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Advancing Climate Change Mitigation in Agriculture while Meeting Global Sustainable Development Goals

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Ever since its inception in 1945, the United Nations has addressed international issues of cultural, educational, economic, and human wellbeing through a series of initiatives that have evolved over time. The most recent of these initiatives is that of the Sustainable Development Goals (SDGs), launched in 2015. Of the 17 SDGs, 8 are strongly dependent on the judicious management of soil processes and their properties. However, many countries are not on track to accomplish these goals, and they also have the problems of soil and water degradation. An effective conservation of soil and water resources, restoration of degraded soils, adoption of conservation agriculture, and recarbonization of soil and vegetation are critical to advancing SDGs. Complementary to SDGs are initiatives, including the "4 per Thousand," to enhance sequestration of carbon (C) in soil for food and climate.

Global human population (in millions) was 200, 275, 450, 500, and 700 in the years 1, 1000, 1500, 1650 and 1750 AD, respectively. The population increased rapidly and was (in billions) 1.0, 1.2, 1.6, 2.0, 2.55, 3.0, 4.0, 6.0, 7.0 and 7.77 in the years 1804, 1850, 1900, 1927, 1950, 1960, 1975, 1999, 2011, and 2019, respectively (Rosenberg 2019). The world population (in billions) is projected to be 8, 9, 10, and 11.2 by 2025, 2043, 2083, and 2100, respectively (UN 2017, 2019).

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The rate of increase in global food production has exceeded that of the population growth since 1960. World cereal production was 785 Mt (865 million tn) in 1962, 998 Mt (1,100 million tn) in 1970, and more than 3 Gt (3.31 billion tn) in 2017 (table 1). Whereas the world population increased by a factor of 2.48 between 1960 and 2017, the total cereal grain production increased by a factor of 4.05 over the same period (table 1). Consequently, the per capita cereal grain production increased from 241 kg (530 lb) in 1961 to 395 kg (869 lb; +64%) in 2017, with an overall increase by a factor of 1.64. Such an impressive gain in food production, however, has been realized with severe environmental consequences, such as warming of climate, degradation of soils, eutrophication of water, pollution of air, reduction of biodiversity, extinction of species, etc. Furthermore, nutritional quality of food may not necessarily improve with an increase in total grain production because the increase in atmospheric concentration of carbon dioxide (CO_2) may threaten human nutrition (Myers et al. 2014). Thus, future needs for food production must be reconciled with the necessity of improving the environment by adopting the food-energy-water-soil nexus approach because of their strong interconnectivity (Kopittke et al. 2019), and by making agriculture nutrition sensitive (Soares et al. 2019). Rather than expanding the land area under agriculture, large yield gaps must be abridged (Neumann et al. 2010; Foley et al. 2011; Tilman et al. 2011; Wu et

Table 1

Total population, global cereal grain production, and the per capita grain production. The data on population is from Rosenberg (2019) and UN (2017), and that of cereal grain production is from the World Bank (2017).

Year	Population (10^9)	Cereal production (10^6 Mg)	Per capita production (kg)
1961	3.05	736	241
1970	3.71	998	269
1975	4.00	1,202	301
1980	4.45	1,342	302
1985	4.85	1,613	333
1990	5.28	1,706	323
1995	5.70	1,885	331
2000	6.08	2,050	337
2005	6.50	2,250	346
2010	6.93	2,463	355
2015	7.36	2,859	388
2017	7.55	2,980	395

al. 2018) and land resources saved for nature conservancy (Lal 2016). These options are properly called "climate-smart agriculture" (Dinesh et al. 2018), or regenerative agriculture (Francis et al. 1986; Rhodes 2017).

There is already an adequate amount of global food production even for a total population of 10 billion. However, the causes of undernourishment of 821 million people globally (FAO et al. 2018, 2019) are those related to inadequate access to and distribution of food, political instability, and internal displacement and civil strife. Additionally, 2.1 billion people are prone to the epidemic of overweight and obesity, and 2 billion to micronutrient deficiency (Beal et al. 2017). Excessive food intake, insufficient physical activity (Hill and Peters 1998), and inappropriate diet (Caballero 2007) aggravate obesity. The increase in atmosphere CO_2 concentration may decrease protein content in rice, wheat, barley, and potato by 7.6%, 7.8%, 14.1% and 6.4%, respectively (Medek et al. 2017), which may contribute to malnutrition. There is the serious problem of food waste (Corrado et al. 2019), and 1.3 Gt (1.43 billion tn) of food is wasted annually (Depta 2018). The amount of food wasted could feed 2 billion people (Huber 2017).

Impressive progress in agronomic production has also perturbed the global C cycle with drastic increase in atmospheric concentration of CO_2, methane (CH_4), and nitrous oxide (N_2O) since 1750 (WMO 2019). The decoupling of the coupled cycling of water, C, nitrogen (N), phosphorus (P), and sulfur (S) has exacerbated environmental degradation.

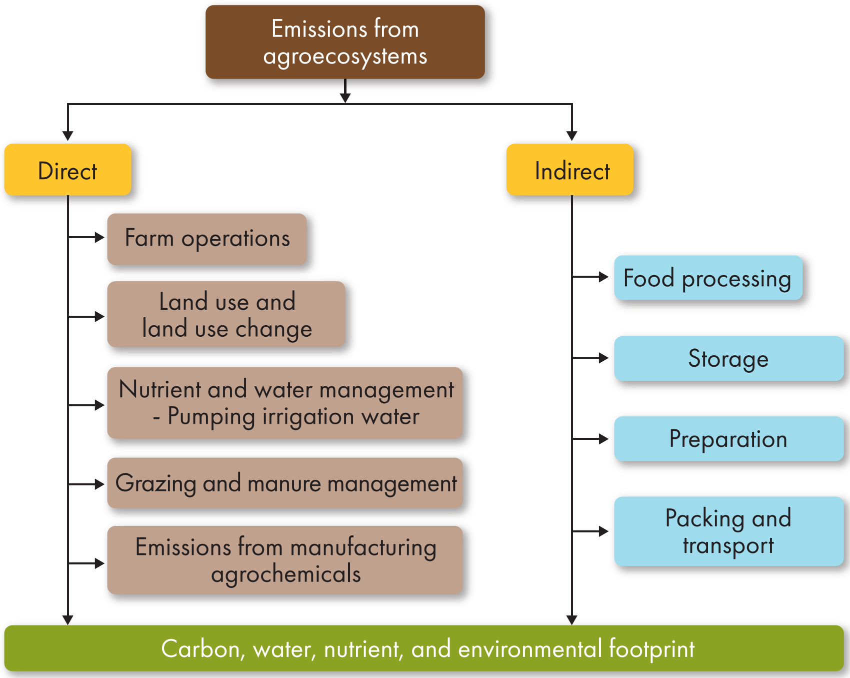
Thus, there is a strong need for a paradigm shift of adopting eco-effective measures of agriculture, which narrow the yield gap, produce more from less, increase food and nutritional security, and advance SDGs of the United Nations. Further, the need for recarbonization of depleted and degraded soils is also in accord with SDGs or the Agenda 2030 (UN 2015). Therefore, the objective of this chapter is to deliberate on the idea that global adoption of restorative and conservation-effective agriculture is critical to food and nutritional security, essential to advancing SDGs, and pertinent to meeting the ambition of climate change mitigation. The review is based on the hypothesis that restoration of depleted and degraded soils can sequester C while creating climate-resilient soils and agroecosystems, and advancing SDGs.

Soil Degradation and the Anthropocene

The so-called "Anthropocene" began with the onset of settled agriculture about 10 to 12 millennia ago, accompanied by deforestation, biomass burning, soil tillage, and drainage of wetlands (Ruddiman 2003). Agriculture, especially extractive farming practices, created a negative ecosystem-C budget, depletion of ecosystem-C stocks, and emission of CO_2 and other greenhouse gases. Cultivation of rice (Sweeney and Mccouch 2007; Callaway 2014) and domestication of animals (Bollongino et al. 2012) caused emissions of CH_4. Production and use of synthetic fertilizers since the mid-20th century have been the major source of N_2O (Smil 2001). Direct and indirect emissions from agroecosystems contribute about 30% of the total anthropogenic emissions expressed as CO_2 equivalent (CO_2 eq; figure 1).

Figure 1

Direct and indirect sources of emissions.



Conversion of natural landscapes to agroecosystems also exacerbated soil degradation by physical, chemical, and biological processes. Soil degradation by erosion affects as much as 1.1 Gha (2.72 billion ac) by water and 0.55 Gha (1.36 billion ac) by wind erosion (Oldeman 1994). Sediment transport into world rivers has increased from 14 Gt (15.43 billion tn) during the prehuman era to 36 Gt (39.7 billion tn) at present (Walling 2008, 2009). Expansion of land area equipped for irrigation in arid and semiarid regions increased risks of secondary salinization and depleted the groundwater level of aquifers around the world including the Indo-Gangetic Plains (Mukherjee et al. 2018), North China Plains (Yang et al. 2017), and the Ogallala of the US Great Plains (Terrell et al.

2002). Depletion of the soil organic C (SOC) stock in world soils is estimated at 133 to 135 Gt C (146.6 to 148.8 billion tn C) (Sanderman et al. 2017; Lal 2018). The negative nutrient budget in croplands of Africa, especially in sub-Saharan Africa (Kiboi et al. 2019), is the cause of low yield and poor nutritional quality of the food (Davidson et al. 2016). Land area vulnerable to diverse degradation processes covers 24% of the ice-free land (Bai et al. 2008) and affects as many as two billion people. Further, risks of soil degradation may be exacerbated by the present and projected climate change (Jiang et al. 2014).

Sustainable Development Goals

Beginning with the report of the Brundtland Commission (World Commission on Environment and Development 1987), the United Nations has thus far focused on sustainable development through three consecutive development initiatives. The Agenda 21 was launched following the US Conference in Rio in 1992. The Millennium Development Goals, initiated in 2000, were built on the Agenda 21. The SDGs of 2015 comprise 17 specific focal points with numerous targets. The common themes connecting these three initiatives, improving the environment (i.e., climate, air, water, biota) and enhancing human wellbeing (i.e., food, equity, poverty, education), are strongly related to soil functionality and health, but especially to the accomplishments of some key SDGs.

SDGs closely related to soil processes include #1 (Ending Poverty), #2 (Zero Hunger), #6 (Clean Water and Sanitation), #13 (Climate Action), and #15 (Life on Land) (Bouma 2014, 2019; Bouma and Montanarella 2016; Hanjra et al. 2016; Keesstra et al. 2018; Lal et al. 2018a; Gil et al. 2019). If world soils are under threat (Montanarella et al. 2016), then SDGs are also under threat (Lal et al. 2018a). Indeed, 5 years into the 2030 Agenda, the world is not where it needs to be, and SDGs are also under increasing threat because of the COVID-19 pandemic and the rapidity of global warming. At the current rate of accomplishment, most SDGs may not be met within the next 10 years (Xu et al. 2020). There are several implications if SDGs are not met: poverty and hunger will perpetuate, human health and wellbeing will be jeopardized, water quality will degrade, aquatic life will be at risk, global warming will accelerate, and land degradation will be exacerbated. Therefore, improving and sustaining soil health is a high priority.

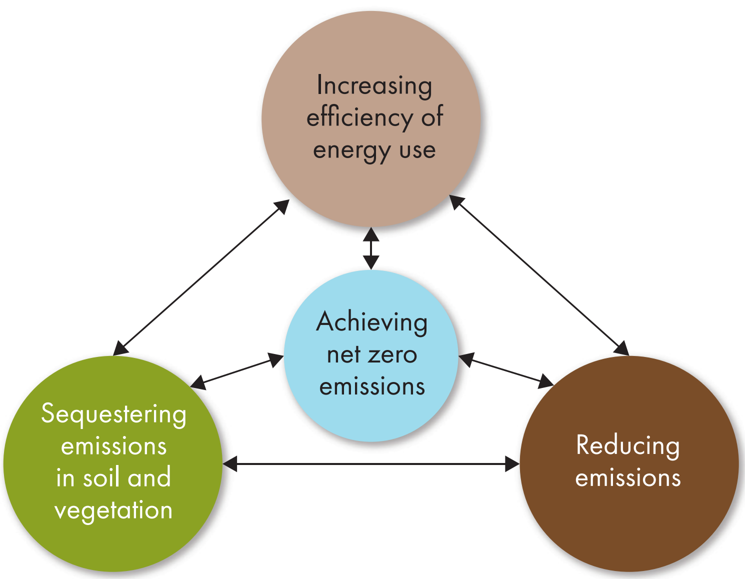
Achieving Goals of Soil Carbon Sequestration

The COP 21 Climate Agreement of 2015 is a voluntary initiative to limit anthropogenic warming below 2.0°C (3.6°F) compared with the preindustrial levels, while also pursuing the options to limit the temperature increase to 1.5°C (2.7°F). In the meanwhile, the global mean temperature is increasing at the rate of 0.2°C ± 0.1°C (0.36°F ± 0.18°F) per decade, and it reached ~1°C (1.8°F) above the industrial levels in 2017 (Allen et al. 2018). With business as usual, the global mean temperature may reach 1.5°C as early as 2030 to 2050 (Allen et al. 2018). Achieving the ambitious target of limiting global warming to 1.5°C would imply achieving net zero greenhouse gas emissions by 2050 (IPCC 2018). However, there is still time to limit the global warming to 1.5°C by reducing anthropogenic emissions and sequestering atmospheric CO_2 in soil and vegetation (Lal et al. 2018b). Reduction in emissions from industry and travel because of the lockdown necessitated by the COVID-19 pandemic indicates that anthropogenic warming can be deaccelerated by judicious and timely action (Lal 2020a). The global land area adversely impacted is estimated at 4% (range of 2% to 7%) with warming of 1°C, 6.5% corresponding with warming of 1.5°C, and 13% (range of 8% to 20%) with the global warming of 2°C (Hoegh-Guldberg et al. 2019). The adverse effects of global warming on ecosystems are more severe for drylands than humid climates (Lal 2019c; Hoegh-Guldberg et al. 2019).

There are three strategies of achieving the net zero emission by 2050 (figure 2): (1) increasing efficiency by substituting low-C fuel sources (e.g., gas versus coal), (2) reducing emissions by implementing non-C fuel sources (i.e., wind, solar, hydro, geo, nuclear), and (3) sequestering emissions (e.g., terrestrial).

Figure 2

Strategies to achieve net zero emissions from agroecosystems.



Agriculture and Soil as a Source of Greenhouse Gases

Since 1751, anthropogenic activities have emitted a total of 1.5 trillion t (1.65 trillion tn) of CO_2 (Friedlingstein et al. 2019), of which the United States has contributed 25% of the total (Ritchie and Roser 2019). In general, one-third of the total anthropogenic emissions are contributed by agriculture (Gilbert 2012). Therefore, adoption of improved agricultural practices (eco-effective techniques such as conservation agriculture) can reduce emissions and limit global warming (Thornton et al. 2018). Low-emission or no-emission agriculture should be the goal (Sà et al. 2017).

Soil is a source or sink of greenhouse gases depending on land use and management. Oertel et al. (2016) used an average rate of emission from all soils of 300 mg CO_2 eq m^{-2} h^{-1} (1,713 lb CO_2 eq mi^{-2} hr^{-1}) or a global annual net soil emission of 350 Gt (385.8 billion tn) CO_2 eq. This is approximately equivalent to 21% of global soil C and N stocks. Total annual emissions from farm soils have been estimated at 68 to 77 Gt C (75.0 to 84.9 billion tn C) (Raich and Schlesinger 1992; Raich and Potter 1995), and at 98 Gt C (108 billion tn C) (Bahn et al. 2010). The Intergovernmental Panel on Climate Change estimated that 35% of CO_2, 42% of CH_4, 53% of N_2O, and 21% of nitric oxide (NO) of the total annual emissions are from soils (IPCC 2007). Globally, food is responsible for approximately one-quarter of greenhouse gas emissions (Poore and Nemecek 2018; Ritchie 2019). With more than 70 billion animals raised annually for human consumption (Arcipowska et al. 2019), meat production has strong implications for resource use and the environmental footprint.

Reducing Emissions from Agricultural Soil and Managing Soil for Enhancing Its Capacity as a Sink of Atmospheric Carbon Dioxide

Emissions from the manufacture and application of agricultural chemicals (Lal 2004a) can be reduced by alternative approaches to managing soil fertility (e.g., biofertilizers and integrated nutrient management) and use of low-chemical or no-chemical pesticides (e.g., integrated pest management), and through enhancement and restoration of soil health that creates disease-suppressive soils (Mendes et al. 2011; Schlatter et al. 2017). Erosion-induced emissions and those from plow-based tillage can be reduced by conversion to conservation agriculture. A system-based conservation agriculture must be implemented in conjunction with crop residue mulch, incorporation of cover crops in the rotation cycle, use of complex cropping systems along with integrated nutrient management, use of perennial systems (Waldron et al. 2017; Gunathilaka et al. 2018), and integration of crops with trees and livestock (Lal 2015). These are pertinent options of land use and soil management for staying within the planetary boundaries (Heck et al. 2018). These are examples of eco-effective techniques (Czyżewski et al. 2018) because not all practices of sustainable intensification always produce the desired results (Mockshell and Kamanda 2018; Dicks et al. 2018).

Soils of agroecosystems are depleted of their antecedent SOC stocks. The soil-C sink capacity thus created can be filled by adoption of recommended management practices (RMPs), which create a positive ecosystem/soil C budget (Lal 2004b, 2010, 2018; Lal et al. 2018b). Conversion from a conventional tillage to conservation agriculture, along with the use of agroforestry, biochar, organic amendments, etc., can lead to SOC sequestration (Lal et al. 2018b). There is also a potential of sequestration of soil inorganic C as secondary carbonates and through leaching of bicarbonates in arid and semiarid climates (Lal 2019c).

The soil is a source of CO_2 if the net ecosystem exchange (NEE), the difference between photosynthesis and ecosystem (soil, vegetation, and biota) respiration, is positive, and a sink if it is negative. The objective of sustainable management of agricultural soils is to enhance their C sink capacity through a negative NEE. Increase in fertilizer use has increased agronomic productivity and improved access to food. It is estimated that N fertilizer supports 42% of all births over the last century (1910 to 2010) (Erisman et al. 2008; Ritchie 2017). As much as 30% to 50% of the yield increases may be attributed to fertilizers (Smil 2001; Stewart et al. 2005).

However, the magnitudes of NEE and net biome productivity are strongly affected by soil moisture regime (Zhao and Running 2010; Green et al. 2019). Drought stress, and loss of soil water in the subsoil, may be exacerbated by climate change (Feddema and Freire 2001). However, the plant available water capacity of the soil can be increased by restoring SOC concentration and sustaining it at the threshold level/range (Lal 2020b).

Low external inputs of organic or inorganic fertilizers have reduced productivity and decreased inputs of biomass C into soil. Aggravated soil degradation has diminished the SOC stocks and reduced agronomic productivity. Soil degradation caused by the severe depletion of SOC is a major problem in sub-Saharan Africa and South Asia, where there is a strong need to address environmental challenges by advancing SDGs (Omisore 2018). Predominant agricultural systems in sub-Saharan Africa and elsewhere in developing countries, based on extractive practices and poor management, contribute to the already serious problem of soil degradation and desertification. The goal is to strike the balance between attaining high agronomic yield and decreasing the environmental footprint of agroecosystems. Global cumulative potential of C sequestration (i.e., the maximum amount of CO_2 that can be transferred via photosynthesis into soil and biomass) in the terrestrial biosphere between 2020 and 2100, through adoption of eco-effective practices, is estimated at 155

Gt C (170.9 billion tn C, at the annual rate of 3.3 Gt [3.64 billion tn]) in the biomass compared with 178 Gt C (196.2 billion tn C, at the annual rate of 3.2 Gt [3.53 billion tn C]) for soil (Lal et al. 2018b). In addition, there exists a large potential of soil inorganic C sequestration in soils of arid regions (Groshans et al. 2018; Lal 2019c).

Toward Low or Zero Emission Agriculture

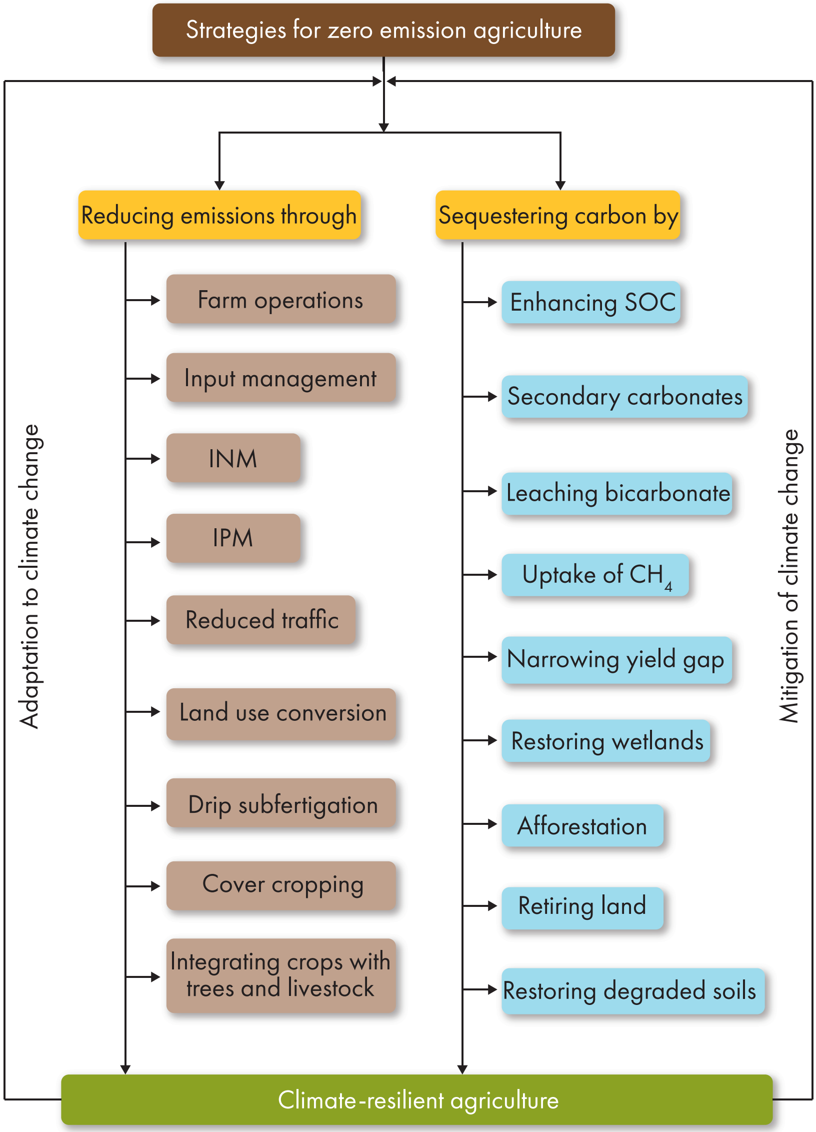
Rather than a problem, improved and science-based agriculture must be a solution to the environmental issues of the 21st century, including the changing climate, contaminated and depleted water resources, polluted air and enriched concentration of greenhouse gases, decreased biodiversity, and degraded landscapes. Important among technologies of achieving low or zero emission agriculture are those that reduce emissions by adopting energy-efficient options or those that are based on renewable sources of energy (figure 3). For South America, Sà et al. (2017) estimated that the terrestrial C sink capacity for adopting RMP-based agriculture is 8.24 Gt C (9.1 billion tn C) between 2016 and 2050. Sà and colleagues calculated that the ecosystem C payback time for RMP-based agriculture may be 50 to 188 years. It may be essential to use payments to incentivize land management for adopting RMPs and strengthening ecosystem services. Payments based on just and fair price of soil C (Lal 2014) may also promote the concept of Rights-of-Soil (Lal 2019a).

Adopting Restorative/Regenerative Agriculture for Advancing Sustainable Development Goals

Adopting improved and restorative/regenerative agriculture is critical to advancing SDGs (Lal et al. 2018b) (figure 4). There is a strong need for adoption of "business unusual technologies" in agroecosystems to advance SDGs and achieve their mission by 2030 (table 2). Improving life on land is essential to achieving the goals of land degradation neutrality adopted by United Nations Convention to Combat Desertification (Lal et al. 2012b; Cowie et al. 2018). Public universities in developing countries can play an important role in advancing SDG #4 focused on education (O'Keeffe 2016). Sustainable management of wetlands can also advance some SDGs (Seifollahi-Aghmiuni et al. 2019), especially SDG #6. Several international initiatives have been launched to promote sequestration of atmospheric CO_2 in world soils. The "4 per Thousand" initiative launched at COP 21 in 2015 encourages farmers to voluntarily enhance SOC concentration in soil at an annual rate of 0.4% to 40 cm (16 in) depth (Chambers et al. 2016). Other initiatives providing region-specific RMPs include Adapting African Agriculture launched at COP 22 in 2016 (Lal 2019b), Global Soil Partnership/Inter-Governmental Panel on Soils (FAO and ITPS 2015), Global

Figure 3

Approaches to making agriculture a solution to climate change.



Notes: INM = integrated nutrient management. IPM = integrated pest management. SOC = soil organic carbon. CH_4 = methane.

Soil Week (Lal et al. 2012a, 2013), land degradation neutrality (Kust et al. 2017; Cowie et al. 2018), the pan-African Great Green Wall across Sahel (Goffner et al.

Table 2

Strategies for mitigation of climate change through achievement of the Sustainable Development Goals or the Agenda 2030.

Specific goal	Specific strategies for mitigating climate change
#2 Zero Hunger	Land saving options, narrowing the yield gap, conservation agriculture, integrated nutrient management, improving use efficiency of inputs
#3 Good Health and Wellbeing	Nutrition-sensitive agriculture, improving soil health by carbon sequestration, enhancing quality of water and air by adopting improved systems
#6 Clean Water and Sanitation	Conservation agriculture, cover cropping, conservation-effective measures, reducing inputs of chemicals, agroforestry with establishment of contour hedges, drip subfertigation
#13 Climate Action	Carbon sequestration in soil and vegetation, producing more from less, integration of crops with trees and livestock
#15 Life on Land	Achieving land degradation neutrality, adopting diverse farming systems, restoring degraded soils

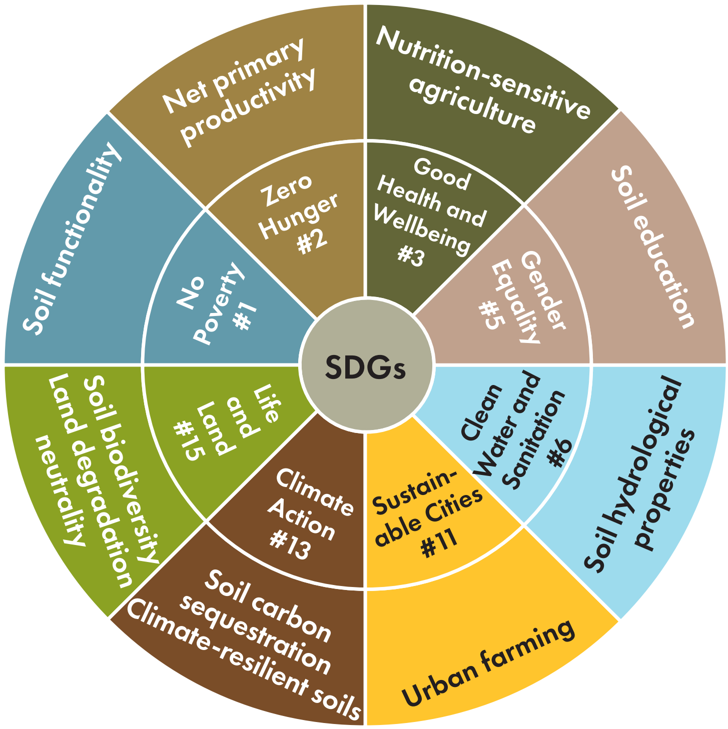
2019), and the Platform on Climate Action in Agriculture for Latin America at COP 25 in Madrid, Spain. Such international initiatives (figure 5), with effective systemic environmental governance (Gupta 2015; Williams et al. 2018; Scown et al. 2019) and political will, are needed to keep the SDGs on track, realistic, and effective (Deonandan and Mathers 2018).

People are the mirror image of the land on which they depend for their livelihood. When people are desperate, hungry, miserable, and suffering, they pass on their suffering to the land (Lal 2009). In turn, the land reciprocates and makes them even more miserable, and people and the land become entrapped in a series of overlapping vicious cycles that are difficult to break (Lal 2020a). It is this desperation and hopelessness that exacerbates the risks of political instability and civil strife and aggravates risks of pandemics (e.g., COVID-19) because of the increase in interactions between humans and the animal kingdom. There are numerous examples of this throughout human history that have resulted in the collapse of once-thriving civilizations (Diamond 2005; Montgomery 2007).

A viable entry point to break these overlapping vicious cycles (Lal 2020a) is the restoration of degraded/desertified soils to enhance their productivity and

Figure 4

Meeting Sustainable Development Goals (SDGs) through soil conservation and restoration.



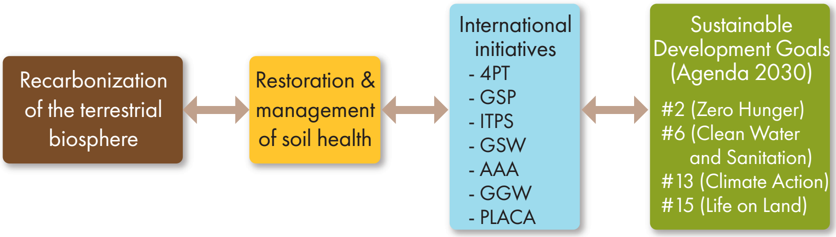
strengthen the provisioning of essential ecosystem services. Recarbonization of the depleted terrestrial biosphere (i.e., soil, vegetation) is a step in the right direction (Lal et al. 2012b).

Conclusions

World soil, water, and other natural resources are adequate to meet rational and just needs of the current and projected population only if the current rate of degradation is curtailed and degraded soils are restored. The commendable progress made in enhancing agronomic production since the 1960s is also linked with large emission of greenhouse gases and the attendant global warming, eutrophication and depletion of water, degradation and depletion of soils, denudation of landscape, and mass extinction of species. While the quantity of grains produced is increased, nutritional quality (i.e., protein and micronutrients) may be adversely affected by soil degradation and global

Figure 5

Recarbonization of soil and terrestrial biosphere through several international initiatives leading to achieving Sustainable Development Goals.



Notes: 4PT = 4 Per Thousand. GSP = Global Soil Partnership. ITPS = Intergovernmental Panel on Soils. GSW = Global Soil Week. AAA = Adaptation of African Agriculture. GGW = Great Green Wall. PLACA = Platform on Climate Action in Agriculture.

warming. Strong threats to soil resources can also endanger SDGs, which are not on track to be accomplished by 2030. Thus, there is a strong need to reconcile the growing demands of the increasingly affluent human population with the necessity of restoring degraded soils and enhancing the environment through recarbonization of the biosphere in general and of the world soils in particular. Adopting the approach of food-energy-water-soil nexus through several international initiatives can keep SDGs on track. There is a need for a paradigm shift in adopting eco-effective measures for agriculture which can narrow the yield gap while restoring SOC stock and improving soil health.

References

Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, K. Zickfeld, P. Dasgupta, H. Eakin, B. Hayward, D. Liverman, R. Millar, G. Raga, A. Ribes, M. Richardson, M. Rojas, R. Séférian, S.I. Seneviratne, C. Smith, W. Steffen, and P. Thorne. 2018. Chapter 1: Framing and Context. *In* Global Warming of 1.5 C: An IPCC Special Report on the Impacts of Global Warming of 1.5 C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, eds. E. Idris, A. Fischlin, and X. Gao. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Arcipowska, A., E. Mangan, Y. Lyu, and R. Waite. 2019. 5 Questions About Agricultural Emissions, Answered. Washington, DC: World Resources Institute. https://www.wri.org/blog/2019/07/5-questions-about-agricultural-emissions-answered.

Bahn, M., M. Reichstein, E. Davidson, J. Grünzweig, M. Jung, M. Carbone, D. Epron, L. Misson, Y. Nouvellon, O. Roupsard, K. Savage, S. Trumbore, C. Gimeno, J.

Curiel Yuste, J. Tang, R. Vargas, and I. Janssens. 2010. Soil respiration at mean annual temperature predicts annual total across vegetation types and biomes. Biogeosciences 7(7):2147–2157.

Bai, Z.G., D.L. Dent, L. Olsson, and M.E. Schaepman. 2008. Proxy global assessment of land degradation. Soil Use and Management 24(3):223–234.

Beal, T., E. Massiot, J.E. Arsenault, M.R. Smith, and R.J. Hijmans. 2017. Global trends in dietary micronutrient supplies and estimated prevalence of inadequate intakes. PloS one 12(4):e0175554.

Bollongino, R., J. Burger, A. Powell, M. Mashkour, J.-D. Vigne, and M.G. Thomas. 2012. Modern taurine cattle descended from small number of near-eastern founders. Molecular Biology and Evolution 29(9):2101–2104.

Bouma, J. 2014. Soil science contributions towards Sustainable Development Goals and their implementation: Linking soil functions with ecosystem services. Journal of Plant Nutrition and Soil Science 177(2):111–120.

Bouma, J. 2019. How to communicate soil expertise more effectively in the information age when aiming at the UN Sustainable Development Goals. Soil Use and Management 35(1):32–38.

Bouma, J., and L. Montanarella. 2016. Facing policy challenges with inter- and transdisciplinary soil research focused on the UN Sustainable Development Goals. SOIL 2(2):135–145.

Caballero, B. 2007. The global epidemic of obesity: An overview. Epidemiologic Reviews 29(1):1–5.

Callaway, E. 2014. Domestication: The birth of rice. Nature 514(7524):S58–S59.

Chambers, A., R. Lal, and K. Paustian. 2016. Soil carbon sequestration potential of US croplands and grasslands: Implementing the 4 per Thousand Initiative. Journal of Soil and Water Conservation 71(3):68A-74A, doi:10.2489/jswc.71.3.68A.

Corrado, S., C. Caldeira, M. Eriksson, O.J. Hanssen, H.-E. Hauser, F. van Holsteijn, G. Liu, K. Östergren, A. Parry, L. Secondi, Å. Stenmarck, and S. Sala. 2019. Food waste accounting methodologies: Challenges, opportunities, and further advancements. Global Food Security 20(2019):93–100.

Cowie, A.L., B.J. Orr, V.M. Castillo Sanchez, P. Chasek, N.D. Crossman, A. Erlewein, G. Louwagie, M. Maron, G.I. Metternicht, S. Minelli, A.E. Tengberg, S. Walter, and S. Welton. 2018. Land in balance: The scientific conceptual framework for Land Degradation Neutrality. Environmental Science & Policy 79(2018):25–35.

Czyżewski, B., A. Matuszczak, C. Burja, and A. Muntean. 2018. Eco-efficiency versus eco-effectiveness in the sustainable development of agriculture: A comparative analysis in EU regions. *In* Proceedings of the 2018 VII International Scientific Conference Determinants of Regional Development, 1(12–13):56-64.

Davidson, E.A., R.L. Nifong, R.B. Ferguson, C. Palm, D.L. Osmond, and J.S. Baron. 2016. Nutrients in the nexus. Journal of Environmental Studies and Sciences 6(1):25–38.

Deonandan, R., and A. Mathers. 2018. Are the Sustainable Development Goals realistic and effective: A qualitative analysis of key informant opinions. International Journal of Sustainable Development 11(3):11–16.

Depta, L. 2018. Global Food Waste and Its Environmental Impact. Reset: Digital for Good. https://en.reset.org/knowledge/global-food-waste-and-its-environmental-impact-09122018.

Diamond, J.M. 2005. Collapse: How Societies Choose To Fail Or Succeed. New York, NY: Viking.

Dicks, L., D. Rose, F. Ang, S. Aston, A.N.E. Birch, N. Boatman, L. Bowles, D. Chadwick, A. Dinsdale, S. Durham, J. Elliott, L. Firbank, S. Humphreys, P. Jarvis, D. Jones, D. Kindred, S. Knight, M. Lee, C. Leifert, and W. Sutherland. 2018. What agricultural practices are most likely to deliver 'sustainable intensification' in the UK? Food and Energy Security 8(1):37.

Dinesh, D., R.B. Zougmoré, J.M. Vervoort, E. Totin, P.K. Thornton, D. Solomon, P. Shirsath, V. Pede, I. López Noriega, P. Läderach, J. Körner, D. Hegger, E.H. Girvetz, A.E. Friis, P.P.J. Driessen, and B.M. Campbell. 2018. Facilitating change for climate-smart agriculture through science-policy engagement. Sustainability 10(8):2616.

Erisman, J.W., M.A. Sutton, J. Galloway, Z. Klimont, and W. Winiwarter. 2008. How a century of ammonia synthesis changed the world. Nature Geoscience 1(10):636–639.

FAO, IFAD, UNICEF, WFP, and WHO. 2018. The State of Food Security and Nutrition in the World 2018: Building Climate Resilience for Food Security and Nutrition. Rome, Italy: Food and Agriculture Organization.

FAO, IFAD, UNICEF, WFP, and WHO. 2019. The State of Food Security and Nutrition in the World 2019: Safeguarding against Economic Slowdowns and Downturns. Rome, Italy: Food and Agriculture Organization.

FAO and ITPS. 2015. Status of the World Soil Resources (SWSR) - Technical Summary. Rome, Italy: Food and Agriculture Organization.

Feddema, J., and S. Freire. 2001. Soil degradation, global warming and climate impacts. Climate Research 17(2):209–216.

Foley, J.A., N. Ramankutty, K.A. Brauman, E.S. Cassidy, J.S. Gerber, M. Johnston, N.D. Mueller, C. O'Connell, D.K. Ray, P.C. West, C. Balzer, E.M. Bennett, S.R. Carpenter, J. Hill, C. Monfreda, S. Polasky, J. Rockström, J. Sheehan, S. Siebert, D. Tilman, and D.P.M. Zaks. 2011. Solutions for a cultivated planet. Nature 478(7369):337–342.

Francis, C.A., R.R. Harwood, and J.F. Parr. 1986. The potential for regenerative agriculture in the developing world. American Journal of Alternative Agriculture 1(2):65–74.

Friedlingstein, P., M.W. Jones, M. O'Sullivan, R.M. Andrew, J. Hauck, G.P. Peters, W. Peters, J. Pongratz, S. Sitch, C. Le Quéré, O.C.E. DBakker, J.G. Canadell1, P. Ciais1, R.B. Jackson, P. Anthoni1, L. Barbero, A. Bastos, V. Bastrikov, M. Becker, L. Bopp, E. Buitenhuis, N. Chandra, F. Chevallier, L.P. Chini, K.I. Currie, R.A. Feely, M. Gehlen, D. Gilfillan, T. Gkritzalis, D.S. Goll, N. Gruber, S. Gutekunst, I. Harris, V. Haverd, R.A. Houghton, G. Hurtt, T. Ilyina, A.K. Jain, E. Joetzjer, J.O. Kaplan, E. Kato, K.K. Goldewijk, J.I. Korsbakken, P. Landschützer, S.K. Lauvset, N. Lefèvre, A. Lenton, S. Lienert, D. Lombardozzi, G. Marland, P.C. McGuire, J.R. Melton, N. Metzl, D.R. Munro, J.E.M.S. Nabel, S.I. Nakaoka, C. Neill, A.M. Omar, T. Ono, A. Peregon, D. Pierrot, B. Poulter, G. Rehder, L. Resplandy, E. Robertson, C. Rödenbeck, R. Séférian, J. Schwinger, N. Smith, P. P. Tans, H. Tian, B. Tilbrook, F.N. Tubiello, G.R. Van Der Werf, A.J. Wiltshire, and S. Zaehle. 2019. Global carbon budget 2019. Earth System Science Data 11(4):1783–1838.

Gil, J.D.B., P. Reidsma, K. Giller, L. Todman, A. Whitmore, and M. van Ittersum. 2019. Sustainable Development Goal 2: Improved targets and indicators for agriculture and food security. Ambio 48(7):685–698.

Gilbert, N. 2012. One-third of our greenhouse gas emissions come from agriculture. Nature News. https://www.nature.com/news/one-third-of-our-greenhouse-gas-emissions-come-from-agriculture-1.11708.

Goffner, D., H. Sinare, and L.J. Gordon. 2019. The Great Green Wall for the Sahara and the Sahel Initiative as an opportunity to enhance resilience in Sahelian landscapes and livelihoods. Regional Environmental Change 19(5):1417–1428.

Green, J.K., S.I. Seneviratne, A.M. Berg, K.L. Findell, S. Hagemann, D.M. Lawrence, and P. Gentine. 2019. Large influence of soil moisture on long-term terrestrial carbon uptake. Nature 565(7740):476–479.

Groshans, G.R., E.A. Mikhailova, C.J. Post, and M.A. Schlautman. 2018. Accounting for soil inorganic carbon in the ecosystem services framework for United Nations sustainable development goals. Geoderma 324 (2018):37–46.

Gunathilaka, R.P.D., J.C.R. Smart, and C.M. Fleming. 2018. Adaptation to climate change in perennial cropping systems: Options, barriers and policy implications. Environmental Science & Policy 82(2018):108–116.

Gupta, J. 2015. Normative issues in global environmental governance: Connecting climate change, water and forests. Journal of Agricultural and Environmental Ethics 28(3):413–433.

Hanjra, M.A., A. Noble, S. Langan, and J. Lautze. 2016. Feeding the 10 billion within the sustainable development goals framework. *In* Food Production and Nature Conservation: Conflicts and Solutions, eds. I.J. Gordon, H.H.T. Pris, and G.R. Squire, 15–41. London, United Kingdom: Routledge.

Heck, V., H. Hoff, S. Wirsenius, C. Meyer, and H. Kreft. 2018. Land use options for staying within the Planetary Boundaries – Synergies and trade-offs between global and local sustainability goals. Global Environmental Change 49(2018):73–84.

Hill, J.O., and J.C. Peters. 1998. Environmental contributions to the obesity epidemic. Science 280(5368):1371-1374.

Hoegh-Guldberg, O., D. Jacob, M. Taylor, T. Guillén Bolaños, M. Bindi, S. Brown, I.A. Camilloni, A. Diedhiou, R. Djalante, K. Ebi, F. Engelbrecht, J. Guiot, Y. Hijioka, S. Mehrotra, C.W. Hope, A.J. Payne, H.-O. Pörtner, S.I. Seneviratne, A. Thomas, R. Warren, and G. Zhou. 2019. The human imperative of stabilizing global climate change at 1.5 C. Science 365(6459):eaaw6974.

Huber, C. 2017. World's food waste could feed 2 billion people. World Vision. https://www.worldvision.org/hunger-news-stories/food-waste.

IPCC (Intergovernmental Panel on Climate Change). 2007. AR4 Climate Change 2007: Synthesis Report. Contributions of Groups I, II, and III to the Fourth Assessment Report of IPCC. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

IPCC. 2018. Global Warming of 1.5 C: An IPCC Special Report on the Impacts of Global Warming of 1.5 C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, eds. V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, and P.R. Shukla. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Jiang, B., Y. Bamutaze, and P. Pilesjö. 2014. Climate change and land degradation in Africa: A case study in the Mount Elgon region, Uganda. Geo-spatial Information Science 17(1):39–53.

Keesstra, S., G. Mol, J. de Leeuw, J. Okx, C. Molenaar, M. de Cleen, and S. Visser. 2018. Soil-related sustainable development goals: Four concepts to make land degradation neutrality and restoration work. Land 7(4):133.

Kiboi, M.N., F.K. Ngetich, and D.N. Mugendi. 2019. Nitrogen budgets and flows in African smallholder farming systems. AIMS Agriculture and Food 4(2):429–446.

Kopittke, P.M., N.W. Menzies, P. Wang, B.A. McKenna, and E. Lombi. 2019. Soil and the intensification of agriculture for global food security. Environment International 132(2019):105078.

Kust, G., O. Andreeva, and A. Cowie. 2017. Land Degradation Neutrality: Concept development, practical applications and assessment. Journal of Environmental Management 195(2017):16–24.

Lal, R. 2004a. Soil carbon sequestration impacts on global climate change and food security. Science 304(5677):1623–1627.

Lal, R. 2004b. Carbon emission from farm operations. Environment International 30(7):981–990.

Lal, R. 2009. Laws of sustainable soil management. Agronomy for Sustainable Development 29(1):7–10.

Lal, R. 2010. Managing soils and ecosystems for mitigating anthropogenic carbon emissions and advancing global food security. BioScience 60(9):708–721.

Lal, R. 2014. Societal value of soil carbon. Journal of Soil and Water Conservation 69(6):186A-192A. https://doi.org/10.2489/jswc.69.6.186A.

Lal, R. 2015. A system approach to conservation agriculture. Journal of Soil and Water Conservation 70(4):82A-88A. https://doi.org/10.2489/jswc.69.6.186A.

Lal, R. 2016. Beyond COP21: Potential and challenges of the "4 per Thousand" initiative. Journal of Soil and Water Conservation 71(1):20A-25A. https://doi.org/10.2489/jswc.71.1.20A.

Lal, R. 2018. Digging deeper: A holistic perspective of factors affecting soil organic carbon sequestration in agroecosystems. Global Change Biology 24(8):3285–3301.

Lal, R. 2019a. Rights-of-Soil. Journal of Soil and Water Conservation 74(4):81A-86A. https://doi.org/10.2489/jswc.74.4.81A.

Lal, R. 2019b. Promoting "4 Per Thousand" and "Adapting African Agriculture" by south-south cooperation: Conservation agriculture and sustainable intensification. Soil and Tillage Research 188(2019):27–34.

Lal, R. 2019c. Carbon cycling in global drylands. Current Climate Change Reports 5(3):221–232.

Lal, R. 2020a. Soil Science Beyond COVID-19. Journal of Soil and Water Conservation 75(4):79A-81A. https://doi.org/10.2489/jswc.2020.0408A.

Lal, R. 2020b. Soil organic matter content and crop yield. Journal of Soil and Water Conservation 75(2):27A-32A. https://doi.org/10.2489/jswc.75.2.27A.

Lal, R., R. Horn, and T. Kosaki. 2018a. Soil and the Sustainable Development Goals, eds. R. Lal, R. Horn, and T. Kosaki. Stuttgart: Catena-Scheizerbart.

Lal, R., K. Lorenz, R. Hüttl, B. Schneider, and J. Braun. 2012a. Recarbonization of the Biosphere: Ecosystems and the Global Carbon Cycle. Verlag, Holland: Springer.

Lal, R., K. Lorenz, R. Hüttl, B. Schneider, and J. Braun. 2013. Ecosystem Services and Carbon Sequestration in the Biosphere. Dordrecht, Netherlands: Springer.

Lal, R., U. Safriel, and B. Boer. 2012b. Zero Net Land Degradation. *In* UNCCD Position Paper for Rio+20. Bonn, Germany: United Nations Convention to Combat Desertification.

Lal, R., P. Smith, H.F. Jungkunst, W.J. Mitsch, J. Lehmann, P.K.R. Nair, A.B. McBratney, J.C. de Moraes Sa, J. Schneider, Y.L. Zinn, A.L.A. Skorupa, H.-L. Zhang, B. Minasny, C. Srinivasrao, and N.H. Ravindranath. 2018b. The carbon sequestration potential of terrestrial ecosystems. Journal of Soil and Water Conservation 73(6):A145–A152. https://doi.org/10.2489/jswc.73.6.145A.

Medek, D.E., J. Schwartz, and S.S. Myers. 2017. Estimated effects of future atmospheric CO_2 concentrations on protein intake and the risk of protein deficiency by country and region. Environmental Health Perspectives 125(8):87002.

Mendes, R., M. Kruijt, I. de Bruijn, E. Dekkers, M. van der Voort, J.H.M. Schneider, Y.M. Piceno, T.Z. DeSantis, G.L. Andersen, P.A.H.M. Bakker, and J.M. Raaijmakers. 2011. Deciphering the rhizosphere microbiome for disease-suppressive bacteria. Science 332(6033):1097–1100.

Mockshell, J., and J. Kamanda. 2018. Beyond the agroecological and sustainable agricultural intensification debate: Is blended sustainability the way forward? International Journal of Agricultural Sustainability 16(2):127–149.

Montanarella, L., D.J. Pennock, N. McKenzie, M. Badraoui, V. Chude, I. Baptista, T. Mamo, M. Yemefack, M. Singh Aulakh, K. Yagi, S. Young Hong, P. Vijarnsorn, G.-L. Zhang, D. Arrouays, H. Black, P. Krasilnikov, J. Sobocká, J. Alegre, C.R. Henriquez, M. de Lourdes Mendonça-Santos, M. Taboada, D. Espinosa-Victoria, A. AlShankiti, S.K. AlaviPanah, E.A.E.M. Elsheikh, J. Hempel, M. Camps Arbestain, F. Nachtergaele, and R. Vargas. 2016. World's soils are under threat. SOIL 2(1):79–82.

Montgomery, D.R. 2007. Dirt : The Erosion of Civilizations. Berkeley, CA: University of California Press.

Mukherjee, A., S.N. Bhanja, and Y. Wada. 2018. Groundwater depletion causing reduction of baseflow triggering Ganges river summer drying. Scientific Reports 8(1):12049.

Myers, S.S., A. Zanobetti, I. Kloog, P. Huybers, A.D.B. Leakey, A.J. Bloom, E. Carlisle, L.H. Dietterich, G. Fitzgerald, T. Hasegawa, N.M. Holbrook, R.L. Nelson, M.J. Ottman, V. Raboy, H. Sakai, K.A. Sartor, J. Schwartz, S. Seneweera, M. Tausz, and Y. Usui. 2014. Increasing CO_2 threatens human nutrition. Nature 510(7503):139–142.

Neumann, K., P.H. Verburg, E. Stehfest, and C. Müller. 2010. The yield gap of global grain production: A spatial analysis. Agricultural Systems 103(5):316–326.

O'Keeffe, P. 2016. The role of Ethiopia's public universities in achieving the United Nations Sustainable Development Goals. International Review of Education 62(6):791–813.

Oertel, C., J. Matschullat, K. Zurba, F. Zimmermann, and S. Erasmi. 2016. Greenhouse gas emissions from soils—A review. Geochemistry 76(3):327–352.

Oldeman, L. 1994. The global extent of land degradation. *In* Land Resilience and Sustainable Land Use, ed. D. J. Greenland and I. Szabolcs, 99–118. Wallingford: CABI.

Omisore, A.G. 2018. Attaining Sustainable Development Goals in sub-Saharan Africa; The need to address environmental challenges. Environmental Development 25(2018):138–145.

Poore, J., and T. Nemecek. 2018. Reducing food's environmental impacts through producers and consumers. Science 360(6392):987-992.

Raich, J., and C. Potter. 1995. Global patterns of carbon dioxide emissions from soils. Global Biogeochemical Cycles 9(1):23–36.

Raich, J.W., and W.H. Schlesinger. 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus B 44(2):81–99.

Rhodes, C. 2017. The imperative for regenerative agriculture. Science Progress 100(1):80–129.

Ritchie, H. 2017. How many people does synthetic fertilizer feed? Our World in Data. https://ourworldindata.org/how-many-people-does-synthetic-fertilizer-feed.

Ritchie, H. 2019. Food production is responsible for one-quarter of the world's greenhouse gas emissions. Our World in Data. https://ourworldindata.org/food-ghg-emissions.

Ritchie, H., and M. Roser. 2019. CO_2 and Greenhouse Gas Emissions. Our World in Data. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

Rosenberg, M. 2019. Current World Population and Future Projections. Thought Co. https://www.thoughtco.com/current-world-population-1435270.

Ruddiman, W.F. 2003. The anthropogenic greenhouse era began thousands of years ago. Climatic Change 61(3):261–293.

Sà, J.C. de M., R. Lal, C.C. Cerri, K. Lorenz, M. Hungria, and P.C. de Faccio Carvalho. 2017. Low-carbon agriculture in South America to mitigate global climate change and advance food security. Environment International 98(January 2017):102–112.

Sanderman, J., T. Hengl, and G. J. Fiske. 2017. Soil carbon debt of 12,000 years of human land use. Proceedings of the National Academy of Sciences 114(36):9575-9580.

Schlatter, D., L. Kinkel, L. Thomashow, D. Weller, and T. Paulitz. 2017. Disease Suppressive Soils: New Insights from the Soil Microbiome. Phytopathology 107(11):1284–1297.

Scown, M., K. Winkler, and K. Nicholas. 2019. Aligning research with policy and practice for sustainable agricultural land systems in Europe. Proceedings of the National Academy of Sciences 116(11):4911-4916.

Seifollahi-Aghmiuni, S., M. Nockrach, and Z. Kalantari. 2019. The potential of wetlands in achieving the Sustainable Development Goals of the 2030 Agenda. Water 11(3):609.

Smil, V. 2001. Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production. Cambridge, MA: MIT Press.

Soares, J.C., C.S. Santos, S.M.P. Carvalho, M.M. Pintado, and M.W. Vasconcelos. 2019. Preserving the nutritional quality of crop plants under a changing climate: Importance and strategies. Plant and Soil 443(1):1–26.

Stewart, W.M., D.W. Dibb, A.E. Johnston, and T.J. Smyth. 2005. The contribution of commercial fertilizer nutrients to food production. Agronomy Journal 97(2005):1–6.

Sweeney, M., and S. Mccouch. 2007. The complex history of the domestication of rice. Annals of Botany 100(5):951–957.

Terrell, B.L., P.N. Johnson, and E. Segarra. 2002. Ogallala aquifer depletion: Economic impact on the Texas high plains. Water Policy 4(1):33–46.

Thornton, P., D. Dinesh, L. Cramer, A. Loboguerrero, and B.M. Campbell. 2018. Agriculture in a changing climate: Keeping our cool in the face of the hothouse. Outlook on Agriculture 47(4):283–290.

Tilman, D., C. Balzer, J. Hill, and B.L. Befort. 2011. Global food demand and the sustainable intensification of agriculture. Proceedings of the National Academy of Sciences 108(50):20260-20264.

UN (United Nations). 2015. Transforming Our World: The 2030 Agenda for Sustainable Development. A/Res/70/1. New York, NY, USA: UN General Assembly. https://www.refworld.org/docid/57b6e3e44.htm.

UN. 2017. World Population Prospects: Key Findings and Advance Tables. 2017 Revisions. Working Paper No. ESA/P/WP/248. New York, NY: United Nations Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp/Publications/Files/WPP2017_KeyFindings.pdf.

UN. 2019. World Population Prospects. Highlights (ST/ESA/SER). New York, NY: United Nations Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf.

Waldron, A., D. Garrity, Y. Malhi, C. Girardin, D.C. Miller, and N. Seddon. 2017. Agroforestry can enhance food security while meeting other Sustainable

Development Goals. Tropical Conservation Science 10(January 1, 2017):1940082917720667.

Walling, D. 2008. The changing sediment loads of the world's rivers. Annals of Warsaw University of Life Sciences – SGGW Land Reclamation 39(January 1, 2008):3-20.

Walling, D.E. 2009. The Impact of Global Change on Erosion and Sediment Transport by Rivers: Current Progress and Future Challenges. Paris, France: United Nations Educational, Scientific, and Cultural Organization.

Williams, J., T. Alter, and P. Shrivastava. 2018. Systemic governance of sustainable agriculture: Implementing sustainable development goals and climate-friendly farming. Outlook on Agriculture 47(3):192–195.

WMO (World Meteorological Organization). 2019. WMO Greenhouse Gas Bulletin #15: The state of greenhouse gases in the atmosphere based on global observations through 2018. WMO Greenhouse Gas Bulletin. Geneva, Switzerland: World Meteorological Organization.

World Bank. 2017. Fertilizers Consumption (Kg/ha) of Arable Land. Washington, DC: World Bank. https://data.worldbank.org.

World Commission on Environment and Development. 1987. Our Common Future. Oxford: Oxford University Press.

Wu, W., Q. Yu, L. You, K. Chen, H. Tang, and J. Liu. 2018. Global cropping intensity gaps: Increasing food production without cropland expansion. Land Use Policy 76(2018):515–525.

Xu, Z., S.N. Chau, X. Chen, J. Zhang, Y. Li, T. Dietz, J. Wang, J. A. Winkler, F. Fan, B. Huang, S. Li, S. Wu, A. Herzberger, Y. Tang, D. Hong, Y. Li, and J. Liu. 2020. Assessing progress towards sustainable development over space and time. Nature 577(7788):74–78.

Yang, X., Y.-Q. Chen, T. Steenhuis, S. Pacenka, W.-S. Gao, L. Ma, M. Zhang, and P. Sui. 2017. Mitigating groundwater depletion in North China Plain with cropping system that alternate deep and shallow rooted crops. Frontiers in Plant Science 8(June 8, 2017):13.

Zhao, M., and S.W. Running. 2010. Drought-induced reduction in global terrestrial net primary production from 2000 through 2009. Science 329(5994):940-943.