

Review

# Impact of Ex-Closure in above and below Ground Carbon Stock Biomass

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**Abstract:** Globally, there is a serious issue in carbon stock due to high deforestation and the loss of land, limited carbon storage pools in aboveground and underground forests in different regions, and increased carbon emissions to the atmosphere. This review paper highlights the impact of exclosures on above and below ground carbon stocks in biomass as a solution to globally curb carbon emissions. The data has been analyzed dependent on the Intergovernmental Panel on Climate Change (IPCC) guidelines, the Food and Agriculture Organization (FAO) Forest Resource Assessment report (FRA, 2020), and scientific journal publications mostly from the last decade, to show the research results of carbon stock and the impact of exclosures, particularly the challenges of deforestation and erosion of land and opportunities of area exclosures to provide a general outlook for policymakers. Overall, the world's forest regions are declining, and although the forest loss rate has slowed, it has still not stopped sufficiently because the knowledge and practice of exclosures are limited. The global forest loss and carbon stock have decreased from 7.8 million ha/yr to 4.7 million ha/yr and from 668 gigatons to 662 gigatons respectively due to multiple factors that differ across the regions. However, a move toward natural rehabilitation and exclosures to reduce the emissions of Greenhouse Gas (GHGs) is needed. In the global production of carbon, the exclosure of forests plays an important role, in particular for permanent sinks of carbon.

**Keywords:** communal grazing land; land degradation; deforestation; ex-closure; carbon stock



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## 1. Introduction

The world's plantation forests occupy about 131 million hectares, which is 3% of the global forest area and 45% of the total planted forest area in the world [1]. Forests store the primary share of carbon biomass in the world's ecosystem. They can store huge carbon stocks, thus reducing the release of CO<sub>2</sub> gas into the atmosphere [2]. For instance, tropical forests store a huge amount of carbon and account for half the world's sum vegetation biomass, and store 40% (428 GtC) of terrestrial carbon stock [3]. The aboveground living woody biomasses (AGWLB) of trees/shrubs are the largest and most easily visible carbon pool and the one that bears the greatest consequences of degradation and deforestation [4]. Human-made activity is among the primary drivers of 21st-century climate change issues and the significant tropical country's greenhouse gas emissions through deforestation and land depletion [5]. After 1990 in two ten-year intervals forests globally decreased from 8.3 million ha to 5.2 million ha by yearly 0.2% [6].

Since 2000, plantation coverage is approximately 5 million ha/yr and deforestation and soil loss are the big ecological threats of the tropical forest [7]. Today, the global community is addressing forest carbon dioxide emissions from degradation and deforestation by developing emissions control mechanisms and enhancing the forest carbon stocks through conservation and sustainable management [8]. Land degradation is affected

by land productivity decline, biodiversity depletion, soil fertility issues, and soil organic carbon loss, with aboveground vegetation biomass ecosystem services decreasing [9]. Due to this high deforestation and land degradation, low levels of aboveground and underground carbon storage in forests occur. Globally, land loss affects 3.2 billion people, in particular, rural societies, small-scale farmers, and the very poor, and it has increased demand for agricultural goods, including food, feed, fiber, and fuel. In 2050, the worldwide population is estimated to grow by around 35% to 9.7 billion. However, due to additional factors, such as less resilient agricultural production systems due to biodiversity losses, and natural factors such as climate fluctuations and severe weather events, there is increasing pressure on the world's land resources. Climate change is exacerbating shifts in agricultural yields and revenues, threatening the resilience of agro-ecosystems and the stability of food production systems [10]. It takes a variety of actions to mitigate such a strain, such as conservation of degraded natural vegetation, area enclosure, and forest plantation [11]. One action that is very essential to communities and provides many benefits is enclosure, a particularly important form of restoration that increases the biomass of forest vegetation. Institutional structures are needed to regulate these resources which are assumed to have a major impact on carbon storage and contribute to livelihoods, in particular, the promotion of local awareness and participation in decision-making to integrate an area's enclosure. "Enclosure" refers to the land management method of degraded land restoration by shielding it from animal intrusion and human disturbance, to preserve an area in its natural state [12]. There are two main forms of enclosure commonly practiced globally. The most common type is the closing of land from livestock and humans to regenerate new vegetation. The second method is to close the degraded land in conjunction with additional steps (e.g., the establishment of soil and water collecting systems, enrichment of exotic and indigenous seedling species) to improve the regeneration process [13].

Enclosures play a significant role in carbon sequestration (by storing carbon stocks), climatic shift mitigation, conservation of soil and water, preservation of watersheds, recycling of organic nutrients from the soil, nitrogen fixation, the creation of microclimates, and biodiversity conservation [14]. Mostly, developing countries' enclosures are typically located in steep slopes, eroded, and despoiled parts that were formerly used for grazing and other illegal tree cutting. Establishing enclosures are inexpensive and the most effective method for restoring, maintaining, and preserving woody species in degraded areas [11]. At present, small-growing bushland, woodlands, or shrublands in the world are currently limited to more inaccessible areas such as mountain tops and hillsides or found around churches, monasteries, mosques, and cemeteries [15]. The natural vegetation which exists in these remote inaccessible areas are species highly affected by several factors including expansion of agricultural activity, wood consumption, lack of a viable land-use policy, settlement in forests, low forest investment (forest income values), low awareness creation, low local community participation in planning development or implementation, and a low forest ownership sense [16]. The most significant criterion for site selection is the degree of land degradation, which is measured as the more degraded an area is, the greater its potential to be regenerated [17]. Next, one must understand the methods and benefits of enclosures and how they reduce bare land, climate warming, a decrease in economic and social values, and depletion in aboveground and underground carbon biomass [11]. Another challenge is the formation of enclosures, as there is no sharing of information and scientific data, a lack of clarity of the regulation of land ownership, a lack of consistent rules and regulations, a lack of real ground community decision making concerning the areas' management and resource utilization, and a lack of knowledge about the range of real benefits [18]. Especially in developing countries, there is less information on the contribution of long-standing enclosure of livestock grazing areas on the accumulation of carbon biomass [19].

To show the ecological impacts of enclosures, there has been very little or virtually no systematic and empirical analysis of enclosures in regions. As a consequence, recorded information on enclosures is scanty or entirely missing.

Therefore, this study aimed to generate and highlight the processes involved in the recovery or dynamics of forestry vegetation, to increase above and below ground carbon biomass, and to assist in making informed decisions on the future fate of exclosures. In particular, such information is crucial for developing strategies, programs, or technical guidelines for regions' conservation and sustainable land utilization.

Therefore, this study was initiated as a step towards understanding the actual and potential impacts of exclosure on the contribution of carbon stock development in the regions to see or to compare the past decades degraded or deforested regions, specifically, by exploring the issue of exacerbating carbon emissions, identify the potential of carbon stock biomass to generate ecological conditions and curb carbon emissions globally.

It also can assist to create better awareness in the regions to enhance their efforts of land rehabilitation. Besides, for politicians, it can help to make critical decisions and assist future studies to change carbon stock over time.

## 2. Materials and Methodology

A literature search was carried out using the Web of Science (or Information Web), Google Scholar Citation, and Research Gate to study and acquire information from current research on the impact of above- and belowground carbon stock biomass in various forest ecosystems in the world, in line with data from the Intergovernmental Panel on Climate Change (IPCC) guidelines and the Food and Agriculture Organization's (FAO) Forest Resource Assessment report (FRA, 2020) report, and scientific journal publications mostly from the last decade. The aim was to demonstrate research results on carbon stock and area exclosures, particularly those relevant to land loss and deforestation problems and opportunities for area exclosures to provide a general outlook for policymakers.

The methodology followed for the search of literature consisted of (a) Using keywords for communal grazing land; land degradation; deforestation; exclosure; carbon stock (b) Search of online literature using several sources (Google scholar citation, science or information web, websites of journals), and the Global Forest Resources Assessment 2020 downloaded from the website. (c) Selection and highlighting of key conclusions in the study (d) Interpretation of results illustrated in scientific journal publications mostly from the last decade, to show the research results in carbon stock and area exclosures, particularly the problems of land loss and deforestation, and opportunities of area exclosures to provide a general outlook for policymakers. The focus of the literature search for this article was the function of exclosures on above- and below-ground carbon stock biomass for sustainable land management, and improving carbon stocks to decrease carbon emissions through area exclosures of degraded regions globally.

To collect more research articles focusing on biomass in global ecosystems, we also compiled research papers on cross-references that were important to our research.

In all, 128 important research papers were found to fulfill the study's aims and goals. Since the studies relevant to the objectives of the present paper were intermittent, not all aspects were included in various papers regarding global forest ecosystems. As the main focus of this review was to highlight the impact of exclosures on carbon stocks in all climatic global forests, we concentrated on data analysis or statistics that mainly highlighted the recent state of knowledge. So although we used all the research articles collected, we have only cited references for the main data used for the present paper.

FRA 2020 estimates were used which are based on official national statistics derived from field inventories, remote sensing, expert estimates, the sequestration cycle for forest carbon from the Inventory of US Greenhouse Gas Emissions and Sinks, as well as the effects of the destruction of grassland on soil organic carbon (SOC) stocks on major environmental controls in degraded and non-degraded topsoil worldwide by considering twenty-eight studies published on the effect of grassland degradation on SOC stocks (Table 1). Under temperate, hot, sub-humid, tropical, and semi-arid conditions, to compare SOC stocks in the topsoil of non-degraded and degraded grassland soils and different environmental factors (mean annual precipitation, mean annual temperature, soil texture, type of grass, soil pH,

and intensity of grazing) variance was conducted that could quantify the impact of grassland degradation on SOC density in the different sites and we could measure the degree of losses (SOCL) and whether it was lightly degraded, moderately degraded, or heavily degraded by comparing the different sites and carbon stock in tropical regions from the Benchmark Map of Forest Carbon Stocks in Tropical Regions across three Continents (Table 2).

**Table 1.** Effect of the destruction of grassland on soil organic carbon (SOC) stocks on major environmental controls up to 0.3 m in grasslands degraded and non-degraded topsoil worldwide.

Reference	Country	Location	N	t	Map (mm)	amt (°C)	z (m)	Clay (%)	Socd-nd (kg Cm <sup>3</sup> )	Socd-d
Abril and Bucher (1999) [20]	Argentina	Salta	3	0.2	550	22.7	217	17.6	41	27.5
Bauer et al. (1987) [21].	USA	North Dakota	2	0.46	538	3.4	670	26.5	2.8	2.4
Chuluun et al. (1999) [22]	China	Mongolia	8	0.06	307	2.6	1165	10.3	88.3	8.3
Cui et al. (2005) [23]	China	Inner Mongolia	21	0.3	350	0.2	1255	21	17.6	11
Dong et al. (2012) [24]	China	Qinghai-Tibetan	6	0.13	570	0.6	4200	20	137.8	13.3
Frank et al. (1995) [25]	USA	Mandan, N. D	59	0.19	404	4.4	573	10	48.7	15.4
Franzluebbers and Stuedmann (2009) [26]	USA	Georgia	34	0.15	1250	16.5	153	10	32	6.1
Ganjegunte et al. (2005) [27]	USA	Cheyenne	8	0.05	384	15	1930	35	21.6	21.8
Gill (2007) [28]	USA	Utah	5	0.15	932	1.3	1600	24.5	50.3	21.7
Hafner et al. (2012) [29]	China	Qinghai-Tibetan	1	0.17	582	1.7	3440	25	41	11.3
Hiltbrunner et al. (2012) [30]	Switzerland	Fribourg	63	0.15	1250	6	1600	52.9	32	7.2
Ingram et al. (2008) [31]	USA	Cheyenne	2	0.1	425	15	1930	10	21.6	11.1
Manley et al. (1995) [32]	USA	Cheyenne	3	0.3	384	13	1930	10	18.9	19
Martinsen et al. (2011) [33]	Norway	Burskerud County	4	0.05	1000	1.5	1211	3	13.8	10.2
Mchunu and Chaplot (2012) [34]	South Africa	Bergville	3	0.02	684	13	1300	16.6	15	5.5
Medina-Roldán et al. (2012) [35]	England	Yorkshire Dales	7	0.2	1840	2.8	400	10	29.5	31.2
Naeth et al. (1991) [36]	Canada	Alberta	14	0.1	355	4	745	15.8	55	40
Neff et al. (2005) [37]	USA	Utah	31	0.1	207	11.7	1500	4.8	5	1.5
Piñeiro et al. (2009) [38]	Uruguay	Rio de la Plata	10	0.3	1100	17.3	110	25.5	36.3	23
Potter et al. (2001) [39]	USA	Oklahoma	4	0.33	842	17	2438	23.3	13.8	3.7
Raiesi and Asadi (2006) [40]	Iran	Shahrekord	4	0.3	860	6.7	2500	50	26.7	22.2
Reeder and Schuman (2002) [41]	USA	Cheyenne	3	0.30	343	15.0	1930	10.0	19.4	12.5
Smoliak et al. (1972) [42]	Canada	Alberta	26	0.10	550	1.3	926	15.8	14.0	14.4
Teague et al. (2011) [43]	Texas	USA	9	0.23	820	18.1	315	30.0	50.6	26.0
Wiesmeier et al. (2012) [44]	China	Inner Mongolia	1	0.10	350	0.7	1260	20.4	20.0	18.1
Wood and Blackburn (1984) [45]	USA	Texas	14	0.03	624	17.0	316	30.0	55.9	46.8
Wu and Tiessen (2002) [46]	China	Tianzhu	21	0.15	416	0.3	2940	27.3	57.8	27.0
Yong-Zhong et al. (2005) [47]	China	Naiman County	48	0.15	366	6.5	360	2.5	3.7	2.9

Source; Dlamini, P.; P. Chivenge, and V. Chaplot., et al. (2016).

**Table 2.** Carbon stocks around three continents in the tropical regions.

Region	Forest Area (Million ha)	AGB Carbon Density (tons/ha)		Total Biomass Carbon Density (tons C/ha)	
		Mean ± SD		Mean ± SD	
Africa					
Tropical Rain Forest	252.9	107 ± 51		135 ± 64	
Tropical Moist Deciduous Forest	110.6	38 ± 18		53 ± 32	
Tropical Shrub Land	1.6	41 ± 25		49 ± 23	
Tropical Dry Forest	36.1	38 ± 18		82 ± 49	
Tropical Mountain System	22.7	64 ± 39		49 ± 19	
Sub-tropical Humid Forest	1.5	38 ± 15		41 ± 21	
Sub-tropical Dry Forest	0.7	31 ± 16		45 ± 14	
Sub-tropical Mountain System	1.1	34 ± 11		45 ± 14	
Africa Total	427.2	80 ± 78		102 ± 98	

Table 2. Cont.

Region	Forest Area (Million ha)	AGB Carbon Density (tons/ha)	Total Biomass Carbon Density (tons C/ha)
		Mean $\pm$ SD	Mean $\pm$ SD
Latin America			
Tropical Rain Forest	587.1	115 $\pm$ 34	146 $\pm$ 42
Tropical Moist Deciduous Forest	179.3	54 $\pm$ 42	69 $\pm$ 53
Tropical Shrub Land	0.9	55 $\pm$ 41	71 $\pm$ 51
Tropical Dry Forest	47.6	27 $\pm$ 23	36 $\pm$ 19
Tropical Mountain System	71.8	86 $\pm$ 50	110 $\pm$ 62
Sub-tropical Humid Forest	20.4	51 $\pm$ 38	66 $\pm$ 48
Sub-tropical Dry Forest	5.3	55 $\pm$ 51	71 $\pm$ 64
Sub-tropical Mountain System	7.2	21 $\pm$ 23	27 $\pm$ 29
Latin America Total	919.8	94 $\pm$ 110	119 $\pm$ 138
Southeast Asia			
Tropical Rain Forest	261.6	121 $\pm$ 50	153 $\pm$ 62
Tropical Moist Deciduous Forest	55.6	105 $\pm$ 49	133 $\pm$ 61
Tropical Shrub Land	2.5	64 $\pm$ 39	82 $\pm$ 49
Tropical Dry Forest	17.6	83 $\pm$ 50	106 $\pm$ 63
Tropical Mountain System	53.6	128 $\pm$ 34	162 $\pm$ 42
Sub-tropical Humid Forest	0.8	88 $\pm$ 34	112 $\pm$ 42
Sub-tropical Mountain System	7.7	101 $\pm$ 41	128 $\pm$ 52
Southeast Asia Total	399.5	118 $\pm$ 114	149 $\pm$ 142
All Total	1746.5	94 $\pm$ 110	122 $\pm$ 221

Source: Benchmark Map of Forest Carbon Stocks in Tropical Regions across three Continents. Source: Saatchi et al. (2011).

### 3. Issues Exacerbating Carbon Emission

The evidence shows that anthropogenic carbon emissions are growing stronger which leads to the planet's rising temperature. It is recommended, as it is impossible to check at the moment, that the connection between CO<sub>2</sub> concentrations and the planet's temperature is as strong as ever, and the need for action by both individuals and governments around the world to protect everyone from rising temperatures is inevitable [48].

A significant role is played by the pace at which carbon dioxide rises via the environment that affects the need to set global and regional carbon budgets, annual sources, and carbon sinks from land-use change [49,50]. Over the last 150 years, the contribution of land-use and land-cover changes (LULCC) to anthropogenic carbon emissions was approximately 33% of total emissions. A change in net carbon flow relative to land usage and soil coverage between 1990 and 2010 of 12.5% anthropogenic carbon dioxide emissions has been reported [51]. Direct human-induced effects on forests and other land use, such as deforestation, agricultural land clearing, and soil erosion, can produce CO<sub>2</sub>. By utilizing reforestation, soil enhancement, and other practices, the land can also reduce carbon dioxide emissions that come from the air [52]. Approximately 24% of emissions from greenhouse gas are primarily from agriculture. Deforestation accounts for 6–17% resulting from human-influenced global CO<sub>2</sub> emissions to the environment [53].

#### 3.1. Deforestation

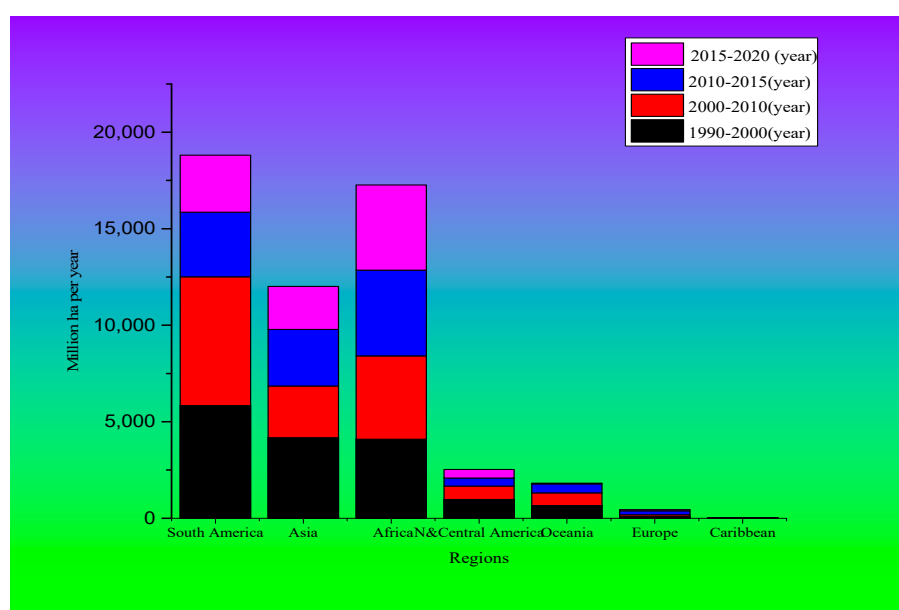
Globally, forest degradation is the main source of carbon emissions. In the 1990s, tropical deforestation generated an average of about 1–2 billion tons of carbon per annum, which was roughly 15–25% of the annual GHGs [54,55]. It reduced: forest sequestration capacity, aboveground forest coverage to provide ecosystem services, soil organic carbon levels, indigenous biodiversity species, and the livelihood benefits of the local community [56]. It is complex to identify the carbon stock changes due to the different coverage of land types, such as species, age, soil types, and altitudinal or shape variation [57]. Forest degradation loses more greenhouse gases than deforestation and accounts for a minimum of 5% of carbon emissions in line with the IPCC analysis [58]. Deforestation of the forest, as defined by the IPCC and FAO, is the “lasting depletion of forest shelter and land withdrawal from forest use and forest conversion for another usage of land” [59]. In the most recent five-year period (2015–2020), the annual rate of deforestation was estimated at 10 million ha [60]. Although, about 20% and 70% of global and Africa's GHG emissions, respectively [61].

The biggest contributor to tropical deforestation is emissions of GHG and climate change influences since the amount of forest that is cleared each year has a high carbon stock, per area unit [62]. For instance, in East Africa, over 200,000 ha per year or 0.78% of tropical forest area was lost, and the above- and underground carbon stock biomass during the period of 2005 to 2010 decreased annually by 0.5 Gt in forest areas globally.

Globally, degraded lands contributed 30–50% of the total atmospheric dust loading over the Atlantic Ocean from the Sahara.

To address these problems, attempts were made to launch the forestation and enclosure program; however, to date, success has been limited [63]. In general, there are two causes of deforestation and degradation: direct deforestation from direct causes, such as wars and the role of the military, air pollution, urbanization and infrastructure, mining, fires, overgrazing, logging, fuelwood, plantations, and expansions of farming land, and; indirect causes, such as land rights and inequitable tenure distribution, economical causes, undervaluing the forest, corruption and political causes, illegal forest contracts with private investors, overpopulation, and poverty. As a result, in most developing countries, only small fragments of uncleared land are left in the most difficult to reach areas like hillsides of mountainous areas or around churches. Since the net shift in the region of forests data alone is insufficient to explain the complexity of land-use dynamics, countries were asked to promote the expansion of forests and maintain deforestation projections [1]. The deforestation rate has been estimated to have lost 420 million hectares of forest globally between 1990 and 2020, although the rate did decelerate over the period. In 1990–2000, deforestation took place at a pace of 15.8 million ha annually, 15.1 million ha a year in 2000–2010, 11.8 million ha a year in 2010–2015, and 10.2 million ha a year in 2015–2020,

According to Figure 1, the annual level of deforestation in Africa was 4.41 million ha, followed by South America at 2.96 million ha, and Asia at 2.24 million ha, which had the greatest annual deforestation rate there in 2015–2020, Most of the deforestation in Africa was in the South and East at 2.2 million hectares per year, and in Western and Central Africa it was 1.90 million hectares per year. Deforestation was mainly carried out in South and Southeast Asia (1.96 million hectares per year). Since 1990, the extent of deforestation has increased in Africa, although the rate has decreased modestly in 2015–2020 as compared to 2010–2015, On the other hand, South American and Asian levels of deforestation are now almost half what they were in the 1990s. The extent of deforestation in Oceania increased marginally in 2000–2010 compared to 1990–2000 but has since decreased from 2015–2020.



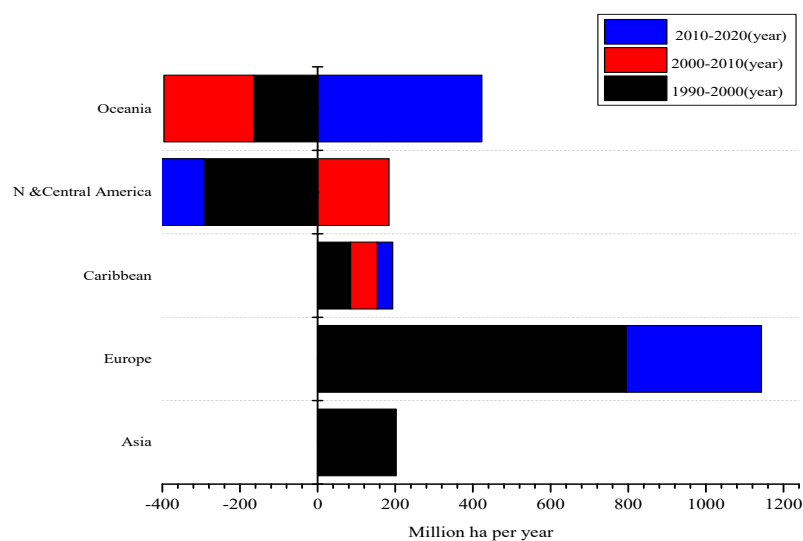
**Figure 1.** Deforestation rate, by region, for four periods spanning 1999–2000, Source: (FAO, 2020).

### 3.2. Land Degradation

Land loss is a significant concern, particularly in dry countries and in developing nations, resulting in the degradation of ecosystem services (ESS) due to the depletion of soil functions. Land loss is an international issue that occurs locally and requires local solutions. To avoid the destruction of land and damage to biodiversity, greater engagement and more successful local-level cooperation is required. Ultimately, our ability to handle trade-offs on the future of land resources will be determined by the size of vegetation, soil, water, and biodiversity, and an assessment of the progress or failure to deliver poverty reduction, the security of food and water, and mitigation of and adaptation to climate change to achieve several of the sustainable development goal's 17 priorities [64]. The knowledge used to recreate changes in land coverage is also used to demonstrate that the forest area declined more rapidly than cropland and pasture areas increased. For example, from 1900 to 1980, China's net depletion of forest land surpassed the net growth in agricultural areas on three occasions. It is assumed that the destruction may have been triggered by unsustainable harvests, the deliberate destruction of forest cover (that protects tigers or bandits), and/or from the negative consequences of long-term intensive agriculture on soil fertility [65]. Whatever the cause, the excessive loss of forests suggests that activities not generally reported are responsible for additional emissions of carbon between 0.1 and 0.3 Pg C yr<sup>-1</sup> which was forecast to have been lost in this period from China [65]. The area of degraded land is rarely enumerated, as the carbon stocks are generally lower than the lands they replace. Many observers consider land degradation to be extremely complex and discontinuous, arising from various causes that affect individuals based on their different economic conditions, social, and political surroundings [66]. Uncertainty about the degree and the influence of land loss is prevalent. The ultimate purpose of this study then is to explore how the process of land degradation, which impacts people locally and differentially, can also be considered to be of global interest with global implications [67]. The world's agricultural and depleted soils have a carbon sink potential of 50 to 66% of the historical loss of 42–78 gigatons of carbon [68]. Degradation of land is a general idea that can be used differently in a variety of contexts. Additionally, there are different causes of land erosion with various effects on the surrounding world [1].

The permanent decrease in the land's productive potential can be seen by biomass depletion of real productivity or potential productivity or a loss or shift in the coverage of vegetation and soil nutrients. This can be estimated from the previous primary land use. The global issue of land erosion is mainly linked to agricultural use and land clearing triggers, including clear-cutting and deforestation, as can be seen in Figure 2. Future changes in greenhouse emissions and forest reduction are difficult to foresee. Net forest conversion greenhouse gas emissions consist of CO<sub>2</sub>, emitted by carbon oxidation in biomass stock that is lost due to forest land conversion of other uses of land, primarily agriculture for cropland or grazing. Since 1990, as a consequence of reduced deforestation, the amount of net forest losses has declined in some regions, with forest growth in others. The annual net loss of forest area decreased from 7.84 million hectares in 1990–2000 to 5.17 million hectares in 2000–2010 to 4.74 million hectares in 2010–2020, The rate of decrease in net forest loss throughout the past decade was mainly because of a fall in forest benefit rates (i.e., forestation and natural forest expansion).

As depicted above in Figure 2, annually the forest area change in 1000 ha/yr from 1990–2000, 2000–2010, and 2010–2020 in the regions of Asia, Europe, the Caribbean, and Oceania show a positive enhancement of the forest region. Whereas Africa increased the reduction of forest area and North and Central America and South America are also decreasing forest area negatively.



**Figure 2.** The overall net annual change in the area of forests by region 1999–2000, Source: (FAO, 2020).

### 3.3. Overgrazing

The removal of vegetation cover and increased soil erosion and removal from upper hillside watershed surfaces has occurred due to overgrazing, urban growth, agricultural growth, creation of roads, construction, and other human activities [69]. Unrestricted access to land resources can result in overexploitation and degradation of the resource [13]. Overgrazing happens when too many animals graze on a patch of land without adequate control over the animals' grazing activities. What constitutes overgrazing is the inability to move animals in a way that is compliant with pasture development. Overgrazing is a major environmental issue where groups of animals eat heavily from one land area without ever allowing the vegetation to completely recover in that area. It is a phenomenon that can be seen both in nature and also on livestock farms. It commonly happens when a farmer or an owner of the livestock keeps too many animals in one particular area [70]. Overgrazing mainly occurs in rangelands and it has been described by pastoralists for hundreds of years in regions around the world with arid, semi-arid, and dry sub-humid climates where the topography and soil are not suitable for large-scale cultivation [71]. Rangelands (including grasslands, shrubs, deserts, and tundra) comprise about half of the world's land and hold more than 33% of the carbon reserves aboveground and underground [72]. Soil carbon change can happen in response to a broad range of environmental and management factors [73]. Livestock grazing is a vitally common issue that affects plant growth, plant species diversity, and soil carbon accumulation [74]. In 2010, between one-third and a half of the entire world's agricultural land was in a degraded condition, and a fifth was considered severely degraded. Another 12 million ha was lost that year as the demand to increase agricultural output rose along with insufficient conservation of soil and water and other unsustainable farming practices [75]. In 2014, the UN reported that the destruction of agricultural ecosystems worldwide cost US \$40 billion, not counting the invisible cost from the use of fertilizers and subsequent biodiversity and rare habitat degradation [76]. Additionally, land loss is also worsened in several regions of developing countries in the world, through rapid population growth and expansion into vulnerable hillsides and wetlands [77]. This transition appears to lead to higher carbon stocks and uptake rates, but can also be subject to devastating losses of carbon in hot and dry fire years after wet years of increased fuel loads [78]. From 2001 to 2005, the Great Plains carbon reserves were measured at 7500 Tg C, with 45% in agricultural land, 34.9% in the shrublands and grasslands, 15.5% in undeveloped forested areas, and nearly 3% in wetlands. Models estimate that by 2050, these figures will adjust to reflect a slight rise in farmland carbon stocks (47%), a substantial reduction in carbon stocks in the grasslands (29%), and a rise in the level of forest carbon stocks (20.4%). There is no improvement in wetlands or other



soil carbon stocks due to woody invasion and forest growth. The conversion of grasslands into agriculture in the years 2001 up to 2050 may result in a cumulative reduction of accumulated carbon by 26 to 157 Tg, a sum that could add up to 4% depletion of the average potential for complete carbon sequestration [79]. Another cause of carbon loss is fire. Burnt areas and carbon release from the fires vary spatially and temporally due to atmospheric, biological, and physical factors. Furthermore, simulations indicate that grassland fires are not expected to change dramatically under future climate conditions.

The average grassland fire emissions range between 0.18 and 24.72 Tg of CO<sub>2</sub> equivalent (CO<sub>2</sub>e) per annum [79]. Soil organic carbon (SOC) ranged from 1.58 to 3.43% in the vast semi-natural grasslands and from 3.90 to 5.60% in the eutrophic soils, and the remaining plant species and roots will gradually decompose and the carbon will be retained in the soil organic matter [80]. Most grassland carbon is kept in the soil, unlike woodlands, where the primary carbon source is vegetation storage. In this research, the adverse impact of overgrazing on biomass from carbon is due to mismanagement and excessive cattle consumption of grasses and other green plants. This results in reduced vegetation growth and reduced plant species diversity due to livestock movement, excessive growth of undesirable plant species, the degradation of soil and forest, and land degradation perpetrated by the negative effects of overgrazing [81].

#### The Impacts of Overgrazing on the Characteristics of Vegetation and SOC

Exclosure of grazing areas has been identified as a successful practice for restoring degraded grasslands, as vegetation and soil characteristics have demonstrated enhancement under the long-term exclusion of grazing [82,83]. The biomass, cover, abundance, and soil characteristics increase in the course of restoration as a product of a rise in the germination of seeds and seed banks for species that are annual and perennial when livestock was excluded [83]. Furthermore, the contact between the plants and the soil during the recovery should be considered the succession process. The grazing process can affect the soil compositions connected with biomass, such as the storage of SOC [84]. The return of organic plant materials back to the soil resulted in faster SOC turnover through litter accumulation [85]. The improvement of SOC is caused by microorganisms decomposing into organic matter [85,86]. In this review, it has been confirmed that SOC has a substantially positive association with above ground biomass (AGB), total biomass (TB), litter, and cover. Increases in the SOC have been closely related to changes in plant efficiency. The SOC has contributed to plant production as a key element of soil fertility. The SOC will enhance the growth of the plants through the provision of sufficient nutrients to the plants [87]. In the meantime, heterogeneous vegetation conservation and linked soil surface structures are important for SOC accumulation in semi-arid grassland habitats [88]. Rises in SOC in these areas reduced soil erosion as a consequence of wind due to increased vegetation cover, which allows nutrients to easily repair the soil following the exclusion of animals [89]. Another explanation concerning grazing was that the soil aggregation increased as SOC's physical defense [90]. The different species alignment of communities in different plots was also possibly related to variations in cover and biomass between different exclosure years [91,92]. There are highly variable grazing impacts on stocks of SOC, with some research demonstrating a drop in SOC with grazing [93]. The primary mechanism of grassland destruction and the resulting degradation of SOC stocks is overgrazing [66]. The high density of stock is one of the defining characteristics of intensively managed grassland [94]. By following the Global Assessment of Soil Degradation (GLASOD), three classes of grassland degradation were considered, each corresponding to a different percentage of plant basal cover, that included 75–100% for “lightly degraded”, 50–75% for “moderately degraded”, and below 25% for “heavy degraded”, as well as easy to access data including the use of remote sensing [95]. This helped to assess SOCL losses between the twenty-eight studies regarding undegraded and degraded grassland which was calculated as follows [69].

$$\text{SOCL} = \frac{\text{SOC}_{\text{D-ND}} - \text{SOC}_{\text{D-D}}}{\text{SOC}_{\text{D-ND}}} \times 100 \quad (1)$$

where soil organic carbon losses (SOCL) were the difference (percent) between the non-degraded grassland (SOC<sub>D-ND</sub>) and the most degraded grassland regarding the SOC<sub>D</sub> in the upper soil layer to 0.3 m (SOC<sub>D-D</sub>).

We believed that SOCL could be restored with degraded grassland restoration. According to [96], for instance, after considering the twenty-eight studies that were published on the effect of grassland degradation on SOC stocks (Table 1). Under different environmental factors (mean annual precipitation, mean annual temperature, soil texture, type of grass, soil pH, and intensity of grazing), variance occurred, which could quantify the impact of grassland degradation on SOC density at different sites. We measured the amount of SOCL and whether it was lightly degraded, moderately degraded, or heavily degraded by comparing the different sites. Grassland management is strongly affected by the SOC density reservoir, where a higher proportion is retained in the topsoil (0–0.3 m). Despite this, how grassland SOC stocks react to degradation it is still not completely understood, particularly for the numerous environmental conditions found worldwide. Where; t (m, thickness in a top-soil layer), n (amount of sites), amt (annual mean temperature), map (mean annual precipitation), z (altitude of above sea level), clay (soil of the clay content), SOC<sub>D-ND</sub> (SOC density in the non-degraded top-soil), SOC<sub>D-D</sub> (SOC density in the degraded top-soil). Table 1 shows the percentage of SOCLs using the GLASOD formula to understand the effect of soil organic carbon losses under different environmental factors from twenty-eight studies. We can see the results from lightly degraded up to heavily degraded areas including China (Mongolia, 90.6%), China (Qinghai-Tibetan 90.34%), the USA (Georgia 80.94%), and Switzerland (Fribourg 77.5%) which are lightly degraded, and the USA (Utah 56.86%), USA (Mandan, N. D 68.38%), China (Qinghai-Tibetan 72.44%), South Africa (Bergville 63.33%), USA (Utah 70%), USA (Oklahoma 73.19%), and China (Tianzhu 53.29%) which are moderately degraded, with the others all heavily degraded. This indicates that the amount of SOC losses is different between and regions under different environmental factors. So, the degree of degradation can represent the impact on the SOC sequestration capacity of grassland soils. SOC losses of up to 30% in slightly degraded grasslands and up to approximately 70% (just below the heavily degraded category) were found in moderate soil as characterized by the different degradation intensities [97].

#### 4. Mitigation Measures to Reduce the Sources of Carbon Emissions

##### 4.1. Exclosure in Land Rehabilitation and Restoration Forest

Long-term efforts that require careful planning, implementation, and monitoring of forest restoration and recovery are challenging. Forest regeneration aims to restore the ability of degraded forest soil to provide products and services from forests. In ecosystems where forest destruction has caused a drop in the quality of ecological resources, forest restoration and forest reconstruction have been implemented. The areas are enclosed and safe from any human-related interference which promotes the regeneration of natural vegetation of degraded, eroded, and bare soils [56]. Area exclosure establishment is the main method to reverse the cycle of land degradation and regenerate soil organic carbon, above-ground carbon biomass, and underground carbon stocks [98]. It is also important to increase the carbon sequestration potential and promote natural regeneration and indigenous species, due to a quick vegetation recovery at a younger stage with minimum cost, and to mitigate the effect of increasing the concentration of atmospheric CO<sub>2</sub>. An area exclosure is an area closed due to degradation and unfavorable environmental conditions [72]. An area closure is also important to the success of an adequate amount of seedlings, saplings, and mature trees, and to improve the potential of new species regeneration in a short time [99]. Over the last few decades, intensive exploitation and associated disturbances have destroyed vast forest areas in the tropics, resulting in large and expanding areas of degraded forest habitats.

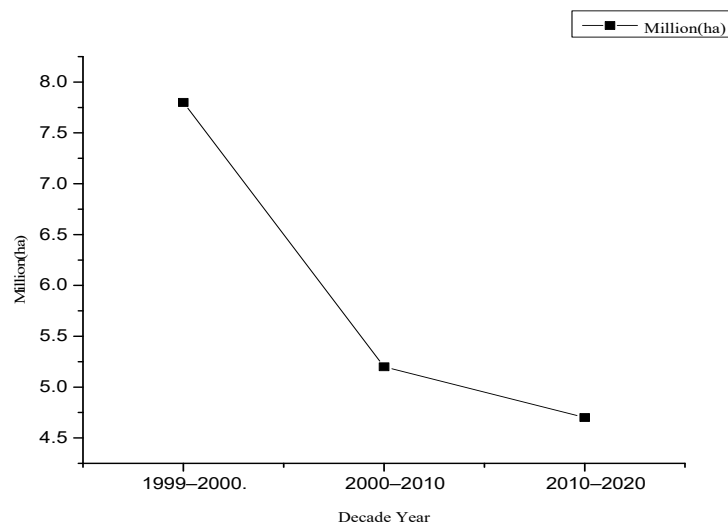
Deforested grasslands, bush lands, scrublands, and under stocked or degraded forests can be protected and restored as can infertile farmland. It is possible to restore and alter forests employing protective measures (e.g., fire or grazing protection and erosion control), natural regeneration acceleration measures, and actions to promote native vegetation (e.g., by control of free grazing on degraded lands and marginal agricultural sites), and by planting native or implanted trees in single-species or mixed-species plantations, as in agroforestry and forest-external production systems.

Riparian regeneration is a common strategy for restoring riparian areas and has shown advantages for riparian vegetation by enhancing in-stream habitat. There is a particularly low level of knowledge on riparian rotational grazing treatments, such as planting and thinning, and few studies have investigated stream factors or biota after riparian treatment [100]. For a range of reasons, forests should be preserved and rehabilitated, such as increasing land productivity, generating and providing environmental services (e.g., maintaining water and soil), and developing ecosystems that absorb large carbon volumes to ensure they are diverse, sustainable, resilient, and immune to negative changes. Carbon credits for projects for forestation and reforestation under the Kyoto Procedure may result in additional investment in degraded areas for rehabilitation. Projects for reforestation including in the context of the climate change process, in both developed and developing nations need the strong facilitation of regional and international systems, i.e., effective institutions, proactive policies, and clear legislation. It is not just in Europe itself that European countries face afforestation problems. Their cooperation on carbon sequestration under the Clean Development Mechanism (CDM) with developing countries outside Europe suggests the need to take into account the ecological values of social and economic nature effects of forests and replantation in areas outside these countries as well [101]. The United Nations Framework Convention on Climate Change (UNFCCC) describes afforestation and reforestation as a human-induced direct conversion through planting and seeding, and from restoring a land area that is not forested to forested land in a human-induced way. Afforestation may occur on the ground if given at least 50 years of protection. On land that has not been traditionally forested but has been subject to other land use, reforestation can occur [102]. A holistic technique to forestry and reforestation is therefore required, which should take into account carbon sequestration, biodiversity protection, soil conservation, and the supportable supply of safe raw local materials to timber and other services and product industries. Then, the area needs enclosure, protected by public boundaries for natural regeneration that are adhered to by the local people through the development of local bylaws for the specific site [103]. The process for an area's enclosure is: First, the agriculture sector and local administration (community representative, local authority) develop a committee and identify the site protection based on set criteria. Finally, it requires agreement with local community members with consideration of welfare at the local community level, including discussion of methods for protecting an area and the enclosure impacts on carbon sequestration of degraded lands demonstrating the effect of overgrazing increasing the bare land and decreasing the carbon reserves of the soil-plant system [56].

As a consequence of the net shrinkage in forest areas, the world's complete growing tree stock fell slightly from 560 billion cubic meters in 1990 to 557 billion cubic meters in 2020. In comparison, the stock is increasing globally per unit area throughout all areas of the world, from a metric cube of 132 per hectare in 1990 to a metric cube of 137 per hectare in 2020. The growing stock per unit area is the largest in the tropical forests of South and Central America and West and Central Africa. Around 606 gigatons of living biomass (above and below ground) and 59 gigatons of deadwood are found in the world's forests. Since 1990, the total biomass has declined marginally, but the biomass has increased per unit area [60].

As illustrated in Figure 3, in some countries, the reduction in deforestation from 1990–2020 reduced the rate of net forest loss, significantly increasing forest areas, with increases in other areas through forestation and natural forest expansion. From a previous annual 7.8 million hectares loss, in the periods 2000–2010 and 2010–2020, forest loss decreased

annually to 5.2 million hectares and 4.7 million hectares, respectively. Additionally, in the 1990–2000 decade, the net forest loss rate decreased. Owing to a reduction in the speed of forest production, the pace of the decrease in net forest depletion has slowed over the previous decade.

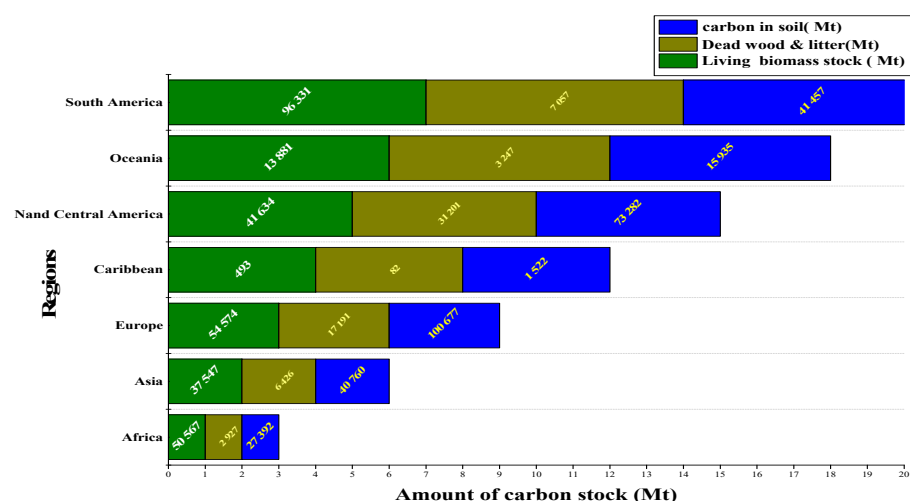


**Figure 3.** The global net shift in the annual forest area (Million ha). Source (FAO, 2020).

#### 4.2. Exclosures on Climate Change Mitigation

Area closures are important to minimize GHGs, reduce deforestation and degradation, and enhance and conserve forest carbon pools [104]. Carbon sequestration is the mechanism of removing CO<sub>2</sub> from the atmosphere, carbon capture, then storing forest carbon pools in carbon sinks by photosynthesis in living organisms and the soil [99]. The primary emphasis of global climate change policies and international climate treaties is to decrease the GHGs [105]. The second-largest cause of the emissions of anthropogenic carbon is carbon pollution from degraded land loss and deforestation [106]. Exclosure leads to a significant rise in carbon stocks aboveground natural carbon and biomass in the soil. Changes in ground cover resulting from exclosure from non-forest to forest areas, foresting practices, and reforestation increase the carbon capture ability of the area. Forest areas are closed to provide groundwater regulation, flood control, soil erosion prevention, and develop organic soil carbon and climatic change mitigation [107]. By sustainably managing an area from any interference, it can increase the restoration of biomass and carbon reserves in the soil and aboveground, as occurs in afforestation [108]. The average biomass measured in the exclosures above the land was greater than twice that of the neighboring grazed land [103]. For instance, carbon stores are predominant in living biomass in Africa accounting for approximately 60%, accompanied by soil carbon (about 34%), while the primary carbon source in Europe is the soil (64%), with living biomass storing just 25% of the carbon [1].

Around half of the overall carbon in forests is contained in living biomass and dead timber, and half in the litter and soil (Figure 4). Forest ecosystems are vital as a carbon sink, storing 335–365 Petagram of their biomass carbon alone with the total C storage in the biomass, deadwood, litter, and soil of forest systems exceeding total atmospheric carbon. Figure 4 illustrates the distribution of different pools of carbon in forests of different regions. The carbon ratios in living biomass and soil vary from region to region but together make up more than 90% of the overall stores. In all regions, the share of deadwood and litter together is less than 11%. In all countries, the carbon in a pool of litter is less than 5%, and the dominant pool of soil carbon is in grassland and cropland systems (Figure 4).



**Figure 4.** Distribution of carbon among different pools in forests and other wooded lands. Source; (FAO, 2020).

#### 4.3. Carbon Stock and Tropical Regions

Tropical forests host 50% of all species in the world and are known to be mega-diverse ecosystems. If these ecological services alter, it will have a serious effect on biodiversity, the natural carbon cycle, and the hydrological cycle, which, in turn, can change the world economy and affect the everyday lives of humans and other animals on the planet. Forest management has traditionally focused on the rise in forest production and growing stock of forest products, along with several other resources such as carbon stock and biodiversity, because deforestation, forest destruction, climate change carbon sequestration, and biodiversity are all closely interlinked [109]. Forest ecosystems have a significant function in the global cycle of carbon and there is an increasing need for large-scale carbon quantification. Due to differences in site quality, forest storage and composition, human activities, and land use management practices, the carbon stock often differs from place to place within the same environment. Additionally, due to climatic and edaphic fluctuations, the growth rate for tree species varies significantly across regions. *Ceteris paribus* decreases the mean annual increase (MAI) of forest habitats from lower to higher latitudes, from wetter to drier areas, and from lower to higher elevations, due to changes in factors such as temperature, soil characteristics, increasing season length, etc. Therefore, tropical and subtropical regions have the highest growth rates of vegetation and the densest vegetation on the globe. The global carbon stock, biodiversity, and global carbon cycle can be influenced by the forest management strategy. It is crucial to consider how various management strategies will promote greenhouse gas mitigation initiatives rather than monetary benefits. For the implementation of effective climate change mitigation policies relating to the reduction of emissions from deforestation and degradation (REDD), developing countries are expected to generate reliable forest carbon stock forecasts. However, there is less convincing evidence of a strong congruence between high carbon storage and biodiversity at national and sub-national levels [110].

To change national policies and expectations of REDD+ outcomes, the potential risks of relocating deforestation activities from high-carbon areas to low-carbon areas should be accounted for, as such relocation will affect habitats with high biodiversity.

Table 2 shows the reported wide variation in both above-ground biomass carbon density and total biomass carbon density in tropical regions across three continents such as Africa, Latin America, and Southeast Asia.

#### 4.4. Carbon Stock Pools and Their Biomass Development

As per the IPCC (2003), biomass is comprised of five carbon ponds belonging to the terrestrial ecosystem, namely AGB, BGB, masses of dead litter, trees debris, and SOC. The

CO<sub>2</sub> fixed by plants is transferred via several carbon reservoirs during photosynthesis [111]. Carbon is over 50% of the dry tree biomass [112]. For example, the bark or any portion of a living or nonliving tree tissue such as branches, leaves, or roots. Carbon is located in the cells inside the plants' cell walls in comparison to animal cells. Carbon is required to create compounds of lignin and cellulose and is therefore sequestered within the plant tissue. The mechanisms for photosynthesis use the sun, water, and CO<sub>2</sub> for glucose and O<sub>2</sub> development. CO<sub>2</sub> is obtained from the atmosphere through the stomata (singular: stoma), small gaps in the epidermis of the plant (in particular, the leaves or stems) that are used to exchange gas for photosynthesis. When trees grow within the forest, so too does the biomass of the tree, and it sequesters more carbon. When the trees are growing and still young, net forest carbon intake is at its highest. While forests have the potential to sequester a large amount, they also release some CO<sub>2</sub> back to the atmosphere. The result of cell respiration is CO<sub>2</sub>, a biological cycle found in plants and animals alike. In plants, the CO<sub>2</sub> from cellular respiration can be recycled for photosynthesis but it returns some CO<sub>2</sub> to the atmosphere at night, when no photosynthesis occurs. CO<sub>2</sub> is also released into the atmosphere when debris or a dead tree (or some other vegetation) starts to break down.

The CO<sub>2</sub> is released if the biomass in the tree is broken down by bacteria. If the canopy of the forest is dense enough to shelter the forest floor from sunlight, decomposition can be slowed down. Another source of CO<sub>2</sub> being released is tree cutting, in addition to natural decomposition, and it depends on what plants are being harvested, as to how fast the carbon is released. For instance, trees cut down to generate short-lived goods such as paper, can very easily release carbon.

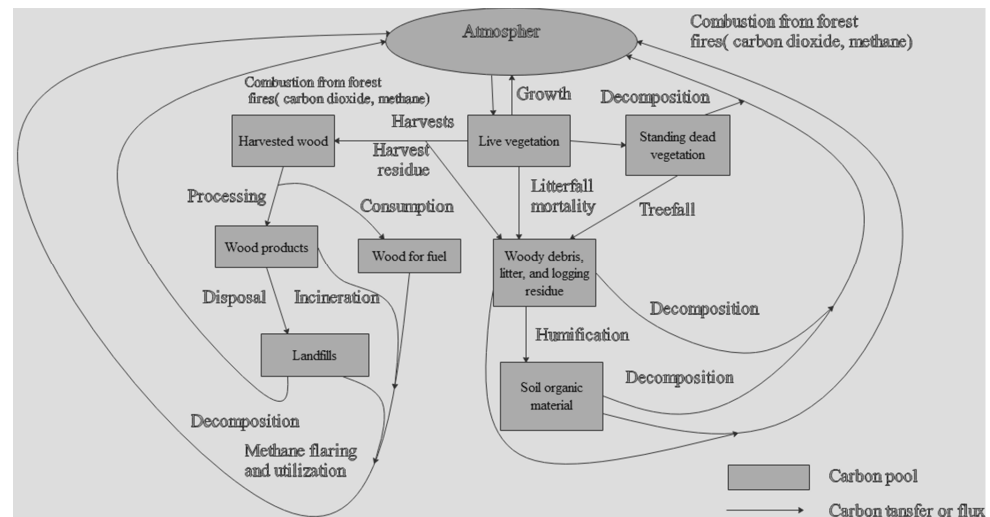
Trees used to manufacture long-term items such as furniture or timber, however, can sequester the carbon for a long time and continue to act as a sink of carbon until the wood decays [113]. The United States EPA (2010) estimated that the forest products harvested sequestered 9% of specific CO<sub>2</sub> deposited inside US land in 2008 [114]. Fires can release a large amount of sequestered carbon within forests, they decompose as fires burn and the trees release CO<sub>2</sub> into the atmosphere once again. The highest CO<sub>2</sub> US-based pollution in 2008 was from fires both wildfires and prescribed fires which amounted to 189.7 teragrams (1012 g) [114].

Figure 5 displays the various ways carbon can be released from forests. It shows that growth is the simple method that CO<sub>2</sub> is sequestered by forests. Although forests release CO<sub>2</sub> into the atmosphere, forests are carbon sinks.

#### 4.4.1. Aboveground Biomass Carbon Stock

As shown in Figure 5, rehabilitation and natural vegetation regeneration status successfully improve the microclimate, the biodiversity of the area closed, and provide soil organic fertility [115]. Above-ground biomass is demarcated as all the woody stems, branches, and leaves of living trees and the carbon pools are expressed as tons of carbon stock per hectare. These are the most noticeable, most visible, and dominant carbon reserves in the closed forest [116]. For instance, in the living aboveground biomass in Africa, 59.5% of the above-ground carbon is deposited. The biggest significant cause of anthropogenic global climate change is carbon dioxide (CO<sub>2</sub>) and global warming by deforestation and the depletion of biomass in the trees [117]. Biomass living above ground (AGLB) in trees generally forms the largest carbon pool and is the one that has the greatest impact from deforestation [118]. It is generally assumed that 50% of the overall total biomass is made up of actual carbon stock above ground. Above ground (AGB) carbon stocks of exclosures were noticeably higher than the surrounding free grazing land [119]. For example, in East Africa in the Ethiopia lowlands, the average difference in AGB carbon stock of exclosures and adjacent open grazing land ranges between 2.3 and 5.6 Mg C ha<sup>-1</sup>. In Northern Ethiopia's highlands, it ranges between 2.0 and 7.0 MgC ha<sup>-1</sup> [56]. Land cover change is a key cause of aboveground carbon stock changes. Overall, carbon stocks were highly variable between types of land cover, for example, dense closed forest areas have high carbon stocks, while carbon stocks in open communal land and bare land are low [107]. The

properties of the aboveground vegetation in SOC stocks could provide a useful estimation in dry Afromontane forests. In dry Afromontane forests, large amounts of carbon can be processed in the biomass aboveground [93]. The enclosure has a sound type of regeneration, stimulated by both the community structure and the structure of the individual species' populations [14].



**Figure 5.** Sequestration cycle for forest carbon from the Inventory of US Greenhouse Emissions and Sinks. Source: Ingerson., et al. (2007)

Litter carbon stock is the carbon biomass in non-living organic matter and soil lying above the soil surface in different states of decomposition [120]. One of the major sources of organic carbon from the soil is the decomposition of litter. When the forest area vegetation is degraded and deforested, the litter carbon stock can be decreased. The litter carbon amount varies by forest type, plant species, the age of the species, the land status, length of time of enclosure, and slope gradient [58].

Deadwood carbon stock is the carbon stock of deadwood on the forest floor (i.e., significant components of dead trees in a mature forest area). Forests have dead trees standing and deadwood falling, which is accumulated in the 30 to 60 years of afforestation or reforestation of closed forest areas.

#### 4.4.2. Belowground Carbon Stock

Below ground biomass consists of all the living roots that play an important role in carbon cycle transferring and carbon contained in the soil by growing an organic accumulation of carbon within the soil following root decomposition [55]. Large trees tend to have large roots, root biomass is mostly measured in ecosystems from root-to-shoot ratios, making a major contribution to SOC [121]. Approximately 50% of the photosynthesized carbon is transported underground and divided between root growth, rhizosphere respiration, and soil assimilation of organic matter [16].

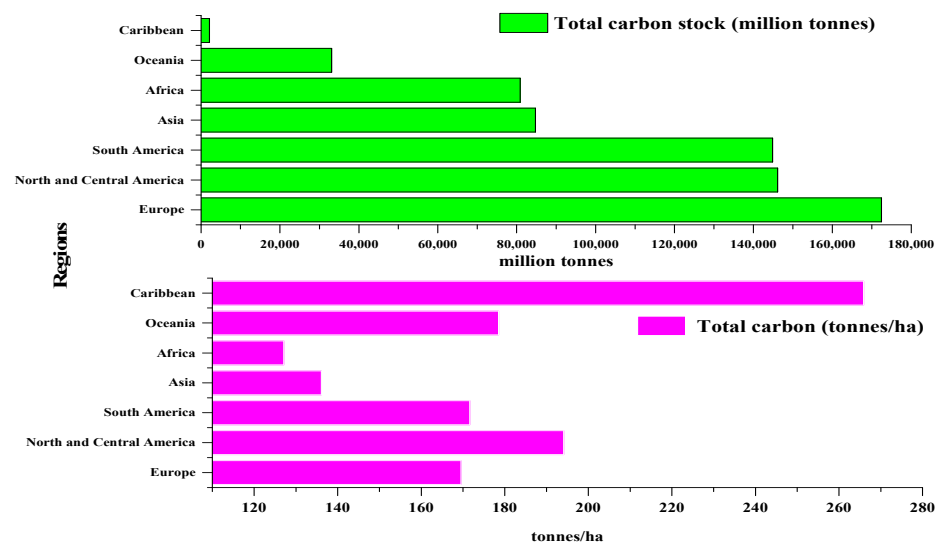
#### 4.4.3. Soil Carbon Stock

As shown in Figure 5, organic matter from the soil is increased through the increase of aboveground carbon biomass after the establishment of an enclosure area enhancing the organic matter of the soil by accumulation [122]. The sequestration of soil carbon implies plant atmospheric carbon dioxide elimination and storing of fixed carbon as organic matter in the soil [123]. The soil is the world's primary carbon source in the carbon cycle; for instance, 34.4% of carbon stocks in Africa are contained in the soil [124]. The soil contains about three times the carbon content of the world's vegetation [16]. The soil carbon stock is affected by environmental factors, such as topography, soil depth, and human activity. For instance, in east Africa, the estimation of Ethiopia's national soil carbon reserve ranged

from 101 MgC/ha to 200 MgC/ha [125]. Soil determines the vegetation of the rangelands, as it affects the availability of water, soil temperature, elemental balance, energy from microbial biomass, soil flora and fauna, and species diversity [72].

Therefore, to reduce soil carbon loss in an established area enclosure it must include government and non-government participants to determine carbon stock monitoring of the forest cover because forest cover is a third of the land on our planet [126]. The enclosure of regions provide raw materials, preserve biodiversity, protect the supply of land and water, and play a role in climate change by mitigating and increasing the capacity for carbon accumulation or release. Globally, the amount of net loss as a consequence of woodlands has decreased since the 1990s, but recent data shows that the pace of this decline has slowed in the latest ten-year period, mainly because forest areas in Asia and Europe have increased less than in the previous decade. To estimate forest biomass in 2020 from 193 countries and territories that account for 99% of the world's forests, the default IPCC guidelines provided conversion factors that were used by several countries to estimate biomass from growing stock. To quantify terrestrial fuel capture and carbon storage systems sinks, tree carbon stocks are necessary and the estimation of potential emissions from shifts in land cover (deforestation, reforestation, forestation) and biotic and abiotic disturbances (e.g., forest fires, windstorms, pests, and diseases). For this reason, a carbon inventory can be used to determine the effect of a land development project on housing, income, and livelihoods through increased production of biomass and the supply of woodland, grassland, and cropland systems, by multiplying it with a dry matter carbon fraction, it converts biomass to carbon, usually about 0.5 [127]. This means the measurement of total carbon = biomass carbon + soil carbon, and the biomass carbon = aboveground biomass carbon + belowground biomass carbon + dead organic matter carbon. Due to an overall reduction of forest area caused by multiple factors, the global carbon reserve of forests has declined. However, there are major regional variations in this trend.

As shown in Figure 6, in Europe, South America, North America, and Asia, the full stock of carbon in forests is highly significant (where the forest areas have increased) and it decreased significantly in Africa, Oceania, and the Caribbean. Around 1990, global forest carbon stocks decreased, and in 2020, for all pools, carbon stocks per hectare increased. By contrast, in all regions, per hectare biomass stock has increased except in Africa, Asia, and Europe between 1990 and 2020, where this attribute was relatively stable. So forests, particularly regarding the worldwide carbon cycle, play a key function and are considered critical and permanent sinks of carbon.



**Figure 6.** Comparing forest carbon stock by region total carbon stock (Mt), tons/ha 2020, Source; (FAO, 2020).



#### 4.4.4. Carbon Stock in Soils and Tree Biomass

Both soils and tree biomass are capable of sequestering large volumes of carbon. When the land is used for agricultural purposes, soil conservation activities play a significant part in sequestering carbon. Tilling is used in agriculture to remove unwanted plants, mix fertilizers, and have the soil ready for seeding. Nevertheless, with both the tillage of soil and the application of fertilizer, the volume of carbon sequestered in the soil has drastically decreased. Microbes come to interact with humus which is rapidly decomposed by soil tilling, and carbon is released. Furthermore, calcareous and sometimes dolomite is added to the soil to avoid acidification, which in turn degrades the soil and releases CO<sub>2</sub>. Nearly 4 million tons of CO<sub>2</sub> equivalents are released each year in the US from soil liming. Forestry has several carbon capture choices with around 50% of dry biomass being gas [114]. Therefore, any net rise in forest biomass results in increased carbon sequestering. However, various agricultural practices can improve soil carbon sequestration [113]. In the area of enclosure practices, such as planting seeds and indigenous plant regeneration, cover cropping involves planting grass season to season to protect the soil [128]. The more carbon that is within the soil improves water quality, reduces nutrient loss, and prevents soil erosion. These operations are based on-site but often include the selection of plants, the complete handling of the stand, replanting after harvest rather than relying on natural regeneration, and maybe under some conditions, fertilization (though fertilization can require some early release of GHGs). Of note, unforested land may be transformed into forests, thereby leading to the overall sequestration of carbon forests. Certain management changes often include understory management, for instance, by a thinning scheme that eliminates the smaller saplings. While such a technique is also used to lift the woody areas, implementing such a strategy may or may not increase the overall carbon sequestered in the trees if fewer trees are grown. To demonstrate the significance of carbon relative to a standing tree, the overall financial rotation would be prolonged to the point where the incremental carbon value is of equivalent importance to the increment of tree growth. Therefore, if forests are managed jointly for carbon and timber production, the harvest would be delayed, and the forest would be managed for longer periods. In the worst case, the forest would not be cleared for timber unless the relative prices of carbon were high enough. All the flows, positive as well as negative, should be measured from the theoretical viewpoint.

Certain existing concerns primarily related to this policy include problems surrounding credits for the quantities of forest-sequestered carbon. Finally, actions could be taken to diminish forest carbon emissions directly by reducing deforestation and degradation, particularly throughout the developing world, where deforestation is the greatest. The gradually expanded REDD program (REDDp) provides financial payments for investments in new forests and the promotion of the production of systems to better administer, manage, and protect existing forested areas. An area of increasing interest is compensation for enhanced biodiversity.

## 5. Conclusions

This review provided evidence about the impact of enclosure for biodiversity conservation and the primary means for mitigation to halting or preventing deforestation and forest destruction, and promotes reforestation or afforestation for atmospheric carbon sequestration and fossil fuel replacement bioenergy ventures. Annually, regional and worldwide levels of deforestation rates were estimated to have lost a forest area of 420 million hectares by deforestation between 1990 and 2020, even though the rate slowed over the period. Deforestation happened at a rate of 15.8 million ha a year in 1990–2000, and since 1990, the loss of forests has increased in Africa, although the rate has decreased modestly in 2015–2020 as compared to 2010–2015. On the other side, in Asia and South America, deforestation levels are now almost half as high as they were in South America in the 1990s. In the same period, the net average change in forest area has increased positively in regions such as Asia, Europe, the Caribbean, and Oceania, while, in Africa, forest area is on the

decline and North and Central America, and South America are also decreasing in forest area negatively.

The overall reduction in forest regions has been caused by multiple factors, and the global carbon reserves of forests subsequently declined. However, between 1990 and 2020, the per hectare biomass stock increased in all areas except for Africa, Asia, and Europe, where this attribute was relatively stable. In general, some good forestry activities are being carried out from time to time in all regions which results in a positive biomass effect. This shows enclosure encourages the growth of plants and they can spread seeds to increase forest biomass that is greater than a deforested or grazing environment. Because the availability of carbon pools are more than half the living biomass in Africa, it accounts for approximately 60%, followed by soil carbon (around 34%). However, soil carbon is the predominant factor in Europe (64%), with living biomass accounting for just 25%. The carbon ratios of living biomass and soil, therefore, vary from region to region, but together they make up more than 90% of the overall biomass in all regions, and the share of deadwood and litter are together less than 11%. So, the formation of enclosures assists to promote the general environmental conditions of saved forest areas. Therefore, this review highlights the knowledge, experience, and perception of the global community about the impact of enclosures on carbon pools (aboveground biomass and below field fossil stock) and the social profitability and manipulation of forest cover that is helpful to minimize, over time, the release of carbon stocks into the atmosphere through deforestation and destruction of forests. We, therefore, recommend that enclosures offer viable choices for future sustainable management that can improve carbon stock biomass.

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