Review Article

Climate Change Resilience and Adaptation Strategies in Ecologically Fragile Urban Mining Communities: A Review of Existing Research and Practice

Abstract

The growing concern about the changing climate and the need to document its observed impacts have led to the development of climate adaptation responses globally. Despite being among the world's most vulnerable regions, mining communities have diverse resources and contribute significantly to urban climate. The location of communities near mining activities has not only attracted urban development in most cities but has also provided these communities with a window of opportunity for sustainable livelihoods. However, most research on mines has focused on impacts of mining on the environment with little focus on communities' climate adaptation responses. This review attempts to address this inadequacy in research by exploring factors enhancing community resilience and the adaptation strategies used. The study used an evidence-review strategy involving collection of information from peer-reviewed articles, books, and reports. A total of 213 documents, which included 122 articles, 60 reports and 31 books, were identified with the help of Google Scholar and Web of Science. First, the study observes that although the resilience and adaptive capacity concepts are extensively explored, their meanings still remain unclear due to multiple interpretations. Second, there is little consensus on factors that lead to increased resilience and the variables that should be used to quantify progress in becoming more resilient due to multiple interpretations of the resilience concept. Third, very few studies have been conducted to assess progress in becoming more resilient in most mining communities. Fourth, there also seems to be a challenge in designing vulnerability and resilience assessment frameworks that are methodologically robust, context-specific and relevant to decision-making related to adaptation action. This study recommends a need to conduct more comprehensive studies which clearly explore factors that increase resilience and adaptive capacity and those that suggest clear policy options for mining communities to supplement the rather limited body of literature in this area.

Keywords: Climate change, vulnerability, resilience, adaptive capacity, fragile environments, policy and practice

1.0 Introduction

1.1 Background to the review

Climate change is one of the most significant, persistent and highly dynamic challenges facing society (Birchall and Bonnett, 2020). The United Nations Framework Convention on Climate Change (UNFCCC, 2007) defines climate change as a change in climate which is attributed directly or indirectly to human activity that modifies the composition of the global atmosphere and which, in addition to natural climate variability, is observed over comparable time periods. Scholars agree that the burning of fossil fuels has elevated the concentration of greenhouse gases (GHG) in the atmosphere (Hansen et al., 2012), resulting in a rise in global average temperatures. With GHG emissions reaching unprecedented levels (Rhodes, 2017), subsequent climate impacts are becoming more pronounced. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) also highlights that climate change is still widely recognized as one of the major challenges facing humanity today. Recent scientific evidence also points to the fact that global climatic conditions are changing mostly for the worst (CGIAR, 2012; Marin, 2010). Furthermore, in its Fifth Assessment Report, the IPCC (2014) reflected on the severity of change by stating that the climate system is warming at alarming rates, sea levels are rising, precipitation and weather events are becoming increasingly variable and glaciers are melting rapidly.

Studies have also predicted that the rapid change in climate, especially in ecologically fragile settings, such as extractive industries, is set to alter the delicate balance that exists between man and

nature (Behara and Vaswani, 2007). The writers fear that the poorest communities, who are dependent on nature-based resources, are likely to suffer the most due to their geographic locations, low income and low institutional capacity and their greater reliance on climate-sensitive sectors such as agriculture, where the extent of vulnerability within sectors varies because the communities' adaptability to multiple stresses also differs (Acosta-Michlick and Espaldon, 2008). A recent online blog post by Van Bronkhorst and Bousquet (2021) observed that climate change can create major strains on a society, especially in fragile settings where governments have limited resources to manage crises and help their populations adapt. The writers contend that the adverse consequences associated with climate change, such as water scarcity, crop failure, food insecurity, economic shocks, migration, and displacement, can aggravate disaster risks. Van Bronkhorst and Bousquet's argument is that climate change can act as a threat multiplier, both in the immediate and long term, by intensifying contestation over scarce resources, reducing economic opportunities and social cohesion, and straining public institutions and trust in the state

The growth of the mining industry has had a positive impact on the country's economy although mining in developing countries can either be a treasure or a trouble depending mainly on factors such as institutional stability, economic management and overall management of the sector itself (WB-IFC, 2002). Other studies also point to the fact that mining plays a critical role in the low-carbon transition and the fulfillment of the UN 2030 Agenda (Hund et al., 2020) although it is also a driver of green-house gas emissions through mineral extraction, energy consumption and by contributing to the loss of forest cover (Bebbington et al., 2018). Mining activities are also associated with a broad range of social and environmental risks in producing sites (L`ebre et al., 2020), many of which are likely to be exacerbated by climate change. For instance, extreme weather events and natural hazards can damage infrastructure and lead to the contamination of land and water. Moreover, water availability is likely to decrease as a consequence of climate change, and as mining requires large amounts of water, the companies' reluctance to reduce their water consumption is likely to affect local mining communities' access to water (Phillips, 2016; Odell et al., 2018).

An often neglected fact in countries struggling against poverty is that mining has a significant impact on its immediate surroundings and/or communities (WB-IFC, 2002). To support this argument, studies have found that the extractive industry, by its very nature, has a massive socioecological impact and far-reaching ramifications on both human health and the environment itself if not properly managed (IFC, 2014). Recent studies suggest that the main environmental problems associated with mines in developing countries are usually pollution of air, soil and water, geotechnical issues and land degradation although the contribution from old mining legacy sites have shown to be minor compared to current mining operations (Lindahl, 2014). In Australia, for instance, all mining projects located in sensitive regions must undergo rigorous environmental assessment to ensure the sustainable development of these areas. While the level of assessment does vary from project to project, operators will generally have to demonstrate that their project will either not have a significant impact or, if there will be, that these can be adequately managed (ICMM Report, 2011).

It is also argued that mining is a controversial development sector due to its ecological and social impacts and the perceived non-renewability of the resource being extracted. However, mining provides an opportunity to convert natural capital to financial capital which in turn can be invested to catalyze more diversified growth. If managed properly, there is evidence to suggest that mining can bring benefits to communities and regions which might not otherwise be realized (Ali, 2009). Such a positive trajectory can be particularly transformative in countries which do not have to contend with upscaling limitations of many technologies and market dynamics. Even a small niche market for particular products and service sector enhancement can have a large national impact.

Research on industry perspectives by Ford et al. (2010) found that although climate change is an emerging concern for the mining industry, limited action has been taken to plan for or adapt to prevailing climatic conditions. There is clearly a growing concern about changing weather patterns and climate stability and the effect on the consistency of future food and water supplies. Literature further points to the fact that the mining sector is one of the major emitters of GHGs and furthermore produces fossil energy resources that also significantly contribute to global CO2 emissions. However, despite threats of impending climate change impacts, most research on mine design, planning, and monitoring has focused on the impact of mining activities on the environment and water resources with very little focus on communities' response or adaptation to changing weather patterns (Ford et al., 2010). While climate data are one of the facets that are incorporated within mining projects, the changing weather conditions are

not always considered, and as such, not much action has been taken to plan for or adapt to these changing climatic conditions (IFC, 2014). Furthermore, although the mining sector does seem to be taking action and playing a part in reducing GHG emissions in certain cases, mitigation alone will not solve the problem (IFC, 2014) if it is not accompanied with adaptation to changing environments.

Until recently however, scholars and practitioners have mainly debated climate change adaptation as a policy challenge to be addressed by subnational and national governmental bodies (Dolsak and Prakash, 2018). Scholars and practitioners have reflected on the tools mining companies have at their disposal to enhance adaptation, particularly in developing countries, where they could develop new technologies and work towards innovative solutions together with the state in public-private partnerships (Averchenkova et al., 2016; Nasiritousi et al., 2016). The writers reveal that recently, companies have started to disclose information about their exposure to, impacts on, and responses to climate risks (Goldstein et al., 2019). Scholars and practitioners argue that such actions exemplify an emerging trend of private adaptation, which refers to the process of adjustment by companies to actual or expected climate change and its effects through changes in business strategies, operations, practices, and/or investment decisions (IPCC, 2014). How the private sector, in particular large national and multi-national companies (MNCs), responds to climate risks can have both positive and negative societal consequences (Hannah et al., 2013; UN Global Compact et al., 2015; Averchenkova et al., 2016).

Literature also indicates that although it is increasingly becoming evident that mining communities are likely to be the most severely affected by climate change, they are still among the least equipped to cope and adapt to climate change (IFC, 2014). Furthermore, although mining companies worldwide are pursuing a range of adaptive practices aimed at protecting the value of existing and/or potential assets and creating value through technological innovation and collaborative initiatives (Nelson and Schuchard, 2010), most of these initiatives have focused on physical risks of climate change with no clear understanding of the site-level social risks and opportunities. The study further found that mining companies have not seized the opportunity presented by climate change to collaborate with communities, development agencies, Non-Governmental Organizations (NGOs), and governments on adaptation to enhance their social licenses to operate.

Therefore, while communities around the world are developing adaptation programs, efforts remain largely uncoordinated and inconsistent (Wallace, 2017) because there is often a deficit in local, relevant, and easily accessible research to support the development of adaptation plans (Baker et al., 2012). It is for this reason that the study of climate change and its impacts on natural systems is inadequate in the face of questions about societal capabilities to cope with or adapt to these impacts—their vulnerability, resilience, and adaptive capacity (Jha et al., 2021). Understanding adaptation to climate change is important in order to develop and implement effective adaptation measures which lead to improved adaptive capacity and resilience at the household level. This is critical, as the velocity of current climate change and variability may outpace adaptation in many parts of the world (Adger and Barnett, 2009), unless serious consideration is given to local-level adaptation strategies that increase resilience in the short term and increase adaptive capacity for future impacts. This review paper, therefore, explores a wide range of factors that enhance resilience and the adaptation strategies used by urban mining communities to adapt to impacts of climate change and variability.

1.2 Rationale and aim

This review paper is designed to conduct a detailed review of literature on factors that enhance resilience and the adaptation strategies used by urban mining communities to adapt to environmental conditions which are largely caused by climate change and, to some extent, by the mines. The review also explores the status of vulnerability in urban mining communities in order to provide baseline information that can guide adaptation strategies and practices. The review specifically focuses on evidence and practice around community resilience, adaptation strategies used and the capacity to adapt to impacts of climate change in environments which are deemed ecologically fragile. The review examines the following key issues: the status of vulnerability and its relationship with resilience; the meaning of community resilience and adaptive capacity and how the terms are used in research, policy and practice; key factors that support the development of resilience in urban mining communities; the nature of emerging practice and how this can be enhanced in different contexts; how policy and practice support the development of greater local resilience in mining communities; and the roles of different stakeholders in supporting this cause.

Results of this review are expected to enhance awareness on the progress of resilience and the adaptation strategies used by fragile urban mining communities to adapt to existing harsh environmental conditions. The results will show which adaptation strategies provide more resilience and therefore, deserve further attention by planners and policy makers in the adaptation action. They are also aimed at contributing additional information to the existing body of literature in this area. This review paper is organized as follows: the methods are explained in the next section. This is followed by the results section, which includes an overview of literature, a bibliographic analysis and a detailed results of literature review on vulnerability, resilience, adaptation and adaptive capacity. Finally, the review paper wraps it up with the section on discussion and conclusion which highlights a detailed discussion of results, gaps in literature and their implications and finally the conclusion.

2.0 Methodology

This review paper employed a cross sectional design, utilizing document reviews covering local and international contexts. In order to identify existing literature available elsewhere in the area of climate change resilience, adaptation and adaptive capacity, efforts were made to trace as many documents as possible such as articles, books and reports. Keywords such as 'climate change vulnerability,' 'resilience,' 'adaptation,' 'adaptive capacity,' and 'mining and climate change,' were used to search the documents and findings recorded. Documents were then searched manually for information relevant to emerging issues of climate change resilience and adaptation in ecologically fragile urban mining communities.

Thus, a qualitative literature review was conducted, which involved collection of relevant information from peer-reviewed articles, book publications and reports. A total of 213 documents, which included 122 articles, 60 reports and 31 books and other gray literature were identified with the help of mainly Google Scholar web search engine and included in the review (see Figure 1). The review focused on a detailed literature search on factors that enhance resilience and the adaptation strategies used by mining communities to adapt to impacts of climate change. The thematic synthesis of documents collected resulted in a wide-ranging array of findings and gaps among scholars relating to climate change resilience and the capacity of mining communities to adapt to climate change impacts.

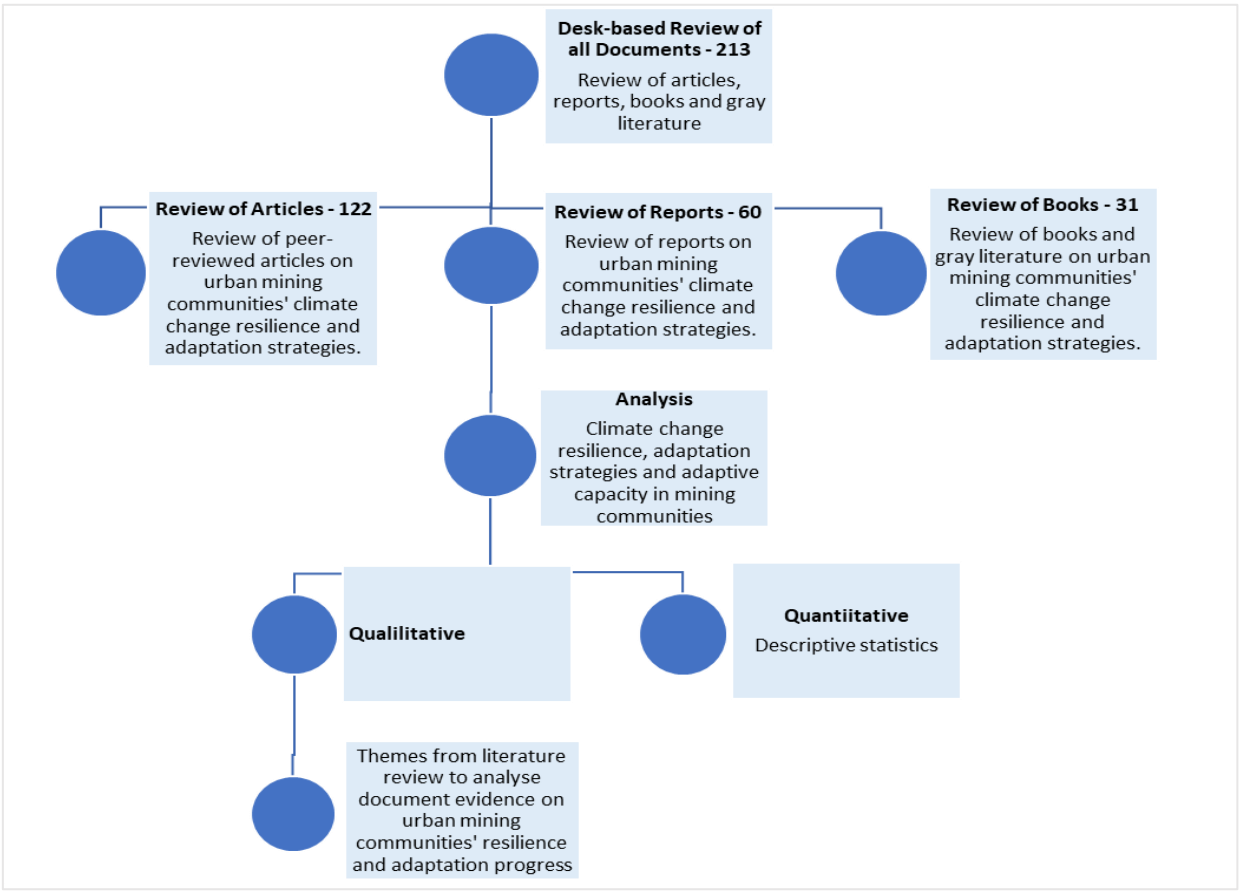

Figure 1: Data selection and review process

The initial search was conducted in October 2021 using Google Scholar search engine. The abstracts and conclusions of the retrieved documents were checked and papers dealing with climate change resilience, adaptation strategies and adaptive capacity especially in fragile urban communities were selected for in-depth analysis. While reviewing the selected papers, it was also found necessary to include other relevant terms such as mining and climate change adaptation in urban communities in the search string. Therefore, an updated literature search including those terms was conducted later in November 2021. The abstracts and conclusions of the newly added documents were also checked and documents that dealt with resilience, adaptation strategies in mining communities were selected for review.

During the review process, the alert functions of Google Scholar and Web of Science were also activated to include recently published papers in the same area. Other relevant information on adaptation measures and responses in mining companies and local communities was collected through detailed content analysis of the selected papers. The author also took advantage of being a member of the research gate and from time to time asked for permission from the research gate members to download and use some of their published works in the area of climate change resilience and adaptation.

3.0 Results

3.1 Overview of the literature

In this section, the author offers results from the literature reviewed. He first focuses on contextualizing vulnerability in order to provide baseline information that can guide adaptation strategies and practice. Then the author moves on to present resilience, factors that characterize it and the existing resilience policy and practice. Adaptation and factors that characterize it are presented next followed by adaptation response using community-based adaptation (CBA) approaches as well as response from mining companies. The author finally presents adaptive capacity, its characterizing factors and measures used for assessing it.

The reviewed papers can be divided into four broad categories in terms of their focus on climate change vulnerability, resilience, adaptation strategies and adaptive capacity. The majority of papers reviewed are focused on both resilience and adaptation in other fragile urban communities while only a few are focused on resilience and adaptation response from mining communities. In terms of document type, the majority of the analyzed documents are research papers, a few review papers, and the rest are book publications and reports. As regards to research methods, the author shares views with Sharifi (2020) that three major categories can be distinguished. These are social science methods, science and engineering methods, and economic methods. The commonly used social science methods include literature review, content analysis, qualitative case study, grounded participatory research, and questionnaire and a few in science and engineering methods. From the papers reviewed, it seems obvious that the social science methods are dominant, followed by science and engineering methods.

3.2 Bibliographic analysis

The graph below (Figure 2) shows the number of papers identified and selected for review by focusing on the year of publication.

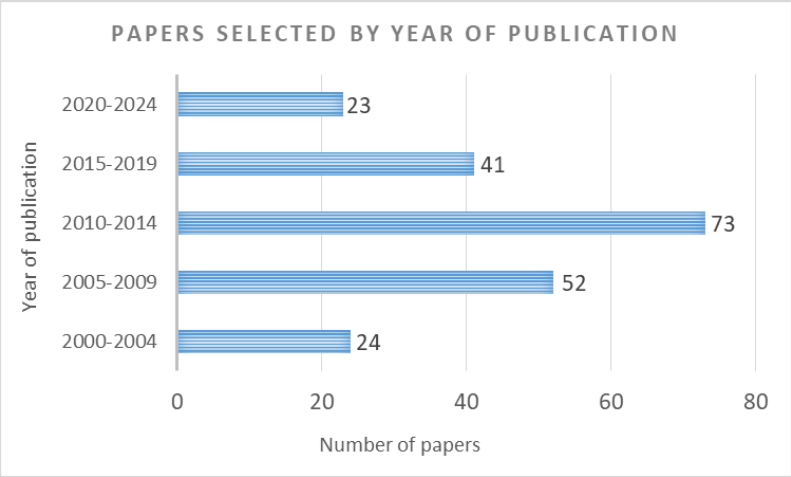

Figure 2 showing number of selected papers by year of publication

Figure 2 indicates that 24 of the papers reviewed were published between 2000 and 2004 while 52 were published between 2005 and 2009. The bulk of reviewed papers adding to 73 were published between 2010 and 2014 while 41 were published between 2015 and 2019. The rest of the 23 papers reviewed were published from 2020 going forward. Thus, the trend shows that the majority of papers reviewed were published at least within the last ten years or so.

The next graph (Figure 3) shows the distribution of selected papers for review by focusing on keywords or themes.

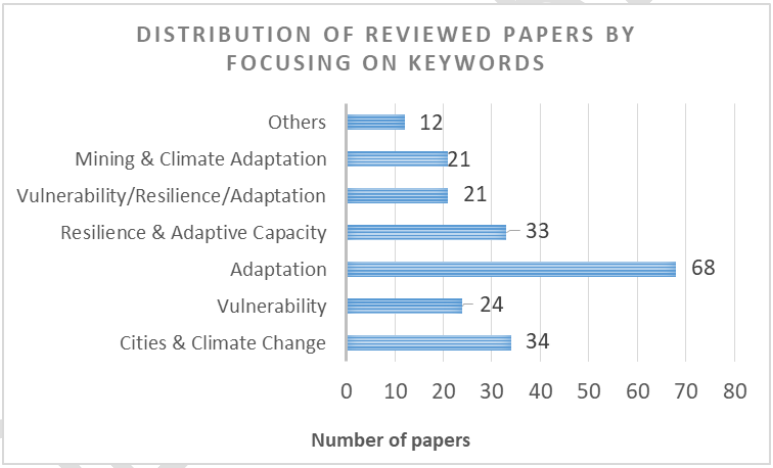

Figure 3 showing distribution of selected papers by keywords

Figure 3 indicates that reviewed papers focusing on cities and climate change were 34 while those on vulnerability were 24. Papers focusing on adaptation topped the list with 68 while those on resilience and adaptive capacity were 33. Papers which had a combination of vulnerability, resilience and adaptation themes were 21 while those focusing on mining and adaptation were 21. The rest of the papers (others) were 12. Thus, the trend shows that the majority of papers reviewed were those focusing on adaptation and resilience while those focusing on mining and adaptation and other themes were the least.

3.3 Climate change vulnerability

3.3.1 Contextualizing vulnerability

Understanding climate change vulnerability as one of the central concepts for this study is of paramount importance. Thus, according to the fourth assessment report of the IPCC (2007), climate change vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. In this definition, vulnerability is seen to be a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. Between the 2001 and 2014 IPCC reports, the

definition of vulnerability has remained the same except that the word 'or' is substituted by 'and' in the first part of the definition in 2007 report. This has been in order that 'sensitivity' and 'lack of adaptability' are considered as co-factors of vulnerability and not as its alternative definitions (Füssel and Klein, 2006). Therefore, a vulnerability assessment based on this definition considers indicators representing exposure, sensitivity and adaptive capacity.

In other studies, vulnerability was represented by a suite of human-ecological factors that reflected exposure (climate stress on households), sensitivity (degree to which a system is exposed), and adaptive capacity (internal/external capacity to cope) (Jha et al., 2021). In this perspective, effective baseline assessment of a socioecological system deals with its capacity to restore or recover from non-structural change; a dimension not included in vulnerability assessments. Likewise, resilience (the capacity of a complex system to remain within a regime in the face of external perturbations and/or internal change), was considered together with vulnerability (Jha et al., 2021). Studies have shown that these definitions of vulnerability and adaptive capacity focus on the damage done by the physical system, which can be quantified in terms of lives lost, land flooded, crops destroyed, species lost, and so on. Similarly, adaptive capacity is treated as a functional term, its function being to reduce the impact of climate change. Thus, vulnerability is in effect a residual term referring to what is left when exposure plus-sensitivity is reduced by adaptive capacity (Malone, 2009).

Therefore, determining appropriate adaptive responses requires ongoing assessment of a community's vulnerability and its capacity to adapt (Birchall and MacDonald, 2020). All the three factors of vulnerability (character, magnitude and rate of climate change and variation) form the equation, which is the rate and degree of climate change, sensitivity and adaptive capacity. Birchall and MacDonald observe that for southern Africa, all the three factors form an alarming picture with overwhelming evidence to suggest that the impact for the sub-region will be acute. These concepts have migrated from the field's food security and disaster risk reduction. Therefore, in recent decades, vulnerability has emerged as a central concept in research into climate change most likely because there has been an increase in climate change-related incidences and activities (Ragab and Prudhomme, 2002).

Previous research indicates that vulnerability to climate change is not solely determined by climate impacts only; it is also largely subject to various non-climate-related elements, including socioeconomic factors, demographic shifts and trends, and resource accessibility (Baker et al., 2012). In developing countries, pressure on land due to rapid urbanization often leads to development of vulnerable spaces such as flood-prone areas, with the poorest of the population living in these locations. Rosenzweig et al. (2011) add that climate change impacts tend to have a greater effect on vulnerable populations such as the elderly or those with low income. Inequities among socioeconomic groups are projected to become even more pronounced as climate change progresses.

Poverty, gender, ethnicity, and age have all been documented as factors that affect vulnerability of urban populations to climate hazards (Tyler and Moench, 2012). The writers argue that these social elements, when combined with the physical processes of climate change impacts, can lead to various, potentially poorly understood, secondary effects such as displacement of vulnerable populations (Carter et al., 2015). Moreover, the IPCC (2014) observes that populations that do not have the resources to adapt to climate change impacts will experience higher exposure to extreme weather events. This is particularly true for low-income populations in developing countries and also remote locations such as the Arctic. The Arctic communities are often located in isolated areas with limited seasonal accessibility and experience greater social, health, and economic disparities, compared to communities in more populated regions. These disparities, along with a strong dependence on the environment, make Arctic communities especially vulnerable to climate change impacts (Larsen et al., 2014).

A study conducted by Jha et al. (2017) found that the vulnerability of socioecological systems is often an outcome of natural disasters and of over-exploitation or unsustainable utilization of available resources. Thus an impact on one component of an ecosystem also alters the stability of associated or interdependent components (Obrist, 2006). Overall, disturbances in socioecological systems lead to poverty, marginalization, and exclusion (Barnett, 2001) and also alter the flow of services (Parmesan and Yohe, 2003). An ability to cope with disturbances is considered to be a critical element in the continuous evolution of resource use patterns and human settlements (Jha et al., 2017). However, additional anthropogenic pressure on resources upsets the natural balance (FAO, 2002) and creates vulnerability in the socioecological system (Pandey and Jha, 2011).

Therefore, Dumaru (2010) argue that analyzing climate change vulnerability involves identifying both the threat and the resilience or responsiveness in exploiting opportunities, and in resisting or

recovering from the negative effects of a changing environment. This focus on vulnerability and resilience can enhance other development areas; providing a framework for studying long-term climate change and greater levels of uncertainty. They say, for example, that a community-based adaptation (CBA) pilot-project on Druadrua Island, Fiji, showcased how climate change adaptation was integrated into an existing community structure where participatory decision-making had led to responses to observed climatic changes. Regrettably, not all these responses were sustainable and the pilot-project highlighted how vulnerability and resilience analysis can identify and prevent maladaptive practices as well as reveal new long-term strategies. Eriksen and Naess (2003) have also identified three examples of groups of factors that influence vulnerability as indicated in Table 1.

Table 1 showing examples of factors that influence climate change vulnerability

Category	**Examples**
Institutional factors	Informal skills, local knowledge, formal education, skills and technology, informal networks, formal security networks, strength of local institutions
Economic factors	Labor, health, access to natural resources, access to communal natural resources e.g. biodiversity, access to alternative economic opportunities
Environmental factors	Risky environments, degraded environments, high dependence on climate-sensitive sectors and natural resources, communal lands and resources

Source: Eriksen and Næss, 2003

However, literature reviews that information on vulnerability assessments of socioecological systems is highly diverse because of the numerous quantitative and qualitative approaches and contexts of these assessments. For instance, Luers et al. (2003) and Tonmoy et al. (2014) argue that since climate vulnerability is a theoretical concept, it cannot be estimated as can physical phenomena such as mass, energy and temperature. Therefore, some scholars (Hinkel, 2011) suggest that the quantification of vulnerability should not be spoken of in terms of 'measurement'. Nevertheless, because of the need to integrate knowledge of climate change vulnerability in decision-making and planning, the processes that generate vulnerability need to be understood and therefore 'measured' in some sense (Luers et al., 2003).

3.3.2 Linking vulnerability to resilience

Climate change adaptation aims at decreasing vulnerability and strengthening resilience to impacts of climate change. For this reason, the relationship between vulnerability and resilience requires clarification. Resilience is often defined as the antonym or flip side of vulnerability (Adger, 2000; IPCC, 2001), while some scholars like Gallopin (2006) object that the opposite or flip side of vulnerability goes beyond resilience and could best be described with the term robustness. However, both vulnerability and resilience are determined by the response of a system to hazard exposure, thus referring to internal properties of a system, and to the interaction of changes within the system (Gallopin, 2006; Miller et al., 2010). Therefore, resilience is nonetheless closely related to vulnerability, as highly vulnerable communities dispose of poor adaptive capacity and are likely to be less resilient. For this reason, although vulnerability and resilience will not be understood as perfect opposites, they will still be considered to be located on different ends of a spectrum that describes a state's relationship to exposure to perturbations (Nett, 2015).

The conceptual links between vulnerability and resilience are explained by Gallopin (2006) using socioecological systems. These domains differ in conceptual structure, and resilience is only weakly correlated with vulnerability (Janssen et al., 2006). Therefore, attempts have been made to assess vulnerability together with resilience of socioecological systems and establish the relationships between them. Exposure, as one of the three dimensions of vulnerability, is the potential impact of climate change (Ebi et al., 2006) and is almost equal for a system and for vulnerability or resilience. It is the beginning, start-point, or initial stage of vulnerability. The impact of exposure relies on its scale, system sensitivity, and adaptive capacity. Sensitivity is "degree of exposure" (IPCC, 2007), and it varies at spatial and temporal scale because it is an internal phenomenon (Pandey and Jha, 2011).

Pandey and Jha (2011) contend that sensitivity is also a non-separable part of resilience and it is an important dimension used for assessment of resilience. They say a sensitive system has lower capacity to

restore itself, that is, weaker resilience. For example, torrential rainfall may increase the sensitivity of soil to erosion and also reduce its capacity to restore itself to its previous state. However, Pandey and Jha also argue that the resilience of a system is not completely explained by these dimensions of vulnerability (exposure, sensitivity, and adaptive capacity). Therefore, in the present study, resilience was considered to be a function of exposure, sensitivity, and restorative capacity. Restorative capacity being a set of indicators that explain the capacity to absorb changes, restore system components, and bring the system back to its previous condition.

Therefore, in addition to considering the ability to cope with disturbances to be a critical element in the continuous evolution of resource use patterns and human settlements (Jha et al., 2017), resilience and adaptive capacity together have also been found to provide a framework that links biophysical climate sensitivity to socioeconomic factors that mitigate or amplify the consequences of environmental changes (Malone, 2009). Studies have shown that a resilient community is well-placed to manage hazards to minimize their effects and/or to recover quickly from any negative impacts (CARE International, 2009) while a high adaptive capacity reduces the vulnerability of communities to environmental change and promotes their resilience to transition with environmental changes (ACCRA, 2010). It is further argued that understanding the causes of vulnerability will support analysis of policy options to address its underlying causes rather than just its symptoms while understanding the concepts of resilience and adaptive capacity will provide guidance on where to direct resources to build on existing strengths or open new areas of support (EEA, 2012; 2017).

Twigger-Ross et al. (2015) give a clear distinction between vulnerability and resilience by stating that resilience is about drawing on and building capacities and should not reproduce social vulnerabilities while resilience, as 'bounce-back' in the context of shocks, is not enough for longer-term management of climate change. They argue that vulnerability is a function of the exposure and sensitivity of a system and that it is the pre-event, inherent characteristics or qualities of social systems that create the potential for harm. Resilience, on the other hand, is the ability of a social system to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as 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). Twigger-Ross et al. (2015) recognize that social vulnerability of communities to effects of climate change is not just the opposite of resilience. The writers argue that a lack of national strategy to build community resilience to climate change makes it less likely that areas of climate vulnerability are prioritized and targeted. They further argue that the most vulnerable areas may be the least likely to develop community-led resilience actions, which could lead to future problems if they are hit by the consequences of climate change.

Therefore, due to the multitude of definitions of both vulnerability and resilience, their mutual relationship is highly debated. A practical approach is to understand resilience and vulnerability as two distinct but overlapping concepts with a negative correlation. This means that systems with high resilience usually exhibit low vulnerability and vice versa (Welle et al., 2014). A report by Twigger-Ross et al. (2015) reviews that the scarcity of evaluations and different framings of issues mean that understanding the key drivers of community resilience to climate change is not straightforward although evidence seems to point to the importance of 1) framing agendas broadly to incorporate actions that address a community's wider priorities and that cultivate skills, understanding and ownership of responses to climate change; 2) existing capacities within a community to inform action on climate change resilience; 3) support from the community and voluntary organisations to act as intermediaries to provide guidance and stepping stones for forming a new partnership aimed at developing community climate change resilience, and supporting skills and knowledge exchange (Twigger-Ross et al., 2015).

3.4 Climate change resilience

3.4.1 Understanding resilience

In order to assess, quantify and monitor climate resilience in practice, a better understanding and clear definition of the term is needed. Different scholars and organisations have defined resilience in slightly different but similar ways. For instance, CARE International (2009: 6) has defined resilience as "*the ability of a community to resist, absorb, and recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity*." Mitchell (2013) defines climate resilience as the ability of socioecological systems to absorb and recover from climatic shocks and stresses, whilst positively adapting and transforming their structures and means for living in

the face of long-term change and uncertainty. USAID further defines resilience as "*the ability of people, households, communities, countries and systems to mitigate, adapt to and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth*" (Sagara, 2018: 1). These definitions all describe the relationship between three elements that form the basis of a resilience measurement framework, which are resilience capacities, shocks and stresses, and well-being of communities or sociological systems.

However, resilience as a word has a long history with diverse and complex meanings (Wilson, 2012 in Steiner and Markantoni, 2014; Olsson et al., 2015). In the socio-ecological systems context, it is seen by interdisciplinary scientists as the ability of human communities to withstand external shocks or distresses to their infrastructure, such as environmental variability or social, economic or political upheaval, and to recover from such perturbations (Olsson et al., 2015). Walker, et al. (2004) further contend that the concept of resilience has evolved considerably over time although different interpretations of what is meant by resilience still cause misunderstanding. The writers argue that the resilience of a system needs to be considered in terms of the attributes that govern the system's dynamics and three related attributes of socioecological systems (resilience, adaptability and transformability) determine their future trajectories. They say that resilience has four components namely latitude, resistance, precariousness, and Panarchy. Walker et al add that adaptability is the capacity of actors in the system to influence resilience while transformability is the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable. The work of Sagara (2018) observes that resilience has emerged as a way to understand and address the increasing complexity and magnitude of risk in humanitarian and development contexts. Yet, the ability to develop strategies and programs that increase resilience requires robust measurement and analysis methods. Against this backdrop, Welle et al. (2014), reports that a practice-oriented explanation of central pillars of resilience has been adopted. These pillars constitute the basis for assessing and monitoring climate resilience.

From the foregoing definitions and explanation, Mitchell (2013) underscores the fact that climate resilience is therefore a combination of absorptive, adaptive and transformative capacities, which can be delineated according to the responses to climatic shocks and stresses they facilitate. These are:

- *Absorptive capacity*: the ability of a system to prepare for, mitigate or recover from the impacts of negative events using predetermined coping responses in order to preserve and restore essential basic structures and functions (e.g. human life, housing, productive assets) (Béné et al., 2012, Cutter et al., 2008). Examples include early warning systems, savings, weather insurance schemes, trained disaster risk reduction teams, dyke systems in flood-prone areas (climate hazard-specific).
- *Adaptive capacity*: the ability of a system to adjust, modify or change its characteristics and actions in order to better respond to existing and anticipated future climatic shocks and stresses and to take advantage of opportunities (Béné et al., 2012, Brooks, 2003, IPCC, 2012). Examples may include adjusted planting behavior, climate change-related information and education events, improved natural resource management, diversification of early warning systems to reach a broader network of actors.
- *Transformative capacity*: the ability of a system to fundamentally change its characteristics and actions when the existing conditions become untenable in the face of climatic shocks and stresses (Béné et al., 2012; Walker et al., 2004). Examples may include livelihood transformation (e.g. from rice farmer to shrimp farmer), migration from rural to urban areas, change from fossil energy system to renewable energies.

Welle et al. (2014) contends that although differentiating the three capacities is useful for analytical purposes, in reality they fall along a continuum and jointly facilitate different types of responses that range from a low to a high degree of structural change. The writers argue that climate resilience depends on the combination of these capacities as different types and intensities of climatic shocks and stresses require different responses. Thus a social-ecological system with a high level of absorptive capacity but virtually inexistent adaptive and transformative capacities cannot be regarded as resilient. An example for such a system would be a farmer's village, whose inhabitants have weather insurance schemes in place but are not able or willing to adjust their planting behavior or diversify their sources of income despite persistent and increasing water scarcity.

Literature further indicates that a resilient community is well-placed to manage hazards to minimize their effects and/or to recover quickly from any negative impacts, resulting in a similar or improved state

as compared to before the hazard occurred. There are strong linkages between resilience and adaptive capacity; consequently, resilience also varies greatly for different groups within a community (CARE International, 2009). The writers argue that resilience can take the form of social resilience, which includes social networks, social capital, and institutional support, or economic resilience, which includes access to financial assistance, available infrastructure and access to technologies, and livelihood diversification. Pelling (2010) adds that the development and support of these facets can assist communities to cope during environmental upheavals and to recover from climate shocks. He says that while adaptation enhances resilience, it can also extend beyond this form of system maintenance to include elements of transition as well as transformation.

Resilience is applied very differently in various disciplines. From a climate change perspective, an integrated social-ecological understanding of resilience is most appropriate. Following this line of thought, our environment is constituted by social-ecological systems, which encompass five main dimensions: a social, ecological, economic, physical and institutional dimension. The concept of resilience considers systems on various levels as well as the interdependencies between these systems. Moreover, it regards risk, uncertainty and change as normal features of every social-ecological system (Welle et al., 2014). The writers argue that in the broadest sense, resilience can be understood as the ability of a socioecological system to deal with shocks and stresses. This ability depends on the capacities to absorb, adapt to and transform in the face of stressors threatening the system. Hence, it does not only include the responsive capacity to already known threats but also considers innovation, learning and anticipation to be prepared for projected impacts of a changing climate. Resilience possesses major commonalities with the concept of vulnerability. However, there is no consensus yet on the exact relationship between the two terms.

Although often used in the context of adaptation, the resilience perspective is not confined to the impacts of climate change. To the contrary, it considers a broad variety of disturbances (e.g. political or economic crises, violent conflicts, geophysical extreme events) as well as their effects on social-ecological systems. 'Climate resilience' is thus a specific form of resilience, namely the ability to deal with climatic shocks and stresses (Welle et al., 2014). However, other scholars like (Adger, 2000; Adger et al., 2001; Gunderson and Holling, 2001) argue that although the concept of resilience is most commonly used in the study of ecosystem dynamics, it can also be applied to social systems, social-ecological systems and the study of global change.

It is clear from the forgoing that the term resilience means different things to different people. Thus, in everyday language, the term resilience may be used simply as a noun to mean 'the ability of a substance or object to spring back into shape; the capacity to recover quickly from difficulties'. However, from a theoretical perspective, there are significant and important variations in how the term is understood. The new, or in some cases, renewed interest in the term is the result of a number of processes. The term is seen to be a useful unifying concept; an umbrella term under which many communities of practice, disciplines and policy realms can relate to one another. Bahadur et al. (2010) argues that one of the most useful mappings of the term comes from outlining sixteen different conceptualizations of resilience ranging from the psychological, social and ecological to the economic. Bahadur et al confess that this is not simply an academic exercise as there has been little attempt to scrutinize the literature to examine how it might underpin an operational approach to resilience. They say that what can be seen is the adoption of a term that is varied and, in some cases, loosely defined. Perhaps more worryingly is the observation that there is also often a lack of awareness that such diversity of interpretation exists. This has real significance when it comes to operationalizing the term as different understandings lead to different notions of the components, characteristics and indicators of resilient systems.

3.4.2 Community resilience factors and measurement

A study by Anokye and Asuah (2016) observed that the unavailability of universally agreed resilience measurement tool makes the concept problematic and subjective (Steiner and Markantoni, 2014; Kulig et al., 2008) in that variables used by some authors are seen as outcome processes by some authors. Thus, situational and case-specific variables are highly useful for measurements. Additionally, the differentiation in a set of cultural, locational and policy context makes the direct application of the normative perspectives inappropriate because local settings and socio-economic characteristics are essential in obtaining desired results (Steiner and Markantoni, 2014). As a result, a mixed-method

analytical framework is required (Steiner and Markantoni, 2014, Magis, 2010). The study borrowed the three resilience variables (local ownership of resources; residents' organizational capacities; and local institutional capacity to respond to change) used by Matarrita-Cascante and Trejos (2013) as a framework for measurement because the study measured similar objectives in a different contextual setting.

Justifying the need for the chosen variables for measurement is the fact that the study was interested in measuring the ability of mining communities in Obuasi 'to cope with, and recover after' (Olsson et al., 2015; Steiner and Markantoni, 2014) the on-going stress or better still to thrive in this time of change and uncertainty (Magis, 2010). Local ownership of resources places the community in a better condition in the light of changing circumstances (Matarrita-Cascante and Trejos, 2013) because local ownership facilitates economic benefits such as increased multiplier effect, reduced leakages (Adger et al., 2005) and non-economic benefits such as increased control/power over decision-making, pride, sense of inclusion, and responsibility. The importance of citizen involvement in community decision-making is much highlighted in literature (Matarrita-Cascante and Trejos, 2013). Such participation ensures the mobilization of resources towards problem-solving (Magis, 2010).

Organizational capacity, particularly in the context of resource dependent communities, is critical given the contribution which local knowledge and citizen input provide when designing and implementing strategies/policies that define natural resource usage, control, and distribution (Matarrita-Cascante and Trejos, 2013). In the views of Kulig, et al. (2008), the presence of leaders and supporters or thinkers and doers; visionary leaders; access to resources and others with influence who are community-minded, enthusiastic, creative, determined, and knowledgeable about local resources and their interdependencies, are characteristics identified as leading to resilience at the community level. These, in addition to institutional adaptability, are critical for the community to receive economic and non-economic benefits, given how regulations and policies can define/redefine resource access, control, and usage and, thus, potentially mitigate the impacts of change (Kulig et al., 2008; Matarrita-Cascante and Trejos, 2013).

Previous research has also shown that due to the complexity and multiple interpretations of resilience theory, however, there is still no consensus on factors leading to climate resilience and variables that should be used in order to assess and quantify progress in becoming more resilient. However, the vulnerability-resilience indicators model (VRIM) (Moss et al., 2001; Brenkert and Malone, 2005; Malone and Brenkert, 2008) identifies 17 factors (as listed in Table 2) that together assess the resilience of a society. The model represents both managed and unmanaged land, economic activities that are natural resource intensive, and socioeconomic characteristics. The VRIM model has been used to compare 160 countries (Moss et al. 2001, Malone and Brenkert in press a), to evaluate adaptive capacity at temperature increases of 1.5°C and 4.5°C (Yohe et al., 2006a, b), to analyze India and Indian states under current conditions (Brenkert and Malone, 2005) and future scenarios (Malone and Brenkert, 2008), and to examine resilience in Mexico and Mexican states (Ibarrarán et al).

Table 2 showing sectors and variables used in the Vulnerability-Resilience Indicators Model (VRIM)

Sectoral Indicators	**Proxy Variables**	**Proxy For**
Food security	Cereals production/crop land area	Degree of modernization in the agriculture sector; access of farmers to inputs to buffer against climate change and variability
	Protein consumption/capita	Access of a population to agricultural markets and other mechanisms (e.g. consumption shift) to compensate for shortfalls in production
Water resource sensitivity	Renewable supply and inflow of water	Supply of water from internal renewable resources and inflow from rivers divided by withdrawals to meet current or projected needs
Settlement/ infrastructure sensitivity	Population at flood risk from sea level rise	Potential extent of disruptions from sea level rises
	Population without access to clean water	Access of a population to basic services to buffer against climate change and variability
	Population without access to sanitation	

Human health sensitivity	Completed fertility	Composite of conditions that affect human health including nutrition, exposure to disease risk and access to health services
	Life expectancy	
Ecosystem sensitivity	Percent of land managed	Degree of human intrusion into the natural landscape and land fragmentation
	Fertilizer use/cropland area	Nitrogen/phosphorus loading of ecosystems and stresses from pollution
Human and civic resources	Dependency ratio	Social and economic resources available for adaptation after meeting other present needs
	Literacy	Human capital and adaptability of labor force
Economic capacity	GDP (market)/capita	Distribution of access to markets, technology, and other resources useful for adaptation
	An income equity measure	Realization of the potential contribution of all people

Source: Brenkert and Malone, 2005

3.4.3 Resilience in mining communities

As alluded to in the previous section, the concept of resilience is one that has been developed around managing and responding to community crises. Resilient communities are those that can absorb and/or adapt quickly to change and crisis. Callaghan and Colton (2008) argue that ultimately the success of building a sustainable and resilient community depends on strong leadership, vision, and clear and open communication. In the same vein, the Community Conservation Resilience Alliance Initiative (CCRAI) (2020) of Chile reports that the communities' resilience and their ability to continue managing and conserving their local environment could be significantly enhanced by policies designed to empower them by promoting self-determination, strengthening cultures and reviving traditional ways of relating to nature. They argue that ecosystem recovery, forest regeneration and sustainable agriculture are key priorities. CCRAI emphasizes the importance of strengthening institutions that evaluate and monitor environmental impacts. The report also suggests that local energy generation projects should be developed in collaboration with communities, supporting them with financial resources and institutions, and taking advantage of the communities' existing decision-making structures. These projects will benefit from communities' interest in participating in projects that will help to resolve their own problems.

A study conducted by Nasdian et al. (2020), using an emic and etic approach to explore community resilience and food insecurity due to ecological changes and the impact of mining policies and activities on community resilience of the mining area and food vulnerability in South Kalimantan, found that the pattern of community resilience in the two communities is in the form of social movements as a form of social adaptation, and agricultural land recovery and changing agricultural commodities as a form of ecological adaptation. The process of community resilience in the two communities is at the level of recovery towards a stable community condition, not yet at the transformation stage. Community capability is the most influential factor on the degree of community resilience so that the handling of food insecurity based on community resilience needs to be done by developing strategies to increase community capability.

Another study by Kanakis (2018), on mining community resilience, reviews that the sustainability of mining communities is subject to many factors such as economic market trends and the longevity of the resource being mined (Black, 2005). Callaghan and Colton (2008) argues that sustainable development requires consideration of the actions needed at a local level that contribute to or hinder sustainability. Kanakis (2018)'s study concluded that factors that influence general community wellbeing reflected the six forms of community capital and highlighted the interconnected relationships between the different forms of community capital. The study indicates that social capital components played a key role in resident's perceptions of the community's wellbeing. Mining activity was perceived to have various impacts on mining communities. Although participants reported positive impacts, they more consistently identified negative impacts on community wellbeing from mining activity. Again, social capital components were recognized as playing a key role in residents' perceptions of the mining industry and the negative impacts of mining activity. Due to these reports of social capital components being a

key determinant of community wellbeing, the study has suggested that these factors need to be considered within sustainable community development approaches.

Pfefferbaum et al. (2013)'s study used the communities advancing resilience toolkit (CART) as a publicly available theory-based and evidence-informed community intervention designed to enhance community resilience by bringing stakeholders together to address community issues in a process that includes assessment, feedback, planning, and action. Tools used include a field-tested community resilience survey and other assessment and analytical instruments. The CART process encouraged public engagement in problem-solving and the development and use of local assets to address community needs. The CART process recognized four interrelated domains that contributed to community resilience and these are connection and caring, resources, transformative potential, and disaster management. The study observed that the primary value of CART is its contribution to community participation, communication, self-awareness, cooperation, and critical reflection and its ability to stimulate analysis, collaboration, skill building, resource sharing, and purposeful action.

A study by Kuir-Ayius (2016), on building community resilience in mine impacted communities in Papua New Guinea, investigated relevant models of community resilience from the literature, and how policy functions could be related to these models. The study also developed a way of quantifying the impact of mining on health service delivery (through the use of community capitals) and the building of resilience in these communities. The analysis showed inconsistencies in the levels of resilience in these communities that varied with the stages of mining. Both the beginning and post- mine closure stages demonstrated significantly lower levels of community resilience than the operational phase. Findings from the research indicated a lack of access to health services - a key influence in building resilience – as the result of a range of factors which included insufficient finances, weak sector governance, and the need for infrastructure and transport.

Matlaba et al. (2021)'s study, on resilience perception of a mining town in eastern Amazonia, used theories as a conceptual orientation for the development of a resilience scale to measure resilience at the community level in the context of large-scale mining. This approach allowed the evaluation of resilience perception using 26 interview statements derived from six resilience theories. The multivariate analysis found that the level of residents' perception of resilience was reasonable. The interviewees pointed out one positive and five negative factors that influenced the level of resilience to be moderate but could have been improved with more economic diversification and infrastructure, and less inequality in access to services and participation in decision-making. The most considered relevant themes were problems caused by mining in the municipality, quality of life issues dealing with change after the arrival of mining, and economic problems.

Another study by Wasylycia-Leis et al. (2014) revealed that despite recent efforts by government to regulate the industry, the mine continues to generate press and pulse disturbances that impact the resilience of the community. Operating from the view that resilience depends largely on the management capacity of stakeholders, the study identified three ways to improve mining governance in Itabira. First, they observed that there is a need for local government to have more power in dealings with the corporation. Concurrent with this power, however, the municipality must demonstrate ownership over its fate ideally through the creation of a sustainability plan. Finally, all key parties must demonstrate commitment to cooperation to resolve outstanding disturbances, even when these fall outside the regulatory approval process. The study observed that while Itabira will remain a mining town for the foreseeable future, actions taken now to address challenges will only strengthen community wellbeing and sustainability moving forward.

3.4.4 Resilience policy and practice

As illustrated in the previous sections, the term resilience has been used in various different guises in academic disciplines for the past few decades and has gained increased traction in policy circles throughout the late noughties. Many programs seeking to build climate and disaster resilience provide effective illustrations of the resilience concept (Nelson, Adger and Brown, 2007; Ensor, 2011). With the increased understanding of the links between disaster risk and climate change, there has been a concerted effort to invest in integrating different approaches which will contribute towards building resilience. This has taken many different forms: mainstreaming disaster risk reduction into development programs; the convergence of climate change adaptation and disaster risk reduction; and the reframing of development through a climate lens. A recent example of an approach aimed at contributing towards building

resilience is the climate smart disaster risk management (CSDRM), which brings together climate change, disaster risk management and development. At the policy level, the United Kingdom (UK)'s humanitarian emergency response review (HERR, 2011) and DfID's response to the review (DfID, 2011) provide useful examples. Despite the inclusion of the term in these and many other important policy and program documents, it is still largely being worked out what resilience means in practice. It remains to be seen to what extent the potentially unifying term will result in significant changes in approach, policy and practice.

Key to addressing climate change is competent, capable, and accountable urban governments that incorporate adaptation measures in a holistic manner (Satterthwaite, 2008). Satterthwaite says many measures require only minor adjustments to current practices such as building codes, land subdivision regulation, land-use management and infrastructure standards - and the sum of these over time can build resilience without high costs. Building policies can help increase energy efficiency, and waste policies can reduce CO2 emissions. Greater transparency, accountability, participation and inclusion should accompany such policies to ensure good governance for adaptation (Tanner et al., 2009).

Shocks and stresses are experienced and interact with one another differently in different contexts. Thus, it is necessary that any attempt to understand what a resilient system looks like is as context-specific as possible. This includes, amongst other things: being historically grounded; taking into consideration the political economy of a given context; considering the role of natural resources and natural resource management in local livelihood systems; taking into consideration the critical role of people's perceptions and values of climate change adaptation (Adger, Lorenzoni and O'Brien, 2009); different perceptions of risk; the role of formal and informal governance mechanisms at different levels; understanding the conflict dynamics at play; the role of indigenous/traditional/local coping mechanisms; and the role of culture in disaster risk (Harris, 2011).

Adopting the position that integrated policies and programmes is a way to operationalize the characteristics of resilience provides a means to explore the value of existing programmes which have sought to bring together a variety of sectors and approaches. Despite there being a lack of rigorous empirical research on resilience in practice from the development sector, as Bahadur et al (2010: 19) correctly point out, "*we are not starting from scratch if we invest in rethinking the way we understand current interventions*". Just because something is packaged within a particular sector, or designed to address a particular shock or stress, does not mean that an intervention may not also be having positive (or negative) contributions to building resilience (Jones et al., 2010).

Zambia's National Climate Change Response Strategy (NCCRS) (2010) identifies agriculture, food security, fisheries, water, forestry, wildlife, health, mining, tourism, human settlements, and physical infrastructure as priority sectors for adaptation based on their economic vulnerability and national development priorities. Priority projects presented in the NCCRS and National Adaptation Programme of Action (NAPA) (2007) include improving the Zambia Meteorological Department (ZMD)'s early warning system to facilitate timely dissemination of weather information so as to enhance preparedness; promoting better land and critical habitat management; diversifying crops and livestock to improve nutrition and food security; promoting alternative sources of livelihood to reduce vulnerability to climate change and vulnerability; enhancing water management to withstand erratic rains through water harvesting, water conservation, and small-scale irrigation; renovating and rehabilitating existing health infrastructure; and climate-proofing sanitation in urban areas (GRZ-NAPA, 2007; GRZ-NCCRS, 2010).

A project by the Network of African Science Academies (NASAC, 2015) recommended the following as some of the adaptation options or measures, as shown in Table 3, which can also be used by both government and local communities.

Table 3 showing adaptation options recommended by NASAC (2015)

Adaptation options/measures
• Enhancement of infrastructural safety (building of flexible flood defense structures);
• Increased water storage in dams;
• Promotion of rainwater harvesting;
• Increasing irrigation efficiencies both off-field and in-field by reducing canal losses, promotion of drip irrigation and appropriate water scheduling;
• Rehabilitation of degraded areas to enhance base flows and reduce storm flows;
• Re-use and recycling of water;

• Development of early warning weather and flood systems;
• Conservation structures on agricultural land;
• Clearing of alien invasive plants in riparian zones;
• Enhanced reservoir operating rules;
• Heeding indigenous coping mechanisms;
• Remapping flood-lines;
• Promotion of resilient and sustainable ecosystems through ecosystem-based management and integrated watershed management, including water demand management;
• Development of drought–tolerant crops; and
• Promotion of agro- forestry practice

Source: NASCA, 2015: 14

Priority challenges and constraints for addressing vulnerability and increasing resilience data, research, and capacity needs include carrying out climate change data collection and monitoring; improving training for policymakers and other relevant stakeholders on tools for developing climate scenarios and analyzing vulnerability; improving inter-ministerial and inter-institutional coordination to facilitate implementation and mainstreaming of cross-cutting environmental and climate change programs, plans, and policies; increasing public awareness on climate change and its potential impacts on social and economic development, livelihoods, and ecosystems; and developing clear and specific legal and policy frameworks for climate change to help direct adaptation planning (GRZ-NCCRS, 2010).

Studies emphasizing governance and institutions represent a branch of work on urban resilience. This literature focuses on questions of how different types of institutional arrangements affect the resilience of local environments and how resilience thinking can influence the development of improved governance mechanisms for promoting adaptation to climate change, such as new types of social contracts and CBA efforts (Avis, 2016). The writer further says governance studies have also considered how resilience principles such as adaptive management can be used to promote sustainability in highly developed coastal zones and which characteristics of urban governance can enhance climate resilience while at the same time reducing vulnerability of urban citizens who are most at risk to climate-related shocks and stress. Some of the many characteristics of urban governance that are identified as promoting resilience include: polycentricity, transparency and accountability, flexibility, and inclusiveness. But rather than prescribing a single, 'best practice' arrangement, the governance literature advocates a diversity of approaches, suggesting that effective institutional arrangements take many different forms.

Twigger-Ross et al. (2015) reports that the policy focus in the UK currently is in relation to community resilience to climate change is generally on direct shocks due to extreme weather events, rather than longer-term stresses, leading to an emphasis on emergency planning and the role of the community linked to other institutions in supporting responses. This emphasizes a predominantly reactive approach. Other areas of policy are directed towards tackling indirect shocks and stresses relating to climate change, but they are framed as climate change mitigation rather than as supporting community resilience.

3.5 Climate change adaptation

3.5.1 Understanding adaptation

The IPCC (2014) defines adaptation as "*the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects*,". McCarthy et al. (2001) describe climate change adaptation as actions targeted at the vulnerable system in response to actual or expected climate stimuli or their effects with the objective of moderating harm from climate change or exploiting opportunities. The writers argue that climate change adaptation is an urgent, yet insufficiently funded priority for poor communities who are already exposed to existing climatic and non-climatic stresses. The key societal response options for reducing climate change-related risks are mitigation and adaptation to climate change (McCarthy et al., 2001). However, our interest, in this review paper, is in responses pertaining to climate change adaptation and community resilience to socioecological impacts of climate change.

Literature reviews that adaptation is not a new phenomenon as historically, societies repeatedly adapted to climate fluctuations and associated environmental changes through migration, changes in agricultural practices, and modifications to shelter. Communities in southern Africa have always adapted to variations in climate by making preparations based on their resources and their traditional knowledge accumulated through experience of past weather patterns (Armitage and Plummer, 2010). They have also reacted to and recovered from climate extremes, such as floods, droughts and hurricanes. However, because climate change poses new threats and new uncertainties, communities' past experience alone can no longer provide a reliable guide to the future (Armitage and Plummer, 2010). Furthermore, while African farmers have developed several adaptation options to cope with current climate variability, it is expected that such adaptation will not be sufficient for future changes of climate (IPCC, 2007). This realization led to the need to develop climate change adaptation approaches that are in sync with present realities and that are also 'forward looking'. It is for this reason, therefore, that a focus on communities' response to changing weather patterns and climatic conditions requires a thorough understanding of the concept of adaptation.

It is argued that probably the largest body of literature on how societies deal with climate change is in the fields of history and archaeology (McIntosh et al., 2000). It is further argued that while the adaptation concepts are known to have developed from the UNFCCC processes around the early 1990s, the concepts are said to have become more prominent in the vocabulary of international climate change negotiations since the Marrakech Accords in 2001 (Eguavoen et al., 2015). The decision not to embrace adaptation as a feasible policy option was based on the fear that pursuing adaptation measures would probably paralyze the political will, within the international community, to reduce greenhouse gases (Schipper and Burton, 2009). Nevertheless, the central argument that later helped turn the tide in favor of adaptation was the scientific report of the IPCC 2, which observed that actually climate change was already happening globally.

Smit and Wandel (2006) argue that the concept of adaptation reoccurs throughout a diverse range of fields; both within the natural and social sciences. In particular, anthropology, ecology and natural hazards have developed substantial literatures with the last two demonstrating the greatest influence on climate change research. These dual literatures offer different readings of adaptation, which at times, have led to a contradiction within the climate change community. Smit and Wandel say that within the field of ecology, adaptation is framed within biophysical ecological change with a focus on flows of matter, energy and information and related concepts of resilience, equilibrium and adaptive management. In contrast, natural hazards focus on perception, adjustment and the management of environmental threats. Perhaps the most widespread application is borrowed from disaster risk reduction whereby individuals and households are shaped and constrained by social, political and economic forces, which determine their adaptive capacity to shocks and stresses (Klein et al., 2003; Schipper and Burton, 2008). Following from this, research into climate change adaptation aims to 1) decrease *vulnerability*, 2) increase *resilience* to climate change impacts, and 3) increase *capacity* to cope with climate change impacts (Schipper and Burton, 2008).

Birchall and Bonnett (2020)'s study reveals that the contested nature of adaptation in practice is further demonstrated through the challenge of defining its basic goals. One goal of adaptation is to increase adaptive capacity or the ability to respond effectively to changing stresses and shocks in order to manage or reduce risk (Engle, 2011). A second goal is to increase resilience or the ability of a social or ecological system to continue functioning when confronted with shock and stress (Nelson et al., 2010). A third goal is to reduce vulnerability or the susceptibility to harm when exposed to an external hazard (Yamin et al., 2005). The origins of these three goals come from a variety of disciplines such as ecology, human geography, sustainability science, risk management, and development, and have converged under the umbrella of adaptation research (Goldman et al., 2018). Often, as Smit and Wandel (2006) explain, these adaptation goals are interconnected. A system with more capacity to adapt should be less vulnerable to harm, thereby more resilient and able to cope when faced with risk. Residents of the Pacific Islands, for instance, have strengthened their adaptive capacity and reduced vulnerability by developing systems to share resources and labor, which has helped communities prepare for and recover from drought and cyclones (de Coninck et al., 2018).

Increasingly, however, adaptation is viewed as more inductive in nature, rooted in the existing coping strategies of communities and individuals to risk (Huq and Reid, 2007). Such a view of adaptation is less fatalistic, focusing on autonomous adaptation at the micro level and building bottom-up solutions. As it is often said, adaptation policies need not start from scratch. People have been managing or failing

to manage climate hazards for centuries; a reality that forms the starting point for approaches such as community vulnerability and resilience frameworks and local adaptive capacity (Prowse and Scott, 2008). This evolution of climate change adaptation also challenges the traditional planned and/or autonomous distinction of adaptation. In the 1990s, planned adaptation generally referred to government interventions by way of laws and programmes; while autonomous adaptation was viewed as spontaneous household and community actions.

CBA attempts to tackle the traditional two-track definition of adaptation to support a holistic view of climate change adaptation. Following from this evolution of adaptation, the development community has become an important partner for the climate change community; lending knowledge and expertise based upon past lessons. Indeed, the goals of the climate and development communities often overlap as unsustainable development is not only the underlying cause of climate change, but development pathways determine the degree to which populations are vulnerable to a changing climate (Huq et al., 2006). A study by Singh et al (2021) reviews that cities are at the forefront of climate action as never before. They argue that cities concentrate risk but also provide opportunities to innovate. Situated at the crossroads of extensive urbanization, unequal development, and high climate vulnerability, Indian cities, for example, face an urgent imperative to adapt to current and projected climate change impacts. While a global assessment of urban adaptation found no examples of municipal government adaptation being reported (Araos et al., 2016), Indian cities are increasingly reporting various planned and autonomous actions that have adaptation co-benefits.

A study by Jiri et al. (2017) found that farmers traditionally adapted to climate risk by diversifying across crops and risk management options. Farmers generally diversified their production systems by using activities that were less sensitive to drought and/or temperature stresses and activities that took full advantage of beneficial climatic conditions. For example, farmers planned their planting and inputs based on their best estimates of the cropping season, and they reduced risk exposure by diversifying their livelihoods. Jiri et al. further found that farmers diversified their cropping practices using a mix of crop species both in space and time, growing different cultivars at different sowing dates and farm plots, combining less-productive drought-resistant cultivars with high-yielding but water-sensitive crops. Nevertheless, the writers admit that managing droughts effectively in vulnerable areas requires diversifying livelihood strategies and income generating options within and outside agriculture, especially into income generating options through non-farm enterprises and employment opportunities.

A study by Gustafsson et al. (2021) found that although the majority of the mining companies respond to climate risks, significant gaps remain when it comes to involving and ensuring that communities benefit from such initiatives. The study suggests that these shortcomings are at least partially due to weak government and civil society pressures that would compel companies to address climate risks in a way that would help to improve societal resilience. The study further found that mining activities place immense pressure on water supplies and livelihood assets, and contaminate the environment (Bebbington and Bury, 2009; L`ebre et al., 2020), and these impacts are likely to be exacerbated by climate change. The writers argue that such "intersecting impacts" have, however, largely been overlooked in scholarly and policy debates about mining governance (Odell et al., 2018). The study recommends the importance of enhancing community participation in the design and implementation of private adaptation in order to avoid inequitable consequences of private adaptation initiatives. The study further suggests that there is a need for systematic analyses of the concrete impacts of private adaptation strategies on local communities, both in the context of mining and in other issue areas.

However, there seems to be little consensus on what counts as effective adaptation in practice. One reason is that initiatives are often proposed and planned but rarely implemented (Bierbaum et al., 2013; Mimura et al., 2014). Barriers that routinely impede adaptation efforts include insufficient resources, prohibitive policies, competing or conflicting priorities for action, and uncertainty about future changes (Moser and Ekstrom, 2010; Biesbroek et al., 2013). Adaptation efforts are shaped by unique and localized combinations of underlying contexts, such as politics, funding, motivation, power dynamics, and cultural values. Initiatives embedded in the context of one community can produce different outcomes in another. Finally, it can be difficult to distinguish climate adaptation from related activities, such as reducing risk to environmental disasters or alleviating poverty, which complicates attribution of successful adaptation efforts. The IPCC, for example, claims that incorporating climate adaptation into sustainable development strategies will result in win-win solutions (Roy et al., 2018). While efforts to mainstream climate adaptation may appear efficient, actions that address present development issues may

conflict with actions that address future climatic risks or vice versa (Barnett and O'Neill, 2010; Roy et al., 2018). These factors make it difficult to disentangle a simple understanding of adaptation in practice.

Nevertheless, a study by Owen (2020) outlines the complexities and challenges of defining adaptation, outlining its objectives, and demonstrating progress toward meeting those goals. The plurality of overlapping frameworks, contexts, and definitions can be overwhelming. But, as Schipper and Langston (2015) emphasize, these complexities should not lead to paralysis of action. Researchers and practitioners can work with the multiplicities inherent to adaptation by making their assumptions, values, and notions of progress explicit and balancing those conceptions with other ways of knowing and understanding. This paper takes stock of adaptation initiatives in practice and presents a snapshot of how effectiveness this has been documented. My analysis offer clarity on what constitutes current adaptation practices, presents categories of effectiveness, and identifies emerging research gaps.

3.5.2 Adaptation measures and effectiveness

In view of this, Owen (2020)'s study outlines a number of indicators of adaptation effectiveness which are based on improvements in resilience, vulnerability, capacity, and/or preparedness, in one or more of the following ways: (a) reducing risk to climate change impacts; (b) enhancing social relationships and community well-being; (c) improving ecosystem health, environmental quality, and natural resources; (d) increasing people's income and access to economic resources; and (e) strengthening institutional connections, influencing policies, and improving governance practices. More than three-quarters of cases revealed effectiveness across multiple indicators. Some case studies showed indicators of effectiveness using quantitative measures and others used qualitative descriptions of improvement. I counted both types of indicators equally.

Owen (2020)'s study observed that about 60.9% of cases demonstrated effectiveness by reducing risk to climate change impacts. He says indicators of risk reduction involved addressing vulnerability to potential climate hazards. Activities that regularly demonstrated risk reduction dealt with availability of water resources by building new reservoirs and irrigation systems, using water more efficiently, and implementing rainwater harvesting. In China, for example, Li et al. (2018) showed that subsidies from the Beijing government for water reservoirs and storage helped farmers reduce their exposure to drought. Another frequent set of risk reduction activities involved investing in information and communication technologies, knowledge sharing platforms, and early warning systems. Eakin et al. (2015) demonstrated that an early warning system in Chile alerted potato producers to protect their crops from potential pest hazards and disease outbreak. This technology had several positive effects including reducing the risk of potato blight.

Owen (2020)'study further found that slightly more than half of the case studies demonstrated enhancements in social relationships and community wellbeing (53.6%). He says indicators included increased cooperation, sharing resources, or improved access to resources associated with human wellbeing like food, water, land, and shelter. For example, in Pakistan, Sterrett (2011) demonstrated how structural adaptations increased food security for 50 village households, increased access to safe drinking water, reduced women's workloads, and decreased the number of lives lost during a cyclone. Adaptations that Sterrett highlighted included enlarging water reservoirs, installing solar-powered water pumps, establishing a plant nursery, and building an emergency shelter. Cooperative development practices and financial incentives also played substantial roles in improving social relationships. In Bolivia, local agricultural cooperatives provided farmers access to informational and physical resources to help them shift from monoculture farming to agroforestry involving cocoa trees (Jacobi et al., 2013). This adaptation created better working conditions (e.g., working in shaded conditions and reduced exposure to chemical fertilizers and pesticides) and led to increased levels of self-organization among farmers who established an extension and agricultural education service.

Improving ecosystem health, environmental quality, and natural resources was also documented in approximately half of the cases (52.7 percent) (Owen, 2020). He says indicators of effectiveness included halting land degradation, improving soil and water quality, restoring ecosystem functions, and increasing biodiversity. Unsurprisingly, ecosystem-based adaptations and policies were most common in addressing environmental issues, such as erosion control, environmental restoration and conservation, adaptive management, and fisheries management. Ryan and Elsner (2016) showed that sand dams, a type of rainwater harvesting system, helped vegetation recover more quickly after periods of drought in Kenya. Another case explained how a fishery on the western coast of the United States implemented co-

management procedures that reduced the risk of overfishing seven ground fish species, as demonstrated by rising population numbers (Lubchenco et al., 2016).

Increasing people's income and access to economic resources was described in 44.5 percent of the activities (Owen, 2020). He asserts that changes to agricultural, aqua cultural, or livestock practices and livelihood diversification frequently led to economic benefits. In Brazil, a community-based fishing management structure was implemented in two aquatic reserves in the Amazon Basin. Freshwater fish populations more than doubled, leading to increased household income in surrounding communities over a period of five years (Oviedo et al., 2015). In the Philippines, Furoc-Paelmo et al. (2018) showed how the introduction of a rubber-based agroforestry system increased household income in two farming areas. Part of the success stemmed from farmers' membership in organizations that helped them access credit, discounts on goods, and insurance.

Strengthening institutional connections, influencing policies and improving governance practices was reported least often (39.1 percent) (Owen, 2020). He says indicators of effectiveness included the creation of new partnerships, improved institutional relationships, conflict resolution, increased local participation and autonomy, and changed governmental structures. Activities in this category relied on collaboration between people from different institutional and cultural backgrounds, such as developing user-friendly decision support tools, building an information network across organizations, or implementing CBNRMS. A co-management approach to mangrove restoration in Vietnam led to formal recognition of local resource users who negotiated an agreement to secure land use and protection rights (Schmitt et al., 2013). In St. Vincent and the Grenadines, a network of institutions and community organizers was strengthened through efforts to fund and build a solar-powered desalination plant to increase local freshwater availability and future water security (Jaja et al., 2017).

3.5.3 Adaptation response using CBA

Wijaya and Luthfi (2021) argue that having a spatial planning model and developing urban physical aspects adaptive to climate change disasters is not enough. It takes the readiness of the human aspect; how urban communities adapt to climate change disasters that are detrimental to their socio-economic life. CBA, a term often used to describe the range of social, cultural, environmental, political, and economic contexts that increase vulnerability and increase community resilience to climate change and other stressors, provides many benefits. The writers suggest that urban communities need to be encouraged to be more adaptive and responsive because they are the ones who are badly affected by climate change disasters, especially the lower middle class. CBA can encourage social capital and build community resilience to climate change and other stresses. Studies on urban adaptation to climate change are still ongoing, and the current issue is building the capacity of local communities to internalize adaptation into societal values and norms.

CBA is a form of adaptation that aims to reduce the risks of climate change to the world's poorest people by involving them in the practices and planning of adaptation. It adds to current approaches to adaptation by emphasizing the social, political, and economic drivers of vulnerability, and by highlighting the needs of vulnerable people. Chishakwe et al. (2012) add that CBA is a bottom-up approach that places the community at the centre of determining how to respond to the impacts of climate change. CBA emphasizes community participation that builds on the priorities, knowledge and capacities of local people. These include aspects relating to the development and transfer of technology to improve adaptive capability and the ascertainment of community vulnerability through assessments of risks that communities face, amongst many others. The writers say, as a development-related concept, CBA is a relatively new approach that is still evolving. CBA can utilize the opportunities and experiences provided by non-climate initiatives that have enabled these communities to deal with other stresses, and in so doing, have established capacity, institutions and models for communities to deal with a range of stresses with minimum outside support. In southern Africa, community-based natural resource management (CBNRM) has used an incentive-led approach to revolutionize conservation and development by devolving responsibility.

CBA evolved from the merger of climate change and development to put community first for climate change adaptation. It is a bottom-up approach whereby the community is the subject of projects including competence development and technology transfer; and also the main entity to implement adaptation (Sekine et al., 2009). CBA uses participatory approaches to harvest existing local knowledge and coping strategies as well as identify new adaptive measures (Prowse and Scott, 2008). In this way,

vulnerability and resilience assessments not only address scientific knowledge of the impacts of climate change but also diverse factors such as poverty, social capital and indigenous knowledge (Sekine et al., 2009). CBA advocates adaptive decision-making in light of climate uncertainty. As explained by Bharwani et al. (2005), this shift 'addresses the need to support strategic and operational decision-making on climate risk management and adaptation. Key concepts are the need to reduce decision uncertainty, the value of climate information and understanding actual decision processes'.

CBA tackles the traditional top-down adaptation approach. Agrawal et al. (2009) cite that 85 percent of all priority projects as identified by the National Adaptation Programs of Action (NAPAs) pay little to no attention to local institutions. CBA targets local communities and institutions, ideally with the aim of feeding into higher-levels; a goal realized with varying degrees of success within CBNRM. Many adaptation projects and interventions will fall short if they cannot address all the underlying determinants of vulnerability such as proprietorship and institutional assess and CBNRM offers a blueprint for such change. Furthermore, CBA puts poverty-reduction and empowerment at its core with the goal to enable communities to take action themselves based upon their own decision-making processes. While CBA is a relatively new approach, it is based on certain established principles borrowed from other development fields (Huq and Reid, 2007):

- Outside agencies must gain the trust of communities through immersion in the field and through using brokers and intermediaries (such as local NGOs or community groups);
- Possible future adaptation initiatives must be embedded in communities' existing knowledge of climate variability, and must be based on community members' participation;
- That CBA is a form of action research, and can only be learnt through practice.

The defining characteristic of CBA is that the researcher is not the teacher but the student. It is crucial that CBA is community-driven and voluntary rather than treating the community as simply the recipient. There also must be trust amongst residents, outside networks and government to ensure the community accepts the knowledge and support offered. This is especially true for climate change adaptation where benefits may only be witnessed over a long term period. As explained by Sekine et al. (2009) for residents in developing countries, the introduction of technologies that do not bring about short-term benefits tends to be recognized as a risk. To avoid such a situation, trust in the local government and trust within the community, amongst others, are indispensable. Moreover, the community defines its own vulnerability and resilience after scientific information is provided. In this way, CBA combines scientific projections from climate change models, seasonal forecasts, remote-sensing, and satellite pictures alongside local, indigenous knowledge about trends and patterns experienced by communities (Reid et al., 2010). This is especially relevant for areas where there is limited historical data about climate trends and where local knowledge can inform regional scientific studies.

There are many studies and reports that demonstrate the accuracy of indigenous climate knowledge (Reid et al., 2009). Of course, co-learning is essential. Whilst communities can chart changes in their local environment, there may exist little knowledge of the global causes and effects of climate change. CBA often employs co-learning approaches, drawing on both local and external scientific knowledge about climate change, explained in the first language of the community and in a way they can assimilate (Reid et al., 2009). The use of forecasting for agriculture or Disaster Risk Reduction, in particular, first requires trust in the forecasts based upon the accuracy and pay-offs of different strategies; taking many years to gradually shift practices (Bharwani et al., 2005). Reid et al. (2009) have identified 11 examples of participatory tools used by CBA approaches as shown in Table 4.

Table 4 showing examples of participatory tools used by CBAs

Participatory Tools	**Uses**
Mental models	• Drivers and effects of climate change
Seasonal calendars	• Seasonality and links with livelihoods can be combined with timelines to show perceived changes in seasonality
Timelines	• Hazards and events trends in climate (i.e. temperature and rainfall)
Community mapping and modeling	• Resources • Types and causes of risks and threats • Extent of vulnerable areas

	• Vulnerable households and individuals • Planning DRR/CC adaptation measures
Transect walks	• Vulnerability/risks • Land-use • Resources
Ranking	• Vulnerabilities and hazards • Coping and DRR strategies (i.e. water management options, crop varieties)
Dream maps and drawings	• Vision of community or farm and how to achieve measures
Theatre, poems and songs	• Awareness raising of risks and risk reduction measures • Advocacy
Participatory videos	• Awareness raising • Farmer to farmer communication • Advocacy
Stakeholder analysis	• Institutions, relationships, power
Key informant discussions	• In-depth discussion of vulnerability • Livelihood sources

Source: Reid et al., 2009

3.5.4 Adaptation response from mining companies

Communities in the vicinity of mines or production sites are often under pressure from multiple stressors, with mining being one stressor among several. For example, most of Zambia's Copperbelt mines operate in areas characterized by high social inequality, food insecurity and water stress. The local communities are often dissatisfied with poor basic services and infrastructure in the region. In addition, these local communities report that they suffer from environmental impacts such as noise, air pollution and water contamination caused by mining operations and have experienced resettlements. Climate change can act as a risk multiplier in such contexts meaning that it can exacerbate already existing social and/or environmental impacts and increase the risks of tensions and conflicts between the mine owners and the communities. For instance, increasing water stress linked to climate change could intensify competition over water between the mines and the local communities in the future if nothing is done.

A study by Gustafsson et al. (2021) identifies three main types of adaptation responses to climate risks which are institutional, infrastructural, and community-oriented responses. Of these activities, community-oriented responses have so far received little attention among researchers and practitioners. The writers classify community-oriented responses to climate risks into activities that primarily or partially aim at improving community resilience. Such responses can support communities to develop agricultural practices to mitigate climate vulnerability and risk, or to set up irrigation system or water storage infrastructure to enable communities to get continued access to water (Sovacool and Linn´er, 2016). There is a growing awareness that community-oriented responses are necessary to ensure that private adaptation actions do not harm local communities (UN Global Compact et al., 2015). This is perhaps the more reason why most of large transnational companies, mostly in the mining sector, engage in some sort of corporate social responsibility (CSR) projects that could be expected to increasingly focus on improving community resilience as climate risks become more pressing (Gustafsson, 2018; Haslam, 2021).

Eriksen et al. (2021) reveal that in respect of community-oriented responses, 26 percent of the companies report that they carry out adaptation initiatives that primarily or partially seek to enhance the adaptive capacity of local communities. However, rather than having a systematic strategy, companies often report isolated cases of CSR projects aimed at enhancing community resilience. When asked about the need to consider the climate impacts on local communities as an integrated strategy, most company representatives emphasized that if companies enhanced their own climate resilience, this would automatically have positive impacts on host communities. Eriksen et al. further say even if company representatives claim that their adaptation initiatives have a positive impact on the community because they reduce the risks, companies still disregard the well-known trade-offs and risks for unintended consequences associated with adaptation interventions. Taken together, the document and interview data

combined suggest that companies have started to address the impacts of climate change on their operations, but that responses do not typically address the vulnerabilities of local communities.

One of the most important concerns for local communities is access to water. Therefore, a more meaningful way of disclosing information and involving stakeholders is represented by the integration of climate risks in existing participatory water management initiatives (UN Global Compact et al., 2015). For instance, South 32 created a community climate action model (CCAM) to manage water consumption in a transparent and participatory manner in Colombia. Other companies report similar initiatives (Kunz et al., 2017). Through these processes, local communities could provide information about their needs, assess corporate strategies, and reach agreements with companies about how to share scarce water resources. However, as Odell (2021) also argues, while such collaborative initiatives may create opportunities for community influence, such close interactions with companies might also lead to internal conflicts and fragmentation among local communities. In short, while the majority of the companies have started to identify risks to core businesses activities, accountability and information disclosure to and involvement of local communities tends to be weak.

One of Gustafsson et al. (2021)'s study findings raise important questions about the societal consequences of private adaptation. Our data suggest that companies adapt to climate risks in order to strengthen business resilience, while taking little responsibility to improve societal resilience. This has implications for affected communities and underlines the importance of further considering how private adaptation interventions affect climate vulnerability (Dolsak and Prakash, 2018; Eriksen et al. 2021; Purdon and Thornton, 2019; Sovacool and Linnér, 2016), not the least in the mining sector. Mining activities place immense pressure on water supplies and livelihood assets, and contaminate the environment (Bebbington and Bury, 2009; L`ebre et al., 2020), and these impacts are likely to be exacerbated by climate change. Such intersecting impacts have, however, largely been overlooked in scholarly and policy debates about mining governance (Odell et al., 2018). Our findings shed light on the importance of enhancing community participation in the design and implementation of private adaptation, in order to avoid inequitable consequences of private adaptation initiatives. There is a need for systematic analyses of the concrete impacts of private adaptation strategies on local communities, both in the context of mining and in other issue areas.

However, a study by Loechel et al. (2013) reveals that effective climate change adaptation in mining communities is reliant on action by both local authorities and mining operations. This view is supported by Ford et al. (2011)'s study which reveals that recent studies on Canadian mining industry indicated that despite being aware of current impacts from climate change and reported actions to adapt, the sector was not undertaking long term adaptation planning. The main barriers to taking action were reported as uncertainty regarding future climate conditions and the cost of adaptation measures. Most effort in response to climate change was directed at mitigation measures rather than adaptation. Lack of knowledge about climate change projections and likely impacts were reported as the main factors constraining the industry's understanding of climate change risks. Therefore, Loechel et al. (2013)'s study suggests that because of the mining industry's importance to the economy, its capacity to affect regional communities and the vulnerability of both industry and mining communities to climate change, there is a need to gain a clear understanding of the respective capacities of the industry and local government to adapt to climate change.

3.6 Adaptive capacity

3.6.1 Understanding adaptive capacity

The final core concept of climate change adaptation is that of adaptive capacity. The IPCC defines adaptive capacity as "*the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences*" (IPCC, 2007: 869). This definition is also intended to apply to physical and social systems. In this study, the term 'adaptive' has been used to mean any response that increases a community's probability of survival from climate change impacts. A distinction is made between coping mechanisms and adaptive strategies. Coping mechanisms are used to mean a bundle of short-term responses to situations that threaten livelihood systems, and they often take the form of emergency responses in abnormal seasons while adaptive strategies are the ways in which individuals, households, and communities change their productive activities and modify local rules and institutions to secure

livelihoods. The two kinds of responses may overlap over time, and coping mechanisms may develop into adaptive strategies over time.

Adaptive capacity is one of the key factors influencing the vulnerability of regions to climate change (Adger et al., 2005, 2007; Park et al., 2012a, b). Adaptive capacity itself, also defined as the ability of the system to reduce the vulnerability and risk to impacts and take advantage of the changes, has been of interest to many researchers within the last decade (Smit and Wandel, 2006; Engle, 2011; Engle and Lemos, 2010; Glaas et al., 2010; Juhola et al., 2012a, b). Adaptive capacity is the capability of the system to protect socio-ecological systems from changes or perturbation (Pandey and Jha, 2011). It involves improvement or adjustment in systems, even without change. Adaptive capacity can also include reactions of the system that modify its sensitivity to perturbation (Gallopin, 2006). In adaptive capacity assessments the focus is on societal aspects, such as technology, infrastructure and knowledge that are steered by public and economic policy, thus making it of interest to decision-makers (Adger et al., 2007). The use of assessment results in decision making is important, given that adaptive capacity, as part of a vulnerability assessment, has the most relevance to policy making in the field of climate adaptation (Engle, 2011).

Adaptive capacity does not refer to short-term coping strategies or mechanisms, which are themselves an adaptation options, but encompasses continuous and permanent change in the system. To highlight this subtle difference, the IPCC (2007) defines the *coping range* as the variation in climatic stimuli that a system can absorb without producing significant impacts. As such, there is an implied limit to coping which may be well addressed within existing natural resource management. What makes adapting or the capacity to adjust unique is that it is permanent and requires a change in the system rather than pushing the limits of the current system.

3.6.2 Adaptive capacity measures and indicators

Too often adaptive capacity is generalized without clear indicators. It is dependent on a variety of social, economic, political, technological and institutional factors: varying in weight depending on the scale of analysis (Vincent, 2007). The relationship between these indicators at the national level changes when the focus turns to the community level. Acknowledging this uncertainty and complexity, for the purposes of this paper, a useful framework is the Local Adaptive Capacity Framework (LACF) by the Africa Climate Change Resilience Alliance (ACCRA) which outlines the main determinants of adaptive capacity. This is made up of the asset base of a community, institutions and entitlements, knowledge and information, innovation and governance (ACCRA, 2010).

The IPCC (2007) also identifies economic wealth, technology, information and skills, infrastructure, institutions and equity as the principal determinants of adaptive capacity. Others include social capital and good governance as additional key components (Adger, 2003; Jones et al., 2010). 'Much of the focus in assessments of adaptive capacity has been at the national level, with a heavy emphasis on assets and capitals with the notable exception is the National Adaptive Capacity Framework (NACF), which focuses purely on a function-based approach (WRI, 2009). Important elements of local adaptive capacity include access to and control over natural, human, social, physical and financial resources as well as knowledge co-production, learning and collaboration. CARE international (2010) has identified five examples of types of resources that affect adaptive capacity as shown in Table 5.

Table 5 showing examples of resources that affect adaptive capacity

Resources	Description
Human resources	Knowledge of climate risks, conservation agriculture skills, good health to enable labor
Social resources	Women's savings and loans groups, farmer-based organizations, traditional welfare and social support institutions
Physical resources	Irrigation infrastructure, seed and grain storage facilities
Natural resources	Reliable water sources, productive land, vegetation and trees
Financial resources	Micro-insurance, possible diversified income sources

Source: CARE International, 2010

Scholars also argue that the resilience of societies and activities is an excellent umbrella concept for those factors that mediate between geophysical conditions and events, on the one hand, and human abilities to

cope with, take advantage of, or adapt to those conditions and events, on the other hand (Rayner and Malone, 2000a). The writers argue that resilience is a composite concept, incorporating environmental, social, economic, political, demographic, cultural, gender and psychological factors, in describing the capacity to recover and survive, to change and grow. This conceptualization draws attention to the amplifiers of the impacts of climate change and points toward characteristics of certain groups, institutions and places. It also emphasizes the degree to which the risks of climate catastrophe can be cushioned by adaptive actions that are or can be brought within the reach of populations at risk.

For instance, Yohe and Tol (2002) identified eight generalized "determinants of adaptive capacity," many of which are societal in character, although the authors draw on an economic vocabulary and framing. These include; i) the range of available technological options for adaptation; ii) the availability of resources and their distribution across the population; iii) the structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed; iv) the stock of human capital, including education and personal security; v) the stock of social capital, including the definition of property rights; vi) the system's access to risk-spreading processes; vii) the ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers themselves; and viii) the public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

Yohe and Toll (2002) argue that each of these outlined factors could be assigned a subjective value from 0 to 5 to construct an index of capacity. The writers apply such an index to a hypothetical example of evaluating water management options in Egypt by their likely outcomes as measured by the index. Therefore, the challenge in adaptation research is to design adaptive capacity assessment frameworks (as shown in Figure 4) that are methodologically robust and context-specific and relevant to those who make decisions related to adaptation action. As an emerging field of study, methodological questions are relevant to ensure quality of research results relevant to climate change adaptation policy (Pittock and Jones, 2000; Malone and Engle, 2011; Roman et al., 2011).

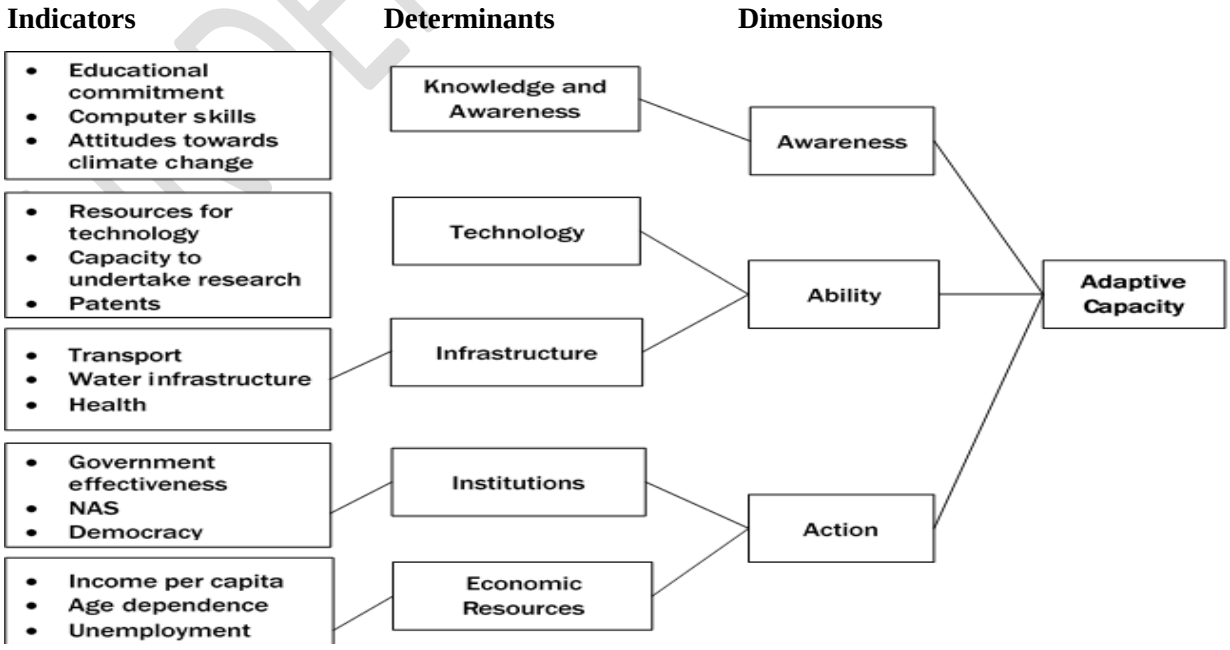

Figure 4: Determinants and dimensions of adaptive capacity

Source: Juhola and Kruse, 2015

Various approaches and methodologies for assessing adaptive capacity of a region have been developed (Engle and Lemos, 2010; Engle, 2011) ranging from indicator-based assessments to stakeholder driven scenario-based assessments (Posey, 2009; Malone and Engle, 2011; Park et al., 2012a,b). The purpose of these studies has been twofold: to characterize the capacity of a system to adapt to climate change; and to identify recommendations for policy makers on how to enhance this capacity and reduce vulnerability and risk, and to take advantage of the changes. Thus, adaptive capacity assessments have moved from being an academic exercise to being a political necessity (Hinkel, 2011; Park et al., 2012a,b). Thus scholars emphasize the need for comprehensive and comparable assessments (Preston et al., 2011) and policy makers on national, regional and international level also have an interest in spatially explicit information regarding vulnerability in order to prioritize adaptation action (Hare et al., 2011) or allocate funding for adaptation (Klein and Möhner, 2011; Klein, 2009). Underlying this is the notion that evidence-based policy making requires sound data and research results (Pielke, 2007; Posas, 2011).

At the same time, the current methodologies for assessing adaptive capacity and their ability to provide reliable and sound information are increasingly being discussed (Hinkel, 2011; Malone and Engle, 2011; Park et al., 2012a,b). For example, Park et al. (2012a,b) developed a standardized, non-contextualized index approach (environmental vulnerability index) and compared the results from this to the results of a participatory assessment (sustainable livelihood analysis). This analysis shows how rankings of relative vulnerability are dependent on the assessment tool that is being used. Furthermore, indicator-based assessments are criticized for not being context specific enough: too static in order to represent the dynamic nature of adaptive capacity on different spatial and temporal scales, and for applying a top down approach and consequently missing the view from below (Engle, 2011).

Birchall and McDonald (2020)'s study reveals that adaptive measures that build resilience to climate change can take many forms depending on the specific vulnerabilities of a community. They can come in the form of institutional, educational, and behavioral change; development of early warning and proactive planning information systems; physical infrastructure development; integrated natural resources management; and so on (IPCC, 2014). Harman et al. (2015) discusses three main categories of adaptation to climate change: planned retreat, accommodation measures, and protective measures. Planned retreat involves organized withdrawal or regulated restrictions on development in hazardous coastal areas affected by sea level rise, erosion, storm surges, and so on (Harman et al., 2015).

Accommodation measures consist of revised building codes and changes to urban design, allowing populations to continue to develop and live in areas affected by climate change impacts while reducing sensitivity and/or exposure to those impacts (Harman et al., 2015). Increasing green space in developed urban areas is considered a valuable accommodation response, as green spaces can mitigate the urban heat island effect by reradiating less heat than built surfaces and providing cooling through evapotranspiration while also creating attractive spaces within urban centers (Carter et al., 2015).

Protective measures can be used to shield coastal communities from the impacts of climate change. These can be implemented through hard defenses, such as dikes or sea walls, or soft defenses such as beach nourishment or coastline naturalization (Harman et al., 2015). As sea levels rise and the potential severity and frequency of storm surges increases, hard defenses can prevent flooding and reduce coastal erosion (Harman et al., 2015). Coastline naturalization can help to protect developed areas from the impacts of climate change (Harman et al., 2015; McDougall, 2017). Thus, the successful implementation of adaptive measures should involve public disclosure at all stages. Open communication with at-risk populations allows the public to be involved in adaptation planning while also making them aware of any hazards associated with climate change in their community (Bulkeley and Tuts, 2013; Harman et al., 2015).

4.0 Discussion and conclusion

4.1 Discussion

The aim of this review paper was to conduct a literature search on factors that enhance resilience and the adaptation strategies used by urban mining communities to adapt to climate change. The paper has attempted to review key factors that support the development of resilience in urban mining communities; the nature of emerging practice and how this can be enhanced in different contexts. A few of the reviewed papers also have written on adaptation response to climate risks in mining communities,

including perceived barriers, collaboration and further information needs. The review findings are discussed in the context of other existing research on climate change resilience and adaptation and other studies of mining industry adaptation in other countries. In this review paper, a total of 213 documents, which included 122 articles, 60 reports and 31 books and other gray literature were screened and selected for inclusion. These were generally documents which contained qualitative information focusing on factors that increase climate change resilience and capacity to adapt to impacts of climate change in ecologically fragile urban mining communities.

A number of reviewed papers have attempted to provide factors that enhance resilience in urban communities while a few others have provided very insightful information on measures and adaptation response to climate risks from mining companies and the surrounding local communities. However, the review paper has found that the gaps in the literature seem to have been most evident on how measurable community resilience and adaptive capacity are in the context of addressing the impact of climate change. Thus, even though the reviewed papers have explored resilience and adaptive capacity quite extensively, the concepts still remain unclear (Walker et al., 2004) due to the multiplicity of interpretations scholars have attached to their meanings. There has also been little attempt to scrutinize the literature to examine how it might underpin an operational approach to resilience and there is often a lack of awareness that such diversity of interpretation exists (Bahadur et al., 2010). As a result of this perceived complexity and multiple interpretations of the resilience concept, there is little or no consensus, among scholars, on factors that lead to increased climate resilience and the variables that should be used in order to assess and quantify progress in becoming more resilient.

The review paper observes that there are also still fears among some scholars and practitioners that the scarcity of evaluations and different framings of issues around climate change resilience implies that understanding the key drivers of community resilience to climate change is not a straightforward exercise. As Twigger-Ross et al. (2015)'s study puts it, evidence seems to point to the importance of 1) framing agendas broadly to incorporate actions that address a community's wider priorities and that cultivate skills, understanding and ownership of responses to climate change; 2) existing capacities within a community to inform action on climate change resilience; 3) support from the community and voluntary organizations to act as intermediaries to provide guidance and stepping stones for forming a new partnership aimed at developing community resilience, and supporting skills and knowledge exchange. The review paper has also noted that very few of the reviewed papers explicitly assessed factors that enhance resilience and adaptive capacity in ecologically fragile urban mining communities per se. Most of the papers reviewed have only discussed resilience, adaptation and adaptive capacity in the context of other equally fragile communities other than those in the contested fragile urban mining communities.

Discussing the issue of adaptation, Ayers and Forsyth (2009) suggests that good adaptation requires consideration of immediate and long-term vulnerability in climatic and developmental terms. The scholars are of the view that there is little or no point in seeking to adapt to likely climate risks without knowing how social and economic trends make people vulnerable, or what their needs are. The review paper has shown that climate change adaptation results not only from the magnitude of the change in a particular area but also from the magnitude of the change in the existing vulnerability and resilience embedded in each community. The paper has also found that although the majority of mining companies respond to climate risks, significant gaps remain when it comes to involving and ensuring that communities benefit from such initiatives. Gustafsson et al. (2021)'s study reports that these gaps are partly as a result of weak government and civil society pressures that would compel mining companies to address climate risks in a manner that would help strengthen and improve community resilience. The paper has also found that although some mining companies have set up procedures to assess climate impacts on business operations, integrated climate risks in water governance, and adapted their infrastructure to suit the changing climate, adaptation is still mainly driven by investor pressures, and not by domestic regulations and civil society. By implication, this means that mining companies rarely engage in community-oriented adaptation responses by cooperating with local mining communities in ways that would benefit these communities (Ford et al., 2011). This shows how limited adaptation from mining companies and barriers to achieving transformative change, and identifying how private adaptation could help improve societal resilience.

Nevertheless, some scholars have suggested that in order to assess and monitor climate resilience in practice, a better understanding and clear definition of the term 'resilience' is needed. This is important in order to remove the misperception caused by the multiplicity of interpretations that the concept carries.

Other studies have recommended that scientific assessments of likely changes in climate need to be open to CBA as a means of integrating concerns about social vulnerability and development with climate change policy. Studies emphasizing urban governance and institutions (e.g. Avis, 2016) have focused on questions of how different types of institutional arrangements affect the resilience of local environments and how resilience thinking can influence the development of improved governance mechanisms for promoting adaptation to climate change. The studies considered for this review paper were collected with the help of mainly Google Scholar web search engine from a diverse array of peer-reviewed articles, relevant book publications and reports.

4.2 Gaps and implications

The review paper highlights a number of gaps in literature which are critical for future studies in this area. First, there has been little attempt to scrutinize the literature to examine how it might underpin an operational approach to the resilience concept. As a result, there is substantial diversity in how the term resilience is understood and used between disciplines, and consequently different understandings of the term may have different implications when translated into policy and practice. Second, the review paper reports a lack of consensus on factors that lead to increased resiliency or progress in becoming more resilient due to the complexity and multiple interpretations of the resilience theory. This, as well, may have serious implications when translated into policy or action. Third, there also seems to be a lack of clear-cut assessment indicators for vulnerability, resiliency and adaptive capacity, making it difficult to assess progress in this area as well. Fourth, there is also observed inadequacy in research focusing specifically on climate change adaptation and resilience in the contested urban mining communities although substantial amount of research has been done elsewhere in similar areas. Fifth, other scholars (e.g. Odell, et al., 2018) point to the gaps in the literature where the relationship between mining and climate change has received limited attention. The argument is that the scholarly literature on mining has been more concerned with themes such as environmental impacts of extractives; corporate social responsibility; and so on, which bear no relationship to climate change.

The author strongly feels that these reviewed gaps in literature, especially the observed inadequacy in research focusing specifically on climate adaptation and resilience in fragile urban mining communities, need serious attention. This is because, as climate change proceeds and intensifies, the implications for a range of economic sectors will become more apparent. The energy and water intensity of large-scale mining operations may make this sector particularly vulnerable. The relative lack of power of resource-poor urban communities living in areas where such mining is making claims on water and energy resources, renders them more vulnerable. Responses to these vulnerabilities of the mining industry, the surrounding local communities and ecosystems will benefit from more evidence-based research in this area.

4.3 Conclusion

This review paper has analyzed the literature on factors and policy options for enhancing resilience and capacity of ecologically fragile mining communities to adapt to climate change impacts. The review paper has identified a number of key results relating to resilience and adaptive capacity and the factors that influence these variables. First, the review paper has found that although the concepts of resilience and adaptive capacity are extensively explored in a few studies and applied differently in various disciplines, their meanings still remain complex and unclear. Second, the paper has found that there is little or no consensus, among scholars and practitioners, on the factors that lead to increased resilience and the variables that should be used to assess and quantify progress in becoming more resilient. Third, the review paper has also found that very few studies have been conducted to assess progress in becoming more resilient and adaptive in the contested urban mining communities. Fourth, the study has also found that the challenge in the current adaptation research has been to design vulnerability, resilience and adaptive capacity assessment frameworks that are methodologically robust, context-specific and relevant to those who make decisions related to adaptation action. Fifth, the review results also seem to suggest that although the reviewed mining companies have started to address the impacts of climate change on their operations, responses do not typically address the vulnerabilities of local mining

communities. By implication, this means that mining companies rarely engage in community-oriented adaptation responses by cooperating with local mining communities in ways that would benefit these communities.

Therefore, to fully understand and appreciate the contextual and varying levels of resilience and adaptive capacity in ecologically fragile urban mining communities, this review paper recommends a need to conduct more comprehensive studies, which clearly explore factors that enhance resilience and adaptive capacity and those that suggest clear policy options for the contested urban mining communities, in order to supplement the rather limited body of literature in this area. This will shed more light on factors that enhance climate resilience and adaptive capacity and will avoid unequal consequences of adaptation initiatives designed by mining companies alone. Through shared initiatives, local urban mining communities could also provide information about their needs, assess corporate strategies, and reach agreements with companies on how to manage their scarce resources. The mining sector also urgently needs to develop robust measures for climate adaptation in order to increase the resilience and capacity of urban mining communities to adapt to climate change impacts and manage future environmental risks.

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