Mitigating Climate Change Through Carbon Sequestration for Sustainable Development: Empirical Evidence from Cameroon's Forest Economy

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Preface

This book is part of the Sustainable Development Goals (SDGs) for Society book series, which comes in two volumes. This particular volume (Volume II) addresses current issues on four various themes: food security, energy, climate action and biodiversity. This volume is organised into five major parts with 19 chapters. The five parts are: (1) introduction and background; (2) food security and sustainable energy; (3) climate action for SDGs; (4) health, water and biodiversity engagements; and (5) conclusion and recommendations. The 2030 Agenda for Sustainable Development that enshrines the 17 interwoven SDGs, their 169 targets and many more indicators is broad. It covers a wide range of goals, including poverty eradication, economic growth, social inclusion, environmental sustainability, peace and partnerships for all by the year 2030. Post 2015, the world is working towards meeting the SDGs. Across the globe, the challenge of domesticating and localising the SDGs in terms of national and local development priorities requires a combination of technical, scientific, administrative and political input. It is clear that a collaborative research approach is needed to stay true to the SDGs' inclusive and bottom-up approach. Of particular interest is the notion that the SDGs represent a development agenda that should be realised by both the developed and developing countries. This provides researchers across and within disciplines with endless novel opportunities to engage with the SDGs, especially at societal levels. Given the foregone, the SDGs remain, therefore, an agenda for society. The world has gone past four years of SDGs implementation, and 2030 is fast approaching. To this end, it is high time to take stock and report what is on the ground to inform further implementation and to scale up implementation activities going forward. The 2030 Agenda for Sustainable Development is also facing severe funding challenges given that it has been disrupted by the Covid-19 pandemic that took centre stage in 2020. Hence, this book also assists in reminding key stakeholders that the SDGs agenda should remain the main agenda. To this end, the cases documented remain valuable as a contribution in highlighting what had been happening in societies relative to the implementation of the SDGs.

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This book is double-blind peer-reviewed. Apart from this being the international best practice norm, this double-blind peer-review process is mandatory for South Africa–based authors to fulfil the requirements of the Department of Higher Education and Training's (DHET) policy for recognised research outputs for subsidy purposes. The authors invested their time to incorporate observations from the blind peer-review process, an aspect that enhanced the quality of the product.

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11 Mitigating Climate Change Through Carbon Sequestration for Sustainable Development: Empirical Evidence from Cameroon's Forest Economy

Ernest L. Molua

Abstract

Climate change is a wicked problem that requires urgent integrated approach for progress across multiple goals. This chapter invokes the connectivity of three United Nations Sustainable Development Goals (SDGs), including SDGs 12, 13 and 15 to highlight the need for concerted efforts to protect, restore and promote sustainable use of forest ecosystems while mitigating climate change in Cameroon. The fulcrum is on the potentials of forest serving as the nexus for climate action. Few economic assessments on carbon supply and sequestration have been done on Africa's forests. Beyond the direct provision of wood, the country's forests within the Congo Basin play different roles in the carbon cycle, from net emitters to net sinks of carbon, and possibly stand to benefit from the emerging global carbon market. The case study examines a carbon supply model and reveals that the short-run sequestration potential increases with rise in expected carbon revenues, forest density and government expenditures for better management of the forest sector. Increases in wood prices, fossil fuel price, timber harvest and consumption potentials have negative and statistically significant effects on carbon supply. In the long run, wood price and forest expenditure have a positive effect on carbon capture and supply. These results have interesting implications for carbon policy for both Cameroon and other developing countries in the sub-continent. Policy will have to address broad-ranged socioeconomic and political impediments for the promotion of carbon supply and sequestration. Affordable, scalable solutions must therefore be sought to enable countries to leapfrog to cleaner, more resilient economies.

Keywords

SDGs · Sustainable development · Climate change · Forest · Carbon sequestration

1 Introduction and Background

The United Nations' ambition to transform the world through the 2030 Agenda for Sustainable Development adopted by all member states in 2015 for the period 2016–2030 "focuses on time-bound targets for prosperity, people, planet, peace, and partnership" (UN 2015). The agenda of the UN Sustainable Development Goals

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(SDGs) or Global Goals provide a holistic and multidimensional view on development (Schröder et al. 2019; Pradhan et al. 2017). Conserving forests and other ecosystems is one of the 17 Global Goals that make up the 2030 Agenda (Sachs et al. 2019). Achieving economic growth and sustainable development requires societies to urgently reduce their ecological footprint by changing the way production and consumption of goods and resources are undertaken. This paper interweaves the nexus of three pertinent SDGs, including SDG-12 on responsible consumption and production, SGD-13 on climate action as well as SDG-15 on life on land which aptly captures the interactive role of the forest economy in climate change and sustainable production and consumption.

Forest ecosystems play important roles in human existence, with a significant number of the SDGs having indicators related to forests for the actualization of the UN goals of human development. Forest as a renewable natural resource is crucial for tackling many of the issues identified in the “Future We Want”, such as poverty, food security, climate change, biodiversity, sustainable production and consumption and social inclusion, particularly meeting the basic needs of vulnerable people and ensuring their wellbeing. For instance, more than 20% of the household income for local families (SDG-1) come from forests. While SDG-15 which deals with life on land extensively addresses the place of forests in sustainable development, however, better forest management is required for SDG-2 and SDG-6, respectively. In the SDG-2 to end hunger, achieve food security and improve nutrition and promote sustainable agriculture, target 2.3 expects that by 2030 countries should achieve an important indicator 2.3.1 relating to an increase in the volume of production per labour unit for forestry as well as for classes of farming and pastoral enterprises. Such an indicator sufficiently accounts for the target to double agricultural productivity and incomes of small-scale food producers, particularly for 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. In same token, SDG-6 to ensure availability and sustainable management of water and sanitation for all has target 6.6 to protect and restore ecosystems and to assist the recovery of those already degraded including mountains, forests, wetlands, rivers, aquifers and lakes. Tropical forests which shelter most of the world’s terrestrial biological diversity (SDG-15) are seen as safe, natural means for carbon capture and storage, as well as recognized as an essential element of any strategy to stabilize global climate (SDG-13). Some other SDG targets related to forests include target 1.4 on access to natural resources for SDG-1; target 2.5 on maintaining genetic diversity of seeds, plants and animals for SDG-2; target 11.7 on accessing green spaces for SDG-11; and target 12.2 on sustainable management of natural resources for SDG-12. These reveal that forests’ contributions are not limited to local livelihoods and global environmental objectives, but that stopping deforestation contributes to many other development goals at scales in between.

Integrated approaches are thus needed for enhancing the multiple contributions of forests to SDGs as they will harness synergies and balance cross-sectoral trade-offs between forests and other closely interlinked development issues. Several international instruments and processes offer a range of goals, objectives, targets and indicators on forests, based on which forest-related targets and indicators for the SDGs can be developed, for example, the UN Convention on Biological Diversity and the Strategic Plan for Biodiversity 2011–2020, including its 5 Goals and 20 Aichi Targets; the UN Framework Convention on Climate Change, the Kyoto Protocol and decisions on reducing emissions from deforestation and forest degradation in developing countries (REDD+); the UN Convention to Combat Desertification, including the concept on land degradation neutrality embraced at Rio + 20; the UN Zero Hunger Challenge; and the Global Partnership on Forest Landscape Restoration (IPBES 2019; IPCC 2013; UN 2002, 2012, 2015).

On the heels of these developmental necessities and quest for human progress, climate change is a real and undeniable emerging threat to human civilization, affecting every country on every continent, disrupting national economies and affecting lives (IPCC 2019a, b). Weather patterns are changing, sea levels are rising and weather events are becoming more extreme. The effects are already visible and will be catastrophic unless we act now. This is important since human life depends on the Earth as much as the forests and ocean for sustenance and livelihood (IPBES 2018, 2019). In fact, forests account for 30% of the Earth's surface, providing vital habitats for millions of species and important sources for clean air and water, as well as being crucial for combating climate change. Promoting the sustainable management of forests and halting deforestations are also vital to mitigating the impact of climate change (Bellassen and Gitz 2008; Duinker 1990). There are calls for urgent action to be taken to reduce the loss of natural habitats and biodiversity which are part of mankind's common heritage (Hess 2016; Zapfack et al. 2014).

In the midst of many interwoven goals, SDG-15 therefore stands out not only as the fulcrum on which many SDGs interconnect (Morton et al. 2017; Dzebo et al. 2018) but a livewire for many developing countries especially south of the Sahara in which daily livelihood is anchored to the environment particularly the forest ecosystems. The UN General Assembly resolution identified Sustainable Forest Management (SFM) as a gauge for Goal 15 and target 15.1 as well as for target 15.2 and formally defines it as "a dynamic and evolving concept [that] aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations" (UN 2020: 1). The FAO (2020: 1) notes that "this definition implies SFM is a concept which varies over time and between countries, whose circumstances – ecological, social and economic – vary widely, and always addresses a wide range of forest values, including economic, social and environmental values, and take intergenerational equity into account". The key results emerging from existing data[1] is that the world continues to make progress in all dimensions of SFM; although forests continue to be lost, the rate of loss has been cut by 25% since the period 2000–2005 (UN 2020). According to the FAO (2020:1), "the change in forest area within legally protected areas is a proxy for trends in conservation of forest biodiversity as well as cultural and spiritual values of forests and thus a clear indication of the political will to protect and conserve forests. This indicator is related to the CBD Aichi Target 11 which calls for each country to conserve at least 17 per cent of terrestrial and inland water areas". The proportion of protected forest area and forests under long-term management plans are increasing with steady progress for Cameroon within the Central African subregion. Both SDG indicators 15.1.1 and 15.2.1 ensure forests are efficiently managed, and a better balance is struck between conservation and sustainable use of natural resources.[2]

Despite this positive outlook, nonetheless, deforestation and forest degradation are still concerns in some regions, particularly in the tropics, indicating the need for more action to reduce deforestation and implement SFM practices. The challenge, however, goes beyond the tropics. For sub-Saharan Africa, there's a small change for aboveground biomass stock in forest, as well as

[1] The UN data series which contributes to the measurement of SDG indicator 15.2.1, classified as Tier I, is officially defined as follows: Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas shows temporal trends in the mean percentage of each important site for terrestrial and freshwater biodiversity (i.e. those that contribute significantly to the global persistence of biodiversity) that is covered by designated protected areas (UN 2020).

[2] SDG indicator 15.2.1 is composed of five subindicators that measure progress towards all dimensions of sustainable forest management. The environmental values of forests are covered by three subindicators focused on the extension of forest area, biomass within the forest area and protection and maintenance of biological diversity and of natural and associated cultural resources. Social and economic values of forests are reconciled with environmental values through sustainable management plans. The subindicator provides further qualification to the management of forest areas, by assessing areas which are independently verified for compliance with a set of national or international standards (UN 2020).

significant positive change for proportion of forest area located in legally established protected area and proportion of forest under long-term forest management plans. However, negative change is reported for forest area under independently verified forest management certification schemes. Overall, nonetheless, efforts are required across all subregions to promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

Sensible sustainable production and consumption do not take place in a vacuum. These happen in a world in which action to combat climate change and its impacts are imperative. An integrated approach is crucial for progress across the multiple goals. The Johannesburg Plan of Implementation of the World Summit on Sustainable Development (UN 2002) and the "Future We Want" outcome document of the Rio + 20 Conference (UN 2012) both recognized that "poverty eradication, changing unsustainable and promoting sustainable patterns of consumption and production and protecting and managing the natural resource base of economic and social development are the overarching objectives for sustainable development". Ensuring Sustainable Consumption and Production (SCP) patterns is therefore an essential requirement for sustainable development (Schröder et al. 2019). SCP not only promotes conservation through resource-use efficiency but has a cross-cutting role in sustainable development and its targets as basis for future development. The High-level Panel of Eminent Persons on the Post-2015 Development Agenda, commissioned by the Secretary-General of the United Nations in 2013, found that the world's consumption and production patterns need to be managed in a more sustainable and equitable way and that only by mobilizing economic, social and environmental action together can we irreversibly reduce poverty (UN 2013). By its cross-cutting nature, SCP addresses interlinkages and adopts a holistic approach, taking into account the economic, social and environmental aspects of sustainable development in a balanced and integrated manner (Schröder et al. 2019).

Human life on land depends on the forest ecosystems (IPBES 2018, 2019). Forest covers provide vital habitats for millions of species of animals, plants and insects and are important sources for clean air and water, as well as being crucial for combating climate change (Schröder et al. 2019; Oyono et al. 2005). Every year, millions of hectares of forests are lost globally, while the persistent degradation of drylands leads to desertification. The severe damage to land through deforestation, loss of natural habitats and land degradation disproportionately affects poor communities. Land use changes, including deforestation, result in a loss of valuable habitats, a decrease in clean water, land degradation, soil erosion and the release of carbon into the atmosphere (Bellassen and Gitz 2008). In the advent of global warming and climate change, carbon storage to offset carbon emissions in the form of carbon dioxide (CO_2) is gaining currency in national and international policy measures (Richards 2004). While acknowledging warming across the continent between 0.2° and 0.5 °C per decade up to the year 2100, the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2013) confirmed that this change will also come with more frequent events such as storms, floods, sea level rise or droughts. Climate change thus represents a fundamental challenge to the sustainability of Africa's growth momentum. Hence, limiting the effects of climate change is necessary to achieve sustainable development and equity. At the same time, some mitigation efforts could undermine action on the right to promote sustainable development (Guariguata et al. 2008; Alig et al. 1997).

Under the United Nations Framework Convention on Climate Change (UNFCCC) established to cooperatively work to prevent dangerous anthropogenic interference with the climate system while coping with inevitable impacts of climate change; mitigation efforts are implemented through various types of policies, strategies and initiatives with the aim of mitigating greenhouse gas (GHG) emissions. Examples include the Kyoto Protocol's market mechanisms such as the Clean Development Mechanism (CDM), the mechanism for Reducing Emissions from Deforestation and Forest Degradation

(REDD+), the Nationally Appropriate Mitigation Actions (NAMAs) and Intended Nationally Determined Contributions (INDCs) (Bellassen and Gitz 2008; Jung 2005; Roslan 1995). The REDD+ and more broadly the Land Use, Land Use Change and Forestry (LULUCF) provisions are perceived to hold key roles in achieving the UNFCCC's ultimate goal – a rise in average global temperature of no more than 2° C by 2100 (Olesen et al. 2017; Campbell 2009; Schlamadinger et al. 2007).

The central feature of the Kyoto Protocol is its requirement that countries limit or reduce their greenhouse gas emissions. To help countries meet their emission targets, and to encourage the private sector and developing countries to contribute to emission reduction efforts, negotiators of the Protocol included three market-based mechanisms – emissions trading, the Clean Development Mechanism (CDM) and Joint Implementation (JI) – to help countries with binding greenhouse gas emissions targets (the Annex I countries) meet their treaty obligations (Jung 2005). The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2 (Michaelowa 2003). These CERs can be traded and sold and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets. Under the JI, countries with commitments under the Kyoto Protocol are eligible to transfer and/or acquire emission reduction units (ERUs) and use them to meet part of their emission reduction targets. Under Article 6, any Annex I country can invest in a project to reduce greenhouse gas emissions in any other Annex I country [referred to as a "Joint Implementation Project", particularly economies in transition (the EIT Parties) noted in Annex B of the Kyoto Protocol], as an alternative to reducing emissions domestically. In this way countries can lower the costs of complying with their Kyoto targets by investing in projects where reducing emissions may be cheaper and applying the resulting Emission Reduction Units (ERUs) each equivalent to one tonne of CO_2, which can be counted towards meeting their commitment of the Kyoto Protocol.

Whether the CER, CDM or JI, they all recognize the important role of forest ecosystems in the global carbon cycle, absorbing large amounts of atmospheric CO_2 through photosynthesis and emission of CO_2 to the atmosphere through respiration, decomposition and disturbances such as timber harvesting, fire, pest infestations and land use change (Depro et al. 2008). The forest sector is therefore strategic to play a major role in climate change mitigation (Guariguata et al. 2008). The important role of forests was flagged in the agreements of the 16th Session of the Conference of the Parties (COP) to the UNFCCC in Cancún. The agreement was emphatic on protecting the world's forests, which are a major repository of carbon. On agreeing to launch concrete action on forests in developing nations, COP-16 imported the essential elements of the Copenhagen Accord of COP-15 which represented key steps forwards to reduce greenhouse gas emissions and help developing nations protect themselves from climate impacts and developed countries build their own sustainable futures through mitigation pledges, a new Green Climate Fund for developing countries and a system to help verify countries' actions. The Cancún pledge hinged on the fact that, depending on their characteristics and local circumstances, forests can play different roles in the carbon cycle, from net emitters to net sinks of carbon (Newell and Stavins 2000; Kotto et al. 1997). Forests can sequester carbon by taking in carbon dioxide (CO_2), a major contributor to greenhouse effect, from the atmosphere, and transforming it into biomass through photosynthesis (Oyono et al. 2005). Sequestered carbon is then accumulated in the form of woody biomass, deadwood and litter in forest soils. In sustainably managed forests, the amount of carbon that can be released as a result of harvesting is equal to or smaller than the amount taken from the atmosphere, making forests "carbon-neutral" or "carbon sinks" (Newell and Stavins 2000). Promoting the expansion of sustainably managed forests, increasing sound mobilization of wood as well as replacing carbon-intensive commodities through wood products and bioenergy would enlarge carbon sink potential and significantly contribute to offsetting greenhouse gas (GHG) emissions (Brack 2018; Youssoufa et al. 2011; Kotto et al. 1997). The release of carbon from forest ecosystems results from natural processes (respiration and oxidation) as well as deliberate or unintended results of human activities (i.e. harvesting, fires, deforestation) (Fry 2008; Oyono et al. 2005).

Stern (2008) notes that cost-effective carbon sequestration from agricultural land use change practices could sequester about 1Gt of CO_2. When soils are exposed to microbial activity, CO_2 emissions are released. These emissions can be reduced by disturbing the soil less, for example, by using conservation tillage techniques and turning land into permanent set-aside. Mitigation and adaptation can positively or negatively influence the achievement of other societal goals, such as those related to human health, food security and biodiversity (Oberthür 2016; Guariguata et al. 2008; Albrecht and Kandji 2003). Supporting this argument are several studies that point out that land use change, including deforestation and forest degradation, accounts for 17% to 29% of global GHG emissions (Sohngen and Mendelsohn 2003). Reducing emissions from deforestation and forest degradation and enhancing carbon sinks (REDD+) are taunted as a panacea by the Parties to the UNFCCC with several initiatives and programmes such as the Forest Carbon Partnership Facility and the Forest Investment Program that build on REDD+ as a climate change mitigation solution (Phelps et al. 2010; Campbell 2009). These programmes have implications of different GHG emission levels for the rate of CO_2 emission reductions from 2030 to 2050. According to the IPCC (2013), delaying mitigation efforts beyond those in place today through 2030 is estimated to substantially increase the difficulty of the transition to low longer-term emission levels and narrow the range of options consistent with maintaining temperature change below 2 °C relative to pre-industrial levels. The Cost-effective mitigation scenarios that make it at least about as likely as not that temperature change will remain below 2 °C relative to pre-industrial levels (2100 concentrations of about 450 to about 500 ppm CO_2eq) are typically characterized by annual GHG emissions in 2030 of roughly between 30 GtCO_2eq and 50 GtCO_2eq.

At the 21st Conference of the Parties (COP-21) in Paris, countries adopted a legally binding global climate deal, requiring all Parties to put forward their best efforts through "Nationally Determined Contributions" (NDCs) and to strengthen these efforts in the years ahead (Nhamo and Nhamo 2016a). The Paris Agreement is a bridge between today's policies and climate neutrality before the end of the century (Kinley 2017; Nhamo and Nhamo 2016b). Governments agreed a long-term goal of keeping the increase in global average temperature to well below 2 °C above pre-industrial levels, and to aim to limit the increase to 1.5 °C, since these would significantly reduce risks and the impacts of climate change. The expectation was for global emissions to peak as soon as possible, recognizing that this will take longer for developing countries, and to undertake rapid reductions thereafter in accordance with the best available science (Nhamo and Nhamo 2016b; Oberthür 2016). In COP-22 in Marrakech, governments welcomed the Paris Agreement with its ambitious goals, its inclusive nature and its reflection of equity and common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

The aim of this chapter is therefore to demonstrate the possibility of mitigating climate change through forest sector carbon sequestration, using information from a tropical African country which is part of the Congo Basin Forest. In achieving this, the chapter specifically interweaves the possibility of ensuring responsible exploitation and consumption of land-based forest resources in a manner that addresses the climate change imperative. The remainder of the chapter is divided into three distinct sections as follows. Section 2 examines theoretical developments connecting sustainable forest management for climate action to ensure sustainable natural capital of land. Section 3 presents a case study on Cameroon by assessing the politico-economic determinants of the country's forest exploitation. Some policy recommendations based on the empirical findings and analytical review are provided in the concluding Section 4.

2 Literature Review: Nexus of Sustainable Forests for Climate Action and Better Life on Land

The three SDGs 12, 13 and 15 are very useful connectors between economic progress and environmental perspectives. The 2030 Agenda embraces the three dimensions of sustainability – economic, social and environmental – in an integrated and interconnected manner. Comprehensive sustainability will require not only ecological but also economic and social sustainability. By adopting the 2030 Agenda and the Paris Climate Agreement, the UN effectively created a framework for national action and global cooperation on sustainable development, while the Paris Agreement committed signatory countries to achieving net-zero greenhouse gas emissions by the middle of the century (Kinley 2017; Nhamo and Nhamo 2016a). This means the SDG 13 on climate change specifically links the Paris Agreement (Bruce et al. 2018; Fawcett et al. 2015), noting that the UNFCCC “is the primary international, intergovernmental forum for negotiating the global response to climate change” (UN 2015). The toolbox of the UNFCCC has as spanner sustainable forest management.

Forests are not only important because they are valuable economic asset providing livelihood opportunities, but promoting a sustainable use of forest ecosystems and preserving biodiversity are key to human survival (Schröder et al. 2019; Zapfack et al. 2014). According to Brack (2019), forests play a critical role in the Earth’s climate system, in a number of different ways, including capturing carbon dioxide from the atmosphere and converting it, through photosynthesis, into living biomass. Forests also store carbon in forest soils, absorbed through leaf litter, woody debris and roots. The complex interactions involving soil minerals, plants, soil organisms and organic components are influenced by local climatic conditions and forest management (IPBES 2018, 2019; Duinker 1990). The acknowledgement of such important forest services pushed the UN (2017) Strategic Plan for Forests 2017–2030 adopted by the Economic and Social Council on 20 April 2017 to specify Global Forest Goals to involve (a) reverse the loss of forest cover worldwide through sustainable forest management, including protection, restoration, afforestation and reforestation, and increase efforts to prevent forest degradation and contribute to the global effort of addressing climate change; (b) enhance forest-based economic, social and environmental benefits, by improving the livelihoods of forest-dependent people; as well as (c) increase significantly the area of protected forests worldwide and other areas of sustainably managed forests, as well as the proportion of forest products from sustainably managed forests.

Granted that natural assets are for man’s exploitation and welfare, however sensible sustainable use calls for stewardship in consumption (Hess 2016). SDG-12 on sustainable consumption and production is of particular relevance to the supply of forest products, and the significant links between SCP and forests is beginning to receive attention among the expert and policy communities. SDG-12 is considered a major contributor to the protection and enhancement of natural resources, including forests (FAO 2020), and is seen to be particularly relevant to the supply of forest products (Brack 2018). For instance, Hess (2016) discusses the importance of natural resources for economic growth and sustainable development and asserts that while increases in the quantity or quality of natural resources available to an economy enhance the productive capacity of the nation, there is increasing evidence of environmental stress-threatening future livelihoods.

With respect to SCP on forests and their conservation, sustainable management and use, as well as forest livelihoods, Schröder et al. (2019, p. 386) remind us that “SCP has been part of the international policy discourse for more than four decades, but the uptake of SCP has not been smooth and has tended to be biased towards relatively weak measures”. Although SDG-12 targets or indicators make no direct reference to forests or forest communities, SDG-12 targets can contribute positively to forest protection and conservation efforts. SDG-12 can contribute to creating enabling conditions for advancing more responsible and sustainable supply of timber and other forest commodities, also linked to more responsible demand.

Glass and Newig (2019) note that the achievement of the SDGs depends on effective governance arrangements. Different aspects of governance, namely, participation, policy coherence, reflexivity, adaptation and democratic institutions on SDG achievement at the national level, may serve to explain SDG achievement. Governance is important since as Morton et al. (2017:81) demonstrate that all the goals are intimately interconnected, and "a failure to appreciate this will perpetuate an approach which will be non-aligned at best and highly ineffective at worst". There is the need to identify and assess synergies between climate and sustainable development policies and avoid or manage trade-offs. It emerges that the interaction of SDGs 12, 13 and 15 enhance both human wellbeing and the ecological health of the planet (Morton et al. 2017). According to Dzebo et al. (2018), there is a great potential for greater policy coherence in the implementation of the 2030 Agenda for Sustainable Development and the Paris Agreement. To take advantage of it, there is a need to identify and assess synergies between climate and sustainable development policies and avoid or manage trade-offs. At the national and sub-national level, where the Paris Agreement is implemented through national climate action plans (or Nationally Determined Contributions – NDCs), there is a need for sufficient understanding of the potential coherence between the implementation of the NDCs and the SDGs.

The attainment of the SDG agenda will greatly depend on whether the identified synergies among the goals can be leveraged. IIASA (2019) considered some key interventions that would be necessary to achieve the SDG outcomes with their implementation being organized into a set of six transformations, namely, education, gender and inequality; health, wellbeing and demography; energy decarbonization and sustainable industry; sustainable food, land, water and oceans; sustainable cities and communities; and digital revolution for sustainable development. In their view, each SDG transformation describes a major change in societal structure (economic, political, technological and social) to achieve long-term sustainable development, with each contributing to multiple SDGs. Excluding any of them would make it virtually impossible to achieve the SDGs.

An important subsector through synergy that is required to transform economies is the forest, with its onerous role in the carbon cycle, yet affected by changing climatic conditions. Evolutions in rainfall and temperature can have either damaging or beneficial impacts on forest health and productivity, which are very complex to predict. Depending on circumstances, climate change will either reduce or increase carbon sequestration into forests, which causes uncertainty about the extent to which the world's forests will be able to contribute to climate change mitigation in the long term (Guariguata et al. 2008; Albrecht and Kandji 2003). Forest management activities have the potential to influence carbon sequestration by stimulating certain processes and mitigating impacts of negative factors (Duinker 1990). The development of a market for carbon emissions is a significant component of the UNFCCC's Kyoto Protocol. Parties with emission reduction targets, i.e. Annex B of the Protocol, are allocated "assigned amount units" (AAUs) that represent the total emissions permitted to meet these targets.[3] Perez et al. (2007) note that in theory, carbon markets present win-win opportunities for buyers and sellers of carbon stocks. This may promote better forest management.

Some other studies have indicated the plausibility of sequestering significant amount of carbon from properly managed forests (Stoffberg et al. 2010; Hennigar et al. 2008; Thomson et al. 2008; Benítez et al. 2007; Karjalainen 1996). For instance, Benítez et al. (2007) note that within 20 years and considering a carbon price of US$50/tC, tree planting activities could offset 1 year of global carbon emissions in the energy sector. Similarly, on assessing the contribution of terrestrial carbon sequestration to climate change

[3] Domestic reduction policies help bring actual emissions in line with the allocated AAUs. Parties then submit national greenhouse gas inventories annually to the UNFCCC that account for all emissions that occurred within that year.

mitigation, Thomson et al. (2008) show that terrestrial sequestration reaches a peak rate of 0.5–0.7 Giga tonnes of carbon per year (GtC $yr.^{-1}$) in mid-century with contributions from agricultural soils (0.21 GtC $yr.^{-1}$), reforestation (0.31 GtC $yr.^{-1}$) and pasture (0.15 GtC $yr.^{-1}$). According to Thomson et al. (2008), sequestration rates vary over time and with different technology and policy scenarios. The combined contribution of terrestrial sequestration over the next century ranges from 23 to 41 GtC. This makes it clear that the contribution of forests to carbon cycles has to be evaluated taking also into account the use of harvested wood, e.g. wood products storing carbon for a certain period of time, or energy generation releasing carbon in the atmosphere. In cases where the net balance of carbon emissions by forests is negative, i.e. carbon sequestration prevails, forests contribute to mitigating carbon emissions by acting as both a carbon reservoir and a tool to sequester additional carbon (Albrecht and Kandji 2003; Sedjo et al. 1995). In cases when the net balance of carbon emissions is positive, forests contribute to enhancing greenhouse effect and climate change.

3 Case Study: Carbon Sequestration in Cameroon's Forests

With a significant landmass covered by the humid tropical rainforest and being part of the Congo Basin, Cameroon is a major source of tropical wood and a reservoir for carbon (Somorin et al. 2012; Ndoye and Kaimowitz 2000). Aside from timber, Cameroon's forest ecosystems are the source of many direct and indirect benefits. They provide habitats for some rare terrestrial species, and they offer watershed protection, control of soil erosion and hence siltation. They also provide a wide range of non-timber products and recreational, cultural, spiritual and amenity benefits (Zapfack et al. 2014). As part of the larger ecosystem of the Congo Basin, the country's forest thus plays an important role in mitigating the emissions of (CO_2), the most important greenhouse gas (Brown et al. 2010; IPCC 2007). Different management regimes in the country affect the ability of Cameroon's forests to sequester carbon. With recent developments in the carbon market, forestry authorities are now recognizing the potentials from financial markets for the ecosystem services that national and community forests provide, such as biomass for renewable energy, clean water, clean air, habitat for wildlife (especially threatened and endangered species) and more importantly carbon sequestration (Zapfack et al. 2014; Brown 2006; Brown et al. 1993; Kotto et al. 1997).[4] Cameroon must therefore better manage its tropical forest resources to sequester carbon. Protecting forests as biodiversity habitat is important as well to mitigate climate change, since deforestation and forest degradation represent a major source of greenhouse gas emissions (Zapfack et al. 2014; Fry 2008). There is, however, inadequate technical information to assist policy-making processes to guide new shifts in the country's efforts towards the UNFCCC's Clean Development Mechanism (Jung 2005; Richards 2004; Brown 1997).

Balancing many different national priorities can be challenging, and so identifying areas of synergy, where more than one goal can be met at the same time, can help developing countries achieve their climate goals and other development goals at the same time. Cameroon like most countries in the Congo Basin has articulated its climate priorities in two major dossiers: the Nationally Determined Contribution to the Paris Agreement and the National Adaptation Programmes of Action (Somorin et al. 2012; Youssoufa et al. 2011). These dossiers define key policies to promote adaptation actions, mitiga-

[4] Carbon sequestration is the general term used for the capture and long-term storage of carbon dioxide. Capture can occur at the point of emission (e.g. from power plants) or through natural processes (such as photosynthesis), which remove carbon dioxide from the Earth's atmosphere and which can be enhanced by appropriate management practices. Carbon sequestration methods include (a) enhancing the storage of carbon in soil (soil sequestration), (b) enhancing the storage of carbon in forests and other vegetation (plant sequestration), (c) storing carbon in underground geological formations (geosequestration), (d) storing carbon in the ocean (ocean sequestration) and (e) subjecting carbon to chemical reactions to form inorganic carbonates (mineral carbonation).

tion actions and cross-cutting actions, particularly on its capacity to engage on mitigation with the REDD+ mechanism (Youssoufa et al. 2011; Campbell 2009; Brown 2006).

Numerous studies have analysed the carbon sequestration potential of forests and forest management, focusing on national and supra-national scales or on the project level, some in the context of the flexible mechanisms of the Kyoto Protocol (Maamoun 2019; Backéus et al. 2005; de Jong et al. 2000; Newell and Stavins 2000; Sohngen et al. 1999; Sedjo et al. 1995; Duinker 1990). A significant number of these studies have demonstrated the plausibility of forests to sequester carbon for both ecological benefits and financial gains (e.g. Gough et al. 2019; Sedjo and Sohngen 2012; Imai et al. 2009; Tonna and Marland 2007; Krcmar et al. 2001). On examining carbon sequestration estimates of indigenous trees, Stoffberg et al. (2010) observe that amelioration of global warming presents opportunities even for urban forests to act as carbon sinks and thereby could possibly be included in the potential future carbon trade industry. In their study on indigenous urban trees (e.g. *Combretum erythrophyllum*, *Searsia lancea* and *Searsia pendulina*), Stoffberg et al. (2010) estimate that the tree planting will result in 200,492 tonnes CO_2 equivalent reduction and that 54,630 tonnes of carbon will be sequestrated over a 30-year period (2002–2032). The carbon dioxide reductions could be valued at more than US$ 3,000,000. This illustrates that when future carbon trade becomes operational for urban forests these forests could become a valuable source of revenue for the urban forestry industry, especially in developing countries (Diaz-Balteiro and Romero 2008).

More research is needed, especially for countries in the Congo Basin, to more accurately capture the impact of either country or region-specific interactions between climate and management of forest resources for carbon sequestration, which are lost in global-level assessments. Being party to global conventions on climate change and signatory to regional environmental initiatives, the redefinition of Cameroon's forest policy now accounts for climate change mitigation and adaptation. Brown et al. (2010) note that climate change presents additional challenges to a diverse country like Cameroon that shares the Congo Basin rainforest. Not only is the population vulnerable to the direct effects of climate change, but forest-dependent communities are also vulnerable to changing environmental policy that may affect their access to forest resources (Brown et al. 2010). In sum, therefore, given the importance of Cameroon's forest to its immediate and future economy, and possessing features of an important laboratory for a green economy, it is pertinent to evaluate and quantify the factors that may motivate the sector for its sequestration potential. This paper thus sets out to evaluate the maximum carbon supply and carbon sequestration and assess the implications of forest management as a significant carbon sink. Optimizing carbon supply has been a matter of concern in the forestry literature (Olschewskia and Benítez 2010; Matheya et al. 2009; Sedjo et al. 1995). There are, however, few published studies addressing the issue in Cameroon under the dispensation of mitigating climate change. Most studies on the forest sector have either assessed forest management choices (e.g. Oyono et al. 2005) or evaluated the costs and benefits of reducing deforestation and forest degradation (e.g. Bellassen and Gitz 2008) and reviewed carbon dynamics in slash-and-burn agriculture (e.g. Kotto et al. 1997; Albrecht and Kandji 2003). In other African countries, analysis has hinged on the potential benefits of carbon sequestration markets and land tenure challenges which impede forest sector response to carbon potentials (Zapfack et al. 2002; Woomer and Palm 1998).

4 Methodological Orientation for the Case Study

4.1 Economic-Ecological Modelling of Carbon Sequestration

A myriad of approaches have been explored to evaluate the effect of forest management activities on the dynamics of the ecological resource stock (e.g. Seong-Hoon et al. 2019; Murphy et al. 2018; Favero et al. 2017; Plantinga 2015; Kim and McCarl 2015; Hernandez et al. 2014;

Yousefpour and Hanewinkel 2009; Lubowski et al. 2006; Benítez et al. 2007; Krcmar et al. 2001; Sedjo et al. 1995). Caparrós and Jacquemont (2003), for instance, used an optimal control model to analyse the choice between two types of forests: (i) one with high timber and carbon sequestration values but lower, or negative, biodiversity values and (ii) one with lower timber and carbon sequestration benefits but with high biodiversity values. To assess four alternative objective functions that maximized (a) volume harvested, (b) wood product C storage, (c) forest C storage and (d) C storage in the forest and products for a hypothetical forest, Hennigar et al. (2008) employed an optimizing forest management model (Remsoft Spatial Planning System). Partial equilibrium econometric methods have also been widely applied (Adam et al. 2020; Ayoade et al. 2018; Murphy et al. 2018; Chakir et al. 2017; Favero et al. 2017; Plantinga et al. 1999), though without attention to the time series properties of the variables to be tested. The current study is set to examine country-level information. The ensuing modelling framework inspired by Sohngen et al. (1999), Bateman and Lovett (2000) and Sohngen and Mendelsohn (2003) assume that carbon sequestration benefits are based on tonnes of carbon stored in the biosphere and the wood market. The short-run wood supply (Q_{wt}), i.e. annual roundwood harvest, forest stock and forest area, in the country is

$$Q_{wt} = f(H_t) \tag{11.1}$$

The harvest (H_{it}) reflects the volume or amount of natural forest stock (S_{it}) available for harvest, where

$$S_t = f(S_{t-1}, G_t, H_t) \tag{11.2}$$

with G_t being the annual change in forest stock per hectare, H_t is annual harvest and S_{t-1} previous stock levels. The country's harvest reflects the amount of forest stock available for harvest, i.e.

$$Q_{wt} \le S_t \tag{11.3}$$

The carbon supply function depends on the wood supply (Eq. 11.1), the forest area and forest stock growth (Eq. 11.2). The forest area and stock are related as

$$S_t = Ae^{b_i t} \tag{11.4}$$

where b_i is the rate of growth in supply. Following developments in climate change mitigation efforts, the maintained forest stock is a function of the annual rent for carbon, R_t, assumed to have the following form:

$$S_t = \varphi R_t^{k1} \tag{11.5}$$

where k_1 is the rate of growth in carbon rents. With no climate change, $k(t)$ is 0. Between Eqs. (11.4) and (11.5), $\varphi R_t^{k1} = Ae^{b_i t}$, where $R_t^{k1} = \frac{A}{\varphi} e^{b_i t}$, which could be summarized as

$$R_t^{k1} = we^{b_i t} \tag{11.6}$$

The linear form of Eq. (11.6) accounting for the growth or decay of carbon supply takes the form:

$$\ln R_t = \frac{1}{k_1}\left(\ln w + b_{it}\right) \tag{11.7}$$

Since greenhouse gases are assumed to increase radiative forcing, emissions cause k(t) to be positive. Studies have shown that the annual relative change in forest area (A_t) is a function of income per capita, tree growth, forest density and other exogenous variables (Diaz-Balteiro and Romero 2008; Backéus et al. 2005; de Jong et al. 2000; Roslan Ismail 1995). The short-run carbon supply equation may thus be expressed as a function of the forest area, A_t; previous stock levels proxied by forest density, FOD_t; price of wood, P_{wt}; carbon rent R_t; level of infrastructural development, TR_t; and consumption proxied by income per capita, $GDPc_t$. The empirical equation is thus modelled as a log linear form:

$$\begin{aligned}\ln S_t = \alpha_0 &+ {}^{2}{}_{0} \ln R_t + {}^{2}{}_{1} \ln P_{wt} + {}^{2}{}_{2} \ln P_{fst} \\ &+\alpha_1 \ln FOD_t + \alpha_2 \ln G_t + \alpha_3 \ln H_t + \\ &+\alpha_4 \ln Z_{it} + \alpha_5 \ln GDPc_{it} \\ &+\alpha_6 \ln FOR_t + \alpha_7 \ln TR_{it} + \mu_t\end{aligned} \tag{11.8}$$

where P_{fst} is the price of fossil fuel energy, FOR_t is forest-related policy (e.g. subsidy and tax)[5] and the other variables are as previously defined. R_t is carbon price as proxy for supply of carbon services,

[5] Subsidy may increase the annual net return to forested land and reduces the annual net return to deforested land.

G_t is change in forest stock, H_t is harvest and Z_{it} is other determinants of supply, e.g. production, transport and marketing infrastructure and structural economic reforms. Substituting for ln R_t as in eqs. (11.7) and Eq. (11.8) then yields

$$\begin{aligned}\ln S_t = {} & \eta_k + \beta_1 \ln P_{wt} + \beta_2 \ln P_{\mathrm{fst}} + \alpha_1 \ln \mathrm{FOD}_t \\ & + \alpha_2 \ln G_t + \alpha_3 \ln H_t + \alpha_4 \ln Z_{\mathrm{it}} + \alpha_5 \ln \mathrm{GDPc}_{\mathrm{it}} \\ & + \alpha_6 \ln \mathrm{FOR}_t + \alpha_7 \ln \mathrm{TR}_{\mathrm{it}} + \varepsilon_t\end{aligned} \tag{11.9}$$

where, η_k is a constant that embodies $\ln R_t = \frac{1}{k_1}\left(\ln w + b_{it}\right)$. The estimation of Eq. (11.9) therefore allows for possible estimation of the elasticity of carbon supply, the rate of growth in carbon rents and the intertemporal effects of climate change on carbon supply. We employ time series econometric techniques to establish the causation in Eq. (11.9). Parajuli et al. (2016) compared the estimation results obtained from the multivariate vector error correction (VECM) method with the traditional simultaneous equations' estimation approach and found that the traditional simultaneous equations' estimation approach produces similar demand and supply coefficients as the VECM method.

4.2 Nature and Source of Data

Secondary data is employed covering the period 1980–2018. Information for Cameroon on land use area (e.g. forest area, A_t), forest stock (S_t), annual harvest (H_t) as well as annual change in forest stock per hectare (G_t) is obtained from the Food and Agriculture Organization (FAO) database (FAOSTAT) and statistical accounts of the Ministry of Forestry and Wildlife. Information on forest density (FOD_t) and price of wood (P_{wt}) are obtained from the International Tropical Timber Organization (ITTO). Information on income per capita (GDP_{ct}), exchange rate and rate of discount are obtained from the Penn World Tables. Information for Cameroon on road infrastructure (TR_t), forest-related expenditure (FOR_t) and fossil fuel (annual fuel pump) prices are obtained from the World Bank. Carbon prices are obtained from pointcarbon.com, an online carbon price data repository.

Table 11.1 Summary statistics for variables used in estimating wood and carbon capture

Variable	Mean
Forest stock (S_{it}) (million m^3)	21.3
Forest area (A_t) (million ha)	18.8
Forest density (FOD_t) (million per ha)	17
Annual harvest (H_{it}) (million per m^3)	2.5
Annual change in forest stock per hectare (G_{it}) (%)	0.98
Forest expenditure (FOR_t) (million US$)	300
Forest carbon (ton of c per ha)	300
Annual rent for carbon (R_t) (US$ per ha)	6000
Price of wood (P_{wt}) (US$ per m^3)	175
Road infrastructure (TR_t) (km/1000 km^2 of land area)	70
Income per capita (GDPc_t) (US$)	1100
Price of fossil fuel energy (P_{fst})	610

Notes: Annual harvest = industrial roundwood and wood fuel. Road infrastructure is proxied with road network density which relates to total network which includes the primary, secondary and tertiary networks. Current carbon prices in the EU emission trading scheme are in the order of $20 per tonne. (*Source*: Author's computation, 2020)

Table 11.1 provides the descriptive statistics of the variables. The average forest stock including secondary forest, primary forest and agroforested areas amounts to about 21.3 million m^3, within a forest area of 18.8 million ha. Cameron's forest density averages 17 million per ha providing opportunity for 2.5 million per m^3 of annual wood harvest. The annual change in forest stock per hectare is 0.98%. Government's effort to manage the forest resource is gauged by annual expenditure of US$300 million which represents 1% of GDP in current values. The country's forest carbon potential is estimated at about 300 tonne of carbon per ha generating a possible annual carbon rent of 6000 US$ per ha or a national forest average of annual rent of carbon averaging US$ 112.8 billion. A road network density of 70 km/1000 km^2 of land area supports the exploitation of forest assets and market linkage.

5 Presentation and Discussion of Findings

5.1 Long-Run Determinants of Carbon Capture

The estimated parameters of the carbon supply equation are shown in Table 11.2. The coefficients report expected signs, although the parameters differed substantially in magnitude. This estimation suggests that wood price and forest expenditure have a positive effect on carbon supply. In the long run, the effects of forest area, forest density and GDP per capita on carbon supply were all positive and significant. For instance, it is deduced that a 1% increase in consumption is linked with 0.8668% decrease in carbon supply. Similarly, rise in price of fossil fuel leads to a 10.2956% decline in carbon supply. It can also be deduced that the model fits the data set well, $R^{-2} = 0.6319$. This means that 63.19% of the variations in carbon supply are explained by changes in forest stock, area, density, price, forest policy and road infrastructure. These results seem plausible and corroborate previous studies. For example, Guariguata et al. (2008) observe that better management of natural forest offers additional opportunities for implementing adaptation to climate change measures, at both industrial and smallholder levels. Härtl and Knoke (2014) show the price of oil to have significant changes in wood supply, tending towards an increase in wood graded for energy use with rising oil and timber prices. Daigneault et al. (2008) indicate that competitiveness in the forestry sector is sensitive both to strong monetary policies and to the weak currency policies pursued by competitive governments, as well as a weak dollar policy that is intended to improve competitiveness in the global timber market and reduce the large trade gap and account deficit.

Table 11.2 Parameter estimates for long-run carbon capture

Variable	Coefficients	t-Statistics	Prob-value
Harvest (ln H_{it-1})	0.6701	2.5422**	0.0741
Change in forest stock (ln G_{it})	0.5256	1.1754	0.0025
Rent for carbon (ln R_t)	0.2619	1.6451*	0.0735
Forest area (ln A_t)	0.6578	3.8901***	0.0541
Forest density (ln FOD_t)	0.3825	2.7614***	0.0421
Price of wood (P_{wt})	0.4917	2.1882**	0.0167
Road infrastructure (ln TR_t)	0.1535	1.9361**	0.0231
Income per capita (ln GDPc_t)	−0.8668	−2.4734**	0.0001
Price of fossil fuel energy (ln P_{fst})	−0.2956	−1.6870*	0.0049
Forest expenditure (ln FOR_t)	0.4566	3.5108***	0.0055
Intercept	0.8904	2.2990**	0.0637

Diagnostic tests:
Adj. R^2 = 0.6319 F-stats = 139.999; DW = 1.8314; χ^2_{auto} (B-G) = 0.7521 (0.6817); χ^2_{norm} (JB) =1.5389 (0.9854); χ^2_{RESET} = 1.3721 (0.3178); χ^2_{white} white = (2.8341) 0.046
Notes:
χ^2_{auto} is the Breusch-Godfrey LM test for autocorrelation; χ^2_{norm} is the Jarque-Bera normality test; χ^2_{RESET} is the Ramsey test for omitted variables; χ^2_{white} is the white test for heteroskedasticity; * and ** indicate statistical significance at the 5% and 1% levels, respectively. (*Source*: Author's computation, 2020)

The economic and ecological implications of the results are instructive for future forest management. The observation on forest expenditure implies that public resources and increased attention to the political economy underlie carbon policies (Hansen and Lund 2011; Marfo and Mckeown 2013). The economic and legal implications of the interrelationship between carbon sequestration programs and biodiversity (Caparrós and Jacquemont 2003), as well as forest management choices, have been shown to influence the levels of carbon sequestration (Duinker 1990). Seidl et al. (2007) investigated effects of alternative management strategies for secondary spruce forests (*Picea abies* (L.) Karst.) and showed that in situ carbon sequestration is sensitive to forest management with the highest amount of carbon stored in the unmanaged strategy, followed by the continuous cover regime. Stern (2008) reiterates that mitigation – taking strong action to reduce emissions – must be viewed as an investment, a cost incurred now and in the coming few decades to avoid the risks of very severe consequences in the future. If these investments are made wisely, the costs will be manageable, and there will be a wide range of opportunities for growth and development along the way. Opportunity cost estimates for carbon sequestration reveal that carbon sequestration through forest management can be a cost-efficient way to reduce atmospheric CO_2, but the achievable quantities are limited due to biological limitations and societal constraints. Seidl et al. (2007) and Diaz-Balteiro and Romero (2008) emphasize the importance of developing sustainable forest management strategies that serve the multiple demands on forests in the future.

5.2 Short-Run Determinants of Carbon Capture

The equation of unrestricted error correction model is specified as follows:

$$\begin{aligned}\Delta \ln S_t = \eta_o &+ \sum_{t=1}^{l}\omega_1 \Delta \ln S_{t-1} + \sum_{t=0}^{m} k_1 \Delta \ln R_{t-m} + \sum_{t=0}^{n}\beta_1 \Delta \ln P_{wt-n} + \sum_{t=0}^{p}\beta_2 \Delta \ln P_{fst-p} + \sum_{t=0}^{q}\alpha_1 \Delta \ln FOD_{t-q} \\ &+ \sum_{t=0}^{r}\alpha_2 \Delta \ln G_{t-r} + \sum^{s}\alpha_3 \Delta \ln H_{t-s} + \sum_{t=0}^{u}\alpha_4 \Delta \ln Z_{t-u} + \sum_{t=0}^{v}\alpha_5 \Delta \ln GDPc_{t-v} + \\ &+ \sum_{t=0}^{w}\alpha_6 \Delta \ln FOR_{t-w} + \sum_{t=0}^{y}\alpha_7 \Delta \ln TR_{t-y} + \mu_{t-1}\end{aligned} \tag{11.8}$$

Table 11.3 provides the details of short-run results. Regarding all other regressors, they exert a statistically significant effect in carbon supply and have the expected signs. The results show that a 0.3971% increase in carbon supply in current period is significantly linked with a 1% rise in carbon in previous periods. Similarly, sequestration potential increases with rise in expected carbon revenues, forest density and government expenditures in the forest sector. The positive coefficients of 0.45927 and 0.3652 for forest density and policy measures indicate a 1% increase in carbon supply by about 0.45927% and 0.3652%, respectively. On the other hand, the results show that a 0.3652% increase in carbon supply in current period is significantly linked with a 1% improvement in road infrastructure. Similarly, increases in wood prices, fossil fuel price, timber harvest and consumption potentials have negative and statistically significant effects on carbon supply in the short run. These findings are robust, corroborating similar experiences. van't Veld and Plantinga (2005) show analytically that if price increases over time, it becomes optimal to delay certain sequestration projects,

Table 11.3 Parameter estimates for short-run carbon capture (dependent variable =$\Delta \ln S_t$)

Variables	Coefficients	t-Statistics	Prob-value
Constant	0.9981	2.2990**	0.0517
$\Delta \ln S_{t-5}$	0.3971	2.3517**	0.0015
$\Delta \ln R_{t-2}$	0.3532	1.7541 *	0.0572
$\Delta \ln P_{wt-2}$	0.5341	3.1647 ***	0.0007
$\Delta \ln P_{fst-1}$	−0.3376	−2.2873 **	0.0013
$\Delta \ln FOD_{t\text{-}3}$	0.4592	3.706 ***	0.0351
$\Delta \ln G_{t-2}$	0.6883	2.3604**	0.0027
$\Delta \ln H_{t-3}$	0.7092	3.2581 ***	0.0413
$\Delta \ln Z_{t-4}$	−0.2714	−4.1473***	0.0002
$\Delta \ln GDPc_{t-3}$	−0.9354	−3.0947***	0.0001
$\Delta \ln FOR_{t-2}$	0.5767	2.1083**	0.0273
$\Delta \ln TR_{t-2}$	0.3652	1.8736**	0.0523
ECM (μ_{t-1})	−0.5906	−3.582***	0.0011

Diagnostic tests:
Adj. R^2 = 0.7516; F-stats = 98.263; DW = 1.8931; χ^2_{auto} (B-G) = 1.868 (0.1873); χ^2_{norm} (J-B) = 0.3145 (0.9568); χ^2_{RESET} = 0.0012 (0.8241); χ^2_{white} white = 0.3551 (0.8061)
Notes:
χ^2_{auto} is the Breusch-Godfrey LM test for autocorrelation; χ^2_{norm} is the Jarque-Bera normality test; χ^2_{RESET} is the Ramsey test for omitted variables; χ^2_{white} is the white test for heteroskedasticity; * and ** indicate statistical significance at the 5% and 1% levels, respectively. (*Source*: Author's computation, 2020)

whereas the optimal timing of energy-based abatement projects remains unchanged. As a result, the optimal share of sequestration significantly falls. Calibrating their analytical model, van't Veld and Plantinga (2005) find that a modest 3% rate of price increase results in about a 60% reduction in the optimal sequestration share relative to constant price projections.

The ECM parameter (μ_{t-1}) for the lagged error terms is negative and significant, indicating the existence of a long-run relationship between the variables. The ECM measures the speed at which equilibrium is restored to the model. The results indicate that some 59.06% of the change in Cameroon's carbon supply is attributed to disequilibrium. Tests for normality of residuals, serial correlation, heteroskedasticity and misspecification of functional form were applied to the ECM. Since none of these tests disclosed any significant evidence of departure from standard assumptions, the empirical validity of the model was confirmed by the various diagnostic tests.

These results have interesting implications for carbon policy for both Cameroon and other developing countries in the sub-continent. Policy must promote sound market signals, overcome market failures and have equity and risk mitigation at its core. Stern (2008) identifies three essential elements of policy for mitigation to include carbon price, technology policy and the removal of barriers to behavioural change. Achieving this could mean, for example, halting deforestation and substantial intensification of sequestration activities. It is therefore imperative for countries to invest in mechanisms that would mainstream climate change into their development strategies to stave off its possible negative impacts (Jung 2005; Michaelowa 2003). Similarly, commensurate efforts must also be made to identify and exploit the opportunities that climate policy presents. Policy promoting REDD+ is important since the AFOLU accounts for about a quarter (~10–12 $GtCO_2$ eq/yr) of net anthropogenic GHG emissions mainly from deforestation, agricultural emissions from soil and nutrient management and livestock. Most recent estimates indicate a decline in AFOLU CO_2 fluxes, largely due to decreasing deforestation rates and increased afforestation (Olschewskia and Benítez 2010; Albrecht and Kandji 2003). However, the uncertainty in historical net AFOLU emissions is larger than for other sectors, and additional uncertainties in projected baseline net AFOLU emissions exist. Nonetheless, in the future, net annual baseline CO_2 emissions from AFOLU are projected to decline, with net emissions potentially less than half the 2010 level by 2050 and the possibility of the AFOLU sectors becoming a net CO_2 sink before the end of century (IPCC 2013).

Policy will have to address broad-ranged socioeconomic and political impediments (Guariguata et al. 2008; Unruh 2008; Fry 2008; Michaelowa 2003). According to Guariguata et al. (2008), the relationship between tropical forests and global climate change must also focus on adaptation not only mitigation, with emphasis placed on how management activities may help forest ecosystems adapt to this change. Youssoufa et al. (2011) draw attention on the lack of awareness and poor flow of information on the potentials of forests for climate change adaptation and highlight the need for integrating forest for adaptation into national development programmes and strategies. They recommend a review of the existing environmental legislations and their implications on poverty reduction strategy and adaptation to climate change (ibid.). According to Unruh (2008), the prospect of using tropical forest to sequester significant amounts of atmospheric carbon as one mitigation approach to climate change under the Kyoto Protocol, the Clean Development Mechanism (CDM) and African land tenure is important and that instead it exists as a prohibitive obstacle to the implementation of afforestation and reforestation sequestration approaches. Five primary tenure problems could be examined and corrected: (1) the disconnect between customary and statutory land rights, (2) legal pluralism, (3) tree planting as land claim, (4) expansion of treed areas in smallholder land use systems and (5) the difficulty of using the "abandoned land" category. The pervasiveness of these tenure-related issues means that the prospects for successfully implementing afforestation and reforestation projects in Africa are in reality quite weak. This will mean that UNFCCC processes be significantly realigned with African reality in order for sequestration expectations to be practical. At COP-21 governments agreed to strengthen societies' ability to deal with the impacts of climate change and also provide continued and enhanced international support for adaptation to developing countries (Nhamo and Nhamo 2016b). The agreement also recognizes the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change. Furthermore, it acknowledges the need to cooperate and enhance the understanding, action and support in different areas such as early warning systems, emergency preparedness and risk insurance. There are positive signs after COP-22, where government's proclamation signals a shift towards a new era of implementation and action on climate and sustainable development, as well as the highest political commitment to combat climate change, as a matter of urgent priority via enhancing adaptive capacity, strengthening resilience and reducing vulnerability.

6 Conclusions

The time-bound targets of the SDGs and the Paris Climate Agreement combine to provide a framework for national action and global cooperation towards sustainable development while achieving net-zero greenhouse gas emissions by the middle of the century. Sachs et al. (2019) note that the SDGs and the Paris Agreement on Climate Change call for deep transformations in every country that will require complementary actions by governments, civil society, science and business. This will require stakeholders to have shared understanding of how all SDGs can be operationalized. This will require SDG transformations as modular building blocks of SDG achievement. For example, six clustered transformations may include (1) education, gender and inequality; (2) health, wellbeing and demography; (3) energy decarbonization and sustainable industry; (4) sustainable food, land, water and oceans; (5) sustainable cities and communities; and (6) digital revolution for sustainable development. Such transformations which come with priority investments and regulatory challenges will need actions by well-defined parts of government working with business and civil society. This implies that governments have an important role to play, with these transformations possibly operationalized within the structures of government while respecting the strong interdependencies across all the SDGs.

While Pradhan et al. (2017) reiterate that SDG-1 (no poverty) has synergetic relationship with most of the other goals, this will mean the other SDGs being studied in this paper, particularly SDG-13 and SDG-15 on climate action and life on land, have a coronary effect with possibility to reduce poverty and improve livelihoods. Though in developing their climate policies, countries like Cameroon have not explicitly mentioned the SDGs, there are however many areas of synergy that can be found between climate policies and the SDGs. This interconnectivity and clear aims of the global goals call for understanding by all stakeholders on how to promote prosperity while protecting the planet. By investing in approaches to sustainable forest management that better preserve and restore the natural resource base and increase the resilience of the ecosystem to a changing climate, developing country governments like that of Cameroon contribute to SDGs 12, 13 and 15.

Achieving healthy ecosystems to protect the planet and sustain livelihoods should be primordial in development policy-making, because of the synergistic effects emanating from the forest ecosystem through its myriad of environmental goods and services. In addition, forests and rangelands sustain a range of industries, generate jobs and income and act as a source of food, medicine and fuel for more than a billion people. A strong case can be made for investments in climate action since forest-related climate policy intersects with other societal goals creating the possibility of co-benefits or adverse side effects. These intersections, if well-managed, can strengthen the basis for undertaking climate action.

Overall, this case study employs partial equilibrium analysis to examine potential carbon supply from ancillary forest services. The rationale hinges on the premise that saving tropical forests as a global warming countermeasure is important not only for ecological benefits and proper forest management but also because of the opportunity for obtaining monetary gain that flows from the global carbon markets. The study finds that timber harvest in the previous period contributes to a decline in the per unit area of carbon supply. However, carbon supply comes from the management of new forest areas. Economic performance has a negative effect on long-run carbon capture and supply. This research thus contributes to policy decision-making within the climate change debate. Given the limitations of the current examination, areas for future research should include evaluating the distributional outcomes (how regions and population subgroups are affected) and understanding market adaptations for regions and individuals. Limiting the effects of climate change is necessary to achieve sustainable development and equity, including poverty eradication. At the same time, some mitigation efforts could undermine action on the right to promote sustainable development and on the achievement of poverty eradication and equity.

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