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VULNERABILITY: A NOTE ON THE CONCEPT, MEASUREMENTS AND APPLICATION IN INDIAN AGRICULTURE

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ABSTRACT

Vulnerability is conceptualised in the academic discourse to assess the degree to which a system is exposed, sensitive and resilient to harm. The conceptualisations of vulnerability are classified in to broad research traditions. While the research on vulnerability has significantly progressed in terms of conceptualisation as well as measurement, the paper observes that a universal measure continues to be elusive. Recent studies from the Economics research tradition have made significant contributions in capturing the issues that are central to the contemporary agrarian question.

Keywords : Vulnerability, adaptation, conceptualisations, agrarian question, Indian Agriculture.

Introduction

Global climate change is a broad phenomenon manifesting through a wide range of events across the planet. The temporal and spatial dimensions of these events are not uniform across the world (Trenberth et al 2007). The variations, in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on various temporal and spatial scales beyond that of individual weather events, are referred to as climate variability (IPCC 2013). The frequency and severity of extreme events and variability in weather patterns are projected to increase as the planet warms (Trenberth et al, 2003; Thornton 2014, Pendergrass et al, 2017). They are the preliminary manifestations through which populations and systems experience the long term change in climate (Parry and Carter 1985; Kelly and Adger 2000). Especially, in the case of agriculture, climate variations on various timescales are observed to influence crop yield (Peng et al 2004; Porter and Semenov 2005; Naylor et al. 2007; Welch et al 2010; Rowhani et al 2011; Hatfield and Prueger 2015; Ray et al 2015) as well as the area and intensity of cultivation (Iizumi and Ramankutty 2015). In the case of Indian agriculture, majority of the farmers are small and marginal land holders; there is significant decline in the total as well as the average

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area owned; and this poses serious concerns regarding the viability of farming (Yadu and Satheesha 2016). Under a changing warming scenario, therefore, we cannot expect the Indian farmer to do undertake some beneficial adaptations autonomously (McCarthy et al 2001, cited in Thripathi and Mishra 2017). Continuous assessments of vulnerability of agriculture and farmers' livelihoods, are therefore imperative to identify the extent to which this sector is 'susceptible to or unable to cope with' climate variations on various temporal and spatial scales. This in turn requires the regular reviews of vulnerability frameworks and measures in such a way that universal and inclusive frameworks can be developed. With this objective, the present paper presents a brief overview of vulnerability studies, focusing the concepts, indicators and their applications in agriculture and rural development. Section 1 discusses the idea of vulnerability in the context of a coupled human-environment system, Section 2 Provides a review of vulnerability studies with regard to Agriculture, Section 3 highlights the methodologies used in vulnerability assessments for agriculture and rural livelihoods, and Section 4 analyses and concludes the discussion

Section 1: The Idea of Vulnerability

In the contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (McCarthy et al 2001), vulnerability is defined as 'the degree to which a system is susceptible to, or 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 variation to which a system is exposed, its sensitivity, and its adaptive capacity'. Here, exposure refers to 'the nature and degree to which a system is exposed to significant climatic variations'; sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a 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)'; and adaptive capacity is defined 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'. While this is one of the most comprehensive conceptual frameworks of vulnerability developed in the context of global climate change, it has been defined from various dimensions in studies belonging to various disciplines.

Vulnerability, in general, is the state of being exposed to the possibility of being harmed. Kelly and Adger (2000) define vulnerability in terms of the ability or the inability of individuals and social groupings to respond to, in the sense of cope with, recover from or adapt to, any external stress placed on their livelihoods and well being. They classify vulnerability studies in to those consider vulnerability as 'starting point', 'focal point', and 'end point'. In the conceptual

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frameworks which identify the likely sensitivities of a system in terms of limited capacity to respond to stress, vulnerability assessment is a potential 'starting point' of impact analysis. Studies following this approach defines vulnerability in terms of adaptive capacity. Yet another set of studies, especially those pertaining to famine and natural hazards set vulnerability as an overarching concept or a 'focal point'. Here, vulnerability is defined in terms of 'exposure to stress and crises, capacity to cope with stress, the consequences of stress and the related risks of slow recovery' (Bohle 1993, cited in Kelly and Adger 2000). Finally, there are studies that consider vulnerability assessment as the 'end point' of impact analysis. In such studies involve a sequence of analysis beginning with projections of future emission trends, development of consequent climate scenarios, analysis of biophysical impacts under the projected scenarios and the identification of adaptive options. At the end stage, if any residual consequences remain, they constitute vulnerability. The definition given by Kelly and Adger (2000) consider vulnerability assessment as the starting point of the impact analysis and the definition in McCarthy et al 2001 approaches vulnerability as the end point of impact analysis.

Fussel (2007) presents a generally applicable conceptual framework of vulnerability that combines a nomenclature of vulnerable situations and a terminology of vulnerability concepts based on the distinction of four fundamental groups of vulnerability factors and characterizes the vulnerability concepts employed by the main schools of vulnerability research. According to him, the generally applicable conceptual framework for vulnerability assessment therefore spans six dimensions; Temporal reference (current vs. future vs. dynamic), Sphere (internal vs. external vs. cross-scale), Knowledge Domain (socioeconomic vs. biophysical vs. integrated), Vulnerable System, Attribute of Concern, and Hazard. Here, household income, social networks, access to information etc. constitute 'Internal Socioeconomic' category while national policies, international aid, globalisation etc come under the 'External Socioeconomic' category. Similarly, topography, environmental conditions and land cover belong to 'Internal Biophysical category' while storms, earthquakes and sea level change come under 'External Biophysical' category. Accordingly the existing approaches to vulnerability are classified as follows.

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Table 1: Classification of Approaches to Vulnerability

Approach	Vulnerability Factors				Denotation
	IS	IB	ES	EB	
Risk hazard	-	X	-	-	Internal Biophysical
Political Economy	X	-	?	-	Cross-Scale Socioeconomic
Pressure and Release	X	X	-	-	Internal Integrated
Integrated	X	X	X	X	Cross-scale Integrated
Resilience	X	X	?	?	Cross-Scale (?) Integrated

Source: Fussel 2007. Abbreviations: IS - internal socioeconomic, IB - Internal Biophysical, ES - External Socioeconomic, EB - External Biophysical. A question mark indicates that it is not clear whether a particular vulnerability factor is included in the respective conceptualisation of vulnerability.

A vulnerable situation, according to Fussel 2007, is characterised by vulnerability of a system's attribute(s) of concern to a hazard with a specific temporal reference. In the specific case of climate change, the vulnerability of a region depends on the type and magnitude of regional climate change, sensitivity to regional climate change, importance of climate-sensitive activities, and the ability of the region to cope and adapt (Fussel 2010 cited in Fussel 2012).

In the case of Economics literature, the conceptualisation of vulnerability is not as developed as in the case of climate change literature. However, the core of vulnerability frameworks in climate change literature significantly owes to concepts in Economics. Kumar et al (2007) analysed 'vulnerability' used in the 'poverty' literature with the conceptualisations in the climate change vulnerability literature. According to them, while economic analysis generally put great emphasis on measurability, in the case of vulnerability this requirement is not balanced by an equally strong focus on conceptualisation and the development of analytical frameworks. In the context of 'poverty', the references to vulnerability are broadly identified as vulnerability to poverty, vulnerability as a symptom of poverty, vulnerability as part of the multi-dimensional nature of poverty, and vulnerability as an outcome of poverty (Prowse 2003).

While the vulnerability to poverty, which is the most commonly used conceptualisation in Economics literature, and vulnerability to climate change are ex-ante measures attempting to provide useful insights about scenarios of the future, they differ significantly in the focus, spatio-

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temporal dimensions of the framework (Kumar et al 2007). Both approaches analyse the externalities, or the changes in social, economic, political or environmental processes and the changes therein, that expose people into poverty or to climate change and pull them back from them. For example, McCulloch and Calandrino (2003) involves a similar discussion wherein vulnerability is defined as the probability of being below the poverty line in any given year. The study observed that 30 percent of the households fell below the lower consumption poverty line at some stage and a majority of them stayed there for one or two years only. However, those who experienced consecutive experience of poverty for longer years may lose their ability to exit from it. Here, poverty and vulnerability gets the notion of transient phenomena when the analyses are in terms of 'means' of human welfare and those studies that analyse vulnerability in terms of outcomes or 'ends' of human welfare or in terms of those factors that limit their ability to escape from poverty can reflect chronic poverty and vulnerability[1].

The second one, 'vulnerability as a symptom of poverty' considers vulnerability as a cause and consequence of poverty. Here, the mutually reinforcing nature of vulnerability-poverty nexus is emphasised. In the third category, 'vulnerability as a part of the multi-dimensional nature of poverty' considers vulnerability as "part of an expanded poverty concept"[2] and in the fourth one, vulnerability is an outcome of poverty.

Kumar et al (2007) makes certain comparisons between 'vulnerability to poverty' and 'vulnerability to climate change'. In vulnerability to poverty, the outcome is specific while the shocks contributing to the outcome is not specific. On the other hand, shocks are specific in climate change literature while the outcome of the shock on the entity is not specific. Poverty analysis is mainly concerned with household level vulnerability while climate change analysis is conducted at regional as well as national scales. The temporal scale of poverty is short while that of climate change vulnerability is longer. However, apart from these differences, Kumar et al 2007 identified significant similarities between the vulnerability metrics of both streams and argue that these two streams can be linked by introducing the notion of sensitivity.

The recent literatures in Economics involve significant discussions about adaptive capacity to climate variability, extreme events and long term changes. Castells-Quintana et al (2018) focusses on the adaptation gaps across various sections of society even when while the socio-economic impacts of weather remains the same. According to them, adaptation to climate change happens at two intertwined dimensions. At one level, it involves making the existing space or sector more resilient and on another level it involves migration across spaces and sectors. Poor people and regions are more exposed to the manifestations of climate change and they often miss beneficial adaptation options because of informational and institutional constraints, infrastructure

[1] Prowse 2003 discusses the notions of transient and chronic poverty in the analyses of 'vulnerability to poverty'

[2] Morduch 1994

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bottlenecks, the smaller scale of economic activity, aversion to experimentation from precarious livelihoods and lack of credit and financial services.

Vulnerability is a concept analysed in multiple dimensions and research contexts. As such it is constructed and operationalised according to the research tradition, knowledge domain, study objectives, subject under consideration etc. This has led to the emergence of a multitude of studies with diverse methods and variables. As the conceptual understanding of vulnerability evolves, these common threads and dimensions are observed as getting accepted across knowledge domains. However, though the broader frame remains the same, assessment measures and methods continue to remain different. Despite the diversity in measurement and reading, the vulnerability assessments have produced observations that are consistent across various research traditions. Still, the development of all encompassing concepts, integrated analytical frameworks and representative indicators are yet to evolve.

Section 2: Methodologies Adopted in Vulnerability Assessments

The diversity in the conceptualisation of vulnerability is visible in the measurement methodologies as well. This section broadly discusses certain measures used in some of the major vulnerability traditions. Kelly and Adger (2000) discusses the operationalisation of their definition based selected characteristics of vulnerability and their assessment (from Adger and Kelly 1999).

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Vulnerability Indicator	Proxy for:	Mechanism for translation in to vunerability
Poverty	Marginalisation	Narrowing of coping or resistance strategies; less diversified and restricted entitlements; lack of empowerment
Inequality	Degree of collective responsibility, informal and formal insurance and underlying social welfare function	Direct: concentration of available resources in smaller population affecting collective entitlements Indirect: inequality to poverty links as a cause of entitlement concentration
Institutional Adaptation	Architecture of entitlements determines resilience; institutions as conduits for collective perceptions of vulnerability; endogenous political institutions constrain or enable adaptation	Responsiveness, evolution and adaptability of all institutional structures

Source : Kelly and Adger (2000)

The assessment was carried out with quantitative as well as qualitative surveys. However, they did not attempt to quantify it in to some composite index as (a) the then understanding was insufficient to reliably identify the processes that determine vulnerability; (b) the possibility that factors that cannot be readily quantified will be neglected and (c) the links between factors that may influence vulnerability and the overall level of vulnerability in a community were not well established (Kelly and Adger 2000).

In the most generalised form, vulnerability to climate change can be expressed as in Luers 2005; Adger 2006; Kumar et al 2007.

$$V^{cc} = \sum_{i} \beta \Big/ {}^{y}_{y_0}{}^{i} \; p_i$$

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Where the numerator (β) represents the sensitivity, the denominator represents the outcome of interest relative to the threshold, and pi is the probability of i th state or exposure to stress. Further, Adger 2006 suggests certain preconditions for a generalised measure for social vulnerability. (a) A vulnerability measure focusing on human well-being should incorporate material aspects and outcomes of vulnerability that lies beyond income; (b) the nature of vulnerability, whether it is transient or chronic must be accounted for; (c) The measure should capture the distribution of vulnerability within the vulnerable system. As such a generalised measure satisfying these criteria is provided. It is broadly based on Foster et al 1984.

$$v_{\alpha} = \frac{1}{n}\left[\sum_{i=1}^{q}\left(\frac{w_0 - w_i}{w_0}\right)^{\alpha}\right]$$

Where Va is the vulnerability indicator, Wi the well-being of individual i; W0 the threshold level of well-being representing danger or vulnerability; n the total number of individuals (whether households, farms, settlements or whatever); q the number of individuals above the vulnerability threshold; a the sensitivity parameter and individuals are ordered from bottom to top (W1 is more vulnerable than W2and so on).

Hahn et al 2009 devised a livelihood vulnerability index consisting of Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Water (W), and Natural Disasters and Climate Variability (NDCV). Each component comprised of several indicators or sub-components. The subcomponents measured in different scales were standardised individually and averaged together to calculate the value of each major component. Once values for each of the seven major components for a district were calculated, they were averaged and a district level livelihood vulnerability index was obtained.

$$LVI_d = \frac{w_{SDP}\,SDP_d + w_{LS}\,LS_d + w_{SN}SN_d + w_H H_d + w_F F_d + w_W W_d + w_{NDCV}NDCV_d}{w_{SDP} + w_{LS} + w_{SN} + w_H + w_F + w_W + w_{NDCV}}$$

.

Where, LVI d is the Livelihood Vulnerability Index for district d and is the the weighted average of the seven major components. The weights of each major component, w, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI. the LVI ranges from 0 (least vulnerable) to 0.5 (most vulnerable).

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Varadan and Kumar (2014) constructed an Agricultural Vulnerability Index (AVI) wherein the study basically belong to the 'end point' tradition of vulnerability assessment. Here, exposure and sensitivity were analysed in terms of growth (G) and instability (I) in South West (SWM) and North East Monsoon (NEM) rainfall as well as resultant instability in area and yield of major crops respectively. Adaptive capacity was analysed in terms of growth in area, yield, cropping intensity (CI), crop diversification (CD) and net cultivated area (NCA). The indicators were measured using various methods of indexing and were normalised. Weights (Σwi) were assigned to the districts for each crop based on its proportional acreage with respect to the state and the component indices of exposure, sensitivity and adaptive capacity were summed up to arrive at the composite vulnerability index.

$$AVI_i = 1\times G(SWM) + 1\times G(NEM) + 1\times I(SWM) + 1\times I(NEM)$$
$$+ \sum_{Wi} \times G(area\ of\ crop) + \sum_{Wi} \times G(yield\ of\ crop) + \sum_{Wi} \times I(area\ of\ crop)$$
$$+ \sum_{Wi} \times I(yield\ of\ crop) + 1\times G(CD) + 1\times G(NCA) + 1\times G(CI)$$

What is evident from the above presented methods is that there is significant differences in the method of measurement as well as choice of indicators even when the studies follow same conceptualisation. The generalised vulnerability measure of Luers (2005); Hahn et al (2009); and Varadan and Kumar conceptualise vulnerability as a function of exposure, sensitivity and adaptive capacity following McCarthy et al 2001. However, the components, indicators and measures significantly differ based on study objective as well as knowledge domain. The method presented in Kelly and Adger 2000 on the other hand belong to a different research tradition.

Section 3 : Vulnerability Assessments on Agriculture in India

Agriculture is the single largest livelihood provider in Indian economy accommodating nearly half of the nation's workforce. Agriculture contributes 17 per cent of the GVA; it is largely dependent on climatic conditions and is characterised by the predominance of small and marginal farmers (Government of India, 2015)**.** The existence and growth of this sector has important implications on poverty, employment, food security and nutritional status of the population. However, the declining size of land holdings seriously affect the viability of farming and those who are dispossessed of their agricultural land find refuge in the growing informal sector where a decent job is hard to find (Yadu and Satheesha 2016). This section examines the extent to which the vulnerability studies capture the contemporary agrarian question.

The agrarian question in India has been discussed in a wide variety of contexts (Patnaik 1986; Vaidyanathan 2006; Lerche 2011; Yadu and Satheesha 2016). However, vulnerability studies in general approach agriculture in terms of the hazards they refer to or the crop specific responses

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they assess. As a result, some of them are limited to the cases of crop yields, plant growth process and adaptation in a warming climate scenario etc (Byjesh et al 2010; Ravindranath et al 2011; Murthy et al 2015; Varadan and Kumar 2015). These studies generally belong to the cross scale biophysical category. On the other hand, there are other studies that has a broader view of vulnerability. They consider the case of farmers livelihoods by incorporating the socioeconomic situations and farm level responses as proxy for adaptive capacity (O'Brien et al 2004; Brenkert and Malone 2005; Panda 2015; Rao et al 2016; Shukla et al 2017; Sam et al 2017). They broadly belong to cross scale integrated category. Similarly there studies that emphasis on development interventions, adaptive capacity and resilience in a changing climate scenario (Patnaik and Narayanan 2009; Bahinipati 2014; Patnaik and Das 2017; Patnaik et al 2017). While these studies generally belong to the cross scale integrated category, they project the dimension of adaptation as a temporal process. All these studies, in some way or the other, subscribe to the generally applied conceptual frameworks and/or measurement methods.

Among the cross scale biophysical category, Byjesh et al (2010) in their vulnerability assessment of maize yield, used a generic crop growth model, InfoCrop, that can simulate the effects of weather, soil, agronomic managements (including planting, nitrogen, residue and irrigation) and major pests on crop growth and yield. The model was adapted simulated for assessing the vulnerability of rainfed maize to climate change. Ravindranath et al (2011) is a study on North Eastern States of India focusing on agriculture, forest and water vulnerability in the region. Interestingly, it considered number of agricultural land holdings less than 2 hectares and rural population density as factors exposing agriculture to climate change and share of area under rainfed crops as the sensitivity factor. Murthy et al (2015), in their study on Haryana, used the mean and CV of rainfall and rainy days from time series data along with drought frequency to assess the exposure while sensitivity was examined using derivatives from times series NDVI (a satellite derived Normalised Difference Vegetation Index which is widely used for crop/vegetation monitoring, crop discrimination, stress detection and crop yield estimation.)—range, CV and drought frequency, based on standardised NDVI—were used to represent sensitivity component. Adaptive capacity was assessed in terms of soil and ground water quality. Varadan and Kumar (2015) considered the growth and instability in Southwest and North East Monsoon rainfalls to represent the exposure, instability in the area and yield of major crops for sensitivity, and Growth in the area, yield, crop diversification, net cultivated area and cropping intensity for adaptive capacity. The study, instead of ranking, categorised districts on the basis of exposure, sensitivity and adaptive capacity. This, in turn, revealed certain aspects that are significant to the idea of vulnerability. That is highly vulnerable districts need not be the highly exposed or highly sensitive ones. This sort of an observation helps to prioritise policy based on location-performance-vulnerability based adaptation strategies.

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In the case of cross scale integrated studies, O'Brien et al (2004) considered vulnerability to climate change along with an additional stressor (globalisation) asserting that vulnerability of a region or a system to a particular stressor does not exist in isolation to other stressors. Adaptive capacity is measured in terms of certain biophysical, socioeconomic, and technological factors that influence agricultural production. Apart from the biophysical factors, socioeconomic factors such as levels of human capital (adult literacy rates) and social capital (degree of gender equity), the presence or lack of alternate economic activities (Presence of alternative economic activities is measured by the percentage of the district workforce that is employed in agriculture and by the percentage of landless laborers in the agricultural workforce.), availability of irrigation[3] and quality of infrastructure were included in the measurement of adaptive capacity. Incorporating globalisation as an additional stressor, the study focused on exposure to import competition assuming that import competition represented a greater and immediate threat to Indian agriculture. The ensuing import sensitivity map takes into account cropping patterns and productivity of a representative basket of crops that may be subject to competition from imports, and the distance of the district to the nearest international port. It is an 'end point' analysis of vulnerability wherein more focus is given to the factors to which a system is exposed. In Brenkert and Malone (2005), vulnerability in terms of responses to exposure (sensitivity) and coping and adaptive capabilities of the society. Adaptive capacity was measured in terms of Per capita GDP, dependency ratio, literacy, population density, air quality and other stresses on ecosystems and percentage of land unmanaged. Sensitivity was examined in terms of flood risk, access to water and sanitation, cereal productivity, per capita protein consumption, ecosystem sensitivity, fertility and life expectancy, water resource sensitivity. This is a 'starting point' analysis wherein vulnerability is measured in terms of sensitivity and adaptive capacity to the stresser. The findings of these studies are also contrasting in accordance with the differences in the orientation and methodology. O'Brien et al (2004) observed that the agricultural sectors of Rajasthan, Gujarat, Madhya Pradesh, as well as in southern Bihar and western Maharashtra as simultaneously vulnerable to globalisation and climate change while Brenkert and Malone (2005) found the coastal states as more vulnerable than the inland states. Panda (2015) brought in a set of socioeconomic variables and the perception of farmers regarding climate change in the measurement of vulnerability. Percentage of people who have agriculture as the sole means on income, average crop diversity index, poverty, indebtedness and dependency and perception regarding impact of drought represented sensitivity of the region while farmers autonomous adaptations at the farm level, increases in non farm income represented the adaptive capacity. Here, while subscribing to the IPCC system of definition, the study has a set of socioeconomic variables including the perceptions of farmers that define their vulnerability. Rao et al (2016) is a cross scale integrated approach to vulnerability wherein adaptive capacity is measured in terms

[3] Irrigation rates are measured by net irrigated area as percentage of net sown area.

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of percentage of rural poor, percentage of SC/ST in total population, gender gap, literacy, market access, rural infrastructure, net irrigated area, fertilizer consumption, ground water availability, Density of livestock population and share of agriculture in the district domestic product. Shukla et al (2017) is an 'end point' analysis of vulnerability wherein adaptive capacity was measured by socio-economic and infrastructural factors. Socio-economic capacity was measured in terms of literacy rate and urban population. Infrastructural capacity was measured in terms of net irrigated area, medical facilities and road facilities. Sensitivity factor incorporates demographic pressure on agriculture as well. Sam et al (2017) examined the vulnerability of rural households of Odisha to drought using Livelihood Vulnerability Index (LVI) and Socioeconomic Vulnerability Index (SeVI). The study used dependency ratio, percent of female-headed households, percent of illiterate household heads, percent of backward caste households, Housing structure index, livelihood diversification, dependency on agriculture, households without migrant members, livestock and durable assets, assistance from self help groups, access to credit, health issues, access to hospital, health insurance, health expenditure, access to water resources, food security, drought induced crop yield reduction and peoples' observation about temperature and rainfall changes to capture the vulnerability. The study was broadly on the rural people's vulnerability and not limited to the vulnerability of farmers. While the study considers the impact of drought on households' health, farm output, their dependency on farm output and their perspectives on drought, it equally considers the role of socio-demographic profile, livelihood strategies and social networks in deciding the role of vulnerability of the households.

Patnaik and Narayanan (2009) assesses the socioeconomic context of vulnerability. Here, the overall vulnerability is a composite of demographic vulnerability, climatic vulnerability, agricultural vulnerability, and occupational vulnerability. The paper also looks at the linkages between vulnerability index, infrastructure index and extreme events occurring across the coastal districts of India. Vulnerability, in this paper, is an overarching concept and more importantly, the paper recognises the temporal dimensions involved in vulnerability by examining the linkages between extreme events, infrastructure index and vulnerability index of the study area. Bahinipati (2014) used population growth, dependency, percentage of female population, share of cultivators and agricultural labourers, death rate and infant mortality rate to measure sensitivity component and used poverty, per capita district domestic product employment, female work participation, Gini coefficient of land holding, area covered by irrigation, information, skills and infrastructure to measure adaptive capacity. Patnaik et al (2017) assessed the vulnerability of drought prone districts of Western Odisha using "Vulnerability as Low Expected Utility" approach. The study used per capita consumption as the dependent variable and represent the welfare of households which can measure their relative level of vulnerability. Per capita income and land ownership were used to represent the household level idiosyncratic risks. The beneficiaries and non-beneficiaries of WORLP, performance of villages, and household

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characteristics. The Per capita consumption, per capita income and land ownership was considered for the years 2000 and 2014. vulnerability was decomposed into poverty, aggregate risk, idiosyncratic risk and unexplained risk. Both aggregate risk and poverty were found to be the major sources of vulnerability, accounting for 87 percentage of the total vulnerability. Households that benefited from WORLP were observed to be less vulnerable, and they faced significantly less poverty and aggregate risk. Patnaik and Das (2017) examined the effects of WORLP (Western Orissa Rural Livelihoods Project) in enhancing the adaptive capacity and reducing the vulnerability of rural households in Bolangir District of Odisha, India. The study used proxies to capture the adaptation practices of the households to deal with the impacts of previous droughts. Socioeconomic characteristics of the households were examined through variables like households living below the poverty line, human development factors like caste, age, education, housing, health, etc. The existing livelihood practices are measured through agricultural production, input cost for crops, cropping pattern, income and consumption, sources of income, assets and migration. The study made certain significant observations with regard to the livelihoods in the Indian rural setting. First, it displays the temporal process in the adaptation or the changes that the development intervention brought about in the livelihoods and adaptive capacity of the population over time and the resultant outcomes with regard to their resilience to climate variability and extremes. Second, it highlights that the beneficial effects of WORLP trickled down only to the small and medium farmers and not to marginal farmers.

While the studies in cross scale biophysical category focused on the biophysical aspects of vulnerability in general, Ravindranath et al (2011) considered uneconomical land holdings, rural population density as having a direct relation with vulnerability. In the case of cross scale integrated studies O'Brien et al (2004) Brenkert and Malone (2005) Rao et al (2016) and Shukla et al (2017) considered social and human capital, lack of alternate economic activities, socioeconomic and environmental characteristics in their analysis. However, the focus of these studies was on regions rather than livelihoods. Having included Percentage of people who have agriculture as the sole means on income, average crop diversity index, poverty, indebtedness and dependency and perception regarding impact of drought represented sensitivity of the region while farmers autonomous adaptations at the farm level, increases in non farm income represented the adaptive capacity, the analysis of Panda (2015) inclined more towards livelihoods while Sam et al (2017) explicitly used the Livelihood Vulnerability Index (LVI) and Socioeconomic Vulnerability Index (SeVI) to assess the vulnerability of rural households of Odisha to drought. Both these studies incorporated variables that represents livelihood vulnerability of the households and involved primary surveys.

A paradigm shift can be observed in the methods and results of Patnaik and Narayanan (2009), Bahinipati (2014), Patnaik and Das (2017), and Patnaik et al (2017) wherein the temporal nature of adaptation is projected. As a result the studies were able to observe the effects of extreme

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events on vulnerability over time, influence of development interventions on the resilience and adaptive capacity of the people, the influence of land fragmentation, land inequality and landlessness, changes in the income and consumption expenditures etc. Patnaik et al (2017) considered the vulnerability of drought prone districts of Western Odisha using "Vulnerability as Low Expected Utility" approach in which income is taken as to differ across households contingent upon the risks and shocks witnessed in the preceding time-periods and land ownership was used to represent the level of exposure faced by the households besides embodying the resilience to a smaller extent. These variables were treated as the idiosyncratic risks at the household level. Patnaik and Das (2017) observed that development interventions confer adaptive capacity to small and medium farmers while the marginal and landless stands excluded.

Summary and Conclusion

In this work, we reviewed the generally applied conceptual frameworks, measurement methods and their application on the vulnerability of Indian Agriculture to Climate variability, climate change and natural hazards. This review was initiated in the context of growing farmer unrest across the country to examine the extent to which the generally applied conceptual frameworks and analyses capture the issues such as increase in the number of marginal and landless, resultant loss of viability of agriculture, limitations in livelihood diversification due to unrewarding opportunities in the rural non-agricultural sector, lack of access to institutional credit, sufficient insurance and a deserving market and price for the output. We observed that, while majority of the vulnerability studies follow the generally applied conceptual frameworks, the affiliation to various knowledge domains and orientation towards specific objectives makes significant differences in the measurement and outcomes of the studies. While it is important to recognise this diversity and the usefulness of studies from different perspectives (O'Brien et al 2007) the lack of consistency in the use and meaning of variety of concepts contributes to increasing confusion in the area (Panda 2009) and integrated or universally accepted measures are more important from a policy perspective. Similarly, we observed significant progress in the vulnerability research from biophysical to regional vulnerability and to livelihood vulnerability. Of late, the vulnerability studies on Indian agriculture has become more dynamic by incorporating the temporal nature of adaptation process, highlighting various issues that are important to the contemporary agrarian question, and more importantly by capturing and projecting how marginal farmers are left behind in development interventions. The significant improvements in the Economics literature with regard to vulnerability has been instrumental in bringing out the issues that are pertinent to the contemporary agrarian question in the context of climate change, climate variability, increasing frequency and severity of extreme events and natural hazards.

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