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THE IMPORTANCE OF MULTIDIMENSIONAL VULNERABILITY ANALYSIS IN SUSTAINABLE DEVELOPMENT

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Abstract: The contemporary development discourse is largely concerned with mitigating vulnerabilities, building resilience, and achieving sustainability. The interconnection of the various factors involved in vulnerability, sustainability assessments, and resilience building necessitates a comprehensive analysis. However, bringing together these factors for a multidimensional analysis of vulnerability or sustainability poses significant challenges. Thus, it is imperative to establish a framework that combines multidimensional vulnerability and sustainability analysis to overcome vulnerabilities and achieve sustainable development. This article presents a framework integrating sustainability into multidimensional vulnerability analysis to establish sustainable intervention. Firstly, we review the key concepts and multidimensional frameworks of vulnerability analysis. Secondly, we discuss the various domains and drivers of vulnerabilities and the role of sustainability in analysing the impact of multidimensional vulnerability and framing sustainable intervention strategies. Lastly, we argue that mitigating vulnerability drivers is central to the preliminary framework, which can be achieved by aligning sustainable intervention strategies with the sustainability goals (SDGs).

Keywords: Framework, multidimensional analysis, sustainability, vulnerability.

Introduction

The vulnerability definitions primarily depend on the context, disciplines, and fields. In many situations, vulnerability is linked intrinsically with natural hazards, disasters and emergencies, yet it implies a broader concept (White *et al.,* 2001; Wisner, 2016; Forbes-Mewett & Nguyen-Trung, 2019). The term "vulnerability" is associated with risk or poor conditions (Cardona, 2003), which was initially applied in risk and disaster studies in the 1940s relating to flood disasters (Wisner, 2016). It took broader attention to vulnerability and capacity within natural hazards and disaster risk reduction in the 1970s (Gaillard, 2010; Wisner, 2016) and viewed natural hazards as the only cause of vulnerability neglecting human factors (Wisner, 2016; Forbes-Mewett & Nguyen-Trung, 2019). According to Cutter (2003), vulnerability science involves understanding and responding to natural disasters as they make people, locations and communities vulnerable. However, some studies in the 1970s and early 1980s underscored that the real vulnerability lies in inadequate social systems, structures and models than the risk perception of the disastrous natural events (Cardona, 2003; Wisner, 2016; Forbes-Mewett & Nguyen-Trung, 2019). Therefore, any vulnerability assessment requires identifying who is vulnerable, the extent of the vulnerability, the source of vulnerability, households responding to vulnerabilities, and the gaps in risk management mechanisms (Hoddinott & Quisumbing, 2010).

Vulnerability is multidimensional and varies according to situations, locations, or time, depending on the scale and potential of stresses (Adger, 2006; Birkmann & Wisner, 2006; Williams *et al.,* 2018). However, many studies did not adequately capture the

complexities of vulnerability posed by multiple stresses or shocks and adaptation measures (Preston & Stafford-Smith, 2009; Wisner, 2016; Zarafshani *et al.,* 2016), despite some studies recognising vulnerability as multi-dimensional. For example, the United Nations (2021) recognised economic, environmental and social vulnerabilities, while Birkmann *et al.* (2013) identified physical, ecological, social, economic, cultural, and institutional vulnerability to natural disasters. Additionally, vulnerability to hazards, vulnerability to entitlements, vulnerability in human ecology, vulnerability to war and conflicts, vulnerability to livelihoods, vulnerability in socioecological systems, vulnerability to climate change, and vulnerability to ecosystems were among the different approaches to vulnerability assessments (Wickham *et al.,* 2000; Adger, 2006; O'Brien *et al.,* 2007; Cardona *et al.,* 2012; Paul, 2013; Welle *et al.,* 2014; Moret, 2014b; Wisner, 2016; Guillard-Gonçalves & Zêzere, 2018; Thomas *et al.,* 2019; Forbes-Mewett & Nguyen-Trung, 2019). Therefore, a critical challenge is integrating different components, disciplines, methodological approaches, and dimensions of vulnerabilities in analytical frameworks (White *et al.,* 2001; Thomas *et al.,* 2019).

Despite recent efforts to bridge the gaps, vulnerability analysis and approaches are distinctively divided between the social and natural sciences (Fuchs *et al.,* 2012; Aksha *et al.,* 2019). However, Ford *et al.* (2018) suggest that revitalising vulnerability research requires multidisciplinary approaches that include the strengths of diversities in vulnerability studies and connect research with decision-making processes. Such attempts are also needed to fill the gaps in vulnerability analyses and link them to sustainable interventions. Another critical challenge is integrating multiple issues and vulnerability dimensions with different methodological approaches within one analytical framework. Hence, multidimensional vulnerability analyses would provide an in-depth understanding of the drivers and domains of vulnerabilities. This serves as the motivation for the present study.

This article consists of three sections. The first section reviews the essential concepts of vulnerability concerning earlier studies. Then, the second section discusses existing vulnerability analysis frameworks, their components, domains and drivers of vulnerability, and their strengths and limitations. In the final section, we argue how vulnerability drivers could be mitigated by attaining sustainability outcomes as a critical element of the new framework. We emphasise the interconnectedness and multidimensional nature of the domains and drivers of vulnerabilities and their impacts on sustainability. Therefore, we introduce a new framework to analyse the domains and drivers of vulnerability, their effects on the economic, social, and environmental dimensions of sustainability, and ways to mitigate the impact of vulnerabilities through sustainable intervention strategies in which the Sustainable Development Goals (SDGs) and their goals would serve as a guiding principle in the formulation of the intervention approach and strategy.

The Key Concepts of Vulnerability

While traditional vulnerability studies primarily focus on the physical environment, recent studies have focused more on social aspects. Despite the shift toward social contexts, these studies are predominantly based on natural hazards and impacts of climate change rather than socioeconomics (Zarafshani *et al.,* 2016). Vulnerability is the effect of multiple forces where climate change is just one; thus, social and ecological vulnerability should focus on future adaptation efforts rather than addressing uncertainties related to climate change (Preston & Stafford-Smith, 2009). This notion is echoed by Ford *et al.* (2018), who imply that climate factors are dominant in vulnerability studies. However, human-environment interactions are still vague and lack conceptual clarity in vulnerability analyses. Moreover, since natural sciences and social sciences define vulnerability differently, conceptualising vulnerability mostly depends on the domains of the studies.

Preston (2012) raises two fundamental questions in a technical study: "The vulnerability of what? and vulnerability to what?". Knowing what is vulnerable to climate change is fundamental as climate change has wider implications, yet Preston (2012) observed that most studies on vulnerability assessments are sectoral. Secondly, 'vulnerability to what' evaluates the determinants of vulnerability and potential threats that determine adaptation actions. Cardona *et al.* (2012) further discuss these concerns in greater detail, explaining that understanding how vulnerability arises, develops, and propagates. It is crucial as vulnerability drives people away from historical, sociocultural, political, economic, and environmental contexts. Therefore, the hazards and other sociocultural, economic, and structural patterns also put vulnerable communities at risk.

Early studies on vulnerability assessments framed vulnerability to hazards as a function of exposure, sensitivity, and adaptive capacity. However, risk depends on the purpose of assessing vulnerability and the way vulnerability is defined (Moret, 2014). Two conceptual models that have been primarily applied are the Risk-Hazard models (RH) and Pressure-and-release (PAR) models (Turner *et al.,* 2003). The RH model focuses on exposure to hazardous natural events and the sensitivity of the exposed entity that determines the risks (Blaikie *et al.,* 2003). However, the definition of vulnerability differs according to various fields, thus resulting in several reasons to measure, define, or conceptualise it (Paul, 2013). Hence, despite being effective in assessing exposure and sensitivity, there are limitations of the RH models, such as neglecting the socio-political and economic context that significantly distinguish the exposure, impacts and differences of exposed entities (Blaikie *et al.,* 2003; Turner *et al.,* 2003; Perdikaris *et al.,* 2011). However, the PAR model does not address sustainability requirements in biophysical systems.

Various schools of thought have drawn attention to climate change impacts and natural hazards in the past decades by introducing different models and approaches (Birkmann *et al.*, 2013; Moret, 2014a; Wisner, 2016; Firdaus *et al.*, 2019; Gunaratne *et al.,* 2021). Most of these models were based on vulnerability assessments, climate change adaptation, or disaster risk reduction, which were divided between social and natural sciences (Fuchs *et al.,* 2012; Birkmann *et al.,* 2013). Thus, researchers from different fields defined vulnerability differently according to their disciplinary scopes and themes (Fuchs *et al.,* 2012). Consequently, Ciurean *et al.* (2013) raised several issues in these models, including definitions of vulnerability; objectives, scales, and time of analysis; types of approaches, hazards, and vulnerabilities; data and resource availability; types of affected communities; and the multifaceted nature of hazards and vulnerabilities.

In response to some early critics, Turner *et al.* introduced a new framework integrating exposure, sensitivity, and resilience components into vulnerability assessments in biophysical systems. The sensitivity of human and environmental conditions determines the extent of sensitivity to exposure. Vulnerability responses collectively determine the system's resilience capacity. This approach revises vulnerability assessment by integrating the human environment into vulnerability (Turner *et al.* (2003). In addition, the IPCC (2012) asserted that the impacts of extreme climate events depend on the severity of the events and the exposure and vulnerability. However, Williams *et al.* (2018) identified four significant gaps in vulnerability assessment processes, namely "(i) inadequate participation of local perspectives and knowledge; (ii) lack of clarity in the operationalisation of vulnerability; (iii) lack of comprehensiveness of the measurement criteria used, and (iv) irrelevance of the assessment in decision support".

Social vulnerability, in contrast, attempts to measure and reduce the vulnerability of hazards in social settings, which has its roots in political ecology and political economy with special attention on socio-political structures. It claims that failures in political and economic systems

are the reasons for inequality, constraints and marginality in environmental hazards (Fischer *et al.,* 2015; Burton *et al.,* 2018). According to Adger *et al.* (2004), vulnerability largely depends on (a) socioeconomic factors (i.e. economy, governance, population density, gender, poverty) and (b) biophysical features such as topography, climatic conditions, and natural hazards. However, its multidimensional nature and tangible and intangible attributes complicate the measure of social vulnerability (Birkmann, 2006; Thiault *et al.,* 2021). The ecosystem vulnerability assessment combines these two attributes by applying integrated socioecological models (Weißhuhn *et al.,* 2018; Fernández Martnez *et al.,* 2020; Cai *et al.,* 2021). Table 1 provides a summary of the concept of vulnerability from selected studies. The following sections then discuss the existing vulnerability analysis frameworks, including their strengths and limitations, critical areas of concern, and the emergence of multidimensional vulnerability analysis in disastrous climate events.

Frameworks for Vulnerability Analysis

Vulnerability studies in the biophysical context focus primarily on hazards, exposure, and risks, which overlook the importance of socioeconomic, cultural, or political contexts (Aksha *et al.,* 2019). Linking vulnerability merely to natural disasters and focusing on disaster risk reduction is like treating the symptoms while bypassing the root courses of vulnerability (Gaillard, 2010; Fernández Martínez *et al.,* 2020). Nevertheless, the complexity and diverse system interactions in analysing human-environment systems' vulnerability and resilience have allowed researchers to assess drivers and consequences of hazards in different spheres (Turner *et al.,* 2003; Angula & Kaundjua, 2016). Several studies conceptualise vulnerability as a multidimensional component, including biophysical, sociocultural, economic and institutional factors (Klein & Nicholls, 1999; O'Brien *et al.,* 2009; Mavhura *et al.,* 2017). Nonetheless, complexity and multidimensionality are rarely envisaged in vulnerability assessments, as most scientific studies consider it a single dimension, i.e., social, biophysical/physical, or institutional (Guillard-Gonçalves & Zêzere, 2018).

Biophysical vulnerability relates to the ultimate impact of a hazardous event and the damage caused to physical systems (Brooks, 2003; Thywissen, 2006). Social vulnerability refers to inherited characteristics in a society, such as poverty, inequality, culture, social status, social values, or quality of life, which are not functions of a hazard, yet make some populations more vulnerable to hazards than others (Guillard-Gonçalves & Zêzere, 2018; Thomas *et al.,* 2019). Social vulnerability recognises that social inequalities make certain people or societies more vulnerable to disasters than others as a complex phenomenon (Burton *et al.,* 2018; Aksha *et al.,* 2019). On the contrary, biophysical vulnerability is a function of the relationship between the magnitude of the hazard process, its impacts on physical structures, and the frequency and duration of the hazards (Brooks, 2003; Guillard-Gonçalves & Zêzere, 2018). Based on various definitions, Guillard-Goncalves & Zezere (2018) claimed that vulnerability is (i) dynamic, (ii) multidimensional, (iii) inherent to any community, (iv) ranging from individual to global, and (v) site-specific. Therefore, vulnerability studies established specific approaches and concepts.

Damage caused to physical structures and the environment in natural disasters will result in many social components and processes undergoing similar consequences (Cutter *et al.,* 2009). However, no clear and comprehensive guidelines exist for integrating them individually or collectively (De-Leon, 2006; Mavhura *et al.,* 2017). Different vulnerability assessments (physical, social, economic, or institutional) are reciprocal and interdependent (Fuchs *et al.,* 2012). Due to the dynamic nature of hazards, exposure, and vulnerability, a multidimensional approach is required to assess vulnerability fully. It requires physical and environmental characteristics to be considered in designing and

Table 1: A summary of the essential concept of vulnerability

Contexts	Key concepts	Related Studies
Conceptualisation and definitions of vulnerability	• Vulnerability is mainly related to natural hazards, disasters, and emergencies but later moved to climate change. • Conceptualising vulnerability depends on the domains of the studies. • Vulnerability is multidimensional, depending on hazards and sociocultural, economic, and political contexts.	Birkmann & Wisner (2006); Gaillard (2010); Paul (2013); Preston & Stafford-Smith (2009); Thiault *et al.* (2021); Turner *et al.* (2003); United Nations (2005); Weißhuhn *et al.* (2018); White *et al.* (2001).
Factors that affect vulnerability	• Vulnerability is context-specific, particularly to situations, locations, and times. • The levels of vulnerability are determined by social, economic, physical, environmental, or institutional factors. • Exposure, sensitivity, and adaptive capacities to hazards determine the levels of vulnerabilities.	Cardona *et al.* (2012); Fernández Martínez *et al.* (2020); Fuchs *et al.* (2012); Paul (2013); Preston (2012); Preston & Stafford-Smith (2009); Turner *et al.* (2003); White *et al.* (2001); Williams *et al.* (2018).
Different approaches in vulnerability analysis	• Measure uncertainties involved in disasters or impacts of climate change. • Fundamental approaches are the risk-hazard (RH) and the Pressure and Release (PAR) models. • Consider exposure, sensitivity, and resilience in the human and biophysical context. • Social and ecosystem vulnerabilities analyse the social and biophysical systems in natural hazards.	Adger *et al.* (2004); Birkmann (2006); Birkmann & Wisner (2006); Birkmann *et al.* (2013); Burton *et al.* (2018); Cai *et al.* (2021); Cardona *et al.* (2012); Ciurean *et al.* (2013); Fernández Martínez *et al.* (2020); Moret (2014); Preston (2012); Thiault *et al.* (2021); Turner *et al.* (2003); Weißhuhn *et al.* (2018).

executing disaster management measures, let alone social components (Cutter *et al.,* 2009). Thus, several studies have integrated biophysical and socioeconomic contexts that enable assessment methods to capture the vulnerability and identify adaptation measures (Posner & Armas, 2014; Sowman & Raemaekers, 2018).

In the following sections, we will discuss a few vulnerability analysis frameworks, namely the independent dimension vulnerability framework (De-Leon, 2006), outcome vulnerability and contextual vulnerability (O'Brien *et al.,* 2007); socio-biophysical vulnerability (Preston & Stafford-Smith, 2009); MOVE framework (Birkmann *et al.,* 2013); and 360º integrated assessment map (Mills *et al.,* 2011). Although most frameworks focus on the vulnerabilities of climate change and natural disasters, they provide broader perspectives on multidimensional vulnerability analysis by bringing biophysical and social vulnerabilities together.

a) Vulnerability Framework of Independent Dimensions

De-Leon (2006) proposed a framework to demonstrate how vulnerabilities could occur due to disasters in various sectors (i.e., housing, education, healthcare, energy and finance). Consequently, vulnerability assessments must be conducted at different levels separately, linking different sectors and components of vulnerabilities. Furthermore, six variables, physical, functional, economic, gender, administrative, and environmental conditions, separate each sector within the framework. Then, the scales of consideration range from human beings to households and local communities to the national level. According to De-Leon (2006),

the framework suggests that the first step is deciding the type of disaster to be addressed in vulnerability assessments, then the corresponding sector, such as housing, agriculture or commerce. Next, determine the geographical level of vulnerability assessment conduct and the components to be assessed.

b) Outcome and Contextual Vulnerability

Discussions on outcome vulnerability and contextual vulnerability bring insights into new approaches in vulnerability analysis. While outcome vulnerability is a linear approach whereby mitigation and adaptation are the means to reduce exposure to climate change impacts, contextual vulnerability, on the other hand, is a multidimensional approach in which contextual conditions of the biophysical environment and socioeconomic factors are integrated to assess and cope with potential impacts of hazards (O'Brien *et al.,* 2007; Okpara *et al.,* 2016). For instance, contextual conditions such as institutional, biophysical, socioeconomic and technological and their levels of exposure (E), sensitivity (S), and adaptive capacity (AC) determine the levels of vulnerability. Therefore, vulnerability is a function of evolving biophysical conditions and dynamic social systems such as political, social, economic, institutional, and technological processes and structures (O'Brien *et al.,* 2007). Integrating biophysical and socioeconomic contexts is crucial to bringing multidimensional methods to vulnerability and adaptation practices (Preston & Stafford-Smith, 2009; Aksha *et al.,* 2019). The outcome and contextual vulnerability of O'Brien *et al.* (2007) have been widely referred to in the analysis of vulnerability literature. Contextual and outcome vulnerability analyses have significantly transformed vulnerability interpretations (Fellmann, 2012) because they consider biophysical and socioeconomic factors as the drivers of vulnerability.

Hopkins (2015) extended the contextual components and emphasised the importance of integrating socioeconomic, physical, and political contexts in assessing climate vulnerabilities and conflicts. Assessing contextual vulnerability in climate conflict discourses allows an understanding of the complexities of resource scarcity-induced conflicts such as land issues, human security, group clashes, ethnic or religious tensions, and environmental conflicts (Okpara *et al.,* 2016). The contextual and outcome vulnerabilities represent a significant shift in interpreting vulnerability as these concepts provide different conceptual frameworks and hierarchies while proposing various strategies to address climate-induced vulnerabilities (Fussel, 2009).

c) Socio-Biophysical Vulnerability

To establish a comprehensive climate risk assessment, Preston and Stafford-Smith (2009) looked at different components of vulnerability in a broader context of biophysical and human environments. In this model, the primary determinants of climate vulnerability are exposure to hazards and systems' sensitivity and adaptive capacity. Their model treats social and biophysical systems as recipients of hazardous impacts, such as potential harm, damage, or costs. Accordingly, social and biophysical variables are the determinants of climate vulnerability. In this model, climate variabilities, associated with the likelihood of hazards, determine the level of exposure to climate risks. One of the advantages of this model is that it considers both the socioeconomic characteristics and biophysical variables in climate vulnerability analysis. Preston (2012) states climate risks are evident when these different components are unified. In short, this model extends the conventional vulnerability model by considering the effects of different elements. It also provides insight into the potential contributing factors of social and biophysical vulnerabilities and climate variability from a broader perspective.

d) The MOVE Framework

The MOVE Framework-Methods for the Improvement of Vulnerability Assessment in Europe- was developed as a holistic approach to disaster risk reduction, vulnerability assessments and management of natural hazards in Europe

(Borg *et al.,* 2014). The framework provides a holistic approach to vulnerability, risk and adaptation assessments (Birkmann *et al.,* 2013). The MOVE Framework assesses vulnerability to natural or socio-natural hazard events that could be internal or external (Vinchon *et al.,* 2011). It considers the causal factors of hazards, such as level of exposure, susceptibility, lack of mitigation and adaptation capacities and vulnerability in different domains (Welle *et al.,* 2014; Kablan *et al.,* 2017). The vulnerabilities assessed in the MOVE Framework are social, economic, physical, cultural, environmental, and institutional. Since these interconnected domains, similar properties may appear in different domains (Birkmann *et al.,* 2013; Welle *et al.,* 2014; Lianxiao & Morimoto, 2019).

e) 360º Integrated Assessment Map

The 360º integrated assessment map provides a comprehensive framework to assess vulnerabilities in different domains using multiple drivers for studies in the fisheries sector (Mills *et al.,* 2011). The framework considers vulnerability a distinctive feature of small-scale fishery systems (Schwarz *et al.,* 2011; Raemaekers & Sowman., 2015). A study using a 360º integrated assessment map in two fishing communities in Mali and Nigeria assessed vulnerability in four domains: people and livelihoods, institutions and governance, external drivers, and natural systems (Mills *et al.,* 2011). This study identifies the drivers of vulnerabilities that have brought about a rich and comprehensive picture of vulnerability assessment.

The framework was first introduced by Garcia *et al.* (2008) and it was an Integrated Assessment and Advisory (IAA) framework without a comprehensive fisheries management appraisal framework in small-scale fisheries. This framework was further improved by Mills *et al.* (2011) by including different components to be considered in assessing the vulnerability and resilience of a fishery system and was later renamed 360º Integrated Assessment Map (Raemaekers & Sowman., 2015).

In an annotated bibliography on climate change and vulnerability assessment methodologies and their relevance to fisheries and aquaculture, Barsley *et al.* (2013) categorised the vulnerability methodologies as (i) indicator-based (produce measurable outputs using indicators and indices), (ii) models and GIS-based (assess vulnerabilities and changes in drivers or domains using statistical and mapping tools), and (iii) stakeholder-based (focus on affected individuals, groups, or communities from local to global or context-specific). They further divided such methodologies based on drivers of change (climate or non-climate-related), scales, different ecosystems, and special considerations such as gender, food security, small-scale fishery and aquaculture or governance and management. Consequently, the 360º integrated assessment map falls under stakeholder-based assessment methods, which promote obtaining information from local communities and providing them with opportunities to rank vulnerability drivers.

Table 2 presents a summary of the studies reviewed in this section. Most vulnerability assessment models reviewed in this section have focused on climate hazards, developed to assess vulnerability to climate change and promote disaster management measures. These multidimensional models emphasise that vulnerability goes beyond exposure, sensitivity, and adaptive capacity to risks. The domains considered in those models were mainly biophysical, social, economic, environmental, institutional, and historical, but the framework that merged these domains into the analyses was relatively limited.

The reviewed literature suggests that most early studies (mainly from the 1970s to 1990s) on vulnerability primarily focused on geophysical factors, including their susceptibility and adaptation capacities, which were incorporated with socioecological systems and sustainable livelihood approaches. Despite the diversity of approaches, there is no universal definition or methodology for assessing multidimensional vulnerabilities (Guillard-Gonçalves & Zêzere, 2018). The complexity

Table 2: A summary of studies focused on multidimensional vulnerability analysis

	Details	Related Studies
Approaches	• Capture complexities in vulnerability and resilience in the human environment. • Use multidimensional vulnerability analysis by integrating socioeconomic and biophysical contexts with hazards, exposure, and risks.	Brooks, (2003); Gaillard (2010); Guillard-Goncalves & Zezere (2018); Klein & Nicholls (1999); Mills *et al.* (2011); Preston & Stafford-Smith (2009); Proagor (2014); Turner *et al*. (2003); Villagran (2006).
Analyses	• Analyses use physical, social, environmental, economic, cultural, or institutional components. • Climate risk assessments in biophysical and human contexts refer to exposure, sensitivity, and adaptive capacity. • Consider different dimensions, scales, magnitudes, and risk governance. • Assess vulnerabilities of natural or socio-natural hazards in physical, ecological, and sociocultural domains. • Assess the domains and their drivers of vulnerabilities in the fishery sector.	Birkmann *et al.* (2013); Brooks, 2003); Ciurean *et al.* (2013); Fellmann (2012); Fussel (2009); Guillard-Goncalves & Zezere (2018); Hopkins (2015); O'Brien *et al.* (2007); Okpara *et al.* (2016); Mills *et al.* (2011); Preston & Stafford-Smith (2009); Proag (2014); Villagran (2006).
Frameworks	• Contextual vulnerability • Socio-biophysical vulnerability 360^{o} integrated assessment map • MOVE Framework	Birkmann *et al.* (2013); Lianxiao & Morimoto (2019); Mills *et al.* (2011); O'Brien *et al.* (2007); Preston & Stafford-Smith (2009). Vinchon *et al.* (2011); Welle *et al.* (2014); Villagran (2006).

of vulnerability and sustainability assessments would require assessing the interconnection of different factors. However, bringing these factors together poses a significant challenge for multidimensional analysis. Moreover, a holistic framework that links multidimensional vulnerability analysis with sustainability principles would help to understand the impacts of vulnerability from a sustainability perspective and establish sustainable interventions or measures. Therefore, in the following section, we propose a preliminary framework that integrates multidimensional vulnerability and sustainability, arguably the missing component in previous studies.

Preliminary Framework for Multidimensional Vulnerabilities

With the complexities involved in multidimensional vulnerability studies and persistent gaps in research domains, we propose a preliminary framework derived from Contextual Vulnerability (O'Brien *et al.,* 2007); MOVE Framework (Birkmann *et al.,* 2013); and 360^{0} Integrated Assessment Map (Mills *et al.,* 2011). The first two frameworks focus mainly on climate-induced hazards and ways to enhance the capacities of the social and biophysical environments to deal with vulnerabilities by promoting adaptation and mitigation measures.

The Integrated Assessment Map of Mills *et al.* (2011) focuses on drivers of vulnerability in different domains. Moreover, Mills *et al.* (2011) did not list all the foreseeable drivers of vulnerabilities. Additionally, keeping the potential drivers open would provide opportunities to find location-specific vulnerability drivers, as the drivers are diverse and complex. Since these frameworks guide the identification of vulnerabilities in different

domains, translating them into sustainability interventions is a prerequisite. For instance, Mills *et al.* (2011) asserted that studies employing conventional vulnerability analyses require immediate attention to resource management as people identify challenges in basic needs, health or micro-credit facilities as a source of vulnerabilities. Figure 1 depicts the proposed preliminary framework for multidimensional analysis.

The domains of vulnerabilities are the different areas of concern, while the drivers of vulnerabilities contribute to intensifying the vulnerabilities in specific domains. Drivers of vulnerabilities make the domains vulnerable. Besides, domains of vulnerabilities are not static, so it is possible to modify them according to the local settings. Whenever these domains of vulnerabilities come together and drivers of vulnerabilities function simultaneously, such situations create multidimensional vulnerabilities in a location, society, or specific area of concern. Therefore, multidimensional vulnerability is the aggregate effects of the drivers of vulnerabilities in different domains, yet they are location-specific and vary according to mitigation and adaptation measures.

The risk depends on exposure, sensitivity, susceptibility, fragility, and resilience capacity (Turner *et al.,* 2003; Birkmann *et al.,* 2013; Ciurean *et al.,* 2013). Therefore, interventions to handle risk, hazards, and vulnerabilities depend on the status and desired changes in domains and drivers of vulnerability. We echo Mills *et al.* (2011) and emphasise the importance of multidimensional vulnerability analysis while facilitating cross-sectoral linkages in vulnerability interventions. We maintain the domains as broader categories and drivers to be identified according to the respective domains. It allows looking beyond a set format with greater flexibility. Hence, the framework would help capture the ground realities and transform the drivers of vulnerability into sustainable outcomes.

The framework in Figure 1 proposes five vulnerability domains, referring to Birkmann *et al.* (2013) and Mills *et al.* (2011). These domains are (a) social environment and systems, (b) governance and institutional systems, (c)

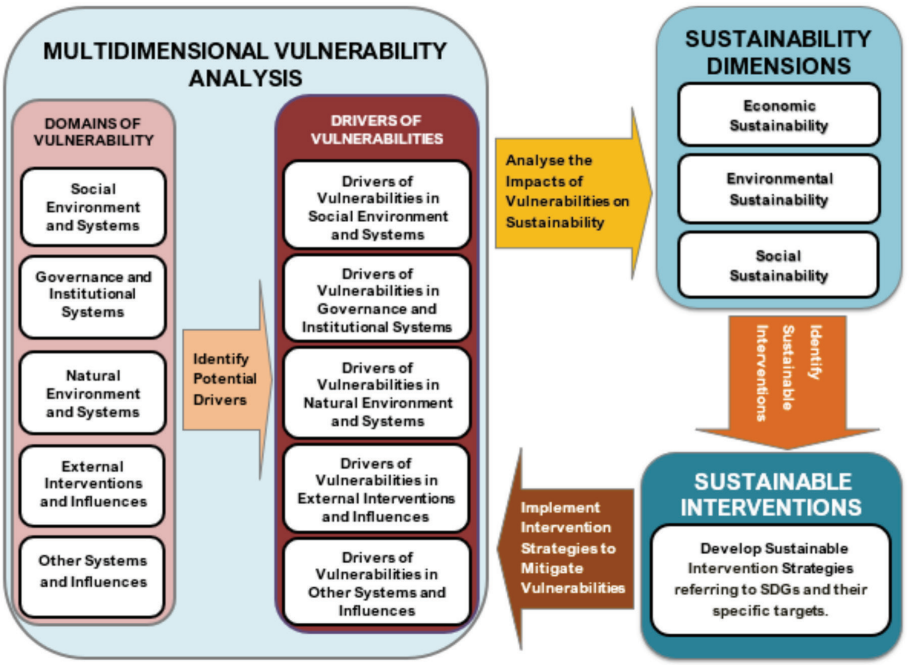

Figure 1: Preliminary framework for multidimensional vulnerability analysis (own figure)

natural environment and systems, (d) external interventions and influences, and (e) other systems and influences. This study proposes that the domains and drivers of vulnerabilities are location-specific so that, conceptually, vulnerability analysis has greater flexibility. More importantly, the proposed framework has a domain named 'other systems and concerns' because it identifies new domains specific to the location of the study. Hence, the proposed framework is flexible compared to existing frameworks such as Birkmann *et al.* (2013), Ciurean *et al.* (2013), Mills *et al.* (2011), O'Brien *et al.* (2007), and Turner *et al.* (2003). These frameworks are considered static and extensively focus on climate change vulnerabilities, as Ford *et al.* (2018) underscored.

As discussed earlier, existing vulnerability analysis frameworks are developed to analyse the impacts of climate change and disastrous natural events. Although they recognise multidimensional domains of vulnerabilities (social, economic, environmental, for example), the driver of vulnerability is natural disasters or climate change. In contrast, different factors or drivers make a person, society, or country vulnerable. For instance, owing to the ongoing Russian war in Ukraine, it is estimated that over 12 million people are displaced, and approximately 13 million people require humanitarian assistance (Guenette *et al.,* 2022). Likewise, global food insecurity in 2022 will increase by affecting 47 million people due to the war in Ukraine (United Nations, 2022). Hence, considering war, conflicts, or similar situations as a domain or driver of vulnerabilities is logical and reasonable. The framework proposed in Figure 1 allows us to identify these local realities and decide whether they are domains or drivers of vulnerabilities.

Theoretically, the proposed framework begins by identifying the domains of vulnerabilities and their respective drivers of vulnerabilities. However, identifying the drivers of vulnerabilities is the first step in practice. Then, these drivers of vulnerabilities are categorised or arranged as per the vulnerability domains already mentioned in the framework. Such initial groupings could be made during the data collection stage using participatory qualitative data collection methods. If specific concerns continuously appear during the data collection or analysis stage (such as the impacts of war), it requires assigning them under the other systems and influences domain. Suppose the source of such specific considerations is unique, for example, the impacts of war or conflicts. In that case, it is advisable to consider them as drivers of vulnerabilities in a new domain. Thus, the proposed framework promotes identifying new domains and drivers of vulnerabilities rather than sticking to a set format, as we have observed in existing frameworks.

The framework then proposes to analyse the impacts of vulnerability drivers on the social, economic, and environmental sustainability of the target communities. Sustainability vastly depends on the balance between economic, social, and environmental dimensions in the three pillars of sustainability. Economic stability and profit maximisation received more attention in development approaches than social and environmental, which promotes the evolving three pillars of sustainability (Basiago, 1999; Purvis *et al.,* 2019). Social sustainability consists of accessibility, cultural identity, equity, empowerment, institutional stability, participation, and sharing (Basiago, 1999), which mostly appear as intangible qualities of a society. Environmental sustainability requires maintaining the balance of the earth's ecosystems and the regenerative capacity of natural resources while utilising them for human consumption (Goodland, 1995; Morelli, 2011). Although people are part of the environment, economic and social sustainability heavily depend on the natural environment. Therefore, mere attention to extracting natural resources intensifies the issues and consequences of these two systems.

Identifying the impacts of the vulnerabilities on the economic, social, and environmental dimensions of sustainability reveals the interconnectedness among different domains

and drivers, demonstrating the multidimensional nature of the vulnerability drivers. For example, a single driver, such as extreme climate events, creates or intensifies vulnerabilities in different domains while impacting economic, social, and environmental sustainability. Such analysis helps to find intervention strategies to address the impacts and drivers of vulnerabilities.

The framework then proposes to identify intervention strategies to mitigate the impacts of vulnerabilities. Since the framework guides the identification of vulnerabilities in different domains and their impacts on the three pillars of sustainability, transforming the vulnerability drivers into sustainability parameters is always possible. More importantly, interpreting the impacts of vulnerability from a sustainability perspective would be crucial to addressing the impacts using the SDGs as an overarching and systematic framework. Mitigating the impacts in line with SDGs would signify a call for systemic change to ensure no one is left behind.

Therefore, it is essential to consider SDGs and their objectives as a guiding principle in framing intervention strategies. The most suitable option for developing sustainability measures is to identify future vulnerability interventions with the consultation of stakeholders or research participants. Thus, sustainable interventions could be derived whenever vulnerabilities and their root courses are identified. In this case, considering Agenda 2030 (United Nations, 2015) as the guiding principle for assessing sustainability would be the most appropriate option. When intervention strategies address the drivers of vulnerabilities, positive outcomes should appear in the domains of vulnerabilities and three dimensions of sustainability.

Domains and Drivers of Vulnerabilities

Vulnerability is 'the conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of a community to the impact of hazards' (United Nations, 2005). While this definition relates to natural hazards, it recognises that biophysical and human environmental conditions determine vulnerability. Therefore, in this study, vulnerability takes a broader perspective by bringing human and natural or biophysical system conditions together to analyse the domains and drivers of vulnerability. Drivers of vulnerability (i.e., poverty, fragile environments, poor mitigation and adaptation measures, internal conflicts, and discriminations) are the factors that contribute to intensifying the vulnerabilities in specific domains such as economic, social, environmental or institutional. In any situation, drivers of vulnerabilities make domains vulnerable. Notably, domains or drivers of vulnerabilities are not static, dynamic and change over time; thus, facilitating favourable changes in domains and drivers would be the essential focus of intervention strategies.

The preliminary framework can be applied in different settings and scales due to its flexibility to modify and define it according to the research requirements. In the framework, we suggest five domains: (i) social environment and systems, (ii) governance and institutional systems, (iii) natural environment and systems, (iv) external intrusions and influences, and (v) other systems and influences; as domains of vulnerabilities, which could apply from person to global. In-depth, these domains reveal that the scope of a domain changes as per the unit under investigation changes. For instance, we could consider the social environments and systems at the individual, family, community, ecosystem, national, or global scale, thus defining the scope of the domains accordingly. The details for each domain are as follows:

i. The social environment and systems, for example, consist of social settings including demographics, social structures such as families and communities, built environment, relationships, social organisations, norms, status, class structure, cultures, religions, attitudes and beliefs, behaviours, functions and systems (Barnett & Casper, 2001).

ii. Governance and institutional systems primarily refer to political and government structures, government institutes, legal

framework and institutes, law and order, political organisations and movements, elections and participation, policies, procedures and implementations, development interventions, and international organisations and governments (The World Bank, 2001; Sakalasuriya *et al.,* 2020).

iii. The natural environment and systems refer to the environment surrounding us, earth's functions, ecosystem services, topography, geology and the climate, land cover and land-use change, soils, water, air and space, natural beauty and resources, species and biodiversity, atmosphere, and the earth's systems (Day, 2017).

iv. The domain of external intrusion and influence is related to the social and governance domains. Nevertheless, we regard such interventions as unwelcoming issues such as war, conflict, military actions, encroachments, invasions, fragmentations, conflicts within, civil wars, campaigns, and propaganda against the component under consideration.

v. Other systems and influences provide space for salient issues and areas of concern that are not explicitly positioned in any other four domains. Accordingly, the drivers of the vulnerabilities are the specific issues of concern.

Vulnerability is multidimensional; hence, it could affect different dimensions or domains. Thus, our preliminary framework first looks at domains or dimensions of vulnerability. Domains are mostly location-specific; thus, identifying new domains wherever possible or modifying the domains mentioned in the proposed framework is necessary. The drivers of vulnerability contribute to intensifying vulnerabilities in specific domains or dimensions. In any situation, the drivers of vulnerabilities make domains vulnerable.

Sustainability Principles and Interventions

Since the domains and drivers of vulnerabilities are interconnected, vulnerability interventions should be multifaceted and far from one-size-fits-all. For example, Mills *et al.* (2011) found that sustainable use of resources remains within different domains, such as "people and livelihoods" and "institutions and governance" instead of "natural systems", which conventional vulnerability interventions focus on. Therefore, assessing the interconnectedness of domains and drivers of vulnerabilities is a fundamental requirement. Therefore, whenever vulnerabilities and their root causes are identified, sustainability should be used as a guiding principle in multidimensional analysis to deliver sustainable interventions.

Sustainability is achieved through a sustainable development process. Sustainability is the final result or end point of the long-term sustainable development process (Diesendorf, 2000). Sustainability is the overall objective of sustainable development, and sustainable development actions contribute to achieving sustainability. The principle of sustainable development emphasises that the development process should be economically, environmentally, and socially sustainable. Thus, promoting sustainable principles would be vital in mitigating, if not eliminating, the vulnerabilities. According to Birkmann *et al.* (2013), vulnerability interventions take different forms: Risk governance, hazard interventions, reductions in exposure and susceptibility, adaptation and resilience improvements, and prevention, mitigation and preparedness. However, such interventions primarily address short-term issues and are inadequate to address multidimensional vulnerabilities in the long run. Therefore, once the drivers of vulnerabilities are identified, it requires them to be transferred into sustainability outcomes, which aim to address the root causes in domains and drivers of vulnerabilities and flaws in the existing interventions.

Attaining sustainable outcomes requires sustainable interventions. In this case, considering the SDGs as the guiding principles for intervention measures would be the most appropriate option. Sustainability acts as the overarching objective

of sustainable development, where actions of sustainable development contribute to achieving sustainability. Sustainability is, therefore, the final result or endpoint of the sustainable development process (Diesendorf, 2000), and any intervention should lead towards sustainability.

Discussion

This section explains other essential aspects not explicitly depicted in our preliminary framework. Besides, we also attempt to articulate how drivers of vulnerabilities could be mitigated by attaining sustainability outcomes through sustainable policies and interventions. First, critical vulnerability assessments have widened from internal risk to multidimensional external factors (Birkmann & Wisner, 2006). The vulnerability is assessed as an intrinsic factor, which then moves to the human experience of the likelihood of harm. These concepts are further expanded from the dualistic approach of susceptibility and coping capacity to multiple structures assessing physical, socioeconomic, environmental, or institutional factors (Birkmann *et al.,* 2013). However, despite the diversity of approaches, there is no universal definition or methodology to assess multidimensional vulnerability (Guillard-Gonçalves & Zêzere, 2018). Hence, bringing different components, methods, approaches, dimensions, concepts, or disciplines together is the main challenge of multidimensional vulnerability analysis (Fuchs *et al.,* 2012; Birkmann *et al.,* 2014).

Second, in a study of 587 peer-reviewed research articles related to climate-induced vulnerability, Ford *et al.* (2018) found the limitations of vulnerability studies in capturing complexities between society and climate challenges. They further detailed seven disconnects in vulnerability studies: (i) neglecting social factors, (ii) failing to capture the dynamic nature of the vulnerability, (iii) confusion due to various definitions and approaches, (iv) negligence of cross-scale strategies and interactions, (v) negative perceptions of affected communities as victims, (vi) limited stakeholder involvement in decision-making and policy process, and (vii) limited multidisciplinary collaborations. We agree with the limitations put forward by Ford *et al.* (2018); thus, our proposed framework recommends future studies to explore those missing elements of vulnerability.

Third, can sustainable policies and intervention strategies mitigate the drivers of vulnerabilities by attaining sustainable outcomes? In short, integrating economic, environmental, and social dimensions in the development process, or sustainability, should be the goal of any development agenda, including mitigating vulnerabilities. According to Diesendorf (2000), sustainability is the result or endpoint of the sustainable development process in the long run. However, social and environmental sustainability continues to be neglected for economic development. Therefore, our preliminary framework proposes that sustainability principles should limit the analysis of the impacts of multidimensional vulnerabilities. Thus, Hopwood *et al.* (2005) describe sustainable development as a response to the mounting concerns of socioeconomic development that degrade the environment and can be useful in addressing the challenges for humanity. Nevertheless, it requires containing and linking human equity, human well-being, environment and society in development.

Finally, sustainable development has become the guiding principle of the Sustainable Development Goals of the United Nations. The SDGs and their targets act in five critical areas of importance, later called the 5Ps: People, Planet, Prosperity, Peace, and Partnership (United Nations, 2015). Concerning the proposed framework, sustainability outcomes are expected to influence the domains and drivers of vulnerabilities and vulnerability interventions. Addressing the root causes of vulnerabilities is a possible way to achieve sustainable development in the long run. Sustainable outcomes can be achieved by identifying drivers behind vulnerabilities, which can then be addressed through sustainable interventions as outlined in our preliminary framework. Therefore, we use

our framework to emphasise the importance of SDGs as the primary guideline for formulating policy and intervention strategies.

Conclusion

The complexity involved in examining vulnerability causes from different perspectives and finding ways to make them sustainable requires a holistic approach to capture the bigger picture. Various methods and research discussed above reveal various dimensions such as social, economic, policy, institutional, livelihood, and physical vulnerability. Nevertheless, several studies assert the complexity of vulnerability and sustainability by detailing the interconnectedness of different factors. Therefore, several studies suggest the importance of a multidimensional approach (Mills *et al.,* 2011; Schwarz *et al.,* 2011).

This study presents a preliminary framework to identify multidimensional vulnerabilities by analysing the various domains and drivers of vulnerabilities in a target community. Through a detailed examination of these drivers, the study seeks to determine how they challenge economic, social, and environmental sustainability. The analysis then explores ways these drivers of vulnerabilities can be mitigated by transferring them into sustainability outcomes by implementing new strategic interventions that align with sustainable development goals. Ultimately, the framework suggests the development of strategic interventions that address multidimensional vulnerabilities while simultaneously contributing to achieving sustainable development goals. By linking intervention strategies with sustainable development goals, this proposed framework addresses several gaps identified in vulnerability analysis and revamps the process.

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