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Climate change, multiple stressors and human vulnerability – a systematic review

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Abstract

We systematically reviewed current climate change literature in order to examine how multiple processes that affect human vulnerability have been studied. Of the 125 reviewed articles, 79 % were published after 2009. There are numerous concepts that point out to stressors other than climate change that were used in reviewed studies. These different concepts were used interchangeably and they illustrate processes that act on different scales. Most widely used concepts included non-climatic (40% of the articles), multiple stressors (38%) and other factors (37%). About 75% of the studies either acknowledged or carefully analyzed the social and environmental context in which vulnerability is experienced. One third of the studies recognized climate change related stressors as the most important, one third argued that stressors other than climate are more important and the rest of the studies did not analyze the relative importance of the different processes. Interactions between different stressors were mentioned in 76% and analyzed explicitly in 28% of the articles. Our review shows that there are studies that analyze the social context of vulnerability within climate change related literature and this literature is rapidly expanding. Reviewed studies point out that there are multiple interacting stressors, whose interlinkages need to be carefully analyzed and targeted by policies, which integrate adaptation to climate change and other stressors. In conclusion, we suggest that future studies should include analytical frameworks that reflect dissimilarities between different types of stressors, methodological triangulation to identify key stressors and analysis of interactions between multiple stressors across different scales.

Keywords: adaptation; non-climatic; driver; exposure; pressure; risk

1 Introduction

Within the literature on climate change and human vulnerability (*i.e.* vulnerability of individuals, communities, societies and human systems), climate change has been conventionally seen as the main driver of vulnerability. This is evident for instance in the definition suggested by the Intergovernmental Panel on Climate Change. The widely used IPCC definition of the Fourth Assessment Report states that "[*V*]*ulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.*" (IPCC 2007).

This definition has become the most widely used in the climate change vulnerability literature (Bassett and Fogelman 2013; Füssel and Klein 2006) thus having a major influence on research. Furthermore, it has been argued that this particular interpretation of vulnerability affects the practical policies considering adaptation to climate change and the reduction of vulnerability (O'Brien et al. 2007).

In addition to the IPCC, there are wide array of different definitions of vulnerability and different frameworks through which the concept has been operationalized in research (Adger 2006; Berry et al. 2006; Birkmann 2006; Eakin and Luers 2006; Füssel 2007; Füssel and Klein 2006; Giupponi and Biscaro 2015; Hinkel 2011; McLaughlin and Dietz 2008; Ribot 2014; Turner et al. 2003). Furthermore, although IPCC definitions did not change considerably between the First and the Fourth assessment report (Bassett and Fogelman 2013), a major change can be seen from the Fourth to the most recent Fifth report. In the 5th assessment report (AR5) of the IPCC working group 2 (WG2), the central focus is on climate-related risks instead of vulnerability.

In the IPCC (2014) climate risk framework, risk is the result of interaction of hazard, exposure and vulnerability. Hazard refers to a physical event, trend or their impacts that have an effect on human or natural systems; exposure means the presence of people or other unit of interest in settings, where there can be adverse effects; while vulnerability is defined as follows: ”*The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.*” (IPCC 2014).

This latest IPCC definition is hence more general as recommended before by various authors (Hinkel 2011; Wolf et al. 2013). Climate change or other biophysical concepts are no longer mentioned in the definition, although they are still embedded in the new hazard concept as part of climate risk. In this climate risk framework, exposure and vulnerability can also increase risks alongside the physical hazards (Mechler et al. 2014). This new conceptual vagueness does not, however, necessarily mean that social factors, which are important issues in shaping the vulnerability context (O'Brien et al. 2007; Ribot 2014), have a more central role in the IPCC climate risk framework and on research and policies that utilize the framework.

These definitions and frameworks have been elaborated within different orientations, which have divergent views on what causes vulnerability (Adger 2006; Birkmann 2006; Eakin and Luers 2006; Füssel and Klein 2006; Giupponi and Biscaro 2015; McLaughlin and Dietz 2008; Ribot 2014). Some political-ecological –oriented researchers have, for example, criticized that the earlier hazard literature did not carefully consider the social aspects of vulnerability (Bassett and Fogelman 2013; Ribot 2014); and the same critique has been directed to the IPCC vulnerability and adaptation framework (Bassett and Fogelman 2013).

Within climate change literature, this duality of approaches has been called end-point and starting-

point (Kelly and Adger 2000), top-down and bottom-up (Dessai and Hulme 2004) or outcome and contextual (O'Brien et al. 2007). The end-point approach evident in the IPCC Fourth Assessment Report (IPCC 2007) considers vulnerability as an outcome of climate change, whereas the second approach regards vulnerability as part of multidimensional, context-specific climate-society interactions. It has been argued that the wider socio-cultural, political-economic and environmental contexts of vulnerability are important both analytically (O'Brien et al. 2007) and also in practical adaptation policy (Eriksen et al. 2011).

Approaching vulnerability as contextual directs attention to the cascading effects of different political-economic, and socio-ecological processes that make people differentially vulnerable to changes in their environment. It consequently has been argued that climate change is but one of 'multiple stressors' (Adger 2006; O'Brien et al. 2004; Turner et al. 2003) that cause vulnerability. In addition to 'multiple stressors', other concepts have emerged, including 'non-climatic factors' (Füssel and Klein 2006), 'double exposure' (O'Brien and Leichenko 2000), 'multiple exposures' (Belliveau et al. 2006; Bennett et al. 2015a) and 'other stressors' (Tschakert 2007).

Some researchers have argued that especially within hazards research 'multiple stressors' have been studied for decades (Kelman et al. 2015); whereas others argue that 'multiple stressors' is a relatively new issue (Bennett et al. 2015a). Although 'multiple stressors' were mentioned already in the first IPCC reports, in fact, the focus has often concentrated on single stressors using *ceteris paribus* assumption (Hashimoto et al. 1990).

This discussion illustrates that the idea of 'multiple stressors' and 'non-climatic factors' has been incorporated as part of the climate change and vulnerability discussion. Some authors have even tried to identify all different driving factors of vulnerability. Zou and Wei (2010) classified in their review 361 different driving factors of social vulnerability in coastal Southeast Asia. In another

118 review, Bennett et al. (2015a) gave examples of different stressors/exposures that are evident in
119 coastal areas constructing a conceptual framework on how ‘multiple exposures’ can be analyzed.
120
121 There are many analyses of different orientations and definitions of vulnerability research (Adger
122 2006; Birkmann 2006; Eakin and Luers 2006; Füssel and Klein 2006; McLaughlin and Dietz 2008;
123 Ribot 2014), approaches with typologies of ‘multiple stressors’ (Bennett et al. 2015a; Zou and Wei
124 2010) and some recent systematic reviews or bibliometric analyses of vulnerability (Delaney et al.
125 2014; Giupponi and Biscaro 2015; McDowell et al. 2016; Tucker et al. 2014; Wang et al. 2014).
126 However, none have looked systematically at how ‘multiple stressors’ have been conceptualized in
127 the climate change and human vulnerability literature.
128
129 We synthesize the current knowledge on ‘multiple stressors’ and show that the current literature
130 about ‘multiple stressors’ is relatively new field. Furthermore, we contribute to the conceptual and
131 analytical clarity of this of study and hence help in bridging various approaches researching
132 vulnerability. Our review has important policy implications because the ‘multiple stressors’
133 literature highlights the various processes which, in addition to climate change, increase
134 vulnerability and which should be accounted for in climate change adaptation policies.
135

136 2 Methods

137
138 Systematic reviews are especially useful in synthesizing current knowledge and they are transparent
139 in their methods (Berrang-Ford et al. 2015; Lorenz et al. 2014). We systematically reviewed
140 selected climate change literature following the methodology suggested by Berrang-Ford et al.
141 (2015). They propose three components for the systematic review of climate change adaptation
142 research: (1) explicit objectives of the review and clear description of the conceptual approach used,
143 (2) justification of the literature source, detailed description of the search process, description of the

144 inclusion/exclusion criteria and documentation of the literature as well as (3) description of the
145 methods and critical appraisal of information quality.
146
147 Our overall objective was to systematically analyze different concepts that denote stressors other
148 than climate and that are used in the literature about climate change and human vulnerability. More
149 specifically, we examined (1) how widely investigated and how novel the literature about 'multiple
150 stressors', 'non-climatic factors' and other similar concepts is within the literature about human
151 dimensions of climate change, (2) how these concepts have been used and what differences there
152 are between concepts and (3) what is the relative importance of different stressors.
153
154 Articles that were selected for review were first screened using SCOPUS and Web of Knowledge
155 searches. These search engines were selected because they have the two most encompassing
156 databases of social and environmental sciences articles (Landauer et al. 2015). We selected only
157 peer-reviewed journal articles. First, the peer-review process of the articles is a measure of quality.
158 Second, we wanted to focus on the state-of-the-art scientific literature on this topic. Third, many of
159 the other sources, such as book chapters, were difficult to obtain. It is also worth pointing out that
160 our selection of the search engines already excluded some gray literature. We acknowledge that this
161 decision might have excluded some relevant documentation but we consider the sample analyzed
162 here to be large enough to gain a systematic overview of the existing literature.
163
164 As the first step, we searched for articles that mention 'non-climatic factors'. We then performed
165 new searches in which we added new terms because we found early on in the search process that
166 many different notions have been used in literature. Finally, we used the following search sequence:
167
168 `("other pressure*" OR "other risk*" OR "other driver*" OR "other stress*" OR "other`
169 `factor*" OR "multiple pressure*" OR "multiple risk*" OR "multiple driver*" OR "multiple`
170 `stress*" OR "multiple factor*" OR "multiple exposure*" OR "double exposure*" OR non-`

climat*) AND (vulnerab* OR adapt*) AND (climat* OR "environmental change*" OR "global change*")

These terms were searched from the title, abstract and keywords of the articles. Full text searches were left out since we wanted to find the articles in which climate change and non-climatic factors were pointed as the central focus of the research in the title, abstract and/or keywords. The result included 888 hits from SCOPUS and 836 hits from Web of Knowledge on June 4th 2015. When duplicates were removed, there were 1081 studies left. From this total, the titles, abstracts and, if needed, full texts of all articles were skimmed based on the following criteria.

We analyzed the quality and relevance of different articles and we selected articles that had a focus on (1) 'non-climatic factors' or 'multiple stressors' and (2) issues of human vulnerability or adaptation. We did not select studies with a focus on ecology (majority of the excluded articles) or environmental vulnerability without clear links to human vulnerability. We further deselected articles in which the focus was infrastructure, medicine-related, law, economics, highly specific commodity studies, energy policy, archaeology, education, migration or conflict and national security. In addition, we excluded studies in which the main focus was on climate change mitigation efforts or which did not include a clear case study or a review of specific case studies. This selection process left us a total of 125 peer-reviewed, English-written journal articles (Supplementary Material).

After the article selection process, we analyzed the content of articles using eight guiding questions that were modified from the relevant vulnerability literature. *First,* we evaluated when and where the studies have been conducted. *Second*, we asked what or who is vulnerable (Malone and Engle 2011). *Third*, we asked about the source of vulnerability ("vulnerability to what" (Malone and Engle 2011)), by examining what kinds of stressors are mentioned in the studies. More specifically, we used the divisions to local/global (internal/external) and cross-scale vulnerability factors and to

social, biophysical and integrated vulnerability factors (Füssel 2007). Moreover, with the help of the IPCC climate-related risk framework (IPCC 2014), we analyzed if the stressors have an effect on hazard, exposure or vulnerability. *Fourth*, we further evaluated, how different concepts such as stressor and factor are used and if there are differences between and within different concepts. *Fifth,* based on the distinctions used by O'Brien et al. (2007), we divided the orientation of the studies into outcome-orientation and contextual-orientation. *Sixth*, by analyzing the vulnerability context, we evaluated if the importance of different stressors is assessed as suggested by Bennett et al. (2015a), and how the importance has been assessed. *Seventh,* we examined if the interactions between different stressors and across different scales are examined as suggested by Turner et al. (2003). *Eighth*, in order to further analyze the novelty of 'multiple stressors' approaches, we examined what traditions and articles are cited in the reviewed literature.

3 Results and discussion

3.1 When and where the studies were conducted

The review shows that there is a significant increase in studies that encompass 'multiple stressors' or non-climatic factors during the last ten years. The number of publications increased after 2006 with a peak of publications being 23 (18 %) in 2014. Of the analyzed articles, 79% were published after 2009 (Fig. 1). It has been found also in other reviews that there has been a recent increase in articles looking at vulnerability (McDowell et al. 2016; Wang et al. 2014). In our sample, the number of articles per year has been increasing with one notable exception; in 2011, the amount of articles published was less than half of the amount of articles published in 2010.

This overall trend reflects the foci of the IPCC assessment reports. For the WG2 AR5 report, studies that were published after October 2006 and accepted for publication (minimum requirement) before

August 2013 were considered. Our sample indicates that there were few studies published before October 2006; therefore, there was relatively limited literature considering 'multiple stressors' to be considered for the IPCC reports prior to AR5. This result resonates with the latest IPCC report where it was pointed out that the AR5 has overcome limitations evident in AR4 in relation to the research analyzing the human dimensions of climate change (Burkett 2014). Our sample also demonstrates that most of the studies that focus on the various processes that cause vulnerability have been published after some founding papers, where 'multiple stressors' and other similar concepts were analyzed explicitly for the first time (O'Brien and Leichenko 2000; O'Brien et al. 2004; Tschakert 2007). This result demonstrates that the analysis of other stressors is a relatively new issue within this field of literature.

In geographical terms, the main focus of the 'multiple stressors' studies is in Africa. In 36% of the reviewed articles, the study area or part of the study area was situated in Africa while the rest of the study areas were located in Asia (22%), North America (18%), Latin America (14%), Europe (14%), and Oceania (14%). These numbers do not sum up to 100% since study areas from multiple continents were included in some of the studies.

3.2 The object of vulnerability

The scope of the study varied in the articles. Majority of the studies evaluated small-scale farming communities in developing countries. Livelihood vulnerability (79%) was the central focus in most of the articles whilst the remainder of the studies analyzed the vulnerability of, for instance, industrial agricultures or wider societal processes. Some of the studies did not particularly analyze vulnerability. For instance, Hageback et al. (2005) examined farmers' land use decisions, and Coulibaly et al. (2015) the reasons behind crop failure. Whilst not explicitly examining a vulnerable entity, the drivers behind these issues were often similar as the causes of vulnerability.

3.3 Types of stressors

Overall, there were hundreds of different stressors mentioned. In our sample, the number of stressors varied between two and 30 within one article. However, it is difficult to explicitly assess the total number of stressors since they were sometimes lumped together or split into smaller entities (for different lists and typologies of stressors, see e.g. (Bennett et al. 2015a; Zou and Wei 2010)). Additionally, stressors covered multiple societal scales ranging from lack of local income opportunities or access to local granaries to globalization and global climate change.

Approximately 25% of the stressors were biophysical while 75% were social. Biophysical stressors identified within the articles were mainly related to natural resource degradation, pollution and pests in addition to climate change and climate-related events such as floods or droughts. Social stressors were mainly related to issues such as poverty, unemployment, health, agricultural markets, governance and globalization. The higher number of social stressors can be due to the fact that social phenomena are more heterogeneous and context-specific.

The distinction between local and global yet alone to internal and external factors is complicated. What is ‘internal’ depends on how the boundaries of the object of study are drawn. If the object of study is a village, internal stressors are different compared to a study in which the object of study is a country (see Gallopín (2006)). In most of the reviewed studies, the object of study was comparably small, often a community or a set of communities. Nevertheless, in the majority of the studies, most of the stressors were not local, such as global climate change phenomena or global trade tariffs or national subsidies, with little possibilities to alleviate these stressors just within the local context of vulnerability.

Cross-scale interactions also hampered the classification of stressors into local and global ones. There were some social stressors or those related to local power relations that were more clearly local. However, most of the stressors such as poverty or environmental degradation can be considered as multi-scale stressors that affect human populations across scales (see also Füssel (2007)). It has been suggested that multi-scale governance could remove some barriers between separate scales but challenges of coordinating actions between different scales remain (Næss et al. 2005).

Most of the stressors were considered to have an effect on either hazard or vulnerability. In other words, stressors were hardly ever related to exposure, as considered by IPCC (2014). One reason behind this issue is that exposure, if understood as being merely a spatial concept, is not always relevant. While exposure to floods tends to be reliant on the location, exposure to other hazards or shocks, such as drought or economic recession, is more independent of the location.

3.4 The use of different concepts

As can be seen from the search terminology, different concepts have been used in the analyses of the effects of non-climatic factors on human vulnerability. Quite expectedly, the concept of vulnerability was used in almost all of the studies (Table 1). Also concepts of risk and factor were widely used. However, key IPCC concept hazard and concepts such as stress and stressor were not used in approximately 30% of the articles. When different concepts were combined with the search words multiple and other, different results were obtained (Table 2). It can be seen that ‘double exposure’, ‘multiple stressors’, ‘other stressors’ and ‘other factors’ together with non-climat* were most widely used; however, these combined concepts were used in less than half of the articles. This shows that none of the concepts is well established to be used widely; furthermore, many of the concepts are used interchangeably.

The term risk is widely used and in many different contexts in different studies. The IPCC climate risk framework (IPCC 2014) is, however, not used explicitly. One reason behind this is that the framework is new and not yet widely established. Another important reason is that risks have dissimilar components in different studies and many different risks are raised ranging from climate and flood risks to risks related to HIV/AIDS. The term hazard is usually used in the meaning of natural hazards and pointing to single events. Some authors, nevertheless, acknowledge that hazards can be slow changes (McNeeley and Shulski 2011) or equate hazards with political-economic shocks (Shackleton and Shackleton 2012). Similar to risk, the term vulnerability is widely used and often with different meanings without a clear framework.

The general components of vulnerability (i.e. exposure, sensitivity and adaptive capacity) are rarely analyzed explicitly. An exception is the study by Hjerpe and Glaas (2012) who examine factors that affect exposure, sensitivity and adaptive capacity in terms of flooding vulnerability in southwestern Sweden. The term exposure is not usually used in the same spatial meaning as in the IPCC in the reviewed studies but in a meaning of a manifestation of a hazard. This is actually in line with the older IPCC framework in which exposure is defined as “the nature and degree to which a system is exposed to” shocks and hazards (McCarthy et al. 2001).

The term ‘double exposure’ refers to two hazards or shocks that together cause risks and vulnerability. In the reviewed literature, ‘double exposure’ was used almost exclusively in this manner, although the concept has been extended to diverse social and environmental changes (McKune and Silva 2013) or broadened to ‘gendered double exposure’ (Nyantakyi-Frimpong and Bezner-Kerr 2015). In addition, the original authors of the ‘double exposure’ concept have later broadened the concept by looking at three pathways of ‘double exposure’, which are outcome (combined impact of processes), context (one process changes the context of the other process and

328 decreases capacity to respond) and feedback (interactions between process impacts and drivers)
329 (Leichenko and O'Brien 2008; Leichenko et al. 2010; O'Brien et al. 2009). The concept of 'multiple
330 exposures' is another extension of the 'double exposure' concept but one that is used slightly
331 differently. For instance, Belliveau et al. (2006) use the term risk as a potential harm, while
332 exposure is a manifestation of this harm (i.e., someone is exposed to a risk). Belliveau et al. (2006)
333 also bring exposure and sensitivity together so that the unit under exposure and its characteristics
334 are evaluated simultaneously. The same kind of terminology is used by Westerhoff and Smit (2009)
335 who employ the term 'multiple exposure-sensitivities'. Other authors such as Bunce et al. (2010)
336 and Bennett et al. (2015b), primarily use the concept of 'multiple stressors' but refer to 'multiple
337 exposures' when the different stressors are manifested. This usage is in accordance with the older
338 IPCC exposure-sensitivity-adaptive capacity vulnerability framework.
339
340 The concept 'multiple stressors' was first used to denote the two phenomena of climate change and
341 globalization that cause 'double exposure' (O'Brien et al. 2004) but the usage of this term has been
342 considerably widened. Stressor is fairly often used synonymously with IPCC's hazard concept but
343 its significance is much broader. For instance, Tschakert (2007) uses terms worry, stress, stressor,
344 hazard and threat interchangeably to denote threats that affect people. Therefore, some of the
345 stressors such as poor health or lack of money used by Tschakert (2007) and also by other authors
346 can be considered merely issues that increase individuals', households' or communities' social
347 vulnerability to hazards rather than hazards per se. Similar issues have been elaborated in social
348 vulnerability literature (Cutter et al. 2003).
349
350 'Factor', 'driver' and 'pressure' further complicate the mixed usage of different concepts. Factor is
351 used in a wide array of meanings: denoting to a statistical connotation, to factors of change, risk
352 factors or more widely to non-climatic factors. Driver is often used to mean the processes that cause
353 changes (drivers of change) and in some cases as a synonym for pressures or stressors (Connolly-

354 Boutin and Smit 2015). Pressure is used in the same way as stressor or in the very wide everyday
355 meaning. For instance, Chandra and Gaganis (2015) use the term 'non-climatic pressures' when
356 referring to issues such as tourism, social change and deforestation, while Suckall et al. (2014) use
357 drivers and pressures in the drivers-pressures-states-impacts-response (DPSIR) framework. In this
358 widely used framework, climate change, economic growth and other *drivers* exert *pressures* (e.g.
359 over extraction of resources), which cause changes in *state* (e.g. in livelihoods). These changes are
360 considered *impacts,* which may be alleviated with adaptive and coping *responses*. DPSIR and other
361 frameworks (Bennett et al. 2015a; Hopkins 2015) are used for organizing complex information and
362 simplify the usage of different concepts, which can otherwise be confusing.
363
364 The usage of the term non-climatic illustrates how one concept can be used in various meanings and
365 in different combinations. The term is originally used as denoting other factors than climate that
366 contribute to vulnerability (Füssel and Klein 2006). In the reviewed articles, non-climatic has been
367 used in combination with factor, pressure, risk, determinant of vulnerability, stress, stressor, impact,
368 stimuli, condition, change, force, issue, exposure-sensitivity, variable and driver. All these
369 combinations show that non-climatic can attain many meanings often denoting to hazards or other
370 issues that have an effect on risks or vulnerability. Hence, the term non-climatic is used as a
371 counterpoint to climatic but in different studies the term is used differently.
372
373 Furthermore, the relative importance of non-climatic versus climatic varies in different studies and
374 in different cases. For example, Lereboullet et al. (2014) model the impacts of future climate to
375 viticulture in southern France and use interviews in order to analyze the relative role of non-climatic
376 factors, while McDowell and Hess (2012) analyze the effect of 'multiple stressors' on indigenous
377 smallholders on Bolivian highlands using the term 'non-climatic stressors' to highlight that not all
378 the stressors are climatic. Whereas the weight is clearly given to climate in the first example,
379 different stressors are considered equally important in the second study. In general, the reviewed

380 studies show that non-climatic and ‘multiple stressors’ do not have different emphasis; rather they
381 illustrate that both concepts are used in versatile ways.
382
383 Overall, our analysis shows that different concepts have been used in a wide range of meanings.
384 One key message is that the different factors cannot be organized to the IPCC framework of
385 hazards, exposure and vulnerability since there is no conceptual clarity of the key concepts among
386 the researchers within this multi-disciplinary field of human dimensions of climate change. Ideally,
387 concepts should be general enough in order to allow their usage in the same meaning across
388 different cases and in different studies. Nevertheless, as Hinkel (2011) suggests, a general definition
389 of vulnerability should be agreed upon but the concept should thereafter be further operationalized
390 based on the conceptual framework used and the context of the case analyzed. In our sample, only a
391 few studies were explicit in how the different concepts were operationalized and on which kind of
392 conceptual framework the studies were based. This mixed usage of concepts and lack of explicit
393 description of frameworks has been found also in a vulnerability review by Delaney et al. (2014).
394
395 This lack of conceptual clarity within the field hinders a better understanding of the dynamics of
396 climate change and human vulnerability. Given the overlapping use of concepts, it is hard to
397 consider to what extent the different non-climatic factors interact or influence each other. There is
398 no abundance of conceptual frameworks or models, par a few examples (e.g. DPSIR), which
399 address this issue and attempt to present a simple model of interactions. Whilst developing even a
400 simplistic framework or model always leads to compromise, it can nevertheless help to clarify some
401 connections within complex system. At the same time we acknowledge that differences between the
402 reviewed studies partly relate to divergences in interpretations that are rooted in different discourses
403 and some of the differences may not be integrated into one common framework (O'Brien et al.
404 2007). More conceptual clarity would nevertheless enable some integration of approaches that are
405 discursively close to each other and also help in bridging the approaches that may fundamentally

406 differ but still complement each other.

407

408 **3.5 Analysis of the vulnerability context**

409

410 We divided the orientation of the studies to outcome-oriented, contextual-oriented and mixed focus
411 using the division by O'Brien et al. (2007). In their distinction, outcome vulnerability is a linear
412 result of projected impacts on the exposed unit, whereas contextual vulnerability builds on a
413 processual and multidimensional approach in which several social, economic, political and
414 institutional structures and conditions also affect vulnerability. They also acknowledge that some
415 approaches lie between the two interpretations of vulnerability and specifically exemplify that
416 'multiple stressors' is an intermediate approach: vulnerability can be an outcome of 'multiple
417 stressors', or 'multiple stressors' can impact the context in which vulnerability is experienced.

418

419 We classified 76 articles (or 61%) as contextual oriented, 32 articles (26%) as outcome focused and
420 17 articles (14%) as mixed. Our analysis thus shows that among climate change literature there is
421 considerable number of studies that analyze the vulnerability context. Furthermore, the number of
422 these studies is rapidly increasing (Fig. 1). Our classification is in line with the analysis of
423 McDowell et al. (2016) but differs from the analysis of Bassett and Fogelman (2013), who stated
424 that 70% of the 558 studies they considered were outcome focused (where the main source of
425 vulnerability was climate impacts), 3% of the studies focused on social roots of the vulnerability
426 and 27 % considered both.

427

428 This disparity results from many reasons. First and foremost, the sample of the studies between the
429 reviews differs. Our review was systematic and we selected articles using systematic searches as
430 recommended by Lorenz et al. (2014), while Bassett and Fogelman (2013) chose four journals and
431 used only one search word: `adaptation`. The article search process was different and our search

words could have favored contextual vulnerability or mixed-focus studies. Second, we selected only studies with clear focus on human vulnerability, whereas Bassett and Fogelman (2013) did not carry out the further pruning of the studies. Third, we classified all the studies where there is a clear analysis of the vulnerability context as contextual. In our view, most of these studies would have been classified as mixed in the analysis by Bassett and Fogelman (2013). Fourth, many of the studies in our analysis were published after 2012 the time when the Bassett and Fogelman (2013) article was submitted for the review.

3.6 Importance of stressors

Quite often, the reviewed articles claimed that climate was not the most important factor or not the most pressing stressor affecting vulnerability (Table 3). In 44 (35%) of the 125 studies analyzed, there was no indication of which the most important stressors are. The rest of the studies were divided into two parts: half ranked climate-related stressors such as drought as the most important, and the other half stressors other than climate as the most important. Stressors other than climate included social issues such as lack of income or capital, health, governance, neoliberalism or globalization and demographics.

As this list suggests, stressors can be found at different scales. While some of the stressors, such as lack of income or poor health, have an effect on everyday lives, other stressors, such as climate change and globalization, are global-scale forces that might exert an effect on more proximate stressors. This indicates interconnectedness of stressors across different scales. Many of the stressors are also fairly heterogeneous and their impacts can vary depending on the context. For instance, while in a remote community in the Norwegian Arctic primary stressor for community adaptation is population decline (Amundsen 2012), in many other contexts one of the major stresses concerning the adaptation to climate change is caused by population growth (Fazey et al. 2011;

458 Laube et al. 2012; Pricope et al. 2013).

459

460 In the reviewed literature, the relative importance of different stressors was analyzed by methods of
461 interviews, participatory approaches and surveys, by judgments made by researchers, by focusing
462 on some stressor(s) and by modeling or by combining different approaches. All these different
463 methodological approaches yield varying results (Table 3). When importance was examined based
464 on data gathered by interviews, surveys or participatory methods, 41% of studies ranked climate as
465 the most important stressor but more articles ranked climate as the most important when importance
466 was evaluated by researchers' judgment (57%) or selection of focus (83%).

467

468 In addition, there were differences in how the evaluations were made or how the interviews were
469 carried out. These interlinked with the conceptual issues of how the object of vulnerability was
470 defined, what the important stressors were considered to be, at what scales they were analyzed and
471 how the interviews and their analyses were framed. Different sorts of stressors were often included
472 in the same analysis. In many of the reviewed studies which were based on interviews most
473 important stressors were considered to be everyday distress or everyday worries. In future, we
474 suggest using triangulation and cross-checking in data interpretation to sort out the importance of
475 stressors at different scales and to examine how stressors might be interlinked. Better explanation of
476 the conceptual framework used would also be important.

477

478 Our review indicates that there are complex interconnections between climatic and non-climatic
479 factors concerning the human vulnerability and climate change. First, climatic factors cannot be
480 analyzed in isolation because other stressors shape the context, in which climate change is
481 experienced (Eriksen et al. 2011; O'Brien et al. 2007). Furthermore, especially in many parts of the
482 global South, adaptation and mitigation policies themselves can sometimes cause further
483 vulnerabilities (Bose 2015). Second, other stressors affect the vulnerability of especially those

484 communities and groups of population that are already experiencing high levels of vulnerability.
485 These communities might become even more vulnerable in the future when the impacts of climate
486 change become more evident. In order to decrease vulnerability, the context of 'multiple stressors'
487 should be taken into account; and the vulnerability to different stressors should be reduced (Eriksen
488 et al. 2011; McCubbin et al. 2015).
489
490 **3.7 Analysis of interactions**
491
492 O'Brien et al. (2009) highlight that 'multiple stressors' literature should analyze interactions
493 between different stressors. Interactions were mentioned or acknowledged in 95 (76% of the
494 studies) of the reviewed studies. However, only 35 (28%) of the studies included explicit analysis of
495 the interactions as also found by Tucker et al. (2014).
496
497 If there is no clear analysis how the different stressors interact and intertwine, the relative
498 importance of different stressors is difficult to assess. For instance, climate change is often a part of
499 the cause for the most proximate and more evident stressors (see e.g. McCubbin et al. (2015)). This
500 was stressed not only in the studies where importance was assessed using researchers' judgments
501 but also by interviewees (Mubaya et al. 2012; Petheram et al. 2010).
502
503 The interconnections between different stressors and different scales also complicate the division
504 between social and biophysical factors, as well as between local and global processes. For instance,
505 Reenberg et al. (2012) report that in the Sahel area, drought (non-local biophysical stressor) forced
506 young men to migrate periodically to find pastures elsewhere. This resulted in lack of labor (local
507 social stressor) and bottlenecks in agricultural production in the next growing season.
508
509 Therefore, it is more important to analyze the interactions and cause-response relationships between

510 different stressors than to divide them to different groups. Interacting stressors and associated
511 processes are also dynamic: they change over time and context and across scales. Some authors
512 (Belliveau et al. 2006; Westerhoff and Smit 2009) have thus used the concept of 'dynamic
513 vulnerability' to emphasize the changing environment and interacting stressors. In future studies, we
514 recommend together with other scholars (Bennett et al. 2015a; Bennett et al. 2015b; Tucker et al.
515 2014) a clear analysis or at least brief exploration of interactions. The analysis of interactions also
516 helps in distinguishing stressors that act at different scales.
517
518 **3.8 Different scientific traditions**
519
520 Multiple stressors have been studied in many scientific traditions such as climate research and
521 hazard research. It has been argued that multiple stressors have been examined for decades in the
522 latter tradition (see Introduction Section). In our sample, only one (Smit et al. 1996) of the papers
523 was published before the 2000s. This suggests that studies of 'multiple stressors' is a relatively new
524 research interest. However, previous studies might have used other terms than the ones we used in
525 our literature searches. Thus, it is possible that we might have missed some studies that did not
526 focus on climate change specifically but belonged to other scientific traditions such as hazards
527 research.
528
529 In most of the reviewed articles, early studies of 'multiple stressors' analysis were not cited
530 exhaustively, though many of the studies such as Lopez-Marrero and Yarnal (2010), Prno et al.
531 (2011) and O'Brien et al. (2009) refer to the earlier traditions such as literature on hazards (Wisner
532 et al. 2004) or social vulnerability (Cutter et al. (2003). In general, it was argued that the earlier
533 papers were merely theoretical, whereas the newer literature either represents empirical case studies
534 or analyzes interactions between different stressors. There are also authors such as Smit et al.
535 (1996) and Smit and Skinner (2002), who acknowledge that there have been studies within other

fields such as agricultural systems analysis where multiple factors have been considered but in many of these studies *ceteris paribus* assumptions have been made. The lack of citation to earlier traditions illustrates perhaps a discontinuity within research traditions and presents a risk of reinventing the wheel, conceptually and methodologically. Nevertheless, a recent bibliometric analysis found some evidence of convergence between different traditions (Giupponi and Biscaro 2015).

4 Conclusions

We systematically reviewed climate change literature in which 'multiple stressors' or 'non-climatic factors' have been accounted for. We chose articles for the review with the help of SCOPUS and Web of Knowledge searches with different keywords. Our searches left out some articles which consider 'multiple stressors' (Adelekan and Fregene 2015; Amoako Johnson and Hutton 2014; McDowell et al. 2016) but our systematic sample consisted of 125 articles. We have contributed to the conceptual clarity of an emerging new field of research on vulnerability that endorses various processes interacting with climate change. Based on our results, following three major conclusions can be drawn.

First, the analysis of 'multiple stressors' is a relatively new field with literature expanding especially since 2010. Although the analysis of 'multiple stressors' builds on earlier literature about hazards, it has made the understanding more profound by using empirical case studies and in some cases by analyzing interactions between different stressors. We recommend that in further studies interactions should be better analyzed to clearly demonstrate which stressors should be targeted simultaneously.

Second, the literature about 'multiple stressors' is heterogeneous. Whilst some of the found differences in part relate to differences in interpretations that are rooted in different discourses,

563 many of the studies are not explicit about the interpretations and conceptualizations they use (see
564 Section The use of different concepts). More conceptual clarity would enable some integration of
565 approaches and also help in bridging the approaches that may fundamentally differ but still
566 complement each other. We recommend usage of analytical frameworks or models which specify
567 differences, interactions and relationships between different drivers, processes and stressors.
568
569 Third, it was often stressed that climate change is not the most evident stressor. This was
570 emphasized 59% of the studies where results were obtained using interviews or surveys. This is
571 logical since climate change is only one of the stressors affecting people's everyday lives and it is
572 not always prioritized in policy implementation. The importance of different stressors is difficult to
573 measure or rank due to interactions between different stressors and changes in time, context and
574 across scales; therefore, we recommend use of mixed methods and triangulation of different data
575 sources in the data analysis to sort out the most important stressors.
576
577 The reviewed literature emphasizes that there are multiple interacting stressors that should be
578 analyzed together and these stressors should be targeted by policies, which integrate adaptation to
579 climate change and other stressors. Risks related to climate change are not caused by climate
580 change alone but by various intertwining biophysical and social drivers and stressors, which have
581 effects on hazards, exposure and vulnerability. Finally, the way vulnerability is conceptualized and
582 approached in research has also relevant policy implications. The different definitions of problems
583 and their consequences outline and justify different kind of policy responses and lead to different
584 kind of operationalization of vulnerability assessments in the adaptation policies. The framings of
585 vulnerability thus have very material effects on the well-being of vulnerable and disadvantaged
586 social groups.
587
588

589

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595

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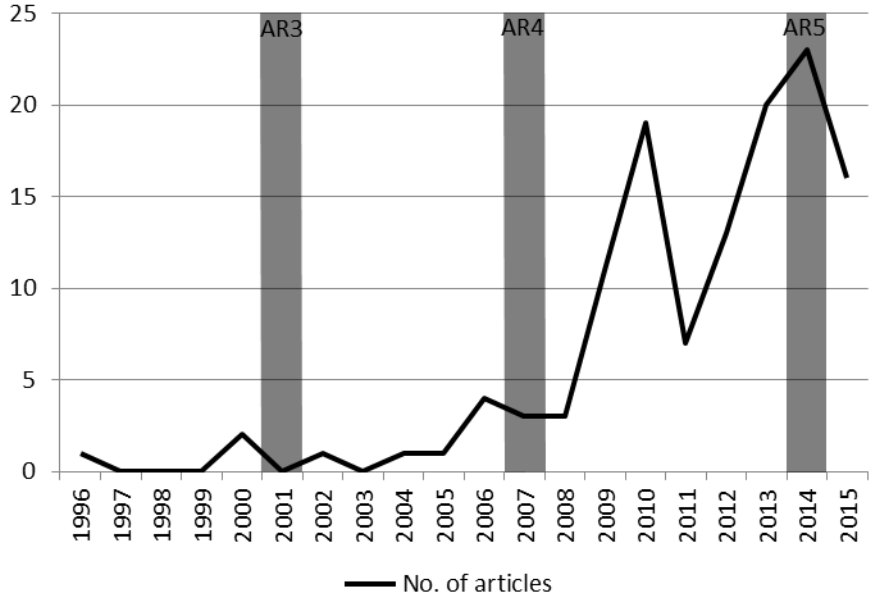

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Figure 1. The amount of articles that were selected for the review, published each year. The publishing years of IPCC Working Group 2 Assessment Reports (AR) are marked with transparent gray. Because the literature search was performed on June 4th 2015, the amount of articles published in 2015 is not comparable to other years.

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Table 1. Different concepts, the percentage of articles in which these concepts were used, and how many times these concepts were overall used in the reviewed articles. Concepts were sought from full-texts including references. All concepts were sought both in singular and in plural form. The overall number of words might not be exact due to problems in character recognition, but their order of magnitude is correct.

Concept	% of articles	Overall
Vulnerability	98 %	4487
Risk	97 %	2561
Factor	97 %	1278
Exposure	83 %	1126
Stress	73 %	1011
Stressor	70 %	1185
Pressure	69 %	342
Hazard	65 %	756
Driver	63 %	502
Sensitivity	58 %	520

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831 *Table 2. Different concepts and the percentage of articles in which these concepts were used.*

832 *Concepts were sought from full-text articles excluding references. All concepts were sought both in*

833 *singular and in plural form.*

Concept	% of articles
non-climat*	40 %
multiple stressor	38 %
other factor	37 %
double exposure	27 %
other stressor	27 %
multiple exposure	12 %
multiple stress	12 %
other stress	11 %
multiple factor	10 %
other risk	10 %
other driver	6 %
multiple risk	6 %
multiple driver	5 %
multiple pressure	3 %
other pressure	0 %

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Table 3. Ranking of the most important stressor based on different analysis method. For each analysis method, and overall, the amount and proportion of articles are given.

		Most important stressor	
Analysis method	Number of articles	Climate	Not climate
Interviews, participatory approaches, surveys	37 (46%)	15 (41%)	22 (59%)
Researchers' judgment	23 (28%)	13 (57%)	10 (43%)
Focusing on some stressors	6 (7%)	5 (83%)	1 (17%)
Modelling	1 (1%)	1 (100%)	0 (0%)
Combination of two or three approaches	14 (17%)	4 (29%)	10 (71%)
Overall	81 (100%)	38 (47%)	43 (53%)

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Climate change, multiple stressors and human vulnerability – a systematic review

Regional Environmental Change

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