Carbon Management in Tropical and Sub-Tropical Terrestrial Systems

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Foreword

The book *Carbon Management in Tropical and Sub-tropical Terrestrial Systems* addresses a theme of global significance. Carbon (C), an important constituent of all ecosystems, is intricately interconnected with numerous ecosystem services for human wellbeing and nature conservation. Cycling of C is coupled with those of water (H_2O), nitrogen (N), phosphorus (P), sulphur (S) and other essential elements. It is the intensity and strength of the coupled cycling of C that is the source of ecosystem services including the net primary production, moderation of climate, renewability and filtration of water, activity and species diversity of biota, etc. Anthropogenic perturbation of the cycling of C, and weakening of its coupling with other elements (e.g. N, P) and water, can jeopardize ecosystem functioning. For example, depletion of the terrestrial stocks of C (comprising of those in vegetation and soil) can have a strong impact on soil quality and functionality. Consequently, the theme of soil C sequestration has received the attention of policy-makers. The year 2015 was declared by the United Nations as the year of soil, and the 2015–2024 decade has been declared by the International Union of Soil Sciences (IUSS) as the "Decade of Soil". In 2002, when the 17th World Congress of Soil Science (WCSS) was held in Bangkok, the IUSS worked with the Thai Government and declared 5 December as the World Soil Day (WSD). The WSD is celebrated on the birthday of the late king of Thailand – His Majesty King Bhumibol Adulyadej, the Rama IX of the Chakri dynasty. In cooperation with the IUSS, the WSD is also celebrated by the Food and Agriculture Organization (FAO) of the United Nations and other institutions throughout the world. In addition, the COP21, held in Paris in 2015, adopted a resolution of "4 per Thousand". It is a voluntary proposal of sequestering C in soils of the world to 40 cm depth at the rate of 0.4% (0.4% or 4‰) per year. The objective is to sequester carbon for advancing global food security, adapting and mitigating climate change and promoting other Sustainable Development Goals of the United Nations.

Therefore, this book is timely and highly pertinent because it addresses the theme of C sequestration in tropical and sub-tropical ecosystems. A majority of farmers and land managers in these regions are resource-poor and small land holders with farm size of less than 5 hectare and often as small as 0.5 hectare. Managed by extractive farming methods (e.g. residue removal, in-field burning, ploughing, flood-based irrigation, negative nutrient budget), soils of these farmers are strongly depleted of their soil organic carbon (SOC) content. Indeed, the SOC concentration in the root zone can be as low as 0.1% or less. Therefore, most soils have degraded physical, chemical, biological and ecological properties. Consequently, agronomic yields are low and stagnating, use efficiency of inputs (i.e. fertilizer, irrigation) is low, and the losses of water and nutrients (caused by erosion, leaching, volatilization) are high with severe adverse impacts on the environment. In addition, nutritional quality of the produce is also poor, and it has exacerbated the widespread problem of malnutrition because of severe degradation and depletion of soils.

It is widely recognized that the health of soil, plants, animals, people and ecosystems is one and indivisible. The concentration of SOC in the root zone, along with its quality and turnover, is a strong determinant of soil health, agronomic productivity, use efficiency of inputs and the environment. The latter includes adaptation and mitigation of anthropogenic climate change, water quality and renewability and aesthetic quality of the landscape.

This book is a pertinent reference material for researchers, students and practitioners in soil science, agronomy, ecology and sustainable management of natural resources with specific focus on the global issues such as food and nutritional security, adaptation and mitigation of climate change, quality, biodiversity and the Sustainable Development Goals of the United Nations.

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1 January 2019

Preface

Terrestrial ecosystems are a significant carbon sink on Earth accounting for about 20–30% of the total anthropogenic carbon dioxide (CO_2) emissions to the atmosphere. When compared with oceans, it can be readily managed to either increase or decrease carbon sequestration by restoring or degrading vegetations available on lands. Any increase in concentration of radioactively active trace gases in the atmosphere is now recognized to modify global climate, affecting terrestrial ecosystems both functionally and structurally. The importance of soil as a sink and source of atmospheric carbon and the need for its additional sequestration in terrestrial agroecosystems through appropriate management are major issues among the scientific community and policy-makers to mitigate CO_2 enrichment in atmosphere. A land-use and management option that optimizes sustainable production and enhanced carbon sequestration in the soil is the need of the hour, particularly with reference to tropical and sub-tropical terrestrial systems, where the soil is hungry for carbon.

Soils have many essential life-supporting functions, of which growing plants and vegetation for food, fuel and fibre is important. Soils store carbon from the atmosphere to mitigate atmospheric greenhouse gas levels, filter contaminants to ensure clean drinking water to aquifers for posterity, provide habitat and maintain a microbial community and gene pool that decomposes and recycles dead organic matter and transforms nutrients into available forms for plants. These functions support many of the goods and services for social, economic and environmental benefits to humankind. They need to be protected and upkept from the increasing pressure of intensive use of land. In fact, the soil resources in tropical and sub-tropical areas are already showing signs of severe degradation and fatigue from human use and management. Soil degradation has been escalated during the past few decades with expansion of cultivation and urban dwelling for increasing human population. As a fallout of such degradation of soil, its carbon content gets lost through water, wind and other forms of erosion. This process is again accentuated by land conversion and associated increased emission of greenhouse gases out of recent phenomenon of burning of crop residues.

Soil management practices which can sequester carbon and reduce the risk of soil degradation in agroecosystems include conservation tillage in combination with planting of cover crops, green manure and hedgerows, organic residue management, mulch farming, water management, soil fertility management, introduction of agro-ecologically and physiologically adopted plant species, adapting crop rotation and cropping/farming systems, controlling grazing to sustainable levels and stabilization of slopes and terraces. These management practices should aim at optimizing CO_2 utilization by plants through photosynthesis to increase crop productivity and content of soil organic carbon. However, the ultimate aim should be to increase the labile fraction of soil organic carbon stored in stable micro-aggregates, reducing its accessibility for oxidation by microorganisms.

The objective of this book *Carbon Management in Tropical and Sub-tropical Terrestrial Systems* is to provide science-driven information for soil carbon management in the tropical and sub-tropical areas/countries in the context of global climate change and sustainable agricultural production. This publication includes 25 chapters grouped into five themes, namely, (I) impact of land-use management for regulating soil organic carbon (SOC) pools; (II) conservation agriculture and carbon sequestration, (III) soil physical and biological factors regulating SOC storage; (IV) carbon management in pastures, grasslands, forests and farming systems; and (V) frontier science regulating SOC storage. Researchers of national and international repute have contributed the chapters on soil carbon dynamics in different land-use and management systems, soil management for regulating carbon pools, soil management practices under the major crops and enhancing carbon sequestration: management options, conservation agriculture and carbon sequestration, soil physical parameters for regulating organic carbon pools, microorganisms regulating carbon cycle in tropical and sub-tropical soils, soil organic carbon stock and water management, grasslands as carbon sink, agroforestry for the enhancement of carbon sequestration, carbon sequestration potential of perennial horticultural and forage crops, developments in measurement and modelling of soil organic carbon dynamics and nanotechnology for improved carbon management in soil. Each chapter has been enriched with the current scientific and technical literatures on soil carbon management to provide updated information of high scientific and technical value.

The editorial team takes this opportunity to express their gratitude to all who have provided moral supports and shown their keen interest in bringing out this publication. The team also likes to convey its sincere gratitude and appreciations to all the distinguished authors and contributors for their dedication and commitments in writing their chapters. Special thanks are due to Professor Rattan Lal for his constant guidance and support in bringing out the book in global perspective and also for writing a thought-provoking Foreword for this book.

It is hoped that besides researchers and students of agricultural sciences, the publication will be useful to the policy-makers, planners, administrators and farmers. Last but not the least, the Springer team also deserves appreciation for their constant inspiration, guidance and cooperation in drafting the publication.

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Soil Carbon Management-Climate Change-Food Security Nexus: An Overview of the Book

Historical agricultural production as well as its ongoing intensification worldwide has intensely impacted global carbon, water and nutrient cycles. And as such, both land-use changes to agriculture and agricultural production continue to contribute significantly to the increase in atmospheric carbon dioxide (CO_2), accounting for as much as 24% of the global greenhouse gas (GHG) emissions. Soils, however, can act as both sources and sinks of carbon, depending upon management, biomass input levels, microclimatic conditions and bioclimatic change. Substantially, more carbon is stored in the world's soils than is present in the atmosphere. The global soil carbon (C) pool to 1-metre depth, estimated at 2500 Pg C, of which about 1500 Pg C is soil organic carbon (SOC), is about 3.2 times the size of the atmospheric pool and 4 times that of the biotic pool. A widespread body of research has shown that land management practices can increase soil carbon stocks in agricultural lands with agronomic practices including the addition of organic manures, cover cropping, crop diversification, mulching, conservation tillage, fertility management, agroforestry and rotational grazing. There is general agreement that the technical potential for sequestration of carbon in soil is significant, and some consensus on the magnitude of that potential is arrived. On this basis, the 4p1000 initiative on soil for food security and climate14, officially launched by the French Ministry of Agriculture at the United Nations Framework Convention on Climate Change: Conference of the Parties (UNFCCC COP 21) in Paris, aims to sequester approximately 3.5Gt C annually in soils. Tropical and sub-tropical croplands in particular will be important in this effort, as these lands have inherently low SOC content.

There is a growing realization that facets of global changes (climate changes, changes in concentration of atmospheric constituent gases, land surface cover and biodiversity) are interlinked and strongly impact the livelihood and survival of the humankind. Since the mid-1990s, accelerated warming has been reported across the world. Temperatures are likely to rise in India by 3–4 °C by the twenty-first century (Pathak and Aggarwal 2012). The average temperatures have increased by 0.25 °C during the *kharif* and by 0.6 °C during the *rabi* season. Some reports suggest that the recent warming has potentially reduced crop yields by 6% in the *rabi* season (Peng et al.2004). The projected warming over the rainfed dry lands may exacerbate water scarcity, leading to a further loss in crop production (Funk et al. 2008).

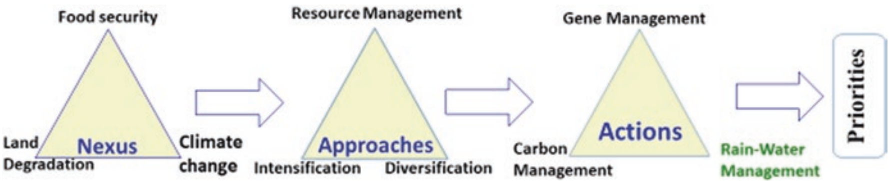

Fig. 1 Future research focus to tackle land degradation-climate change-food security nexus

Biomass production in tropical and sub-tropical regions of the world is mainly constrained by limited water availability and low nutrient supplying capacity of soils. Again, wilful and random intensification of agriculture with external inputs in these regions accentuates land and environmental degradation. Developing strategies for halting such land degradation and improving livelihoods of the poor of the region is an important issue that warrants urgent attention to achieve the Sustainable Development Goals. Based on remotely sensed NDVI data, Liu et al. (2015) estimated that 16% of the Indian territory (47 mha) showed a declining trend in NDVI between 1982 and 2006. Out of the area, 29 mha belongs to croplands and 12 mha to forest. The decline in canopy cover in croplands is a matter of serious concern, since it is associated with the on-going process of land degradation. Such degradation contributes to climate change through loss in biodiversity, SOC, soil moisture and biomass, etc. and brings a land degradation-climate change-food security nexus (Fig. 1). Poorly managed farms, degraded lands and natural resources are an ecological, social and economic liability. For the survival of civilizations, it is crucial that land degradation processes are attended, on a priority. One of the best ways of curbing such degradation is carbon sequestration in soils. In fact, sequestration of C has numerous co-benefits. Important among them are advancing food security, improving the environment, enhancing water quantity and quality, increasing biodiversity, etc. The future of SOC research requires through understanding of the linkages between land degradation, food security and climate change (Fig. 1). It also needs focussed strategies and approaches of resource management in order to make cohesiveness between intensification and diversification. Finally, action-oriented research for manipulation of crop genetics along with water and nutrient management need to be addressed.

This book has drawn together various perspectives on some of the key issues regarding carbon sequestration in soils of the tropical and sub-tropical regions for achieving sustainable production and neutrality in land degradation.

Understanding of Basic SOC Pools and Dynamics in Tropical and Sub-tropical Environment

Sequestration of carbon in soil is governed by various edaphic, environmental and management factors; of them, soil aggregation and structure are important (Chap. 14 by Bandyppadhyay this volume). Kashyap et al. (2017) have indicated that nanomaterials due to their unique properties at nanoscale can enhance carbon stabilization and its sequestration in soil. In these chapters, the positive effects of nano-zeolite, nanoZnO particles and nano-Fe on aggregation and carbon build-up in agricultural soil have been documented (Aminiyan et al. 2015; Raliya et al. 2015; Tarafdar et al. 2013). Once C is sequestered in soils, it alters soil aggregation. The resulting aggregates, in turn, protect the C from microbial degradation within stable micro-aggregates (<250 mm), adsorbed on the inner surfaces of clays or chemically formed organo-mineral complexes (Lal 1997; Chap. 25 by Sangeeta et al. this volume). Additional research is, however, needed to elucidate the mechanisms of such nano-materials led SOC sequestration, its magnitude and economics. Also, cereals-based cropping system had low carbon storage compared to that of legume-based. It is highlighted that growing of bamboo, cane and rice or similar grass crops has significant potential of phytolith C bio-sequestration. In the case of rice, C content of phytolith varied from 1.4% to 3.37% in straw, from 1.13% to 2.27% in roots and from 2.13% to 6.3% in rice husk. In wheat and maize, the percent of PhytoOC is 0.16%, offering good opportunity to sequester C. It is estimated that growing high PhytoOC-yielding cultivars provides additional 1.0 million tonnes of carbon per year in these croplands (Chap. 3 by Kundu et al. this volume). This calls for a reorientation of crop breeding efforts for improving SOC sequestration. The usefulness of such sequestered C in maintaining ecosystem functions of soil is also studied.

Modelling C behaviour and its dynamics in soils is a tortuous exercise (Chap. 23 by Benbi and Nisar this volume). And till now, most of the C models to predict its pool and fluxes from soils are developed using studies concentrated mainly in temperate regions and with SOC in surface soils. Subsoil edaphic conditions, such as pH, oxygen concentration, microbial load and SOC distribution in pools, are different from those of surface soils and have hardly been considered in the existing widely used models. This is particularly true for models used in tropical and subtropical regions. Modified approach is needed to predict the turnover of organic C in subsoil up to 1.0 M of depth. Increasing C sequestration in subsoil profile may be possible by adopting deep-rooted perennials in the cropping systems.

Strategy to Create a Positive C Budget in Tropical and Sub-tropical Agroecosystems

The various chapters included in this publication have presented a wide range of topics including forestry, agroforestry, perennial horticulture and grasslands and the carbon stocks and C pools dynamics therein; effect of tillage and nutrients on SOC management; impact of amendments such as organics, nano-particles, etc. on carbon sequestration and crop productivity; etc. Soil carbon pool varied in the order of wet temperate forest (165.24 Mg ha^{-1}) > deciduous forest (138.64 Mg ha^{-1}) > tropical thorny forest (135.42 Mg ha^{-1}) > tropical riparian fringing forest (104.94 Mg ha^{-1}). Tropical thorny and riparian forest had more labile carbon fractions, whereas wet temperate forest had more non-labile carbon fractions (Sreekanth et al. 2013). Recently, Christopher Poeplau et al. (2018) have made a comprehensive method comparison for isolation of organic carbon fractions with varying turnover rates for a mechanistic understanding and modelling of soil organic matter decomposition and stabilization processes. They confirmed the importance of clay- and silt-sized particles (<50 μm) for SOC stabilization. At the same time, other groups have highlighted the brilliance of sesquioxides in storing a good amount of C in soils. Weighing the importance of soil components for C sequestration and its stabilization and prediction of its stocks over regions will be useful for judging soils as to their potential as a sink of C. How such potential of soils is changed over adoption of different management practices followed by farmers of tropical and sub-tropical regions needs to be assessed not only for upkeeping soil health but also curbing land degradation.

Sequestration of the atmospheric CO_2 in soil has long been considered as one of the potential strategies for mitigating global warming and improving soil health. Recent evidences show that conservation agriculture (CA) can reduce emissions of GHGs as well as sequester C in soils. Some of the management options associated with CA for increasing SOC sequestration includes (i) reduced tillage, (ii) cover crops, (iii) efficient nutrient management, (iv) efficient water management, (v) restoring degraded soils, (vi) practicing crop diversification, (vii) minimizing soil and water erosion, (viii) efficient pasture management, (ix) afforestation and efficient forest management, (x) efficient management of urban soils, etc. (Chap. 6 by Bhattacharya et al. this volume). Additionally, enhancing soil aggregation and structure for better retention of soil organic carbon (Chap. 24 by Pragati et al. this volume) is also an important management strategy to reduce CO_2 emissions from soils into the atmosphere.

It has been shown that among the different land-use systems, total C stock was highest in soils under forest followed by soils under fodder system, the cereal system – paddy, maize, cotton, redgram, intercrop, chilli and permanent fallow – and lowest in soils under castor system (Venkanna et al. 2014; Chap. 3 by Kundu et al. this volume). Ganeshamurthy et al. (this volume) in Chap. 20 has indicated that soils under perennial horticultural crops in tropical India, which cover an area of 12.1 million hectares (6.10 Mha fruits, 3.22 Mha plantation crops, 2.63 Mha spices and 0.14 Mha nuts) with an annual production of 214 million tonnes, is also a good sink for carbon. They further narrated that in horticultural systems, soil factors (soil moisture status, soil temperature, drainage, soil acidity, soil nutrient supply, soil clay content and mineralogical makeup) influence the microbe-mediated processes and organic matter behaviour in soils. Carbon sequestration potential in soils under some of the perennial horticultural crops is as follows: mango > cashew > rose > vegetable > medicinal and aromatic plants (Bhavya et al. 2017).

Carbon Sequestration Through Land Reclamation and Management

Improved soil management practices, such as growing of cover crops, sowing crops with conservation tillage, maintaining balanced level of soil fertility and converting marginal and degraded lands to restorative land uses, help in capturing and storing carbon in soils through a favourable impact on soil structure. A comprehensive database on C sequestration potential of various land reclamation options has been illustrated in chapter "Soil Management for Regulating C Pools: Perspective in Tropical and Sub-tropical Soils". Land reclamation through agroforestry has also been recognized as a good option. It accumulates C in the range of 0.29–15.21 Mg $ha^{-1}year^{-1}$. The amount can further be improved through imparting biochemical recalcitrance and physical protection and also by reducing C losses (Chap. 19 by Dhyani et al. this volume). Growing guinea grass, berseem and cowpea crops between main crop reduce fallow period, provide soil cover during peak summer months, reduce runoff and soil erosion and help in more C build-up.

Grazing Land Management

Carbon sequestration potential of grasslands is higher than that of cropland. The Indian mountainous line of more than 4500 km running from north-west to north-east provides an excellent space for the grasslands and can stock SOC at the rate of 37 Mg ha^{-1} at altitudes between 500 m and 1000 m. The rate is increased exponentially with altitude to 142.14 t ha^{-1}at altitude of above 2500 m (Chap. 17 by Pasricha and Ghosh this volume Chap. 18 by Mahanta et al. this volume). In Chapter "Soil Management for Regulating C Pools: Perspective in Tropical and Sub-tropical Soils", Debashis Mandal stated that transformation of degraded croplands to grassland can result in an annual increase of 3% or more SOC concentration (Conant et al. 2001). Through this conversion, C sequestration rate of 0.3–0.8 Mg ha^{-1} $year^{-1}$ was achieved in West Africa (Batjes 2001). Some researchers even reported a higher sequestration rate between 1.2 and 1.7 Mg ha^{-1} $year^{-1}$ in case of land conversion from degraded cultivated land to grassland (FAO 2004; Vagen et al. 2005). Rehabilitating degraded land converting to grassland is thus a good option for sequestration of carbon. Such effect of land-use change on C enrichment in soil was also observed in temperate climate wherein a 1.7 times higher SOC storage has been reported in agroforestry system than the croplands without trees (Chap. 22 by Rai et al. this volume).

A common practice that is followed by farmers of the SAT regions is to go in for deep tillage in peak summers and leave the field bare fallow before the onset of the monsoon rains. Adoption of such practices accelerate the loss of SOC due to both an increased mineralization of the SOC and erosion of sediments with runoff water (FAO and ITPS 2015), although mineralization of the SOC influences the biogeochemical nutrient cycles orchestrated by the soil microbial flora (Chap. 15 by Singh et al. this volume). Because of these, SOC is getting depleted at faster rates compared to its replenishment in SAT regions. However, processes of SOC loss/gain due to changing cultivation or management practices are usually slow unless the losses are linked to soil erosion. This is why cultivated or disturbed soils tend to lose SOC, whereas permanent grasslands and forests gain SOC over time (Jones et al. 2012). Again, bare fallows are neither conducive to any carbon build-up, nor in situ conservation of the summer monsoon rainfall, nor protect soils against erosive forces of the high-intensity rainfall. Therefore, the challenge for the SAT farmers is to close the summer window with some cover crops to conserve soils and rainwater. Kar (this volume) in Chap 16 has indicated that soil organic matter affects water retention in soils through greater structural effect close to field capacity than close to wilting point. This suggest that SOC amended surface soil layers are likely to possess increased capacity for absorption and conservation of rainwater into soil moisture which already has emerged as the most serious limitation to achieve the goal of global food security.

In 1960, Jenny and Raychaudhuri made a comprehensive study and showed that climate had the most impact on SOC reserve in Indian soils, although they did not make any estimate of its total carbon reserve. The first attempt for estimating OC stock was made by Gupta and Rao (1994) who pegged the SOC stocks of Indian soils at 24.3 Pg (1 Pg = 10^{15} g; billion tons). They considered 1-m depth surface of 48 Benchmark soil profiles for this assessment. A significant observation emerging from this study was that the salt-affected and other degraded soils having the least SOC had the maximum potential to sequester additional carbon if reclamation measures are initiated to rehabilitate them. Based on a detailed geographical distribution of soil series in the country and taking the soil depth further to 150 cm, Bhattacharyya et al. (2000a, b, 2008) estimated the SOC stocks of Indian soils at 63 Pg.

Increasing the SOC pool by 1 Mg C $ha^{-1}year^{-1}$ can enhance agronomic production in developing countries by 32 and 11 million tonnes per year in case of cereals and food legumes, respectively (Lal 2006). Such enhancement in SOC and the associated improvement in soil quality can be ensured by adopting resource conservation technologies. It is shown that no-till soils have a higher C stratification ratio over the other cultivated types [NT (2.11) >RT (1.77) >CT (1.53)] ensuring better soil quality and soil ecosystem functioning in the former (Chap. 16 by Hati et al. this volume. This gain in SOC in the top layers improves the ability of the soils to absorb and conserve rainwater in the SAT region. In fact, among the tillage practices, conservation agricultural practices and long-term recycling of crop residue support the natural systems by storage of more crop residues in soil. Adopting integrated nutrient management (INM) may improve carbon sequestration in soils by supplying N, P, S and other nutrients essential for humification process, and as such, optimally fertilized rice-wheat system was found to sequester more carbon compared to maize-wheat system (Kukal 2009). Furthermore, long-term fertilizer experiments in India also revealed that integrated or balanced nutrient management resulted in build-up organic carbon content of soils. Some major strategies for the enhancement of C sequestration potential in soils are thus no-till farming with crop residue mulch and cover cropping (conservation agriculture), an integrated nutrient management including the use of compost and manure and liberal use of biosolids (Chap. 9 by Sharma and Behera this volume, Chap. 10 Singh et al. this volume Chap. 13 by Bandyopadhyay et al. this volume). It is estimated that they could mitigate more than 50% of the total GHG emissions in India, but it all depends on the extent and speed of adoption of these measures by farmers which remain unsatisfactory (Chap. 23 by Benbi and Nisar this volume; Sapkota et al. 2018). The scale of soil carbon sequestration thus relies more on understanding the barriers and overcoming the constraints rather than on filling in the gap in our scientific and technical knowledge. However, sincere efforts are needed to be made in changing government policies to promote these technologies across the tropical and sub-tropical regions of the world in order to provide livelihood security to its teeming population.

Governance and Policy

Soil degradation with depleted soil C exacerbates challenges of livelihood of billions of people in tropical and sub-tropical regions of the world. At present, about 70% of the population in tropical region practice unsustainable cultivation that contributes to soil degradation. The main problem is that SOC sequestration does not have an immediate solution to food security. Farmers need the goods and services (provisioning services) that could immediately sustain their livelihood. Therefore, the presence of carbon markets and payments for ecosystem services may be an additional incentive for resource-poor farmers of tropical region while implementing soil rehabilitation and adoption of RMPs. Even with the large technical potential to sequester carbon in soils, there are often major limitations in achieving that potential in tropical countries and within specific farming systems. With any efforts to sustain prominent changes in practice, a significant understanding of sociocultural, political and socioeconomic contexts is required. Therefore, governance and policy play a very important role in implementing various strategies. Updating our understanding of the achievable potential for carbon sequestration in soils, and the practical implementation of improved soil management and farming practices aimed towards increasing SOC, offers a strategy for mitigation of climate change with potentially positive implications for food security and ecological resilience in the long term.

Following the conversion of cropland to forest and grassland across the Loess Plateau of China through their ambitious Grain for Green project, the average C sequestration rate that increased by 0.3 Mg ha^{-1} $year^{-1}$ in 16 years is an example of good governance and policy. Although the initial goal of the project was to control soil erosion, it has been remaining greatly influential in increasing both the rate and overall quantity of C sequestration in the soil. Interestingly, land converted to grassland had higher C sequestration rate than even forest and shrub land. All the examples narrated in this chapter clearly showed that rational and judicious soil management practices with suitable cropping systems enhanced C stocks in soils and thereby improved soil structure, curbing soil erosion and land degradation.

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Contents

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