Applying IPCC 2014 framework for hazard-specific vulnerability assessment under climate change

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Applying IPCC 2014 framework for hazard-specific vulnerability assessment under climate change

Jagmohan Sharma[1] and **Nijavalli H Ravindranath**[2]

[1] Karnataka Forest Department, Malleshwaram, Bengaluru—560 003 India
[2] Indian Institute of Science, Bengaluru—560 012 India

E-mail: jagmohan_gaur@yahoo.com and nhravi@iisc.ac.in

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Abstract

The Intergovernmental Panel on Climate Change (IPCC), Working Group II Report (2014) presents vulnerability as a pre-existing characteristic property of a system. Accordingly, indicators for 'sensitivity' and 'adaptive capacity', which are internal properties of a system, are employed to assess it. Comparatively, the IPCC 2007 report includes 'exposure', an external factor, as the third component of vulnerability. We have compared the construct of vulnerability presented in IPCC 2007 and 2014 reports. It is argued that the results of vulnerability assessment obtained by adopting IPCC 2014 framework are practically more useful for reducing current vulnerability in preparedness to deal with an uncertain future. In the process, we have articulated the novel concepts of 'selecting hazard-relevant vulnerability indicators' and 'assessing hazard-specific vulnerability'. Use of these concepts improves the contextualization of an assessment and thereby the acceptability of assessment results by the stakeholders.

1. Introduction

The single most important purpose in addressing climate change is to reduce the risks to natural and social systems emanating due to it. In this regard, the impact-risk framework presented in the Intergovernmental Panel on Climate Change (IPCC) Working Group (WG) II Report (2014) in figure 1 shows that the risk of impact from climatic and non-climatic hazard(s) is caused by the interaction of hazard, exposure and vulnerability. Separating hazard and exposure from the concept of vulnerability in the IPCC 2014 report is a paradigm change from IPCC 2007 report. This paradigm change in 2014 report presents vulnerability as a characteristic internal property of a system delinked from exposure to hazard. This has implications for assessing vulnerability. While under IPCC 2014 Framework, indicators for only sensitivity and adaptive capacity are selected, that under IPCC 2007 report vulnerability is presented as a consequence of the interaction of exposure, sensitivity and adaptive capacity, and indicators for all the three are selected to assess it. A comparison of the concept of vulnerability in 2007 and 2014 reports is shown in figure 1.

The studies that assess vulnerability by operationalizing the IPCC 2014 definition of vulnerability ('the propensity or predisposition to be adversely affected') are limited (e.g., Shukla *et al* 2016, Sharma *et al* 2017). Most vulnerability studies continue to use the IPCC 2007 definition of vulnerability (Mussetta *et al* 2017) and directly account for exposure component to assess vulnerability (Metzger *et al* 2006, Hahn *et al* 2009, Lung *et al* 2013, Simane *et al* 2016, Kumar *et al* 2016). Typically these studies ask the following questions: what is vulnerable? What is vulnerability? and, Vulnerability to what? (Malone and Engle 2011). Under the changed paradigm of 2014 report, the vulnerability assessment studies are grappling to address the third question—Vulnerability to what? Because, while the vulnerability is presented as not-dependent on exposure and hazard, the decision-makers and planners want to know the vulnerability of natural and social systems to climatic hazards such as landslide or drought or unseasonal rainfall. This concern is the motivation for the present paper. We discuss that though vulnerability under IPCC 2014 report is shown not dependent on hazard, it is still

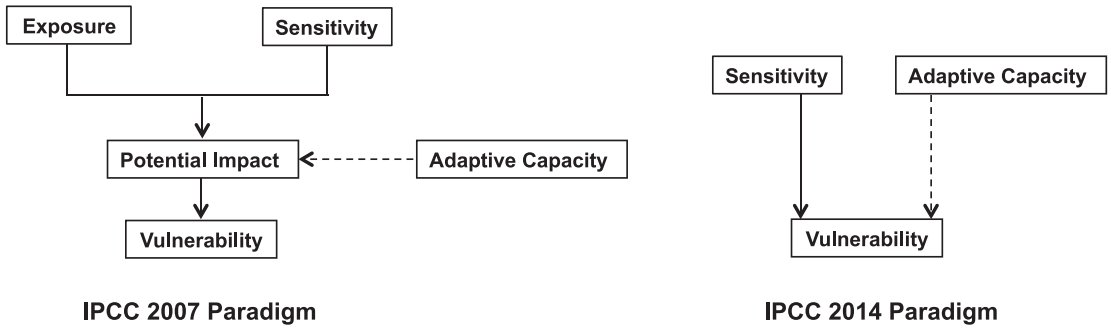

Figure 1. The concept of vulnerability as presented in the IPCC 2007 and 2014 reports. Solid and dashed arrows respectively show a positive and negative functional relationship of a component with vulnerability.

assessed in the context of an anticipated hazard by selecting 'hazard-relevant' indicators for sensitivity and adaptive capacity of a system.

Further, in this paper, we have referred to the understanding of vulnerability according to the IPCC 2007 report (exposure, sensitivity and adaptive capacity as co-factors of vulnerability) as 'old paradigm' and that according to the 2014 report (vulnerability being not-dependent on exposure and hazard) as the 'new paradigm'. We argue that the use of 'new paradigm' to understand and assess vulnerability offers a robust approach for vulnerability and risk reduction under an uncertain future. We have developed the argument by analyzing the changes in the concept of vulnerability from IPCC 2007 to 2014 reports and discussing the use of hazard-specific indicators for sensitivity and adaptive capacity to operationalize the concept of vulnerability.

2. The concept of vulnerability

2.1. The IPCC 2007 report

According to the fourth assessment report (AR4) of IPCC (2007) vulnerability to climate change 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. Vulnerability is 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 2007 IPCC reports, the definition of vulnerability has remained 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). A vulnerability assessment based on this definition considers indicators representing exposure, sensitivity and adaptive capacity (old paradigm).

2.2. The SREX 2012 and IPCC AR5 2014 reports

The IPCC (2012) special report on 'Managing risks from extreme events and disasters to advance climate change adaptation' (SREX 2012) has presented the disaster risk management framework that shows risk arising from the interaction of weather and climate events (hazard), exposure and vulnerability. Under this framework, the '…focus is on reducing exposure and vulnerability and increase resilience…' (IPCC 2012, page 4). Notably, in this framework, the elements of hazard and exposure are presented separate from vulnerability. Vulnerability in this construct is considered an internal property of the system comprising of its sensitivity and adaptive capacity. Accordingly, in the SREX 2012 report 'vulnerability is considered independent of physical events' (section 1.1.2.1, page 33). It also compares and contrasts vulnerability with capability, and considers vulnerability arising also due to 'relative lack of capacity' (section 1.1.2.1, page 33). The IPCC 2014 report has adopted this construct of vulnerability and defined it as propensity of a system to be adversely affected. Thus vulnerability is not linked to exposure to a hazard and is a characteristic property of a system that shows its current internal state (Sharma *et al* 2013). Accordingly, the vulnerability assessments that follow IPCC 2014 framework select the indicators representing sensitivity and adaptive capacity of the system (new paradigm). Unlike IPCC 2007 framework, indicators representing exposure (to hazard) are not selected while assessing vulnerability under IPCC 2014 framework.

2.3. The change in vulnerability paradigm

In the context of risk management, two major changes are noted in the way the concepts of exposure and vulnerability are understood in the 2007 and 2014 IPCC reports. Firstly, exposure is defined in the third

Table 1. Comparison between IPCC 2007 and 2014 Frameworks to understand the changes in the conceptualization and assessment of vulnerability (Table source: adapted from Sharma *et al* 2018).

IPCC 2007 Report (Old Paradigm)	IPCC 2014 Report (New Paradigm)
Vulnerability (V) components: a. Exposure (E) a. Sensitivity (S) a. Adaptive capacity (AC)	Vulnerability (V) components: a. Sensitivity (S) a. Adaptive capacity (AC)
E represents disturbance dosage from a climatic hazard (H)	E represents presence of a vulnerable system at a location where harm is experienced if hazard occurs.
Occurrence of H is subsumed in E	H is a co-factor with E and V that interact and cause Risk.
Exposure is an external factor to a system	E gets associated with the system as its spatial attribute. However, E is presented separate from V in the overall Impact-Risk Framework.
Exposure and the adverse affect(s) it causes on the system are central to the status of vulnerability	The status of the present internal state of system is central to the status of vulnerability
Vulnerability is assessed using indicators for E, S and AC	Vulnerability is assessed using *hazard-relevant* S and AC indicators. Refer to section 3.2.
Vulnerability is the impact realized after the first order (potential) impact caused by the exposure due to the sensitivity of the system is moderated by its adaptive capacity	Vulnerability is a system property determined by its sensitivity and adaptive capacity. It is the propensity of a system to be adversely affected
The 2007 definition prompts an assessment approach that is closer to the 'end point' approach (Kelly and Adger 2000). Once adaptation is applied to the vulnerability assessed using the 2007 definition, the residual vulnerability is referred as 'Outcome Vulnerability'	The 2014 definition leads to the 'starting point' approach (Kelly and Adger 2000) for vulnerability assessment and represents 'Contextual Vulnerability'.

assessment report (TAR 2005, WG II, Glossary) as 'the nature and degree to which a system is exposed to significant climatic variations'. IPCC 2007 report does not include a definition for exposure. Earlier to IPCC 2014 report therefore, exposure is understood as an external stress that drives vulnerability. Definition of exposure thus includes hazard up to 2007 report (Jurgilevich *et al* 2017). The IPCC 2014 report defines exposure as 'the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected'. This definition imparts spatial connotation to exposure i.e., location of the system at a place where a hazard occurs and causes adverse impact. Thus exposure is understood as a 'spatial concept' in the 2014 report compared to the 'driver perspective' attributed to it in the 2007 and earlier reports (Jurgilevich *et al* 2017).

Secondly, in the 2007 report, vulnerability is understood as a function of exposure, sensitivity and adaptive capacity. Exposure therein practically stands for external stress e.g., a climatic hazard. However, in the 2014 report, exposure is separated from vulnerability and is about 'presence of a vulnerable system at a location that could be adversely affected'. Hazard is shown as the third co-factor, along with exposure and vulnerability, that causes risk. Thus vulnerability is shown as not dependent on exposure (and hazard). It however gets manifested as adverse impact when a vulnerable system is exposed to a hazard. The repercussion of the abovementioned changes for conceptualization and assessment of vulnerability is presented in table 1 through a comparison between the two constructs.

3. Operationalizing the concept of vulnerability under the 'new paradigm'

3.1. Conceptualization of vulnerability for assessment

The IPCC 2007 report conceptualized vulnerability as the adverse impact after a system is exposed to a hazard. Accordingly, exposure, the third component of vulnerability, is directly accounted for by selecting appropriate indicators to assess and operationalize vulnerability. Comparatively, the IPCC 2014 report considers vulnerability as a pre-existing state, which is assessed without selecting indicators for exposure (to hazard). This is akin to assessing vulnerability as 'contextual' (O'Brien *et al* 2007) or 'starting point' vulnerability (Kelly and Adger 2000). Thus adopting IPCC 2014 report, assessment of vulnerability practically assesses the current system weaknesses and its lack of capacity to deal with the adverse impacts from exposure to a hazard.

3.2. Operationalizing vulnerability through assessment

At the outset, we note that vulnerability is a theoretical concept (Hinkel 2011). Further, vulnerability and its constituting components (adaptive capacity and sensitivity) are internal, non-observable and non-measurable properties of a system (Downing *et al* 2001, Hinkel 2011). Vulnerability is operationalized during its assessment by employing appropriate proxy indicators and their measurable parameters for its components. Functionally, vulnerability is related directly with sensitivity and inversely with adaptive capacity i.e., it increases with increasing sensitivity and decreasing adaptive capacity.

According to IPCC (2014, WGII, Glossary) adaptive capacity is 'the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences'. Such ability is granted to a system by its strength-attributes. For example, biological richness makes a forest ecosystem resilient, availability of irrigation facility or higher crop diversity makes agriculture systems robust, and, availability of insurance hedges communities against crop failure. Such system attributes provide it the capacity to respond to and overcome adverse impacts. However, it is the lack of adaptive capacity that contributes to vulnerability and therefore the indicators are parameterized accordingly. For example, lack of adaptive capacity can potentially be indicated by the lack of crop insurance facility to a farming community parameterized as the number (percent) of farmers without crop insurance backup.

The second component of vulnerability is sensitivity. According to IPCC (2014, WGII, Glossary) sensitivity is the 'degree to which a system or species is affected, either adversely or beneficially by climate variability or change. The effect may be direct (e.g., change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)'. According to this definition, sensitivity is the 'degree to which a system or species is affected…'. This implies that sensitivity of a system operationalizes through a 'cause-effect' or 'dose-response' mechanism. While cause (dose) is exposure to a hazard, effect (response) is sensitivity. However, sensitivity considered in the vulnerability construct is only the first order impact caused by a dose of exposure to hazard. Such first order impact is countered and reduced by the adaptive capacity of a system, and the manifested impact is lesser. Vulnerability is equal to this reduced impact.

The attributes that make a system weak are identified as sensitivity indicators e.g., high ground slope of a farmland or marginalization of households in a community. Such attributes predispose a community system to higher adverse impacts in case of exposure to a hazard. Thus, while inherent strengths represent and boost adaptive capacity of a system, inherent weaknesses represent and increase its sensitivity. The indicators for sensitivity are accordingly selected to operationalize vulnerability. The framework approach for assessment of vulnerability adopting IPCC 2007 and 2014 definitions is presented in figure 2.

3.3. Selecting 'hazard-relevant' indicators for assessment

As discussed above, under the new paradigm, vulnerability is conceptualized as not dependent on (exposure to a) hazard. However, for vulnerability reduction under climate change, systems are considered in the context of a single or multiple hazards. Thus practically vulnerability is always assessed with reference to a hazard. Selecting 'hazard-relevant' sensitivity and adaptive capacity indicators makes it feasible to assess 'hazard-specific' vulnerability. For example, to assess the vulnerability of traditional coastal fishing communities to sea surge, 'distance of dwellings from sea' and 'elevation of dwellings from sea level', which are system properties, are hazard-relevant sensitivity indicators. These indicators however, would not be relevant to assess their vulnerability to modern mechanized fishing. Similarly, 'lack of irrigation' is a hazard-relevant indicator to assess the drought vulnerability of farming communities, however this indicator is not relevant to assess their vulnerability to unseasonal rainfall.

It is easy to see from the above that reply to the question, vulnerability to what, is answered under the 'new paradigm' through hazard-specific vulnerability assessment by selecting hazard-relevant indicators for sensitivity and lack of adaptive capacity. Results of such hazard-specific assessments are contextual and practical. Contextualizing vulnerability assessment and linking it directly to an anticipated hazard enhances the value and acceptability of assessment for stakeholders. It helps by strengthening the perception of relevance of such assessment for them. This endorses the utility of the results of assessment and boosts the confidence of stakeholders to plan and undertake vulnerability reduction measures.

3.4. Application of 'hazard-specific' vulnerability for risk reduction

Dealing with the risk involves management of three factors (i.e., Hazard, Exposure and Vulnerability) that give rise to it. Occurrence of a climatic hazard such as an event of cloudburst or a long spell of drought cannot be altered. Climatic hazards have no manageability with regard to their occurrence at least in the short term. However, over the long term, their occurrence and or intensity may be reduced in case efforts to contain global warming are successful. Exposure is understood as a spatial concept under the 2014 report. Thus, to manage exposure, system-portability is vital. For example, forests are non-portable systems and therefore offer no manageability of exposure.

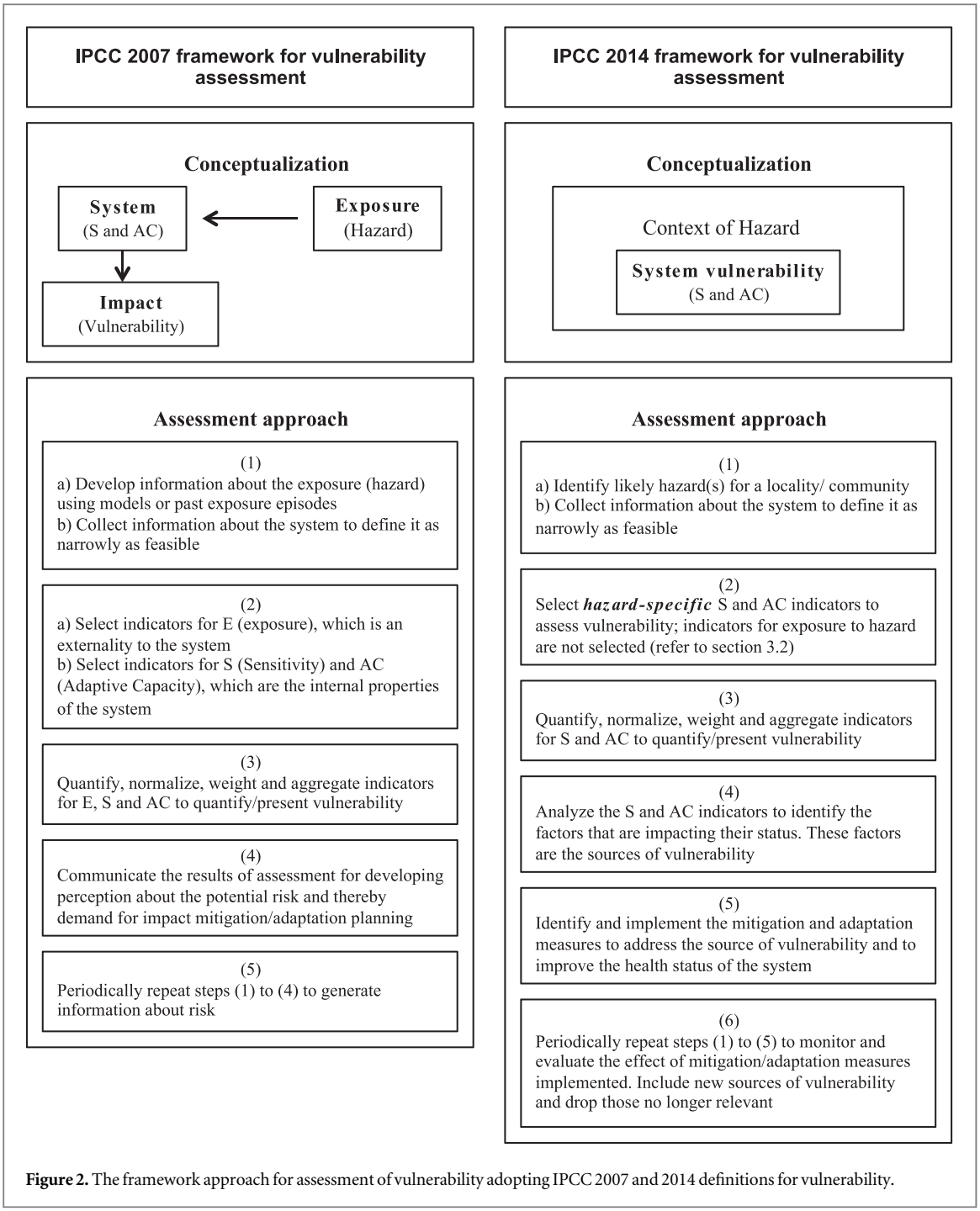

Figure 2. The framework approach for assessment of vulnerability adopting IPCC 2007 and 2014 definitions for vulnerability.

However, exposure to flood can be reduced for a community living in the flood plain of a river by either moving them away from the flood plain or modifying their dwelling houses by providing stilted-dwellings. Such manageability of exposure provides options to reduce risk. The third co-factor causing risk i.e., vulnerability, which is system-based property and can be treated and reduced, holds largest potential for managing risk.

Further, policy makers, practitioners and other stakeholders want to reduce risk from the major climatic hazard(s) at a locality. This entails undertaking vulnerability assessment to so identified hazard(s). Further, it is seen that a given region is either prone to drought or flooding, and rarely both. Thus it is practical to assess 'hazard-specific' vulnerability rather than assessing general vulnerability or combined vulnerability to all probable hazards. It is particularly so in view of the limited availability of resources for carrying out the assessment. Further, outcome of a 'general' or 'multiple-hazard' vulnerability assessment is likely to distort the prioritization of the vulnerability reduction measures for managing risk.

As discussed in section 3.2, assessment of 'hazard-specific' vulnerability under the new paradigm informs about the 'hazard-relevant' indicators/drivers of vulnerability. Addressing such drivers potentially improves the

internal state or inherent resilience ability of the system. It thus reduces the predisposition to adverse impacts by reducing the sensitivity of the system and building its capability to resist and adjust under exposure from an external stress (hazard). For example, managing anthropogenic pressure can regenerate a forest that has degraded under such pressure. The regenerated and restored forests with richer biodiversity and multi-tiered forest canopy structure show higher resilience under external stresses (Thompson *et al* 2009). Similarly, improving literacy rates and reducing the incidence of poverty among households reduce their vulnerability under climate change. Addressing the drivers of vulnerability informed by 'hazard-specific' vulnerability assessment that is anchored in improving the current internal state (system health) of a system is practical, robust and actionable for risk reduction of natural as well as social systems under climate change.

4. Assessment under the 'new paradigm' is robust and practical

The 'new paradigm' adopts 'starting point' approach to assess vulnerability, while the 'old paradigm' assesses vulnerability as the impact of an anticipated hazard. Assessment under the 'old paradigm' directly accounts for exposure (to a hazard) by selecting indicators for exposure. Thus under the 'old paradigm', the assessment team essentially has to start with defining hazard in terms of its nature and intensity. Information that enables characterization of a future hazard is sourced either from the data from past hazard occurrence (Sharma and Patwardhan 2008) or from models (Metzger *et al* 2006, Lung *et al* 2013). However both sources, past hazard-based and model-based information, at best enable an approximation of the anticipated hazard and thus involve uncertainty. Such uncertainty is avoided under the 'new paradigm', as indicators for exposure to hazard are not employed to assess vulnerability. Instead, as discussed in section 3.2, hazard-relevant indicators for sensitivity and lack of adaptive capacity are employed. From this fundamental difference in the approach to assess vulnerability under the two paradigms, it is seen that vulnerability assessment adopting the 'new paradigm' is distinctly advantageous over the 'old paradigm' for reducing vulnerability in actual life. Such advantages include the following.

(a) 'Old paradigm' considers a system in the aftermath of a hazard occurrence, when the opportunity to reduce vulnerability is limited to addressing the impact(s) of hazard. However, the 'new paradigm' considers a system in anticipation of a hazard thus enlarging the scope for reducing vulnerability to both, before and after hazard occurrence.

(b) Unlike the 'old paradigm', the focus under the 'new paradigm' is on the system and not on the impact(s) of hazard on the system. This provides for treating the system weaknesses and thereby restoring its potentially best-resilient internal state. This is particularly advantageous in case of natural systems such as forests and oceans, as otherwise their scale and spontaneity permit limited scope for human assisted adaptation.

(c) As the adaptation measures identified by adopting the 'new paradigm' are based in addressing the current weaknesses of a system and stresses impacting it, that the scope for maladaptation is minimized. However, the assessment results obtained by adopting the 'old paradigm' involve uncertainty associated with (exposure to) hazard data making maladaptation more likely.

(d) Under the 'new paradigm', it is the current status of the health of a system and the factors impacting it that are in focus, and as both these can be demonstrated to and appreciated by the stakeholders, that the assessment easily becomes participatory and hence acceptable, reliable and actionable.

(e) Vulnerability assessment adopting the 'new paradigm' (starting point approach) is more useful as compared to that carried out adopting 'old paradigm' or the 'end point' approach, as '… due to uncertainties in the climate scenarios, climatic effects on sectors, and future socio-economic conditions, it becomes practically impossible to formulate specific climate change adaptation policies' (O'Brien *et al* 2004).

(f) The 'new paradigm' offers a ready opportunity for benchmarking the current status of a system of interest that may be under the risk from climate change.

(g) Restoring and strengthening the health of a system by addressing the sources of vulnerability identified by adopting the 'new paradigm' is a 'no regrets policy', as higher system performance is achieved whether or not there is threat from climate change.

5. Conclusion

The 'new paradigm' presented by the IPCC 2014 report to understand vulnerability as an internal property of a system enables assessment of 'hazard-specific' vulnerability by selecting 'hazard-relevant' indicators for

'sensitivity' and 'adaptive capacity'. Such assessment offers more fundamental treatment of vulnerability and is practically more useful, as the results of assessment and the indicators selected to assess vulnerability can be analyzed to identify the drivers of vulnerability. Addressing the drivers of vulnerability offers a reliable approach to reduce the current vulnerability and manage potential risk(s). Under climate change, strengthening the health status of a natural or social system to enhance its resilience potential is a robust and field-based approach, whether or not there are climatic and/or non-climatic impacts.

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ORCID iDs

Jagmohan Sharma https://orcid.org/0000-0002-4852-0115
Ravindranath Nijavalli H https://orcid.org/0000-0003-2937-368X

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