CHAPTER 3

Exploring Societal Intersections of Geoethical Thinking

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Abstract This chapter explores geoethical thinking as a means for offering alternative modes of living in a world where humans and natural systems are inextricably linked. Real-world examples demonstrate the societal relevance of geoethics. Four essays illustrate different aspects and specific contexts. The first explores the societal significance of geoscience as a 'stewardship-science' and elicits the often hidden influence of geoscience in contemporary societies. The second describes an adaptive and collaborative governance approach affording more sustainable futures for small-scale fisheries. This approach combines universal values with contextual practices to inform geoethics-inspired governance approaches. The third argues that more rigorous engagement with citizen science

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would demonstrate the societal relevance of geoethics. The final essay explores how 'society–Earth-centric' narratives can help citizens better understand their (inter)actions within the Earth system.

Keywords Geoethics · Earth system · Stewardship · Planetary human niche · Citizens' narratives

Global shifts are occurring in interconnected social, technological and environmental systems at such a scale and rate of change as to reshape the context in which decision-making and sustainable development interventions are taking place. In the face of global pressures on the environment and societies, like climate change, governments and other actors are increasingly dependent on reliable foresight capabilities to help them plan and test for potential future climate conditions and their interactions with other (economic, political, socio-cultural) uncertainties (Vervoort and Gupta 2018). Seeking to guide action for the unknown and unknowable future trajectories of changes to the Earth system is fraught with normative and scientific uncertainties and governance challenges. Now, more than ever before in the history of human niche-making endeavours, the drivers of global Earth system changes are linked to the unintended and non-linear effects of the cross-scale impacts of human actions (Ellis 2015; Steffen et al. 2015; Turner et al. 2016).

The central challenge of this interlinked condition of social and natural systems lies in the recognition that humans are dependent on natural systems for sustaining their lifestyles and livelihoods. At the same time this dependency is changing natural systems and resources in profound ways, resulting in unpredictable effects on natural systems, lifestyles and livelihoods (Fischer et al. 2015; Homer-Dixon et al. 2015). One of the most critical challenges facing people navigating this interdependency is examining and governing the trade-offs that inherently characterise land-use and sea-based activities to produce food, and the associated demands on water, energy and the environment (Kramer et al. 2017; Cashion et al. 2018).

Affluent human development is associated with processes of rapid global change. Many of the world's cities and regions now stand on the brink of making significant infrastructure investments (Elmqvist et al. 2018). The next few decades are likely to see a remarkable increase in global infrastructure investment, which will have profound impacts on the geosphere. The unpredictability of the effects of the decisions made, and trade-offs chosen, is of course linked to the fact that we now know that human actors are an integral part of the biophysical world (Schoon and Van der Leeuw 2015). The subsequent physical changes that we can observe in the geosphere are a direct result of the normative and value-driven decisions that influence land/sea-use changes and niche-making practices.

The aims and values proposed as constituting geoethical thinking in this book imply that addressing this challenge requires integrated governance approaches that account for the multiple interlinkages and dependencies that characterise coupled socio-ecological systems (Walker et al. 2006; Galaz et al. 2012; Biggs et al. 2015). Recognising that the interlinked dynamics of environmental and societal change can be better understood as being complex adaptive systems (Preiser et al. 2018; Liu et al. 2007) empowers geoscientists, other professionals and societal actors with conceptual frameworks and practical methods to study and navigate these dynamics more effectively (Audouin et al. 2013).

Developing normative guidelines for navigating uncertainties and non-linear dynamics requires conceptual innovation and integration across disciplinary boundaries. As Schmidt et al. (2016, p. 2) argue, traditional ethical frameworks that seek to generate 'universal maxims for right action (deontology) or those that make calculations of human welfare (consequentialism) mistakenly apply old normative categories in a new era that demands new conceptual foundations'.

In its aim to amalgamate views from various inquiries into geoscience research, professional best-practice guidelines and the imperative for societal engagement, this chapter offers examples of how conceptual innovation can be stimulated. Explicitly considered are: (1) the broader societal implications and relevance of the geosciences; (2) examples of policy innovation in processes that guide human niche-building practices; (3) promoting processes of participatory knowledge co-creation and sharing; and (4) developing society–Earth-centred narratives. This chapter comprises four essays that illustrate the possible ways to integrate normative strategies spanning a diverse set of knowledge and experiential domains. Crafting novel futures together in a world defined by complexity, diversity and uncertainty calls for creative, collaborative and experimental tools and methods that create spaces for transformative understanding and action (Pereira et al. 2018).

As such, the first two essays show how contemporary societies apply geoscience expertise, and hence depend on geosciences for their general functioning and governance of socio-ecological systems. The third essay describes why geoethical thinking and participatory research processes align. The fourth essay offers a framework for society–Earth-centric narratives, for fostering sense-making capacities drawn from geoscience expertise. Together these four essays demonstrate the societal relevance of geoethical thinking and the implications of geoethics in a broader context that extends beyond the habitual reach of geoscience professions.

By highlighting what kind of policy innovations are needed to guide, for example, small-scale fisheries in developing economies, we demonstrate that geoethical conceptual innovation should provide guidelines for navigating the uncertainty of human-induced change, the impacts of technological development and the effects of climate disruption. In response to these challenges, geoethical practices should foster context-specific governance strategies that are adaptive and collaborative to build resilient governance capacities. To enhance social resilience, for example, management policies that promote the actions of ecological stewardship groups should foster more collaborative people–place connections to build social capital based on knowledge sharing and learning. This goal suggests developing new, more engaged governance forms, like co-management, with a diverse set of multi-sectoral stakeholders.

Referring to issues that were outlined above, agent-centric governance approaches are to be favoured where human agency is considered to be accountable and responsible for its actions. Such governance approaches foster participatory knowledge co-creation between multiple stakeholders by encouraging dialogue between geoscience experts and citizens to develop capacities across various science–policy and societal interfaces. By aiming at conceptual innovation and normative resilience, geoethical thinking needs to critically reflect on the values that underpin the behaviour and practices that inform cultural and societal institutions. Geoethical thinking has the potential to co-shape cultural values by facilitating society-Earth-centric narratives that are essential sense-making tools for catalysing networks as well as collaborative and responsible action (Ingram et al. 2015; Lövbrand et al. 2015). Cultivating an understanding of what kind of norms and practices could inform responsible action is of course a crucial challenge for any ethical framework, especially if these actions are to inform context-dependent governance strategies. Developing new social norms (as geoethics is endeavouring to do, as presented in this book) goes hand in hand with the generation of knowledge and various platforms for communicating and disseminating new insights. Stimulating and fostering new narrative strategies as a form of knowledge sharing and sense-making, geoscientists, practitioners and community members may establish situational awareness and understanding of the conditions in which governance responses and geoethical considerations are to be realised. As a means of orienting oneself in domains of uncertainty and complexity, sense-making offers some practical reflections that enable the integration of diverse knowledge and experiences to inform more effective action and interventions.

The four essays relate to one another, yet each of them can be read on its own. The presentation is brief and simplified to align with the conceptual suggestion made here and the purpose of this publication. These concepts could be developed in more detail in the future, as such an exposition is beyond the scope of this book.

3.1 First Essay: Knowledge Base—Geosciences as a Stewardship Science

This essay illustrates the all-embracing use of geosciences in contemporary societies, be it for their economic activities or for setting values in social, cultural and individual contexts. Stated simply, understanding the features of rock, soil, water and air is essential to producing many goods. Artisans, technicians, architects and engineers apply geoscience expertise when altering environments or creating objects. Likewise, affection for the landscape, sea or minerals is part of a person's identity and influences their perception and attitudes towards the world (Peppoloni and Di Capua 2012). Here and in the following, the term geosphere shall name collectively the abiotic parts of the natural Earth system, consisting of the lithosphere, atmosphere, hydrosphere and cryosphere. In juxtaposition, the term biosphere shall be used to name the biotic parts of the Earth system collectively.

To capture the scale of how geoscience knowledge is used in contemporary societies, the meaning of the notion 'engineering' must be detailed. This essay will use the English word 'engineering' in the sense that it has, for example, in French or German languages. These languages refer to 'engineering' as '*génie civil*' (French for '*civil genius*' or '*Ingenieurskunst*' (German for 'art of engineering'), respectively. The rather restricted meaning of the English term 'engineering' does not capture the richer interpretation and connotations that the French or German languages allow, which communicate a more substantial meaning, namely the design and operation of purposely built and often larger scale environments of artefacts like human dwellings, production systems and consumption patterns. This re-framed interpretation of what 'engineering' means is essential to understanding the central position held by geosciences in the knowledge base of contemporary societies.

3.1.1 Intersections with the Geosphere, an Illustration

The phenomena that describe the intersections of human activity and the geosphere are pervasive. However, they may go unnoticed by many because they are implicitly present in the conceptual and practical structures of people's meaning-making. Hence, they constitute part of the cognitive frameworks that form people's practical knowledge, general education or specific vocational training. As such, insights into human–geosphere interactions may not be recognised because they are an integral part of our tacit cognitive understanding, interactions or experiences of the world.

Examination of the purpose and function of human engineering endeavours shows that they aim to design processes and mechanisms that give people access to resources to produce commodities, goods or services, such as transport, energy, dwellings, food or waste treatment. To achieve their purpose, engineering efforts must couple economic activities with processes in the geosphere. Hence, the overarching function of many engineering endeavours is to connect human activities with the geosphere. There are many specific examples (Viollet 2000; George 2000). Civil engineering works lead to visible interconnections between human spheres and the geosphere, for example, dredging a waterway, building a bridge or constructing a hydroelectric power plant. Other engineering works lead to subtler geomorphological changes to landscapes (Brown et al. 2017; Tarolli et al. 2018). Less visible intersections are the fluxes of matter, energy and information, which are embedded in the design of production systems and consumption patterns that couple human activity and the geosphere.

Vast aggregations of engineering exertions, like urban built spaces, constitute both a visible intersection with the biogeosphere and an invisible coupling through exchanges of matter and energy. These fluxes are massive. For example, cities receive drinking water and discharge wastewater, receive electrical power and fuels and emit heat, receive food and produce manufactured goods. At the end of their lifecycles these goods are discarded or recycled, either locally or elsewhere across the globe.

The accumulated impact of engineering of systems of production and consumption (Ellis 2011; Schwägerl 2014; Waters et al. 2016), which are harnessed to sustain a human population of currently 7 billion people, might be called 'terra-engineering'; see Chung et al. (2010) for 'terra-forming' that describes a hypothetical alteration of other planets to meet human needs. The successful engineering of Earth can only be made possible through concerted efforts to use geoscience expertise competently and responsibly. In this spirit, any engineering of solar radiation (an instance of what is habitually called geoengineering or climate engineering) is a deliberate use of geoscience expertise at the planetary scale, with a dedicated engineering purpose (Morton 2015). This kind of engineering at the planetary scale is not new, even though it was not described as such in the past. The Haber–Bosch process for the industrial fixing of nitrogen, supporting the modern agricultural industry, is one such example. Since the beginning of the twentieth century the global nitrogen cycle has been deeply altered (Zhang et al. 2015; Ren et al. 2017). The planetary change to the nitrogen cycle can be taken as a classic example of industrial 'terra-engineering/geoengineering'.

Besides physical interactions, the intersection of engineering systems and the geosphere is constituted as a societal process (Di Baldassare et al. 2015). How storm surges in the harbour of Hamburg have changed may serve as an example (von Storch et al. 2015). In recent years the River Elbe, downstream from Hamburg, was dredged so that bigger ships could reach the Port of Hamburg. The harbour is situated about 100 km upstream of the mouth of the Elbe estuary. After dredging, storm surges flowed more effectively through the deeper river channel and the flood risks in Hamburg increased. In response, river dykes in Hamburg had to be raised. During the decision-making process about how the hydraulics of the river might be altered, the possibility of relocating the harbour (or part of it) to the mouth of the estuary to keep the river channel unchanged was not a politically viable option. However, during the same period, construction of a new harbour on the German North Sea coast was undertaken: the 'Jade-Weser-Port' 150 km west of Hamburg (Weber 2005). Operating the Port of Hamburg at its current location and dredging the Elbe River was the best strategy for maintaining existing production patterns and also for maintaining Hamburg's political and cultural standing as a 'first class' international port. Surprisingly, given the expected long-term sea-level rise due to climate change (Slangen et al. 2016), a gamble is currently being taken; namely, whether the Port of Hamburg will be safe, whether the line of dykes can be kept and whether the 'Jade-Weser-Port' will be flooded.

3.1.2 Niche-Building and Stewardship

Generalising the reflections made so far in this essay, when considering socio-ecological systems on the planetary scale, the concepts 'human niche-building' (Ellis et al. 2013; Steffen et al. 2011; Ellis 2015; Fuentes 2016) and the 'Anthropocene' come to mind (Steffen et al. 2016; Zalasiewicz et al. 2017). The notion of the 'human niche' stems from ecological research and describes the processes and practices that people employ to make the biological environment fit for supporting human well-being. The notion 'Anthropocene' indicates that human niche-building goes well beyond shaping only biological environments.

Regarding the notion of the 'Anthropocene', it was initially coined by natural science research communities. Scholars in the social sciences and humanities have subsequently questioned it because it conceals responsible actors and historical contexts (Sayre 2012; Palsson et al. 2013; Haraway 2015; Lövbrand et al. 2015; Autin 2016; Rosol et al. 2017; Olsson et al. 2017). A comprehensive introduction to the current global changes and related societal impacts constituting the Anthropocene can be found in the book by Frank Biermann (2014, pp. 2–8). Notwithstanding scholarly debates, the term 'Anthropocene' seems a suitable shorthand for our times (Clark and Gunaratnam 2017; Walton and Shaw 2015; Veland and Lynch 2016; Lorimer 2017) because 'the genie is out of the bottle' (Lorimer 2017, p. 123).

An illustration of both notions (human niche and Anthropocene) can be giving by the damming of rivers. On one side, the design of a dam for a hydroelectric power plant relies on adherence to safety rules and the laws of hydrodynamics. On another side, the retention of water in the lake behind the dam depends, among other things, on the hydrological regime of its catchment area, the intended use of water downstream of the dam (e.g., for irrigation and shipping) and the societal needs for electrical power (Linton and Budds 2014). Hence, the design and operation of the dam in regular and extreme situations are done to appropriate resources for human use. To that end, the design decisions and rules of operation for dams in a river basin lead to value-driven societal choices that assess opportunities and risks (Sternberg 2008), often extending beyond single national constituencies. Only to a first approximation do dams only impact river hydrology (Sivapalan et al. 2012; Sivapalan 2015). Damming of rivers, for example, may result in the retreat of deltas (Syvitski et al. 2009). The Aswan Dam provides one well-studied example (Donia 2013; Abd-El Monsef et al. 2015; Sutcliffe et al. 2016). So far, a global consequence of damming many rivers is a relative, anthropogenically driven decrease in mean sea level of about 3cm (Fiedler and Conrad 2010; Slangen et al. 2016; Dangendorf et al. 2017).

Illustrating the Extent of Geosciences

The following list of geoscience disciplines, albeit eclectic and incomplete, offers an initial sense of the different disciplines that are included by the overarching notion of 'geosciences': atmospheric sciences, biogeosciences, cryospheric sciences, engineering geology, geochemistry, geodesy, geography, geomorphology, geology, geophysics, glaciology, hydrological sciences, limnology, meteorology, mineralogy, ocean sciences, petrology, physical geography, soil system sciences, sedimentology, seismology, tectonics, volcanology and more. Each of these disciplines has its own societal application. Hence, it can be seen that geoscience expertise is used by people in their daily endeavours, at least implicitly.

Nowadays, to support affluence in industrialised societies, organising global supply chains is the primary driver shifting the dynamics of the Earth system (Heede 2014; Golden et al. 2017). The ongoing globalisation of supply chains sets the extent to which contemporary geosciences are relevant for both the functioning of production systems and consumption patterns and people's daily lives, spanning work and leisure activities. Here are some examples. Geosciences inform architectural plans and practices that shape urban spaces with regards to choices concerning the stability of foundations for buildings and their exposure to natural hazards. Geosciences enable global positioning systems to make reliable estimates, despite magnetic storms hitting Earth. Australia will adjust its geodetic datum due to the rapid drift (~7cm/year) of continental plate on that it is situated.[1] Finally, in an obvious manner, geosciences infiltrate our homes by means of television weather forecasts.

Geosciences for Engineered Structures and Culture

At times of anthropogenic global change, all geoscience disciplines have societal relevance, albeit to variable degrees. As already emphasised, geosciences are applied rigorously in the engineering of production systems

[1] http://www.ga.gov.au/scientific-topics/positioning-navigation/datum-modernisation.

and consumption patterns. This feature is at the root of the societal impact and scope of geosciences. However, the societal scope and relevance of geosciences are also witnessed in the history of natural sciences and the cultural perception of nature, including its non-living parts.

Simplified, some centuries ago, geosciences included two or three main fields of study, namely mineralogy, geology and physical geography. Regarding the latter two, one discipline referred broadly to matters below the subsurface and the other to anything else. Both disciplines were deeply related to the quest to discover the Earth and to explore and exploit natural resources. To illustrate this point, in 1855 the US Navy officer M. F. Maury published the first modern treaty in oceanography (about the Gulf Stream along the east coast of the United States) to facilitate coastal transport. The publication followed shortly after a first international meteorological conference in history, which had been convened 1853 in Brussels to standardise marine observations (Dirección de Hidrografía 1863). Very soon after, the French hydrologist P. A. Terquem translated Maury's book under the title *Géographie Physique de la Mer* and published it in the Librairie Militaire, Maritime et Polytechnique (Maury 1858). Thus it can be noticed that the societal scope and relevance of geosciences in the past and present are similar, namely to support 'human niche-building' through intersecting with the geosphere.

It is becoming increasingly evident that people have purposefully altered their environments since prehistoric times at local, regional and/or continental scales. Such human niche-building is a historical process that has accelerated greatly since the mid-twentieth century and now also includes coastal zones and open seas (Mee 2012; Ellis et al. 2013; Bonneuil and Fressoz 2013; Duarte 2014; Latour 2015; Catlin 2016; Chew and Sarabia 2016). Since then, the human population has tripled, the world has become much more urbanised[2] and the affluence of people living in the developed world has increased very rapidly (Zalasiewicz et al. 2015). Under such circumstances, maintaining the correct functioning of socio-ecological systems has become a 'wicked' task, resulting in additional challenges to governance structures and people's capacities for sense-making (Brown et al. 2014; Hämäläinen 2015; Pollitt 2016; Termeer et al. 2016; Bohle 2018). Under such circumstances,

[2] United Nations, 2014: http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html.

geosciences also gain societal relevance because of the cultural and emotional relations and narratives that they can offer people to help them understanding the environments in which they live (Kleinhans et al. 2010; Stewart and Nield 2013).

To illustrate this, the cultural and emotional relations of people with geosciences take different forms. In some cases, the phenomena that geoscientists study trigger people's affective relations. For example, people like the sea, the mountains or minerals, and subsequently they may value geosciences that relate to the objects of their affection. Another relation to geosciences may be established through cultural activities, for example, people may visit geoparks or may admire geoheritage. Similarly, people's relations with geosciences may be established through points of intellectual reference. People may favour scientific concepts, such as ecosystem services or global change, because they relate to their values or to the worldviews to which they adhere. People may even appropriate a philosophical view and conceptualise the Earth as being a living planet (Hazen 2012).

Moreover, people may assign ethical values to the notion of pristine nature or a historical landscape. People may also be concerned about the morality and actions of others (individuals or groups) or may search for ways to relate to nature through artistic practices. A wide range of artworks portray geoscience phenomena in various forms because they triggered the curiosity of artists (Pizzorusso 1996; Bohle 2015; Pizzorusso 2015).

People's cultural and emotional relations with geosciences may be something other than 'to like' or 'to favour' something. They can also be negative, denialist, etc., for example, in relation to climate change; or they may be motivated by fear, for example, because of the threat of natural hazards. Furthermore, relations can have a different quality or strength and they can be ambivalent or may follow affective connotations that escape semantic logic (Salvatore et al. 2018a). Although such cultural and emotional relations as sources of the relevance of geosciences are somewhat evasive, they represent what people perceive as reality. Hence, they shape people's identities, including their attitudes towards geosciences, and contribute to what people value and share as part of their worldviews. Therefore such cultural and emotional relations support the societal relevance of geosciences and are part of its scope (Moores 1997).

Finally, these cultural and emotional sources of geoscience relevance are very much dependent on interactions between people and their symbolic practices that, in turn, enable them to share and communicate established norms and worldviews (Salvatore et al. 2018b). Once aggregated, they shape decision-taking and societal action and hence, ultimately, the dynamics and functioning of socio-ecological systems. Hence, the societal roles and responsibilities of geoscientists include to nurture the cultural and emotional relations of people with the subjects of geosciences, for example, through fostering Earth science literacy (Wysession et al. 2012).

Daily Niche-Building

So far, this essay has offered some perspectives to support the argument as to why geoscience expertise is vital for the functioning of contemporary societies; and thus why it is a kind of embedded house-holding expertise for the functioning of socio-ecological systems. Initially, it might seem that these perspectives offer only an account of some visible phenomena and physical features. However, a closer look suggests a complex image comprising societal features and mental processes. Geoscience expertise seems to be, to use a figurative saying, somewhat 'hidden underground', that is, in the depths of societal processes and people's behaviour and thinking. This makes it all the more difficult for the citizen to be conscious of how much the human niche depends on geoscience knowledge.

Geosciences, geoscientists and their work do not usually belong overtly to the regular and daily experiences of citizens. Typically, geoscientists are 'hidden away in the engine room of society'. The lucky exception is the weather report that shows a geoscientist in action on the television screen. Even if it is a presenter who is reporting the news, at least some geoscience expertise is being utilised in direct application to daily life.

To elaborate, the 'weather' represents possibly one of the most evident geoscience phenomena that sits at the intersection of the geosphere and human activities. Weather is a topic of primordial interest for most people (Orlove 2003; Strauss 2003; Veland 2017). Consequently, it offers an exemplary narrative of the relevance of geoscience expertise (meteorology), how such expertise has evolved over the last two centuries and how (scientific) weather-forecasting practices have become embedded in the functioning of contemporary societies. Other geosciences are comparably embedded in societal functioning but have not (yet) reached similar regular public visibility as meteorology, other than in the case of disasters and natural hazards.

The weather has had a significant impact on people (Sirocko 2012), whether in connection to where they live and settle, their food, mobility, production or conflicts. Weather news went 'prime-time' during the early 1950s. Since then, regular broadcasting of weather forecasts has become common. Meteorologists inform the public daily about their work. Before that state of public broadcasting was achieved, the art of systematic weather observations was practised for several centuries, supported by the development of instruments, communication technologies and common observation protocols and organisations (Dirección de Hidrografía 1863). Weather reports for specialised professional audiences have been produced manually and published since the mid-nineteenth century with increasing regularity. Numerical weather forecasting became feasible since the early 1950s. From those early days, it took half a century to build our current web of weather product providers and consumers (Lynch 2008; Bauer et al. 2015). Modern media combine, in a single narrative, weather forecasts with additional information on meteorological phenomena and news about potential impacts on economic and social activities. The reliability and accuracy of these forecasts directly impinge on the work and life of people who are dependent upon reliable information and professional practice.

A similar narrative about the development of a specific geoscience discipline, consisting of systematic observations, development of instruments, communication technologies, protocols, organisations, specialised professional audiences, numerical forecasts, providers of products, consumers, reliability, accuracy and sound professionalism, could be spun for geosciences other than meteorology, aside from the part relating to achieving regular public visibility.

Simple, Yet Abstract Concepts

Drawing on the examples that have been presented in this essay so far, we can attempt to derive some insights. To that end, some abstract concepts are outlined. (They will be taken up systematically in Chapter 4; building also on further explorations of the societal relevance of geosciences that will be presented in the remainder of this chapter.) These concepts aim to consolidate the contention that geoscience knowledge and the sound professional ethics of geoscientists are public goods.

Socio-ecological systems are constituted by natural and societal processes and consist of human systems and practices, natural systems and processes, and their dynamic intersections. Socio-ecological systems can change at various scales and exhibit non-linear system dynamics, multiple feedbacks and counterintuitive behaviour (Liu et al. 2007; Hulme 2011; Tickell 2011; Smith and Zeder 2013; Monastersky 2015; Seitzinger et al. 2015; Schimel et al. 2015; Bohle 2016; Head and Xiang 2016).

For the following, we conceptualise the global 'socio-ecological system' to be composed of a geosphere, biosphere and noosphere. The notions geosphere, biosphere and noosphere offer a simple answer to the question 'what is the Earth system?', to facilitate a better understanding of expressions like 'socio-ecological system' or 'composite of natural and societal processes'. The following discussion will start by describing the three notions geosphere, biosphere and noosphere in a manner that leads to a conceptual framework, which will enable readers to orientate themselves to understand the societal relevance of geosciences.

A century ago, when these three notions were coined, the notions biosphere and noosphere had a strong metaphysical undertone. Since then, scientific engagement with these concepts has resulted in the demystification of the notion biosphere. Still, the meaning of the notion noosphere might provoke metaphysical interpretations and may appear to be disconnected from the conceptual meanings attributed to the notions geosphere and biosphere (Moiseev 1989; Oldfield and Shaw 2006; Korobova and Romanov 2014; Hamilton and Grinevald 2015). Nonetheless, the meaning of noosphere can be amended so that it loses its metaphysical connotation. Instead, it can offer an orientation that relates to the meaning of geosphere and biosphere. Such an altered notion can help to explain why the intersections of people's activities and the Earth are much more than matters merely pertaining to geosciences, technology and economy but are as much a mirror image of their value systems, cultural choices, lifestyles, virtues and the practical justifications of their actions.

The terms biosphere and geosphere refer to two distinct categories. On the one hand, they refer to the physical features of the Earth system that comprises natural biotic and abiotic parts. On the other hand, the same terms are also used to describe the temporal and spatial processes that govern the interactions and transformations of these parts within the Earth system. Hence, the notions biosphere and geosphere refer to objects and their physical features as well as to how these are being processed. Both notions are used in a dichotomous manner to distinguish nature, and hence the biogeosphere, from the human sphere.

In its habitual usage, the notion noosphere does not refer to temporally and spatially dependent processes that govern the interaction of physical objects. Specifically, such an interpretation is proposed in the following, that is, that the term noosphere should refer to temporally and spatially dependent processes that govern the interaction of objects that have physical features. The proposed reinterpretation also captures the purpose of engineering, that is, to design, build and operate technological objects to sustain people's lives. So, to reinterpret the notion noosphere; first, the 'objects in the noosphere' are those physical structures and processes (objects) that are designed and engineered by humans. People, when making and using objects, undertake complex processing of their insights, whatever those insights might be. The processing is cognitive, highly flexible and may draw on multiple associations. It entrains people's cognitive and behavioural traits in building a mental model of the object, which is highly adaptive. Second, the 'processes in the noosphere' are constituted by the mental worldviews and processes that shape and govern human interactions. These processes include, for example, the mechanisms by which personal insights are developed (e.g., how to design, engineer and use physical artefacts), how these insights are shared among people and how they lead to people's actions (intentional and unintentional).

When altered in this manner, then, the notion noosphere refers to physical objects (e.g., engineered systems) and processes (e.g., thinking about how to engineer objects and their interaction). Thus the structure of the reinterpreted notion matches the structure of the notions geosphere and biosphere. By combining the notions geosphere, biosphere and noosphere, a conceptually simple description of the entire Earth system is possible, namely, of physical objects and processes that govern the interactions of these objects, including in relation to people who act and interact. Consequently, a unified description of the Earth system is conceived: 'a kind of hybrid Earth, of nature injected with human will, however responsibly or irresponsibly that will may have been exercised' (Hamilton 2017, p. 68). When considered like this, the Earth can be described as a multitude of socio-ecological systems, which comprise individual people and their activities, motives and knowledge, the interactions of people, human agency and societal processes as well as manufactured technological objects (simple and complex) and natural environments.

Conceptualising the Earth in the manner outlined above has implications for practising geosciences and understanding its societal meaning. First, when applying geoscience expertise, people are understood to be an inherent part of the system. Geoscience expertise is an operational skill of societal relevance. Second, whenever the intersections of the noosphere, biosphere and geosphere are altered, and hence the socio-ecological system is modified, these changes will impact on people. Consequently, people will judge alterations according to their values and insights into these intersections, and frame their actions accordingly.

To summarise the views outlined in this essay; engineering means to make and shape physical objects (or systems), which link human activity with the geosphere in a value-laden manner. Engineering also means to conceive (in the noosphere) how these physical objects (systems) are deployed to appropriate resources from the biogeosphere. Put differently, when using geoscience expertise, the engineering of, for example, production systems, urban dwellings and consumption patterns is the intended, value-driven alteration of the Earth system with the purpose of facilitating production of goods and services and, ultimately, biological reproduction. Therefore contemporary geoscience expertise and engineering are intertwined such that geosciences are among the stewardship sciences that shape the socio-ecological systems of which the Earth system is constituted.

3.2 Second Essay: Comparison—Fisheries and Geoethics

This essay, drawing on Bohle (2018), sketches what geoethical thinking may learn from other approaches for guiding the interactions of humans and nature. The guidelines of the Food and Agriculture Organisation (FAO) for small-scale fisheries (SSF) that are called 'Voluntary guidelines for securing sustainable small-scale fisheries in the context of food security and poverty eradication'[3] serve as an example. They were issued by FAO Member States in 2015. Based on a human rights approach, these guidelines aim to foster the sustainable development of fishing communities in coastal regions.

[3] http://www.fao.org/3/a-i4356e.pdf.

A relationship between the guidelines for small-scale fisheries and geoethics is established by combining four lines of inquiry and two ancillary notions, 'human niche' and 'Anthropocene'. The first line of inquiry, which is illustrated by the paper 'Global change and the future ocean: a grand challenge for marine sciences' (Duarte 2014), describes the state of the global ocean and coastal seas under the impact of anthropogenic global change, that is, within the Anthropocene. The second line of inquiry, which is illustrated by the paper 'Global Ocean Governance: New and Emerging Issues' (Campbell et al. 2016), describes marine issues of concern, such as small-scale fisheries, ocean acidification, seabed mining or blue carbon, for which developing better marine governance arrangements is critical. The third line of inquiry, which is illustrated by the paper 'Walking the talk: implementing the international guidelines for securing sustainable small-scale fisheries' (Jentoft 2014), emphasizes that governance is the key challenge to implementing the FAO SSF Guidelines. The fourth line of inquiry, which is illustrated by the book 'Earth System Governance—World Politics in the Anthropocene' (Biermann 2014), shows that the implementation challenge of the FAO SSF Guidelines is a realisation of the common challenge: how to govern the global commons sustainably?

The global commons are socio-ecological systems, which are composed of human systems and practices, natural systems and processes, and their intersections. Socio-ecological systems exhibit non-linear system dynamics, multiple feedbacks and counter-intuitive behavior that can change simultaneously on a local, regional and planetary scale (Hulme 2011; Tickell 2011; Monastersky 2015; Seitzinger et al. 2015; Schimel et al. 2015; Preiser et al. 2018). When considering planetary-scale socio-ecological systems, an implicit reference is made to the notions 'human niche-building' (Ellis 2015; Fuentes 2016) and 'Anthropocene' (Steffen et al. 2016; Zalasiewicz et al. 2017). As noted in the previous section, although the notion Anthropocene might be ill-conceived because it may conceal actors, responsibility and historical contexts, it is a shorthand for our times (Sayre 2012; Palsson et al. 2013; Haraway 2015; Lövbrand et al. 2015; Walton and Shaw 2015; Autin 2016; Chakrabarty 2016; Veland and Lynch 2016; Clark and Gunaratnam 2017; Lorimer 2017; Olsson et al. 2017; Rosol et al. 2017). *Mutatis mutandis*, philosophers may say that 'the Anthropocene for the first time gave birth to a universal "Anthropos"' (Hamilton 2017, p. 118) in the human niche.

3.2.1 *Small-Scale Fisheries as Part of Building a Human Niche*

Since prehistoric times, people have purposefully altered their environments at the local, regional and continental scale, including coastal zones (Mee 2012). Niche-building is a historical process (Bonneuil and Fressoz 2013; Latour 2015). It is acknowledged (by many) that cumulative anthropogenic change in natural environments has triggered a new stage of the Earth system—the Anthropocene—that, for some, is functionally different from the Holocene (Waters et al. 2016). Some consider that the onset of this new stage happened at the middle of the twentieth century (Zalasiewicz et al. 2015). Since then, the human population has tripled and, more importantly, the affluence of people living in the developed world has increased dramatically. The subsequent impact on the marine environment is recognised in the 14th United Nation's Sustainable Development Goal, that is, to 'conserve and sustainably use the oceans, seas and marine resources'.

Aimed at building and maintaining prosperous standards of living in industrialised societies, the many processes of production that together constitute global supply chains are the main drivers that are currently shifting the dynamics of the Earth system (Heede 2014; Golden et al. 2017). The cumulative effects of local or artisanal activities also have an impact, triggering shifts in environmental systems already strained by industrial exploitation. The collapse of the small-scale fisheries off Central West Africa may serve as an example (Galaz et al. 2011, pp. 7–8):

> Fish stocks have declined along the Central West African coast to a large extent due to rapid exploitation by high-tech international fishing fleets and due to the degradation of mangrove forests, seagrass beds and coral communities because of, for example, climate change and pollution. Consequently, diets and trading activities shift to so-called 'bushmeat' such as chimpanzees and flying foxes. These are well-known sources of zoonotic diseases such as Ebola, Marburg viruses and human monkey-pox … The combined impacts of fish stock decline, epidemic outbreaks, additional losses in ecosystem services, water stress, and poverty put already fragile states such as Congo and Cameroon under severe pressure.

Turning from this example to understand more general patterns of transformed marine systems, small-scale fisheries in the context of industrialised use of the coastal zone provide a key example of how people are changing the marine environment (Newton et al. 2012; Pauly and Zeller 2016). The small-scale fisheries business (artisanal, subsistence and recreational) contributes about half of the global catch of fish and employs about 90% of the respective workforce, as outlined in the FAO SSF Guidelines (p. 4). Small-scale fisheries have the potential to contribute to better sustainable development approaches of many (not only developing) countries because they contribute directly to food and livelihood security, balanced nutrition, poverty reduction and wealth creation, foreign exchange earnings and rural development. Therefore in June 2014, after a decade-long process, FAO Member States endorsed voluntary FAO SSF Guidelines, offering a comprehensive framework consisting of several building blocks.

Facilitated by the political choice to make the adherence of stakeholders voluntary, it was possible to make the FAO SSF Guidelines comprehensive in terms of topics covered. They could integrate social, cultural and economic sustainability issues and address resource access (allocation) as well as being guided by human rights principles. Founded on human rights-based approaches to social development and an empowerment process for community organisations (including the decision-making power of women), the FAO SSF Guidelines argue in favour of adaptive co-management strategies that acknowledge the importance of traditional knowledge systems and the customary rights of indigenous communities. Further essential building blocks of the FAO SSF Guidelines highlight the need to protect (and to legislate for) the rights of small-scale fishing communities to fishery resources and land, and to promote market access through improved post-harvest handling and access to credit. Furthermore, emphasis is also placed on supporting diversified livelihoods, including access to essential social services and overarching capacity building interventions and networking opportunities. Hence, the FAO SSF Guidelines provide an opportunity to develop a coordinated strategy for institutional and individual actors to safeguard the sustainability of small-scale fisheries and their communities. However, implementing the FAO SSF Guidelines will require developments in policy intervention and innovation on many levels, contributions of civil society organisations and academia, and the empowerment of fishers as participants in decision-making processes. Hence, effective implementation of the FAO SSF Guidelines, whether at local, national, or regional levels will have to package many threads of action in a context-specific and actor-dependent manner (Jentoft et al. 2017).

3.2.2 Entangling Small-Scale Fisheries and Geoethics

This section offers three threads of thought.

First Thread: Bearings, Complexity and Scales
Niche-building seems to be a generic activity of our species (Bonneuil and Fressoz 2013; Zalasiewicz et al. 2015; Fuentes 2016). It is evident that human niche-building practices also affect coastal seas. In 2016, the United Nations Economic and Social Council identified five coastal seas 'at risk from coastal eutrophication'.[4] Likewise, niche-building affects the world's oceans; Duarte (2014) gives multiple references to support this argument and summarises:

> The rapid increase in human population since the industrial revolution and their preferred settlement in coastal areas … has led to a major physical transformation of the shoreline … associated with the widespread loss of habitats fringing the shoreline … Together with human settlement in coastal areas, changes in the land use in watersheds and river regulation through the massive construction of reservoirs over the past 60 years have affected the delivery of materials, from sediments and organic matter to nitrogen, phosphorous … Efficient atmospheric transport also delivers dust, organic carbon, nitrogen and pollutants to the most remote regions of the ocean …. (pp. 4–5)

He mentions further the underlying issues that represent stumbling blocks to addressing these changes to global socio-ecological systems:

> … the largest source of uncertainty rests with human drivers, as not only social dynamics and shifts in the consumer attitudes are difficult to forecast, but the introduction of new, disruptive technologies are intrinsically unpredictable … A third source of uncertainty is the prevalence of non-linear systems that can lead to abrupt changes … departing from the linear, smooth responses that are amenable to prediction …. (p. 6)

These three general issues, namely the uncertainty regarding human drivers, the impact of disruptive technologies and the behaviour of non-linear systems, are frequent features of terrestrial and marine socio-ecological

[4] https://unstats.un.org/sdgs/files/report/2016/secretary-general-sdg-report-2016--EN.pdf, Vol. E/2016/65, p. 18.

systems. These features make sustainable governance of these systems a tough problem. The multiple spatial scales (local, regional and global) of these systems, the diversity of actors and their shifting attitudes towards exploitation and governance of resources add to the complexity. Geoscientists have shaped geoethical thinking to handle uncertainty and to address multiple scales and the diversity of actors; hence, geoethical thinking aligns with thinking underpinning the FAO SSF Guidelines.

Second Thread: Context Dependence in Socio-Ecological Systems
Over the last 200 years, people have considerably developed their skills to appropriate resources from terrestrial and marine environments. Depending on how skills have developed, the perceptions of people have varied as to what appropriate exploitation and governance practices are. For example, Purdy (2015) describes the history of public opinion and politics in the United States relating to how terrestrial wilderness was perceived and how a specific worldview reinforced the right, or even the moral obligation, to exploit such resources. In the same manner, the marine environments were portrayed as 'unpeopled spaces of nature, but not society … [that] support a commitment to freedom of the seas' (Campbell et al. 2016, p. 519). Such a perception of freedom supports exploitation by actors that have the necessary means to do it. For example, some decades ago, the notion of a 'common heritage of mankind' qualified the conditions that would justify the mining of mineral resources on the ocean floor. Nowadays, when mineral exploitation in deep waters is more feasible, this view is challenged (Silver et al. 2015; Campbell et al. 2016; Jaeckel et al. 2017). Correspondingly, views (of the individual actor and of codified guidance) vary regarding what is sound exploitation and rightful appropriation (Vidas 2011). The context for planning, decision-making and action shifts depending on both the abilities of the various actors to exploit resources and the actors' understanding of fair appropriation rights; reflecting what, in Campbell et al. (2016, p. 519), is termed 'three environmental governance themes: "actors, scale and knowledge"'. To manage context-dependent systems requires strategies which (1) by nature are adaptive, participatory and transdisciplinary (Head and Xiang 2016), (2) apply a collaborative rationality (Innes and Booher 2016), and (3) provide for a governance capability, which Termeer et al. (2016) frame with attributes such as reflexivity, responsiveness, resilience, revitalization and rescaling. Such strategies are a genuine part of the FAO SSF Guidelines and make context-dependence an explicit part of their design (Jentoft 2014).

Geoscientists have shaped geoethics to navigate context dependence, uncertainties and ambiguous situations experienced in their professions. This feature aligns the thinking that underpins geoethics and the FAO SSF Guidelines. Analysed in that perspective, it is essential that geoethics examines and reflects upon the role of societies, people and individual citizens, their skills and insights, and their activities to appropriate geo-resources (Peppoloni and Di Capua 2015, 2016). As Bobrowsky et al. (2017, p. 207) summarise: 'geoethics is an orientation tool for geoscientists, able to provide them with the ethical dimension of their actions'. This focus encompasses (1) the responsibilities of individual geoscientists and their services to society, (2) how to conduct and communicate research, and (3) the functioning of professional organisations and commercial activities. Such considerations deeply entangle geoethics and the FAO SSF Guidelines.

Third Thread: Agent-Centric Approaches to Governance

Geoethics is distinct from utilitarian concepts, ethics of justice or conservation for its own sake—approaches which have been discussed elsewhere in respect of ocean ethics (Auster et al. 2009; Ott 2014)—and from proposals such as those 'to reclaim the concept (ecosystem services) as a useful one in terms of the wider ethical debates surrounding human–nature relations' (Jax et al. 2013, p. 266). Recent inquiries into geoethics have put the individual, the human agent at the centre of general sustainable development considerations (see, e.g., Druguet et al. 2013 [geoconservation]; Mayer 2015 [integrity]; Pievani 2015 [history]; Potthast 2015 [technology]; Peppoloni and Di Capua 2015a [societal responsibility]; Tubman and Escobar-Wolf 2016 [development]; Bohle and Ellis 2017 [individual responsibility]).

Such an agent-centric approach to ethical practices may seem obvious for geosciences because codes of practice for chartered professionals are usually are framed in this way.[5] Notwithstanding an agent-centric tradition in the ethics of chartered geoscience professions, the emergence of the notion of the Anthropocene has challenged many geoscientists. The discussion about whether to amend the geological timescale, by naming modern times the Anthropocene, bears witness to this unease (Zalasiewicz et al. 2015; Finney and Edwards 2016). Nevertheless,

[5] See, for example, http://www.geoethics.org/codes.

considering together the notions Anthropocene and geoethics sharpens focus on the behaviour of human actors (Hamilton et al. 2015; Schmidt et al. 2016). Therefore when understanding geoethics as 'research and reflection on the values which underpin appropriate behaviour and practice, wherever human activities interact with the Earth system' (Peppoloni and Di Capua 2012), as an integral part of geoscience professionalism, geoscientists can internalise a more comprehensive understanding of the human actor and the societal implications of geosciences.

Campbell et al. (2016, p. 535) emphasise that by internalising the human role 'actors, scale and knowledge (that) are relevant for efforts to govern new and emerging ocean issues' become apparent. Such ocean issues are described, for example, by Hughes et al. (2017, pp. 84–85):

> … locally, the consumption of reef fish is shaped by a combination of the size, socioeconomic status and cultural norms of the human population. By emphasising proximal drivers rather than more distant human ones, we often inadvertently simplify and re-scale a complex social–ecological problem into a subsystem that is entirely biological, which can distract from the underlying causes and ways to address them. A social–ecological approach for sustaining ecosystems is beginning to emerge that explicitly links the resilience of ecosystems to governance structures, economies and society.

Campbell et al. (2016, p. 536) generalise this example and argue that '[t]he FAO SSF Guidelines stand out as an exception …, attending as much to questions of resource access, human-rights and food security as they do to questions of fisheries ecology'. Hence, they define the FAO SSF Guidelines as actor-centric, representing an 'opportunity to create governance regimes that support environmental sustainability and human well-being' (p. 536), notwithstanding that their 'implementation … is likely to be an ongoing, adaptive and iterative process, as small-scale fisheries are dynamic' (Jentoft 2014, p. 12). Generalising such insights, Biermann (2014, pp. 22–24) argues for Earth system governance as a common normative approach for human handling of socio-ecological systems that interrelate agency, accountability, legitimacy and fair allocation; or as Biermann writes (2014, p. 146):

> … [a] global situation of large inequalities in resources and entitlements… (t)he analysis of agency in earth system governance – that is, of those actors who have the authority to set and enforce rules and norms

> – requires an understanding of the vast social divisions on our planet … questions of fairness in adaptation arise as well, including concerns about compensation and support by the global community of the most affected and most vulnerable regions.

The FAO SSF Guidelines provide an example of how to perceive the governance arrangements of a given socio-ecological system through a common normative approach. The actual design of geoethics follows a similar path, as reflected in the Cape Town Statement on Geoethics[6]:

> It is essential to enrich the roles and responsibilities of geoscientists towards communities and the environments in which they dwell … Human communities will face great environmental challenges in the future. Geoscientists have know-how that is essential to orientate societies towards more sustainable practices in our conscious interactions with the Earth system. By applying a wider knowledge-base than natural sciences, geoscientists need to take multidisciplinary approaches to economic and environmental problems, embracing (geo)ethical and social perspectives. Geoscientists are primarily at the service of society. This is the deeper purpose of their activity.

3.2.3 Outlook

This essay explores the characteristic features of the FAO SSF Guidelines and geoethics. To summarise, it illustrates how several threads of disjunct experiences encourage putting the individual human actor (its needs, preferences, thinking and actions) at the centre of concerns for context-dependent and path-dependent governance of socio-ecological systems. This shared focus entangles both experiences, enriches the related frameworks (the FAO SSF Guidelines and geoethics, respectively) and invites also to use them outside their initial realms. This essay notes further that both approaches embed participatory governance strategies. However, only the FAO SSF Guidelines address them explicitly. In geoethics, participatory governance strategies are inherent to its definition and explicit in some practices (Lanza 2014; Nurmi 2017). In some geoscience applications, particularly those connected with the extractive industries, the increasingly important concept of 'social licence to

[6] http://www.geoethics.org/ctsg.

operate' is helping to build participatory governance strategies, essential to meeting resource needs in an ethical and sustainable manner (for further discussion see, e.g., Buhmann 2016; Owen and Kemp 2013).

The operation of small-scale fisheries in the context of industrialised exploitation provides an example of the complexity of handling anthropogenic global change. It involves 'overall values, norms and principles that guide institutions and actions' (Chuenpagdee and Jentoft 2013, p. 344) to guide agents in managing the never ending succession of problems. Generalising, for citizens as agents of change, approaches like geoethics offer an 'actor-centric virtue ethic' to identify the appropriate behaviour and practices required to develop a sustainable human niche governed by mutually respectful actors.

3.3 Third Essay: Participation—Citizen Geoscience

People's 'human niche' is composed of socio-ecological systems that interconnect the biogeosphere and the sphere of human social, economic, cultural and political activities. Against this background, this essay explores the interface of geoethics and citizen participation in science and research.

In the following, notions like citizen science shall refer to participatory knowledge generation processes that include some members of the public in some aspect of scientific research (Eitzel et al. 2017), that is, activities including but going beyond people taking part in data gathering, observation and analysis. Participation may be, for example, through collaborative processes that allow the co-design of research questions, participation in data gathering and analysis, and shared communication of results. Citizen science, as one kind of public involvement in research and development domains, is a well-established mode of knowledge generation for some disciplines (Riesch and Potter 2014; Vayena and Tasioulas 2015; Grey et al. 2016). It allows for collaborative engagement that captures and communicates multiple perspectives and interpretations, and offers opportunities for shared learning from other disciplines and practice-orientated stakeholders (Bonney et al. 2014; Aceves-Bueno et al. 2015; Follett and Strezov 2015; Paul et al. 2018).

This essay starts by presenting some examples of the evolving state-of-play of citizen science in geosciences. Then a brief history of the involvement of citizens in the societal process of doing science is sketched and the definition of geoethics read from a citizen science perspective.

Reflections about citizen science are then presented that take the notion of 'niche-building' as their departure point. The essay summarises these views with a reflection about participatory geoscience research in times of anthropogenic global change.

3.3.1 Examples: Citizen Science and Geosciences

A brief review of the current uptake of citizen science in geosciences shows that participatory geoscience research is not yet very popular, although the situation is evolving. For example, when searching the Google Scholar database for 'citizen geoscience' (13 February 2018) only one result is displayed—a paper by Powell et al. (2013) about recording temporary geological exposures. However, searching more widely (Google Scholar database, 13 February 2018, no patents, no citations), a trend emerges that displays a slight increase in interest considering citizens in geosciences. A search for the two terms 'citizen' and 'geoscience' revealed 3320 publications for the period from 2013 to 2017. This number is a little less than twice the number of references (1790) for the preceding 5-year period (2008–2012). A search for 'citizen geoscience' in the blogs of the European Geosciences Union (EGU) delivered two results (13 February 2018). Roberts-Artal[7] features the gathering of (meteorological) data and Wardlaw[8] writes about image analysis projects to track geological changes in remote-sensing imagery from Mars. The programmes of major geoscience conferences may serve as a further indicator of the interest of geoscientists in citizen science. For example, the General Assembly of the EGU, which annually hosts well over 10,000 participants, has a low (although rising) number of citizen science contributions in geosciences. In 2017, it featured one session that included citizen science research and just over 10 contributions mentioned various forms of citizen science initiatives. In 2018, the EGU General Assembly hosted six sessions with contributions that included citizen science projects.[9] Aside from such big events, some specialised

[7] https://blogs.egu.eu/geolog/2014/12/05/citizen-geoscience/.

[8] http://blogs.egu.eu/geolog/2015/11/25/mars-rocks-introducing-a-citizen-science-project/.

[9] The draft programme for 2019 includes 11 session that mention 'citizen science'.

conferences featuring citizen science initiatives in geosciences have recently been organised, such as the 'Citizen Observatories for Natural Hazards and Water Management' (Venice, 27–30 November 2018).

Depending on search terms, literature searches lead to examples of citizen science in various geosciences, such as hydrology (Buytaert et al. 2014), geothermal research (Meller et al. 2018) or public awareness of natural hazards (Lanza 2014). When doing a bibliometric analysis of the 1935 publications of citizen science projects (retrieved from Web of Science in December 2015), Kullenberg and Kasperowski (2016) estimated that less than 5% of the projects were in geosciences. Overall, citizen science seems less popular in geosciences than in environmental sciences (Hyder et al. 2015; Vann-Sander et al. 2016). It might be that environmental issues are more aligned to people's interests than geosciences or that scientists perceive them as more accessible for public participation, with the possible exception of hydrology (Paul et al. 2018).

To illustrate why it is important to increase citizen science-based research in geosciences, a quote from a commentary published in *Nature* may serve as an example. The authors, El-Chichakli et al. (2016), call for more investment in the bioeconomy[10] to support the United Nations Sustainable Development Goals:

> A global bio-economy must rebuild natural capital and improve the quality of life for a growing world population. It should balance managing common goods, such as air, water and soil, with the economic expectations of people. … Also needed will be citizen science evaluations of new houses, local wood-recycling and construction efforts. Sustainable food systems will require advances in plant breeding, food products, and farming and cultivation techniques… Inclusiveness and knowledge transfer are important. (p. 222)

Besides how the role of citizen science is perceived, the authors discuss the human niche when mentioning 'common goods, such as air, water and soil … farming and cultivation techniques'. Although they identify the need to 'rebuild natural capital and improve the quality of life', the dependence of the bioeconomy on geoscience knowledge is not mentioned when 'managing … air, water and soil'. The comment argues in

[10] The bioeconomy encompasses various economic sectors, such as health, the biochemical industry, agriculture, forestry and bioenergy (see Bugge et al. 2016).

favour of interventions on a planetary scale when referring to a global bioeconomy and common goods. Literacy of the authors in terms of their geoscience knowledge can be assumed. It looks like that this knowledge is deeply integrated into their expertise but does not get mentioned explicitly in the quote.

Furthermore, the quote should be read against the insight that agriculture represents the anthropogenic land-use process that has had global impact throughout history and pre-history (Ruddiman 2013; Liu et al. 2017; Song et al. 2018), affecting the global cycles of carbon, water, dust and nutrients. Furthermore, since the beginning of the twentieth century, the industrial nitrogen fixing (Haber–Bosch) process has supported agricultural industry and has led to a profoundly altered global nitrogen cycle (Morton 2015; Zhang et al. 2015; Ren et al. 2017). This is a classic example of geoengineering through the bioeconomy, albeit unintentional.

The quote analysed above illustrates how people conceptualise the relations that characterise the links between production systems, consumption patterns and geosciences. The embedding of geoscience knowledge in the expertise of other disciplines conceals it or favours a restricted relation, like engineering geology (Srbulov 2014).

Throughout this book, however, we demonstrate the benefits of embracing a comprehensive concept of geosciences to understand the interconnectedness of the biogeosphere and the human sphere. It also becomes apparent how many knowledge domains impinge on the geosciences. These mutual relations should be made more explicit. Consequently, citizen geoscience, and hence public engagement with geoscience practices and approaches, would increase the public visibility and exposure of geosciences. To this end, it is vital to encourage participatory research processes and practices in geosciences. Advocating citizen science in geosciences should thus be inherent to geoethical thinking and practice.

3.3.2 History: Geosciences, Citizens and Participation

The present-day relationship between geosciences and citizen science is part of a more common historical trail:

> Two centuries ago, almost all scientists made their living in some other profession. Benjamin Franklin (1706–1790) was a printer, diplomat and politician; Charles Darwin (1809–1888) sailed on the Beagle as an unpaid companion to Captain Robert FitzRoy, not as a professional naturalist.

> The rise of science as a paid profession is a relatively recent phenomenon, dating from the later part of the 19th century. However, citizen scientists have never disappeared, particularly in sciences such as archaeology, astronomy and natural history, where skill in observation can be more important than expensive equipment. (Silvertown 2009, p. 467)

Joel Mokyr's book 'A Culture of Growth—The Origin of Modern Economy' (2016b) inspires the following sketch, which *mutatis mutandis* also applies to geosciences.

The development of modern science and research in Europe began in the seventeenth century among a small number of mainly urban citizens that had opportunities to study natural phenomena. Renaissance scholars such as Leonardo da Vinci or Galileo Galilei had pursued a diversity of activities, such as developing techniques for painting (perspective, colours), observing natural phenomena (rocks, plants, water flows) or designing engineering plans for bridges, fortifications and instruments. For this purpose, they experimented with new, innovative tools, such as lenses and telescopes. Often, creative individuals served influential leaders who provided them with resources and protection against persecution. Even when sponsored in such a manner, new insights usually trickled down slowly into daily experiences and understanding of the world.

Nevertheless, the cumulative effects of these insights can be traced through changes in production systems (Mensing et al. 2016). It took about two centuries of social, economic and political developments before more individuals (gentry or bourgeois, men and some women) engaged in scientific activities and modern scientific educational and professional structures started to emerge (Mokyr 2016a). For the better part of the eighteenth century, it was a small network of privileged people across Europe who engaged in scholarly discoveries and research, often using their wealth to support their studies. New developments were stimulated by government prizes, like the 'longitude prize' (navigation), investments in infrastructure (bridges, roads, channels, and mapping of the landscape) and mining technology, and developing the means for military power; many of these required a significant share of geoscience expertise. Much trial and error (including terrible accidents) were needed before citizens and authorities accepted them (Fressoz 2012).

In the wake of industrialisation and the consolidation of capitalist production forms in the nineteenth century, the social and cultural basis for doing research, science and technological development was broadened (Mokyr 2016b). Scientific expertise, technological means and a culture that valued knowledge and purposeful expropriation developed as new societal norms (Purdy 2015). Finally, in the wake of the Second World War the number of researchers, scientists and engineers grew massively.[11] Since the middle of the twentieth century, a significant percentage of the population in developed countries work as researchers, scientists or engineers. Their expertise has facilitated regional infrastructure development, the production of goods and the provision of services in industrial and post-industrial cultures, supported massively by governments, wealthy individuals and corporations (Wolfle 1957; Waterman 1960; Bronk 1975). The present-day network of inequitable global supply chains has developed, and our contemporary affluent knowledge-based societies have taken shape, resulting in massive alterations to natural (and social) environments as a consequence of production systems and consumption patterns. Consequently, the spirit of technological progress which characterised western cultures a few decades ago has partly faded.

Over a centuries-long process of change, the domains of science and research have become professionalised, and industrialised production forms have shaped the societal institutions that nowadays segregate daily life, culture, the development of technologies and the search for scientific innovation. Generally, the assessment of innovations is regulated. This is done by specialised institutions tasked with protecting the public against risk, accidents and disastrous failures, as experience had taught us to do (Fressoz 2012). Subsequently, as they spread through societies, innovations cause debates, political and legal struggles, for example, about environmental risk, squandered opportunities or doubts about the assessment process itself. The fate of carbon capture and storage technologies may serve as a geoscientific example of such an experience (Lofstedt 2015).

Furthermore, in a citizen's daily practices innovation often comes in the form of a bundle of changes. The regional management of the Ebro River (Spain) delta is one such example (Zografos 2017). Outcomes of bundled changes, which are difficult to forecast and understand, may be unexpected and therefore strain the intrasocietal links of citizens (and authorities) with professionalised research and development processes (David and Foray 2002; Allenby and Sarewitz 2011; Roco and

[11] https://futureoflife.org/2015/11/05/90-of-all-the-scientists-that-ever-lived-are-alive-today/.

Bainbridge 2013; McNie et al. 2016). The case of stratospheric ozone depletion and its management may serve as an example of how to handle such a strain of intrasocietal links successfully (Jacobs 2014).

Nevertheless, the societal strain may be overbearing when systems exhibit hysteresis and locking-in, and when environmental change and alteration of societal infrastructure and practices are therefore path-dependent and difficult (or impossible) to reverse. It is this feature that makes anthropogenic global change so difficult to tackle. The case of greenhouse gas emissions illustrates such an overbearing strain. To handle the dynamics of change in a competent manner requires strong integration of scientific research and technological development with day-to-day societal practices and governance arrangements. To that end, participatory research approaches, development practices and implementation strategies are needed, which enable co-creation of knowledge and collaboration with citizens (scientists); and appropriate methods must be developed. One example is scenario analysis:

> Mapping policy pathways in assessments is an iterative exercise that frequently requires adjustment if new forks in the road, alternative destinations, pitfalls and uncharted territories turn up. Due to the high uncertainties, long-term issues, such as global environmental change, require trial-and-error policy-making. Assessments can strongly support this through ex-post policy analyses. In the light of newly discovered practical consequences, objectives might be revised and means can be adjusted. Mistakes in policy-making can occur, and from them, society as a whole can learn for the future. (Edenhofer and Kowarsch 2015, p. 63)

When bound into participatory processes, working in such a manner would enhance public literacy in the respective scientific fields, *mutatis mutandis* in geosciences. Hence, the explicit involvement of citizens in science and research is to be recommended all the more when considering the relevance of geosciences for the functioning of contemporary societies.

3.3.3 Citizen Science: A Generic Application of Geoethics

Geoscience professionals should be well placed to recognise people's diverse economic, social and cultural living conditions when acting in their professional capacity (Peppoloni and Di Capua 2015a; Bobrowsky et al. 2017).

The wide range of applications of geosciences mirrors the diversity of the global social sphere and offer incentives for the participatory conduct of science and research. Furthermore, a conceptual relationship between geosciences and citizen science is implicitly built into the frameworks and professional codes that underpin geoscience professions. In professional practices, for example, the relationship of geosciences and citizens forms part of the risk analyses and impact studies (Di Capua and Peppoloni 2014; Hall et al. 2015; Hino et al. 2017). Notwithstanding this ample conceptual relation, 'citizen science' and other ways to conduct research and science in a participatory manner seem little used in geosciences.

Driven by professional practices, the relationship of geosciences and citizens is enshrined implicitly in the definition of geoethics[12] (Peppoloni and Di Capua 2017), which states that it 'consists of research and reflection on the values which underpin appropriate behaviours and practices, wherever human activities interact with the Earth system'. The phrasing 'wherever human activities interact with the Earth system' is inclusive of any human agent. The definition posits further that geoethics 'deals with the ethical, social and cultural implications of geoscience education, research and practice, and with the social role and responsibility of geoscientists in conducting their activities'. The notions of social role and responsibility offer another lead to the potential of citizen science in geosciences.

The application case of geoethics, namely 'appropriate behaviours and practices, wherever human activities interact with the Earth system', is about building the 'human niche'. Hence, geoethics is about the conduct of (all) people, their professional activities and individual lifestyles.

Drawing on the above, 'geoethics' is equally cognisant of citizen knowledge as it is about geoscientific knowledge. Hence, geoethical thinking calls for us to configure our perceptions of citizens and geoscientists, their professional activities and their lifestyles, to be complementary. Their active cooperation should therefore be sought, and geoscientists seem ideally positioned to initiate and coordinate participatory research practices.

[12] http://www.geoethics.org.

3.3.4 Niche-Building: A Dedicated Application of Citizen Science and Geoethics

As discussed elsewhere in this book, the effects and impacts of the interactions of human activities with the Earth system are ubiquitous. These interactions come about through the way in which production systems and consumption patterns are designed and result in physical changes in the geosphere. In turn, such engineered socio-ecological systems then re-shape the daily lives of citizens. Consequently, many professional activities as well the daily dealings of citizens are implicitly intertwined with geoscience expertise. In some cases, the use of geoscience expertise may involve only geoscientists acting in professional capacities. However, geoscience knowledge often is embedded in established (professional and daily) practices, such as building codes or design practices for construction on slopes or on floodplains. People who apply these practices may not be 'geoscience literate', and therefore have little chance to question the 'embedded knowledge', for example, given altered environmental circumstances, like precipitation patterns. When dealing with any matter of environmental design or intervention, geoscience literacy is likely to be relevant for many informed professional activities and daily courses of action.

The manner in which geoscience expertise, production systems, consumption patterns and the daily lives of citizens are interlinked is demonstrated by the way in which people have built an anthropocentrically manipulated biogeosphere, that is, a global socio-ecological system (Fressoz 2012; Foley et al. 2013; Ellis 2015; Fuentes 2016; Waters et al. 2016). The human niche for modern societies has resulted from the increasingly effective design (or engineering) of production systems and patterns of consumption of resources. Unintended side-effects of these design activities have accumulated and are the main drivers of anthropogenic global change. The accelerating process of anthropogenic global change is not an accident. It is an unintended consequence of a historical process that was intended to maintain affluent individual well-being, mutual caretaking and (biological) reproduction.

Considering its purpose, a comfortable human niche requires a well-functioning biogeosphere that only occasionally gets disrupted by natural hazards. Likewise, its well-functioning should not be threatened by ignorance, for example, when citizens ignore natural features, such as slope stability or floodplains. Hence, when exploring societal contexts of anthropogenic niche-building and global change, geoscience expertise is a public good. Its use should promote the informed participation of citizens in decision-making processes. Geoscience expertise is only one of several contributions to the complex knowledge base our societies require to facilitate sustainable development. The basis of societal or political decision-making processes is thus rarely straightforward and seldom based only on facts (Hulme 2009; Cairney 2016; Kowarsch et al. 2016). It is this insight that requires geoscientists and citizens to share and embed expertise that stems from various sources. Participatory processes, like citizen science, are an appropriate means to ensure that collaborative processes take account of the relevant knowledge, and that this is effectively exchanged among stakeholders.

Considering geoscience research and practices, the participation of citizens in science is compatible with the professional activities of geoscientists. Participation of citizens should at least be deemed obligatory in the outreach and communication activities of geoscientists. Beyond such activities, which are either downstream of the actual research activity or related to the social and political embedding of the research, geoscience research communities should accustom themselves to involving citizens directly in the execution and design of geoscience research projects. When looking beyond the domain of geosciences, there are abundant examples of collaborative research practices and multi-stakeholder engagement processes that demonstrate how participatory processes can successfully contribute to delivering high-quality research outcomes (Tengö et al. 2014; Reyers et al. 2015). Within geosciences, the approach termed 'social licence to operate' provides an example (Dare et al. 2014; Moffat and Zhang 2014; Hall et al. 2015; Buhmann 2016). This approach, which has its intrinsic difficulties (Boon 2015; Falck 2016; Moffat et al. 2016), is used in the mining industries to facilitate long-term (mining) operations. Seeking a social licence to operate focuses on commercial activities and their social embeddedness. Informed by these experiences, which have had mixed results, geoscientists should explicitly further 'citizen geoscience' to deepen the involvement of citizens in their research and practices. Against the additional backdrop that geosciences knowledge is a public good, citizen geoscience is valuable to advance citizen empowerment beyond participation in geoscience research.

3.3.5 Outlook

In their paper 'The Anthropocene is functionally and stratigraphically distinct from the Holocene', Waters et al. (2016) emphasise the ongoing functional changes to the Earth. The behaviours and practices of people, in creating current production systems and consumption patterns, have caused these changes (Steffen et al. 2015). Participatory research and development practice in geosciences, also involving citizen science, is needed to reduce the strain that upcoming changes in living conditions imply (Kowarsch et al. 2016).

The current unfolding of anthropogenic global change will cause significant adjustments to people's living conditions in most parts of the globe. To tame these change processes and to change the direction of current development pathways, much geoscience expertise will have to be installed within societal practices in a socially sustainable manner. To this end, the depletion of stratospheric ozone that was caused by emissions of some industrial gases provides an informative example (Wu et al. 2013). From a geoscience perspective, the underlying cause–effect relation was quite simple. The single cause was the use of gases (chlorofluorocarbons and other substances) in cooling installations and foams. These gases persist in the atmosphere and reach cold stratospheric clouds in polar regions. In the presence of ice and light, chlorofluorocarbons break up ozone molecules that otherwise would absorb ultraviolet radiation, which instead reaches the Earth's surface and can damage cells. The solution to the problem was technically unassuming, namely to substitute some specific substances. The economic impact of the required technological change was limited. The changes for citizens were humble, namely to replace appliances (fridges) in a controlled manner. The societal process that prescribes how to govern emissions was put in place (through an international treaty), and satellite-based monitoring of emissions of ozone-depleting substances was implemented. Hence, societal processes delivered a solution to a well-defined problem. Implementing the solution did not need much citizen involvement; technical and political elites could handle the issue. Compared with the experience of managing the replacement of ozone-depleting substances, efforts to mitigate the effects and damaging impacts of climate change pose a different challenge. The required modification of production systems and consumption patterns (de-carbonisation) is much more profound, the monitoring of implementation agreements is much more demanding and the ethical dilemmas regarding justice or choices of development paths are much more severe. Hence, the societal processes required to deliver a solution are challenging, implementing the solution needs much citizen involvement, and technical and political elites alone likely cannot handle this issue.

Encouragingly, the notion of the Anthropocene has rapidly attained intellectual and public attention over the last decade. Now it is driving debates among many audiences and resulting in a call to rethink how to understand humankind's place in the world (Latour 2015; Hamilton 2017). This societal feature offers a metric of the perceived urgency and expectations, given the scale and momentum of the changes anticipated. Under such circumstances, organising research and development in a responsible and participatory manner would strengthen the intrasocietal links between geosciences and citizens. Means for achieving this include, for example, increased transparency of research and development initiatives and increased awareness of how abiotic environments are linked across various scales and societal domains. In this context, citizen scientists are a known resource, both to provide experiences that are rooted in conventional societal practices and to facilitate uptake of geoscience-based practices in everyday societal dealings. Societies that face anthropogenic global change need both of these features in order to orient research and to guide practices. Consciously applying geosciences and geoethics is a common good which needs the active participation of citizens to bear fruit.

3.4 Fourth Essay: Narratives and Sense-Making

This essay explores how storytelling may be framed to be a vehicle for geoscience narratives. The essay reflects on how people's awareness is related to their storytelling practices to communicate insights and to induce or inspire behaviour (Bohle et al. 2017).

Anthropogenic change in natural environments has caused public concern since the onset of the industrial revolution (Fressoz 2012). More recently, humankind's economic activities have intensified and grown to the extent that they have significant impacts on the mechanisms that drive Earth system dynamics (Ruddiman 2013; Waters et al. 2016; Steffen et al. 2018). Hence, studying Earth system dynamics at the present time necessitates interdisciplinary engagement that draws from both the natural sciences and humanities (Smith and Zeder 2013; Bergthaler et al. 2014; Castree 2017). The interactions between people (technical, economic, social, cultural, artistic, public, collective or individual) are incorporated into the understanding of Earth system dynamics (Biermann 2014; Bauman 2015; Ellis 2015; Clark and Gunaratnam 2017; Hamilton 2017; Kunnas 2017).

Due to anthropogenic global change, people will have to appraise their preferences regarding lifestyle choices and the impact that production and consumption patterns have on Earth's geochemical and physical systems. Hence, governments, elites, influential individuals and other citizens should adopt frameworks that consider both the intertwined nature of Earth system dynamics and human activities and also the values, world-views and cultural or social prejudices which influence each other and shape human activities (Press 2008; Rickards 2015a, b; Wright et al. 2018). Navigating the dynamics of human and Earth system linkages requires integrated governance approaches that combine the value-driven ethical, social and cultural influences that shape human activities with rigorous scientific findings and engineering expertise (Steffen et al. 2011; Wilson 2014; Murphy et al. 2015; Veland and Lynch 2016).

Engineering is the socially learned and socially enacted human activity by which people intersect their environments, including the abiotic subsystem of the Earth system, the 'geosphere' (Ellis et al. 2013, 2016; Bohle 2016, 2017). Intersections of human activities with the geosphere may happen by means such as engineered infrastructures, production systems for goods and services or social activities like politics or lifestyles. Some intersections are more evident than others, such as motorways, irrigation systems, hydro-power plants or shore defences, because they more visibly change the geomorphology (Brown et al. 2017). Other intersections are less visible, such as slope destabilisation, pumping of groundwater, sewage water treatment, beach nourishment, anthropogenic climate change, ocean acidification or enhanced nitrogen/phosphorous cycling. These ordinary intersections of human activities with the geosphere seldom become part of citizens' narratives. There are exceptions, such as dramatic events (e.g., tsunamis) that reach the headlines and, only after years of effort, climate change (Krauss 2015).

As anthropologists have found, the cultural evolution of the human species can be tracked by our capacity to be storytellers (Pagel 2012; Wilson 2012; Lynam and Brown 2012; Lieberman 2013; Stewart and Nield 2013; Arroyo 2017). Throughout the history of humankind, narratives have formed the symbolic means by which societies have shared their perceptions and insights, which in turn have shaped the moral imagination to develop shared values that aim to guide social dynamics and behaviour. Hence, it is likely that this universal human trait, namely to make sense of the world using narratives, could provide an entry point for introducing issues that concern geoscience into public debates. To that end, this essay will reflect on how different concerns can be woven into common threads that might then be made more visible and tangible, so that people might become more aware of the interconnectedness of human actions with the geosphere.

3.4.1 Traditional and Modern Earth-Centric Narratives

As an example, a set of western cultures is considered as a point of departure for reflecting on how narratives might shape a more general understanding of geoscience phenomena. In some traditional, rural European cultures narrative devices were used to conserve and transmit their traditions, myths and cultural identities to new generations over many centuries.

Durand (1960) describes the narratives of some traditional rural communities, their symbols and beliefs. In these communities, for example, the 'red moon' anticipated disasters (catastrophic crop failures). The 'red moon' is a total eclipse of the full moon, which in former times was hard to explain other than by referring to the 'sacrum'.[13] Therefore from Brazil to Armenia, people consider the black or red moon to be

[13]The concepts of 'sacred' and 'sacralization' have been used, for example, and among others, by Durkheim, Caillois, Eliade, Lévi-Strauss and Ries (see Fabietti and Remotti, 1997, and references therein) as having a specific meaning. Therefore it is cautiously proposed to use the term 'sacrum', which does not correspond to a specific definition used in anthropology nor ethnography but is related to the above and to the concept of the 'supernatural'. The latter is used as an additional element mediating the opposition between nature and culture, i.e., the three-term relation of culture/human–nature–supernatural. When inquiring into the relationships between culture and environment, the available technology may instead be considered as a third element. More recently Philippe Descola (1986, 2011) developed the teaching of Lévi-Strauss to overcome the traditional western dualism between culture and nature, stating:

> To the question 'who owns nature?' the answer in the present case is indeed 'to each and every one of the species that make it up', but, as none of them, excepting our own, has made its feeling known on the matter, it is some of its members' point of view which is bound to prevail. It should, therefore, be stated that any ethics of nature is by definition anthropogenic and that it necessarily articulates values propounded by humans.

http://www.laviedesidees.fr/Who-owns-nature.html (2008, interview with Philippe Descola).

malevolent. For example, a severe drought that impacts a community is understood to occur because of the disrespect of a well-known prescription by one of its members.

Compared with such supernatural associations, narratives from the Aosta Valley may serve as an illustration of more Earth-bound views (Sibilla 2012). Dwelling in rough natural environments on the border between Italy, France and Switzerland, local people have kept alive traditional thinking in the form of narratives, symbols and beliefs. Despite the ongoing urbanisation processes in their region, these communities have preserved much of their former cultural identity, such as that expressed in the narrative of the 'Lost Valley', whose boundaries are set by Mount Rose (*Monte Rosa*). This narrative captures the fascination of the unknown and boundaries with 'the other'. It includes the potential dangers of overcoming limits that are natural and physical but also cultural. Finally, the narrative portrays the rough nature that protects its greenest and most fertile territory, which is just on the other side of the glacier.

Many narratives of rural communities of earlier times have been lost or modified radically in the global urbanisation and industrialisation processes. These traditional narratives were 'Earth-centric' to encapsulate advice and justification for behaviour to sustain stable human–geosphere intersections. They guided the use of natural resources, such as plants, animals, soil, farmland, water or ecosystems, like forests. These narratives were part of a more complex social and economic fabric. They were an essential although not sufficient means to sustain the intersection of people's activity with the geosphere (Diamond 2005). To stay effective, these traditional narratives related to the '*sacrum*'. They were explained with faith-based reasoning, based upon values and beliefs referring to the supernatural, which were common and shared in the community (Botero et al. 2014). The reference to the 'sacrum' took different forms, for example, in Greek mythology, gods and people were directly affected by forces (agents) of Earth. In Jewish/Christian traditions, faith-based reasoning alternates between claims to subjugate the environment or to respect creation; nevertheless, divine command of environmental processes comes as a last resort, for salvation or punishment.

In former times, when natural phenomena were not explicable using scientific understanding of processes and technologies, shared social constructions (values and beliefs) ruled explanations. Although based on faith and beliefs, traditional thinking was functional because it encoded accumulated experiences into a stable frame of reference, or worldview.

The combination of faith and experience had the function of coercing the believer into distinct behaviours that were favourable for existence (Purzycki et al. 2016; Johnson 2016). The rituals that ruled such behaviours navigated a balance between Earth-centric and society-centric goals. It takes time and effort to accumulate and to encode tested practices into rituals (Whitehouse and McCavely 2005). Hence, once established, these rituals are stable despite being costly to people. Among other purposes, such rituals enshrine how human activities and the geosphere intersect in a sustainable manner (Brown 2012).

If faith, values and beliefs are disrupted by explanations based on insights into processes and technologies, then the traditional balance between Earth-centric and society-centric goals gets broken. Consequently, traditional Earth-centric behaviour erodes because its sacrum-based philosophical foundations are questioned. Still, the customs relating to traditional behaviour may continue to exist in popular folk cultures, without serving their initial purpose.

Modern societies require different narratives to traditional societies to promote Earth-centric behaviour. Nowadays, people can base their Earth-centric behaviour on a substantial knowledge base. However, the intersection of people and the geosphere does not form part of the storylines of historical sciences (Carpentier et al. 1992; Roberts 1997), exceptions apart (Diamond 2005). Nevertheless, modern storytellers can draw on rich conceptual and methodological contributions from the humanities for putting Earth-centric narratives into a historical context. For example, Viollet (2000) tells a history of hydraulic engineering works for irrigation systems, waterways, power systems and sanitary systems. A description of the historical context of humankind's development path over the last two centuries (Landes 2003; Malanima 2010) also provides a robust vision of how the modern world and people's power to intersect with the geosphere has emerged:

> … *histoires nous invitent à reprendre politiquement la main sur des institutions, des élites sociales, des systèmes symboliques et matériels puissantes qui nous ont fait basculer dans l'Anthropocène* [history invites us to politically take over the institutions, social elites, powerful symbolic and material systems that have rocked us into the Anthropocene] (Bonneuil and Fressoz 2013, p. 271)

In present times, mainstream public concern focuses on issues like pollution, hazard mitigation, demographics and sustainable use of resources (Goldsmith et al. 1972; Gibson-Graham and Roelvink 2010; Schwägerl 2014). Such concerns are neither new nor unfamiliar for urban populations (Brown 2012; Fressoz 2012). It is possible that the Montreal Protocol, the international agreement on banning ozone-depleting substances concluded in 1987, marked a turning point in public perception of the global scale of anthropogenic change (Wu et al. 2013). Nowadays, global anthropogenic change is a distinctive part of the Western public's perception of the state of the globe, with people perceiving threats to their lifestyle and well-being (Steffen et al. 2011; Barnosky et al. 2012; Biermann et al. 2012; Cardinale et al. 2012; Ehrlich et al. 2012; Brown and Schmidt 2014; Walton and Shaw 2015).

Contemporary narratives of human–geosphere intersections can use natural, human and social sciences to strike a knowledge-based balance between 'Earth-centric' and 'society-centric' elements. How can such narratives be re-imagined?

3.4.2 Perspectives on Geoscience Narratives

To start with the obvious; to develop narratives that combine geoscience matters and societal concerns, landscapes, history and art provide many opportunities for a storyteller, ranging from the spectacular to the daily (Bohle 2015):

- The Colorado River has cut the Grand Canyon (United States) but no longer discharges into the ocean because its water has been extracted and redirected for the irrigation of agricultural production processes in neighbouring states.
- The motorway stretching east from Brussels (Belgium) cuts open aeolian deposits from the Ice Age that originated from the basin of the North Sea lying dry because of low sea level when a significant volume of water was bound up in global ice sheets.
- The recreational area of Lago Banyoles (Spain) has no outlet and is fed by underground springs of salty water. This geologically young lake, which hosted Olympic competitions, may transform into a saltwater lake accommodating flamingos that feed on brine shrimp.
- Human activities have marked landscapes with mining sites, irrigation channels, abandoned networks of local trains and

historical names that memorialise their past use or natural demarcations.

- At the time of the eruption of Vesuvius that covered Pompeii in ash, artists (commissioned by the wealthiest patrician households) had painted impressions of the volcano before the tragic event. Archaeologists have discovered these paintings which help them to reconstruct the shape of the volcano, the neighbouring landscape along the coast between Ercolano and Pompeii as well as the engineered artefacts of the Romans, such as aqueducts and roads.
- Crater Lake is situated in a caldera in south-central Oregon. It has neither an inflow nor outlet and is known for water clarity and thus its dark blue colour (reflecting the sky and backscattering blue light). The deep lake was formed around 7700 years ago by the collapse of a volcano (Zdanowicz et al. 1999). This unique lake was a sacred site for the native Klamath tribe. Their legends tell of battling gods of the sky and underworld, and observe the belief that Crater Lake is a spiritual site.

Going beyond such examples of storytelling that involve geoscience knowledge, modern society–Earth-centric narratives can draw comprehensively on humanities and natural sciences perspectives to illustrate the societal relevance of geosciences, for example, to daily matters, value creation (including economic or cultural value) and urban lifestyle.

Regarding daily matters. When discussing geosciences as part of the knowledge base of society, the weather was mentioned as a topic of primordial interest for most people because it impacts on humans' lives (Sirocko 2012). Weather news went prime-time during the early 1950s when numerical weather forecasting became feasible. From these early days, it took half a century to build the web of providers of weather products and their consumers (Lynch 2008; Bauer et al. 2015). Modern media combine, in a single narrative, the 'simple' weather forecast with additional information on meteorological phenomena and news on impacts on economic and social activities.

Regarding economic value. Societies apply geosciences for their functioning, and the related narratives are a common good, although they may not be recognised as such. Knowing the characteristics of rock, soil, water and air is essential for many economic activities. The production of goods or the maintenance of living conditions and individual well-being requires know-how about the dynamics of planet Earth (Langmuir and Broecker 2012). The know-how may be implicit in many general experiences, common sense, general education or specific vocational training. Artisans, technicians, architects and engineers apply geosciences when engineering artificial environments, e.g., extraction of minerals, stability of foundations or ventilation of buildings.

Regarding cultural value. Geosciences provide know-how about the evolution of life-bearing planets, the life-supporting functions of the Earth system, and the impact of humankind's activities on these systems (Hazen 2012). Narratives about these matters offer an understanding of the development of 'human geosphere intersection' and as such influence the perception of history and human development (Peppoloni and Di Capua 2012; Latour 2013). A marker for this influence on perception is the rapid spreading of interest in the notion of the Anthropocene among scholars from different disciplines. Moreover, the emotional responses of individuals influence and shape perceptions of future human and planetary well-being. The prolific emergence of apocalyptic projections that promote, for example, doomsday visions or denials of evidence is stoked by the fears of individuals about threats to their current lifestyles, and promotes related worldviews.

Regarding urban lifestyle. The Gilgamesh poem tells the story of Uruk, one of the first cities to be built 5000 years ago in Mesopotamia (George 2000). The poem is a fascinating cultural artefact of how these first city dwellers recorded their experiential connections with the geosphere. Faith-based Earth-centric features were interwoven with society-centric features about people–people interactions, earthly gods and godly earthlings. However, modern people have different experiences. Densely packed, urban people are living on a relatively small percentage of the Earth's habitable surface. Nowadays, every second person on Earth is living in a city. In 2050, urban dwellers will make up two-thirds of the global population.[14] Thus most modern people will experience their intersections with the geosphere differently. Living a modern urban

[14] United Nations, 2014: http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html.

lifestyle is altering people's experiential connections with the geosphere, up to the point that they may disconnect fully. For example, the beauty of the nightly star-filled sky is not visible when living in well-lit towns. Also, in cities, many weather phenomena may pass unnoticed. Urbanites' experiential connections with the geosphere are biased towards events that disrupt the well-functioning of the engineered structures that form their dwellings and support their lifestyles, such as air and water pollution. People are engineering their (urban) environments to shelter them from hazards, to limit dependence on the natural pace of Earth system dynamics and to appropriate and process natural resources. When sheltered by means of engineered environments, people favour their intraspecies experiences. To that end, an urban lifestyle resonates in dense people–people interactions and associated society-centric narratives, nowadays including narratives of 'virtual reality'.

3.4.3 Narratives in Times of Anthropogenic Global Change

The impact of people's activity on Earth has been noticeable for several thousand years (Foley et al. 2013). However, humankind's present patterns of consumption and use of renewable and non-renewable resources affects Earth beyond regional scales of industrial pollution, urbanisation of rural areas or replacing pristine wilderness with rural landscapes (Ellis et al. 2013; Ellis 2015). The intersection of humankind's economic activity with the biosphere and geosphere can be illustrated by various indicators. For example, more than 25% of terrestrial biomass is for consumption by humans (Krausmann et al. 2013); within just a few decades the amount of carbon dioxide in the atmosphere has reached levels last observed during the mid-Pliocene, 3 million years ago (Pearson and Palmer 2000); and erosion and the global rate of weathering of rock has approximately doubled to its current 50–80 Gt/year (Ball 2005; Smil 2007) compared to natural background. The intersections of humankind's activity with the geosphere (and biosphere) depend on both people's needs (e.g., for food or shelter) and preferences (e.g., for lifestyle, patterns of daily life or individual well-being). Whenever possible, people design (engineer) their economic activities to match both their needs and preferences, depending strongly on their culture and values. Discussions about geoengineering approaches to mitigate anthropogenic climate change are an example of this approach (Corner and Pidgeon 2010; Lawrence et al. 2018).

To handle intersections of humankind's activity with the geosphere effectively, citizens would benefit from re-imagining them as being part of their daily activities. To that end, telling stories about these intersections has to be society-centric and Earth-centric (Bohle et al. 2017).

As most people will live in cities, narratives that address them as urbanites are particularly needed. Also, the involvement of influential social groups is needed—usually urbanite with access to a high density of attractively packaged information of reliable or spurious content. People like digestible multi-faceted messages that are connected to the daily life of their social groups. Hence, their understanding of anthropogenic global change requires an attractive society-centricity to narratives; a bare Earth-centric story would not be compelling. Under such circumstances, narratives with a double Earth-centric and society-centric focus provide citizens with opportunities to develop an informed position regarding governance of anthropogenic global change, building on understanding both relevant Earth system dynamics and the appropriateness of value-systems or practices that have grown over the centuries (Hauser et al. 2014; Lanza 2014; von Storch et al. 2015). To that end, such narratives should also engage those who have more or less expert-knowledge, are practitioners or embody traditional knowledge, or share views of lobbies or political representatives (Hulme 2011).

3.4.4 A Framework for Society-Earth-Centric Narratives

The thoughts presented in the previous sections suggest a framework for society–Earth-centric narratives.

First, people shape their environment in response to their needs and perceptions as recognised by them through the filter of their worldviews and biases. The activities of present-day people intersect heavily with the geosphere. To ignore these intersections is not a viable option for them.

Second, experiences suggest that storytelling is useful for analysing the complexities of human experiences. Narratives provide cognitive tools for developing and expressing values, worldviews and beliefs, which in turn shape individual and societal perspectives. Storytelling is a means to develop abstract mental concepts, to compare observations, to construct critical thoughts or creative ideas, to assess cultural and social contexts and to make value statements. Furthermore, the ability to share narratives is a skilful human practice that allows us to show our affective relations, to describe our perception of values in different contexts and to spread or to challenge the application of both. People reinforce common views and values by sharing narratives.

Third, people's narratives about the intersections of their activities with the geosphere have evolved throughout history. Narratives of former times about supernatural agents ruling these intersections have been replaced by scientific descriptions and by the integration of traditional and scientifically valid knowledge-based narratives. These modern, content-rich, Earth-centric narratives can be harnessed to make people aware of those intersections. Such narratives do not need to employ metaphysical persuasion to enforce responsible behaviour or sustainable practices.

Fourth, to make choices and to manage uncertainties, many would benefit from understanding matters such as: How do the intersections of human activity and the geosphere function? What impacts on the economy and living conditions are possible? What are the options for mitigation or adaptation? What are the costs and consequences? What are the consequences of a 'business as usual' approach? Decision-makers, powerful individuals and elites as well as ordinary people will make their choice based on facts and value-laden worldviews. The latter will have regard to what they consider to be a satisfying life—for them, their relatives, their group or other people. Beyond such an ambivalent basis for making choices, these value-laden worldviews also determine what an individual may perceive as constituting factual knowledge or uncertainty. Narratives about the intersections of human activity and the geosphere contextualise facts within the common value-laden frame of reference of citizens.

Fifth, to create public awareness for narratives relating the nature of the intersections of people's activities and the geosphere, a double bearing is needed. Narratives must be both Earth-centric and society-centric. Society–Earth-centric narratives raise awareness of the specific processes or phenomena at the intersections of the geosphere and people's activities (e.g., engineered infrastructures, production of goods and services, arts, politics, social activity or daily lifestyles), and weave into the sphere of people–people intersections, including cognitive and affective relations.

Sixth, society–Earth-centric narratives benefit from geoscience know-how that is relevant for both economic development and cultural value-setting. Geoscience knowledge has many bearings on the production of goods, on living conditions or individual well-being, on the functioning of the Earth system and on the impact of humankind's activities on the Earth system or the evolution of life-bearing planets. When interwoven with the arts, linguistics and cultural histories, this multiple bearing offers a rich matrix for society–Earth-centric narratives of people's intersections with the geosphere.

Seventh, critical features of society–Earth-centric narratives seem to be: (1) a relevance for ordinary everyday matters and regular public presentation of work undertaken by geoscientists, (2) contribution to a broad range of value-related subjects (e.g., economic usefulness or ethical matters), and (3) addressing urbanites and their lifestyles to convey the essence of the narrative.

3.4.5 Outlook

Modern geoscience narratives should influence practices regarding how people's activities intersect with the geosphere. To that end, geoethical thinking calls for society–Earth-centric narratives that offer a full range of perspectives beyond geoscience know-how. Diverse narratives can draw on a broad range of perspectives, such as: (1) beauty or particularity of ordinary or unusual geoscience phenomena, (2) evaluating hazards for or from mundane environments, (3) relevance for everyday matters, (4) creating value, and (5) relating to people–people interactions. Likewise, these narratives can draw on the arts, humanities, history and philosophy to couple the mainstream of people–people interactions with their experiential connections with the geosphere.

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