

Geoscience Engagement in Global Development Frameworks

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Abstract

During 2015, the international community agreed three socio-environmental global development frameworks, the: (i) Sustainable Development Goals, (ii) Sendai Framework for Disaster Risk Reduction, and (iii) Paris Agreement on Climate Change. Each corresponds to important interactions between environmental processes and society. Here we synthesize the role of geoscientists in the delivery of each framework, and explore the meaning of and justification for increased geoscience engagement (active participation). We first demonstrate that geoscience is fundamental to successfully achieving the objectives of each framework. We characterize four types of geoscience engagement (framework design, promotion, implementation, and monitoring and evaluation), with examples within the scope of the geoscience community. In the context of this characterization, we discuss: (i) our ethical responsibility to engage with these frameworks, noting the emphasis on societal cooperation within the Cape Town Statement on Geoethics; and (ii) the need for increased and higher quality engagement, including an improved understanding of the science-policy-practice interface. Facilitating increased engagement is necessary if we are to maximize geoscience's positive impact on global development.

1. INTRODUCTION

The agreement of three global development frameworks in 2015 reflects 'a global consensus that business as usual is no option any longer, that changing the development trajectory is necessary' (Spangenberg, 2016, p.1). The UN Sustainable Development Goals (SDGs), Sendai Framework for Disaster Risk Reduction (SFDRR) and COP21 Paris Climate Change Agreement (Paris Agreement) will be at the forefront of national and international policy discourse for the next 15 years. Collectively they aim to shape the strategies that guide economic growth, human welfare, access

to natural resources, and environmental management. Each of the SDGs, SFDRR, and Paris Agreement relates to the interaction of human activities with the natural environment. Advances in science and technology, including geoscience, are central to each framework (e.g., Lubchenco et al., 2015; Aitsi-Selmi et al., 2016; Boucher et al., 2016; Gluckman, 2016; Gill, 2017). For example, managing natural resources, characterizing natural hazards, or modelling future climate all require multi-scale (spatial and temporal) understanding of Earth materials and/or processes. This requirement for geoscience input presents an opportunity for the geoscience community. It also places

upon us a social responsibility to engage, which we define to mean *'actively participating in framework design, promotion, implementation, monitoring and evaluation'*. Scientific business as usual, however, will not be sufficient, with changes to geoscience practice required for successful engagement (Lubchenco et al., 2015).

In this paper, we describe each global development framework and opportunities for geoscientists to help deliver their objectives (Sections 2-4). We then discuss engagement by geoscientists, reflecting upon types of engagement, our ethical responsibility to engage, catalyzing increased engagement, and characterizing effective engagement (Section 5).

2. SUSTAINABLE DEVELOPMENT GOALS

In September 2015, member states of the United Nations formally adopted the Sustainable Development Goals (SDGs), an ambitious set of 17 goals and 169 targets (UN, 2015a). The SDGs aim to eradicate global poverty, end unsustainable consumption patterns, and facilitate sustained and inclusive economic growth, social development, and environmental protection over a 15-year period, 2015-2030 (UN, 2015a).

The SDGs have been described as *'science intensive'* (Gluckman, 2016), with their environmental focus meaning geoscience is essential to their success (Lubchenco et al., 2015). Gill (2017) produced a matrix, which illustrates the role of geoscience in the SDGs (Fig. 1). The matrix was populated by analyzing the text of the specific SDG sub-goals and targets, identifying links between SDG requirements and geoscience. Interconnections between many SDGs (Nilsson et al., 2016) results in this approach giving a conservative estimate of the true impact of geoscience interventions. For example, goals on education (SDG 4) and gender equality (SDG 5) do not specifically refer to access to water/sanitation (SDG 6), but increased access to water/sanitation can support both. Fig. 1 shows a role for geoscience within all 17 of the SDGs. Contributions will be required from all sectors and sub-disciplines of geoscience, in-

cluding those working in research, industry, the public sector and civil society.

Examples of geoscience activities helping to deliver the SDGs include research projects, industry engagement, and civil society activities. We provide specific examples in Section 5.

3. SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION (SFDRR) 2015-30

The SFDRR was adopted at the 3rd UN World Conference on DRR in March 2015, supported by the UN Office for Disaster Risk Reduction (UNISDR). Through its implementation, the SFDRR aims to reduce substantially disaster risk and losses in all forms (UNISDR, 2015).

The SFDRR includes four Priorities for Action (PfA), with a 2016 UNISDR conference demonstrating the scope for science and technology in delivering each (Aitsi-Selmi et al., 2016). We introduce each PfA in Table 1, with a description of geo-sciences' role and examples of engagement. Underpinning the four PfA of the SFDRR are 13 guiding principles, many of which require geoscience input. For example, one guiding principle requests that decision-making use a *'multi-hazard approach'*. UNISDR (2017) defines multi-hazard as considering interrelationships between natural hazards, including hazardous events occurring simultaneously, in cascades, or cumulatively over time. Geoscientists have experience in contributing to the understanding and communication of multi-hazard dynamics. For example, following the 2015 M7.8 earthquake in Nepal, the British Geological Survey compiled inventories of triggered landslides (BGS, 2017a).

Inventories, and associated maps, demonstrate where landslides block rivers (potentially triggering floods), and can be used by organizations responding to disasters. Other guiding principles can inform change within the geoscience community, helping to improve engagement in the SFDRR. For example, research collaborations should reflect on the principle *'international cooperation to be effective, meaningful and strong'*.

Group Definitions		Geological Sciences										Notes	
Sustainable Development Goals (SDGs)	Earth Materials, Processes & Management	Agrogeology	Climate Change	Energy	Engineering Geology	Geohazards	Geoheritage & Geotourism	Hydrogeology & Contaminant Geology	Minerals & Rock Materials	Education*	Capacity Building*	Miscellaneous	
	Skills & Practice	Agrogeology	Climate Change	Energy	Engineering Geology	Geohazards	Geoheritage & Geotourism	Hydrogeology & Contaminant Geology	Minerals & Rock Materials	Education*	Capacity Building*	Miscellaneous	
1	No Poverty	End poverty in all its forms everywhere.											
2	No Hunger	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.											
3	Good Health	Ensure healthy lives and promote well-being for all at all ages.											
4	Quality Education	Ensure inclusive and equitable quality education and promote life-long learning opportunities for all.											
5	Gender Equality	Achieve gender equality and empower all women and girls.										[a]	
6	Clean Water & Sanitation	Ensure availability and sustainable management of water and sanitation for all.											
7	Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all.											
8	Good Jobs & Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.											
9	Innovation & Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.											
10	Reduced Inequalities	Reduce inequality within and among countries.											
11	Sustainable Cities & Communities	Make cities and human settlements inclusive, safe, resilient and sustainable.											
12	Responsible Consumption	Ensure sustainable consumption and production patterns.											
13	Protect the Planet	Take urgent action to combat climate change and its impacts.											
14	Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.											
15	Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems...*											
16	Peace & Justice	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.											
17	Partnerships for the Goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development.											

Figure 1: A matrix highlighting the role of geoscientists in helping to achieve the SDGs (Gill, 2017).

Table 1: *Geoscience and the Sendai Framework for Disaster Risk Reduction.*

Priority for Action (PfA)¹	Description and Use of Geoscience	Example Output
1. Understanding disaster risk	Research on earthquakes, volcanic eruptions, tsunamis, landslides, subsidence, and other hazards addresses this priority. PfA-1 also requests comprehensive surveys of multi-hazard disaster risk, regional assessments and maps, and enhanced access to and support for long-term multi-hazard research.	An interrelated hazards approach to anticipating evolving risk (Duncan et al., 2016).
2. Strengthening disaster risk governance to manage disaster risk	Geoscience information informs laws, regulations and policy tools. For example, understanding ground conditions is a necessary input to building codes. PfA-2 also emphasizes the development of strategies to strengthen environmental resilience, environmental and resource management standards, and policies to prevent settlement in disaster-risk prone zones.	Earthquake science in DRR policy and practice in Nepal (Oven et al., 2016).
3. Investing in disaster risk reduction for resilience	Resilience is enhanced through investment in both structural and non-structural measures. For example, retrofitting critical infrastructure to the effects of earthquakes (structural), and ensuring coherence of DRR and urban development strategies (non-structural). PfA-3 seeks to mainstream disaster risk assessment into land-use policy development and implementation. It also encourages cooperation between scientific networks and the private sector to develop new products/services to reduce risk.	Setting, measuring and monitoring targets for reducing disaster risk (Mitchell et al., 2014), with comment on insurance and catastrophe modelling.
4. Enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation, and reconstruction	PfA-4 requests development and maintenance of people-centered multi-hazard, multisectoral forecasting, early warning systems, and hazard-monitoring communications. Geoscience information will need integrating with appropriate knowledge in communications, development, and psychology. PfA-4 also encourages preparedness, response and recovery exercises, and sharing of resources.	Using video games for volcanic hazard education and communication (Mani et al., 2016).

¹ See UNISDR (2015) for full description, and lists of local/national and regional/global objectives.

4. PARIS CLIMATE CHANGE AGREEMENT

Geoscience has significantly contributed to our understanding of anthropogenic climate change. For example, evidence of climate change in the geological record forms an important, independent evidence base for anthropogenic climate change (GSL, 2010). The Paris Agreement, published at the end of the 21st Conference of the Parties (COP21) in De-

cember 2015, secured a legislative agreement with a long-term goal to limit climate change to well below 2°C above pre-industrial averages (UN, 2015b). At the time of writing 132 parties ratified this agreement. The Paris Agreement consists of an opening statement and 29 'Articles' which detail the component parts of the agreement. Many Articles refer to requirements for which geoscience expertise and capacity are essential, as described in Table 2.

Table 2: *Geoscience and COP21: The role of geoscience in delivering the agreement.*

Relevant Articles (UN, 2015b)	Contribution of geoscience to article	Example Output
Article 2.1(a): <i>'Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.'</i>	Exploring for and extracting fossil fuels with a lower carbon impact; researching and implementing Carbon Capture and Storage (CCS); investigating geothermal energy sources; and working to develop geological disposal for radioactive waste from nuclear power stations.	Geological Disposal of Depleted, Natural and Low Enriched Uranium (RWM, 2016)
Article 2.1(b): <i>'Increasing the ability to adapt to the adverse impacts of climate change and foster resilience...in a manner that does not threaten food production.'</i>	For secure food production, geoscience is essential to (i) the mapping and understanding of groundwater resources to maintain water security for agriculture, (ii) mineral extraction for fertilizer, and (iii) mapping of soil quality.	Soil type influences crop mineral composition in Malawi (Joy et al., 2015)
Article 4.1: <i>'... reach global peaking of greenhouse gas emissions as soon as possible... undertake rapid reductions thereafter in accordance with best available science... achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases...'</i>	Globally we need to reduce greenhouse gas emissions to a point where there is a sustainable balance between gas emission and sequestration. This can be through both natural carbon sinks and CCS implementation. Locating suitable reservoirs and characterizing these for CO ₂ sequestration over large timescales will require geoscience expertise in stages of design, testing, and implementation.	CO ₂ sequestration and storage capacity at Sleipner in the North Sea (BGS, 2017b).
Article 7.1: <i>'Parties hereby establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response...'</i>	Geoscientists support research into climate-linked hazards (e.g., flooding, landslides, drought). Engineering, hydro- and structural geology are essential for effective siting of infrastructure and homes. Long-term monitoring data (e.g., slope movement) can be used to inform new development. Geologists' understanding of climate change in the deep past, and its impact on environments can inform mitigation and resilience strategies.	Resilience assessment for geotechnical infrastructure assets (Shah et al., 2014)
Article 10: <i>'Parties share a long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions.'</i>	The technical capacity required to realize the ambitions of the Paris Agreement will come, in part, from geoscientists. Cooperation is needed over areas such as technology transfer and knowledge exchange. Sharing of appropriate disciplinary knowledge across political and geographic borders will support the implementation of the Paris Agreement.	Collaborative geoscience research, such as that funded by the UK Government's Global Challenges Research Fund.

5. DISCUSSION

In Sections 2-4, we describe geoscientists' role in the SDGs, SFDRR and Paris Agreement, noting the significant scope for geoscientists to engage in all three. Engagement can take many forms, as noted in Table 3. Here we outline four types of engagement, with examples of actual/potential activities associated with each. The examples in Table 3 are illustrative, rather than exhaustive, and intended to promote discussion. In the remainder of this section, we consider this diversity of engagement in the context of (i) our ethical responsibility to engage, (ii) catalyzing increased engagement, and (iii) ensuring effective engagement for maximum development impact.

5.1 Ethical Responsibility to Engage

The geoscience community have a professional and social responsibility to reflect on the engagement required to help deliver these frameworks. There is a professional responsibility as the geoscience sector must be equipped and ready to respond to the demands placed on us by government and industry. There is a social responsibility, as our failure to engage, or engage well, can limit what is achieved or reduce sustainability. Poor quality engagement (e.g., a weak understanding of the social context of a project, or limited dialogue with stakeholders) may detrimentally impact a project (Gill, 2016). We discuss this in Section 5.3.

The Cape Town Statement on Geoethics (Di Capua et al., 2016) includes a set of geoethical values that help to frame our responsibility to engage in global development frameworks. For example, it encourages sharing knowledge and a spirit of cooperation, and promotes geo-education and outreach to further sustainable development. The broad range of organizations supporting the Cape Town Statement (e.g., American Geophysical Union, European Federation of Geologists, African Association of Women in Geosciences) is indicative of the widespread international support for an out-

ward looking geoscience community.

5.2 Catalyzing Increased Engagement

Throughout this contribution, we have included examples of activities, projects, and publications that demonstrate existing engagement by the geoscience community in global development. There is scope, however, for this to expand (Lubchenco et al., 2015; Stewart and Gill, 2017), as illustrated by one example. Consider the engagement labelled 'Framework Promotion' in Tab. 3. The 2017 European Geosciences Union (EGU) General Assembly included 1059 scientific sessions and side events (EGU, 2017). In the session descriptions, only nine (0.85%) of these 1059 sessions referred to the Sustainable Development Goals, five (0.47%) to the Sendai Framework, and five (0.47%) to the Paris Agreement or COP 21. The remaining 1040 (>98%) sessions did not refer to any of the global frameworks, despite many being on pertinent topics. The proactive promotion of development frameworks, including in settings such as the EGU General Assembly, would help improve awareness and foster greater engagement. It would also demonstrate the role of geoscience to other disciplines and the broader policy-making community. Improved awareness could catalyze other types of engagement. For example, helping to shape new research questions, or improving research dissemination to policy makers.

5.3 Effective Engagement

Engagement must be effective, culturally appropriate, and sustainable. As previously noted, poor quality engagement can hinder development progress and does not serve society well. The Cape Town Statement on Geoethics (Di Capua et al., 2016) presents a helpful articulation of the necessary values if the geoscience sector is to make a full and positive contribution to the delivery of global development frameworks (e.g., honesty, integrity, competence, commitment to life-long-learning).

Table 3: *Types and Examples of Engagement.*

Type of Engagement	Example of Engagement		
	SFDRR	SDGs	Paris Agreement
A. Framework Design: Informing the process that determines what is included, defining key terms, determining indicators of success.	Submission (individual or institutional) to UNISDR Expert Working Group on Indicators and Terminology.	Early-career scientists engaging with the UN Major Group for Children and Youth submission to SDG negotiations.	Research contributions to IPCC assessment reports (IPCC, 2013).
B. Framework Promotion: Ensuring that members of the geoscience community are aware of the framework, and potential geoscience inputs.	Panel discussion on <i>'Geohazards: From Sendai to the SDGs'</i> at a GfGD Conference.	SDGs workshop at the European Geosciences Union General Assembly.	Joint Learned Societies' <i>'Climate Communiqué'</i> (GSL, 2015).
C. Framework Implementation: Research, outreach, and industry activities to support the successful delivery of the framework.	Research: Triggered landslides after the 2015 M7.8 earthquake in Nepal (BGS, 2017a).	Research: <i>'Unlocking the Potential of Groundwater for the Poor'</i> (UPGro, 2017).	Research: Carbon capture and storage (NERC, 2017).
	Practice: Developing tools to support earthquake education (Parsquake, 2017).	Practice: Construction of sustainable water points (e.g., boreholes) and sanitation facilities.	Research: Groundwater resilience to climate change in Africa (MacDonald et al., 2011).
D. Framework Monitoring and Evaluation: Assessing the efficacy of interventions to support implementation.	Evaluation of landslide education to assess its impact on perceptions of landslide triggering.	Data collection on access to geoscience training, monitoring progress on SDG 5 (gender equality).	Long-term monitoring of ocean acidification (IOCCP, 2017).

Professional and learned societies, such as the Geological Society of London (see www.geolsoc.org.uk), also play an important role in ensuring effective engagement through their focus on professionalism. Chartership and the emphasis on Continued Professional Development, encourages the geoscience workforce to reflect on the skills and experiences required to serve society.

Effective engagement is also rooted in understanding the science-policy-practice interface. This includes, for example, determining the information needs of stakeholders (e.g., policy makers, community groups, development NGOs), how they will use this information,

and how best to present it to support policy-makers. Translating geoscience knowledge into tools to support policy and practice requires dialogue and partnerships between geoscientists and other stakeholders (Lubchenco et al., 2015). Engaging diverse stakeholders early in the research-process helps to ensure a shared perception of the problem, defines data needs, and ultimately results in the production of useful knowledge (Weichselgartner and Kasperson, 2010).

Increased dialogue, critical to our contributions being relevant, may also require the geoscience community to invest in additional and complementary skills (Gill, 2016). The geoscience

community readily embraces advances in technology, informatics, and other physical sciences to advance their science. In contrast, whereas cultural and ethical understanding, cross-disciplinary communication, and social science research approaches can also support effective engagement and enhance our science, they are rarely included in a geoscientist's education (Stewart and Gill, 2017). To engage with policy-makers, for example, we should enhance our socio-political understanding (e.g., how government works), and recognize the complexity of policy-making and the role of science as one form of evidence in this process (Boyd, 2016; Gluckman, 2016).

Dissemination approaches may also need to change if geoscience engagement is to be most effective. Geoscientists are well trained in the skills required to collect, analyze and publish data in scientific journals, and present information at (geo)scientific conferences. These are important opportunities to communicate with other scientists, but may not be the most appropriate medium for communicating with other stakeholders (Marker, 2016). Priority for Action 1 of the SFDRR, for example, includes an objective 'promote the collection, analysis, management and use of relevant data and practical information and ensure its dissemination, taking into account the needs of different categories of users, as appropriate' (UNISDR, 2015). To realize this objective, we should embrace forms of communication other than the scientific journal, and be proactive at presenting information across disciplinary silos.

6. CONCLUSIONS

In this article, we have highlighted the role of geoscientists in three development frameworks, designed to address global priorities of sustainable development (SDGs), disaster risk reduction (SFDRR), and climate change (Paris Agreement). These frameworks offer the geoscience community an exciting opportunity for innovative research and application of our science. The successful implementation of these frameworks through 2015-30 will require in-

creased engagement from the geoscience community. This engagement can take many forms, and we include in this contribution examples that demonstrate this broad scope. Common across all engagement is the need for it to be of the highest quality, embracing the values and skills required to work at the science-policy-practice interface. A geoscience community that invests in the skills and understanding that are required for effective engagement is well-positioned to help deliver a sustainable future.

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