A community resilience index for Norway: An adaptation of the Baseline Resilience Indicators for Communities (BRIC)

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PII: S2212-4209(18)31203-2
DOI: https://doi.org/10.1016/j.ijdrr.2019.101107
Article Number: 101107
Reference: IJDRR 101107

To appear in: International Journal of Disaster Risk Reduction

Received Date: 18 October 2018
Revised Date: 1 March 2019
Accepted Date: 4 March 2019


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Dear Satish and Aravind Somasundaram,

The order of the authors is as follows:

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If you require any additional information, please let me know.

With kind regards

Sabrina
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an Adaptation of the Baseline Resilience Indicators for Communities (BRIC)

Abstract
In recent years, building disaster resilient communities has become a primary objective of crisis management institutions across the globe, as a resilient community is likely to suffer fewer losses and recover more quickly when faced with an adverse event. In order to strengthen a community’s resilience, however, one needs to first establish a baseline, an initial measure that can be used to compare communities and to track changes over time. This article presents such a baseline, a community resilience index, for Norway. Following the approach outlined by the Baseline Resilience Indicators for Communities (BRIC), the article constructs a hierarchical index, using 47 indicators divided into six subdomains, to describe the resilience capacities of the Norwegian municipalities. The results show considerable variations in the relative levels of resilience. Most markedly, there seems to be a north-south divide; i.e. many of the northern municipalities having lower levels of overall resilience and many of the southern municipalities having higher levels of overall resilience. These initial observations are further analysed by deconstructing the overall index into its components to identify driving forces behind the overall resilience score. To validate the results, the resilience scores are compared to previously established vulnerability metrics. The resilience and vulnerability metrics are then used to identify potential low-risk (high resilience, low vulnerability) and high-risk (low resilience, high vulnerability) areas across Norway.

Keywords
Resilience measurement, natural hazards, vulnerability, composite indicators
1. Introduction
Given its direct exposure to the North Atlantic Ocean and its steep terrain, Norway is prone to a number of natural hazards, such as storms, storm surges, floods, landslides, and avalanches (MoCE 2012). According to data from the Norwegian Natural Perils Pool, natural hazards resulted in approximately NOK 21.7 billion (USD 2.7 billion) in property damages in the period from 1980 to 2017.\(^1\) Researchers anticipate that natural hazard events will increase in frequency and intensity in the future due to climate change (Hov et al. 2013; IPCC 2012). Their consequences, i.e. damages to infrastructure and buildings, as well as personal injuries and loss of life, the latter having been a rarity in Norway thus far, are therefore likely to increase as well.

One way to deal with the increased risk of severe natural hazard events is to build upon existing qualities within the society, to strengthen capacities that allow affected communities to better prepare for, deal with and recover from the adverse effects. In the disaster management literature, this strategy is now commonly referred to as resilience building. Resilience, when applied to communities, can be defined as “the ability of a community to prepare and plan for, absorb, recover from, and more successfully adapt to actual or potential adverse events in a timely and efficient manner including the restoration and improvement of basic functions and structures” (Cutter et al. 2014, p.65). Resilience is generally considered to be a positive, desirable attribute, as a community that is resilient will suffer fewer losses and will recover more quickly when faced with a hazardous event.

However, in order to strengthen a community’s resilience, one needs first to establish a baseline, an initial measure that allows for the comparison of communities’ resilience capacities based on certain criteria. Once the baseline is established, the identified indicators can be used to track changes over time and to potentially plan for targeted interventions prior to, during or after an extreme event. Whilst the measurability of a vague concept like resilience is questioned by many (Cumming 2005; Levine 2014; Weichselgartner and Kelman 2014), there is also a growing number of scholars and practitioners alike that argue for the usefulness of resilience measures in disaster risk reduction (Burton 2015; Cutter 2016; IFRC 2016), stressing that without a quantitative resilience assessment it is not possible to compare between entities, to monitor progress, to identify areas for improvement or areas in need of greater assistance (Béné 2013; IFRC 2016; National Academies 2012). Numeric indicators can, according to the proponents of resilience measurement, become important planning tools at local, regional, and national levels.

In Norway, resilience research is still in its infancy. The little that has been done is case study-based, focusing on individual communities (Amundsen 2012; Broderstad and Eythórsson 2014; Nystad et al. 2014), changes in the marine ecosystem (Gjelsvik Tiller et al. 2014), psychological development (Hjemdal 2007; Hjemdal et al. 2007), or the use of social media.

\(^1\) Own calculations based on data from the Norwegian Natural Perils Pool; NOK values adjusted using the Consumer Price Index.
during a traumatic event (Kaufmann 2015). As to the authors’ knowledge, no attempts have been made yet to identify measurable indicators of Norwegian community resilience.

This article constructs a community resilience index for Norway. The index is composed of six sub-indices and 47 indicators and has been inspired by the Baseline Resilience Indicators for Communities (BRIC), originally development by Dr Susan Cutter and her colleagues at the Hazard & Vulnerability Research Institute at the University of South Carolina (Cutter et al. 2010; Cutter et al. 2014). The resulting maps show the geography of community resilience in Norway, identifying places with particularly high or low levels of resilience. Further, the article compares the composite measure against previously established vulnerability metrics. This comparison serves two purposes: (1) the validation of the community resilience index and (2) the identification of potential low risk (low vulnerability – high resilience) and high risk (high vulnerability – low resilience) areas. Finally, this article addresses potential practical implications of the index as a resilience measurement tool, discussing shortcomings and areas for improvement in data collection, construction and validation.

The article proceeds as follows. Section 2 provides an introduction to the community resilience literature. It presents alternative resilience perspectives, outlines different measurement approaches, and introduces the selected framework with some of its limitations. Section 3 presents the index construction process and section 4 the results. Section 5 compares the community resilience index to previously established vulnerability metrics. Section 6 discusses practical implications and section 7 concludes with some final remarks.

2. Measuring Community Disaster Resilience

2.1 Introducing the Resilience Concept

Resilience, generally referring to the ability of a system to overcome stresses and shocks, has been widely adopted by international and national organizations as the must-have buzzword of policymaking in recent years. It seems that every system, every organization, every group, every individual can and should be resilient. It is prescribed as something to aim and aspire for, as a desirable quality. Packed with positive connotations, promising inherent strength, endurance, and the ability to successfully deal with constantly changing circumstances and disturbances, resilience is apparently the answer to many challenges in today’s complex and uncertain world. Yet despite its popularity and omnipresence, the concept of resilience is rather ambiguous. Whilst there is general agreement on the underlying notion that it is a good thing to be able to bounce back after a disturbance, it is hardly ever used quite that literally in academic, political, and policy discourses. Rather it is used metaphorically, as an “image […] capable of sparking human imagination” (Norris et al. 2008, p.127), as a lens through which to view the world. This however means that, at least in academia, there is little agreement on what it means to be resilient for most entities and systems.

The origins of the concept of resilience are often traced back to the seminal work of C.S. Holling (1973), who in order to explore the instabilities and dynamics of nature introduced the
concept of resilience in ecology. Resilience according to him is “a measure of persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables” (Holling 1973, p.14). Resilience is not, however, “the ability of a system to return to an equilibrium state after a temporary disturbance” (Holling 1973, p.17). That is what Holling coins stability. Yet in the ecological literature, two definitions of resilience emerged. The first embraces persistence, change, and unpredictability in a non-linear, non-equilibrium system; the second focuses on efficiency, constancy, and predictability in a single-equilibrium system that is always near a stable state. The first, in line with Holling’s school of thought, is now termed ecological resilience. Whereas the second is termed engineering resilience (Holling 1996). Engineering resilience focuses on a quick and efficient return to a normal state of functioning after a disturbance (Folke 2006). Ecological resilience, on the other hand, is about absorbing changes and persisting, about “staying in the game” (Pickett et al. 2004, p.373). An ecologically resilient system does not need to be stable. In fact, it “may be quite unstable, in that it may undergo significant fluctuation” (Klein et al. 2003, p.39).

The concept of resilience in ecology received enormous attention not least due to its promise of a system’s “continuous ability to manage change and surprises, to meet demands without eroding future needs, […] to maintain control” (de Bruijne et al. 2010, p.16). The concept eventually evolved from pure ecosystems research to include the human sphere. In studies of the resilience of social-ecological systems, or human-nature systems, it is acknowledged that human and natural systems are inextricably linked (Dovers and Handmer 1992), and “sufficiently complex that our knowledge of them, and our ability to predict their future, will never be complete” (Berkes 2007, p.284). The emphasis thus remains on embracing uncertainty and change. Yet with the introduction of the human element, the system under investigation is no longer passive and reactive, but rather it can be influenced directly and proactively through human agency. Human beings have the ability to learn and adapt, to anticipate, to take preventive action, and to influence their surroundings (Davidson 2010; Brown and Westaway 2011). That is why the resilience of social-ecological systems discourse usually entails notions of learning and adaptation (Brown and Westaway 2011), of adaptability and transformability (Walker et al. 2004; Folke et al. 2010).

Similarly, in the growing field of resilience engineering, which studies complex socio-technical systems, it is acknowledged that these systems are essentially dynamic, as they must be able to adjust to changing conditions and unexpected occurrences. For these adjustments and the overall efficiency of the system, the adaptability and flexibility of human actions are seen as crucial (Hollnagel 2006). However, in comparison to social-ecological systems, engineering systems exhibit a greater degree of human intention. They are artefacts designed and maintained to serve specific purposes (Park et al. 2013). Resilience of a complex engineering system can be understood as adaptive processes within the system that work toward maintaining or regaining a dynamically stable state in the presence of a disturbance or a persisting stress (Hollnagel 2006).
The first to connect the concept of resilience with the study of natural hazards and disasters was likely Timmerman (1981). Building on Holling’s work, he defined disaster resilience as “the measure of a system’s, or part of a system’s capacity to absorb and recover from the occurrence of a hazardous event” (Timmerman 1981, p.21). According to him, however, there are two strategies for averting or dealing with possible crises: the first, and most common, perhaps even today, is a strategy of reliability, the second a strategy of resilience. A reliable system has continuous defence mechanisms in place that shield against the consequences of adverse events. A resilient system, on the other hand, is able to absorb the negative effects and recover. Timmerman (1981, p.32) warns that “failure of the first type of defence (reliability strategy) [may be] catastrophic in a way unmatched by the second [resilience strategy]; since failure of the shield [may reveal] a lack of absorptive capacity underneath”. This notion is today strongly supported by the school of thought found in resilience engineering. Risk management, or in Timmerman’s words ‘the reliability strategy’, which seeks to prevent system failure by guarding against identified threats, should be supported by resilience management, which embeds adaptation and mitigation strategies within the system to allow for a quick recovery when an adverse event occurs (Linkov et al. 2014; Park et al. 2013).

Traditional approaches in disaster management focus on damage prevention and efficient response and recovery operations rather than on mitigation and capacity building (Manyena 2006). Consequently, many studies of disaster resilience are outcome-oriented and focus on the possibility and speed of recovery or the minimization of damages (see e.g., Bruneau et al. 2003; Cimellaro et al. 2010; Yu et al. 2015). However, in contrast to this rather technical approach, there is a growing body of literature that focuses on the human side of disaster resilience, on individual and community capacities that are essential for coping and adapting in times of crisis (Manyena 2006). There are numerous studies that support the notion that during periods of hardship, facing imminent danger and physical harm, it is at the local level that resilience first manifests. It is the affected people, their knowledge, networks, and capacities as individuals and as a group that often serve as safety nets in times of crisis and ultimately determine their level of resilience (see e.g., Aldrich 2012; Kendra and Wachtendorf 2003; Longstaff et al. 2010).

Whilst the concept of resilience is now often seen as a new holistic paradigm of disaster and crisis management (IFRC 2016; Manyena 2006; McEntire et al. 2002; O’Brien et al. 2006; Sanderson 2016), it remains intrinsically flexible; there is no one all-encompassing definition, and no one set of indicators for every context. Which entities (e.g. individuals, households, communities, cities, societies) should be resilient to which shocks (e.g. earthquakes, storms, man-made threats) at which magnitudes (e.g. everyday struggles or rare extreme events) within which boundary conditions (e.g. targeted speed and level of recovery) need to be defined for every case, every research study.
2.2 Measurement Approaches
With the rise of resilience as a unifying policy catchword, interest in measuring resilience grew. In order to justify large-scale programmes and projects, which aim to make communities, economies, and infrastructures more resilient when facing disturbances, one needs tools to assess initial conditions, monitor progress, and evaluate impacts. With regard to disaster resilience, the World Disasters Report 2016 (IFRC 2016) distinguishes between three assessment approaches: quantitative, qualitative, and participatory.

Participatory approaches build on the premise that people at risk are knowledgeable and resourceful and are therefore able to define and assess their own resilience capabilities. Participatory toolkits, such as the Characteristics of a Disaster-Resilient Community (Twigg 2009) or the Community-Based Resilience Analysis (CoBRA) (UNDP 2014), may be limited in scope, often focusing on only one community, but they can be immensely valuable for local disaster risk management, as they allow for targeted, customized interventions that consider the particular needs of the community.

Qualitative approaches, applying methods such as interviews, life stories or observations, can provide in-depth accounts of people’s lived resilience, depicting the realities on the ground and exploring amongst other things the interwoven drivers of vulnerability and resilience across space and time (see Amundsen 2012 for an example of a qualitative case study of community resilience). Qualitative studies can also aim to create theoretical frameworks, highlighting key components of resilience and their schematic connections. Two prominent examples are Norris et al.’s (2008) ‘set of networked capacities’ and Cutter et al.’s (2008) ‘Disaster Resilience of Place’ (DROP) model. Both frameworks were later translated into measurable indicators (see Sherrieb et al. 2010; Cutter et al. 2010; Cutter et al. 2014).

Quantitative approaches seek to make resilience comparable between entities (e.g. households, communities, businesses) and locations, and/or trackable across time. They usually take the form of indices, ranks, or scores and are based on secondary data or surveys. During the last few years, numerous metrics have been developed to measure different types and different interpretations of resilience. Generally, these metrics can be divided into two groups: the first looks at resilience through a lens of past and potential losses, mirroring disaster impacts; the second understands resilience as a quality of people and places (IFRC 2016). Yu et al. (2015) and Hallegatte et al. (2016) are examples of the former, and Cox and Hamlen (2015) and Henly-Shepard et al. (2015) of the latter.

2.3 The Baseline Resilience Indicators for Communities (BRIC)
The inspiration for the index in the present article are the Baseline Resilience Indicators for Communities (BRIC) (Cutter et al. 2014). The BRIC metric developed for all counties (serving as community proxies) across the contiguous United States is a comprehensive hierarchical index composed of 49 indicators divided into six resilience subdomains; these are social, economic, institutional, infrastructure & housing, community capital, and environmental (for further information on the subdomains see Section 3.2).
BRIC builds on the theoretical framework of the Disaster Resilience of Place (DROP) model (Cutter et al. 2008). One aspect of the DROP model looks at antecedent conditions created through the interaction of social systems, natural systems and the built environment. It is assumed that the antecedent conditions, which include both inherent vulnerabilities and inherent resilience, are in place prior to the occurrence of a hazardous event. BRIC is the quantification of the inherent resilience component of the DROP model.

Cutter et al. (2014, p.66) stress that the metric they create is “a static snapshot of inherent resilience, recognizing that the production of resilient community characteristics is dynamic and can vary on an annual, monthly, weekly, daily, or even hourly basis”. It further needs to be emphasized that BRIC focuses on the existing resilience capacities of a community and not their application. Community resilience is often portrayed as a process, an adaptive response to adversity, in which community actors utilize community resources (social, economic, environmental capital) to adapt to changing circumstances and to moderate or avoid negative consequences (Chaskin 2008, Magis 2010). Although it is implied that better scores on certain resilience indicators support resilience processes, such as adaption and recovery, BRIC does not seek to measure community resilience as a process nor a community’s resilience performance given a specific hazard scenario. Finally, it should also be noted that ‘community’ in the BRIC model is reduced to a locality, sidelining social and relational aspects of community that so often are of critical importance in crises.

3. Community Resilience Index for Norway
The community resilience index for Norway presented in this article is an adaptation of BRIC (Cutter et al. 2010, Cutter et al. 2014). It is not, however, a direct translation of the US resilience indicators for the Norwegian context, as done by Singh-Peterson et al. (2014) for the Sunshine Coast, Queensland, Australia. As the community resilience index for Norway needs to be country-specific, the ultimately selected indicators should be sensible and justifiable for the Norwegian context (Holand and Lujala 2012). That is why the list of indicators proposed by Cutter et al. (2010) and Cutter et al. (2014) served only as a rough guide for data collection and were complemented with other studies of vulnerability and resilience measurement. What remained the same for the community resilience index for Norway are the conceptual framework with its six resilience subdomains and the hierarchical approach to index construction.

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2 The Disaster Resilience of Place (DROP) model portrays overall disaster impacts as resulting from a combination of antecedent conditions (i.e., inherent resilience and vulnerability), hazard even characteristics, and coping responses. The model stipulates that the event impact can be moderated by the absorptive capacity of the community. Consequently, the degree of recovery is determined by the magnitude and severity of the event and the adequacy of the absorptive capacity. The model also includes adaptive resilience, through improvisation and social learning, as a community quality aiding recovery (Cutter et al. 2008). BRIC, however, focuses only on the inherent resilience component of the model (Cutter et al. 2014).

3 Singh-Peterson et al. (2014) used the indicator selection of Cutter et al. (2010) and translated them to the Australian setting, collecting matching indicators where possible and suitable alternatives where necessary.
3.1 Indicator Selection and Data Preprocessing

As a first step in the data collection process, a wish list of 139 indicators was compiled inspired by the works of Birkmann et al. 2013; Burton 2012, 2015; Cox and Hamlen 2015; Cutter et al. 2010; Cutter et al. 2014; Flanagan et al. 2011; Frazier et al. 2014; Holand et al. 2011; Holand and Lujala 2012; Singh-Peterson et al. 2014; Tate 2012; Wood et al. 2010. Of this wish list, 112 variables were collected for all Norwegian municipalities for the year 2014. All variables were already preliminarily assigned to a resilience subdomain. In an academic focus group with scholars involved in climate change and resilience research, the variables were discussed at the conceptual level with respect to their relevance and adequacy for the intended purpose and 65 were selected for potential inclusion in the index. After screening the 65 variables for potential errors, two variables were excluded for containing too many missing values, making the variables unreliable, and four variables were excluded for applying to only a limited number of municipalities, potentially skewing the results.

The remaining 59 variables were then normalized using min-max transformation (0 to 1 scaling). Normalization allows for the comparison and combination of otherwise very different variable constructs, such as percentages, per capita counts or distance measures. To ensure that all variables had the same theoretical orientation, that is, higher values corresponding with higher levels of resilience, a number of variables were reverse scaled by subtracting the min-max score from 1.

After normalization, a correlation analysis was run to identify potential problems arising from multicollinearity between variables. Seven variables were found to be correlating highly (Pearson’s r>0.7) with other variables. To not selectively choose one over the other, all seven variables were omitted from the indicator selection. This resulted in an initial selection of 52 variables. The Appendix presents the 52 variables, their definitions, theoretical justifications for inclusion and summary statistics.

3.2 Resilience Subdomains and Selected Indicators

The selected indicators are assigned to the six resilience subdomains as outlined by the Baseline Resilience Indicators for Communities (BRIC) framework (Cutter et al. 2014). The social resilience subdomain intends to capture general demographic characteristics of the population that enhance the ability of the population to deal with adverse events. For instance, it is often assumed that people of working age are generally better able to help themselves and others than minors, especially young children, or the elderly. Similarly, it can be seen as advantageous to have fewer vulnerable people in the community, such as people solely (or mostly) dependent on social assistance. Moreover, adequate access to health care tends to increase the overall health of...
the community, which in turn can strengthen the resilience capabilities of the individual and the community. Likewise, good access to means of transport or communication infrastructure can be critical during crises.

The community capital subdomain is related to the social resilience subdomain but kept separate to accentuate capacities within the community that strengthen the whole community. The community capital subdomain comprises attributes of social and human capital. For instance, it includes proxy indicators for people’s involvement in local organizations, such as youth clubs, sports clubs, or religious institutions, as it is presupposed that active community involvement results in the formation of social networks which often provide informal safety nets and support in times of crisis and recovery. It also captures sources of innovation and with it the ability to think outside the box, to improvise; a crucial quality when dealing with unexpected stresses and shocks. Furthermore, the community capital subdomain contains indicators that represent valuable community resources, such as information providers and childcare services.

The economic resilience subdomain intends to portray the health of the local economy. Its focus lies not on the resilience of individual businesses, but rather on the benefits of a functioning and healthy economy for a community in a crisis situation. Indicators representing the general vitality of the local economy are for example the overall employment rate, retail turnover, or the number of businesses in the community. Another key element of any functioning economy is access to financial resources. Moreover, in a crisis, larger businesses are often better suited to deal with and recover from unexpected shocks. They are also better placed to bring in resources from outside the community through their business networks. On the other hand, the primary sector and the tourism industry are usually impaired when disaster strikes, making people working in these sectors vulnerable to losing their jobs.

The institutional resilience subdomain seeks to capture aspects related to community governance and crisis management. In the Norwegian context, it turned out to be one of the hardest subdomains to describe using quantitative indicators. The subdomain includes two financial indicators; these are the overall financial health of the community (municipality) and the financial resources attributed to fire and accident prevention. Further it is assumed that proximity to a seat of power (county capital) and a larger percentage of people working for governmental institutions can help a community in attracting political support and in securing economic resources for recovery.

In the original BRIC studies (Cutter et al. 2010; Cutter et al. 2014; Burton 2015), the infrastructure & housing resilience subdomain relates to the quality of housing, to evacuation and sheltering potential, as well as to the provision of emergency services. In this study, however, the majority of the indicators relate to qualities of infrastructural systems that will facilitate response and resupply during emergencies, such as proximity to the nearest airport, hospital, fire or police station, road safety, lengths of road and railway networks, or employment in public utilities.
Housing resilience is only marginally represented through the percentage of the population living in urban settlements.\footnote{In Norway, an urban settlement (‘tettsted’) can be as small as 60-70 buildings inhabited by at least 200 persons if the distance between buildings does not exceed 50 meters; exceptions may apply (Statistics Norway).}

The environmental resilience subdomain combines indicators capturing nature’s absorptive capacities with indicators relating to a community’s (non-)exposure to certain natural hazards as well as previous natural hazard experiences. For Norway, it also includes two indicators relating to agricultural food production. In times of crisis, the ability to produce food can be critical, especially if supermarket supply chains are interrupted.

3.3 Index Construction

One advantage of replicating or adapting the Baseline Resilience Indicators of Communities (BRIC), and not another community resilience framework, has to do with the clear and easily understandable design. Rather than to use more complicated statistical methods such as factor analysis or principal component analysis to create the index, the BRIC metric is based on a straightforward hierarchical add and average design. After min-max transformation (Formula 1), the indicators are summed in their respective resilience domains and averaged to create the sub-indices (Formula 2). The scores of the sub-indices are again min-max transformed (Formula 1) and then added to create the final community resilience index (Formula 3). In the original BRIC studies by Cutter et al. (2010; 2014), all indicators within the subdomains and all sub-indices are weighted equally.

\begin{align*}
\text{Min-max transformation:} & \quad x' = \frac{x - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \\
\text{Sub-index score:} & \quad SUB = \left( \frac{1}{N} \sum_{i=1}^{N} x'_i \right) \\
\text{BRIC score:} & \quad BRIC = SocR_m + EconR_m + InstR_m + ComC_m + InfR_m + EnvR_m
\end{align*}

Formula 1 is used to bring all values of an indicator (or subsequently a sub-index) into the range from 0 to 1. $x$ denotes the value of any observation for a given indicator, and $x_{\text{min}}$ the minimum value and $x_{\text{max}}$ the maximum value of that indicator. $x'$ is the min-max transformed score for the observation. Formula 2 describes the calculation of the sub-indices ($SUB$), for which all indicators $x'$ belonging to a specific subdomain are summed and divided by the total number of indicators in that subdomain $N$. Formula 3 shows the calculation of the final community resilience index ($BRIC$). It is the sum of the six sub-index scores: social ($SocR$), economic ($EconR$), institutional ($InstR$), community capital ($ComC$), infrastructure & housing ($InfR$), and environmental ($EnvR$). The subscript ‘$m$’ indicates that the sub-index scores are also min-max transformed prior to the addition.

Following a procedure developed by Becker et al. (2017), after constructing the index using the BRIC approach, we assessed the importance of each indicator for its respective sub-index using
first order sensitivity indices (also called correlation ratios or main effect indices). The first order sensitivity indices, divided into their correlated and uncorrelated parts, are graphically presented in six bar charts in Figure 1. (Exact values can be found in the Appendix.) Simply put, indicators with higher bars have greater influence on their sub-index score. For instance, in the economic resilience subdomain, one indicator, female labor force participation (FEMALE_EMPLOYED), has a sensitivity index score of 0.473, indicating that if this indicator were fixed to any value across its range, the expected variance of the economic sub-index would be reduced on average by 47.3 percent. This indicator can thus be considered influential. However, it should be noted that the majority of this indicator’s influence actually comes from correlation with other indicators. Within all the subdomains, many of the indicators gain or lose influence due to correlations. Two indicators that due to their negative correlations with other indicators lose all their influence (Si < 0.01) are ‘owner-occupied housing’ (OWNER_OCC) in the economic resilience subdomain and ‘school restoration potential’ (SCHOOLS) in the infrastructure & housing resilience subdomain. Since these two indicators do not contribute to their respective sub-indices, we excluded them from the final resilience index.

The Becker et al. (2017) procedure further allows for the computation of optimized weights that would better match the intended influence of each indicator. When we computed the optimized weights, aiming for equal influence of all indicators and constraining the weights to be positive, three indicators received weights of less than 0.01. These are ‘gender income equality’ (RATIO_FM_INCOME) in the economic resilience subdomain, ‘non-immigrant population’ (NOT_NON_WESTERN) in the social resilience subdomain, and ‘HOTELS’ in the infrastructure & housing resilience subdomain. Following Becker and colleagues, these indicators can be considered for omission because the information these indicators provide is contained in the other indicators through correlation. Although the optimized weights are not applied in this article, to be true to the original BRIC design, the three indicators with optimized weights of close to zero were omitted.

Following the sensitivity analysis, the community resilience index for Norway was reconstructed based on the remaining 47 indicators (see Table 1 for summary statistics). A correlation analysis shows that the resulting six sub-indices measure very different facets of community resilience: the highest correlation can be found between the social and the economic resilience subdomains (Pearson’s r = 0.50) (see Table 2).

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8 First order sensitivity indices can be interpreted as “the expected variance reduction of the composite indicator scores, if a given variable were fixed” (Becker et al. 2017, p.13). The Matlab Toolbox developed by Becker (2017) was used for the calculations.

9 Equal weights are often applied for lack of a justifiable weighting scheme (Stapleton and Garrod 2007). However, applying equal weights implicitly assumes that all indicators have the same influence upon the construct they create; an assumption that rarely holds true.
Figure 1: Estimates of the first order sensitivity indices (full bars), divided into uncorrelated (blue) and correlated (orange) parts, for all 52 initially selected indicators.
### Table 1: Summary statistics for the indicators included in the community resilience index for Norway

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Working Age (% population)</strong></td>
<td>64.64</td>
<td>2.07</td>
<td>58.46</td>
<td>71.62</td>
</tr>
<tr>
<td><strong>Cars (per 1,000 persons)</strong></td>
<td>524.74</td>
<td>55.53</td>
<td>257.67</td>
<td>719.22</td>
</tr>
<tr>
<td><strong>Internet (subscriptions per 1,000 persons)</strong></td>
<td>322.82</td>
<td>51.41</td>
<td>114.80</td>
<td>723.63</td>
</tr>
<tr>
<td><strong>Not Single Parent (% households)</strong></td>
<td>94.87</td>
<td>1.09</td>
<td>91.12</td>
<td>98.57</td>
</tr>
<tr>
<td><strong>Not Assistance (% population)</strong></td>
<td>97.47</td>
<td>1.05</td>
<td>90.89</td>
<td>100</td>
</tr>
<tr>
<td><strong>Psychologists (per 1,000 persons)</strong></td>
<td>0.35</td>
<td>0.75</td>
<td>0.00</td>
<td>6.77</td>
</tr>
<tr>
<td><strong>Doctors (per 1,000 persons)</strong></td>
<td>1.72</td>
<td>2.74</td>
<td>0.00</td>
<td>26.69</td>
</tr>
<tr>
<td><strong>Gender Index</strong></td>
<td>0.67</td>
<td>0.04</td>
<td>0.56</td>
<td>0.79</td>
</tr>
<tr>
<td><strong>Employed (% labor force)</strong></td>
<td>97.51</td>
<td>1.01</td>
<td>92.88</td>
<td>99.55</td>
</tr>
<tr>
<td><strong>Female Employed (% labor force)</strong></td>
<td>76.92</td>
<td>3.67</td>
<td>66.3</td>
<td>88.8</td>
</tr>
<tr>
<td><strong>EM_Not_PRIMARY (% employed persons)</strong></td>
<td>85.60</td>
<td>7.10</td>
<td>46.48</td>
<td>97.68</td>
</tr>
<tr>
<td><strong>Ratio_Ls_Businesses</strong></td>
<td>0.01</td>
<td>0.01</td>
<td>0.00</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Enterprises (per 1,000 persons)</strong></td>
<td>73.98</td>
<td>18.12</td>
<td>36.37</td>
<td>172.98</td>
</tr>
<tr>
<td><strong>Banks (per 1,000 persons)</strong></td>
<td>1.62</td>
<td>1.35</td>
<td>0.00</td>
<td>11.79</td>
</tr>
<tr>
<td><strong>Turnover_Retail (per capita in NOK)</strong></td>
<td>58464</td>
<td>28031</td>
<td>802</td>
<td>208395</td>
</tr>
<tr>
<td><strong>Fire ACC Spending (per capita in NOK)</strong></td>
<td>976.57</td>
<td>617.12</td>
<td>307</td>
<td>8453</td>
</tr>
<tr>
<td><strong>Net Op Surplus (% gross op. revenues)</strong></td>
<td>1.24</td>
<td>3.14</td>
<td>-9.00</td>
<td>18.20</td>
</tr>
<tr>
<td><strong>DIST_COUNTRY_CAP (in meters)</strong></td>
<td>61897</td>
<td>44563</td>
<td>546</td>
<td>215381</td>
</tr>
<tr>
<td><strong>EM_MUN_PUBLIC (% employed persons)</strong></td>
<td>29.19</td>
<td>8.63</td>
<td>13.16</td>
<td>86.78</td>
</tr>
<tr>
<td><strong>EM_CREATIVE (% employed persons)</strong></td>
<td>19.89</td>
<td>5.35</td>
<td>7.23</td>
<td>40.34</td>
</tr>
<tr>
<td><strong>RD FIRMS (per 1,000 persons)</strong></td>
<td>3.96</td>
<td>2.29</td>
<td>0.00</td>
<td>14.01</td>
</tr>
<tr>
<td><strong>Migration (% population)</strong></td>
<td>10.43</td>
<td>2.96</td>
<td>4.46</td>
<td>20.60</td>
</tr>
<tr>
<td><strong>Worship (per 1,000 persons)</strong></td>
<td>2.72</td>
<td>1.98</td>
<td>0.19</td>
<td>10.83</td>
</tr>
<tr>
<td><strong>Museums (per 1,000 persons)</strong></td>
<td>2.17</td>
<td>2.87</td>
<td>0.00</td>
<td>20.04</td>
</tr>
<tr>
<td><strong>Sports (per 1,000 persons)</strong></td>
<td>2.62</td>
<td>2.33</td>
<td>0.00</td>
<td>15.69</td>
</tr>
<tr>
<td><strong>Voter Turnout (% voting age pop.)</strong></td>
<td>76.98</td>
<td>3.75</td>
<td>65.10</td>
<td>91.10</td>
</tr>
<tr>
<td><strong>Clubs (per 1,000 persons)</strong></td>
<td>8.63</td>
<td>7.95</td>
<td>0.00</td>
<td>48.39</td>
</tr>
<tr>
<td><strong>Childcare (per 1,000 persons)</strong></td>
<td>1.39</td>
<td>0.52</td>
<td>0.42</td>
<td>4.74</td>
</tr>
<tr>
<td><strong>Broadcast (per 1,000 persons)</strong></td>
<td>0.27</td>
<td>0.45</td>
<td>0.00</td>
<td>4.21</td>
</tr>
<tr>
<td><strong>Response (per 1,000 persons)</strong></td>
<td>0.35</td>
<td>0.53</td>
<td>0.00</td>
<td>4.74</td>
</tr>
<tr>
<td><strong>DIST_FIRE_POLICE (in meters)</strong></td>
<td>8993</td>
<td>9749</td>
<td>1.00</td>
<td>68740</td>
</tr>
<tr>
<td><strong>DIST_HOSPITAL (in meters)</strong></td>
<td>35282</td>
<td>26283</td>
<td>1566</td>
<td>176594</td>
</tr>
<tr>
<td><strong>Accidents (per 1,000 persons)</strong></td>
<td>1.11</td>
<td>0.80</td>
<td>0.00</td>
<td>6.66</td>
</tr>
<tr>
<td><strong>Railway_Km (in kilometers)</strong></td>
<td>9.95</td>
<td>17.78</td>
<td>0.00</td>
<td>101.00</td>
</tr>
<tr>
<td><strong>Road_Km (in kilometers)</strong></td>
<td>169.17</td>
<td>98.93</td>
<td>5.68</td>
<td>659.85</td>
</tr>
<tr>
<td><strong>DIST_AIRPORT (in meters)</strong></td>
<td>48165</td>
<td>33764</td>
<td>1369</td>
<td>152770</td>
</tr>
<tr>
<td><strong>EM_UTILITIES (% employed persons)</strong></td>
<td>7.22</td>
<td>4.95</td>
<td>0.60</td>
<td>43.60</td>
</tr>
<tr>
<td><strong>Urban Pop (% population)</strong></td>
<td>53.34</td>
<td>27.24</td>
<td>0.00</td>
<td>99.14</td>
</tr>
<tr>
<td><strong>Not Flood Area (% land area)</strong></td>
<td>96.36</td>
<td>3.02</td>
<td>79.73</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Not Slide Area (% land area)</strong></td>
<td>95.66</td>
<td>5.86</td>
<td>69.64</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Not Impervious (% land area)</strong></td>
<td>77.06</td>
<td>22.57</td>
<td>9.72</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Not Water (% land area)</strong></td>
<td>94.58</td>
<td>3.53</td>
<td>69.86</td>
<td>99.93</td>
</tr>
<tr>
<td><strong>Nat Buffer (% land area)</strong></td>
<td>18.14</td>
<td>13.79</td>
<td>0.00</td>
<td>60.05</td>
</tr>
<tr>
<td><strong>Dev Openspace (% land area)</strong></td>
<td>0.45</td>
<td>1.56</td>
<td>0.00</td>
<td>21.15</td>
</tr>
<tr>
<td><strong>Arable Land (% land area)</strong></td>
<td>11.59</td>
<td>13.71</td>
<td>0.00</td>
<td>83.27</td>
</tr>
<tr>
<td><strong>AG HOLDINGS (per 1,000 persons)</strong></td>
<td>21.93</td>
<td>18.85</td>
<td>0.00</td>
<td>93.93</td>
</tr>
<tr>
<td><strong>Hazards Freq (5-year average)</strong></td>
<td>32.33</td>
<td>41.87</td>
<td>0.40</td>
<td>403.80</td>
</tr>
</tbody>
</table>

Note: Asterisks (*) indicate variables that were reverse scaled to match the theoretical orientation of the construct.
Social Economic Institutional Infrastructure & Housing Community Capital Environmental

<table>
<thead>
<tr>
<th>Social</th>
<th>Economic</th>
<th>Institutional</th>
<th>Infrastructure &amp; Housing</th>
<th>Community Capital</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic</td>
<td>0.50***</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional</td>
<td>0.04</td>
<td>0.03</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastr. &amp; Housing</td>
<td>0.42***</td>
<td>0.22***</td>
<td>-0.12**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Community Capital</td>
<td>0.02</td>
<td>0.26***</td>
<td>-0.30***</td>
<td>-0.27***</td>
<td>1.00</td>
</tr>
<tr>
<td>Environmental</td>
<td>0.03</td>
<td>0.09*</td>
<td>-0.05</td>
<td>-0.10***</td>
<td>-0.03</td>
</tr>
<tr>
<td>Final index</td>
<td>0.68***</td>
<td>0.73***</td>
<td>0.31***</td>
<td>0.41***</td>
<td>0.38***</td>
</tr>
</tbody>
</table>

Note: Table shows Pearson correlation coefficients. ***p-value<0.01, **p-value<0.05, *p-value<0.1

Table 2: Correlation coefficients for the sub-indices

3.4 Robustness Check
To assess whether the same indicator selection could lead to similar results using a different indexation approach, an alternative index using the same 47 variables was constructed inductively using principal component analysis (PCA). Based on the results of parallel analysis, eight components explaining 54.2 percent of the variance in the data were retained. Considering the component loadings, all of the retained components have a very different composition than the original subdomains. Component 1, for instance, combines elements from the social, institutional, infrastructure & housing resilience and community capital subdomains, whereas component 2 combines elements from the social, economic, environmental resilience and community capital subdomains. Although the resulting eight components are not conceptually congruent with BRIC, the resulting PCA index (sum of the eight components) correlates highly with the community resilience index for Norway (Pearson’s $r=0.81$), indicating that even though the two indices are constructed differently, they measure very similar latent phenomena.

4. Results
4.1 Overall Resilience Score
In 2014, the year for which the data was collected, there were 428 municipalities in Norway, which were grouped into 19 counties and 5 regions (see Figure 3 for reference). Figure 2 graphically presents the results of the sub-indices and the final resilience index. The average overall resilience score for all municipalities is 2.48 with a standard deviation of 0.45. The highest score is 3.94 (most resilient) and the lowest score is 0.92 (least resilient). In the maps, the resilience scores are visualized using the standard deviation classification.

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10 STATA 14 was used in all data construction and analysis unless otherwise indicated. Replication data and detailed replication instructions will be made available through Mendeley Data should the article be accepted for publication.
Figure 2: Final community resilience index (1) and sub-indices; social (2), economic (3), community capital (4), institutional (5), infrastructure & housing (6) and environmental (7)

Municipalities with scores greater than 1.5 standard deviations above the mean (scores above 3.17) depicting levels of high relative resilience, are scattered throughout Norway (Map 1, Figure 2). In many instances, they coincide with larger urban areas. Norway’s five biggest cities Oslo, Bergen, Stavanger, Trondheim, and Drammen all have high resilience scores. Moreover, five municipalities that are part of Oslo’s greater metropolitan area also fall into this category; the same with two municipalities in Stavanger metropolitan area. The two biggest cities in the north, Tromsø and Bodø, are also among the highly resilient municipalities. However, there are also six municipalities with less than 2,000 inhabitants that fall into the same category.
Figure 3: Reference map for Norway

Moderately high scores of resilience (scores between 2.71 and 3.17) seem to follow a zigzagging belt from northern Trøndelag (Central Norway) to Østlandet (Eastern Norway), Vestlandet (Western Norway) and Sørlandet (Southern Norway). Moderately high scores can also be found for municipalities surrounding Oslo and Stavanger metropolitan areas and several scattered along the coast, coinciding mostly with larger towns.
Whilst only three moderately high scores can be found in the northern region, including the municipality bordering with Russia, most low resilience scores (<2.26) can be found there. The average score for Northern Norway is 2.04 with a standard deviation of 0.43. For the other four regions in the south, the average score is 2.60 with a standard deviation of 0.38.

4.2 Sub-indices
Additional insights can be gained about the composition of the resilience index by looking at each sub-index separately. For the social resilience subdomain (Map 2, Figure 2), municipalities with higher and lower scores are scattered throughout Norway. Yet most higher scores can be found in Eastern Norway; and clusters of lower scores can be found in Southern Norway, especially in Vest-Agder county, in the southern part of Western Norway, especially in Rogaland county, in Nord-Trøndelag county and throughout Northern Norway.

Higher economic resilience scores (Map 3, Figure 2) are concentrated in the south with a spatial tendency towards Western Norway. Even though pockets of lower scores exist in the south, for instance in Hedmark county, most lower scores can be found in Northern Norway.

Higher community capital scores (Map 4, Figure 2) are also concentrated in the south. However, there is a large cluster of lower scores in Eastern Norway, spanning peripherally around Oslo metropolitan area from Vestfold county to Buskerud county, to Oppland county, Hedmark county, Akershus county and finally Østfold county. Compared to the economic resilience domain, lower scores are less dominant in the north and higher scores can be found more frequently.

In the institutional resilience domain (Map 5, Figure 2), clusters of higher and lower scores spread throughout the country. In Troms county in Northern Norway, all scores but one (Sørreisa municipality) indicate levels of medium or higher institutional resilience, whereas in Finnmark county to the north the picture is mixed between lower and higher scores and in Nordland county to the south lower scores dominate the picture. In the four regions in the south, medium to high levels of institutional resilience set the scene, but there is a number of disrupting clusters of lower scores. In Western Norway, lower scores can be found in Sogn og Fjordane county and in the southern and northern parts of Møre og Romsdal county as well as smaller pockets in Hordaland and Rogaland counties; in Central and Eastern Norway, a cluster of lower scores stretches from the southern part of Sør-Trøndelag county through parts of Oppland county to Buskerud county and concludes in an agglomeration of municipalities in Akershus, Hedmark and Østfold counties.

The infrastructure & housing resilience subdomain (Map 6, Figure 2) presents several clusters of lower resilience scores in the south and smaller pockets throughout the north. One cluster starts in Vest Agder county going north through Aust Agder county and Telemark county and branching off into Hordaland county. Another one comprises municipalities of Eastern and Western Norway, more specifically Buskerud county, Oppland county, Sogn og Fjordane county and Møre og Romsdal county. Scores of higher resilience are scattered throughout Norway.
Many coincide with larger urban settlements, but there are equally as many municipalities that are rural and sparsely populated.

The *environmental resilience* domain (Map 7, Figure 2), though not intended, nicely depicts the topography of Norway. Most lower scores mark the mountainous regions of Norway and most higher scores span across the flatlands and along the Western coast up to approximately Bodø municipality in Northern Norway.

### 4.3 Top Ten and Bottom Ten

To understand how the individual components contribute to the overall resilience construct, the ten most resilient and the ten least resilient municipalities are examined in more detail in Table 3. The top ten resilience scores, ranging from 3.46 to 3.94, are all located in the south, more specifically in Southern Norway (ranks 3 and 9), in Western Norway (ranks 2, 5 and 7) and Eastern Norway (1, 4, 6, 8 and 10). The most resilient municipality, Bærum, is a part of Oslo metropolitan area and one of the wealthiest municipalities in Norway in terms of gross per capita income (NHO 2018). Its overall resilience score is driven by very good scores (falling within the top ten percent) in the social, economic, infrastructure & housing resilience, and community capital subdomains. Its high score in the social resilience subdomain is determined by an excellent score in car ownership (*CARS*) per 1,000 persons, which serves as a proxy measure for transport capabilities, good scores in gender equality (*GENDER_INDEX*) and very few people depending on social assistance (*NOT_ASISTANCE*). In the economic resilience subdomain, Bærum owes its fifth place to above average scores of all seven indicators, with very good scores associated with the overall employment rate (*EMPLOYED*) and the percentage of people not working in the primary sector and tourism (*EM_NOT_PRIMARY*). With regard to infrastructure & housing, Bærum scores well because of above average scores of seven out of nine indicators, with its urban makeup (*URBAN_POP*) and people working in public utilities (*EM_UTILITIES*) as strong plus points. In terms of community capital, Bærum’s high score is driven by a very good score in creative class employment (*EM_CREATIVE*), a high number of research & development firms per 1,000 persons (*RD_FIRMS*) and good voter turnout for parliamentary elections (*VOTER_TURNOUT*).

The shared second place goes to Sola and Bykle, two very different municipalities with very different resilience signatures. Sola is a wealthy municipality located in the metropolitan area surrounding Stavanger, Norway’s oil capital. Bykle on the other hand is a small mountainous municipality that is a very popular destination for winter sports activities. Whereas Solas’s overall resilience score is driven by very good scores in the economic, infrastructure & housing and environmental resilience subdomains, Bykle’s is driven by very good scores in the social, economic, institutional resilience and community capital subdomains. Bykle ranks in the top ten in all four subdomains. However, it is in the bottom ten in the environmental resilience subdomain.
When considering the individual indicators, starting with the economic resilience subdomain in which both Bykle and Sola are ranked in the top ten, further differences emerge. Sola’s third place is determined by overall employment (EMPLOYED) and the ratio of large to small business (RATIO_LS_BUSINESSES), whereas Bykle’s tenth place is determined by overall employment (EMPLOYED), female labor force participation (FEMALE_EMPLOYED) and enterprises per 1,000 persons (ENTERPRISES). In the environmental resilience subdomain, in which Sola occupies rank 14 and Bykle rank 420, a contrasting picture presents itself. Sola does well because it has a lot of agricultural land (ARABALE_LAND), is not prone to floods or landslides (NOT_FLOOD_AREA, NOT_SLIDE_AREA), and does not have a lot of impervious surfaces or water bodies (NOT_IMPERVIOUS, NOT_WATER). Bykle, on the other hand, performs poorly in all but two indicators; that is, (1) it is not prone to landslides (NOT_SLIDE_AREA) and (2) it has suffered few loss-causing natural hazard events over the five-year period prior to 2014 (HAZARD_5YRS).

Taking a closer look at the capital Oslo, ranked fourth overall, one finds that it scores amongst the top ten in the social and infrastructure & housing resilience subdomains. The former is driven by excellent scores in working age population (WORKING_AGE) and gender equality (GENDER_INDEX), the latter by very good scores in urban population (URBAN_POP), road safety (ACCIDENTS) and railway access (RAILWAY_KM). Its relatively high score in the economic resilience domain is determined by a large part of its population not working in the primary sector or tourism (EM_NOT_PRIMARY). Like Bykle, Oslo is not faring well with regard to environmental resilience.

The bottom ten resilience scores, ranging from 0.92 to 1.49, are all located in Northern Norway. Looking at the ranks, very few of the contributing subcomponent scores make it in the top half. An exception is for instance Berlevåg, which is ranked 64th in the institutional resilience subdomain, due to an above average score in municipal net operating surplus (NET_OP_SURPLUS), an indicator of the financial health of the municipality. Gamvik, which has the lowest overall resilience score, is among the bottom five percent in four resilience subdomains: social, economic, environmental resilience, and community capital. It is in midfield for the other two, institutional and infrastructure & housing resilience. Some of the key indicators that are low, are access to medical services, both physical (DOCTORS) and mental health support (PSYCHOLOGISTS) and dependence on social assistance (NOT_ASSISTANCE) in the social resilience subdomain; access to lending institutions (BANKS) and the size of the local economy, that is number of enterprises (ENTERPRISES) and size of businesses (RATIO_LS_BUSINESSES) in the economic resilience subdomain; cultural resources (MUSEUMS, SPORTS), information providers (BROADCAST) and sources of innovation (EM_CREATIVE, RD FIRMS) in the community capital subdomain; and agricultural resources (ARABLE_LAND, AG_HOLDINGS) and developed open spaces (DEV_OPENSPACE) in the environmental resilience subdomain.
Table 3: Total resilience and sub-indices scores for the ten most and ten least resilient municipalities in Norway (ranks for the sub-indices in parentheses)

5. The Geography of Resilience and Vulnerability

In order to see how the resilience index relates to previously established metrics, we compared the overall resilience score to the integrated vulnerability index developed by Rød et al. (2015). Vulnerability and resilience are often portrayed as related yet distinct concepts that overlap to a degree but point in opposing directions (Cutter et al. 2008). This relationship has been explored by e.g. Bergstrand et al. (2015), Cutter et al. (2014) and Sherrieb et al. (2010).

The Rød et al. (2015) integrated vulnerability index is a hierarchical index that combines three composite measures into one: (1) an exposure index containing information on flood, storm and landslide exposure; (2) a socioeconomic vulnerability index, and (3) a built environment vulnerability index.\(^{11}\) The latter two were constructed first for Norway by Holand et al. (2011) in

\(^{11}\) For a detailed description of the construction of the index, please see Rød et al. (2015).
an attempt to adapt the social vulnerability index developed by Cutter et al. (2003) to the Norwegian context.

As a first step in assessing the relationship between the two indices, Pearson correlation coefficients with 95 percent confidence intervals (using Fisher’s z-transformation) were calculated for the final resilience index and the integrated vulnerability index and its subcomponents.\textsuperscript{12} Table 4 shows that there is a negative relationship between the resilience index and the vulnerability indices. The final resilience index and the integrated vulnerability index as well as the socioeconomic vulnerability sub-index present moderately high levels of negative correlation ($r = -0.53$ and $r = -0.60$ respectively), which is in accordance with the conceptual assumption that vulnerability and resilience are related and generally pointing in opposing directions but not perfect opposites of one another. The relationships of the other two subcomponents to the final resilience index are less strong but still significant.

<table>
<thead>
<tr>
<th>Resilience</th>
<th>Vulnerability</th>
<th>Pearson’s $r$</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final index</td>
<td>Integrated</td>
<td>-0.533***</td>
<td>-0.598 -0.461</td>
</tr>
<tr>
<td>Final index</td>
<td>Socioeconomic</td>
<td>-0.601***</td>
<td>-0.659 -0.537</td>
</tr>
<tr>
<td>Final index</td>
<td>Built environment</td>
<td>-0.220***</td>
<td>-0.308 -0.127</td>
</tr>
<tr>
<td>Final index</td>
<td>Exposure</td>
<td>-0.371***</td>
<td>-0.450 -0.201</td>
</tr>
</tbody>
</table>

Note: Table shows Pearson correlation coefficients using Fisher’s z-transformation. *** $p$-value < 0.01

\textbf{Table 4:} Correlations between the overall resilience index and the integrated vulnerability index and its subcomponents

The integrated vulnerability index is designed to range from 0 (low vulnerability) to 100 (high vulnerability). To facilitate further comparison between the two indices by mimicking the scale of the vulnerability indices, the final resilience index was first min-max scaled to range from 0 to 1, then inverted and multiplied by 100 so that values close to 0 are associated with high resilience and values close to 100 with low resilience. The inverse resilience index was then plotted against the integrated vulnerability index with the five regions of Norway color-coded so that they can be distinguished from each other (Figure 4). The scatterplot in Figure 4 also shows the 25\textsuperscript{th} and 75\textsuperscript{th} percentiles for both variables (indicated by the dashed lines), dividing the plot in nine sections. Each dot represents a municipality.

The scatterplot shows that there are marked differences between the regions. Northern Norway, on average, tends to be less resilient and more vulnerable than the rest of the country. There also seems to be a tendency for Eastern Norway to outperform the rest of the country with regard to vulnerability. On average, it is the least vulnerable region. Southern Norway is also less vulnerable than Western, Central and Northern Norway.

\textsuperscript{12} Pearson correlations with confidence intervals were introduced for this type of analysis by Bergstrand et al. (2015).
Overall, the scatterplot in Figure 4 suggests that there are areas at greater risk of performing poorly when hit with an adverse event: areas with both relatively high levels of vulnerability and low levels of resilience. On the other hand, there are also those areas that are posed to do well; areas with relatively high levels of resilience and low levels of vulnerability. In addition, one can also find discordant data points, outliers, the areas that do well in terms of either vulnerability or resilience yet not in terms of the other.

Figure 4: The integrated vulnerability index plotted against the inverse resilience index

To further investigate these potential low-risk and high-risk areas, a bivariate choropleth map was created (Figure 5). The map is color coded according to sequential color schemes commonly used for these maps (Brewer 1994). The two variables used are the integrated vulnerability index and the inverse resilience index. Using three classes for each of the variables results in a nine-class scheme. As class breaks, the 25th percentile and 75th percentile were used for both variables. The scheme is based on two hues whose mixtures produce a neutral (desaturated) gray diagonal used for municipalities where the two variables correlate. The more saturated colors (here the orange in the bottom right corner and the blue in the top left corner) represent divergent municipalities. Municipalities that score high on the integrated vulnerability index, associated with high levels of vulnerability, and low on the inverse resilience index, associated with high levels of resilience are marked in orange; on the other end of the spectrum, those with low levels of vulnerability and low levels of resilience are marked in blue. Low-risk municipalities with high levels of resilience and low levels of vulnerability are marked in light...
gray (bottom left corner), whereas high-risk municipalities with high levels of vulnerability and low levels of resilience are marked in dark gray (top right corner).

As anticipated, the choropleth map shows that low risk municipalities (light gray) are more prevalent in the south. Most are inland municipalities located in Eastern Norway. On the other hand, most high-risk municipalities (dark gray) are located along the coast and stretch from Central Norway northward. The discordant municipalities are scattered but most are located in the south.

Figure 5: Comparing the inverse resilience index to the integrated vulnerability index. Orange (bottom right corner) and blue (top left corner) are used to mark discordant municipalities, i.e.
those municipalities that portray low (high) levels of resilience and low (high) levels of vulnerability. Light gray (bottom left corner) and dark gray (top right corner) portray low-risk (high resilience, low vulnerability) and high-risk municipalities (low resilience, high vulnerability).

6. Practical implications

This article set out to create a baseline of community resilience for all Norwegian municipalities. It needs to be stressed, however, that this is only a first version, that further refinement and validation, especially by expert evaluation, are needed to turn the community resilience index for Norway into a useful planning tool. The construction of indices aimed at measuring complex ambiguous concepts such as sustainability or resilience always is a subjective process tainted by uncertainty and driven by pragmatic choices (OECD/JRC 2008). From the compilation of the initial wish list of indicators to data collection and preliminary selection by focus group to omission through statistical analysis, it is not difficult to see that the index presented here could have turned out differently if we had made different choices along the way or if a different group of people had worked on it.

Even though all data used in the construction of this index is publicly available and can be reproduced (see the Appendix for data sources), it should be noted that data collection is a lengthy process. For any potential user of an index, it is therefore desirable to have a set of indicators that is as standardized as possible and easy to compute (e.g. number of doctors per 1,000 persons). In this study, however, some indicators are based on spatial data and were extracted using GIS software, requiring some expertise and relying to a degree on subjective judgement. These indicators may need reconsideration for future adaptations. This holds particularly true for the distance measures. Although mean Euclidean distances (straight lines) from denser settlement areas to the nearest facility or place (e.g. hospital, county capital) are sufficient for this first attempt of measuring community resilience in Norway, they may not accurately present the complexity of the Norwegian road system. Actual road distances or, better yet, travel time may be better indicators of proximity.

Once all data is collected, indicator selection is not a straightforward process. Although group assessment and statistical procedures help, decisions still need to be made about which indicators to include or which cut-off criteria to use in the statistical analyses. Furthermore, of the 112 indicators initially collected for this study at least ten percent were alternatives, that is, closely related indicators that measure similar aspects of an underlying category. For instance, to measure level of education, two indicators were collected, percentage of the population with at least a high school diploma and percentage of the population with a university degree. The former was chosen by the academic focus group and then omitted following the correlation analysis.

Another issue that arise during the construction process has to do with the allocation of the indicators to the specific subdomains. It is not always obvious which indicator should go into
which subdomain. For instance, doctors and psychologists could on the one hand be seen as proxies for physical and mental health, as done in this article, placing them into the social resilience subdomain. On the other hand, however, they could also be seen as community assets, placing them into the community capital subdomain. Burton (2015) took yet another stand on the matter and placed doctors in the economic resilience subdomain. These blurred lines between subdomains warrant further investigation. Although the original BRIC design is based on previous research literature, the six subdomains may not fit every context. In this article, the infrastructure & housing subdomain has in fact very little to do with housing. It largely represents a municipality’s emergency response and resupply potential. Moreover, the number and conceptual framing of the subdomains could also be reconsidered. For instance, Mayunga (2007) and Peacock et al. (2010) apply a capital-based approach to community disaster resilience. Drawing on the Sustainable Livelihoods Framework (DFID 1999), they divide the subdomains into human, social, financial, physical, and natural capital.

Finally, and perhaps most importantly, any artificially constructed composite measure needs to be validated. In this regard, a common first-step approach is to compare the newly created metric with a previously established one. Here, the community resilience index for Norway was compared to the integrated vulnerability index. Whilst this exercise points toward the conceptual soundness of the construct, it by no means ensures its usefulness and usability in a real-world setting. That is why, if the community resilience index for Norway is to grow into a practical planning tool, it needs to be evaluated by experts in the field of disaster management and planning and should be redeveloped in collaboration with them.

7. Concluding remarks
This first version of a community resilience index for Norway is inspired and guided by the Baseline Resilience Indicators for Communities (BRIC) originally developed for the United States by Dr Susan Cutter and colleagues (Cutter et al. 2010, Cutter et al. 2014). The index embraces the fact that resilience is a multidimensional complex concept that cannot be described by a single variable. The six resilience subdomains were adopted from the BRIC studies and the index constructed using 47 indicators. The indicators were selected using a combination of academic expert assessment and statistical analysis. While 47 may seem like a high number of indicators, it is justified if one thinks of community resilience as a multifaceted concept that seeks to encompass diverse subdomains, such as economic and environmental resilience.

As to the authors’ knowledge, this is the first time a community resilience index was created for Norway. Although Norway may serve as an example of a ‘particularly resilient’ country when it comes to climate change impacts (O’Brien et al. 2004), this article demonstrates that there is considerable geographic variation in levels of resilience across municipalities and regions. As the community resilience index for Norway is a composite of multiple sub-indices, variations in the resilience levels can be assessed through the individual sub-indices as well as
through the indicators that contribute to specific sub-indices. However, selectively choosing one sub-index over another would result in incomplete pictures of community resilience.

Since assessing resilience using the BRIC design allows for easy deconstruction and indicator- or subdomain-specific analysis, the community resilience index for Norway can potentially be a useful tool for regional planning. Not only can it be used to identify the most and least resilient localities, but it can also be used to explore why these places have relatively high or low scores. As such, the community resilience index for Norway can support decision-makers by identifying areas and regions that require more detailed assessments, which then can inform targeted interventions aimed at strengthening specific resilience capacities.

However, the potential to use the index as a planning tool relies both on the scientific validity and the societal credibility of the constructed index. In an attempt to increase the scientific validity, the final resilience index was compared to previously established vulnerability metrics. However, as already stressed above, it should also be assessed by experts. Furthermore, in order to gauge the robustness of the results and reveal different aspects of community resilience, it would be of value to compare the index to differently constructed community resilience indices for Norway, when and if they become available. More attention should also be paid to sensitivity and uncertainty analysis (Saltelli et al. 2008) to reduce the subjective biases that are intrinsic to the index construction process. With regard to societal credibility, the presented index could form the basis for future participatory research, following a suggestion by Næss et al. (2006) who argued that research at different levels (e.g. global top-down approaches vs. local bottom-up approaches) should supplement and inform each other.

There is no question that assessing resilience using indices has limitations. Indices simplify complex realities, that is in fact their main purpose, but whether this simplification reflects realities in the best possible way will always be a matter of concern. In the creation of the community resilience index for Norway, a number of theoretical, technical and pragmatic choices were made that influence the results and resulting maps and thus confirm the geographical truism that “every map is the product of a particular, socially conditioned conception of space, and therefore a mental map” (Axelsen and Jones 1987, p. 461). Although all the choices in the production of this article were made on the basis of the authors’ best knowledge, they could and should be challenged.

(Funding information and acknowledgements will be added should the article be accepted for publication.)

8. References

Chicago, IL: The University of Chicago Press.


Burton, Christopher G. (2015). A Validation of Metrics for Community Resilience to Natural...


Holand, Ivar S. and Päivi Lujala (2012). Replicating and Adapting an Index of Social


### Appendix

#### Social Resilience

<table>
<thead>
<tr>
<th>Count</th>
<th>Name</th>
<th>Description</th>
<th>Justificato Source</th>
<th>Summary Statistics</th>
<th>Sensitivity Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WORKING_AGE</td>
<td>Percent of the population that is of working age (16-66 y) Cutter et al SSB</td>
<td>64.64 2.07 58.46 71.62 0.158 0.167</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CARS</td>
<td>Cars per 1,000 persons Cutter et al SSB</td>
<td>524.74 55.53 257.67 719.22 0.086 0.200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>INTERNET</td>
<td>Broadband internet subscriptions per 1,000 persons Cutter et al SSB</td>
<td>322.82 51.41 114.80 723.63 0.151 0.145</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>NOT_NON WESTERN</td>
<td>Percent of the population that does NOT have a non-west Cutter et al SSB</td>
<td>96.68 2.38 80.76 100.00 0.028 0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>NOT_SINGLE_PARENT</td>
<td>Percent of households that are NOT single-parent Cutter et al SSB</td>
<td>94.87 1.09 91.12 98.57 0.082 0.158</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>NOT_ASSISTANCE</td>
<td>Percent of the population that is NOT dependent on social Cutter et al SSB</td>
<td>97.47 1.05 90.89 100.00 0.114 0.150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>PSYCHOLOGISTS</td>
<td>Psychologists per 1,000 persons (mental health) Cutter et al SSB</td>
<td>0.35 0.75 0.00 6.77 0.340 0.058</td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>DOCTORS</td>
<td>Physicians per 1,000 persons (general health) Cutter et al SSB</td>
<td>1.72 2.74 0.00 26.69 0.332 0.074</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>GENDER_INDEX</td>
<td>Gender Equality Index Cutter et al SSB</td>
<td>0.67 0.04 0.56 0.79 0.384 0.048</td>
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</table>

#### Economic Resilience

<table>
<thead>
<tr>
<th>Count</th>
<th>Name</th>
<th>Description</th>
<th>Justificato Source</th>
<th>Summary Statistics</th>
<th>Sensitivity Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>OWNER_OCC</td>
<td>Percent of dwellings that are owner occupied Cutter et al SSB</td>
<td>74.04 6.79 36.13 85.03 0.007 0.217</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>EMPLOYED</td>
<td>Percent of the labour force that is employed Cutter et al SSB</td>
<td>97.51 1.01 92.88 99.55 0.385 0.304</td>
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<td></td>
</tr>
<tr>
<td>12</td>
<td>FEMALE_EMPLOYED</td>
<td>Percent of women in the workforce Burton 2015 SSB</td>
<td>76.92 3.67 66.30 88.80 0.473 0.451</td>
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<td></td>
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<tr>
<td>13</td>
<td>RATIO_FM_INCOME</td>
<td>Ratio female average income to male average income Cutter et al SSB</td>
<td>0.69 0.07 0.48 1.16 0.047 0.015</td>
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<td></td>
</tr>
<tr>
<td>14</td>
<td>EM_NOT_PRIMARY</td>
<td>Percent of employed persons NOT working in primary inc Cutter et al SSB</td>
<td>85.60 7.10 46.48 97.68 0.045 0.045</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>RATIO_LS_BUSINESSES</td>
<td>Ratio large to small businesses (in terms of employees): Cutter et al SSB</td>
<td>0.01 0.01 0.00 0.11 0.142 0.161</td>
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<td></td>
</tr>
<tr>
<td>16</td>
<td>ENTERPRISES</td>
<td>Commercial establishments/enterprises per 1,000 persons Burton 2015 SSB</td>
<td>73.98 18.12 36.37 172.98 0.258 0.282</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>BANKS</td>
<td>Lending institutions per 1,000 persons Burton 2015 SSB</td>
<td>1.62 1.35 0.00 11.79 0.317 0.301</td>
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<td></td>
</tr>
<tr>
<td>18</td>
<td>TURNOVER RETAIL</td>
<td>Turnover per capita retail sales Burton 2015 SSB</td>
<td>58463.61 28030.63 8027.00 208395.00 0.153 0.239</td>
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#### Institutional Resilience

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<th>Count</th>
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<th>Description</th>
<th>Justificato Source</th>
<th>Summary Statistics</th>
<th>Sensitivity Analysis</th>
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</thead>
<tbody>
<tr>
<td>19</td>
<td>FIRE ACC SPENDING</td>
<td>Net operating expenditure, fire and accident protection Cutter et al SSB</td>
<td>975.57 671.12 307.00 8453.00 0.232 0.297</td>
<td></td>
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<tr>
<td>20</td>
<td>NET(OP) SURPLUS</td>
<td>Net operating surplus as a percentage of gross operating Holland et al SSB</td>
<td>1.24 3.14 -9.00 18.20 0.408 0.187</td>
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<td></td>
</tr>
<tr>
<td>21</td>
<td>DIST COUNTY CAP*</td>
<td>Mean distance in meters from denser settlement areas Cutter et al SSB</td>
<td>6189.72 44563.44 545.54 215380.50 0.190 0.284</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>EM MUN PUBLIC*</td>
<td>Percent of employed persons working in public administration Cutter et al SSB</td>
<td>29.19 8.63 13.16 86.78 0.304 0.232</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Infrastructure & Housing Resilience

<table>
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<tr>
<th>Count</th>
<th>Name</th>
<th>Description</th>
<th>Justificato Source</th>
<th>Summary Statistics</th>
<th>Sensitivity Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>HOTELS</td>
<td>Hotels and motels per 1,000 persons Burton 2015 SSB</td>
<td>15.49 25.06 0.00 224.84 0.107 0.144</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>RESPONSE</td>
<td>Fire, police, ambulance stations and shelters per 1,000 p Burton 2015 SSB</td>
<td>0.35 0.53 0.00 4.74 0.243 0.263</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>DIST FIRE POLICE*</td>
<td>Mean distance in meters from denser settlement areas (tettsted N5 Kartverket)</td>
<td>892.77 9749.16 1.00 68739.58 0.153 0.171</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>DIST HOSPITAL*</td>
<td>Mean distance in meters from denser settlement areas (Holand et SSB)</td>
<td>35281.56 26283.12 1565.50 176593.70 0.319 0.363</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>SCHOOLS</td>
<td>Schools per 1,000 persons Cutter et a Geonorge (Kartverket)</td>
<td>1.76 1.12 0.21 10.72 0.007 0.008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>ACCIDENTS*</td>
<td>Traffic accidents per 1,000 persons SSB</td>
<td>1.11 0.80 0.00 6.66 0.154 0.184</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>ROAD_KM</td>
<td>Length of major road network in km Cutter et a Kartverket</td>
<td>169.17 98.93 5.68 659.85 0.198 0.170</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>RAILWAY_KM</td>
<td>Length of railway network in km Cutter et a Jernbaneverk</td>
<td>9.95 17.78 0.00 101.00 0.149 0.239</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>DIST AIRPORT*</td>
<td>Mean distance in meters from denser settlement areas (tettsted N5 Kartverket)</td>
<td>48164.71 33764.10 1368.64 152769.90 0.238 0.157</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>EM UTILITIES</td>
<td>Percent of employed persons working in public utilities Wood et al SSB</td>
<td>7.22 4.95 0.60 43.60 0.184 0.200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>URBAN POP</td>
<td>Percent of the population living in urban areas Burton 2015 SSB</td>
<td>53.34 27.24 0.00 99.14 0.427 0.477</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
34 **EM_CREATIVE**
Percent of employed persons working in creative class occupations (here: architects, engineers, and scientific researchers)  
Cutter et al. 2010, Burton 2015  
SSB  
19.89  5.35  7.23  40.34  0.031  0.171

35 **RD_FIRMS**
Research & development firms per 1,000 persons  
Burton 2015  
SSB  
3.96  2.29  0.00  14.01  0.083  0.097

36 **WORSHIP**
Places of worship per 1,000 persons  
Burton 201 Geonorge (  
SSB  
2.72  1.98  0.19  10.83  0.280  0.075

37 **MUSEUMS**
Museums, libraries, zoos and botanical gardens per 1,000 persons  
Burton 201 Geonorge (  
SSB  
2.17  2.87  0.00  20.04  0.279  0.049

38 **SPORTS**
Sports facilities per 1,000 persons  
Burton 201 Geonorge (  
SSB  
2.62  2.33  0.00  15.69  0.255  0.109

39 **VOTER_TURNOUT**
Storting election voter turnout (Percent of voting age population)  
Cutter et al. 2014, Cutter et al. 2010, Holand et al. 2011, Singh-Peterson et al. 2014  
SSB  
76.98  3.75  65.10  91.10  0.117  0.083

40 **CLUBS**
Cinemas, youth centres, and clubs per 1,000 persons  
Burton 2015  
SSB  
8.63  7.95  0.00  48.39  0.279  0.049

41 **CHILD_CARE**
Kindergartens (child care services) per 1,000 persons  
Burton 2015  
SSB  
1.39  0.52  0.42  4.74  0.157  0.120

42 **BROADCAST**
Broadcasters per 1,000 persons (access to information)  
Burton 2015  
SSB  
0.27  0.45  0.00  4.21  0.083  0.142

Environmental Resilience

44 **NOT_FLOOD_AREA**
Percent land area that is NOT in a flood/storm surge zone  
Burton 201 NVE  
96.36  3.02  79.73  100.00  0.222  0.109

45 **NOT_IMPERVIOUS**
Percent land area that does NOT contain impervious surf  
Cutter et al. CORINE 20:  
77.06  22.57  9.72  100.00  0.407  0.038

46 **NOT_SLIDE_AREA**
Percent land area that is NOT in landslide zones  
Burton 201 NVE  
95.66  5.86  69.64  100.00  0.280  0.072

47 **NOT_WATER**
Percent of land area that is NOT covered by water bodies  
Cutter (personal discussion)  
Kartverket (Norge N50)  
94.58  3.53  69.86  99.93  0.148  0.024

48 **DEV_OPENSPACE**
Percent land area that is developed open space  
Burton 201 CORINE 20:  
0.45  1.56  0.00  21.15  0.066  0.275

50 **ARABLE_LAND**
Percent land area that is arable (cultivated) land  
Burton 201 CORINE 20:  
11.59  13.71  0.00  83.27  0.359  0.085

51 **HAZARDS_SYRS**
5-year average number of loss-causing extreme weather events  
Burton 201 NNP  
32.33  41.87  0.40  403.80  0.036  0.179

52 **AG_HOLDINGS**
Agricultural holdings per 1,000 persons  
Cutter et al. SSB  
21.93  18.85  0.00  93.93  0.054  0.119

*Note: Asterisks (*) indicate variables that were reverse scaled during the index construction process to match the theoretical orientation of the construct*