

# Grand Challenges in Global Sustainability Research: A Systems Approach to Research Priorities for the Decade

December 21, 2009 – Draft 6

*We propose a focused global initiative addressing five Grand Challenges in Global Sustainability Research. These challenges must be addressed over the next decade if society is to manage the global environmental change that is now underway and cope with the change that we cannot manage. Given the pace and magnitude of human-induced global change, immediate action is needed to avoid the most dangerous outcomes for people and for the planet. In this context, science has to focus on delivering to society information that will directly and effectively inform and support the responses and actions of decision-makers and citizens in all regions of the world. The International Council for Science (ICSU) and its partners are leading an international consultative process to: (a) define today's grand challenges in global sustainability; (b) identify high priority research that must be carried out; and (c) mobilize social scientists, natural scientists and the humanities around an unprecedented 10-yr initiative to address these challenges.*

The study of the Earth System has reached a point of transition. For the past two decades, our priority has been to understand the functioning of the Earth System and, in particular, the impact of human actions on that system. While many critical research questions remain in this area, science has advanced to the point that we now have a good understanding of how the Earth System is changing and a growing understanding of how those changes will affect society and human well-being. Earth System science has provided invaluable new insights over the past decade regarding the biophysical processes that determine the functioning and resilience of planet Earth, the sensitivities of the components of the Earth System, evidence of the accelerated pace of global environmental change caused by the human enterprise, the possible consequences of those changes, and the human dimensions of how to address these challenges.

This science also tells us that the rate of global environmental change is, so far, vastly outpacing our response. Even though many questions remain to be answered, we know enough to state with a high degree of scientific confidence that humanity has reached a point in history at which a prerequisite for development – the continued functioning of the Earth system as we know it – is at risk. Without fundamental changes in the human drivers affecting the Earth System and without actions designed to enhance the resilience and decrease the vulnerability of human communities, it is now clear that changes in climate, hydrological cycles, food systems, sea level, biodiversity, ecosystem services and other factors will cause massive human suffering. If unchecked or unmitigated, these changes will retard or reverse progress towards broadly shared economic, social and environmental goals.

40 Building on the scientific advances that have been made over the past two decades, the research  
41 frontier is now shifting from a primary focus on understanding human impacts on the Earth System  
42 to a broader agenda that also includes a strong focus on understanding and forecasting the  
43 consequences of global environmental changes and how to respond to those changes. New,  
44 strategic, inter-disciplinary research is needed to improve our understanding of the social-  
45 environmental risks facing humanity and to provide science-based support for actions to address the  
46 growing challenge of global environmental change. **Over the next 10 years the global scientific  
47 community must take on the challenge of delivering to society the knowledge and supporting  
48 information necessary to assess the risks humanity is facing from global environmental change,  
49 and to understand how society can effectively mitigate dangerous changes and cope with the  
50 change that we cannot manage.** We refer to this field as “global sustainability research.”<sup>1</sup> Global  
51 sustainability research builds upon expertise within the basic natural and social sciences and applies  
52 it to pressing coupled social-environmental research questions.

53 Just as we are at a point of transition in the focus of global social-environmental research, we are  
54 also at a point of transition in the disciplines that must be involved and the processes by which that  
55 research is undertaken. Social sciences have long been a component of Earth System research, but  
56 tackling the grand challenges described here requires a stronger involvement and greater  
57 integration of the social sciences and humanities, along with the natural sciences. It is increasingly  
58 clear that pathways to address rapid global environmental change can only be found through  
59 inquiries that integrate the social sciences, humanities and the natural sciences in ways that may  
60 lead to significant transformations in these disciplines as they are currently understood. It also  
61 requires the inclusion of local, traditional and indigenous knowledge. And, it requires the co-  
62 creation of new knowledge with a broad range of stakeholders. Research will be most useful if  
63 priorities are shaped with the active involvement of potential users of research results and if the  
64 research is carried out in the context of a bi-directional flow of information between scientists and  
65 users. These changes in the disciplines involved and research processes are needed because they  
66 will bring greater expertise to bear in addressing the research priorities, because they help to ensure  
67 that the research priorities are relevant to key stakeholders, and because the answers to the  
68 research questions can more readily inform decision making.

69 In light of the urgent needs, ICSU and its partners are seeking to mobilize social and natural scientists  
70 and researchers in the humanities around an unprecedented, 10-year scientific effort to address the  
71 grand challenges in global sustainability. The process to reach consensus on the grand challenges  
72 and research priorities began with an Internet consultation in July and August 2009.<sup>2</sup> The Internet  
73 consultation yielded more than 300 proposed Earth System research priorities contributed by  
74 scientists from 85 countries. These proposed research priorities formed the background for a

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<sup>1</sup> We consider the field of “global sustainability research” to be largely equivalent to “Earth System research,” but with a more explicit recognition of the human dimension. The Earth System is defined as the unified set of physical, chemical, biological, and social components, processes and interactions that together determine the state and dynamics of the Earth, including its biota and its human occupants. Although Earth System science includes humans as an integral component of the Earth System, this term is seen by many to focus primarily on the natural system. The term “global sustainability research,” helps to give greater emphasis to the central importance of the social sciences in this research agenda.

<sup>2</sup> The full process is described in detail at: <http://www.icsu-visioning.org/the-visioning-process/>. The Internet consultation ([www.icsu-visioning.org](http://www.icsu-visioning.org)) attracted over 7000 unique visitors from 133 countries and over 1000 registered users from 85 countries, who posted research questions, made comments and voted on the questions. By the end of the consultation, 323 distinct Earth system research questions had been posted on this moderated site.

75 workshop held in September 2009 involving senior researchers, early career scientists, science-policy  
76 experts and representatives of research funding agencies. The workshop generated the selection  
77 criteria, grand challenges, and research priorities contained in this draft. We are now seeking a  
78 broader review of this document with the aim of producing a widely shared vision of the scientific  
79 priorities for global sustainability research in the coming decade.

80 The final outcome of this process is intended to: a) guide the prioritization of research topics by  
81 scientists and policy makers; b) inform decisions by agencies funding research in the areas of global  
82 sustainability and Earth System research, and social and natural sciences; and, c) inform potential  
83 users of the research findings, including scientific assessments like the Intergovernmental Panel on  
84 Climate Change, and technical advisors to decision-makers in the private sector and governments.  
85 Representatives of these stakeholder groups have been involved in the development of the current  
86 draft and will continue to be involved in the ongoing consultation and revision of the draft.

87 The research that this process aims to catalyze, and the knowledge that will be generated, is  
88 intended to help the public and decision-makers in government, the private sector, and non-  
89 governmental organizations in their efforts to achieve economic, social and environmental goals.  
90 More specifically, progress in addressing the grand challenges of global sustainability will assist  
91 efforts to: minimize adverse global environmental change and limit further environmental  
92 degradation in socially acceptable sustainable ways; achieve food, water, energy, health and human  
93 security; address goals for economic, environmental and social sustainability and equity; and,  
94 alleviate global poverty.

## 95 **Criteria**

96 We have used the following criteria in selecting the grand challenges and research priorities.

- 97 1. **Scientific importance.** Does the question address a cutting-edge research challenge that, if  
98 answered, could significantly advance our understanding within the next decade of how to  
99 achieve global sustainability?
- 100 2. **Relevance to decision-makers.** Will the answer to the question help to inform actions to  
101 meet urgent global needs, especially promoting sustainability, reducing poverty, and  
102 assisting the most vulnerable in coping with global environmental change?
- 103 3. **Broad support.** Does the question have support from the research and funding community  
104 (even those not directly involved in answering the question)?
- 105 4. **Global coordination.** Is a coordinated international or global approach involving multiple  
106 researchers in different regions and often in different disciplines needed to answer the  
107 question? If not, then such a question would fall outside the remit of this framework,  
108 despite its importance to a given field.
- 109 5. **Leverage.** Does the answer to the question involve a scientific or technical breakthrough, or  
110 would it create a transferable theory, model, scenario, projection, simulation or narrative  
111 that would help to address multiple problems or other challenges related to global  
112 sustainability research?

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## 116 **The Grand Challenges in Global Sustainability**

117 Consistent with the use of the concept of grand challenges in other areas of science, we consider a  
118 grand challenge in global sustainability research to be a call for scientific innovation or  
119 understanding that would remove a critical barrier to deciding how to manage global change and its  
120 impacts. We list five grand challenges in global sustainability. Within each, we list several top-level  
121 research priorities that must be addressed to solve the problem posed by the grand challenge during  
122 the next decade. The list of research priorities is neither exhaustive nor necessarily sufficient.  
123 However it is our judgment that these questions must be addressed to achieve the most rapid  
124 progress. In virtually all cases, a deep base of research and knowledge already exists in the areas  
125 identified by these research priorities and, building on that base, it is thus plausible that the research  
126 area can be substantially advanced in less than a decade. However, it is by no means inevitable that  
127 all the questions can be answered. These are, by definition, big and difficult problems, and will  
128 require a focused, multidisciplinary, and integrated research commitment to have a reasonable  
129 prospect of success.

130 The five grand challenges are a package, and the topics are not prioritized either across or within the  
131 challenges. **Progress on every one of the challenges and research questions is urgently needed.** The  
132 global sustainability research community has unique capacities to contribute to the solution of these  
133 challenges, but all of them will require working with partners outside of this research community as  
134 it currently exists.

### 135 **Challenge #1: Improve the usefulness of forecasts of future environmental** 136 **conditions and their consequences for people.**

#### 137 **Priority Research Questions**

138 **1.1. What significant environmental changes are likely to result from human actions, how**  
139 **would those changes affect human well-being, and how are people likely to respond?**

140 **1.2. What threats does global environmental change pose for vulnerable communities and**  
141 **groups and what responses could be most effective in reducing harm to those**  
142 **communities?**

143 Our limited ability to anticipate the outcomes that result when complex human societies interact  
144 with equally-complex natural processes is a significant barrier to timely and effective decision-  
145 making and action. Although we may never be able to accurately forecast the future of coupled  
146 social-environmental systems beyond a time horizon of several decades, there is tremendous  
147 potential for improving our ability to use scenarios and simulations to anticipate the impacts of a  
148 given set of human actions or conditions (e.g., greenhouse gas emissions, deforestation, increased  
149 agricultural productivity, etc.) on global and regional climate and on biological, geochemical, and  
150 hydrological systems on seasonal to decadal time scales. In turn, we should be able to forecast the  
151 potential impact of those changes on human well-being (e.g., impacts on economies, health, food  
152 security, energy security, etc.). Forecasts should be tailored to respond to the questions and needs  
153 of the people potentially affected, and the uncertainty of the forecast should be quantified and

154 communicated. By meeting this challenge, models and analyses of global and regional  
155 environmental change will be able to provide direct support to governance and management at  
156 national and regional scales, and over the typical time-frames of political and management  
157 decisions.

158 Significant improvement is needed in our ability to develop contingent forecasts or scenarios that  
159 address the full range of plausible outcomes within a probabilistic framework, and at appropriate  
160 spatial and temporal scales to assess impacts on economies, ecosystem services and human well-  
161 being. Importantly, such scenarios must improve representation of the dynamic response of both  
162 the natural and social system. Progress in this area of research will require advances in modelling  
163 capability (including development of the ultra-high performance computing infrastructure that will  
164 be needed for that modelling) and a more interdisciplinary framework of analysis.

165 Examples of key questions that need to be answered include: How will regional climate change over  
166 decadal time scales? What adaptation strategies are needed to reduce vulnerability to global  
167 environmental change? When do individual human actions aggregate to cause consequences for  
168 larger regions or the Earth system? How are changes in ecosystems and biodiversity going to affect  
169 ecosystem services and human well-being? What trade-offs occur among services and human well  
170 being, and are there strategies to minimize such trade-offs? What kinds and levels of biodiversity are  
171 needed to buffer the impacts of environmental change on ecosystem services? To respond these  
172 questions we will need scientific advances and better observation systems.

## 173 **Challenge #2: Develop the observation systems needed to manage global and** 174 **regional environmental change.**

### 175 **Priority Research Questions**

176 **2.1. What do we need to observe in coupled social-environmental systems, and at what scales,**  
177 **in order to respond to, adapt to, and influence global change?**

178 **2.2. What are the characteristics of an adequate system for observing and communicating this**  
179 **information?**

180 The current supply of information needed to manage the social-environmental system, especially at  
181 a global scale, as well as the system for delivering that information to decision-makers, is inadequate  
182 for the task. Further advances in theories, models, scenarios, projections, simulations, or compelling  
183 narratives used to understand the Earth System and to forecast changes are constrained by limited  
184 availability of data needed to set parameters and validate predictions. Moreover, the paucity of  
185 empirical data on changes in social-environmental systems undermines the ability of decision-  
186 makers and the public to establish appropriate responses to emerging threats and to address the  
187 needs of vulnerable groups of people. Although the observation systems currently in place are  
188 insufficient to meet the needs, they do provide a firm foundation upon which the necessary systems  
189 can be built.

190 The observation systems required need to encompass both natural and social features, be of high  
191 enough resolution to detect systematic change, assess vulnerability and resilience, include multiple  
192 sources of information (quantitative, qualitative and narrative data and historical records), involve

193 multiple stakeholders in the research process, support effective decisions at global to local scales,  
194 and be formally part of adaptive decision making processes. They would include critical data needs  
195 such as: comprehensive time-series information on changes in: (1) land cover and land use, biotic  
196 systems, air quality, climate change and changes in use and ecological characteristics of the oceans;  
197 (2) spatial patterns and changes in freshwater quantity and quality, for both ground- and surface-  
198 water; (3) changes in stocks, flows and economic values of ecosystem services; (4) trends in  
199 components of human well-being (particularly those not traditionally measured, such as access to  
200 natural products that are not marketed); (5) socio-economic indicators, including population  
201 distribution, economic activities and mobility; and, (6) patterns of human responses to these  
202 developments. The design of such a system would need to address the question of how local and  
203 regional environmental changes can be scaled accurately and effectively to enhance the assessment  
204 of global changes, and vice-versa. The entire design should include a process and institutional  
205 arrangements for observation systems to be aligned with assessment and policy processes.

206 This grand challenge is both a research challenge and a challenge for science policy. Fundamental  
207 scientific questions need to be addressed in the design of cost-effective systems that can meet the  
208 needs of managers and decision-makers. The implementation of such systems, on the other hand, is  
209 not a research challenge but will nevertheless require an ongoing and concerted effort by the  
210 scientific community if it is to be achieved, even beyond the timescale of the work envisaged here.

## 211 **Challenge #3: Determine how to anticipate, avoid and cope with dangerous** 212 **global environmental change.**

### 213 **Priority Research Questions**

214 **3.1. Which aspects of the coupled social-environmental system pose significant risks of**  
215 **runaway dynamics?**

216 **3.2. How can we identify, analyze and track our proximity to thresholds and discontinuities in**  
217 **coupled social-environmental systems? When can thresholds not be determined?**

218 **3.3. What strategies for avoidance, adaptation and transformation are effective for coping**  
219 **with abrupt changes, including massive cascading environmental shocks?**

220 **3.4. How can the need to curb global environmental change be integrated with the demands of**  
221 **other inter-connected global policy challenges, particularly those related to poverty,**  
222 **conflict, justice and human security?**

223 **3.5. How can improved scientific knowledge of the risks of global change and options for**  
224 **response most effectively catalyze and support appropriate actions by citizens and**  
225 **decision-makers?**

226 Linear changes in the global environment can have dangerous impacts on people if their magnitude  
227 or rate is sufficiently high. In addition, it is increasingly likely that we will encounter discontinuous  
228 ('abrupt' or 'non-linear') changes in the global environment such as abrupt changes in regional  
229 climate, rapid collapse of ice sheets, rapid methane release associated with melting permafrost, and  
230 abrupt change in the structure and functioning of biological systems. Moreover, an increasingly



231 interconnected world generates linked trends and shocks in seemingly disparate sectors such as  
232 energy, finance, food, health, water and security. A major focus of research must be to better  
233 determine strategies for avoidance, adaptation or transformation of social-environmental systems  
234 to accommodate changes that are dangerous because of their speed, scale, non-linear nature,  
235 cumulative impact, self-amplifying nature or irreversibility. Research into appropriate response and  
236 adaptation strategies must also extend beyond considerations of 'optimal' approaches to advance  
237 understanding of the political and social dynamics of responses. Under what conditions are policy  
238 innovations more likely to occur (e.g., many significant policy changes take place during times of  
239 crisis) and what are the implications of these patterns for the design and promotion of response  
240 options?

241 An effective response to global environmental change will also require much greater understanding  
242 of the inter-relations between global environmental change, global poverty and development needs,  
243 and global justice and security. For example, how will global environmental change influence  
244 progress toward the goals of reducing poverty and hunger and improving maternal and child health?  
245 What are the risks posed by global environmental change to human security? How does global  
246 environmental change shift the agenda for sustainable development in the world?

## 247 **Challenge #4: Determine what institutional and behavioural changes can best** 248 **ensure global sustainability.**

### 249 **Priority Research Questions**

250 **4.1. What institutional structures are effective in balancing the trade-offs inherent in social-**  
251 **environmental systems at local, regional and global scales and how can they be achieved?**

252 **4.2. What changes in economic systems would contribute most to improving global**  
253 **sustainability and how could they be achieved?**

254 **4.3. What changes in behaviour or lifestyle, if adopted by a particular society, would contribute**  
255 **most to improving global sustainability and how could they be achieved?**

256 **4.4. How can institutional arrangements prioritize and direct resources to alleviate poverty and**  
257 **address social injustice under rapidly changing local environmental conditions and growing**  
258 **pressures on the global environment?**

259 **4.5. How can effective, legitimate, accountable and just collective environmental solutions be**  
260 **mobilized?**

261 Global change exposes gaps in social institutions, including governance and economic systems, for  
262 managing emerging global (and local) problems. The time and spatial scales of global change differ  
263 fundamentally from the types of problems that humanity has addressed in the past. Currently,  
264 decision-makers have incentives that favour local, short-term and private benefits, rather than long-  
265 term and collective benefits. Addressing the problems of global change, including resource use,  
266 pollution of the global commons and population growth, will require a step change in research  
267 addressing fundamental questions of governance, economic systems and behaviour.

268 Determining how to achieve such changes in social institutions and behaviour is just as important as  
269 establishing what changes are desirable. In many cases, successful changes in institutions will stem  
270 from steps taken to achieve collective social action in response to the challenge. How can timely  
271 action be undertaken at unprecedented geographical and geopolitical scales, where the nature and  
272 scale of the issues involved means that the actors have widely differing – and disconnected – values,  
273 ethics, emotions, spiritual beliefs, levels of trust, interests, and power? How can we better  
274 understand the role of individual decisions as the building block of societal decisions? How can we  
275 better understand the factors shaping individual behaviour, values and perceptions of threats and  
276 risks and how those values and perceptions influence both individual action in relation to global  
277 change and the potential for collective action? Recognizing individuals, not just policymakers, as a  
278 fundamental unit forces attention to a new level of detail on how information about the  
279 environment and feedback on thresholds being reached and breached can impact social changes and  
280 actions. Such information can influence individuals, who then incorporate this information along  
281 with other factors such as institutions or policies, to make decisions that then aggregate to impact  
282 society and the environment.

## 283 **Challenge #5: Develop and evaluate innovative technological and social** 284 **responses to achieve global sustainability.**

### 285 **Priority Research Questions**

286 **5.1. What incentives are needed to strengthen national systems for science and technology**  
287 **innovation to respond to global environmental change and what good models exist?**

288 **5.2. What incentives are needed to strengthen policy and institutional innovation to respond**  
289 **to global environmental change?**

290 **5.3. How can global energy security be provided entirely by sources that are renewable and**  
291 **that have neutral impacts on other aspects of global sustainability, and in what time**  
292 **frame?**

293 **5.4. How can food production be increased to meet anticipated needs over the next half**  
294 **century while dramatically reducing land-use greenhouse gas emissions, protecting**  
295 **biodiversity, and maintaining or enhancing ecosystem services?**

296 **5.5. What are the potentials and risks of technological strategies (e.g., geo-engineering) to**  
297 **address global environmental change, and what local to global institutional arrangements**  
298 **would be needed to oversee them, if implemented?**

299 Unprecedented challenges require novel, innovative responses. While many of these grand  
300 challenges address the need for solutions-oriented research, it is increasingly clear that the scale and  
301 potential impact of global environmental change may necessitate the consideration of entirely novel  
302 technologies, institutions and policies. Considerable work is underway to explore innovative  
303 approaches such as geo-engineering and green energy technologies. How can such innovation be  
304 responsibly intensified? How can risks associated with global environmental management be  
305 adequately assessed?



306 Three issues demand particular research attention in this regard. First, it is clear that fundamental  
307 changes are needed in our systems of energy production and use in order to avoid dangerous  
308 climate change. Research is needed to help identify and develop new systems for energy  
309 production and use and to assess the impacts of these systems on the environment and society.  
310 Second, at current rates of growth in agricultural yield it is highly unlikely that we can simultaneously  
311 meet the needs over the next half century for: a) increased food demand from growing (and  
312 wealthier) populations; b) reduced greenhouse gas emissions associated with land use change and  
313 agricultural production; c) increased production of biofuels; d) reduced rates of loss of biodiversity;  
314 and, e) enhanced ecosystem services. What are plausible scenarios for addressing this problem?  
315 What are the costs, benefits, and risks of different policy, technological or ecosystem-based  
316 management strategies that might be applied? Finally, although research is needed to explore the  
317 entire set of policy, institutional and behavioural changes that could mitigate climate change and  
318 enhance adaptation to climate change, increased attention should now be given to research to  
319 understand the costs, benefits, and risks of various geoengineering strategies and the institutional  
320 arrangements that would be needed to oversee such strategies if they were implemented.

## 321 **Expected Outcomes**

322 The primary product of the research that will be guided by this 10-year initiative is the knowledge  
323 base needed to manage global change and to cope with the change that cannot be managed. This  
324 knowledge base, and the process of developing it, should make a major contribution to efforts to  
325 reduce global poverty and improve global justice in ways that do not unduly exacerbating  
326 environmental stresses. This research will yield a set of more tangible products:

- 327 • Validated theories, models, scenarios, projections, simulations, or compelling narratives of  
328 social-environmental systems at global to local scales. (Challenge 1 and 2)
- 329 • Prioritized needs for Earth system observations of physical, chemical, biological and social  
330 variables and the design features of a system for delivering that information. (Challenge 2)
- 331 • A framework for forecasting the likelihood, location, drivers, severity and risk of high  
332 magnitude, abrupt or non-linear changes associated with global environmental change.  
333 (Challenge 3)
- 334 • Options for practices and institutions that allow effective action (or provide sufficient  
335 resilience) in response to signals of impending dangerous changes. (Challenge 3 and 4)
- 336 • Designs for institutions, procedures and practices that will serve to align disconnected  
337 interests, rebalance power asymmetries and facilitate collective action. (Challenge 4 and 5)
- 338 • Options for policies and practices that accelerate social and technological innovation  
339 relevant to the needs of managing global environmental change. (Challenge 5)
- 340 • Methods for exploring the costs, benefits and risks of alternative strategies to achieve global  
341 sustainability. (Challenge 5)
- 342 • New methods for doing research, in which stakeholders are empowered, informed and  
343 motivated through the research process to take effective action. (All Challenges)

## 344 **Next Steps**

345 This document is part of an agenda-setting consultation that is intended to guide and stimulate  
346 scientific research on global change and global sustainability over the next decade. As such, it is a  
347 'living document' that will be improved and revised as more stakeholders contribute to its content  
348 and confirm its basic premises. It is expected to become part of a broader process among scientists  
349 and scientific institutions to commit themselves to work together systematically – across disciplines  
350 and geographic regions – on agreed priority research questions that are critical to the sustainability  
351 of our planet for the future. The collaboration will likely be transformative for all involved, and one  
352 in which the goals are recognized as going far beyond science itself. As the process goes forward we  
353 invite contributions to this document to expand and improve it.

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## 356 **Definitions**

357 **Coupled social-environment system:** A system in which the social and biophysical subsystems are  
358 intertwined so that the system's condition and responses to external forcing are based on the  
359 synergy of the two subsystems.

360 **Earth system:** The unified set of physical, chemical, biological, and social components, processes  
361 and interactions that together determine the state and dynamics of the Earth, including its biota  
362 and its human occupants.

363 **Ecosystem services:** The benefits people obtain from ecosystems. These include provisioning  
364 services such as food and water; regulating services such as flood and disease control; cultural  
365 services such as spiritual, recreational, and cultural benefits; and supporting services such as  
366 nutrient cycling that maintain the conditions for life on Earth.

367 **Global change:** Changes in biophysical environment caused naturally or caused (or strongly  
368 influenced) by human activities and the associated changes in society, institutions and human  
369 well-being. These may either manifest at the global scale or be occurring on a local scale but so  
370 widespread as to be a global phenomenon.

371 **Global environmental change:** Changes in biophysical environment caused naturally or caused (or  
372 strongly influenced) by human activities. These may either manifest at the global scale (e.g.  
373 increasing atmospheric CO<sub>2</sub>) or be occurring on a local scale but so widespread as to be a global  
374 phenomenon (e.g. soil degradation).

375 **Human well-being:** A context- and situation-dependent state, comprising basic material for a good  
376 life, freedom and choice, health and bodily well-being, good social relations, security, peace of  
377 mind, and spiritual experience.

378 **Resilience:** The level of disturbance that an ecosystem can undergo without crossing a threshold to a  
379 situation with different structure or outputs. Resilience depends on ecological dynamics as well  
380 as the organizational and institutional capacity to understand, manage, and respond to these  
381 dynamics.