2 Zero Hunger

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J. C. Gill and M. Smith (eds.), *Geosciences and the Sustainable Development Goals*, Sustainable Development Goals Series, https://doi.org/10.1007/978-3-030-38815-7_2

Abstract

2 ZERO HUNGER
Overview
Hunger is a state of deprivation where an individual cannot satisfy their basic food needs
842 million people are food insecure, root causes are intertwined with poverty and agricultural production
Most vulnerable are the rural poor in economically depressed and ecologically vulnerable areas
Hunger drives and impacts upon:
Migration and creation of environmental refugees
Urbanisation
Land use – environmental impacts caused by deforestation, land clearing and use of fertiliser
Land rights, justice and equality
Sold
Hunger is impacted by climate change
Soil erosion
Declining water
Rising temperatures
Increasing drought
Current status
Current food systems are inefficient and unsustainable accounting for 60% of biodiversity loss and 24% of global greenhouse gas emmisions
Agriculture increasingly competes for land and water supply with forestry, mining and urbanisation
Most global water withdrawal is for agriculture
Better policies and investment in agriculture are needed
Geoscience and hunger
Managing national to regional mineral and soil resources with input of satellite technology, geology and soil maps
Understanding chemical products of rock weathering to develop local sources of natural (mineral) fetilisers
Developing soil data science and digital sensor technologies to monitor soil quality
Improve understanding of groundwater supply, catchment studies and moisture retention in soils
Input to land use and distribution of resources — understanding distribution and quality to optimise the use of natural resources and mitigate potential conflict

2.1 Introduction

Over the past century, the global population has quadrupled from about 1.8 billion people in 1915 to about 7.3 billion people, with a projection of reaching 9.7 billion by 2050 (Elferink and Schierhorn 2016). This growth, along with rising incomes in the Global South (which drives dietary changes resulting in greater consumption of protein and meat), means food demand is expected to increase by between 59 and 98% by 2050 (Valin et al. 2013). At the same time as food demand is increasing, we are already failing to meet the needs of many of the world's poorest communities. In 2017, the number of undernourished people around the world reached 821 million, including 151 million children under the age of 5 with stunted growth (GHI 2018). Nearly 45% of deaths of children under the age of 5 were due to starvation (GHI, 2018). The absolute number of undernourished people increased from 2015 to 2017, by approximately 40 million, with this increase attributed to conflict, especially in regions experiencing climate change (FAO et al. 2017, 2018). Collectively these figures highlight the need for urgent action to *'end hunger, achieve food security and improve nutrition and promote sustainable agriculture'*—as articulated in **SDG 2** (United Nations, 2015). **SDG 2** has five targets (2.1 to 2.5) and three means of implementation (2.A to 2.C) as shown in Table 2.1. These span many dimensions of food security, tackling hunger, and improving agricultural productivity (Fig. 2.1).

Hunger is a multidimensional and complex problem (von Grebmer et al. 2015), and is defined as the distress associated with lack of food and understood as 'a *state of deprivation according to which an individual cannot satisfy his/her basic food needs (quantity and quality),*

Table 2.1 SDG 2 targets and means of implementation

Target	Description of target (2.1 to 2.5) or means of implementation (2.A to 2.C)
2.1	By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round
2.2	By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons
2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment
2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality
2.5	By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed
2.A	Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries
2.B	Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round
2.C	Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility

Fig. 2.1 Agriculture **in Hainan Province, China.** With almost 300 million farmers, China is one of the most significant agricultural producers. Its population of approximately 1.4 billion people also makes it the largest consumer of agricultural produce. *Credit* Anna Frodesiak (used under the Creative Commons CC0 1.0 Universal Public Domain Dedication, https://creativecommons.org/publicdomain/zero/1.0/)

required for a healthy and active life' (IRIS and AAH 2017, p. 5). For the Food and Agriculture Organization of the United Nations (FAO), hunger is synonymous with undernourishment which can be defined as the deprivation of food and the consumption of less than 1,800[1] kilocalories per day, the minimum that most people require to live a healthy and productive life (FAO et al. 2014). The ambitions of **SDG 2**, however, extend far beyond ensuring enough calories to also include the complex interactions between food, nutrition, access to food, and resilience of food-producing systems. Hunger, therefore, includes the '*supply, access, consumption, and intake of food at levels that are insufficient to fulfill human requirements'* (FAO 2018a). Related to hunger are the terms '*undernutrition*' and '*malnutrition*' (Box 2.1) both of which extend beyond calorie consumption and can result from both transitional and chronic situations. For example, acute food shortage leading to famine may be transitional, while long-term systemic food shortage causes chronic undernourishment.

[1]This value can range from 1,650 to more than 1,900 kilocalories per person per day for countries in the Global South. Each country's average minimum energy requirement for low physical activity is used to estimate undernourishment (FAO et al. 2014).

Box 2.1. The Concepts of Hunger (adapted from von Grebmer et al. 2015, and FAO et al. 2017)

Hunger is usually *understood* to refer to the distress associated with lack of food. The FAO defines food deprivation, or undernourishment, as the consumption of fewer than about 1,800 kilocalories a day —the minimum that most people require to live a healthy and productive life.

Undernutrition goes beyond calories and signifies deficiencies in any or all of the following: energy, protein, or essential vitamins and minerals. Undernutrition is the result of inadequate intake of food—in terms of either quantity or quality—poor utilisation of nutrients due to infections or other illnesses, or a combination of these factors. These in turn are caused by a range of factors including household food insecurity; inadequate maternal health or childcare practices; or inadequate access to health services, safe water, and sanitation.

Malnutrition refers more broadly to both undernutrition (problems of deficiencies) and over nutrition (problems of unbalanced diets, such as consuming too many calories in relation to requirements with or without low intake of micronutrient-rich foods).

Food insecurity refers to a lack of 'secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life' (FAO et al. 2017).

In this chapter, we reflect on all four aspects above, and use the term *'zero hunger'* to mean access to sufficient calories, adequate intake of food in terms of quality and quantity, and access to a balanced diet that meets the specific requirements of the individual to live an active and healthy life.

SDG 2 (Zero Hunger) recognises the role of agriculture in alleviating hunger especially for those rural households who largely depend on farming for their food provisions. Agriculture is the main primary activity that produces food but when demand outstrips supply, people suffer from starvation and hunger. However, the root causes of hunger are more complex, as we explore in this chapter. Hunger is linked to poverty (**SDG 1**), gender equality (**SDG 5**), inequality (**SDG 10**), responsible consumption and production (**SDG 12**), land degradation (**SDG 15**), and climate change (**SDG 13**). Agricultural management may also be affected by weak marketing policies, priorities for development investment, implementation of sustainable technologies, and governance, together with a lack of political will to develop and implement inclusive policies.

Some key geoscientific inputs to **SDG 2** include the following:

- *Agrogeology* (or agricultural geology). The use of rock and mineral resources can support agriculture through improving soil fertility, water retention, and reducing soil erosion (Van Straaten 2002). Understanding the underlying geology of a region can guide decision-making on what crops may flourish in a region, and what interventions may be needed to support them. Agrogeology can contribute to ending hunger by increasing access to local fertilisers (e.g., from phosphorite), liming materials, and geological resources that improve water retention and reduce soil erosion. Agrogeology can also generate employment in the agro-mineral mining industry, supporting **SDG 8**.
- *Water Resources Management* (including hydrogeology). Identifying, characterising the physical and chemical properties of, and managing groundwater resources in a sustainable manner (see **SDG 6**) can help to support agricultural practice, improve the health of the poor, and support increased productivity.
- *Geochemistry*. Understanding the accumulation and distribution of major and trace elements in agricultural soils can inform decision–making around interventions to protect and improve human health and food safety (Sun et al. 2013).

We explore these themes and examples through this chapter, illustrating the contribution of geoscientists in informing research, practice, and policy to deliver the ambitions of **SDG 2**.

In this chapter, we first examine the key context to **SDG 2**, including the spatial and temporal extent of hunger (Sect. 2.2), and social and environmental factors contributing to hunger (Sect. 2.3). We proceed to examine the role of geoscientists in tackling hunger around the world (Sect. 2.3), focusing on characterising geological resources, groundwater management, and geochemistry to improve health through agriculture. Collectively these contribute to **SDG Targets 2.1** to **2.4.** We finish by synthesising key learning and recommendations (Sect. 2.4).

2.2 The Extent and Distribution of Hunger

It is challenging to measure and supply reliable estimates of hunger to inform policy and progress with development agendas, as it is multi-dimensional, can change rapidly over time, and may vary significantly at very local scales. The FAO annual series of reports called the *State of Food Insecurity and Nutrition in the World*, tracks hunger in the world using the prevalence of undernourishment as a primary indicator, and (as of 2019), also tracking the prevalence of moderate or severe food insecurity. The proportion of undernourished people in developing regions fell from 23.3% in 1990–1992 to 12.9% in 2014–2016 (United Nations 2015b). While there has been a general decline in the share of the population that is undernourished in most regions since 2000, there are some indications that this is changing and an increased share of the population was undernourished in sub-Saharan Africa (for example) in 2014–2016, compared with the previous years (Fig. 2.2).

Another measure used to understand the severity of hunger (in its broadest definition) in a population is the *Food Insecurity Experience Scale (FIES)*, conducted by the FAO of the United Nations. This indicator is assessed by reviewing the answers to eight questions administered at either an individual or household level, and includes the dimension of access to food, making it an improved measure of food insecurity. Collecting this data has, however, proved to be difficult given the resources required. Figure 2.3 shows the prevalence of severe food insecurity by region, using the FIES global reference scale. While data is only shown for 3 years, Africa in general, but particularly sub-Saharan Africa is more affected by food insecurity, with a greater population affected by food insecurity than undernourishment. Where individuals are just above national and global extreme poverty lines (see **SDG 1**), food insecurity may push people back below the line as they will be particularly susceptible to the impacts of social, economic, and environmental shocks.

The International Food and Policy Research Institute (IFPRI) and partners compute an annual index termed the *Global Hunger Index* (GHI)[2] to monitor the level of hunger in the world, and how it is changing. The GHI reflects undernourishment, child wasting, child stunting, and child mortality (von Grebmer et al. 2015), as defined in Box 2.2. This multidimensional index reflects both the nutritional situation of the whole population, and a particularly vulnerable subset (children). When children lack calories, protein of micronutrients, it can lead to illness, poor development or death (von Grebmer et al. 2015).

Box 2.2. Components of the Global Hunger Index, GHI (adapted from von Grebmer et al. 2015)

Undernourishment: the proportion of undernourished people as a percentage of the population (reflecting the share of the population with insufficient caloric intake).

Child Mortality: the mortality rate of children under the age of five (partially reflecting the fatal synergy of inadequate nutrition and unhealthy environments).

Child Undernutrition: Nutrition targets are measured by stunting and wasting levels in children below the age of five. This includes:

[2] https://www.globalhungerindex.org/.

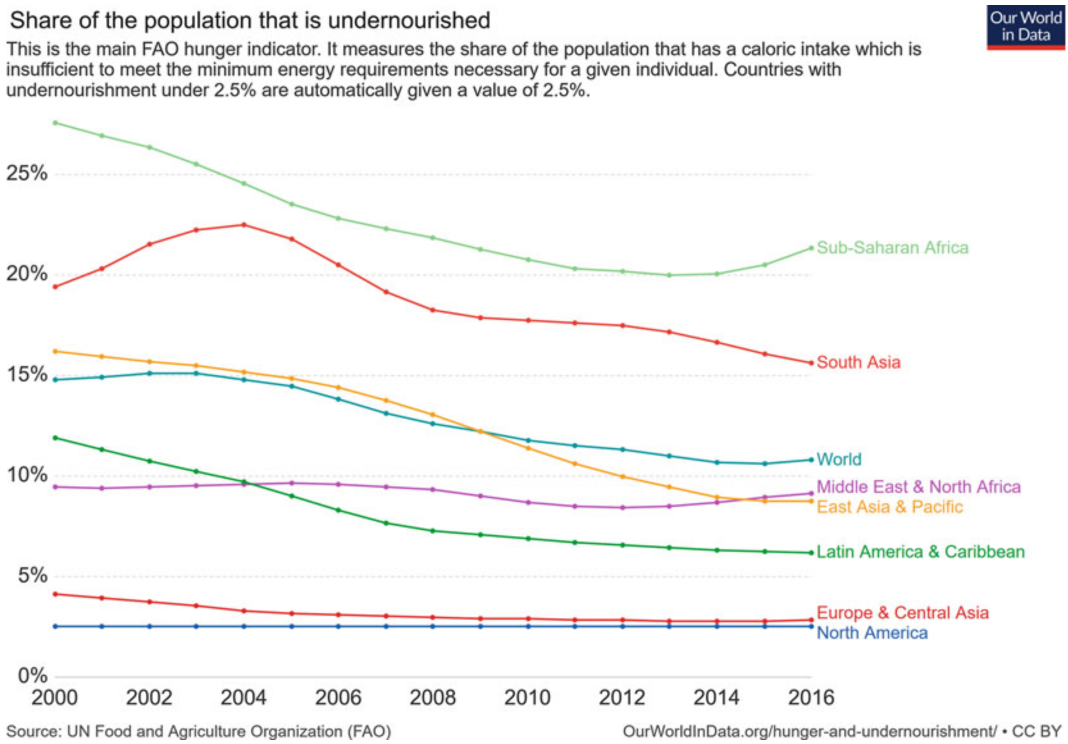

Fig. 2.2 Share of the population that is undernourished, by region. Image from Roser and Ritchie (2019), created using data from the FAO. Used under a CC-BY License (https://creativecommons.org/licenses/by/4.0/)

- **Child Wasting**: the proportion of children under the age of five who suffer from wasting (that is, low weight for their height, reflecting acute undernutrition). Wasting is a result of acute deprivation of nutritious food.
- **Child Stunting**: the proportion of children under the age of five who suffer from stunting (that is, low height for their age, reflecting chronic undernutrition). Stunting indicates long-term nutritional deprivation and may affect mental development, school performance and intellectual capacity.

GHI scores, computed from the above components are then mapped to a severity scale, showing low, moderate, serious, alarming or extremely alarming levels of hunger.

Read more: www.globalhungerindex.org/about.html.

The Global Hunger Index 2019 (von Grebmer et al. 2019) shows declining GHI values in all regions between 2000 and 2019, although there was a slight increase in the GHI of the Near East and North Africa region between 2010 and 2019. Global hunger has a GHI score of 20.0 (moderate to serious), with this being a reduction from 29.0 in 2000 (von Grebmer et al. 2019). This progress reflects improvements in each of the four GHI components (undernourishment, child stunting, child wasting, and child mortality, Box 2.2), although there has been more progress in tackling stunting than wasting in children. The overall trend is, therefore, generally positive, but with more work to do to reduce levels of hunger. Both South Asia and sub-Saharan Africa have GHI scores that indicate serious levels of hunger (von Grebmer et al. 2019). In 2019, the Central African Republic was the only country to have an 'extremely alarming' hunger level, with Yemen, Chad, Madagascar, and Zambia all having 'alarming' levels of hunger. A further 43 countries had

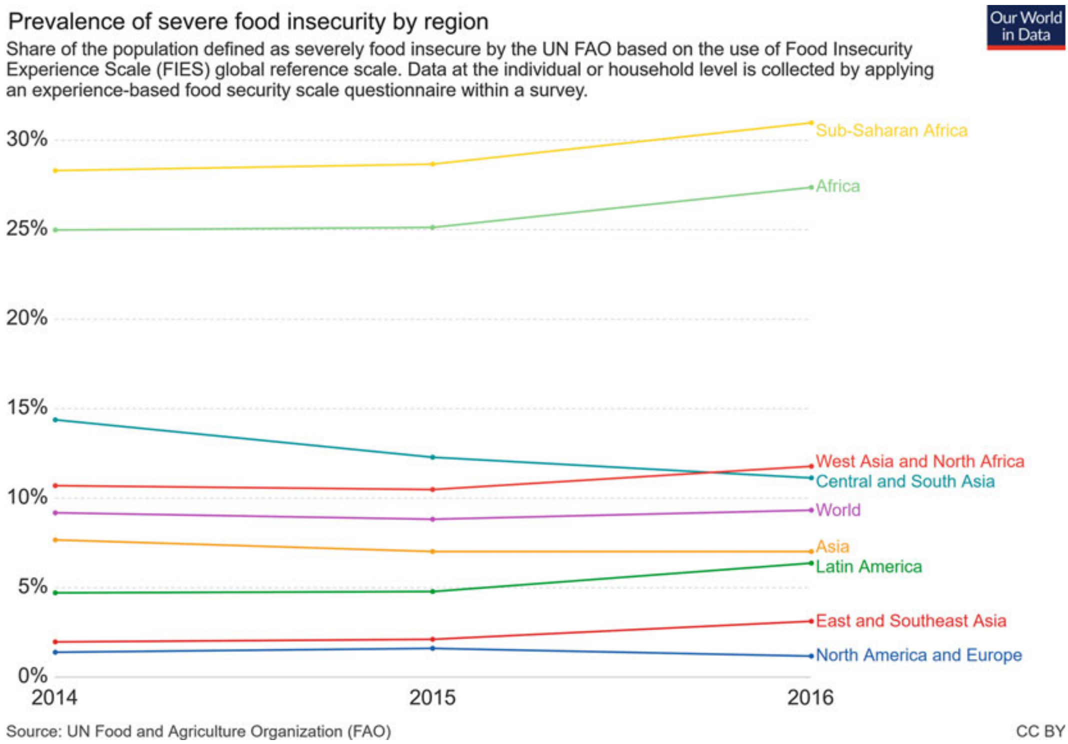

Fig. 2.3 Prevalence of severe food insecurity by region. Image from Roser and Ritchie (2019), created using data from the FAO. Used under a CC-BY License (https://creativecommons.org/licenses/by/4.0/)

'serious' levels of hunger, many of them corresponding with the world's least developed countries. Figure 2.4 shows a map of the 2018 GHI scores for many countries around the world.

Through this section, we see that undernourishment, food insecurity, and multidimensional assessments of hunger all vary spatially, with significant challenges in the Global South. Across the world, we have seen positive steps towards eliminating hunger in the past 20 years, but there are still serious, alarming and extremely alarming levels of hunger in many places. Understanding the complex factors causing this hunger is the first step to determining what actions are needed to tackle hunger and achieve **SDG 2**.

2.3 Hunger Dynamics, Causes, and Catalysts

The root causes of hunger are complex, with links to both human and environmental factors. While our interest is primarily in the links between the natural environment and the challenges and ambitions of **SDG 2**, it is impossible to separate these from other socio-economic processes that drive land-use decisions, land degradation, environmental change, and fluctuations in food demand (the amount of food of the right quality that consumers want at any given time) and production. In this section, we briefly explore two themes that inform the *challenges* around **SDG 2**: (i) social factors contributing to increases in demand for food, and reductions in agricultural productivity, and (ii) environmental impacts of increasing demand for food, the effects of climate change, and water insecurity. In Sect. 2.4, we move from challenges to solutions, particularly examining how geoscientists from across a range of sectors can support these, working in partnership with other disciplines.

2.3.1 Social Factors

An increasing global population is associated with a corresponding increase in demand for

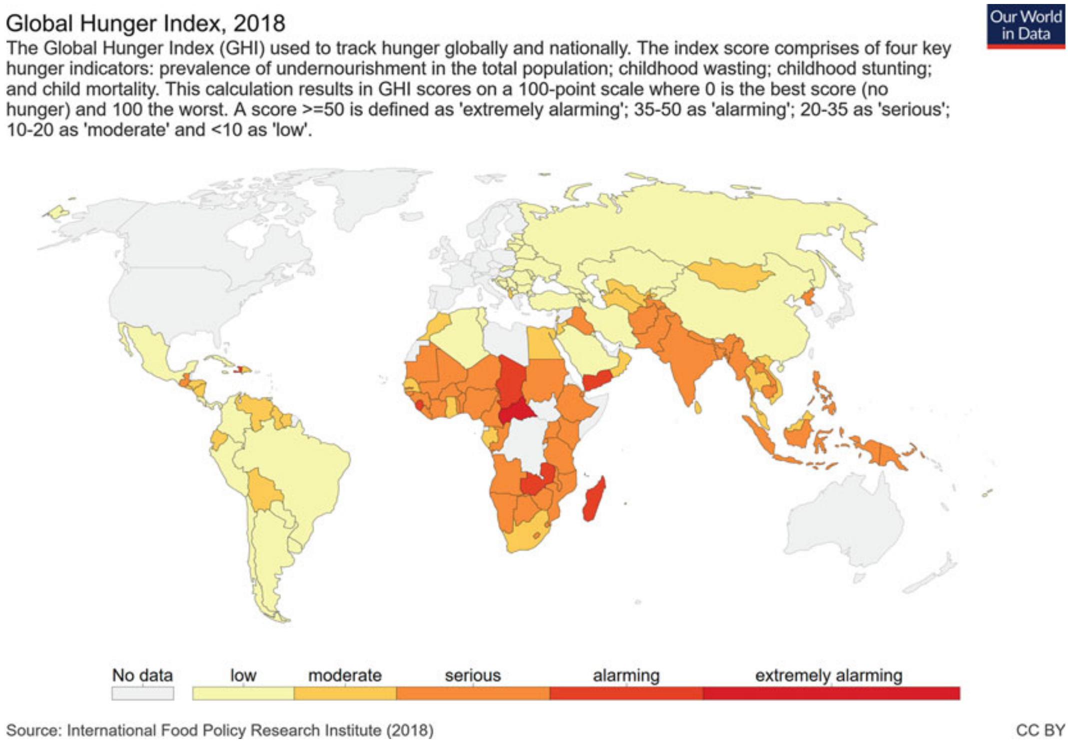

Fig. 2.4 Global Hunger Index as of 2018. Data is not shown for many countries where the prevalence of hunger is considered to be low (e.g., much of North America and Western Europe). *Credit* Roser and Ritchie (2019), with data from von Grebmer et al. (2018). Figure reproduced under a CC-BY license (https://creativecommons.org/licenses/by/4.0/)

food. The world annual population growth rate has been declining for nearly five decades, but in regions such as Africa and Asia the population growth rate is projected to increase well beyond 2050, and even into the next century (FAO 2017). With technological advancement and progress on other SDGs (e.g., good health and well-being, **SDG 3**), life expectancy at birth has also been increasing. Some countries are currently projected to grow very rapidly, with annual growth rates of more than 2.5% to 2050 projected for Angola, Burundi, Chad, the Democratic Republic of the Congo, Gambia, Malawi, Mali, Senegal, Somalia, the United Republic of Tanzania, Uganda, and Zambia. The share of the population over the age of 65 is also increasing, including in some rural areas of low-income countries. This has an impact on the availability of labour to support agricultural production.

The rural poor, vulnerable, and marginalised groups, and those below or just above the poverty line are particularly susceptible to hunger (see **SDG 1**). They are highly dependent on seasonal rainfall to support agriculture, and often live in economically depressed and ecologically vulnerable areas. Communities living in poverty may have limited access to agricultural information (e.g., meteorological forecasts), services, technologies, and markets. Those in poverty are disproportionately affected by disease and the effects of economic, social, and environmental shocks—reducing productivity through time away from agricultural tasks. Gender inequality (**SDG 5**) can also have significant implications for hunger and poverty. Globally, about 60% of people who go hungry are female (UN Women 2012), amounting to almost half a billion women and girls not having access to the food required to live healthy lives.

Despite agricultural food production being mainly a rural activity, more people now live in cities (see **SDG 11**), and this has important implications for food supply and future in terms of a transition in dietary patterns with significant impact on food systems (FAO 2017). Indeed, the **SDG 2** targets have been criticised as being too limited in scope, taking only an agricultural and rural-centred approach and overlooking growing urban populations and the role of non-agricultural sectors (Burchi and Holzapfel 2015).

Increasing life expectancy and population sizes, the persistence of extreme poverty and inequalities, and urbanisation will have a significant effect on world hunger due to an increase in demand for food, with important repercussions on the agricultural labour force and the socio-economic fabric of rural communities (FAO 2017). These effects are most likely to have the greatest impact in the Global South.

2.3.2 Environmental Factors

There is an ecological and socio-economic trade-off between clearing land to increase the quantity and quality of investment in agriculture and protecting the environment and mitigating climate change in many parts of the world, but particularly in many of the world's least developed countries. Meeting increased food demands entails both land clearing and the intensive use of existing agricultural land to increase crop production. Both activities can have a major impact on the natural environment.

Forests are important for the provision of ecosystem services (e.g., carbon sequestration and biodiversity conservation, see **SDG 15**), but are affected by commercial logging and large-scale land-use change, including the development of palm oil plantations. Deforestation and land clearing drive habitat fragmentation and threaten biodiversity (Dirzo and Raven 2003; Varsha et al. 2016). Palm oil plantations support much fewer species than natural forests, and often also fewer than other tree crops, contributing to habitat fragmentation and pollution (Fitzherbert et al. 2008). Almost all oil palm grows in areas that were once tropical moist forests, and the conversion of these areas, and future expansion, threatens biodiversity and increases greenhouse gas emissions (Varsha et al. 2016). As forest habitat is cleared, endangered species are pushed closer to extinction, and indigenous people who are mostly smallholder farmers who have inhabited and protected the forest for generations are often driven from their land. Many communities engaged in rural agriculture traditionally depend on neighbouring forests for commodities such as fruits and wood to supplement their diet and income.

Land degradation is occurring in almost all world regions, affecting about 20% of the global land area and impacting upon around three billion people (described further in **SDG 15**). This leads to nutrient depletion, especially in Africa, the intensive use of fertilisers, and soil contamination. Continued degradation of land may lead to a rise in rural poverty triggering human conflict, rural instability, and large-scale population migrations crossing borders and regions (von Braun et al. 2017). The annual global cost of land degradation is about US$ 300 billion, with a quarter of this cost relating to degradation in sub-Saharan Africa (Nkonya et al. 2016). This includes both costs to immediate land users due to a reduction in the functioning of the land, and a significant social cost due to loss of local and global ecosystems services (von Braun et al. 2017). Pressures on land use create wider socio-economic effects, including reductions in the size of household farms and reduced household food production, potentially reducing food security, impacting on health, and exacerbating poverty (GRAIN 2014).

While recognising problems of deforestation and land degradation, there is also, however, a growing concern that the amount of crops harvested per unit of land cultivated is not enough to meet the forecasted demand for food. The effects of climate change-driven water scarcity, rising global temperatures, and extreme weather will impact on volumes and distribution of crop yields at both local and national scales, exposing many vulnerable people in rural communities who rely on agriculture. Weather-related events are already affecting food availability in many countries and contributing to a rise in food insecurity (drought and flood) diminishing livestock and productivity, resulting in migration and an expanding the pool of environmental refugees with broadly held grievances (FAO 2019). Many communities across sub-Saharan Africa are affected by an increase in the frequency and intensity of extreme weather conditions and environmental change, as a result of anthropogenic-driven climate change. This includes rising temperatures, declining groundwater tables, changing water flows, droughts, floods, and strong winds which can slow progress toward increasing the productivity of crop and livestock systems and undermine long-term food security (De Pinto and Ulimwengu 2017; von Braun et al. 2017). These effects will particularly impact those regions that are most food insecure (i.e., many communities in sub-Saharan Africa), together with large food producers such as China and India.

Mining, forestry, and urbanisation all put pressures on water security, which affects agricultural capacity and productivity. Agriculture is estimated to account for 70% of water consumption and 30% of energy consumption and greenhouse gas emissions globally (Janus and Holzapfel 2016). In low-income countries, however, the average share of total freshwater withdrawals used for agriculture is as high as 90%, contrasted with 41% in high-income countries (Ritchie and Roser 2019), illustrated in Fig. 2.5. The agriculture sector is the largest consumer of groundwater resources, with food security therefore inextricably linked to the effective management of groundwater and other freshwater resources around the world (see **SDGs**

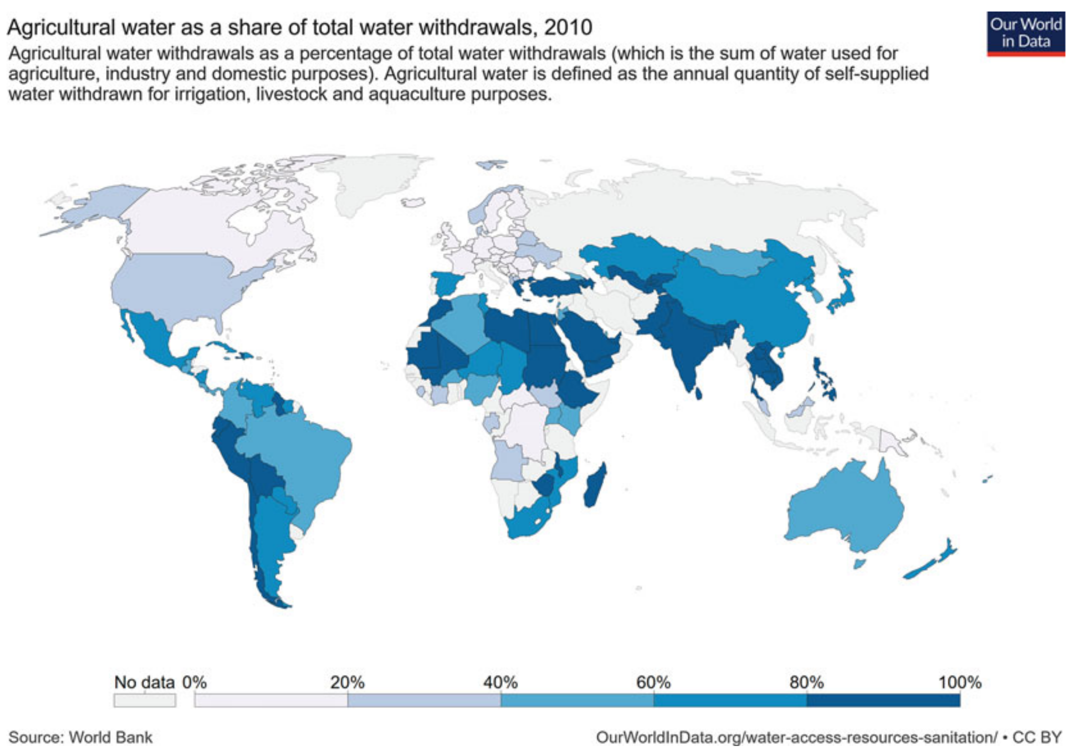

Fig. 2.5 Agriculture Water as a Share of Total Withdrawals (2010). Share of total water withdrawals (agriculture, industry, domestic), used for agriculture, as of 2010, including water for irrigation, livestock, and aquaculture purposes. *Credit* Ritchie and Roser (2019), with data from the UN Food and Agricultural Organization (FAO) AQUASTAT Database. Figure reproduced under a CC-BY license (https://creativecommons.org/licenses/by/4.0/)

6 and **15**). Pressures on water resources from agriculture will increase with the expansion of irrigation and changes to diets and food consumption. The water requirements for the production of different food types differ enormously (Mekonnen and Hoekstra 2012). One tonne of beef requires more than 47 times the amount of water to produce compared to one tonne of most vegetables. One kilocalorie from beef requires almost 20 times the amount of water to produce compared to one kilocalorie from cereals.

Sustainable land and water use are therefore critical to delivering **SDG 2**, and many other parts of the UN sustainable development agenda, including improved health (**SDG 3**), access to safe drinking water (**SDG 6**), sustainable urbanisation (**SDG 11**), and restoration of ecosystems (**SDG 15**). The UN Environment Programme (UNEP) note that a major overhaul of the global food system is urgently needed if the world is to use natural resources more efficiently and stem environmental damage (UNEP 2016). Food systems are considered to be inefficient and unsustainable, responsible for 60% of global terrestrial biodiversity loss, 24% of global greenhouse gas emissions, overfishing of 29% of commercial fish populations, and overexploitation of 20% of the world's aquifers (UNEP 2016). The concern is also voiced that more than two billion suffer from micronutrient deficiencies—mainly vitamin A, iodine, iron, and zinc—and more than two billion people are overweight or obese (UNEP 2016). The report notes that '*land degradation, the depletion of aquifers and fish stocks and contamination of the environment will lower future food production capacity, thus undermine the food systems upon which our food security depends, as well as cause further degradation of other ecosystem functions*' (UNEP 2016, p. 17). Actions to deliver **SDG 2** must therefore work in coherence with the actions proposed to address **SDGs 6**, **14**, and **15**. Geoscientists contributing to these other goals—in the myriad of ways outlined through this book—should have in mind the needs of **SDG 2**, and the ways in which their actions to deliver one or more goals can support or hinder food security and access.

2.4 Delivering SDG 2—The Role of Geoscience in Reducing Hunger

In the previous section we have outlined a range of challenges contributing to hunger and hindering efforts to deliver SDG 2, and demonstrated the need for diverse disciplines and coherence across the SDGs. Environmental and climate change are impacting on agricultural yields, and efforts to drive up agricultural production to meet rising demand are contributing to environmental change. Global and local actions are needed to reduce the environmental impacts of agriculture, manage the human influence on the environment, and achieve both food security and environmental quality (Chen 1990). Geoscience research, knowledge exchange (particularly building partnerships with those developing water, land, health, and agricultural policies), and practice can support efforts to end hunger, achieve food security, improve nutrition and promote sustainable agriculture.

2.4.1 Geological Characterisation to Improve Agriculture

Good management and sustainable use of the Earth's natural resources is essential to eliminating global hunger (addressing SDG **Targets 2.3** and **2.4**), including geological resources such as minerals and rock materials (as well as water resources, discussed in Sect. 2.3.2). Land degradation is a common consequence of poor management of natural resources, affecting food availability. To combat the challenges described in Sect. 2.2, UNEP (2016) recommend a switch to a 'resource-smart' food system, changing the way food is grown, harvested, processed, traded, transported, stored, sold, and consumed. These stages should all have a low environmental impact, use renewable resources sustainably, and use all resources (e.g., soils, fertilisers, water) efficiently. UNEP (2016) recommends approaches to generate higher yields without increasing environmental impacts (e.g., reducing forest loss, making agriculture supply chains carbon neutral), improvements in nutrient efficiency, and reduction of overconsumption and change of unhealthy dietary patterns.

The emphasis on efficiencies in the UNEP (2016) recommendations, provides many opportunities for geoscientists to inform planning and policies. Geological materials and processes influence landscapes and both soil structure and chemistry, and therefore affect the ability to grow crops in any given location. Geological mapping and mineral resource assessment, combined with high-resolution satellite remote sensing data, would therefore provide useful information on national scale soil resources to inform planning. At the community (village or small town) scale, where greatest change is needed, improved understanding of soil chemistry (e.g., mineral depletion and carbon content) can lead to better targeted application of fertilisers.

Geology will also determine the availability of local mineral resources for fertilisers, rock materials for liming and crop cover, and water resources for irrigation. Appleton (1994) notes that in some contexts the direct application of finely ground phosphate rocks (Fig. 2.6) and potassium feldspar rich rocks may provide nutrients for crops. *Rocks for Crops*: *Agrominerals of Sub-Saharan Africa* by Van Straaten (2002) describes the potential for naturally occurring nutrient-providing rocks and minerals to support agriculture, alongside 'soil amendments' (e.g., sources of lime, and pumice to reduce water evaporation and soil erosion). Van Straaten (2002) summarises the potential role that geological materials can play in sustaining and enhancing soil productivity and biomass production, and provides an inventory of known agricultural mineral resources for 48 countries in sub-Saharan Africa. Understanding local availability of such resources, and utilising these, together with changing tilling practice can all help to improve crop yields, extend the growing season, and mitigate the impacts of drought.

Agricultural geology (or agrogeology) therefore provides information about the state of soil resources and potential means to improve them to increase productivity, particularly of small-scale food producers (**Target 2.3**). There is an urgent need for high-resolution maps of land resources, to help address the challenges of climate change and meeting the ambitions of **SDG 2** in an environmentally sensitive manner. Such

Fig. 2.6 Phosphorite Mine (Oron, Negev, Israel). Phosphorite, or phosphate rock, is a sedimentary rock with large amounts of phosphate minerals. Mining of phosphorite is an important source of fertiliser (as well as animal feed supplements)

information can support reliable crop forecasts in order to project food availability. Despite the importance of crop production, and the associated challenges, some countries in Africa (e.g., Kenya, Senegal, Zimbabwe) lack reliable and timely agricultural production forecasting systems to support decision-making at the national to household levels (FAO 2018b).

Box 2.3 Examples of Soil Mapping and Database Projects

There are global calls to have all soil resources mapped, and this data made freely available. Examples of key initiatives and ongoing projects from national to global scales, include the following:

- A consortium of institutions, coordinated by the FAO, are developing a *Harmonized World Soil Database*[3] with more than 15,000 different soil mapping units (FAO et al. 2009).
- FAO and UNESCO have developed a *Soil Map of the World*[4] at a scale of 1:5,000,000.
- The *Africa Soil Information Service* (ALFSIS)[5], funded by the Bill and Melinda Gates Foundation, works to ensure the application of world-class information technology and data science to Africa's soil and landscape resources.
- The *UK Soil Observatory*[6] is an online archive of UK soils data from nine research bodies, helping people to access soil data, knowledge, and expertise from across a wide range of institutions.
- The European Soil Data Centre have produced a free-to-access *Soil Atlas of Latin America and the Caribbean*[7] published in English, Portuguese, and Spanish.

Initiatives such as these should be welcomed, supported, and disseminated by geoscientists. They could be complemented with additional knowledge of geological resources to ensure soils are protected, restored, and remain productive for future generations.

2.4.2 Efficient Management of Water Resources

Geoscience underpins our knowledge of both the availability of water resources and the sustainable management of these resources to prevent serious depletion, degradation (e.g., due to salinity), and prolonged water stress. Sustainably managing water resources is key to SDG **Target 2.4**, implementing resilient agricultural practices and strengthening capacity for adaptation to climate change and extreme hydrometeorological events. For example, in some regions, groundwater resources may have a reasonable degree of resilience to climate variability. Understanding location-specific precipitation–recharge relationships can therefore guide decision-making about how to increase climate resilience of agriculture, through improved water management (Cuthbert et al. 2019).

To assess the extent of groundwater resources and how these change over time, there is a need for data. This includes geological and hydrogeological characterisations of the region (i.e., understanding the subsurface, the potential availability of groundwater, aquifer yields, and groundwater chemistry). There is also a critical need for long-term monitoring networks to assess changes to groundwater resources over time. Many places around the world lack hydrological monitoring networks or data is not made available to the public (McNally et al. 2016), making it difficult to monitor and interpret

[3]http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/.
[4]http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/faounesco-soil-map-of-the-world/en/.
[5]http://africasoils.net/.
[6]http://www.ukso.org/.
[7]https://esdac.jrc.ec.europa.eu/content/soil-atlas-latin-america.

hydrometeorological variables such as soil moisture (Myeni et al. 2019). Improved understanding of interactions between soil moisture and groundwater could, however, inform preparations for times of water scarcity and adaptation strategies for crop management to improve food security. Soil moisture deficit is the difference between the amount of water actually in the soil and the amount of water that the soil can hold (AMetSoc 2012), and normally results in reduced crop production. Where monitoring networks do not exist, satellite data can provide information on rainfall and vegetation changes (McNally et al. 2016). Improved monitoring and more research is needed, however, to understand long-term changes in seasonal rainfall and accompanying extreme events such as floods and dry spells (Chabala et al. 2013), and their impacts on agricultural production.

Finally, geoscience can ensure water is used efficiently, contributing to coherent and comprehensive water management plans. Section 2.2 illustrated the significance of water withdrawals for agriculture in low-income countries, noting that this forms a major share (compared to domestic and industrial use), and much greater than in high-income countries. Expanding industrialisation (**SDG 9**) and meeting growing domestic demands (**SDG 6**) will both exacerbate water stress, unless significant efficiencies are made in agriculture. This could include: (i) better matching water quality to water use, (ii) more efficient irrigation methods, and (iii) selection of crops and food products that require less water. These measures together with the use of geological resources (e.g., pumice, scoria) to reduce water evaporation from soils could all help.

2.4.3 Geochemistry, Agriculture, and Health

The growth and development of plants is affected by the geochemical characteristics of soil and water, with subsequent impacts on human and livestock health (Thornton 2002; Ma and Li 2019; Rawlins et al. 2012). Elements essential to plant, animal, and human health (micronutrients) are not distributed across all soils evenly. Element abundances being too low can result in nutrient deficiencies and element abundances being too high can result in toxicity, both associated with health problems (Fordyce 1999), as discussed in **SDG 3** Problems may also occur when pollution associated with industry or pesticides has contaminated soils, and this is taken up into plants and then ingested by humans. Regional and national geochemical atlases, developed through a systematic sampling of soils or stream sediments, can inform the optimisation of land-use (Thornton 2002), guiding whether regions are suitable for crop growth or whether they are contaminated by heavy metals, excessive pesticide residues, or organic chemicals (Ma and Li 2019). Geochemists can, therefore, contribute to the delivery of **SDG 2** through understanding the chemistry of soils and the uptake and bioavailability of nutrients (and contaminants) in food crops. This informs interventions to deliver **Target 2.2** (end all forms of malnutrition), as well as other related SDG targets linked to health and well-being (**SDG 3**).

In regions where soils have become depleted of essential micronutrients for plants (e.g., boron, chlorine, copper, iron, manganese, molybdenum, nickel, zinc), biofortification can be used or treatments can be added to soils (Alloway 2008). Understanding the soil geochemistry and structure can help to determine what micronutrient deficiencies may occur, and how to treat these (Fig. 2.7). For example, soils with a high calcium carbonate content, with a low pH, or that are heavily limed may give rise to zinc deficiencies in crops (Alloway 2008). This can be treated using a zinc sulphate or oxide, added to the soil to help improve plant health. How effective this is, and the time needed before a further treatment will again depend on the soil chemistry (e.g., soils being limed to reduce acidity may find treatment ineffective).

Fig. 2.7 Zinc Deficiency in Macadamia Shoots. The youngest leaves, those at the tips of the branches, show yellowing (production of produce insufficient chlorophyll), dwarfing, and malformation. *Credit* Alandmanson (licensed under the CC-BY-SA 4.0 International license, https://creativecommons.org/licenses/by-sa/4.0/)

2.5 Summary and Conclusions

The crucial role that geoscience will play in global food security cannot be overemphasised. This chapter sets out how an understanding of geological resources and processes can help improve soil and water management, contributing to both improved agricultural productivity and agricultural resilience to environmental change. In turn, these contributions will support the global targets of ending hunger and malnutrition.

Geoscience information must be integrated into land-use planning, to ensure conservation and prudent use of resources. Demands for land from diverse sectors and urbanisation will increase. For example, growing biofuels has been cited as contributing to hunger through a reduction in available land for food production (Wahlberg 2008). Geoscientists can help decision-makers at all scales to consider how the subsurface will impact upon the surface activities, helping to appropriately allocate land. Geological materials shape the quality of soils, and this understanding can guide decisions about what additives are required to improve soils—ensuring this is as efficient as possible. Understanding of locally available geological materials—from groundwater, to nutrient-rich rocks, to soil amendments—can assist in soil management and agriculture. Nations must, therefore, invest in (i) systematic data collection and monitoring networks, (ii) mapping of resources at smaller resolutions, and (iii) research and training of experts, to provide technical advice on how geological resources can be managed to meet the food demands of future generations, while also protecting the environment, and adapting to or indeed mitigating climate change.

We have not covered in this chapter the contribution of geoscientists to developing reliable, resilient, and sustainable infrastructure, essential to getting agricultural produce to markets (see **SDG 9**). We also refer the reader to **SDGs 6** and **15** for a more detailed overview of how geoscientists contribute to water management and protecting ecosystems essential for agricultural productivity. Other innovations such as conservation agriculture and agroforestry are essential for sustainable use of land resources for food production, and we include additional reading associated with these themes at the end of this chapter.

Agricultural and health experts come from many disciplines themselves, and draw on skills ranging from chemistry to statistics, agronomy to meteorology to support sustainable agriculture. Geoscientists must actively build partnerships with these disciplines and listen to their priorities to understand how our science can help to deliver **SDG 2.** Ensuring the end of hunger, food security, and improved nutrition for all demands engagement from many disciplines, working together to increase global food production, with minimum negative impacts on the environment.

2.6 Key Learning Concepts

- Population growth and rising incomes in the Global South (driving dietary changes) are resulting in increased demand for food. We are not meeting the food and nutrition needs of many of the world's poorest communities. In 2017, the number of undernourished people around the world reached 821 million (including 151 million children under the age of 5 with stunted growth), and the absolute number of undernourished people increased by approximately 40 million from 2015 to 2017. **SDG 2** aims to meet this demand and tackle this injustice, ending malnutrition, and ensuring agriculture is efficient and sustainable.
- The Global Hunger Index monitors the level of hunger in the world, and how it is changing, reflecting undernourishment, child wasting, child stunting, and child mortality. Globally, levels of hunger have been falling since 2000, but there remain 48 countries with serious, alarming, or extremely alarming levels of hunger.
- Causes and catalysts of hunger are diverse, with both social and environmental factors and interactions between these. Increasing life expectancy and population sizes, the persistence of extreme poverty and inequalities, a growing middle class, environmental degradation, and poor management of natural resources can all result in production not meeting demands.
- Understanding the underlying geology of a region can inform crop selection, help to understand what additives are required to improve soil performance, and increase efficiency by maximising the use of locally available natural resources for improved soil structure, nutrition and water retention, guiding the extraction of these in a safe and responsible manner.
- Geoscience underpins our knowledge of the availability of water resources and the sustainable management of these resources to prevent serious depletion, degradation, and prolonged water stress. Sustainably managing water resources is key to implementing resilient agricultural practices and strengthening capacity for adaptation to climate change and extreme hydrometeorological events.
- Geochemistry can help inform the optimisation of land use and guide decision-making about where agriculture is or is not suitable. Understanding the bioavailability and uptake of nutrients and contaminants in food crops can inform interventions are appropriate and efficient, contributing to improved nutrition and supporting efforts to deliver **SDG 3**.
- These three contributions require systematic data collection, management, integration, and access to inform decision-making. Investment in (i) systematic data collection and monitoring networks, (ii) mapping of resources, and (iii) research and training, can all support the achievement of **SDG 2**.

2.7 Educational Ideas

In this section, we provide examples of educational activities that connect geoscience, the material discussed in this chapter, and scenarios that may arise when applying geoscience (e.g., in policy, government, private sector international organisations, NGOs). Consider using these as the basis for presentations, group discussions, essays, or to encourage further reading.

- Using the OneGeology Portal[8] explore the rock types in your region and describe their chemistry. Are any of these exploited commercially to support agricultural production (e.g., for fertiliser)? Using van Straaten (2002) as a reference guide, is there any potential for farmers to use geological resources in your region to support agriculture?
- A national Ministry of Water approach you and ask for advice on reducing the share of water withdrawals used for agriculture. Consider the examples mentioned in this chapter to improve water efficiency in agriculture (*e.g., better matching water quality to water use, improved irrigation methods, selection of crops and food products that require less water*) and investigate what each of these may involve and how geoscientists can contribute (you may prefer to have different groups exploring different methods). Present your results to the class.
- What geochemical mapping has been done in your country? Review the scale of mapping, and what exactly has been mapped (e.g., what elements, what regions if not the whole country). How easy is to access this information? Is it available to the public? Discuss with your peers locally appropriate ways that you could improve access to and understanding of geochemical information to inform agriculture.
- What are the components of a healthy diet? How easy is it to access this range of food products in your region? Think about the origins, transport, processing, and marketing of this range of food products. What are the contributions geoscientists can make to ensure access to this food, and to reduce the environmental impact of generating, transporting, processing, and marketing the food?

[8]http://portal.onegeology.org/OnegeologyGlobal/.

Further Resources

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