

1 Review article: Towards a context-driven research: a state-of-the-art
2 review of resilience research on climate change

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5 Ringo Ossewaarde¹, Tatiana Filatova², Yola Georgiadou³, Andreas Hartmann⁴, Güл Özerol⁵, Karin
6 Pfeffer⁶, Peter Stegmaier⁷, Rene Torenvlied⁸, Mascha van der Voort⁹, Jord Warmink¹⁰, Bas Borsje¹¹

7 *Correspondence to:* Ringo Ossewaarde (m.r.r.ossewaarde@utwente.nl)

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¹ Department of Public Administration, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands

² Dept of Governance and Technology for Sustainability, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands

³ Department of Urban and Regional Planning and Geo-Information Management, University of Twente, Enschede, Hengelosestraat 99, 7514AE, Netherlands

⁴ Department of Construction Management and Engineering, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands.

⁵ Dept of Governance and Technology for Sustainability, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands

⁶ Department of Urban and Regional Planning and Geo-Information Management, University of Twente, Enschede, Hengelosestraat 99, 7514AE, Netherlands.

⁷ Department of Science, Technology and Policy Studies, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands.

⁸ Department of Public Administration, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands.

⁹ Department of Design Production and Management, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands.

¹⁰ Department of Water Engineering and Management, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands.

¹¹ Department of Water Engineering and Management, University of Twente, Enschede, Drienerlolaan 5, 7522NB, Netherlands.

9 **Abstract**

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11 The twofold aim of this paper is to provide an overview of the current state of resilience research with
12 regard to climate change in the social sciences and propose a research agenda. Resilience research
13 among social scientists is characterized by much more diversity today than a few decades ago.
14 Different definitions and understandings of resilience appear in publications during the last ten years.
15 Resilience research increasingly bears the mark of social constructivism, a relative newcomer
16 compared to the more long-standing tradition of naturalism. There are also approaches that are
17 indebted to both “naturalism” and “constructivism”, which, of course, come in many varieties. Based
18 on our overview of recent scholarship, which is far from being exhaustive, we have identified six
19 research avenues that arguably deserve continued attention. They combine naturalist and
20 constructivist insights and approaches so that human agency, reflexivity and considerations of justice
21 and equity are incorporated into systems thinking research or supplement such research. Ultimately,
22 we believe that the overarching challenge for future research is to ensure that resilience to climate
23 change does not compromise sustainability and considerations of justice (including, environmental,
24 climate and energy justice).

25

26 Keywords: adaptive resilience, climate change, just resilience, transformative resilience,
27 transformational adaptation, wicked resilience

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30 **1. Introduction**

31 A brief and non-exhaustive overview of resilience scholarship published in the period 1970-2020
32 reveals a diversification of research foci and themes, approaches and methods, and theoretical
33 frameworks. Resilience has been a prevalent research topic among ecologists for several decades and,

34 very soon after, among cyberneticists. Given the association of resilience with the natural sciences and
35 engineering (cf. Indirli, 2019), it is perhaps not so surprising that most social scientists did not see the
36 need to have recourse to the terminology or concept until much later. And if they did adopt the idea
37 earlier, they were likely to embrace the naturalist theoretical framework that accompanied it (Holling,
38 1973; 2001; cf. Chandler, 2014). Other social scientists are still reluctant to accept resilience as a universal
39 and unifying concept, pointing out that the “core concepts and principles in resilience theory that create
40 theoretical tensions and methodological barriers between the natural and social sciences” (Olsson et
41 al., 2015). This conceived opposition between the natural sciences and social sciences may not be
42 experienced by all naturalists or social scientists. Even more importantly perhaps, such opposition – real or
43 surmised – may hinder fruitful collaborations in the face of our ecological crisis. Yet, collaboration,
44 integration or “transdisciplinarity” in the real worlds of universities and research institutes may not always
45 reflect a genuine transcendence of disciplinary boundaries, but instead largely consists of natural sciences
46 and engineering research in sustainability (Groß and Stauffacher, 2014). That said, there have been genuine
47 attempts to transcend the limitations of both naturalism – in the strict, technical sense of the term (Andler,
48 2014) – and forms of social constructivism that border on relativism (Proctor, 1998a; 1998b; Popa et al.,
49 2015). Such “transdisciplinary” research is typically problem-oriented (Groß and Stauffacher, 2014).

50 Crawford Stanley Holling’s ecological notion of resilience (Holling, 1973) is considered by some
51 as a bridge between the social sciences and engineering (Ostrom, 2007; Thorén, 2014). The appeal of
52 Holling’s socio-ecological systems (SES) approach among some social scientists may be due to its being
53 a corrective to the tendency of Holling’s fellow ecologists to unconditionally embrace the methods and
54 premises inherited from classical physics (cf. Holling, 1973; Thorén, 2014; Estêvão, Calado and
55 Capucha, 2017; Davoudi, 2018). Holling corrected what he considered to be a flawed view of the world
56 and of ecosystems, namely, as closed, or stable. Against the “equilibrium-centered” view, he
57 emphasized the influence of random events (natural or human-caused) on ecological systems (Holling,
58 1973, 15). Yet, even this complex systems approach does not score very highly at the level of reflexivity,
59 which is required to discover and “acknowledge overt or covert forms of dominance shaping public

60 discourse and participation" (Popa et al., 2015). Slightly more positively framed, societal resilience to
61 climate change also involves political and institutional factors, lifestyles and consumer habits,
62 production patterns, and structures of power in general (cf. Douglas and Wildavsky, 1983; Blühdorn,
63 2013; Kolers, 2016; Fischer, 2017; Dryzek and Pickering, 2019). Resilience research that takes into
64 account such social factors (which do not necessarily obey physical laws) can be broadly classified as
65 belonging to "social constructivism".

66 The Tsunami in 2004 and Katrina in 2005 seem to have acted as catalysts for generating more
67 resilience research among social scientists (Pizzo, 2015). This increasing interest for resilience on the
68 part of certain social scientists (and other scholars from different disciplines) cannot be detached from
69 the popularity that the terminology started to gain among national governments and global
70 governance actors, including the Rockefeller Foundation, for instance, at the beginning of the new
71 century. Such tendency became stronger with the global financial crisis of 2007-2008. The widespread
72 recourse to the language of resilience by powerful private and public actors has incited a series of
73 scholarship critical of such discourse (Chandler, 2014; Pizzo, 2015; Lockie, 2016; Derickson, 2016;
74 Hilhorst 2018). The latter, it is observed, easily hides vested political and economic interests, and
75 distracts attention from structural and institutional defects by emphasizing resilience through
76 technological innovations. Katrina and, even more recently, Covid-19, it is argued, reveal a vulnerability
77 that is not simply an unavoidable fragility in the face of natural hazards, but is also the fruit of
78 institutions and political decisions over a long period of time. Natural disasters tend to be perceived as
79 indiscriminate and indifferent as to whom they affect. Yet, as Belkhir and Charlemaine (2007, p. 12)
80 point out, "hurricanes may not single out victims by their race, or gender or class but neither do such
81 disasters occur in historical, political, social, or economic vacuums". In other words, social, cultural,
82 political, and economic conditions are conceived to be involved in the resilience or non-resilience of a
83 nation or of particular groups to natural calamities (Henkel et al., 2006; Tierney, 2015; Lockie, 2016).
84 In this regard, it is interesting to take note of the discussion surrounding the terminology "natural
85 disaster" vs "disaster" (Kelman, 2020).

86 The aim of this paper is to provide an overview of the current state of resilience research with
87 regard to climate change in the social sciences and propose a research agenda. Resilience research
88 among social scientists is characterized by much more diversity today than a few decades ago.
89 Different definitions and understandings of resilience appear in publications during the last ten years
90 (cf. Indirli, 2019). Resilience research increasingly bears the mark of social constructivism, a relative
91 newcomer compared to the more long-standing tradition of naturalism. Given this history, it is hardly
92 surprising that social scientists focusing on resilience to climate change should initially have borrowed
93 the research methods common to natural and applied sciences. “Social constructivist” approaches
94 gradually made their entrance, especially in reaction to both the perceived inadequacy of particular
95 naturalistic approaches and the increasing normative use of resilience in policy agendas
96 (Weichselgartner and Kelman, 2015). There are also approaches that are indebted to both
97 “naturalism” and “constructivism” (which, of course, come in many varieties). “Ecological naturalism”,
98 for instance, departing from ecological science, integrates constructivist insights about power and
99 mastery, the diversity of human knowledge, and the politics of knowledge. It thereby resists the
100 reductionistic tendencies of positivist empiricism (Code, 2005). “Critical realism” (Carolan, 2005)
101 similarly wishes to avoid the danger of reductionism while profiting from the wealth of (applied)
102 natural sciences.

103 Hence, though we acknowledge the many varieties of both “naturalism” and “constructivism”
104 and the various endeavors to transcend the limitations of both naturalism and constructivism, we
105 observe that most resilience research in the social sciences still takes place in the dialectical field
106 constituted by these two approaches, in their strict, traditional senses (cf. Andler, 2014). This is the
107 theme of the next section. But first we briefly examine how resilience research in the social sciences
108 has undergone a thorough diversification. Such diversity, however, sometimes means that research
109 takes place in parallel worlds and that there is little cross-fertilization between scholars. It is suggested
110 that social scientific inquiry into resilience in the context of climate change could be raised to a next
111 level if these two different approaches meet and interact. To this end, we reconstruct contemporary

112 debates in that particular field of studies and distil recurrent research topics that divide social
113 scientists. The issues of adaption and transformation in the context of severe disturbances or shocks
114 that come with climate change (such as hurricanes, floods, droughts, and heatwaves) appear to be
115 such divisive topics. Finally, naturalist and constructivist directions, as well as possible cross-
116 fertilizations of these two currents, for future resilience research are identified. We point out that
117 future resilience research in the social sciences – that is, the types of questions raised, theoretical
118 frameworks and modes of analysis – will also be determined by changing conditions (ecological,
119 political, and socioeconomic).

120

121 **2. The diversification of resilience research in the social sciences**

122 One of the earliest appearances of the term resilience – in European literature at least – seems to have
123 been in one of Aesop’s fables, namely, that of *The Oak Tree and the Reeds*. According to one of the
124 versions of that story, the Oak Tree becomes uprooted during a storm while its fellow reeds survive it.
125 In a conversation, the Oak Tree expresses its bewilderment that the fragile reeds were able to resist
126 such a mighty storm while it succumbed. The reeds reply that it is precisely their non-resistance that
127 saved them. Through their capacity to bend, they moved with the direction of the wind (which thus
128 did not break them) and rose again when the storm was gone. They were flexible enough. The reeds
129 “bounce” back and are thus “resilient”. Indeed, the English word resilience derives from Latin (*resilire*),
130 which generally meant rebounding. This Latin word can be found in the writings of Seneca the Elder,
131 Pliny the Elder, Ovid, Cicero, and Livy; to rebound is also the sense in which *resilire* is used by Cicero in
132 his *Orations* (Alexander, 2013). The term also appears in Lucretius’ *On the Nature of Things*, where it
133 denotes “being forced back by a resisting surface [...] with reference to the action on Nature” (Pizzo,
134 2015). Along this line, nature compels all things to “spring off”.

135 Despite the various meanings attributed to the term, the connotation attached to *resilire* was
136 commonly that of rebounding (cf. Indirli, 2019). Up to the early nineteenth century, this was the

137 predominant understanding of resilience in common language and imagination. A slight shift appeared
138 when engineers started to use the term to refer to the properties and capacities of materials to absorb
139 tensions and release energy, and recover their original forms, without breaking or disfiguration after
140 undergoing some external shock or disturbance (such as extreme weather conditions; Estêvão, Calado
141 and Capucha, 2017; Bergström, 2018; Davoudi, 2018). In the 1950s, psychologists re-adapted the
142 common sense of the term to mental health and used it to study the coping mechanisms of
143 concentration camp survivors. Later, the concept is used to study various kinds of trauma, misfortune,
144 adversity, stress, and mental recovery (Bourbeau, 2015; Estêvão, Calado and Capucha, 2017;
145 Bergström, 2018; Schwartz, 2018). In the 1970s, the ecologist C.S. Holling (1973, p. 14) redefines
146 resilience as “a measure of the persistence of systems and their ability to absorb change and
147 disturbance.” Thus understood, resilience is widely conceived as the opposite of vulnerability, which is
148 defined as the inability to absorb change and disturbance (Gallopin, 2006; Miller et al., 2010). For
149 instance, a coastal system that is vulnerable to accelerated sea-level rise is not resilient enough (Smit,
150 Goosen and Hulsbergen, 1998). In such accounts, greater resilience means becoming less vulnerable
151 to change and shocks. That said, a system can still be vulnerable to other changes while being resilient
152 in other respects (Gallopin, 2006). Holling incorporates resilience in a socio-ecological systems (SES)
153 approach to analyze the stability and strength of ecological systems, which are constituted by the
154 interaction between natural ecosystems and human societies (Alexander, 2013; Bergström, 2018;
155 Béné et al., 2018; Hoekstra, Bredenhoff-Bijlsma and Krol, 2018). Ecosystems, as noted earlier, are
156 rarely closed systems, but are instead subjected to natural and human influences.

157 In the social sciences, resilience research has been influenced by these earlier studies. As a
158 result, some social scientists have recourse to mathematical and simulation models and consider
159 resilience as a property of a system, which can be (made) weak or strong. In these studies, society is
160 modelled as a social system that consists of parts (including agents and technologies) and physical
161 properties that can be objectively studied (Aiken, 2006; Floridi, 2017). Resilience as a system property
162 is an objective measure of the dynamic equilibrium, stability, strength, or survivability of a socio-

163 ecological system, including coastal systems, urban systems, forest systems, etc. (Hoekstra,
164 Bredenhoff-Bijlsma and Krol, 2018). Such approaches, indebted to applied natural sciences and the
165 complex systems theory, can be very useful, especially when both the problem and the solution are
166 primarily and solely of a technical nature. That said, even an apparently purely technical process such
167 as water purification involves reckoning with various social factors (for instance, changing habits,
168 medicine uses and particular surroundings of water collection systems).

169 The story becomes even more complicated when, for instance, attempts to make communities
170 more resilient to climate change overlook the political and cultural reasons why particular groups living
171 in particular areas are more vulnerable to the effects of climate change (such as heavy rainfall,
172 droughts, and heatwaves). These problems may not even get sufficient attention due to, for instance,
173 “cultural racism and “institutional racism” (Henkel et al., 2006, p. 102). Social constructivism provides
174 social scientists with the conceptual and analytical tools to understand social realities. Historically,
175 constructivism in the social sciences arose in reaction to what was experienced as the narrowness of
176 the naturalist approach (once again, in the technical/strict sense of the term, according to which “the
177 social is part of nature, social processes are natural processes, with causal powers reducible to natural
178 causation” [Andler, 2014, p. 286]). Most social constructivists do not believe that reality is objective in
179 the naturalist sense (strictly defined) and thus cannot be fully grasped. Instead, it is conceived that
180 natural and social phenomena can only understood by taking into account diverse factors that
181 determine and influence human perceptions, experiences, meanings, interests, values, identities,
182 patterns of domination, etc.

183 In resilience research, social constructivists typically model society as a historically embedded
184 construct that is the result of particular understandings of nature, society, and the person, of values,
185 symbols and historical practices (which may not be very rational or just), and power relations. These
186 social scientists tend to be more sensitive to the potential and actual abuse of power. When engaging
187 with resilience issues in the context of climate change, they typically express concern for vulnerable
188 communities. Research topics can thus include the (un)equal distribution of environmental burdens,

189 struggles for recognition, claims to participation, and unequal impacts of anthropogenic climate
190 change (Braun, 2014; Yanarella and Levine, 2014; Skillington, 2015; Sjöstedt, 2015; Weichselgartner
191 and Kelman, 2015; Pizzo, 2015; Lockie, 2016; Derickson, 2016; Lyster, 2017; Schlosberg, Collins, and
192 Niemeyer, 2017; Mummery and Mummery, 2019). Davoudi (2018, p. 5), for instance, problematize the
193 very notion of “resilience”, pointing out that there are “unjust resilience building programs” that do
194 not only neglect disadvantaged communities, but also create resilient enclaves” for privileged elites”.
195 Similarly, Glaser et al (2018, p. 3) observe that resilience can be “wicked” when an undesirable status
196 quo is being maintained. Reflexivity is arguably an indispensable part of resilience research (cf. Popa
197 et al., 2015).

198

199 **2.1. The dialectic between naturalism and constructivism**

200

201 Social scientists focusing on resilience to climate change have inherited an enormous body of
202 scholarship on resilience stemming from the physical sciences and engineering, cybernetics,
203 evolutionary biology, and psychology, among others. In the 1970s, social scientists could thus have
204 recourse to both closed-systems theories and complexity theory to think about resilience to climate
205 change (Dahlberg, 2015; Davoudi, 2018). Some of them also merged the two models so that socio-
206 ecological systems became conceptualized as adaptive complex systems (Wiese, 2016; Bergström,
207 2018). Holling’s SES is an example of the integration of complexity theory in ecological science.
208 According to the adaptive complex system line of thought, the resilience of a system depends on the
209 capacity of individual agents to cope with uncertainty and complexity. They are able to interact and
210 self-organize, learn, and adapt (in an incremental or transformative way), thereby making the system
211 flexible enough to absorb shocks and develop even in face of drastic changes (Jesse, Heinrichs and
212 Kuchshinrichs, 2019).

213 Social scientists drawing on complexity theory and evolution-based models tend to emphasize
214 a type of laissez-faireism, pointing out that adaptive complex systems have their own self-

215 organizational structures that should not be interfered with (Adger et al., 2011). Bureaucratic
216 interventions to address vulnerability and increase resilience to climate change are said to generate
217 unintended consequences that may well reduce a system's ability to absorb changes and disturbances.
218 In 2001, Holling introduced the notion of “panarchy” as an alternative to hierarchy, to safeguard the
219 self-organization of complex systems against the threat of bureaucratic intervention (Holling, 2001).
220 Derived from the ancient Greek god of the woods, Pan, panarchy refers to the structure in which
221 complex (ecological and social) systems are interlinked in an evolutionary process of adaptive cycles
222 of growth, accumulation, restructuring, and renewal (Berkes and Ross, 2016). Accordingly, when
223 confronted with shocks (like extreme weather events), adaptive systems stabilize with supporting self-
224 organizing structures until those structures are overstretched and can no longer absorb changes and
225 disturbances; this is when there is a transformation of the system (Allen et al., 2014). Resilience is
226 therefore conceived as a primary system property that is measured by the magnitude of shocks that
227 can be absorbed before the structures of system change (Boyer, 2020).

228 Some social scientists show a predilection for agent-based modelling (ABM) as their mode of
229 analysis in resilience research (cf. Cote and Nightingale, 2012; Pumpuni-Lenss, Blackburn and
230 Garstenauer, 2017; Patriarca et al., 2018; Mirchandani, 2020). They therefore aim at the constant
231 refinement of simulation tools that can integrate complexity, uncertainty and multiplicity of agents
232 and techniques of regulation in favor of adaptation. Since the 1970s, when it emerged from
233 mathematical sociology, ABM has been used in complexity-theoretic research for analyzing complex
234 systems (Conte and Paolucci, 2014). ABM is a computational mode of analysis that simulates complex
235 (non-linear) systems that include diverse agents that make decisions, interact, and learn or adapt in
236 their ever-changing environment, according to programmable rules (Hawes and Reed, 2006; Farmer
237 and Foley, 2009; Van Duinen et al., 2015; Martin and Schlüter, 2015; Sun, Stojadinovic and Sansavini,
238 2019). ABM computes, in probabilistic terms, the recovery process of complex (non-linear) systems
239 under stress and tracks the emergence of new stages, phases or entries into new adaptive cycles
240 (Filatova, Polhill and Van Ewijk, 2016). Resilience to climate change, as a system property, can thus be

241 calculated (Pumpuni-Lenss, Blackburn and Garstenauer, 2017). Since ABM traces feedbacks between
242 micro and macro scale explicitly, it also enables scholars to estimate the resilience of a system's
243 individual agents, communities or (sub)groups of agents.

244 The above approaches to resilience rely on what can be broadly defined as "natural" sciences
245 and their applied variants. Society and human persons are conceived according to the theories and
246 models common in these disciplines. The application of conceptual frameworks and models developed
247 to study allegedly objective and objectifiable things to the interaction between humans and their social
248 and natural environments is not without its challenges and dangers. Scientists, including social
249 scientists, may unwittingly serve political agendas if they are oblivious of their own political and
250 ideological commitments (Popa et al., 2014). The blurry line between science and politics is illustrated
251 by Holling's and Friedrich Hayek's re-appropriation of complexity theory to criticize government
252 interventions (Walker and Cooper, 2011; Davoudi, 2018). The historical context of both men, namely,
253 one marked by Keynesian policies, should arguably also be borne in mind. One of the possible
254 (side)effects of scientific models presuming resilient individual agents is that they can lend credence
255 to the idea of self-reliant and self-sufficient individuals and further the "neoliberal individualization of
256 responsibility" (Davoudi, 2018, p. 5). Such alliance, perhaps unwitting, between political agendas and
257 science is the great fear of those social constructivists whose primary commitment is to justice and the
258 protection of vulnerable individuals and groups (Fainstein, 2014; Derickson, 2016; Kokers, 2016;
259 Lockie, 2016; Lyster, 2017; Mummery and Mummery, 2019).

260 One of the major points of contention between naturalism, in the strict sense, and social
261 constructivism is that most social constructivists are unwilling to conceive resilience to climate change
262 as a system property (an intellectual attitude that does not imply that all naturalistic approaches
263 actually conceive resilience as a system property; cf. Andler, 2014). Instead, resilience is perceived as
264 a socio-political construct created by diverse stakeholders (Walsh-Dilley and Wolford, 2015;
265 Weichselgartner and Kelman, 2015; Kythreotis and Bristow, 2017). This means that it is not a neutral
266 or technical element and, accordingly, requires constant critical scrutiny to uncover its possible

267 ideological and mythical nature (Alexander, 2013; Bourbeau, 2015; Boas and Rothe, 2016; Juncos,
268 2018; Wessel, 2019). Some scholars have pointed out the neoliberal ideology underpinning both
269 theories/models and policies that rely on the idea of adaptive cycles governed by invisible laws, which
270 make intervention undesirable (Chandler, 2014; Tierney, 2015). It is thereby overlooked that the so-
271 called self-organizing system is itself the result of political decisions over a long period of time.
272 Governments are thus accused of shifting the responsibility for vulnerable systems (which are
273 themselves the products of formal and informal institutions and political decisions, among other
274 things), floods, pollution, safety, welfare, health, etc. onto “resilient” individuals or individuals who
275 ought to be become more resilient, which is another word for self-reliant (Braun, 2014; Pizzo, 2015;
276 Tierney, 2015; Howell, 2015; Anderson, 2015; Ksenia et al., 2016; Schwartz, 2018; Davoudi, 2018). In
277 some cases, such resilience discourse enables governments to avoid their public responsibility. An
278 instance of such “wicked” dynamics is governments’ shifting the responsibility for the provision of
279 access to water onto local “communities” while the latter might be absent due to strife or inadequate
280 management capacities (Katomero and Georgiadou, 2018). In such situations, vulnerable individuals
281 and groups are denied this basic human right, while other powerful groups claim sole access to water.

282 Social constructivists are generally critical of the very language of resilience. Those who point
283 out the discursive or narrative nature of resilience-based political speeches and policies are usually
284 indebted to Michel Foucault’s idea of a discourse. The latter refers to systems of thoughts and beliefs
285 expressed through language and practices that systematically construct subjects and societies of which
286 they speak. In other words, both language and practices are creative acts. Through resilience
287 discourses, a particular type of subject (like resilient or self-reliant) and a particular type of society (like
288 a market-based “society”) are discursively constructed and reinforced (Miller et al., 2010). Evans and
289 Reid (2013) thus argue that resilience has the character of a doctrine, according to which the resilient
290 subject must accept and constantly adapt to a dangerous and changing world. Given this doctrine,
291 vulnerability is rejected as weakness or a moral flaw, which is very much like a lack of character or will
292 power (Cole, 2016). A problematic normativity is brought into existence when citizens are expected to

293 adapt to ecological and societal catastrophes by becoming self-reliant (Fainstein, 2014; Tierney, 2015;
294 Kolers, 2016; Ribault, 2019). In other words, some (or most) social constructivists do not merely try to
295 answer the question of how to make societies and individuals resilient to climate change, but instead
296 question the normativity of the concept “resilience”. Such a critical approach is arguably problematic
297 and counterproductive in some cases. The urgency of real problems (like rising sea levels that threaten
298 millions of people) makes a dialogue between different approaches highly desirable.

299

300 **3. Bridging the naturalist and constructivist view on resilience**

301

302 Given the different appraisals of the very concept of resilience with respect to climate change among
303 social scientists, it has been widely questioned whether resilience can possibly operate as a theoretical
304 model or a unifying paradigm – and whether such a unifying paradigm would be desirable in the first
305 place (Alexander, 2013; Thorén, 2014; Bourbeau, 2015; Fainstein, 2015; Pizzo, 2015). The question of
306 whether such unifying paradigm is possible or desirable need not be answered here. It can still be
307 argued that it is desirable to bring together the insights gained from naturalistic and constructivist
308 approaches to enrich and renew understandings of resilience to climate change. Climate change
309 resilience research that relies on naturalist and naturalistic premises may be able to provide quick
310 solutions to crises precisely because various unpredictable and apparently irrelevant elements are
311 discounted. The focus on the obvious problem without taking into account the broader context – which
312 may be problematic – has many advantages, certainly if the bigger picture is taken into account after
313 recovery from an acute crisis. In the event of a flood, for instance, the first concerns should arguably
314 be evacuation and preventing another flood. Once everyone is safe, the question as to why the flood
315 has affected a particular group can be raised. The particular choices made with regard to urban and
316 rural planning can be critically scrutinized. Answers to the various questions that a flood and its
317 aftermath raise will require knowledge from many disciplines. “Resilience” to floods will mean much
318 more than building dams. It will also involve criticism of particular social structures, institutions and

319 decisions that have rendered some people or areas more vulnerable to natural hazards or the effects
320 of climate change.

321

322 **3.1 The debate on adaptive and transformative resilience**

323

324 Resilience research in recent years reveals divergence among social scientists when it comes to the
325 issue of adaptation and transformation (Chandler, 2014; Redman, 2014; Fainstein, 2014; Dahlberg et
326 al., 2015; Sjöstedt, 2015; Boas and Rothe, 2016; Duit, 2016; Zervogel, Cowen and Ziniades, 2016;
327 Clément and Rivera, 2017; Lyster, 2017; Schlosberg, Collins and Niemeyer, 2017; Fazey et al., 2018;
328 Glaser et al., 2018; Hoekstra, Bredenhoff-Bijlsma and Krol, 2018; Jesse, Heinrichs and Kuchshinrichs,
329 2019; Dryzek and Pickering, 2019). Such disagreement can partly be explained by a particular ambiguity
330 in Holling's SES approach (Redman, 2014). In the 1970s, Holling (1973) reinterpreted resilience as
331 bouncing back or forward in terms of SES adaptation. Adaptation refers, on the one hand, to the
332 capacity of agents to influence the system (and influence or strengthen resilience as a system
333 property). And on the other hand, it alludes to panarchical adaptation to new (ecological and social)
334 environments, as an evolutionary process towards a new stage, phase, or adaptation cycle (Boyd et
335 al., 2015).

336 Yet, as Holling emphasizes, the bouncing back and bouncing forward of a system not only refers
337 to a return to some previous (dynamic) equilibrium or to the persistence and endurance of systems. It
338 also refers to socio-ecological transformation in an ongoing process of non-equilibrium and instability
339 and reinvention of systems in changing environments marked by different adaptive cycles, such as
340 growth, accumulation, restructuring, and renewal (Folke, 2006). Transformation means that agents are
341 capable of creating a new system and a new discourse, particularly when the existing system is
342 untenable or illegitimate. This focus on undesirable status quo and hence on transformation – after a
343 crisis, for example – is characteristic of many social constructivists, but may also be important to those
344 who have somehow combined the goods of several worlds (Carolan, 2005; Code, 2005). Scholars

345 critical of resilience discourses propounded by national and international governance actors,
346 therefore, do not try to find ways to increase resilience, but above all things, try to ignite new
347 imaginations and counter-discourses necessary for realizing less unsustainable futures (Fazey et al.,
348 2018). Recently, a middle ground between adaptation and transformation has been developed, in the
349 form of “transformational adaptation” (Pelling, O’Brien and Matyas, 2015; Mummery and Mummery,
350 2019). Examples of transformational adaptations include green growth or the greening of present
351 economies. These are changes that are aligned with the scale of projected, possible and desirable
352 changes within systems that are informed by considerations of justice.

353 Resilience research that emphasizes system adaption to climate change focusses on the degree
354 to which complex systems can build capacity for learning, as a way to respond to shocks or
355 disturbances, embrace evolutionary change, and live with complexity and uncertainty (Thorén, 2014;
356 Juncos, 2017; Warmink et al., 2017; Béné et al., 2018). Given unpredictability and uncontrollability,
357 adaptive resilience is especially a matter of short-term planning, uncertainty reductions, incremental
358 and path-dependent changes (Borsje et al, 2011; Haasnoot et al., 2013). Adaptive resilience – the
359 system’s re-stabilizer – is conceived as inherently positive, while disturbances and shocks (de-
360 stabilizers) are negative (Duit, 2016; Lockie, 2016). Research building on the premise that adaptive
361 resilience is desirable thus partners well with climate risk management (Boyd et al., 2015; Berbés-
362 Blázquez et al., 2017). The response of the Dutch government to the overflowing of the Meuse River
363 in 1993 and 1995 illustrates research-based risk reduction through adaption that involves a break with
364 the past. The Dutch government did not simply have recourse to building more dykes and
365 strengthening existing barriers, which has been the traditional approach, but instead opted for river
366 deepening and widening measures (Dijkman et al., 1997; Hamers et al., 2015). Since its completion in
367 2015, the Room for the River project is considered effective thus far, particularly as its secondary
368 objective to increase ecosystem values in the river appears to be successful. However, research
369 completed in 2013 (Ward et al., 2013) points out that the risk of flooding in certain parts of the
370 Netherlands is expected to increase in the future (two- to three-fold increase by 2030 compared to

371 2010) and emphasizes the need for change with respect to land-use. Indeed, the researchers found
372 that the impact of land-use on flood risk is likely to be greater than climate change itself. This means
373 that households, for instance, can help to reduce the risk of future floods through a change of behavior.
374 But that is easier said than done. The authors of the report note that there are few means to move
375 Dutch households to participate in such risk reduction and point out the need for further research on
376 ways to implement new measures and motivate people to change their behavior (Ward et al., 2013:
377 45).

378 Research that prioritizes transformative resilience in the context of climate change looks at a
379 system's internal capacities, capabilities and relations that enable it to create a new condition marked
380 by new or different power relationships and different priorities. In such cases, constructivists typically
381 point out the undesirability and injustice of status quo (Ziervogel, Cowen and Ziniades, 2016; Rothe,
382 2017; Béné et al., 2018). According to this perspective, "anthropological shocks" (Beck, 2015, 80) open
383 up new horizons, reassessments (including of past ideas, beliefs, and practices) and rediscoveries
384 (Fazey et al., 2018). "Anthropological shocks" refer to the disruptive and lasting effects of certain
385 horrendous events on people. There is no going back to how it was before these shocks. According to
386 these critical voices, adaptive resilience research and policies based on that research contribute to
387 maintaining systems that are unjust (Skillington, 2015; Derickson, 2016; Fazey et al., 2018; Mummery
388 and Mummery, 2019). This does not mean that adaptive resilience research – which usually draws on
389 "naturalistic" methods – does not include justice in its models (Redman, 2014; Thorén, 2014; Ksenia
390 et al., 2016; Schlosberg, Collins and Niemeyer, 2017; Bergström, 2018). Yet, such models are based on,
391 and reflects, existing systems. They do not take structures of power into account (Howell, 2015; Pizzo,
392 2015; Lockie, 2016; Derickson, 2016; Davoudi, 2018). This also means that they cannot possibly
393 integrate thoroughly unequal power relationships – such as the Global North-Global South relationship
394 – into their models (Swyngedouw, 2011; Pizzo, 2015; Clément and Rivera, 2017; Davoudi, 2018; Glaser
395 et al., 2018; Dryzek and Pickering, 2019).

396 The limitations of models need not be a problem unless they become the political tools to
397 implement adaptive measures (Fainstein, 2014; Weichselgartner and Kelman, 2015; Huang, Boranbay-
398 Akan and Huang, 2016; McGreavy, 2016; Ziervogel, Cowen and Ziniades, 2016; Ribault, 2019). Adaptive
399 responses to shocks and disturbances may blur long-term sustainability visions and enable powerful
400 stakeholders to maintain their positions (Lockie, 2016; Derickson, 2016; Rothe, 2017; Estêvão, Calado
401 and Capucha, 2017; Ribault, 2019). Kythreotis and Bristow (2017) call this phenomenon the “resilience
402 trap” – the reinforcement of established power relations and contemporary resilience discourses
403 (Blühdorn, 2013; Redman, 2014; Yanarella and Levine, 2014; Lockie, 2016; VanderPlaat, 2016; Schilling,
404 Wyss and Binder, 2018; Glaser et al., 2018; Ribault, 2019). Hence, some constructivist scholars reject
405 Holling’s panarchy concept, emphasizing that transformation towards more sustainable worlds is not
406 an evolutionary process of adaptive cycles but a political-administrative phenomenon (cf. Boyer,
407 2020).

408

409 **3.2 Transformative resilience and sustainability**

410

411 For some constructivist scholars, genuine sustainability presupposes transformative resilience because
412 inherently unsustainable systems cannot be made more wholesome by tweaking a few of their
413 constituents. In cases of inherent or structural defects, resilience refers to the capacity to “use” a crisis
414 to reappraise critically the social, cultural, and political choices underpinning SES, and if necessary, to
415 make new choices (Pizzo, 2015; Weichselgartner and Kelman, 2015; VanderPlaat, 2016; Ziervogel,
416 Cowen and Ziniades, 2016; Hughes, 2017; Jesse, Heinrichs and Kuchshinrichs, 2019). The
417 reconfigurations of SES do require interventions by all governance actors. Transformative resilience
418 used in this sense is thus a post-neoliberal concept. When applied to the energy transition,
419 transformative resilience entails a more radical change than adaptive resilience does. In the former
420 case, this means concrete plans to phase out fossil fuels and hence to reorganize economies, where
421 the old fossil fuel industry no longer holds the reins (Alexander and Yacoumis, 2018; Stegemann and

422 Ossewaarde, 2018; Bergmann and Ossewaarde, 2020). Adaptive resilience is involved when the
423 phasing out of fossil fuels is being delayed and when certain discourses ensure that the fossil industry
424 is given carte blanche to carry on business as usual (Buschmann and Oels, 2019). Geels (2014, p. 24)
425 explains how “the coal regime has so far resisted climate change pressures through a “clean coal”
426 discourse and the innovation promise of carbon capture and storage (CCS).”

427 It is widely agreed that non-renewable fossil energy sources like coal, oil and gas are largely
428 responsible for landscape degradation, air and water pollution, as well as greenhouse gas emissions
429 that have been causing global warming (Cook et al., 2016). The sustainable energy transformation,
430 accordingly, is, amongst other things, a response to climate change. In a more robust sense, it is more
431 than simply a response to climate change. Instead, the latter is a symptom of the inherent
432 unsustainability of the present socioeconomic system and is therefore an additional, urgent reason to
433 radically transform the latter (Alexander and Yacoumis, 2018). Hence, those who conceive an energy
434 transition as an adaptive necessity are primarily concerned with what several scholars call “energy
435 resilience” (Béné et al., 2018, p. 120; Jesse, Heinrichs and Kuchshinrichs, 2019, p. 21), that is, with the
436 continuing supply of energy to support the prevailing socioeconomic system and prevention of power
437 outage during the transition. In other words, reliable energy supplies at stable costs must be kept going
438 to support the present socioeconomic system (Wiese, 2016). Since system collapse is to be avoided
439 at any cost, adaptive resilience to climate change means incremental changes and the increasing use
440 of renewables without stopping the use of fossil fuels (Berbés-Blázquez et al., 2017; Schilling, Wyss and
441 Binder, 2018; Stegemann and Ossewaarde). Adaptive resilience here means the gradual greening of
442 energy and hence the gradual greening of the system through green technological innovation without
443 essentially changing the old system (Geels, 2014). In fact, important stakeholders of the “old regime”
444 resist the transition to a new order (*ibid*). Such resistance takes, among other things, the form of
445 continuing investments in fossil-fuel-based energy and greening measures – which create the
446 impression of a transition (especially in the media) – thereby further anchoring the existing system

447 (Alova, 2020; Gençsu et al., 2020). The incentives to “destabilize” such a flourishing economic system
448 are thus weakened.

449 Scholars who challenge existing social structures therefore critically point out that the primary
450 and sole focus on “energy resilience” (that is to say, energy security) is more likely to maintain the
451 energy system’s status quo, which further allows powerful stakeholders to promote fossil energy and
452 keep their established positions. As Simpson (2013, p. 249) notes, the “critical approach to energy
453 security challenges the existing economic, political and technical assumptions that underpin traditional
454 debates on energy production and consumption, but it also challenges traditional notions of security
455 that have the nation-state as their referent object”. An uncritical adaptive energy resilience approach
456 can thus reinforce “energy injustice”, that is, the “the unequal distribution of ills” throughout the
457 energy system, whereby that system is defined as “the entire energy chain, from mining, conversion,
458 production, transmission, and distribution, right through to energy consumption and waste” (Jenkins
459 et al., 2016, p. 179). Scholars who focus on the transformative resilience of energy systems are
460 therefore generally committed to energy justice and have a more critical approach to energy resilience
461 (or security) because the latter presumes the socioeconomic order and unequal structures of power
462 (Jenkins et al., 2016; Heffron and McCauley, 2017). They propose the creation of a renewable energy-
463 based system, energy commons and collaboratives beyond the energy establishment (VanderPlaat,
464 2016; Bourbeau and Ryan, 2018; Juncos, 2018; Schwartz, 2018; Acosta et al., 2018; Jesse, Heinrichs
465 and Kuchshinrichs, 2019).

466

467 **4. Six emerging themes in diversified resilience research**

468

469 Current research on resilience to climate change in the social sciences reflects a diversity of focusses
470 and commitments, ranging from climate-resilient infrastructure to issues of justice and power. Some
471 critical scholars question the very notion of resilience and point to the “wicked” dynamics involved as
472 “resilience” becomes a policy instrument to consolidate one particular, often established social reality

473 at the expense of other, fairer possible alternatives. Research that unwittingly supports such political
474 purpose has thus attracted the criticism of scholars who emphasize transformation towards new social
475 constellations, where power (to influence the course of things), responsibility, burdens, and benefits
476 are fairly distributed (Derickson, 2016; Jenkins et al., 2016; Heffron and McCauley, 2017; Alexander
477 and Yacoumis, 2018; Davoudi, 2018; Glaser et al., 2018; Stegemann and Ossewaarde, 2018).
478 Ultimately, the overarching challenge for future research is to ensure that resilience to climate change
479 does not compromise sustainability and considerations of justice (including, environmental, climate
480 and energy justice). Based on our overview of recent scholarship, which cannot possibly be exhaustive,
481 we have identified six research avenues that deserve continued attention.

482 One of them is the further development of transdisciplinarity, which includes the collaboration
483 between constructivist and naturalistic approaches to resilience, not only at the institutional level, but
484 especially at the level of research itself. Such transdisciplinarity thus means that a scholar draws on
485 different scientific traditions to approach one particular problem. In other words, transdisciplinarity
486 does not restrict itself to “forced” collaboration between scholars from different disciplines, which is
487 a prevalent organization of inter-, multi- and trans -disciplinarity (cf. Pohl, 2001). It also does not mean
488 homogenization of science and the repression of the diversity of human thinking. It entails an
489 appreciation of diverse scientific vocabularies, of the variety of scientific knowledge, and the
490 acknowledgement of clashes, which can be conducive to the advancement of human knowledge (cf.
491 Pfeffer and Georgiadou, 2019). Bringing together various perspectives of a complex reality arguably
492 fosters our understanding of that same reality.

493 There have been several attempts to “bridge” the disciplinary divide, some more successful than
494 others. Such attempts at integration are deemed even more desirable when it comes to environmental
495 issues (Pompe and Rinehart, 2002; Mooney et al., 2013). Edward O. Wilson’s famous “consilience” is a good
496 example of a failed attempt since he takes the natural sciences and their methods to be hegemonic. Wilson
497 (1998, p. 11) thus notes:

498

499 Given that human action comprises events of physical causation, why should the social
500 sciences and humanities be impervious to consilience with the natural sciences? [...] Nothing
501 fundamental separates the course of human history from the course of physical history,
502 whether in the stars or in organic diversity.

503

504 Similarly, the allegedly transdisciplinary “Earth System Analysis” approach, developed at the Potsdam-
505 Institute for Climate Impact Research (Germany), makes use of mathematical modelling in which the
506 world is conceived as a cybernetic organism (Pohl, 2001, p. 40).

507 More successful integrative approaches do not allow the methodology and theoretical framework
508 of one particular scientific tradition to dominate the other. We have mentioned “ecological naturalism”
509 above as an example of such an approach. The “critical realist” (Proctor, 1998) is yet another way to
510 benefit from the realism of the naturalist approach, thereby avoiding relativism, without falling into
511 the trap of reification and determinism. With regard to energy, for instance, Jenkins et al (2016, p. 179)
512 argue that a “combination of the social science account of energy (policy) with its natural science
513 counterpart (systems)” helps us to determine where injustices lie, even more accurately than through
514 social constructivist approaches alone. Conversely, evolutionary resilience approaches that draw on
515 systems thinking can be enriched by taking into account human agency, the issue “unequal power
516 relations that can disrupt feedback loops and channels of communications” (Davoudi, 2018, p. 4), and
517 more generally, the idea that we cannot simply wait for evolutionary change, or for systems to explode,
518 but instead have to realize alternatives through human imagination.

519 This brings us to the second theme, which could be dubbed “critical resilience” research.
520 Critical thinking is arguably a precondition for, and characteristic of, science in general. This means that
521 reservations with regard to the very concept “resilience”, in policies and models, need to be taken
522 seriously. Research that constantly analyses the dominant and new – and often, implicit – conceptions
523 of resilience must thus be stimulated even if it does not seem to serve practical purposes. Critical
524 resilience research thus also includes the integration of reflexivity in transdisciplinary research, which

525 involves “a reflexive questioning of values, background assumptions and normative orientations”
526 (Popa et al., 2015, p. 46) of various approaches to resilience. Critical resilience research is expected to
527 pay attention to diverse conceptions of resilience and also to address the “question of outcomes and
528 who gets to define them as resilient or otherwise”, “the potential exclusions in determining system
529 ‘boundaries’”, and “the question of the political—resilience from what, to what, and who gets to
530 decide?” (Porter and Davoudi, 2012, p. 331). Such critical resilience research can accompany other
531 resilience research, thereby preventing science from serving ideological goals.

532 A third research avenue, somewhat related to the second theme, consists in the
533 contextualization of resilience research and discourse, that is, in embedding them in their political and
534 cultural context. By understanding the bigger picture in which both the ecological crisis and the
535 responses to it arise, it may be possible to govern resilience research towards sustainability and justice,
536 and to identify the factors – which may be institutional, cultural or political – that stimulate or deter
537 such changes (cf. Bahadur and Tanner, 2014). In a systems thinking language, such research can
538 identify the various agents that maintain or disrupt the system. An example of disruptive forces may
539 then be environmental movements that are able to develop a leverage required to transform
540 established systems (such as energy systems) and their governance arrangements. Agents that
541 maintain the system, on the other hand, include those who hold power, thanks to such arrangements,
542 and typically use tactics of repression and criminalization, particularly in the extractive sectors of the
543 Global South (Szablowski and Campbell, 2019). Research focusing on the different fields of forces in
544 various political contexts may discover how differences in system adaptation and reconfiguration
545 relate to particular administrative capacities and governance arrangements (cf. Blühdorn, 2013;
546 Fischer, 2017; Davoudi, 2018; Köhler et al., 2019; Mummery and Mummery, 2019). It can also generate
547 insights into the (possible) connection between particular resilience policies and models, on the one
548 hand, and new forms of power inequalities, polarization, injustice, and democratic deficits, on the
549 other hand. and Bierbaum and Stults (2013, p. 18) point to the “growing recognition of the need for a
550 new model of deep and long-term stakeholder engagement”. Such a model ensures that all (local)

551 stakeholders are involved in determining a “vision of resilience, impediments to achieving that vision,
552 and contextually relevant actions for achieving that vision” (Bierbaum and Stults, 2013, p. 30). It can
553 safeguard both the effectiveness and equitability of solutions.

554 A fourth promising topic for future resilience research is the interplay between adaptive
555 resilience and transformative resilience and transformational adaptation (Clément and Rivera, 2017).
556 The focus can be on the ways in which transformational adaptation manifests itself, how multiple
557 adaptations may lead to transformational adaptation and the threshold that needs to be surpassed for
558 adaptation to be considered as transformational (Grove and Chandler, 2017; Glaser et al., 2018). The
559 notion of “tentative governance” appears particularly relevant in the context of transformational
560 politics, when it comes to phasing out systems and weakening adaptive resilience. Tentative
561 governance is marked by interventions that are designed as preliminary rather than as persistent, for
562 purposes of probing and learning rather than for stipulating definite targets or fixating existing systems
563 and their underlying assumptions (Kuhlmann, Stegmaier and Konrad, 2019). It is likely that stakeholder
564 engagement (including resistance) in transformational politics and tentative governance varies, and
565 manifests itself differently, across different policy fields. For instance, the sustainable energy
566 transformation may include multi-layer governance challenges, many pro-active stakeholders, new
567 investment opportunities and job opportunities. In contrast with the sustainable energy
568 transformation, sea level rise and the disruption and relocation of coastal cities may trigger a more
569 limited transformative politics, despite inevitable transformation of systems due to shocks and
570 disturbances (metamorphosis). Yet, in the coming decade, transformational politics and tentative
571 governance – including anthropogenic topics like population displacement, privatization of climate
572 adaptation, conflict surrounding scarce resources (like water resources), intergenerational
573 environmental conflict, and the shutting down of old infrastructures that are too costly to maintain –
574 become more urgent research topics.

575 The fifth research theme concerns the relationship between the phasing out of unsustainable
576 systems and societal transformations. What are the implications of the disintegration of old systems

577 for societies, that is, for their cultures, collective identities, traditions, economies, political-
578 administrative power constellations, class structures, etc.? Which societal transformations promote
579 such disintegration? Research topics encompass the governing and accelerating of the decline of
580 existing systems and their adaptive cycles (Stegmaier, Visser and Kuhlmann, 2014; Hoffmann, Weyer
581 and Longen, 2017; Stegmaier, Visser and Kuhlmann, 2020); the particular circumstances in which
582 accelerations can manifest themselves; the identification of, and coping with, uncertainties in
583 processes of adaptation and transformation and transformational adaptation; and the construction of
584 new incentive structures, for accelerating sustainable transformation (cf. Clément and Rivera, 2017;
585 Warmink et al., 2017; Köhler et al., 2019). This branch of discontinuation research assumes that
586 technologies influence socio-ecological systems. Some technologies threaten resilience to climate
587 change, while others enhance it (Smith and Stirling 2010), which brings us to another, related research
588 topic, namely, the implications of the so-called “AI Revolution” and the (top down and politically
589 steered) making of the alleged “Age of Artificial Intelligence” for resilience research and SES (Berendt,
590 2019).

591 Given worldwide investments in AI technologies and top-down AI strategies that global
592 governance actors and national governments have recently published (Ossewaarde and Gülenç,
593 2020), AI will most plausibly become a major force that shapes or undermines resilience to climate
594 change. New interplays between automation, (un)sustainability, and adapting and transforming
595 systems trigger new questions for future resilience research (cf. Köhler et al., 2019). Hoefsloot et al
596 (2019) have expressed the concern that the total and unconditional reliance on the data generated by
597 AI technology may lead to a flawed prediction of climate disasters. For instance, the coverage of
598 climate disasters – satellite data, drone data, sensor data, social media data, volunteer geographic
599 information (VGI) data, among others – may be incomplete and leave out certain geographical areas
600 and even certain social groups (Hoefsloot et al., 2019). Other sources of information are necessary to
601 ensure more accurate measurements (and predictions), complement data gaps and identify the needs
602 of local communities (Bierbaum and Stults, 2013; Pfeffer and Georgiadou 2019). A recent example of

603 the integration of different sources of knowledge is the resilient settlement program led by UN
604 HABITAT, which brought together a multitude of actors (policy, private, academic, community
605 organizations) and data and algorithms and local knowledges to identify settlements at risks (UN-
606 Habitat, 2019). This example illustrates the importance of embedding AI technologies in particular
607 contexts so that the needs of particular communities, for instance, are served, and fairness and
608 transparency are safeguarded. Resilience research and models must therefore include an evaluation
609 of AI technologies. How has data been acquired and by whom? What are the implications of particular
610 AI technologies for the SES in question? Which new power relations are established through the
611 reliance on AI technologies? Which stakeholders are being included and which ones are being excluded
612 during the whole process, beginning with the problem definition to the formulation of solutions that
613 involve an intensive application of AI? (Rajan and Saffiotti, 2017; Taddeo and Floridi, 2018; Khakurel et
614 al., 2018; Vahedifard, et al, 2019; Miller, 2019; Saravi et al., 2019).

615 A sixth theme for future resilience research concerns the role of environmental, energy and
616 climate justice in theorizing, modeling, interpreting, and explaining resilience to climate change (cf.
617 Skillington, 2015; Fazey et al., 2018; Mummary and Mummary, 2019). What kind of research results
618 from the integration of theories of environmental justice, energy justice and climate justice into
619 adaptive and transformative resilience and transformational adaptation models? Future resilience
620 research will somehow have to confront wicked problems: given unstable political contexts, scarcity
621 of “resources” and struggles for survival and power, how can principles of equity, fairness and access
622 to resources and services be secured? In the problematic context of mobilities and a political
623 environment marked by anti-immigration policies, how can the wellbeing of migrants be ensured and,
624 in general, human rights be safeguarded? How can the disparity and inequality in the distribution of
625 risks, locally and globally, be tackled? Equity in this regard will mean much more than equality. Other
626 challenges include the incorporation of cross-sectional dimensions of justice, particularly gender and
627 ethnic relations, into climate justice (Terry, 2009), and energy justice (Feenstra and Özerol, 2018)
628 frameworks. And in the Global South, addressing issues of corruption, violence, poverty and lack of

629 access to resources (and violent battles for resources) and services (like education and sanitation) may
630 have a higher priority than global environmental considerations (Köhler et al., 2019).

631

632 **5. Conclusion**

633

634 In the social sciences, resilience to climate change is a concept that is incorporated in different
635 theoretical approaches that are linked to contrasting scientific approaches. Holling originally
636 reinterpreted and incorporated the notion of resilience in his SES approach, which was then picked up
637 by naturalist scientists and embedded in cybernetic complexity theory, for instance. The complexity
638 theory was for a very long time the preferred approach to resilience to climate change in the social
639 sciences. This situation changed as resilience increasingly became the theme of political discourses and
640 policies a decade ago, especially in the wake of socio-ecological catastrophes, financial crises, and
641 pandemics. The instrumentalization and decontextualization of resilience by local and global
642 governance actors invited the critical response of scholars who often had recourse to constructivist
643 approached. The diversification of resilience research and expansion of the social scientific jargon
644 resulted from this development. The question of whether resilience should operate as a unifying
645 paradigm is not yet settled. However, it may well facilitate interdisciplinary dialogue and even
646 transdisciplinarity. Such cooperation or dialogue is arguably necessary given the extremely complex
647 nature of our socio-ecological predicaments. New light may be shed on how new political-
648 administrative institutions (including panarchical self-organization) and practices can respond in
649 legitimate ways (taking justice and vulnerability considerations into account) to the challenges of
650 addressing climate change impacts, in different ecological, political and technological contexts (cf.
651 Johnsson et al., 2018).

652 The six themes for future resilience research that we have identified combine naturalist and
653 constructivist insights and approaches so that human agency, reflexivity and considerations of justice
654 and equity are incorporated into research that predominantly involves systems thinking. In fact,

655 further cooperation is the first identified research theme. Interdisciplinary and multidisciplinarity
656 between naturalist and constructivist approaches and the many varieties of these approaches can
657 prove to be challenging, not only because of clashing methodologies and conceptual frameworks, but
658 also because of institutional factors. Yet, there have been attempts to reduce the gap between these
659 approaches, without eliminating a fruitful tension. The second research area could be called “critical
660 resilience” research. It includes questioning the very concept of resilience and proposing alternatives
661 or supplementary concepts. Such critical resilience research will most probably be a complement to,
662 or necessary component of, other resilience research. The third theme consists in the contextualization
663 of resilience research, which serves the multiple purposes of effectiveness (of measures), sustainability
664 and justice. The interaction as well as the blurry line between adaption (adaptive resilience) and
665 transformation (transformative resilience) is the fourth research area. Related to the latter topic is
666 research focusing on the two-way relationship between the phasing out of unsustainable systems and
667 societal transformations. Given the increasing incorporation of AI technologies in resilience research
668 and policies, a fifth research topic pertains to the implications of AI technologies for societies, and
669 more specifically, for sustainability and justice. The final theme is the integration of various forms of
670 justice (such as inter-racial) and theories of justice into resilience research. We believe that the
671 multifariousness of climate change resilience research is inevitable and also desirable given the
672 complexity of the issues under consideration. Whether such diversity is maintained will depend on
673 external factors, such as the preferences of research institutes (and governments) and the availability
674 of funding for all lines of research.

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