risks, as these are beyond the domain and capacity of just one actor (WEF 2016b). Furthermore, there must be significant reform and renewal in the state in providing leadership, as well as promoting a culture of learning, deliberative and collaborative engagement, and development partnerships (GGLN 2014). Fostering public–private partnerships can assist in harnessing required resources, improving the uptake of a multiscale approach, stimulating innovation from stakeholders and ensuring that the needs of users are at the centre

(Erisman et al. 2015). Partnerships are important not only because they facilitate learning and co-generation of outputs, but also ensure complementarity by bringing actors with similar or different sets of capabilities and combining them to achieve more. For instance, the private sector usually brings more professionalism, better capabilities research and management, and resources, while the local government and civil society have experience, demonstrated impact, better understanding and operational capacity at the local level (Mitchell 2013).

There are efforts to promote partnerships to enhance resilience in some communities in South Africa. For example, Santam (a private insurance company), the Department of Cooperative Governance (CoGTA), and the South African Local Government Association (SALGA) forged a partnership through the Business Adopt-a-Municipality (BAAM) programme. Santam helped in disaster management, improving sustainability, and service delivery in vulnerable municipalities by providing support for fire-fighting, flood and storm water management (Santam 2016). In the initial phase, Santam supported 5 municipalities (four local and one district municipality) across various provinces in the country. The programme was later expanded to 10 district municipalities which comprise of 54 local municipalities (Santam 2016). There are two-way benefits associated with this approach; building the capacity of municipalities helps the municipalities to deal with risk and disasters, which is also beneficial to the insurers as there can be a reduction in insurance claims.

Moore et al. (2001) observed that while new partnerships among academic, industrial and government research institutions are being forged, there is a need to formalise, consolidate and strengthen these initiatives. Collaboration should also be between countries. South Africa in the National Climate Change Response White Paper explicitly stated that cooperation and collaboration is critical to dealing with climate change risks.

> *All states in the Southern African sub-region … often face similar risks due to climate change and may also have similar adaptation needs. South Africa will therefore strive to develop climate change adaptation strategies … in collaboration with its neighbours where appropriate, and seek to share resources, technology and learning to coordinate a regional response. A regional approach that achieves climate resilience will have significant socio-economic benefits for South Africa* (DEA 2011, 16).

3.6 Conclusion

Global change and its associated risks are getting increased attention from various stakeholders across the world. In South Africa, global change is one of the grand challenges that have been enunciated in policy documents. Moreover, significant amounts of resources have been allocated to enhance its understanding, in particular, how it relates to the country and region. Based on the literature review, the chapter explored issues of risk, resilience, and adaptation in the context of global

change. It is evident that terms like ‘resilience’ and ‘adaptation’ mean differently to various stakeholders, however at the core of their meaning they point to desired outcomes in relation to responding to global change. In this discussion, it was also revealed that the scale at which these issues are assessed is important. For instance, the factors that determine resilience, vary at different spatial and temporal scales. Spatial scale is associated with the relationship between local and global contexts, whereas the temporal scale relates to short-term versus long-term dynamics.

Some of the factors that were highlighted as important in promoting resilience and adaptation to global change include: taking a “glocal” approach, promoting information generation and dissemination, enabling relevant and responsive institutions, promoting flexibility and learning, building the asset base of households and communities, promoting stakeholder buy-in and stewardship in programmes, enhancing ecological infrastructure, and forging partnerships and collaborations.

Strides are being made in terms of understanding and responding to global change. However, due to complexity, more effort is still needed to establish and understand several relations between global change processes. Global change science has a lot of work to undertake in a limited time space (Schlesinger 2006), which calls for more multi-disciplinary stakeholder partnerships in order to realise synergies. Adaptation to global change is of paramount importance, hence continued effort should be dedicated to creating awareness and building positive perception of the need to adapt amongst various stakeholders. Proper assessment methodologies should be employed to evaluate various adaptation options before their implementation in order to avoid maladaptation. Global change should be embraced at the local level in the context of multiple stressors that tend to exacerbate vulnerability. Resilience building and adaptation are likely to cushion households, communities and nations from the effects of global change, and it is everyone’s duty to take appropriate action in that regard.

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