Preface

This is the era of global warming with the associated climate change, and increase in the frequency of extreme events. Beginning with the Industrial Revolution since circa 1750, the atmospheric concentration of heat-trapping greenhouse gases (GHGs) has increased significantly as a result of anthropogenic activities. Three major GHGs and their current atmospheric abundance relative to Industrial Era circa 1750 are carbon dioxide (CO_2) 145%, methane (CH_4) 254%, and nitrous oxide (N_2O) 121%. Other human-created GHGs are sulfur hexafluoride (SF_6), and many halogenated species. Emission of GHGs to the atmosphere is of a primary concern worldwide because the radiative properties of the atmosphere are strongly impacted by their abundance in the atmosphere. These gases have sometimes been referred to as well-mixed or long-lived GHGs because they are sufficiently mixed in the troposphere such that concentration measurements from few remote surface sites can characterize their atmospheric burden and their atmospheric lifetimes are much greater than timescales of few years of atmospheric mixing.

The Earth′s climate is determined by the flows of energy into and out of the planet and to and from the Earth's surface. Increasing GHGs in the atmosphere therefore, creates imbalance in energy flows in and out of the Earth system by trapping more radiation energy. Trapped energy is manifested in many ways, including rising global surface temperatures, melting Arctic sea ice, accelerating the water cycle, altering the intensity and frequency of storms, and many more changes. In addition to impact on global climate, CO_2 also interact strongly with the biosphere and oceans. The atmospheric content of these gases also represent gaseous phase of the global biogeochemical cycles that control the flows and transformation of C and N between the different compartments of the Earth system, namely atmosphere, biosphere, hydrosphere, and lithosphere, by both biotic and abiotic processes. The increase in atmospheric CO_2 concentration is the main driver of the anthropogenic climate change, accounting for 1.939 of 2.974 W m^2 or 65% of the global-radiative forcing between 1750 and 2015. From 1990 to 2015, the radiative forcing by the long-lived GHGs increased by 37.4% with CO_2 accounting for about 80% of this increase. The two major sources of CO_2 emission are fossil fuel combustion and land use conversion. As a result of increase in anthropogenic emission of GHGs, the global annual mean land and ocean temperature increased by about 1.11 °C between 1750 and 2015, accompanied by the worldwide melting of glaciers and rising of the sea level.

Whereas the land use conversion was the major source of atmospheric CO_2 emissions ever since the dawn of settled agriculture, fossil fuel combustion has been increasingly important since the Industrial Revolution that began circa 1750. Presently, energy production and the environment are the two most important challenges facing the humanity in the twenty-first century. More than 80% of the energy comes from the fossil fuel combustion, and fossil fuels will remain the dominant energy source for years to come. Emission of CO_2 from the fossil fuel combustion process is the dominant anthropogenic GHG causing climate change because burning fossil fuels releases the CO_2 to the atmosphere that was stored millions of years ago, and thus, was unavailable for C cycling. Therefore, fossil fuels combustion transfers large quantities of C from slow domain C cycling to fast domain C cycling. Fossil fuel combustion accounts for about 75% of anthropogenic CO_2 emissions and is expected to further increase by 53 to 55%, while meeting 83% of the increase in energy demand by 2030. Prompt global action to resolve CO_2 emission crisis is needed in the short term, and the need to move away from C economy in longer term. In addition to energy conservation, C sequestration is one of an alternative method to reduce the rate of atmospheric CO_2 increase and mitigate climate change.

Global climate change presents a unique challenge to mankind, which requires a joint global effort to address. Whether global governments and public will act sufficiently fast to stabilize the global temperature at an acceptable levels and avoid dangerous impact remains the most uncertain proposition. For the policy makers, regulating fossil fuel use to the levels that will avoid dangerous warming is most difficult task because fossil fuel use has direct impact on economic prosperity. To the experts in physics, climate scientists, and others, the physics of radiation and energy balance, together with ocean circulation and Earth's long climate history, the global warming evidence is compelling.

Carbon (C) sequestration is the process of transferring atmospheric CO_2 that would otherwise be emitted into and/or remain in the atmosphere, and securely storing it in other long-lived C pools or protecting C that is stored in long-term pool that would otherwise be emitted, either through natural biological, enhanced natural biological processes, or anthropogenically driven non-biological engineering techniques. It aims at prevention of CO_2 from emission into atmosphere or transferring C from the atmosphere into long-lived pools—including biota, soil, geologic strata, and ocean. Strategies for C sequestration can be grouped into biotic and abiotic. Biotic strategies utilize ecological process of photosynthesis and transfer of CO_2 from atmosphere into plant biomass C through mediation of green plants, followed by utilization of biomass to substitute for fossil fuels or use of wood to substitute cement in construction. Biomass also can enhance soil organic C (SOC) storage, transferred to pedologic storage through OM burial and transformation into fossil C. Ocean CO_2 fixation also occurs through photosynthesis, followed by OM burial in deep ocean sediments. Abiotic strategies involve separation, capture, and storage of CO_2 into geologic strata using geoengineered processes which keeps industrial CO_2 emissions from reaching the atmosphere. The overall objective of the C sequestration—both biological and anthropogenic—is to balance the global C budget such that the current and future economic growth is based on C neutral or C negative strategy where there is either no net CO_2 emission or net negative CO_2 emission.

The *Carbon Sequestration and Climate Change Mitigation and Adaptation* book sets out a scientific basis of the current understanding of the role of increased CO_2 emission on climate change. The book explores an extensive field of current scientific knowledge that includes the general science of Earth's climate, how and why climate is changing, and consequences of those changes to food security and prosperity. The paleoclimatological studies form the basis of distinguishing between natural and anthropogenic climate change. The book also describes the role of C sequestration—both ecological engineered and geoengineed options—for mitigating the increasing atmospheric CO_2 concentration. In addition, the role of a proposed and emerging climate engineering and chemical sequestration option is briefly examined with the emphasis on their limitations and possible risks. Information from different scientific disciplines is collated and integrated to present a holistic approach towards the role of CO_2 and other GHGs on global warming, climate change, and the approaches for mitigating climate change and its impacts. The book is specifically prepared to provide academic and research knowledge for undergraduate and graduate university students, scientists, researchers, and policy makers interested in general understanding of the anthropogenic CO_2 emissions and its impact on global C cycling and C budgets, approaches for reducing CO_2 emissions, and available options for mitigating global warming.

We thank Springer Dordrecht and the Life Sciences staff for extending the opportunity to publish with them and share this knowledge. Particularly, we are indebted to Melanie van Overbeek and the staff of the Agronomy for their patience and tireless guide which allowed the completion of this task.

Columbus, OH, USA David A.N. Ussiri
Rattan Lal

Springer

http://www.springer.com/978-3-319-53843-3

Carbon Sequestration for Climate Change Mitigation and Adaptation

Ussiri, D.A.N.; Lal, R.

2017, XIV, 549 p. 57 illus., 53 illus. in color., Hardcover
ISBN: 978-3-319-53843-3