Vulnerability to Poverty and Vulnerability to Climate Change: Conceptual Framework, Measurement and Synergies in Policy

K.S. Kavi Kumar
Madras School of Economics
Gandhi Mandapam Road, Chennai – 600 025, India
Tel: +91-44-2235 2157, 22300304 / 7
Fax: 91-44-2235 2155, 22354847
E.mail: kavi@mse.ac.in

Richard J.T. Klein
Stockholm Environment Institute
Kräftriket 2B, 106 91 Stockholm, Sweden

Cezar Ionescu
Potsdam Institute for Climate Impact Research
P.O. Box 601203, 14412 Potsdam, Germany

Jochen Hinkel
Potsdam Institute for Climate Impact Research
P.O. Box 601203, 14412 Potsdam, Germany

and
Rupert Klein
Potsdam Institute for Climate Impact Research
P.O. Box 601203, 14412 Potsdam, Germany

WORKING PAPER 19/2007

August 2007

Price: Rs.35

MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

Phone: 2230 0304/ 2230 0307/2235 2157
Fax : 2235 4847 /2235 2155
Email : info@mse.ac.in
Website: www.mse.ac.in

Vulnerability to Poverty and Vulnerability to Climate Change: Conceptual Framework, Measurement and Synergies in Policy

K.S. Kavi Kumar, Richard J.T. Klein, Cezar Ionescu, Jochen Hinkel and Rupert Klein

Abstract

This paper attempts to compare the concepts and metrics related to vulnerability notion as used in the poverty literature with those in the filed of climate change. Such comparison could shed light on the understanding of the perceived and real differences between the two fields and also help to identify possible policy synergies between the climate change and poverty communities.

The analysis shows that while vulnerability concepts in both the disciplines are defendable, broader policy relevant statements about vulnerability could be made if the analysis clearly identifies three primitives introduced in Ionescu et al. (2006) – namely, the entity that is vulnerable, the stimulus due to which the entity is vulnerable, and the preference criteria on the outcome of concern.

The analysis shows significant similarities between the two fields in terms of vulnerability measurement. The link between the vulnerability metrics in the two fields can be established through the introduction of sensitivity notion. The analysis also shows that the vulnerability metrics in both fields demand a stricter restriction (namely, complete preorder) on preference criteria on the outcome(s) of concern.

The analysis identifies two issues that, if addressed, could create synergies between vulner-ability assessments in the climate change and the poverty communities. First, the climate change community could benefit from exploring a notion analogous to that of "poverty". In development policy, the notion of poverty enables one to recognise that there is a need to focus not only on peo-ple who are likely to become poor due to some exogenous input, but also on those who already are poor (and may become even poorer). Second, it would be interesting to explore the analogous concepts of "mitigation" and "adaptive capacity" in poverty research. Simi-lar to their use in climate research and policy, the analysis of these concepts could lead to the more explicit consideration of the multidimensional nature of both causes and outcomes of poverty, as well as of the multiple time scales on which these occur.

Key Words: Vulnerability; Poverty; Climate Change; Adaptation

JEL Codes: *I3, O1, Q25*

Acknowledgement

This paper is presented at WIDER Conference on Fragile States – Fragile Groups: Tackling Economic and Social Vulnerability, at WIDER, Helsinki, 15-16 June 2007. The authors would like to thank the conference participants for useful comments and Brinda Viswanathan, Maithili Ramachandran and V. Raghupathy for motivating discussions. This paper is a result of PIK and SEI joint project FAVAIA and substantial part of the work was completed during the first authors' visit to Potsdam Institute for Climate Impact Research in summer of 2006.

1.0 INTRODUCTION

In the development economics literature the term vulnerability is typically used in the context of poverty. As Kanbur and Squire (1999) summarize in their excellent survey on evolution of thinking about poverty, the induction of the vulnerability notion in the poverty debate has enabled the poverty reduction interventions to be pre-emptive. The World Development Report (WDR) in 2001 brought the notion to the forefront and triggered several scholarly articles on its measurement. While WDR (World Bank, 2001) defined vulnerability as a measure of resilience against shock, several studies that used the notion not necessarily defined it in similar manner. Compared to the relatively broad consensus that exists with regard to the definition and meas-urement of poverty (e.g., Sen, 1979; Foster *et al*., 1984; Atkinson, 1987), the notion of vulnerability is not only underdeveloped in the economics literature, it has been defined in too many different ways. There is a strong emphasis on measurement in the economics literature but in the case of vulnerability, this is not balanced by an equally strong focus on conceptualisation and the development of analytical frameworks. Consequently, as Alwang *et al.* (2001) argued, the economics litera-ture is an example of an empirically strong but conceptually weak strand amongst numerous disciplines analysing vulnerability.

Conceptual papers in economics dealing with the notion of vulnerability have emerged in recent years (*e.g.*, Moser, 1998; Dercon, 2001; Ligon and Schechter, 2003; Prowse, 2003). Over the same period vulnerability has be-come a familiar term in the climate change literature,

which has produced its own conceptual literature (*e.g.*, Jones, 2001; Brooks, 2003; O'Brien *et al.*, 2004; Füssel and Klein, 2006). Given these si-multaneous yet separate developments and the increasing calls in the climate change literature to learn from experiences in other fields, including development studies, it seems timely to compare the two notions of vulnerability. Such comparison should increase our understanding of the perceived and real differences between the conceptualisations of vulnerability when applied to poverty and to climate change, respectively. In addition, it could lead to the identi-fication of possible synergies between vulnerability assessments in the two fields. This is pre-cisely the motivation for this paper. Synergies are assessed with particular focus on measurement and policy perspective. Using generic metrics introduced in Cesar and Dercon (2005) and Luers *et al.* (2003) and Luers (2005) for vulnerability measurement in poverty and climate change fields, respectively, the paper tries to assess potential overlap. Further the scope for applicability of a common formal framework developed by Ionescu *et al.* (2006) is also explored.

The structure of the paper is as follows: Brief evolution of thinking about the concept of vulnerability in poverty and climate change literature, along with similarities and dissimilarities is presented in the next section. The third section introduces the metrics used for measuring vulnerability to poverty and vulnerability to climate change. The policy context of vulnerability in both literatures is then explored in the fourth section to identify syn-ergies across the two disciplines. Finally, the fifth section presents concluding remarks.

2.0 VULNERABILITY TO POVERTY AND VULNERABILITY TO CLIMATE CHANGE

Vulnerability is a forward looking notion as it refers to *potentiality* of something, often negative, happening. Vulnerability is assessed before the uncertainty about the future is resolved, or in other words the exact nature of future unfolds. Since it is an *ex-ante* concept, the vulnerability assessment has immense policy relevance, especially for policies aimed at preventing undesirable outcomes in future. Among numerous disciplines analysing the vulnerability notion, as Adger (2006) argues it is in the field of human-environment interaction that the term has common (though contested) meaning. Two broad fields of research – development economics and global climate change – capturing the interface of human-environment interaction are chosen for critical review in this study.

2.1 Vulnerability to Poverty

Much attention in the development economics literature is centred on the analysis of poverty. Notwithstanding the debate on the multidimensionality of poverty (*i.e.*, consumption, level of nutrition, education, *etc.*), it is broadly agreed that poverty represents "deprivation" of out-come(s). Thus, if consumption were taken as an outcome of interest, typical poverty assess-ments would measure in some way the deprivation of people below an accepted "norm" (*e.g.*, a poverty line defined on the basis of a basic minimum consumption level). Measures of dep-rivations include for instance the proportion of poor (headcount) and the extent of poverty (poverty gap).

In the context of poverty, reference to the notion of vulnerability can broadly be seen in one of the following three contexts (Prowse, 2003):

- *Vulnerability to poverty*: This strand of literature describes vulnerability as the potential for people to enter into poverty. Prominent in the poverty dynamics literature, this con-ceptualisation is the most widely used in the economics literature. While much of the empirical literature focuses on the so-called "transient" poor (*i.e.*, the population at risk of entering into poverty due to some shock), the literature also recognises the impor-tance for policy purposes of focusing on people who are already poor (even without the shock).

- *Vulnerability as a symptom of poverty*: Similar to the global change and disaster man-agement communities, vulnerability here is seen as vulnerability to some external shock. In line with Sen's (1981) influential work on poverty and famines, it is often ar-gued that vulnerability to external shocks is intimately linked with poverty. Hence this strand of literature visualises vulnerability as "cause" and "symptom" of poverty.

- *Vulnerability as part of poverty*: Increasing acceptance of multi-dimensional nature of poverty has meant the inclusion of risk and vulnerability as components of poverty (Hulme *et al.*, 2001).

In addition to these three contexts, vulnerability is sometimes also used with respect to the ef-fects of poverty, rather than just poverty. This creates a distinction between the means and ends of human welfare, where means constitute income, consumption of food or access to health services,

and ends refer to life expectancy, literacy or nutrition level. However, in the economics literature 'vulnerability to poverty' is the most commonly used conceptualization and the same will be the focus in this paper.

In a conceptual framework for vulnerability to poverty proposed by Dercon (2001), the start-ing point of analysis are assets held by households (*e.g.*, financial capital, human capital, so-cial capital) that provide them with income (*e.g.*, interest returns from financial capital, re-turns on activities, transfers and remittances, returns from asset disposal), which in turn are used to achieve various capabilities, or measures of well-being (*e.g.*, consumption, nutrition, health, education). Figure 1 shows a visual representation of this conceptual framework.

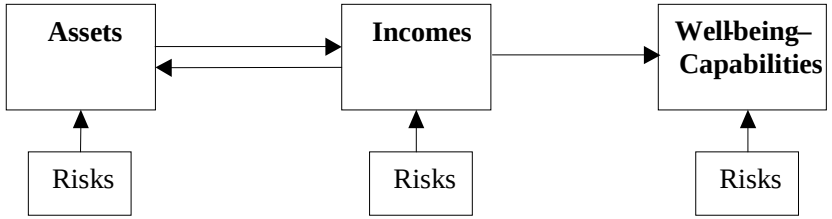

Figure 1: Framework for vulnerability to poverty
(Adapted from Dercon, 2001)

Households face risks at every stage of this chain. For example, if one considers a fixed de-posit held by a household in a bank, it represents the financial asset that gives interest income to the household, which can be used for achieving consumption (a measure of well-being). The household could face risks to the asset, say through bank insolvency, or to the incomes, say through interest rate fluctuations, or to the indicator of well-being, say through price fluctuations. Examples of risks to assets

include loss of skills due to ill health, asset damage due to climatic shocks, war or disaster, violations of commitment and trust, *etc.*; examples of risks to incomes include output risk due to climatic shocks or disease, risk in asset returns from savings and investment, uncertainty about enforcement of informal arrangements, *etc.*; examples of risks to well-being include price risk in food markets and risk associated with ra-tioned food availability through public distribution system.

Given this framework, poverty is the ex-post outcome of a process in which the household is making decisions about assets and incomes while faced with a range of risks. On the other hand, vulnerability (to poverty) describes the outcome of this process ex ante. So, vulnerabil-ity captures the exposure to poverty rather than the poverty itself. It is this notion of vulnerability that is implicit in several empirical studies discussed in section 3.

2.2 Vulnerability to Climate Change

With growing consensus on the threat of climate change that the society faces the focus is firmly now on its likely impacts. Available evidence shows that the impacts are not likely to be uniform across regions. This could be due to differential changes in climate experienced by different regions and also due to inherent differences of the regions to withstand the damage inflicted by the changing climate. Several studies over the past two decades have analyzed the impacts of climate change and have used the word 'vulnerability'[1] without necessarily providing careful definition to it.

In a careful analysis of the evolution of vulnerability notion in the climate change literature, Fussel and Klein (2006) argue that driven by the policy question addressed the term vulnerability attained different meanings in the various climate change vulnerability assessments. They categorize the large body of climate change vulnerability assessment studies into four groups: impact assessment studies, first and second generation vulnerability assessment studies, and adaptation policy assessment studies. The impact assessment and first generation vulnerability assessment studies mainly focused on climate change mitigation policy as they attempted to estimate the biophysical and socio-economic impacts associated with climate change, respectively. The second generation vulnerability assessment studies are largely driven by the policy questions pertaining to resource allocation to the regions most vulnerable to climate change. In these studies the vulnerability of a system is the end result after feasible adaptation options are considered. The adaptation policy assessment studies specifically focused on adaptation policy and analyzed feasible adaptation options that could reduce the vulnerability due to climate change. In these studies vulnerability of a system is the starting point of analysis. As could be visualized the temporal and spatial scales of analysis differ widely across these four groups of climate change vulnerability assessment studies.

The Intergovernmental Panel on Climate Change (IPCC) described in its Third Assessment Report vulnerability as, 'a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity' (McCarthy *et al.*, 2001, p. 995). While much confusion surrounds the operationalization of this definition, it at least captures the wide range of concerns that vulnerability to climate change poses.

In comparison with the vulnerability to poverty notion described above the concept of vulnerability to climate change appears to be broader in scope. However both notions are *ex-ante* measures that attempt to provide insight before the uncertainty about the future states of the world is resolved. Table 1 summarizes the broad features of the two notions and figure 2 depicts typical pathways of vulnerability causation in the prevailing models of vulnerability for poverty and climate change.

Table 1. Features of vulnerability to poverty and vulnerability to climate change

	Vulnerability to Poverty	**Vulnerability to Climate Change**
Typical question	Vulnerability of an entity to the threat of poverty	Vulnerability of an entity to the climate change threat
Focus	Outcome; the shocks contributing to the entity's outcome are often not specified	Specific shock(s); the outcome(s) of concern for the entity is often not specified
Spatial scale	Concerned mainly with individual or household level vulnerability (aggregate vulnerability also matters but relatively less studied)	Concerned mainly with aggregate analysis (regional or national), but often generalizes from representative individual level analysis
Temporal scale	Typically focus is on short temporal scale (e.g., vulnerability to the threat of poverty in the next year or so)	Focus is on long time horizon, allowing for co-evolution of system with the shock

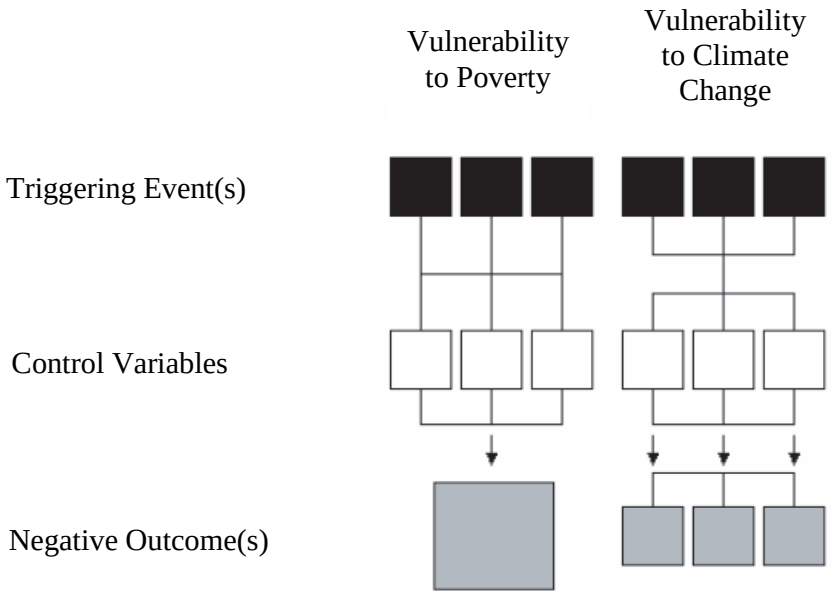

Figure 2. Prevailing Models of Vulnerability for Poverty and Climate Change (Adapted from Patt *et al*., 2005)

2.3 Vulnerability to poverty or climate change?

As the above sections describe the notion of vulnerability has its intrinsic appeal in both poverty and climate change debates. Focus on 'outcome' in poverty stream and 'shock' in the climate change literature creates an impression that these two fields are describing two entirely different concepts. That there is indeed close link between the two disciplines could be illustrated through an example. Here a hypothetical example introduced in Ionescu *et al*. (2006) is expanded to defend both the notions and outline the relevant policy interventions that are discussed in detail in section 4.

Consider a motorcyclist riding his motorcycle on a winding mountain road, with the mountain to his left and a deep valley to his right. Unbeknownst to the motor-cyclist an oil spill covers part of the road ahead of him, just behind a left-hand curve. In natu-ral language one would say that the oil spill represents a hazard and that the motorcyclist is at risk of falling down the cliff and being killed. One could say that the motorcyclist is vulnerable to the oil spill with respect to the prospect of an accident. This is the notion of vulnerability in the context of climate change introduced above. Alternatively one could also say that the motorcyclist is vulnerable to the threat of an accident, possibly caused among other things by the oil spill on the road. This captures the notion of vulnerability in the poverty literature described above.

One would normally say that a second motorcyclist who drives slowly and/or more carefully is less vulnerable to the oil spill and/or to the threat of accident. Both disciplines are interested in capturing such comparative statements about vulnerability. One can also expand the time horizon and think of a third motorcyclist who is aware of the likelihood of shocks on mountain roads in general or oil spill in particular and gears up for it by improving her driving skills and buys a new set of tyres. Such actions constitute the adaptive capacity of the vulnerable entity. Of course a fourth motorcyclist who is aware of the actions needed but is unable to implement them due to variety of constraints (e.g., lack of money) represents an entity with lower adaptive capacity.

Vulnerability to climate change not only accounts for different time scales, but also introduces new aspects such as the ability of the vulnerable entity to act proactively to avoid future hazards. That is, the

motorcyclist in collaboration with her fellow road users can influence the local administration to relay the road more frequently to reduce the probability of oil spill and hence her exposure and sensitivity to the same.

On the other hand, as in the context of vulnerability to poverty, the motorcyclist could worry about the prospect of an accident independent of a specific shock such as oil spill mentioned here. For instance, she could be confronted with a speeding truck or a brake system failure. Since a large set of her response strategies (such as wearing a helmet) primarily aim at reducing the damage, it may not be meaningful to focus on any single exogenous shock, but instead look at the distribution of outcomes, along with their probabilities. In this context it may not be inappropriate to refer the motorcyclist's vulnerability to sustaining damage. In a similar vein, the economics literature focuses on vul-nerability to poverty that could have been caused by a range of exogenous inputs.

2.4 Applicability of Common Formal Framework

Ionescu *et al*. (2006) developed a formal framework of vulnerability to climate change and argued that for meaningful statements about the notion of vulnerability the analyst must clearly specify three primitives: (i) the entity that is vulnerable, (ii) the stimulus to which it is vulnerable and (iii) the preference criteria to evaluate the outcome of concern for the entity. Among these three primitives, two can be readily mapped with the IPCC definition mentioned above. The 'degree to which a system is susceptible to, or unable to cope with' part of the definition corresponds to the preference criteria and the stimulus is captured through, 'character, magnitude and rate of climate variation to which a system is exposed'. The other elements of IPCC definition, namely

sensitivity and adaptive capacity, can not be directly mapped to the primitives of the formal framework. But they can be defined using these primitives as demonstrated in Ionescu *et al*. (2006).

The domain-independent nature of this formal framework makes it suitable to analyze the conceptualization of vulnerability in other fields. In poverty literature, vulnerability to poverty as mentioned above refers to the magnitude of the threat of future poverty. The entity in this literature is often individual or household and preference criteria are captured through a clearly defined poverty line. As against less restrictive partial strict order, the preference criteria are often specified using total order in economics. While this assumption enables the vulnerability metric to be developed satisfactorily, it puts great restriction on the nature of outcome(s) that one focuses in vulnerability assessment. This issue is further elaborated in the next section on measuring vulnerability. The stimulus to which the entity is vulnerable is not specified with the underlying assumption that the entity is exposed to several stimuli simultaneously and the outcome of concern is independent of the stimuli. This may be true if the response strategies are primarily targeted towards the outcome alone, but one may want to expand the responses to include reduction and/or elimination of the stimulus also.

A rich menu of vulnerability definitions outlined by Ionescu *et al*. (2006) in the context of climate change is summarized in table 2. Given that vulnerability makes comparative statements, the definitions differ mainly in terms of what is being compared and with reference what it is being compared. For instance, if the state of a system (subjected to a stimulus) in next period is worse than the initial state of the system, then the system is said to be simply vulnerable. Other vulnerability definitions follow similar reasoning.

Table 2. Various Vulnerability Definitions

Vulnerability	What is Compared	Compared with What
Simple	State in next period under a given stimulus	Initial state
Comparative	State in next period under a given stimulus	State in next period under a reference stimulus
Transitional	Transition between present state and that in the next period under a given stimulus	Transition between present state and that in the next period under a reference stimulus
n-Step Simple	State in the n^{th} period under a given stimulus	Initial state
n-Step Comparative	State in the n^{th} period under a given stimulus	State in the n^{th} period under a reference stimulus
n-Step Transitional	Transition between present state and that in the n^{th} period under a given stimulus	Transition between present and that in the n^{th} period under a reference stimulus
Transitional States-Comparative	Transition between present state and that in the n^{th} period under a given stimulus	Transition between present state (at a different starting point) and that in the n^{-th} period under a given stimulus
Transitional Systems-Comparative	Transition between present state and that in the n^{th} period under a given stimulus	Transition between present state (of a different system) and that in the n^{th} period under a given stimulus

While the notion of vulnerability to poverty maps well with the simple vulnerability defined in table 2, other notions are also meaningful in the context of poverty. More formally, representing the entity as deterministic dynamical system[2], the transition function in the context of poverty is given by:

$$f: X \rightarrow X,$$

where, X is the set of states of the system. Give the current state of the system x, the transition function identifies which element of X will be the next state of the system: $f(x)$. Considering preference criteria to be represented by a partial strict order[3] and assuming z to be an exogenously given poverty threshold, simple vulnerability to poverty can be defined as:

A system f in state x is vulnerable to an exogenously specified poverty threshold z with respect to the partial strict order $\prec$ *if* $f(x) \prec z$.

Or, equivalently simple vulnerability can also be defined in lines similar to the definition given in the context of climate change in table 2. For this the preference criteria can be appropriately modified:

A system f in state x is vulnerable to an exogenously specified poverty threshold z if $f(x \mid z) \; x$, *iff* $x > z$ *and* $f(x) < z$.

While simple vulnerability compares the future state with a static poverty threshold, a more appropriate definition could include comparison of the future state with a reference future. Reference scenario in global change often means maintaining status quo of system as against its deterioration through some adverse shock. In contrast maintaining status quo may not be a highly desirable objective as far as individual's poverty status is concerned. In general, the reference scenario should relate to a brighter future. While it could be maintaining status quo of an ecological system, it may be conceived as improved standard of living in social systems. Thus, the poor in future could be identified on the basis of a higher threshold value, z^* (where, $z^* > z$).

Comparative vulnerability to poverty can be defined as:

A system f in state x is vulnerable to poverty threshold $z (\in Z)$ *compared to* $z^* (\in Z)$ *if* $f(x \mid z) \prec f(x \mid z^*)$.

Other notions of vulnerability may also be developed in similar manner in the context of poverty.

3.0 MEASURING VULNERABILITY

While debate on appropriate conceptualization of the vulnerability notion could continue, for policy interventions empirical analyses are essential. Several studies in both poverty and climate change disciplines have focused on measuring vulnerability and significant progress has been made so far in both fields (see, Chaudhuri *et al*., 2002, Suryahadi and Sumartho, 2003, and Kamanou and Morduch, 2004 for vulnerability to poverty estimates; and Metzger *et al*., 2004, and DINAS-COAST Consortium, 2004 for vulnerability to climate change estimates). This section uses the vulnerability metrics proposed in two recent studies from poverty and climate change disciplines to examine the similarities and scope for learning between the two literatures. The vulnerability metric of poverty literature is from Dercon (2005) and Cesar and Dercon (2005), and that of climate change literature is from Luers *et al*. (2003) and Luers (2005). While the metric proposed in Dercon (2005) and Cesar and Dercon (2005) synthesizes the significant progress made in economics literature on vulnerability measurement, the metric developed by Luers *et al*. (2003) marks an important shift from indicator based measures (e.g., Moss *et al*., 2002, Brenkert and Malone, 2004) that dominate the literature on vulnerability to climate change.

3.1 Vulnerability Metrics

Assessments of vulnerability to poverty consider exogenous input to be manifold and omni-present. Capturing all types of exogenous input (to represent the entity's exposure) is there-fore difficult. As a result, the metrics defined in the poverty literature typically focus on out-come, which takes into account a series of exogenous inputs and the entity's response to these inputs, and on the distribution of outcome. Various measures used to assess vulnerability to poverty can be summarised as (Dercon, 2005; Cesar and Dercon, 2005):

$$V^* = \sum_{i=1}^{n} p_i v(x_i) \ , \quad x_i = \frac{\hat{y}_i}{z} \ , \quad \hat{y}_i = \min(y_i, z) \qquad (1)$$

where V^* is the vulnerability measure

$v(x_i)$ is monotonically decreasing and convex

y_i is the outcome of interest (*e.g.*, consumption) in state *i*

z is the corresponding poverty line

p_i is the probability of occurrence of state *i*

n represents the number of states of the world

This metric means that vulnerability is the probability-weighted average of some (convex) function of outcomes. More specific measures that correspond with the FGT measures of poverty (Foster *et al.*, 1984), used by Suryahadi and Sumartho (2003), Kamanou and Morduch (2004) and Chaudhuri *et al.* (2002), can be repre-sented as:

$$V^{EP} = \sum_{i \forall y_i < z} p_i \left(\frac{z - y_i}{z} \right)^a \qquad (2)$$

Since most studies see vulnerability as some form of expected poverty, the vulnerability is re-ferred to as V^{EP} in the above formula. For a=0 and a=1, the above measure captures vulner-ability as either the probability of being poor and as the expected shortfall from the poverty line, respectively. Arguing that the V^{EP} (and also the vulnerability measures based on expected utility developed by Ligon and Schechter (2003)) does not satisfy certain desired properties developed on the basis of welfare-economic foundations (such as, normalization and constant relative risk sensitivity), Dercon (2005) and Cesar and Dercon (2005) develop a new class of vulnerability measures given by:

$$V^{\alpha} = 1 - E\left[x_i^{\alpha}\right], \text{ where } \alpha \text{ can be interpreted as a weight, } 0<\alpha<1. \quad (3)$$

Thus, vulnerability is measured as one minus the probability weighted value of outcomes that are normalized (to be between 0 and 1) and weighted by the risk sensitivity parameter (α).

A crucial input required for implementing these metrics is knowledge on possible outcomes in different states of the world, for which one needs a forecasting model for outcomes and data to estimate and calibrate a distribution of outcomes. Most empirical studies infer the distribu-tion of possible outcomes from the error process in a cross-sectional regression model ex-plaining outcomes by household characteristics and community variables. Use of cross-sec-tional data is mainly due to their easy availability (for *e.g.*, most countries conduct consumption surveys among households at regular intervals). The most stringent assumption of empirical studies that rely on cross-sectional

data is that cross-sectional variance can be used to estimate inter-temporal variance. Cross-sectional vari-ance can explain a part of the inter-temporal variance (*e.g.*, due to idiosyncratic shocks), but the assumption does not hold for the impact of inter-temporal (or aggregate) shocks that are invariant across households but vary across time. In other words, the models built on this as-sumption will produce good estimates of vulnerability for only those situations where the dis-tribution of risks and risk-management instruments are similar over time[4].

However, shocks such as climate change or economic crises are time-variant shocks necessitating the need for characterization of exposure of the entity to the shock and the sensitivity of outcome to the shock. Luers *et al.* (2003) and Luers (2005) defined vulnerability of an entity to climate change as the expected value of the ratio of the sensitivity of the entity's state to the exogenous input over the relative posi-tion of the state to a certain threshold. The expected value is calculated based on the distribu-tion of the exogenous input of interest. Vulnerability to climate change in its most general form can be represented as (Luers, 2005; Adger, 2006):

$$V^{CC} = \sum_i \frac{\beta}{y_i / y_0} p_i \qquad (4)$$

where, numerator (β) represents the sensitivity, the denominator represents the outcome of interest relative to a threshold, and p_i is the probability of the ith state.

For interpreting V^{CC} consider that one is interested in measuring vulnerability of representative farmers in several regions to a climatic shock. For the sake of illustration consider the farmer's vulnerability with regard to poor wheat yield caused by potential changes in temperature. In line with the discussion in the previous section, the representative farmer's vulnerability can be meaningfully expressed by either of the two statements: (i) vulnerability to poor wheat yield due to temperature change, or (ii) vulnerability to temperature change with reference to poor wheat yield. While in poverty literature non-consideration of external stimulus causing vulnerability enables simple projection of the outcome of concern in several states of the future, the vulnerability metrics in climate change should first establish link between the outcome of concern and the stimulus in question. That is, in the present example the analyst must identify how yield of wheat changes due to temperature changes. In other words, the sensitivity of the entity must be assessed. This is represented in the numerator of equation 4. The denominator captures the relative position of the yield with reference to the threshold. Finally using the probability of the future states the vulnerability is calculated as expected value as in (4). Note that in this formulation as expected with increase in outcome (y) the vulnerability decreases. However, vulnerability also increases with sensitivity, irrespective of the direction of change of the stimulus. One drawback of this interpretation is that outcome of concern is not assessed in the future states of the world and the nature of the future state (revealed by the value of the exogenous input) would only influence the sensitivity of the entity.

Alternatively, vulnerability to climate change can be interpreted as follows: Continuing with the above example of farmer, for each future state, the shock (or stimulus) is assessed in terms of the change in temperature with respect to present (or some normal value). With the help of sensitivity the change in temperature can be translated into corresponding change in the yield and from which state specific yield can then be generated. Once state probabilities and the associated outcome (y) values are known vulnerability can be measured in similar manner as it is done in the case of vulnerability to poverty as in equation (1). Again similar to vulnerability to poverty only adverse shocks could be considered for vulnerability assessment. In this interpretation all the axioms that Cesar and Dercon (2005) introduced in the context of vulnerability to poverty will be equally applicable for the vulnerability to climate change metric. Equation 5 shows the general expression for vulnerability to climate change and table 3 provides a comparative overview of the vulnerability metrics in poverty and climate change fields.

$$V^{CC} = \sum_{i=1}^{n} p_i [v(\hat{y}_i, \beta_i)] \qquad where\ \hat{y}_i = \frac{y_i}{y_0}, \beta_i = \frac{\Delta y}{\Delta T} \qquad (5)$$

where y is an indicator of well-being of the entity (e.g., wheat yield of representative farmer)

y_0 is the threshold level of well-being (e.g., break-even level of yield)

T is the exogenous input affecting the entity (e.g., temperature change)

p_i is probability of occurrence of state i

β is the sensitivity of the entity

$v(.)$ is monotonically decreasing in y and increasing in β

Table 3. Comparison of Vulnerability Metrics

Vulnerability to Expected Poverty	**Vulnerability to Climate Change**
$V^{EP} = \sum_{i=1}^{n} p_i v(x_i)$, $x_i = \frac{\hat{y}_i}{z}$, $\hat{y}_i = \min(y_i, z)$	$V^{CC} = \sum_{i=1}^{n} p_i [v(\hat{y}_i, \beta_i)]$, $\hat{y}_i = \frac{y_i}{y_0}$, $\beta_i = \frac{\Delta y}{\Delta T}$
Vulnerability as expected value.	Vulnerability as expected value.
Future states of the world are generated based on the outcome of concern	Future states of the world are generated based on the stimulus causing vulnerability (e.g., temperature change)
Outcome is censored with all values above the threshold having no influence on the level of vulnerability	Outcome is not typically censored and hence higher outcome values in 'good' states could bring down the vulnerability of an entity
Higher value of outcome (after censoring) leads to lower vulnerability	Higher value of outcome results in lower vulnerability
Does not depend on the sensitivity of the entity to the stressor, as the focus is not any one stressor causing vulner-ability of the entity.	Depends on the sensitivity of the entity to the stressor as it is the crucial link between the stimulus and the outcome of concern for the entity.
Non-availability of panel data for long time series requires the analyst to infer outcome distribution based on either cross-sectional data or short panel data. In case of non-stationary outcomes such inferences may prove to be biased.	Distribution of exogenous input is typically generated through multiple scenarios, developed using parameters estimated from past data.

3.2 Common Formal Framework – Revisited

In light of the vulnerability metrics discussed above it could be illuminating to revisit the common formal framework developed by Ionescu *et al*. (2006). Though both the metrics introduced above deal with stochastic systems, for simplicity the analysis here is restricted to deterministic systems. Consider a simple dynamical system represented by a transition function:

$$f : XxE \rightarrow X$$

where, X is the set of states of the system and E is the set of exogenous inputs. For further simplicity let us consider exogenous input as given/ chosen. Thus the transition function could be represented as:

$$f : X \rightarrow X$$

Now consider a vulnerability metric V that maps X to the positive real number space (R_+). If V were to be a vulnerability measure then it must satisfy the following conditions

(a) *V(.)* is a characteristic function.
That is, $V(x) > 0$ *iff* $f(x) \prec x$
and $V(x) = 0$ *iff* x is not vulnerable.

(b) *V(.)* is a monotonic function
That is x^* is more vulnerable than x, *iff* $V(x^*) > V(x)$.

The vulnerability metric would require additional restrictions placed on the preference criteria assumed in Ionescu *et al*. (2006). The formal framework assumed partial strict order to represent the preference criteria of the entity. That is, $\prec$ is not expected to be total. For certain outcomes and definitely for combinations of outcomes, it may not be

feasible for the entity to clearly order them and hence assuming partial strict order to capture the preference criteria is justifiable. However, if the vulnerability metrics of the kind discussed in this section were to be used in practice the preference criteria should be represented through complete or total preorder.

4.0 SYNERGIES IN POLICY

4.1 Policy Focus

To understand the policy relevance of vulnerability to poverty it is useful to consider a public health analogy. One is typically interested in treatment as well as prevention of diseases such as AIDS. In a society affected by AIDS, there will be people who are currently suffering and people who could suffer in the future, if adequate preventive measures are not taken now. In a similar vein, there are people in society who are currently classified as “poor” (as per some accepted norm), but in order to design forward-looking policies one also needs to know who could become poor in the future. Policies should address those likely to become poor in the future, as well as those who are already poor. More specifically, as Dercon (2001) argues, vulnerability research should focus on at least four groups: (*i*) those who are currently poor and permanently poor (also referred as the chronically poor), (*ii*) those who are likely to be-come poor in the future due to some trend evolution, (*iii*) those who are likely to become poor due to predictable events such as seasonality, and (*iv*) those who are likely to become poor due to risk and shocks.

Vulnerability is a characteristic not only of the non-poor or the temporarily poor, so the focus of policy should therefore be on all four of the above groups. Focusing on "shock" in the analysis of vulnerability is appropriate because it enables one to make a meaningful distinc-tion between ex-ante and ex-post analyses. However, since everybody is affected by shocks to a greater or lesser extent, it is likely that those who are currently poor may be (even) worse off due to the shock. By considering only group (*iv*) one might be wrongly narrowing the policy focus. Having said that, there is a tendency in the poverty literature (as is the case for climate change) to focus only on (*iv*) in assessments of vulnerability.

There is no concept analogous to "poverty" in the climate change literature, but it might be useful to develop one for academic and policy purposes. For example, if one takes crop yield as an outcome of interest, then a vulnerability assessment in the context of climate change should focus on those regions that are currently (*i.e.*, without climate change) experiencing crop yield to be below some accepted norm (*e.g.*, the economic breakeven yield level), in ad-dition to those regions that are likely to fall below the norm upon experiencing climate change (*i.e.*, those expected to experience impacts from climate change). Such extended vulnerability assessment could be useful in contributing to the "mainstreaming" of climate change adapta-tion measures into plans and policies aimed at reducing poverty and improving people's well-being.

4.2 Response strategies

Strategies that can reduce vulnerability to climate change can be classified as (*i*) mitigation, which is aimed at eliminating unavoidable

hazards that the entity faces for all time periods, and (*ii*) maintaining adaptive capacity, which is aimed at ensuring the entity's access to effec-tive response strategies for all time periods (Ionescu *et al.*, 2006). In the context of vulner-ability to poverty policy responses are typically categorised as (*i*) ex-ante risk management strategies, and (*ii*) ex-post coping strategies. Ex-ante risk management strategies are adopted by the entity before experiencing a shock, while the ex-post coping strategies are imple-mented after the shock. Ex-ante strategies can be further classified as (*i*) damaging fluctua-tions (DF) reduction or removal strategies, and (*ii*) actions aimed at reducing exposure to DF (Sinha and Lipton, 1999).

Damaging fluctuations are a form of exogenous input experienced by the entity. There are no readily available examples of actions that reduce DF, as the poverty community's focus is not so much on any specific exogenous input that causes vulnerability[5]. Such actions would be close to what is termed mitigation by the climate change community. A range of re-sponses can be considered that reduce exposure to DF, including protecting, decoupling, hedging, consumption smoothing and availing credit. In addition, Moser (1998) and Devereux (2001) discussed a range of coping strategies that the entity can undertake after experiencing the shock. Some of these coping strategies (*e.g.*, insurance) overlap with strategies aimed at reducing exposure to DF. The choice of coping strategies, especially the entity's internal ones, is made on the basis of, among other things, the reversibility of the option. Destitute behav-iour, such as migration or taking children from school, are opted as last-resort strategies by the entity, as the effects of such strategies are often irreversible. External coping strategies in-clude accessing community help

groups, *etc.* Table 4 presents the classifications of response strategies by the climate change and the poverty communities, respectively.

The rich sub-classification in the poverty literature of what is broadly referred to as maintain-ing adaptive capacity in the climate change community appears useful for the effective targeting of support to improve the adaptive capacity of populations vulnerable to climate change. On the other hand, the poverty community could benefit from the explicit identification of determinants of poverty and of vulnerability to poverty, so that effective strategies aimed at reducing or removing damaging fluctuations (similar to mitigation in the context of climate change) could be proposed.

Table 4: Strategies to Reduce Vulnerability to Climate Change and Poverty

Community	**Response Strategies**	
Climate Change	Mitigation Reduction or removal of exogenous input For example: reduction of greenhouse gas emissions, which in turn reduces the mag-nitude of climate change	Maintaining Adaptive Capacity Ensuring access to and use of effective response strategies by the entity. Includes strategies that the entity undertakes both before and after being exposed to the exogenous input. For example: irrigation, building seawalls, migration
Poverty	Ex-ante Risk Management DF reduction or re-moval: actions tar-geted towards the re-duction or elimination of the risk	Ex-ante Risk Management Reduction of (the exposure to) DF • Protecting (*e.g.*, im-munisation) • Decoupling (*e.g.*, di-versification) • Hedging (*e.g.*, de-layed sowing) • Consumption smoothing (*e.g.*, grain storage) • Credit (*e.g.*, insurance)
	Ex-post Risk Management Internal coping strategies For example: insurance mechanisms, disposal of productive assets, destitute behaviour	Ex-post Risk Management External coping strategies For example: informal safety nets, community support systems

Source: Adapted from Moser, 1998; Sinha and Lipton, 1999; Devereux, 2001.

Note: DF: damaging fluctuations.

5.0 CONCLUSIONS

This paper attempted to review the main concepts and metrics related to vulnerability as used in the poverty literature and to compare them to their counterparts in the field of climate change. This work was in-tended to serve four purposes. First, it should shed some light on the apparent dissimilarity between the approaches to vulnerability assessment in the two communities (*viz.*, vulnerabil-ity to *climate change* focuses on an exogenous stimulus while vulnerability to *poverty* focuses on an outcome). Second, the application would be a test of the versatility of the formal frame-work developed by Ionescu *et al*. (2006), the development of which was primarily informed by knowledge on vulnerability to climate change. Third, it would help to identify the

similarities in vulnerability measurement across the two fields and throw light on implications for the formal framework. Fourth, it could help to identify possible synergies between vulnerability as-sessments in the climate change and poverty communities.

Critical appraisal of vulnerability concept in the two disciplines showed that while both the notions are defendable, broader policy relevant statements about vulnerability could be made if the analysis clearly identifies the three primitives – namely, the entity that is vulnerable, the stimulus due to which the entity is vulnerable, and the preference criteria on the outcome of concern that is affected by the stimulus. Thus, while 'vulnerability to poverty' in itself could be a useful phrase, a more meaningful phrase would be say, 'vulnerability to poverty due to an epidemic'. Similarly, 'vulnerability to climate change' could be rephrased as say, 'vulnerability to poor wheat yield due to climate change'.

The analysis presented clearly showed significant similarities between the two fields in terms of vulnerability measurement. It is argued that the link between the two metrics can be established through the introduction of notion of sensitivity – i.e., the effect of stimulus on the outcome of concern for the entity. The vulnerability metric in climate change could be further refined by imposing desired properties as it was done in case of vulnerability to poverty.

The vulnerability metric in both fields demands a stricter restriction (namely, complete preorder) on preference criteria on the outcome(s) of concern for the entity. It would be interesting to inquire

into the conditions that a vulnerability measurement would have to satisfy when considered in the context of more general preorders.

Comparison between the han-dling of issues of mitigation and adaptive capacity within the two communities threw light on potential synergies. There is a richer classification of strategies for maintaining adaptive capacity in the poverty community; the notion of mitigation, on the other hand, seems to be more developed in the climate change community. This comparison suggests that each community could benefit from an import of know-how from the other.

In addition, the application has shown that an important feature of vulnerability to poverty is the existence of a threshold expressing some socially accepted norm. In contrast, vulnerability to climate change is usually expressed in terms of a more complicated (and usually implicit) preorder relation on some set of indicators. The introduction of threshold values to the as-sessment of vulnerability to climate change may be beneficial: the mathematical descriptions become simpler and require less data to model, which could make them useful for rapid as-sessments (even if the threshold value is controversial, at least potential problem areas can be discovered quickly).

REFERENCES

Adger, W.N., 2006: Vulnerability, *Global Environmental Change*, 16, 268-281.

Alwang, J., P.B. Siegel and S.L. Jorgensen, 2001: *Vulnerability: A View from Different Disciplines*, Social Pro-tection Discussion Paper, World Bank, June.

Amin, S., A. Rai and G. Topa, 2000: *Does Micro-Credit Reach the Poor and Vulnerable? Evidence from North-ern Bangladesh.* CID Working Paper 28, Harvard University, Cambridge, MA, USA.

Atkinson, A.B., 1987: 'On Measurement of Poverty', *Econometrica*, 55, pp.749-764.

Brenkert, A.L. and E.L. Malone, 2004: Modeling Vulnerability and Resilience to Climate Change: A Case Study of India and Indian States, *Climatic Change*, 72(1), 57-102.

Brooks, N., 2003: *Vulnerability, Risk and Adaptation: A Conceptual Framework*. Working Paper 38, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK, 16 pp.

Cesar, C. and S. Dercon, 2005: 'Measuring Individual Vulnerability', Working Paper # 229, Department of Economics, University of Oxford.

Chaudhuri, S., J. Jalan, and A. Suryahadi, 2002: *Assessing household vulnerability to Poverty: A Methodology and Estimates for Indonesia.* Columbia University Department of Economics Discussion Paper 0102–52, Columbia University, New York, NY, USA.

Dercon, S, 2001: Assessing Vulnerability to Poverty, Report prepared for DfID, http://www.economics.ox.ac.uk/members/stefan.dercon/assessing-vulnerability.pdf, 80 pp.

Dercon, S. and P. Krishnan, 2000: In sickness and in health: risk sharing within households in rural Ethiopia. *Journal of Political Economy*, 108(4), 688–727.

Dercon, S., 2005: *Vulnerability: A Micro Perspective.* Annual Bank Conference on Development Economics, 23–24 May 2005, Amsterdam, The Netherlands, 39 pp.

Devereux, S., 2001: Livelihood insecurity and social protection: a re-emerging issue in rural development. *De-velopment Policy Review*, 19(4), 507–519.

DINAS-COAST Consortium, 2004: *DIVA 1.0.* Potsdam Institute for Climate Impact Research, Potsdam, Ger-many, CD-ROM.

Foster, J.E., J. Greer, and E. Thorbecke, 1984: A class of decomposable poverty measures. *Econometrica*, 52(3), pp. 761-766.

Füssel, H.-M. and R.J.T. Klein, 2006: Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change*, 75(3), 301-329.

Hulme, D., K. Moore, and A. Shepherd, 2001: *Chronic Poverty: Meanings and Analytical Frameworks.* CPRC Working Paper 2, Chronic Poverty Research Centre, University of Manchester, UK.

Ionescu, C., R.J.T. Klein, J. Hinkel, K.S. Kavi Kumar and R. Klein, 2006: Towards a formal framework of vul-nerability to climate change. *Environmental Modeling and Assessment*, revised draft submitted.

Janssen, M.A., M.L. Schoon, W. Ke, and K. Borner, 2005: 'Scholarly Networks on Resilience, Vulnerability and Adaptation within the Human Dimensions of Global Environmental Change', paper presented at the workshop, *Key Challenges for Human Dimensions Research*, 9-11 February, Arizona State University, Tempe, AZ.

Jones, R.N., 2001: 'An Environmental Risk Assessment/Management Framework for Climate Change Impact Assessments', *Natural Hazards*, 23(2-3), pp.197-230.

Kamanou, G. and J. Morduch, 2004: Measuring vulnerability to poverty. In: S. Dercon (ed.), *Insurance Against Poverty*, Oxford University Press.

Kanbur, R. and L. Squire, 1999: *The Evolution of Thinking About Poverty: Exploring the Interactions*, http://www.worldbank.org/poverty/wdrpoverty/evolut.htm.

Ligon, E. and L. Schechter, 2003: Measuring vulnerability. *Economic Journal*, 113(March): C95–C102.

Luers, A., D. B. Lobell, L.S. Sklar, C.L. Addams, P.A. Matson, 2003: A method for quantifying vulnerability: applied to the agricultural system of the Yaqui Valley, Mexico. *Global Environmental Change*, 13(4), 255–267.

Luers, A.L., 2005: The Surface of Vulnerability: An Analytical Framework for Examining Environmental Change. *Global Environmental Change*, 15, 214-223.

McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White (eds.), 2001: *Climate Change 2001: Im-pacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, x+1032 pp.

Metzger, M.J., R. Leemans, D. Schröter, W. Cramer and the ATEAM Consortium, 2004: *The ATEAM Vulner-ability Mapping Tool.* Quantitative Approaches in Systems Analysis 27, C.T. de Wit Graduate School for Production Ecology and Resource Conservation, Wageningen, The Netherlands, CD-ROM.

Moser, C., 1998: The asset vulnerability framework: reassessing urban poverty reduction strategies. *World De-velopment*, 26(1), 1–19.

Moss, R.H., E.L. Malone, A.L. Brenkert, 2002: Vulnerability to Climate Change: A quantitative Approach, prepared for US Department of Energy, http://www.globalchange.umd.edu/cgi-bin/Details.pl?sref=PNNL-13765.

O'Brien, K., S. Eriksen, A. Schjolden and L. Nygaard, 2004: *What's In a Word? Conflicting Interpretations of Vulnerability in Climate Change Research*. Working Paper 2004:04, Centre for International Climate and Environmental Research Oslo, University of Oslo, Norway, iii+16 pp.

Patt, A.G., R.J.T. Klein and A.C. de la Vega-Leinert, 2005: 'Taking the Uncertainty in Climate Change Vulnerability Assessment Seriously', *Comptes Rendus Geosciences*, 337(4), 411-424.

Prowse, M., 2003: *Towards a Clearer Understanding of Vulnerability in Relation to Chronic Poverty.* CPRC Working Paper 24, Chronic Poverty Research Centre, University of Manchester, UK.

Sen, A.K., 1979: 'Issues in the Measurement of Poverty', *Scandinavian Journal of Economics*, 81, pp. 285-307.

Sinha, S. and M. Lipton, 1999: *Damaging Fluctuations, Risk and Poverty: A Review*, Background Paper for the World Development Report 2000/2001, Poverty Research Unit, University of Sussex.

Suryahadi, A. and S. Sumarto, 2003: Poverty and vulnerability in Indonesia before and after the economic crisis, *Asian Economic Journal*, 17(1), 45–64.

World Bank, 2001: *World Development Report 2000-2001 – Attacking Poverty*, New York: Oxford University Press.

---

[1] Janssen et al. (2005) note that more than seven hundred articles in the global change literature have used the term 'vulnerability' as key word.

[2] The poverty filed often uses stochastic system to define vulnerability, but the definitions under deterministic system discussed here can easily be extendable to the stochastic system.

[3] It may be noted the choice of partial strict order, as against a more conventional (in economics) total order, is made to keep the definition more flexible and correspond to a wide range of outcomes that may not necessarily be mapped to real numbers.

[4] A few studies use short panel data (e.g., Ligon and Schechter, 2003), and a few other studies (e.g., Amin et al., 2000; Dercon and Krishnan, 2000) avoid this strong assumption about the statistical error process by focusing explicitly on shocks (such as illness, crop failure and rainfall) and the household's ability to cope in prediction models.

[5] Irrigation is often misleadingly considered as an example of a DF-reducing action. However, irrigation will re duce the entity 's exposure to DF, rather than reduce or remove the DF itself.