Introduction

Rising levels of atmospheric carbon dioxide (CO_2) and associated global warming have moved to the center stage of climate change discussion in the past two decades. Global warming as well as the gradual rise of earth temperature is a result of accumulation of greenhouse gases in the atmosphere. Although many dispute with the global warming hypothesis but projected doubling of atmospheric CO_2 by the latter half of the Twenty-first century raises concerns for everyone. Over the past century, carbon dioxide (CO_2) concentrations in the atmosphere have been increasing significantly as compared to the rather steady level of the pre-industrial era (about 280 parts per million in volume) have observed by climate scientists.

In the atmospheric CO_2 concentrations reduction significantly can only be achieved with substantial additional costs and major changes in living standards. Hence, adoption of CO_2 reduction strategies are widely debated not well received and not agreed upon by all nations. The world needs carbon (C) sequestration techniques that provide social, environmental and economic benefits while reducing atmospheric CO_2 concentration (Jose, 2009). The United Nations Framework Convention on Climate Change (UNFCCC) states carbon sequestration as the process of removing C from the atmosphere and depositing it in a reservoir. It involves the transfer of atmospheric CO2, and its secure storage in long-lived pools.

Management of agricultural systems to sequestrate C has been accepted as a partial solution to climate change (Morgan *et al.,* 2010). Minimal environmental and health risks practice is establishing and maintaining perennial vegetation which enhance C sequestration is less costly compared to most other techniques. Perennial vegetation is more efficient than annual vegetation as it allocates a higher percentage of C to below-ground and often extends the growing season (Morgan *et al.,* 2010) therefore enhancing C sequestration potential of agricultural systems even further (Jose, 2009).

Agroforestry systems have the capacity to reduce the carbon emissions from the atmosphere through carbon storage in trees and soil through accumulation in living tree biomass, wood products and Soil Organic Matter (SOM) and through protection of the existing forests.

C can be stored in above- and below-ground biomass, soil, and living and dead organisms within agroforestry systems (AFS). The quantity and quality of residue supplied by trees/shrubs/grass in agroforestry systems enhance soil C concentration. In addition, C stored by trees could stay in soils or as wood products for extended periods of time. If agroforestry systems are managed sustainably, C can be retained in these systems for centuries (Schroeder P., 1994).

The amount of C stored on a site is a balance between long-term fluxes and the net C gain depends on the C content of the previous system that the agroforestry practice replaces (Morgan *et al.*, 2010).

The enhanced C sequestration concept is based on efficient use of resources by the structurally and functionally more diverse and complex plant communities in agroforestry systems compared to sole crop or grass systems. Agroforestry practices accumulate more C than forests and pastures because they have both forest and grassland sequestration and storage patterns active (Sharrow and Ismail, 2004).

Objectives:

(1) To have an idea regarding the status and latent effect of CO_2 in Global warming and its consequences;

(2) To be familiar with different opportunities of **C** sequestration available under various Agroforestry systems.

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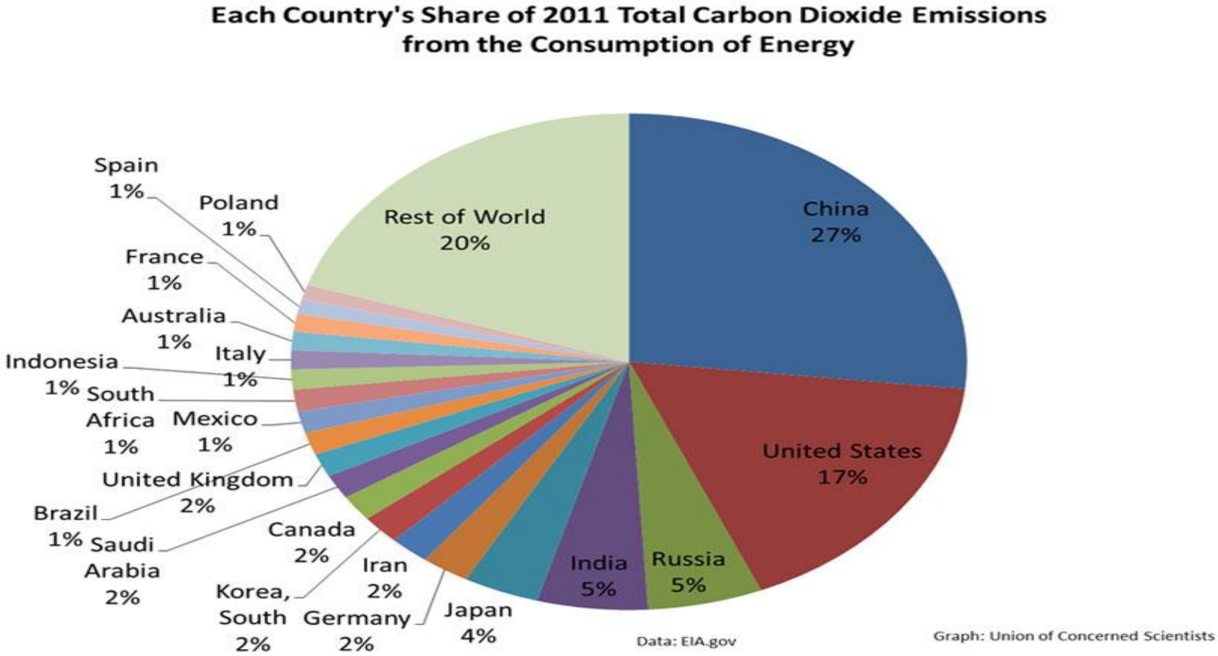
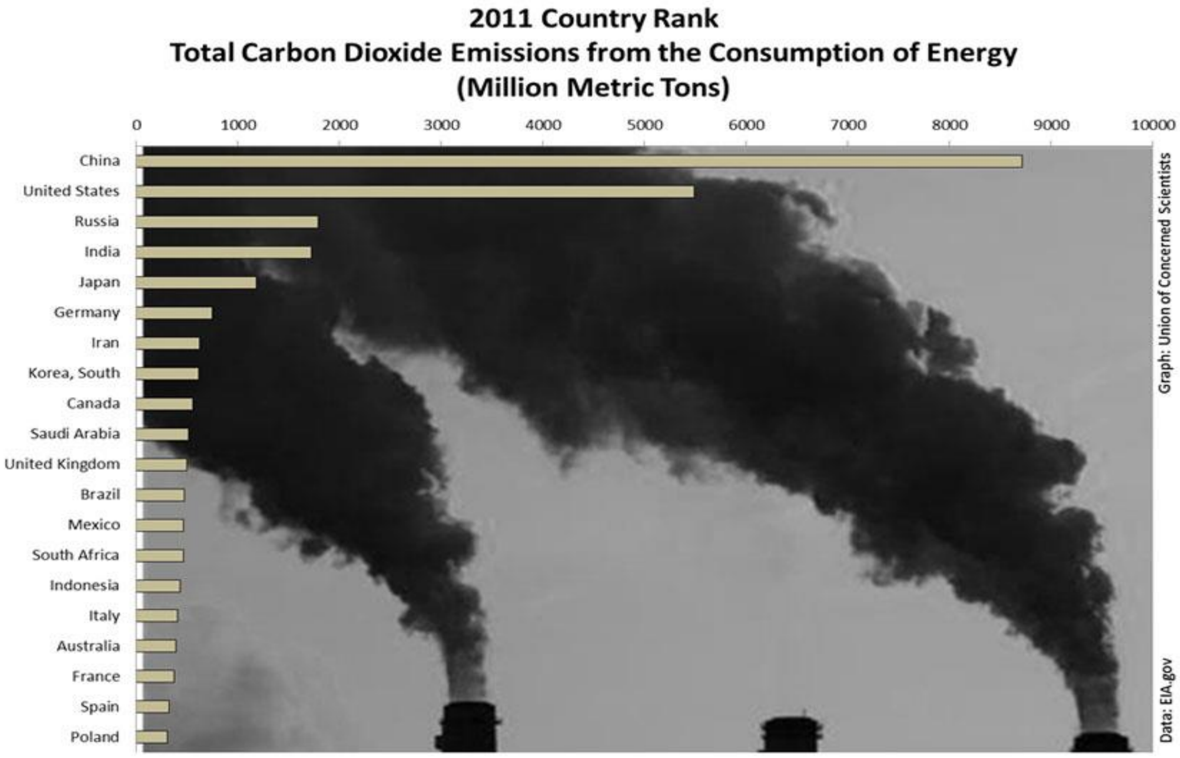
Materials and Methods

This Seminar paper is completely a review paper, thus all of the information has been collected from the secondary sources. All through preparation of this paper I went over and done with various relevant books, journals, publications etc. Findings related to my topic have been reviewed with the help of the library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) as well as searched related internet web sites to collect information. I got valuable suggestion and information from my major professor and course instructors how to collect information and preparation a seminar paper. Later, collecting all the information, it compiled and prepared this seminar paper.

Review of Findings





Global warming is a burning issue in the twenty first century. The main causes for global warming are the increasing of greenhouse gases. The primary greenhouse gases thought to be major contributors to global warming are; carbon dioxide emissions (CO_2), methane & bio methane emissions (CH_4), chlorofluorocarbons, and nitrogen oxides (N_2O), water vapor, while others are exclusively human-made (like gases used for aerosols).

The global warming potential (GWP) of CO_2 is 1, but it is highly destructive compare than other greenhouse gases because of their higher concentration and rapid increasing rate into the atmosphere. In February 2014, the concentration of CO_2 was 398.03 ppm (Figure 1), about 41% higher than in the mid-1800s, with an average growth of 2 ppm/year in the last ten years. It is predicted that the level may rise to about 450 ppm by the year 2050 which is 1.5 times higher than the preindustrial level.

Sources &contribution of carbon dioxide in global warming:

IPCC tried to find out the relative contribution of Greenhouse gases in global warming and here CO_2 contribute alone 60% in global warming (Figure 2). The main driving forces of increasing carbon dioxide in the atmosphere are the increasing trend of populations (Figure 3).

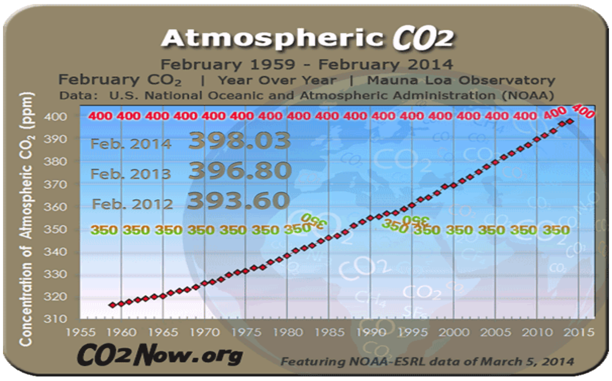


Figure 1: Present atmospheric CO_2 concentration **Source:** www.co2now.org

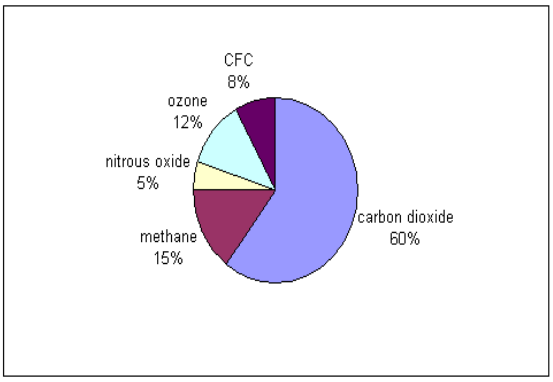


Figure 2: Contribution of carbon dioxide in global warming. **Source:** IPCC, 2007.

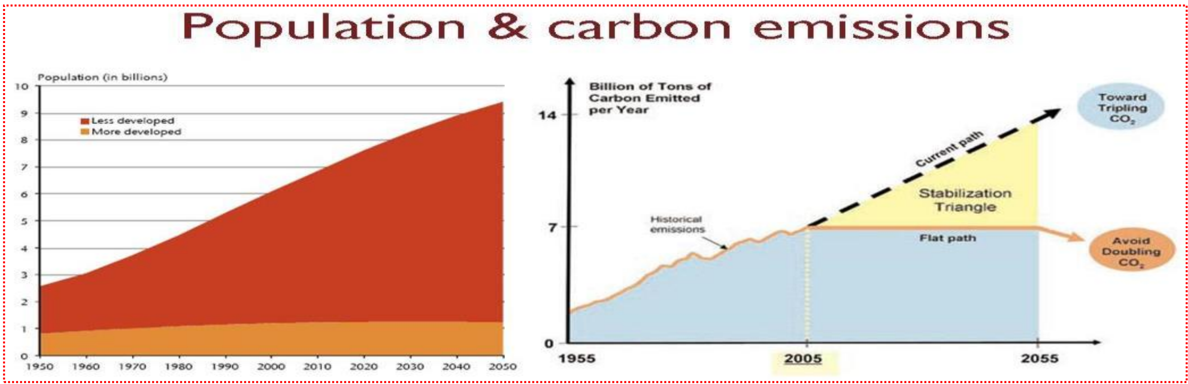


Figure 3: Relationship of CO_2 with increasing population **Source:** IUCN, 2008.

The Fifth Assessment Report from the Intergovernmental Panel on Climate Change states that human influence on the climate system is clear (IPCC, 2013). Among the many human activities that produce greenhouse gases particularly CO_2, the use of energy represents by far the largest source of emissions., Mainly CH_4 and N_2O produced from domestic livestock and rice cultivation by smaller shares correspond to agriculture, and to industrial processes not related to energy, producing mainly fluorinated gases and N_2O (Figure 4).

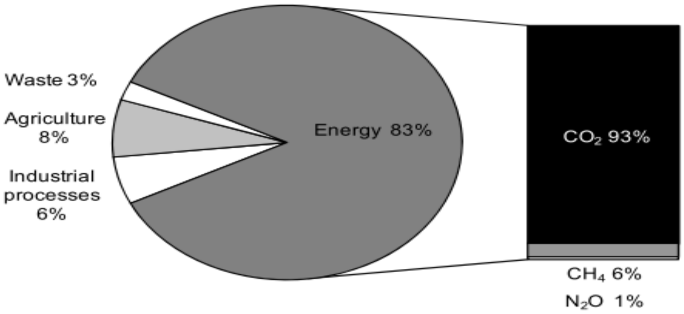


Figure 4: Shares of anthropogenic GHG emissions in 2011.
Source: IEA statistics, 2013.

Growing demand for energy comes from worldwide economic growth and development. Mainly relying on fossil fuels, global total primary energy supply (TPES) more than doubled between 1971 and 2011, (Figure 5).

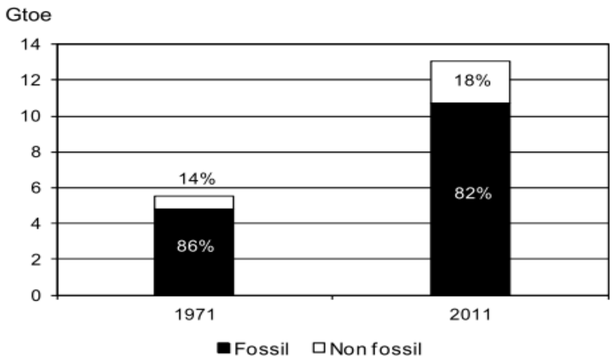


Figure 5: World primary energy supply.

Source: IEA statistics, 2013.

Global CO_2 emissions from fossil fuel combustion was 9.9 ± 0.5 $GtCyr^{-1}$ on average during 2012–2013, 8.8 ± 0.6 $GtCyr^{-1}$ during 2000–2009, 6.4 ± 0.5 $GtCyr^{-1}$ during 1990–1999 and 5.5 ± 0.4 $GtCyr^{-1}$ during 1980–1989 (Figure 6). Global fossil fuel CO_2 emissions increased by 2.7% yr^{-1} on average during the decade 2003–2012 compared to 1.0% yr^{-1} during the decade 1990-1999 (Le Quéré *et al.*, 2013).

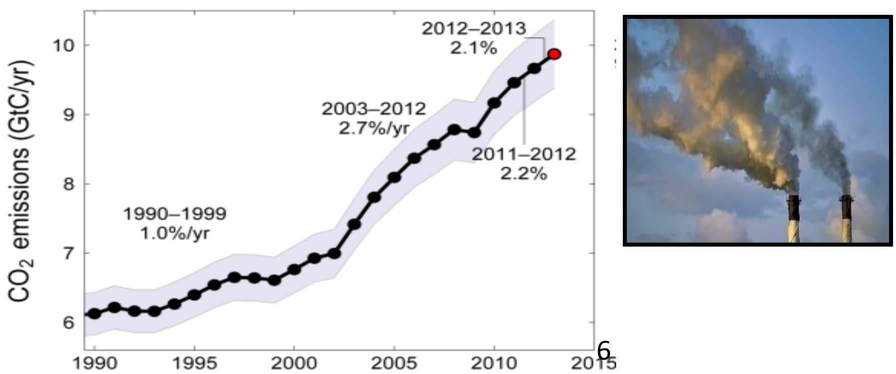


Figure 6: Trend in CO_2 emissions from fossil fuel combustion.
Source: Le Quéré *et al.*, 2013.

Beside this, CO_2 is emitted to the atmosphere by land use and land use change activities, in particular deforestation, and taken up from the atmosphere by other land uses such as afforestation and vegetation regrowth on abandoned lands. Global net CO_2 emissions from land use change are estimated at 1.4, 1.5 and 1.1 $GtCyr^{-1}$ for the 1980s, 1990s and 2000s, respectively (Figure 7). Global land-use change emissions are varied between 0.8 ± 0.5 GtC during 2003–2012 (Le Quéré *et al.*, 2013).

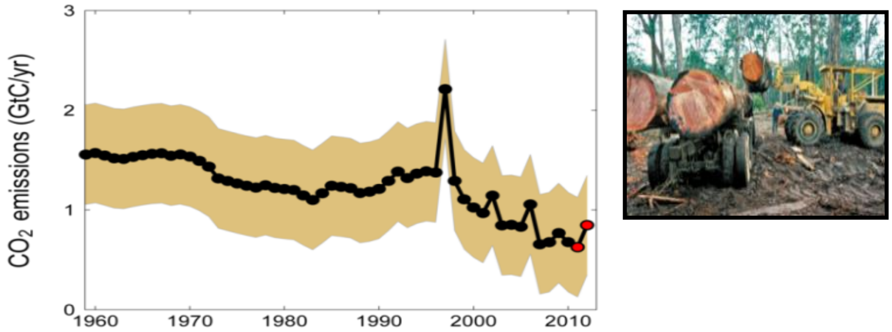


Figure 7: Land-Use Change Emissions.

Source: Le Quéré *et al.*, 2013.

Global carbon cycle

Atmospheric CO_2 is the main atmospheric phase of the global carbon cycle. Exchange fluxes of carbon are connected by the global carbon cycle can be viewed as a series of reservoirs of carbon in the Earth System. A schematic of the global carbon cycle with focus on the fast domain is shown in Figure 8. In the atmosphere, CO_2 is the dominant carbon bearing trace gas with a current (2011) concentration of approximately 390.5 ppm, which corresponds to a mass of 829 PgC (Schroeder P., 1994)

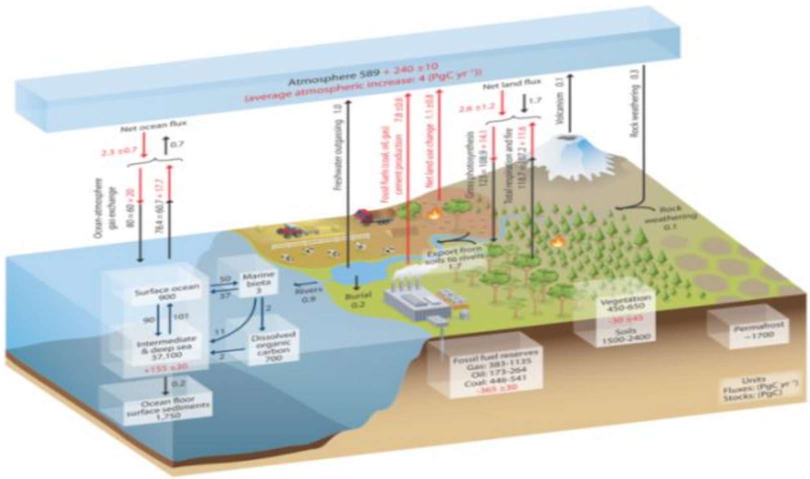


Figure 8: Simplified schematic of the global carbon cycle.

Source: IPCC fifth assessment, 2013.

Fate of Anthropogenic CO_2 Emissions

From fossil fuel emission (7.8±0.6) 91% → Atmosphere (4 PgC) 44%

\+ → Ocean (2.3±0.7) 26%

From land use changes (1.1±0.8) 9% → Forest (2.6±1.2) 28%

Relative consequence of CO_2 in global warming

Global Temperature

According to an ongoing temperature analysis conducted by NOAA found that, when the CO_2 concentration goes down, temperature goes down and when the CO_2 concentration goes up, temperature goes up- particularly since 1970. The average global temperature on Earth has increased by about1.4°Fahrenheit (0.8°Celsius) since 1880 (Figure 9). Two-thirds of the warming has occurred since 1975, at a rate of unevenly 0.15-0.20°C per decade. Therefore, severe extreme event will occur when temperature increases continuously (Figure 10).

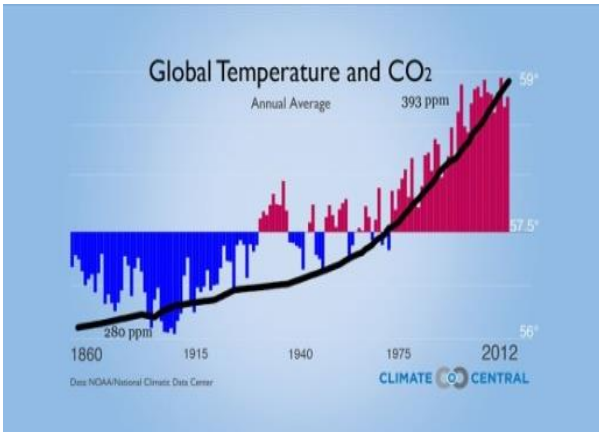


Figure 9: Rising Global Temperatures and CO_2
Source: IPCC, 2013.

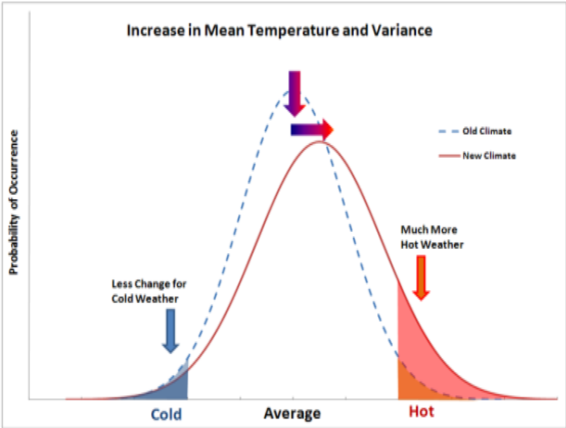


Figure 10: Increase in mean temperature and variance. **Source:** IPCC, 2001.

Sea surface temperature

Global sea surface temperature is approximately 1 degree C higher now than 140 years ago (Figure 11), and is one of the primary physical impacts of climate change.

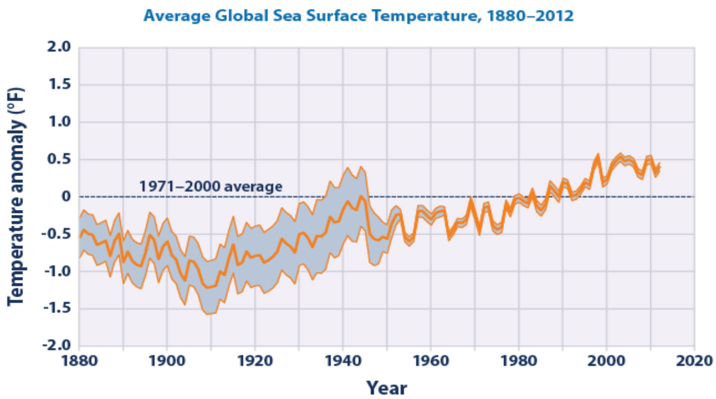


Figure 11: Sea surface temperature increasing trend.

Source: Lott *et al.*, 2011.

Sea ice extent

Sea ice occupies about 7% of the surface area of planet Earth and the sea ice thickness, its spatial extent, and the fraction of open water within the ice pack can vary swiftly and profoundly in response to weather and climate. In the last 30 years, the Arctic atmosphere has warmed by about twice the global average, resulting in record reductions in Arctic sea ice extent and thickness, especially in summer. As a result, Arctic sea-ice reductions have significant impacts locally, regionally and globally through effects on climate, wildlife and humans, and indirectly on sea level.

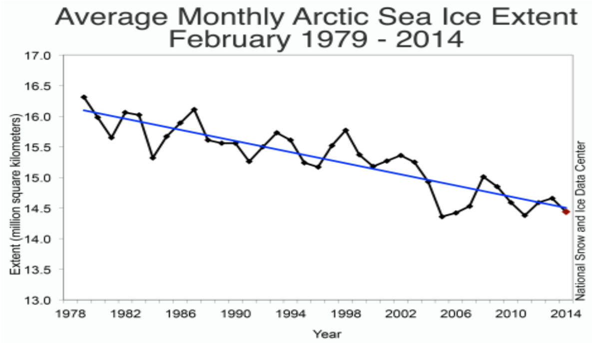


Figure 12: Arctic sea ice extent

Source: www.nsidc.org

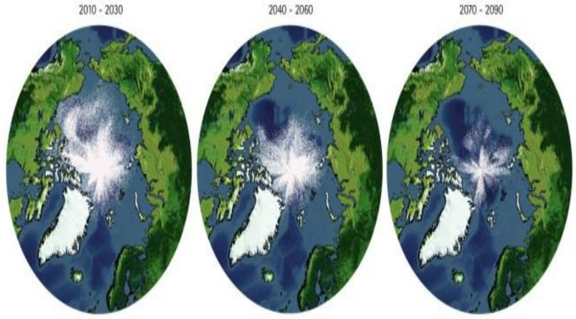


Figure 13: Reduction of arctic sea ice over time.

Source: Susan Joy, 2004.

Sea level is rising

Current sea level rise is about 3.2 mm/year worldwide (Figure 14). This rise in sea levels around the world particularly in Bangladesh, potentially affects human populations in coastal and island regions and natural environments like marine ecosystems (Figure 15).

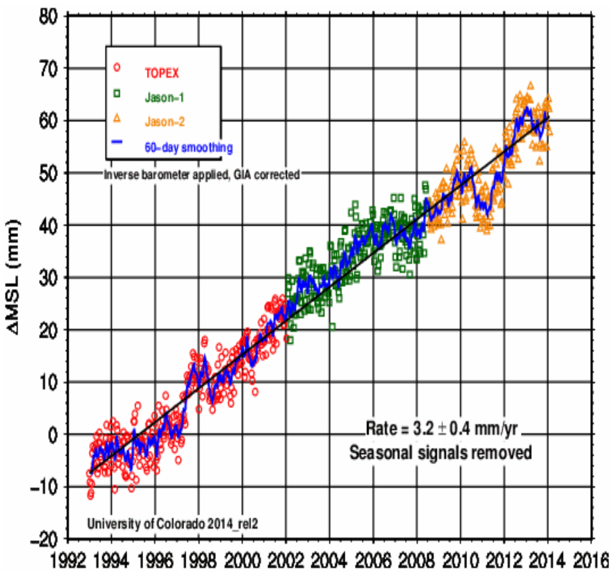


Figure 14: Global mean sea Level over time

Source: www.oarval.org

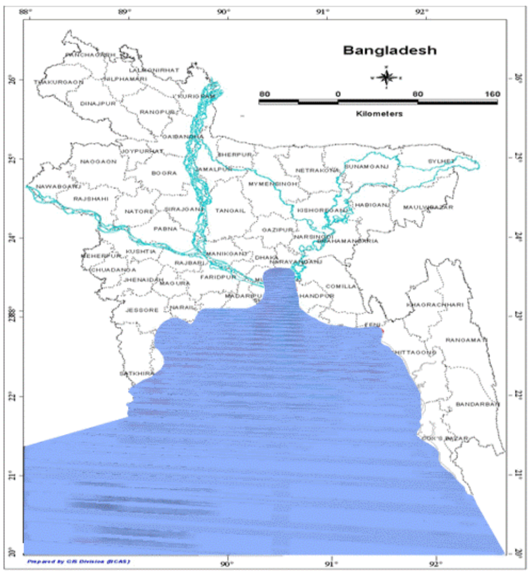


Figure 15: Risk of sea level rise in Bd.

Source: www.geologywales.co.uk

Flooding

As normal global temperatures increase, the warmer atmosphere can also hold more moisture, about 4 percent more per degree Fahrenheit temperature increase. Thus, when storms occur there is more water vapor available in the atmosphere to fall as rain and thereby excessive rain causes flooding situation (Figure16).

Figure 16: Flooding situation in Bangladesh **Source:** www.abc.net.au

Drought

A drought is a prolonged period of dry weather caused by a lack of rain or snow. As temperatures rise due to global climate change, additional moisture evaporates from land and water, leaving less water behind. Some places are receiving more rain or snow to make up for it, but other places are receiving less.

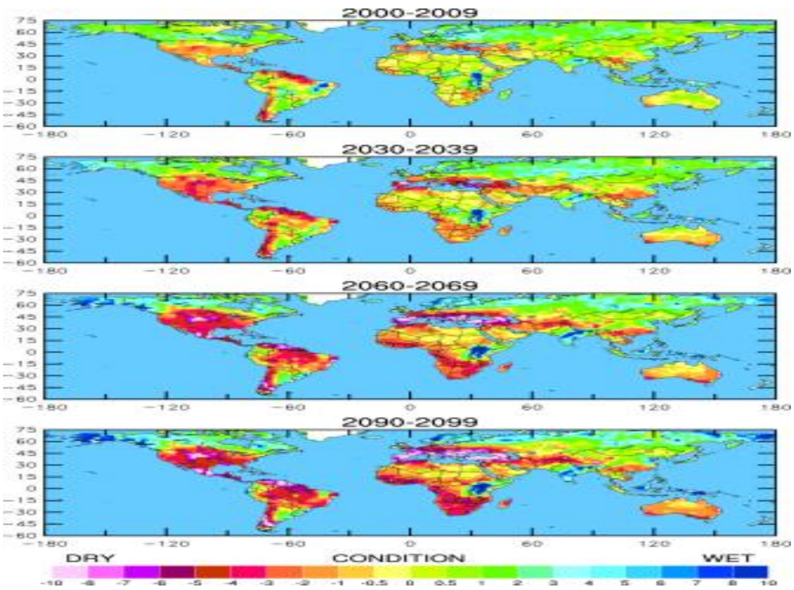


Figure 17: Drought under global warming.

Source: Dai A., 2011.

Potential of agroforestry for carbon sequestration

Adoption of agroforestry practices has greater potential to increase C sequestration of predominantly agriculture dominated landscapes than monocrop agriculture (Figure 18) (Morgan *et al.*, 2010). In the tropics, Palm *et al.*, (2000) report that agroforestry systems helped to regain 35 percent of the original C stock of the cleared forest, compared to only 12 percent by croplands and pastures.

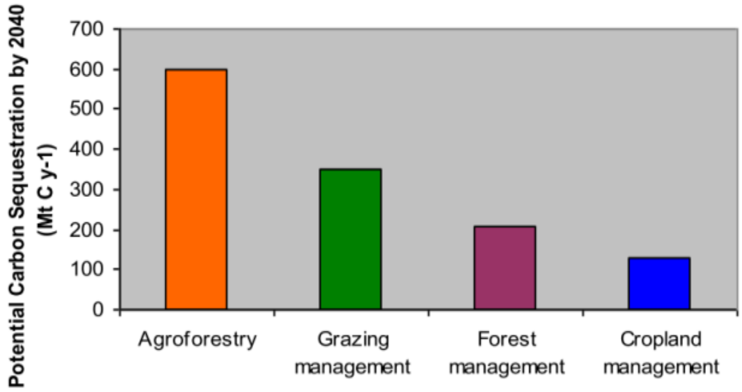


Figure 18: Carbon sequestration potential of different systems. **Source:** IPCC, 2000.

The total carbon emission from global deforestation at the currently estimated rate of 17 million ha yr^{-1} is 1.6 Pg. It is assumed that one hectare of agroforestry could save 5 hectares from deforestation and that agroforestry systems could be established in up to 2 million hectares in the low latitude (tropical) regions annually, a significant portion of carbon emission caused by deforestation could be reduced by launching agroforestry systems (Palm *et al.*, 2000).

There are some Agroforestry systems by which it will help in sequestrating carbon in mitigating Global Warming.

Agrisilvicultural systems

Alley cropping

Alley cropping includes widely-spaced rows with one or more species of trees and/or shrub in rows with agronomic crops grown in the alleys for improvements in environmental quality, microclimate, C sequestration, economic returns, and wildlife benefits. In these systems, tree/shrub and crop row configuration, differences in C input into the soil, decomposition rate, previous management, and associated soil micro fauna determine C sequestration (Bambrick *et al.*, 2010).

In a 5 year-old alley cropping system in northeast Missouri could sequester 0.05 Mg C ha^{-1} in 5 years (Udawatta *et al.*, 2005). Another study in Georgia, reported 50 times greater C than the Missouri study (Rhoades *et al.*, 1998).The Carbon input from pruning of leaves and twigs (second year at 1 m height) were 1.42 and 1.08 Mg ha^{-1} $year^{-1}$, respectively. In Southern Ontario, Canada, Peichl *et al.*, (2006) presented that 13 year-old poplar and spruce alley cropping, and barley monocrop contained 96.5, 75.3, and 68.5 Mg C ha^{-1} (Table 1). Based on the data, we estimate that alley cropping has an average above-ground C sequestration potential of 2.7 Mg ha^{-1}.

Table 1: Above ground carbon sequestration in Alley cropping systems

Agroforestry Practices	Location	Age	Species/Treatment	C (Mg ha $^{-1}$)	References
Alley cropping	Georgia, USA	1	Mimosa tree mulch with grain sorghum and winter wheat	2.5	Rhoades *et al.*, 1998.
	Canada	15	Poplur intercrop	96.5	
			Sprauce intercrop	75.3	Peichl *et al.*, 2006.
			Barley monocrop	68.5	
		21	Poplur	57	
			Norway sprauch	51	Bambrick *et al.*, 2010.
			Conventional system	51	
	Missouri, USA	5	Pin oak	0.03	
			Bur oak	0.01	Udawatta *et al.*, 2005.
			Swamp white oak	0.015	
	Florida,USA		Pecan orchard	28-51	
			Pecan-cotton	76.7	Lee and Jose, 2003.
			Pecan orchard	224	
			Pecan-cotton	15-18	
	North Eastern German	14	*Robinia pseudoacacia* L.	9.5	Quinkenstein *et al.*, 2011.

Generally, soil C sequestration potential is much greater in alley cropping than in monocropping agronomic systems. In alley cropping, differences in SOC do not occur in a short period of time (Bambrick *et al.*, 2010). In a study, hybrid poplar leaves and branches had C stocks of 1.3 and 5.5 Mg C ha^{-1} when trees were 13 year-old (Peichl *et al.*, 2006). After 13 years the tree component of the system added 14 Mg C ha^{-1} in addition to the 25 Mg C ha^{-1} added by litter and fine roots (Thevathasan and Gordon, 2004). The total C sequestration was therefore 39 Mg C ha^{-1} after 13 years and the system could potentially sequester significantly more C at the end of a 40 year harvest cycle. Similar trend was observed in Germany (Figure 19).

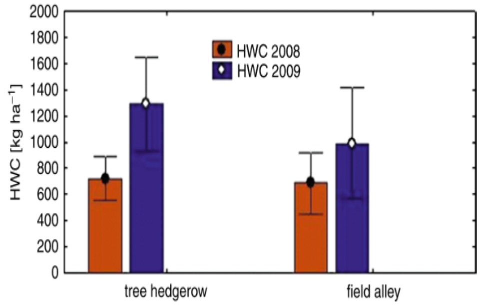


Figure 19: Organic carbon in the surface (0–30 cm) soil, 1 year (HWC, 2008) and 2 years (HWC, 2009) after establishing an alley cropping system, in a mining reclamation landscape, Germany
Source: Quinkenstein *et al.*, 2011.


Figure 20: Alley cropping systems in Nebraska

Source: www.commons.wikimedia.org

Windbreak

Windbreaks are designed with one or more rows of trees or shrubs planted across crop or grazing areas to reduce wind speed and enhance microclimate for crop and/or animal production. In addition to C sequestered by trees, windbreaks provide additional C sequestration due to improved crop and livestock production and energy savings (Kort and Turnock, 1999). If we convert some portion of our cropland into windbreak carbon sequestration potential is greatly increased (Table 2)

Table 2: Comparison of CO_2 sequestered under two management options (all no-till and no-till with windbreaks) hypothetically in Saunders County, Nebraska

Practice	Years	Ha	%Total	MT C/ha/yr	MT CO_2/ha/yr	MT CO_2	Total MT CO_2
Option A: no-till	1-10	254	100	0.32	1.17	2,972	2,972
Cropland in no-till	11-20	254	100	0.35	1.28	3,251	6,223
	21-30	254	100	0.18	0.66	1,676	7,889
	31-40	254	100	0.09	0.33	838	8,737
	41-50	254	100	0,05	0.18	466	9,203
Option A Total							9,203
Option B: no-till and crop windbreaks	1-10	243	96	0.32	1.17	2,843	2,843
Cropland in no-till	11-20	241	95	0.35	1.28	3,085	5,928
	21-30	238	94	0.18	0.66	1,571	7,449
	31-40	238	94	0.09	0.33	785	8,840
	41-50	238	94	0.05	0.18	428	8,712
Cropland in Windbreak	1-10	11	4	0.64	2.36	260	260
	11-20	13	5	2.44	8.99	1,169	1,429
	21-30	16	6	4.69	17.23	2,757	4,186
	31-40	16	6	2.54	9.34	1,495	5,681
	41-50	16	6	2.95	10.84	1,735	7,416
Option B Total							16,128

Source: Zhou, 1999.

Figure 21: Pictures of Windbreak **Source:** en.wikipedia.org, www.forestasyst.org

Riparian Forest Buffer

Riparian areas are the green zone along rivers, streams and wetlands and trees grow rapidly in riparian zones because of favorable moisture and nutrient conditions. Forest barriers help protect rivers, streams and wetlands, and improve water quality by catching eroded soil and preventing sedimentation, filtering nutrient runoff, protecting and enhancing the stream environment, and buffering against floods and droughts. An study was carried out in Coastal Plain of North Carolina by the Department of Biology of East Carolina University showed that, the carbon content of riparian zone cover/condition types ranged from 17.9 Mg C/ha for Annual Row crop agriculture to 241.7 Mg C/ha for Mature Forest (> 50 y old) (Table 4).

Table 3: Mean stored carbon (Mg C/ha) of living and detrital components for condition types in Headwater riparian

Condition Type (n)	Tree	Shrub	Sapling	Herb	Woody Seedling	Vine	Litter	Snag	Large Down Wood	Soil	Total Live	Total Detrital	Total **C** Stored (MgC/ha)
Mature Forest	155.7	0.1	0.2	0.1	-	0.2	34.4	8.3	3.6	39.2	156.3	85.4	241.7
Young Forest	59.4	0.0	0.3	0.1	0.1	0.2	20.6	2.4	11.9	33.4	60.1	68.2	128.4
Regenerating Forest	59.2	0.1	0.4	1.3	0.1	0.2	6.8	1.1	4.5	28.6	61.3	41.0	102.3
Recently Clear-cut	1.2	0.0	0.1	0.6	0.2	0.1	15.5	4.0	19.3	41.4	2.2	80.3	82.5
Perennial Herb	-	0.2	0.2	3.9	0.4	1.3	0.7	-	-	29.1	6.1	29.8	35.8
Shrub Sapling	-	-	-	3.6	-	0.0	4.3	-	-	21.0	3.6	25.3	28.9
Annual Row crop	-	-	-	0.8	-	-	0.8	-	-	16.3	0.8	17.1	17.9

Mature forest (> 50 y old), Young Forest (26-50y), Regenerating Forest (5-25y), Recently Clearcut Forest (0-5 y) **Source:** Rheinhardt *et al.*, 2012.

Figure 22: Picture of riparian buffers **Source:** news.mongabay.com

Riparian systems store C in above- and below-ground biomass of the vegetation and in soils. The diverse species mixture of riparian buffers helps enhance C sequestration potential spatially and temporally compared to monocropping systems. The different functional groups such as trees and grasses in these systems colonize and capture both the above- and below-ground resources more effectively than the row crop agriculture (Balian and Naiman, 2005). Total carbon content of Mature Forest is 7-13 times that of non-forest condition types (Perennial Herb, Shrub/Sapling, and Annual Row crop).

Multipurpose trees on crop lands

The multipurpose tree species (MPTs) form an integral component of different AFS interventions in crop sustainability. The MPTs, besides supplying multiple outputs such as fuel, fodder, timber and other miscellaneous products, help in the improvement of soil health and other ecological conditions. Screening of MPTs is an important prerequisite for determining the suitability of AFS models for various agro ecological regions.

Figure 23: Picture of Multipurpose tree species in a crop field **Source:** bzfieldnotes.blogspot

Jha *et al.,* (2010) recommended that inclusion of species like *P. Juliflora, L. Leucocephala, A.nilotica* and *A. indica* could be a better choice for restoring and rehabilitation of degraded ravine lands in the riparian zone. They reported that the SOC contents in forest systems with these MPTs to be twofold higher in comparison to the reference site (Table 5).

Mishra *et al.*, (2004) also stated increase of SOC under 6-year-old plantations of *P. juliflora*, *D. sissoo* and *E. tereticornis*. The poplur based AFS improves aggregation of soil through amendment of huge amounts of organic matter in the form of defoliant leaf biomass. Gupta *et al.,* (2009) stated that the poplar trees could sequester higher soil organic carbon in 0–30 cm profile during the first year of their plantation (6.07 Mg ha $^{-1}$ year $^{-1}$) than in the subsequent years (1.95–2.63 MgC ha^{-1} year $^{-1}$). The level of improvement may be affected by the age of the poplar trees.

Table 4: Changes in SOC (Mg C ha^{-1}) over the years under various MPTs in humid tropics

MPTs	Years			
	4	8	12	16
Acacia auriculiformis	11.1	11.9	17.9	21.9
Mimosa alba	9.9	9.9	9.9	15.9
Leucaena leucocephala	11.5	11.5	12.8	16.7
Dalbergia sissoo	13.1	12.5	13.1	13.9
Acacia indica	10.9	10.9	14.7	28.6
Tectona grandis	11.5	11.3	11.5	12.9
Gmelina arborea	12.2	12.2	12.8	21.8
Open space (Control)	11.9	11.9	11.1	9.1

Source: Datta and Singh, 2007.

Silvopastoral Systems

Silvopasture is an agroforestry practice that intentionally integrates trees, forage crops, and livestock into a structural and functional system for optimization of benefits from planned biophysical interactions (Nair *et al.,* 2010). Conversion of pasture land to silvopasture has the potential to enhance rooting depth and distribution, quantity, and quality of organic matter input and thereby C sequestration potential (Haile *et al.*, 2010). These systems could outperform C sequestration of either forest or pastures as they have both forest and grassland mechanisms of C capture that can maximize C sequestration both above- and below-ground (Figure 25). Silvopasture is the most common form of agroforestry in North America (Nair *et al.*, 2010). Pasture and grazed forestland areas in the United States are 237 and 54 million ha respectively. According to Nair and Nair (2010), the C sequestration potential of silvopasture in USA was 6.1 Mg C ha^{-1} year^{-1}. Using a sequestration potential of 6.1 Mg C ha^{-1} year $^{-1}$ on 10% marginal pasture land (23.7 million ha) and 54 million ha of forests, the total C sequestration potential for silvopastoral lands in the Unites States could be as high as 474 Tg C year^{-1} .

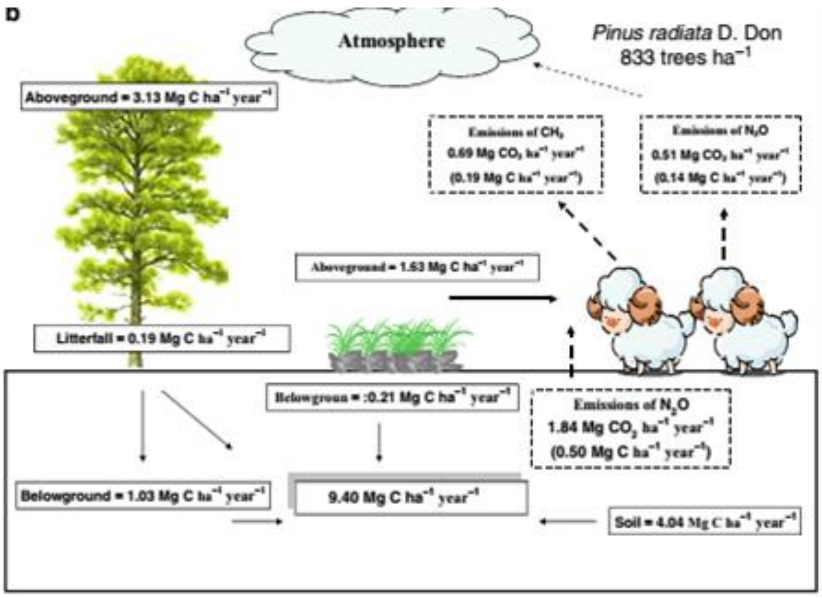


Figure 24 : Carbon pools in a silvopasture system including GHG emissions in a 11 years-old *Pinus radiate* in Spain

Source: Fernández Núñez *et al.,* 2010.

Table 5. Carbon sequestration potential of Silvopastoral systems at different regions

Agroforestry Practices	Location	Species/ Treatment	C (Mg ha –1)	References
Silvopasture	Oregon, USA	Pastures	102.5	Sharrow and Ismai, 2004.
		Agroforestry	108.14	,,
		Plantation	98.53	,,
	Oregon, USA	Understory		Sharrow and Ismai, 2004.
		Pastures	1	,,
		Agroforestry	1.17	,,
		Plantation	2.23	,,
	Florida, USA	Pastures	1033	Haile *et al.*, 2010.
		Center of alley	1376	,,
		Between tree row	1318	,,
	Australia	Silvopastoral	28-51	Dixon *et al.*, 1994.
	Spain	Silvopastural	76.7	Howlett *et al.*, 2011.
	Chilean Patagonia; Chile	Silvopasture	224	Jha *et al.*, 2010.
	Northern Asia	Silvopastoral	15-18	NRCAF, 2007.
	India (Uttar Pradesh)	Silvopastural	10.70tC/ha/yr	NRCAF, 2007.

Figure 25: Picture of Silvopastoral Systems **Source:** www.comet2.colostate.edu

Soil Carbon Sequestration

Soil carbon sequestration is the process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass and soils (Ogle *et al.,* 2005). Through the process of photosynthesis, plants assimilate carbon and return some of it to the atmosphere over and done with respiration. The carbon that remains as plant tissue is then consumed by animals or added to the soil as litter when plants die and decompose (Figure 27). The principal way that carbon is stored in the soil is as soil organic matter (SOM).

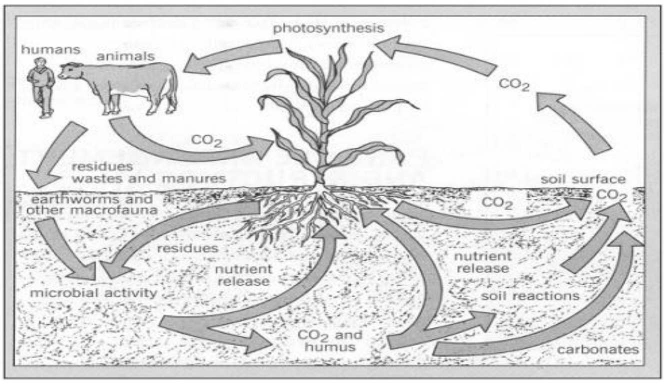


Figure 26: A simplified illustration of the carbon cycle in soil

Source: Dubbin, 2001.

Agroforestry maintains soil organic matter and biological activity at levels suitable for soil fertility. Different agroforestry practices store considerable amount of carbon in soils (Table 8).

Table 6: Modeled cumulative soil carbon sequestration potential by 2030 (Mt C) under different land management practices

Practice (Residue management)	Africa	Asia	Europe	Middle America	North America	Oceania	Russia	South America
Barley	8	16						
Maize	37	209.574						
Millet	11	9.993						
Pulses	14	32.995						
Rice	18	516.843		1.637				3.279
Sorghum	21	11.562						
Soybean	1	35.12						
Wheat	35	360.996						
No-tillage		20.763	33.209		33.128	0.7	0.557	7.131
Cover crops	513	1009.402	772.082	14.727	632.415			136.495
Direct manure	400	203.703	23.556	2.252	549.558	1.74	0.08	20.098
Compost manure	428	478.064	57.106	5.46	586.731	4.18	0.193	48.721
Agroforestry	1,130	2416.434	803.907	18.608	727.361	81.229	19.868	210.233

Source: Potter K. *et al.*, (2007).

Agroforestry also help to increase soil carbon through different land management practices particularly residue management. Carbon sequestration through residue management depends much on the land area devoted to a given crop (Table 8). In Asia, the sequestered carbon varies from 10 Mt for millet to 517 Mt for rice. The lowest amount of sequestered carbon from cover crops was recorded for Middle America (15 Mt), while the highest was recorded for Asia (1 Gigaton). The highest sequestration potentials for direct and composted manure (550 and 587 Mt, respectively) were observed for North America, while Russia has the least (less than 0.2 Mt). Carbon sequestration potential of the land management practices is in the order of agroforestry > cover crops > manure > crop residues > no-tillage.

Wood Products

Carbon sequestration will lead to application of wood in design and construction, and thus it will counteract global warming. It is influenced by on the type of wood and the way of sourcing. If a tree is harvested from a well-managed forest (thus replaced by a new tree), depending on the wood species (density) approximately 1 ton of CO_2 is locked per m^3 of timber product manufactured (wood species with a density of 550 kg/m^3 absorb 1 ton of CO_2, the higher the density the more CO_2 is stored).

Figure 27: Carbon sequestration option in wood product

Source: www.coastforest.org

Carbon Sequestration in Bangladesh

Forestry is an important sector in Bangladesh. There are three major types of forest in Bangladesh (Figure 29). The Forest Department (FD) of Bangladesh with assistance from USDA Forest Service, USAID and other collaborators conducted a survey. According to the report, the Sundarbans can capture 56 million tons of carbon and its price is at least Tk 150 billion the international markets. The index estimated that Bain, Passur and Kankra trees reserve high amount of carbon while Geoa and Keora reserve least, and Sundari reserves moderate amount of carbon.

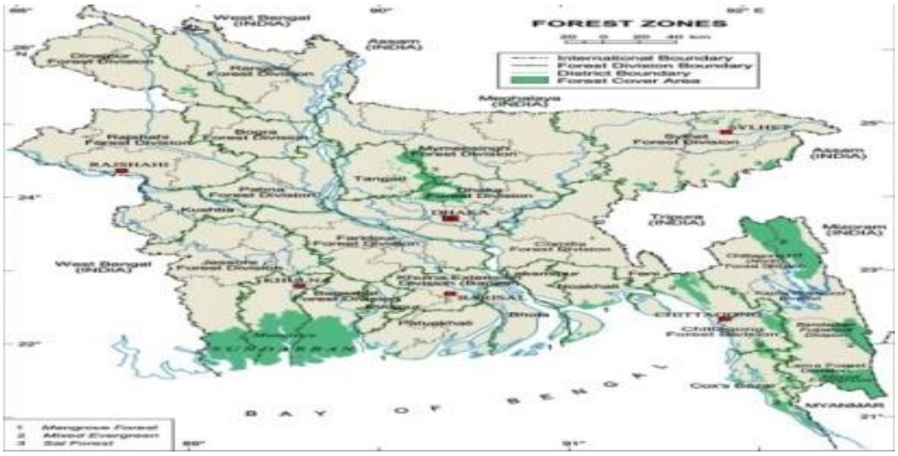


Figure 28: Forest cover map of Bangladesh.

Source: Bangladesh forest department, 2010.

Shin *et al.,* (2007) reported that the average carbon sequestration potential in Bangladesh forest is 92tC ha^{-1} (Table 9).

Table 7: Carbon density in the forests of Bangladesh

Forest types	Carbon stock (t C ha^{-1})
Closed large crowns	11
Closed small crowns	87
Distributed closed	110
Distributed open	49
Average	**92**

Source: Shin *et al.*, 2007.

An experiment was conducted in Hilly areas by S. K. BARUA and S. M. S. HAQUE relating to the impacts of trees on soil characteristics in the degraded hills of Chittagong District. The carbon sequestration potential and the present value of carbon revenue flow were also assessed for the degraded hills of Chittagong using *A. auriculiformis* plantations for the purpose. The results showed that about 17 Mg C could be sequestered in the degraded hill areas of Chittagong District by planting *A. auriculiformis* trees in a 15-year rotation (Table 10). **Table 8:** Potential carbon sequestration in *A. auriculiformis* plantations in the degraded hills of Chittagong district

Crediting Period (Y)	Storage of organic carbon (Mg ha^{-1})			Carbon sequestration (Million Mg)
	In Biomass	In soil (10cm)	Total	
5	22.29	3.68	25.96	3.93
10	65.31	7.53	72.66	10.99
15	101.86	11.03	112.88	17.07

Source: Shin *et al.*, 2007.

Conclusion

Human activities, particularly the burning of fossil fuels such as coal, oil, and gas, have caused a substantial increase in the concentration of carbon dioxide (CO_2) in the atmosphere. This increase in atmospheric CO_2 from about 280 to more than 395 parts per million (ppm) over the last 250 years is causing measurable global warming.

Potential adverse impacts include sea surface temperature rise, reduction of sea ice extent, sea-level rise, floods, droughts, increased frequency and intensity of wildfires and tropical storms; fluctuations in the amount, timing, and spreading of rain, snow, and runoff; and disturbance of coastal marine and other ecosystems. Increasing atmospheric CO_2 is also increasing the absorption of CO_2 by seawater, causing the ocean to become more acidic, with potentially disruptive effects on marine plankton and coral reefs.

Adoption of different agroforestry systems like alley cropping, windbreak, riparian buffer, silvopastural system etc. provide greater potentials of carbon sequestration because in agroforestry systems, C is located in five main pools, namely, aboveground plant biomass (tree and understory), plant roots (tree and understory), litter, microbial, and soil C.

Beside this it also provide diverse benefits including compatibility of some tree species with crops and livestock production, increased income through production of indigenous fruit trees, and suitability of certain tree species for bio-energy.

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