Chapter 12

Managing Carbon in Forests

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Abstract

This chapter is not only helpful for forestry students, forest managers, people working on REDD+ and forest carbon budgeting as well as for policymakers. Forests are of utmost importance for mitigating the change in global climate as they are the huge reservoirs of carbon and have the potential to sequester more from the atmosphere. Investigations on forest biogeoochemistry, climate, disturbances, as well as the spatial and temporal heterogeneity of carbon sequestration across regions has gain importance in the last two decades. This chapter provides a comprehensive synthesis and review of the science of carbon in forests at the start and then reviews the different ways of measuring and estimating carbon in forests and summarizes the best-known estimates of storage and loss. Later, it reviews methodologies for estimating carbon in above ground pools, a key topic for many nations in international policy discussions because of the need to develop standardized methods of carbon accounting with an emphasis on verifiable results. This chapter closes with analyzing the relationship between forests, socioeconomic and policy considerations round the world and particularly in Pakistan.

Key Words: Climate change; Above and below ground biomass; Carbon; Measurements; Simulation and Policy.

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12.1. Forest and Carbon Sequestration

12.1.1. Links between Climate Change, Carbon Dioxide and above Ground Tree Biomass

Climate change is a change in the statistical distribution of weather patterns, especially, when that change lasts for an extended period of time (i.e., decades to millions of years). Changes in climate are happening which are unparalleled. Global warming is among the greatest terrible horrors of the modern times. It is believed that carbon is among the most significant causal factors which cause global warming. The mean concentration of CO_2 in the atmosphere was 280 μ mol mol^{-1} before the development of industries. And in the year of 1994 after industrial development it has reached up to 364 μ mol mol^{-1}. Now-a-days, the rate at which concentration is increasing is about 1.5 μ mol mol^{-1} $year^{-1}$ (Kerr, 2007). It has strengthened the importance to understand the terrestrial global carbon cycle. Trees store up to 90% of the global plant biomass and are therefore a very important variable in the global carbon cycle. This above mentioned fact tells us about the significance of forest ecosystem and the importance of determining the accurate amount of carbon which is being stored in these forest ecosystems.

12.1.1.1. Climate Change

The climate on Earth is driven by interactions between incoming solar radiation and the Earth's atmosphere and surface. Incoming solar radiation is partially filtered by the upper atmosphere with the majority continuing on to be absorbed or reflected by the Earth's surface. Reflected radiation predominantly returns to space, with the absorbed solar radiation being re-emitted back into the atmosphere as lower energy radiation. This low energy radiation is partially trapped within the troposphere (lower atmosphere) by greenhouse gases before finally making its way back into space (Figure 12.1). The amount of low energy radiations trapped by the troposphere determines the climatic conditions of earth (Gribbin 1982; IPCC 2001a; Kininmonth 2004).

After water vapour, carbon dioxide (CO_2) is the most important greenhouse gas (IPCC 1996). Average atmospheric CO_2 concentrations have increased from 280 ppm (in CA 1750) to 401 ppm (as of 2005; CO_2 Now, 2014). These increases have been attributed to human activities predominantly relating to burning of fossil fuels and land clearing (IPCC 1996; Schlesinger 1997). Climate models indicate that increasing concentrations of greenhouse gases have trapped additional radiation, leading to increases in global temperatures and causing climate change (Gribbin 1982; IPCC 2001b; Schlesinger 1997). Global climate change threatens water supplies, food production and ecosystem health and viability (Lowe 2005; Oldfield 2005; Schneider et al. 2007).

12.1.1.2. Carbon (C) Cycle

Carbon cycle comprises of those natural processes which are involved in the storage and transfer of Carbon between different spheres of earth. These spheres include biosphere, geosphere, hydrosphere and hydrosphere (IPCC 2001b; Schlesinger 1997; SCOPE 1984).

The rates and amounts at which carbon is being transferred between these stores is different at different intervals of time. Different types of biological processes, geological phenomenons and climatic conditions are responsible for controlling the rates and amounts of Carbon (Figure 12.2; IPCC 2001b; Schlesinger 1997). Terrestrial ecosystems are one store that has the ability to sequester C in a short time-frame that is relevant in addressing climate change. It is also a store that can and has been altered by human activity (IPCC 2001b; Schlesinger 1997).

12.1.2. Forest C and Forest Components

Of all terrestrial ecosystems, forests contain the largest store of C (Table 12.1; IPCC 2001b; Schlesinger 1997; SCOPE 1984). The term forest has been defined as vegetation with a minimum height of 2 m and minimum crown cover of 10% in the Marrakesh Accords, which specify the rules that are to be used in the Kyoto Protocol (UNFCCC 2001). Worldwide, forests covers $4x10^9$ ha (30% of land area) and, relative to non-woody vegetation, have a large biomass per unit area of land (FAO 2005). Carbon is mainly stored in the plant biomass whether it is above ground or below ground, woody debris which is abrasive in nature, litter and soil (containing organic and inorganic C; Figure 12.2; IPCC 2003; Richards & Evans 2004). These are the major carbon sinks in the forest ecosystem. The amount of carbon stored in these carbon pools continues to rise as the life cycle of forests increases until it reaches up to the state of equilibrium. When equilibrium state is gained then the amount of CO_2 which is released by plants and soil in the process of respirational and degradation of biomass equals the growth rate (e.g. Acker et al. 2002; Smithwick et al. 2002).

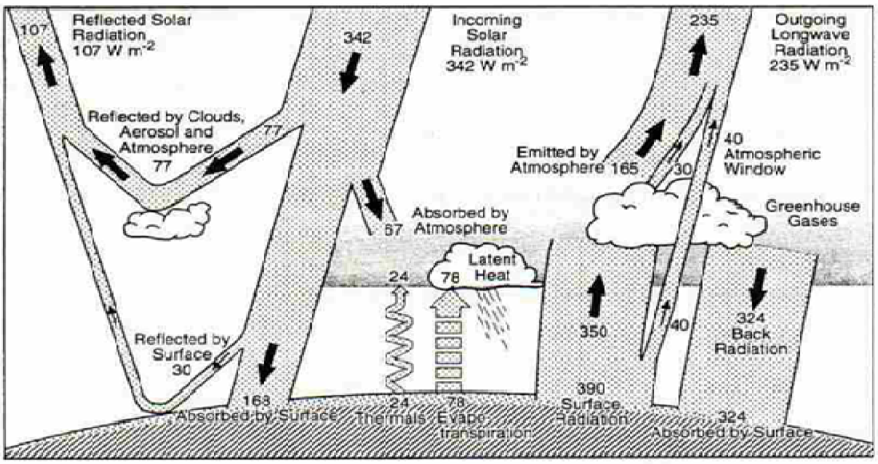

Fig.12.1 Interactions between incoming solar radiation (W m^{-2}) and the surface and atmosphere of the Earth. *Source: Kiehl and Trenberth (1997)*

Where the forest growth is disturbed or the forest is destroyed, CO_2 and other greenhouse gases (i.e. Methane 'CH_4', nitrous oxide 'N_2O') are released back into the atmosphere via respiration, combustion or decomposition (IPCC 2003; Richards & Evans 2004; Schlesinger 1997).

Forests have the capability of both sequestering and releasing greenhouse gases. Moreover, the rate at which forests are being removed are the main factors to include the forests and land use change in the United Nations Framework Convention on Climate Change (UNFCCC) and in the Kyoto Protocol (KYOTO 1997; UNFCCC 1992).

Table 12.1 Area, carbon stock and density, and net primary productivity (NPP) of world terrestrial ecosystems

Ecosystem (biome)	Area (10^9 ha)[1]	Global carbon stock (Pg C)			Carbon density (Mg C ha^{-1})		NPP (Pg C yr^{-1})[1]
		Plants[1]	Soil[2]	Total	Plants[1]	Soil[2]	
Tropical forests	1.75	340	213	553	194	122	21.9
Temperate forests	1.04	139	153	292	134	147	8.1
Boreal forests	1.37	57	338	395	42	247	2.6
Tropical savannas & grasslands	2.76	79	247	326	29	90	14.9
Temperate grasslands& shrublands	1.78	23	176	199	13	99	7.0
Deserts and semi deserts	2.77	10	159	169	4	57	3.5
Tundra	0.56	2	115	117	4	206	0.5
Croplands	1.35	4	165	169	3	122	4.1
Total	14.93	654	1567	2221			62.6

1. From Mooney, Roy and Saugier (2001); wetlands are not recognised in this classification; temperate grassland and Mediterranean shrubland categories combined; 1.55x10^9 ha ice cover not listed
2. From IGBP-DIS (International Geosphere-Biosphere Programme – Data Information Service) soil carbon spatial database (Carter & Scholes 2000
Source: *IPCC (2001b)*

The amount of C stored in plant biomass is more than that of atmospheric CO_2. It is also estimated that almost 90 % of plant biomass carbon is being captured by tree biomass (Table 12.1). This tells us that how much forest ecosystems are important in the global carbon cycle, the requirement of precise evaluation of the amount of C accumulated in forest ecosystems, and the implications a change in land-use will have for C-storage in forests. For example, a replacement of old, slow-growing, high-C-stock forests by a young, fast-growing, low-C-stock forests always represent a dramatic net loss of C per unit land area over a 100 year time period (Körner 2006). Hence, reforestation has the potential to mitigate increased atmospheric CO_2 concentrations, but a much greater effect in terms of C pools comes from the preservation of old forests, a point often overlooked (Körner 2000).

12.1.3. Political Responses to Climate Change

The UNFCCC was developed at the 1992 Rio 'Earth Summit' (Kininmonth 2004). It was the first international political response to the threat of climate change (ICSU 2006; SCOPE 2004), and was based on scientific conferences preceding the summit (Kininmonth 2004; SCOPE 2004). Scientific evidence arose from research that stretched back to the 1960s when the Global Atmosphere Research Programme (GARP) – a joint initiative of the International Council of Scientific Union (ICSU) and the World Meteorological Organization (WMO) – was initiated to understand global weather (Bierly 1988; ICSU 2006). GARP was a result of technical advancements and political requirements relating to long-term weather forecasts that were needed to improve food security (Bierly 1988; ICSU 2006).

The Kyoto Protocol is the highest international agreement ever developed for greenhouse gases (GHGs), and builds on the UNFCCC by setting binding targets for GHG emissions from industrialised countries. Development of the Kyoto Protocol involved extensive negotiations from its initial adoption in 1997 to its enforcement in 2005 (SCOPE2004). These negotiations were needed to clarify protocol coverage, and to address the political concerns of a sufficient number of countries to ensure the protocol was ratified (SCOPE 2004). Nonetheless, a number of countries did not sign the protocol, notably the United States of America (largest GHG emitter) and Australia (largest GHG emitter per capita). Similar political concerns prevented inclusion of binding targets in the UNFCC thirteen years earlier (Kininmonth 2004). This meant that there were more UNFCCC signatories than the Kyoto Protocol, but that the UNFCCC had minimal impact on GHG emissions (Kondratyev et al. 2003; SCOPE 2004).

12.2. Protocols of Measuring Carbon in Forests

12.2.1. Measuring Carbon in Forests

Broadly speaking, there are two primary approaches to measuring carbon stocks and fluxes in each forest carbon pool: Generally, biomass, which is readily measured, are widely used to estimate certain stocks using proven formulas for the ratio of carbon to biomass instead of measuring carbon directly, particularly for aboveground carbon (Brown 1997).

Generally speaking, carbon stocks and fluxes can be measured by two key approaches in any forest carbon pool: (i) measuring changes in carbon stock, and then inferring a carbon flux under a certain degree of confidence; and (ii) measuring carbon flux directly. Normally, biomass is calculated by the help of established formulas. Biomass is easy to measure. After measuring biomass carbon is estimated with the help of formulas which are generally based on biomass. The ratio of carbon to biomass is the main tool to calculate. Above ground carbon is estimated by using this method (Brown 1997).

It is easy to classify the carbon stocks which are present in forests into different measurement pools. These stocks can be classified into five different measurement pools:

- Aboveground biomass– As it is obvious from the name that it includes all the living biomass which is present above the soil. Stem, bark, seeds, stump, branches, and foliage all are included in aboveground biomass. We can also that live understory is included in this category.

- Belowground biomass– As it is obvious from its name, all living biomass of roots which is greater than a particular defined diameter is included in it.
- Dead wood– All non living biomass is included in it whether it is standing, lying on the ground (litter is not included in it) or present in the soil.
- Litter – This includes all the non living biomass which is lying on the ground and has attained a certain diameter. Litter and humus layes of the surface of soils are included in it.
- Soil organic carbon (SOC) – All the organic material which is present upto the soil depth of 1 m is included in this except the layer of litter and coarse roots of the belowground biomass.

In this chapter, four categories of methods which are currently used to measure forest biomass and estimate carbon have been reviewed: i) forest inventory (biomass); ii) remote sensing (relationship between biomass and land cover); iii) eddy covariance (direct measurement of CO_2 release and uptake); and iv) the inverse method (relationship between biomass, CO_2 flux and CO_2 atmospheric transport).

Level of accuracy is different for every method and the resolution which is feasible to obtain data is also variable. There are advantages and disadvantages of every technique and each is suitable for circumstances to measure CO_2 flux and carbon storage for variable temporal and spatial scales of assessment and calculation.

12.2.2. Forest Inventories and Aboveground C Stock Assessments

Forest inventories can be used to determine the carbon stock. The reason behind using this method is this method is that national forest inventories are easily accessible to numerous countries. There are different techniques which have been developed to calculate the above ground biomass (AGB) from inventories

These can be divided into different types according to the source from which data is collected. Data can be collected from field measurement, remote sensing or ancillary data which is used in GIS based modeling (Lu 2006; Wulder et al. 2008). Table 12.2 shows different approaches to estimate the stocks of carbon from each of these different sources of data.

12.2.2.1. Field Based Methods

The field based study is commonly mentioned as inventory assessment. It can be classified into two additional categories. The two main approaches are volume to biomass and diameter to biomass. The approach is selected on the basis of the availability of the data and the anticipated results. Timber volume is generally available. So, the approach is used to convert timber volume into biomass. Although, it has more uncertainty but less details are required in this approach. The allometric equations are more useful because this approach is capable of giving more accurate results but it requires the detailed information about diameter and field measurements. If these two parameters are available than allometric equations are preferred.

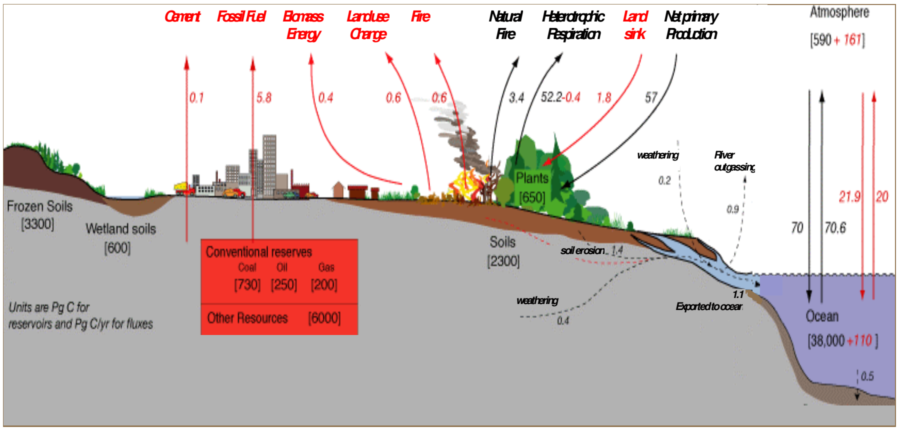

Fig. 12.2 The current global carbon cycle in Pg (1Pg = 10^{15}g = 10^{9} t). Black arrows and numbers indicate background or pre-anthropogenic carbon stocks (in square brackets) and carbon fluxes. Red arrows and numbers indicate human induced changes in stocks and fluxes. *Source: SCOPE (2004)*

In an ideal situations the parameters which should be recorded in every inventory dataset are included prevailing species, diameter of trees at breast height which is commonly known as DBH, height of trees, age of the stand, increment of any kind (age, diameter etc.) and defects (LeBlanc 2009).

The above mentioned scenario is of ideal conditions but in reality different countries have different datasets of information due to different standards to calculate inventory information. Moreover, capacity and resources also play an important role in detailing the inventory information.

As, in Pakistan, the basic purpose of practicing forest inventories is to develop forest working plan for different types of forests. These inventories are conducted by forest department of each province. Not only the growing stock of existing forest is estiamated but also the stock for coming years is projected by these inventories. Nevertheless, carbon stocks estimation has been undertaken in these forests by the provincial forestry departments. The, FAO has prepared a report known as The Global Forest Resources Assessment (GFRA) in 2005. Ten workshops at regional and sub-regional levels were organized by FAO to prepare this report. Experts were invited in these workshops and discussions were conducted to gather data about Pakistan's growing stock.

The data regarding Pakistan in GFRA 2005 presents the total carbon stocks (Mt) for the entire country. This report gives us information about the total carbon stocks (Mt) in the whole country. But there is lack of any scientific work to estimate the actual measurements of carbon stock and biomass for any specific forest type of Pakistan. The estimates in GFRA (2005) were made on the basis of remote sensing. Remote sensing is not a very reliable technique and there can be errors in this report GFRA (2005).

i. Estimating biomass from Timber volume

The ratio between all the above ground standing biomass (AGB) to that of volume of the growing stock (Mg/m^3) is known as biomass expansion factor (BEF) (Fang et al. 2001). If the data regarding timber volume among the classes of diameter is available then BEF can be used for the estimation of AGB (Brown 2002). BEF is of great significance to estimate the AGB in those countries which are still in the phase of development. These countries don't have detailed information regarding forest biomass.

Simply, the regression relationships are used to estimate carbon stock with the help of BEF. The three parameters which are related to above ground biomass are: merchantable tree volumes, non-merchantable tree volumes and their annual increment. Afterwards this above ground biomass which was calculated by trees volumes could be further expanded to large areas. Uniformity of size, stocking age-class distribution should be given due consideration while manipulating the results (see Fig.12.3) (Wulder et al. 2008). BEF is not a constant value and it varies from one forest stand to another forest stand. It depends on numerous factors like age of forest, class in which site falls, stand density, and various biotic and abiotic factors (Brown et al. 1999; Fang et al. 2001).

ii. Estimating biomass from tree diameter or diameter plus height

Reliability of the forest carbon and the understanding of the dynamics of carbon in forest ecosystem can be increased by applying the current knowledge concerning tree allometry in the form of volume and biomass allometric models (Jenkins et al., 2003; Zianis and Mencuccini, 2003; lethonen et al., 2004). The biomass allometric models can be used to directly estimate the stand tree biomass, from tree measurement data (diameter or combination of diameter and height) in forest stand inventory, or by adding specific gravity or wood density and the biomass expansion factor (IPCC, 2003) or the biomass conversion and expansion factor (IPCC, 2007) in using tree volume allometric models.

By using the allometric models that are already formulated, the biomass of one tree can be estimated just by entering the parameters of the results of the measured dimensions of the tree like diameter at breast height (dbh) and height. The stand biomass can be estimated by having information on stem density and then by extrapolating methods. If we want to take the precise allometric equation for any type of forest, the sample of tree sizes and species should be taken in an adequate amount. If there is sufficient data regarding size and species of trees, we can find very precise result by the help of allometric approach. This approach is being used on limited scale. The reason behind its limited use is that there is not sufficient allometric information for each forest type and every region (especially in Pakistan).

12.2.2.2. Remote Sensing Methods

This method is based on the monitoring of forests at various temporal, spectral, altitude, latitude and spectral resolution (Patenaude et al. 2005). There are a great number of applications which are available for mapping the land cover with the help of remote sensing. These applications can be classified into two main branches passive (optical) or active (radar).

Optical or passive remote sensing consists of mainly following types: i) aerial photographs of dffferent kinds i.e. infrared, color, black and white, ii) NDVI images that are captured by using radiometer of high resolution (AVHHR) sensor, iii) images at a low resolution obtained from using Landsat Thematic Mapper.

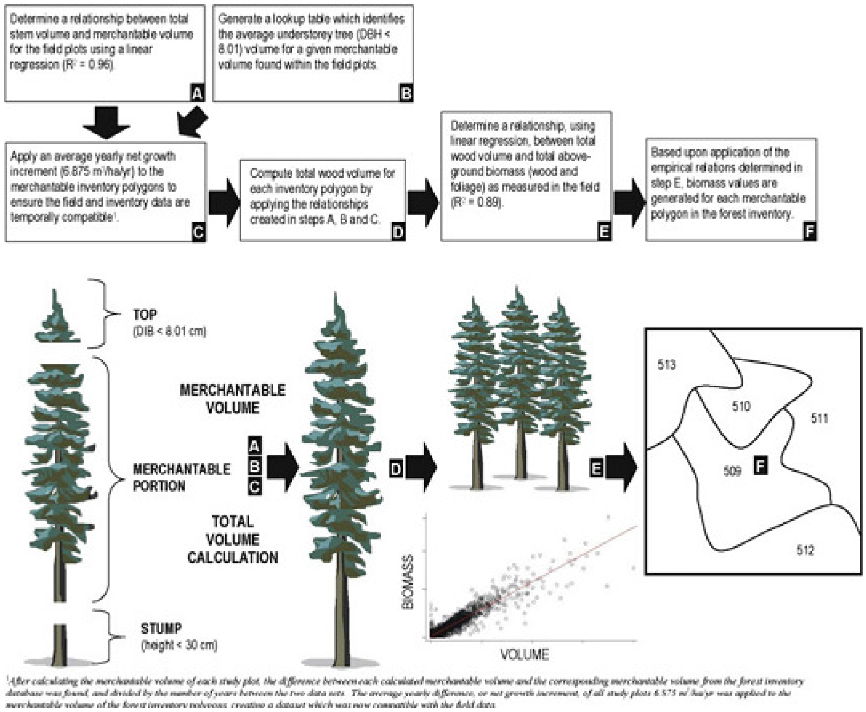

Fig. 12.3 An overview of the process used to estimate biomass from the forest inventory data. *Source: Wulder* et al. *(2008).*

Active remote sensing is a technique in which images are being derived from radar and LiDar.

12.2.2.3. Eddy Covariance Technique

In this method, different sensors are installed on a tower at different heights and continuous data of fluxes are recorded with the help of data loggers. After downloading the data from all the sensors via data loggers different software is used to do analysis of data.

Now a days, a great number of software programs have been developed which are able to derive the above mentioned quantities like momentum, heat and fluxes of gas (including CO_2) after processing the data of eddy covariance. The programs are available at a wide range which are specifically designed to work according to the conditions of data available. The complexity, litheness, availability of instruments, variables, help system and user support. There are two types of programs used in this eddy covariance. They can be open source software or closed source software. EddyPro is the free fully supported open source software, ECO_2S, ECpack is unsupported open-source software, EdiRe, TK3, Alteddy are closed programs softwares, Matlab is a commercial software which uses eddy covariance.

12.2.2.4. Inverse Method

Atmospheric CO_2 concentration can be estimated from sink and source measurements of carbon (forest inventories, flux measurements) combined with transportation models (that model gas movement) using meteorological information.

Atmospheric CO_2 concentration can be calculated from sink and source measurements of carbon along with transportation models by means of meteorological data. We can also measure it directly. Inverse method is used to estimate the sinks and sources of CO_2 with the help of a Bayesian inversion technique from (Gurney et al. 2002; Rodenbeck et al. 2003).

This is known as an inverse method because with the help of three-dimensional transport models sinks and ources of carbon are backed out in this method (Gurney et al. 2002) The precision of this method is mainly dependent on the transportation models which are being used and the data of atmospheric CO2 concentration (Patra et al. 2006).

The summary of above mentioned four categories is presented in Table No: 12. 3. Each method has some advantages and there are also some limitations of every method.

12.3. Forest Stand Dynamics and Simulation of C Stocks

The community of flora and fauna dominated by woody vegetation is known as forest. The major proportion of forests is made of plants. Plants could be of different sizes and different species. Diversity is one of the main characteristics of forests. Structure and composition of forests is not static. The structure and composition of forest change over the period of time. The study of forest dynamics chiefly deals with this change. The behavior of forest population is also in response to any external stimuli whether it is natural or anthropogenic is also studied in forest dynamics. The amount of biomass which is being produced by a plant or stand in a certain time period is known as growth. This time period could be 1 day, 1 week, 1 month, 1 year or 5 years etc. on the other hand yield can be defined as the amount of biomass which is being accumulated since the time of the establishment of the stand. The forest dynamics are greatly influenced by thr growth of trees and disturbances. These two factors are heavily associated with resources available (e.g. Radiation, water, nutrient supply) and environmental conditions (e.g. Temperature, soil acidity, or air pollution).

While considering the assessments of C stocks in the forest, as the forest keeps on increasing biomass ultimately the C stocks are changing.

The parameters of the forest biomass, which are the determent of C stock dynamics over the time are: dbh, height, volume, CAI, mortality, turnover rates, relative growth rates etc. In addition to these soils, products and Bioenergy parameters are also important.

There are different models which are used not only for estimation of C stocks, but also simulate these stocks for a certain period of time. One such example is CO_2 Fix which describes in detail as follows:

Table 12.3 Summary of different methods for estimating carbon budgets

Methods	Temporal Scales	Spatial Scales	Data availability	Uncertainty	Targat
Forest inventory	Annual or decades	Regional	Historical data worldwide	1% for the growing stock volume 2-3%of net volume growth and removal, and almost 40% of changing in growing stock volume.	Carbon stocks in the forests.
Remote Sensing	Daily to annual	Regional and Global	Stat from the end of 70`s	The RMSE for an aggregation area of 510 ha of the unit land area 8.7% for ACIS and 4.6% for world volum	Carbon stocks in the forests.
Eddy Covariance	Hours to years	Over the course of year or more	Starts fom 1960`s	±50 $gCm^{-2}year^{-1}$ (ideal size)	Net CO_2 exchange across the canopy-atmosphere interface
Inverse method (Carbon Tracker)	Weekly	Global, at 1° × 1° resolution	2000–2006	−1.65 PgCyr (for North American terrestrial biosphere)	Net CO 2 exchange between the terrestrial biosphere and the atmosphere

Sources: Brown (2002); Patenaude et al. *(2005); Lu (2006); Baldocchi (2008); Giglio* et al. *(2006) and Peters* et al. *(2007).*

12.3.1. The CO_2 FIX V3.2 Model

The full carbon accounting approach is the basics of this CO_2 FIX model. The C stocks and fluxes are quantified by using this approach in CO_2 FIX Model. The differences in the carbon stocks over the period of time for all carbon pools are calculated in this approach (Noble et al., 2000).

The total carbon physically stored in the system at any time (C_{Tt}) can be calculated by using this equation

$$C_{Tt}= C_{bt} + C_{st} \ldots\ldots\ldots\ldots \text{(Mg ha}^{-1}\text{)}$$

Where C_{bt} is the total carbon stored in living (above plus belowground) biomass at any time 't' (Mg ha^{-1}) and C_{st} is the carbon stored in soil organic matter (Mg ha^{-1}).

12.3.2. Carbon Stored in Living Biomass

Cohort Model Approach is basically used to measure the carbon stock and flows in the living biomass of forests (Reed, 1980). This approach is based on cohorts. Cohort is based on the growth response. A group of individual trees or group of species which have an almost similar growth rate are combined to form a cohort. And this cohort will be considered as a single factor in the model (Vanclay, 1989, Alder and Silva, 2000). The total biomass at any time is estimated as the sum of stem (including bark), foliage, branches and root biomass of all cohorts (Masera et al., 2003). If we want to calculate the total biomass then the biomass of stem (including bark), foliage, branches and root is calculated of every cohort. Then this biomass of each cohort is added (Masera et al., 2003). Then, the biomass of each cohort is added to calculate the carbon stored in the living biomass of the whole stand. It can be expressed as:

$$Cb_t = \sum Cb_{it} \ldots\ldots\ldots\ldots \text{(Mg ha}^{-1}\text{)}$$

Where Cb_{it} is the carbon stored in the living biomass of cohort 'i' at time 't' (Mg ha^{-1}). For each new time step, Cb_{it} is calculated as the balance between the original biomass, plus biomass growth (Gb_{it}), minus the turnover of branches, foliage and roots (T_{it}), minus tree mortality due to senescence (Ms_{it}), minus harvest (H_{it}) minus mortality due to logging (Ml_{it}), i.e.

$$Cb_{it+1}= Cb_{it}+ Kc\ [Gb_{it}- Ms_{it}- T_{it}- H_{it}- Ml_{it}] \ldots\ldots \text{(Mg ha}^{-1}\text{)}$$

Where Kc is a constant to convert biomass to carbon content (Mg Mg^{-1} biomass dry weight).

12.3.3. Biomass Growth

The growth rates of stem volumes are being used as an input to simulate Gb_{it} in this model. The stem volumes can be easily calculated by the help of yield table or forest inventories. Time- dependent allocation coefficients are used to calculate the growth rates for foliage, branches, and roots from stem volume.

It is obvious that the stem volume growth rate in $m^3ha^{-1}yr^{-1}$ acts as the main input in this model. Allometric approach is being applied to estimate the growth from stem volume of major biomass components. After estimating the growth rate for each cohort, these growth rates are altered by the interactions among themselves and with other cohorts.

The site quality is not same. Good, medium and poor sites conditions could be prevailed in the forest stand. To correct these and other differences which are present due to the differences in growth parameters, modifications could be made accordingly (Nabuurs and Mohren, 1995).

Mathematically,

$$Gb_{it} = \{KvY_{ist}\,[1+\Sigma\,(F_{ijt})]\times Mg_{it}\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (Mg\ ha^{-1}\ yr^{-1}).$$

Where Kv is a constant to convert volume yields into dry biomass (basic density, in kg DM $m^{-3}$of fresh stemwood volume); Y_{ist}, the volume yield of stem wood for each cohort "i" in $m^3ha^{-1}yr^{-1}$, F_{ijt}, the biomass allocation coefficient of each living biomass component "j" (foliage, branches, and roots) relative to stems, for each cohort "i" at time t (kg kg^{-1}) and M_{git} is the dimensionless growth modifier due to interactions among and within cohorts.

12.3.4. Tree Mortality due to Senescence

Mortality due to senescence is estimated as a function of tree age or as a function of the relative biomass (standing biomass divided by the maximum stand biomass):

$$Ms_{it} = f\ (age)\ \text{or}\ Ms_{it} = f\ (B_{it}/B_{imax})$$

Where, Ms_{it} is the cohort mortality due to senescence at time t in years. If data on mortality related to age is not available—a typical situation for tropical natural forests, the mortality can be modelled as a function of relative cohort biomass.

12.3.5. Turnover

In addition to tree mortality, an accurate estimation of carbon dynamics in living biomass needs to account for the turnover of foliage, branches, and roots. This turnover is also very important to adequately model the carbon dynamics of soil organic matter. We model the turnover for each cohort (Tit) as the sum of the turnovers of each component "j", which in turn is simply the existing biomass of the particular component "j" multiplied by a decay or turnover constant (KijT). Mathematically,

$$T_{it} = \Sigma\ B_{ij}\ K_{ij\ T} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (Mg\ ha^{-1}\ yr^{-1})$$

Where K_{ijT} ranges between 1 per year (i.e. All the component biomass are lost during the year) to 0 per year (no turnover at all).

If the forest ecosystem which is under analysis is sustained properly, part or the greater part of the tree biomass may be evacuated through thinning, particular logging or clear-cutting. This collected biomass is subtracted from the current biomass, and is designated to the soil module.

12.3.6. Mortality due to Logging (Harvesting) Damage

Forest logging operations brings about improvement of the mortality of the rest of the trees. This destruction especially depends upon the nature of forest, the type of expertise and procedures used as a part of logging. Logging results in high mortality rate, up to 20% of the enduring basal area in tropical forests (Alder and

Silva, 2000). The mortality because of logging is straightforwardly identified with the intensity of logging and can be stated as the basal area, volume, total number of trees or biomass logged. Additionally, it may bring about mortality several years after the operation. In several cases, initially the mortality rate is high through the early years after the logging, and this rate will reduces slowly, achieving 0 in 10–20 years, depending upon the nature of forest and the methods used (Pinard and Putz, 1997). In the CO2FIX V3.2 model, logging harm mortality coefficient (Kl_{it}) years after logging, as a linear function of time with three parameters is determined as:

Initial mortality (Moi), (b) duration of the damage (π), and (c) intensity of the initial logging (Ioi).

Mathematically, $Mlit = B_{it} \times Kl_{it}$………………. (Mg ha^{-1} yr^{-1})

Where $Kl_{it} = Moi - \pi \times Ioi$

12.3.7. Carbon Stored in Soil Organic Matter

The dynamic soil module of YASSO in the model can be used to evaluate the soil carbon stocks. The input factor of soil carbon could be specifically introduced from biomass module having three lingering portions and five disintegrating parts. Soil module for soil carbon requires several Parameters such as litter input (Mg ha^{-1} yr^{-1}), fine roots, twigs; coarse roots and stems, evaluated from turnover rates, natural death rate, and mortality during management and logging slice gave by the stimulator in different modules of the model. For calculating prospective evapotranspiration of a certain area the mean temperature and precipitation for the region is required, significant in explaining the rates of decay. The mass of non-woody litter, fine and coarse litter pools pools is dictated by contributions from number of litter sources, minus the fractionation rate per pool. The extent distributed to solvent mixes, holocellulose, and lignin-like mixtures is thus controlled by fractionation rates and litter quality classes (Nabuurs et al., 2001).

The production of the carbon stocks can be any number of years. The yield of the model can be expressed in both forms i.e. tubular and graphic. Graphically the simulation is showed in Figure 12.3.

Managing carbon Stocks both in Forest and Forest products means using methods which can decrease carbon loss and enhance carbon storage in the forests. For example around 15% of total global greenhouse gas is emitted annually from Tropical forests as a result of deforestation and degradation. Policy makers are working to create explanations that speak climate change, there has been significant spotlight on joining forests into the overall climate solution. Several silvicultural practices should be a necessary of diminishing carbon loss and enhancing carbon capture and storage if we are to resolve this worldwide task while addressing resource needs.

12.4. The Management of Carbon in Forest and Products

A little work on silviculture has been carried out in the tropical forests (ever-wet and semi-evergreen), however just in particular places; while in montane or deciduous forests almost no work has been has carried out so far. Forests can be considered economically feasible as compared to other land uses. Through the incorporation and cultivation of different species forests provide both timber and non-timber products that are arranged and are perfect with service values i.e. water quality and capturing and storage of carbon. For increasing forest carbon stock it is important to involve the societies to develop forest stands which ultimately results in increase in carbon storage. Numerous logged over and succeeding forests are perfect possibility for recovery through improvement planting of supplemental long-lived trees for capturing carbon.

12.4.1. Important Considerations and Trends

Managing forests on sustainable basis is a key factor to attain carbon emission reductions, to negotiate the global climate change, providing chances in forest management. Managing forests for carbon the most imperative aim is to protect already standing forests, particularly primary growth forests which have high carbon contents.

Carbon uptake and storage by forests differs considerably and based on several factors like environment, soils, hydrology, and kind of trees. While managing a forest for carbon sequestration it is necessary to give prime importance to above mentioned factors. Although Reduced impact logging (RIL) is known as an imperative application to decrease carbon loss, but to increase the storage of carbon it is essential to focus beyond RIL by establishing new refined, thoughtful forest management systems with better silvicultural practices that give high regeneration establishment, post establishment relief, and prolonged rotations of the new woodlands.

12.5. Socio-Economic and Policy Consideration of Carbon Management in Forests

Different traditional standards along with economic and policy are used to formulate authentic practices to manage forest stands. The financial policy drivers that can disturb the probabilities for managing forest stands with carbon view point are essential to be explored. Generally, the economic pressures and incentives coming on the way are: high deforestation rates as forestland is transformed to new agricultural land. The remaining huge regions of comparatively complete forests are a outcome of physical or market remoteness; furthermore, in Pakistan, where the financial matters of creating area for buildings far out-measures the incentives for conserving land as farmhouses and forests, discovering approaches to utilize arrangement to conquer these incentives for land managers to change forestlands to more lucrative practices of the area are of most extreme significance. The elements to be considered when choosing utilization of the carbon markets (through offset schemes) or protecting the forests through direct public funding can be defined at both the worldwide level as part of the REDD+ consultations.

12.5.1. Why to Protect Large Intact Forests?

Large and intact forests (e.g steep forest on Moist and Dry temperate forests in Pakistan) are extremely crucial for the large number of the environment services they give. Although they are globally very important, yet, only 18% of the area had been assigned as protected as of 2008 (Potapov et al. 2008). Unluckily, even with this label, protection is negligible. Though these forests persisted mostly intact, they are repeatedly in the regions which are under continuous pressure from conversion of forest land into agricultural land, construction of buildings along roadside and timber removal. In recent years in Borneo deforestation rate because of illegal felling and land conversion for agriculture and buildings is very fast (Curran et al. 2004). High deforestation rates have a great influence on greenhouse gas emissions globally. Therefore illegal felling of trees and land conversion issues should be discussed immediately, either through business sector incentives for example carbon credits, supervisory organizations to progress authority, or a mixture of both (Zhang et al. 2006; Betts et al. 2008; Buchanan et al. 2008; Nepstad et al. 2008) .

12.5.1.1. Carbon Sequestration and Storage

High amount of carbon is stored in large and intact forests so carbon markets may offer actual economic incentives to prevent conversion of land and illegal felling in these woodland areas. Three of the four countries i.e. Brazil, Russia, and the Democratic Republic of Congo are with the biggest area of enduring intact forestland. The forested area of these countries holds an expected 384 billion tons of carbon dioxide equivalents in terms of carbon storage including above and below ground biomass along with living and dead biomass (FAO 2005). In association, globally energy utilization is responsible for 29 billion tons of carbon dioxide emissions in 2006 (EIA 2006). These three countries have higher amount of carbon stored in their primary and intact forests is due the reason that those forests contain higher concentrations of carbon both in soils and aboveground biomass than despoiled or secondary forests due to consistently larger numbers of sluggish growing trees with heavier wood.

12.5.1.2. Co-Benefits of Protecting Large and Intact Forests

These large intact forests not only play a significant role in global carbon cycle but they protect the land as well, showing their role in controlling local climate (Hoffman et al. 2003; Spracklen et al. 2008). These intact forests provide a substantial cooling effect on both regional and global climate in the boreal region of the world by the gathering of clouds from the evapo-transpiration of boreal forests (Spracklen et al. 2008). In tropics, especially in the Amazonian region this cooling outcome is produced via evapo-transpiration of large forests. An extensive part of the precipitation in inside and mainland areas of the Amazon Basin is gotten from evapo-transpiration that is discharged through the span of a day (Makarieva and Gorshkov 2007). It is not possible for inner areas of wet tropical forests to maintain their present forest type, because of the change of rainfall patterns along with deforestation at the forest boundaries, (Makarieva and Gorshkov 2007). At the point when huge swaths of earlier intact tropical forests are cleared, rate of evapotranspiration increases which results in disturbance of rainfall patterns (Roy et al. 2005). In one study, a model of rainfall in the Congo Basin proposed that rainfall could be diminished by 10% in specific regions as a consequence of deforestation (Roy et al. 2005).

Second, in tropical forests when rainfall patterns changes, they can prompt to reformed fire regions which results in when changes to precipitation patterns occur in tropical forests, they can lead to altered fire regimes, which can affect the resilience of residual forests. Many nations in the tropics with noteworthy rates of deforestation and land conversion now facing more regular and severe fires (Siegert et al. 2001; Hoffman et al. 2003). These subsequent fires can intensify deforestation and land degradation rates in residual forests, ultimately have a great influence on worldwide carbon emissions (Hoffman et al. 2003). This impact was found in the 1997 fires on the island of Borneo, discharged an expected range of 8–25 billion tons of CO_2 equivalent into the air, equivalent to 13–40% of the mean annually global emissions from the burning of fossil fuels.

Third, there is adequate proof that forest destruction and degradation substantially affect both floral and faunal species composition within a given area (Curran and Leighton 2000; Hoffman et al. 2003; Roy et al. 2005). Several variations in tree species structure can negotiate the strength of a whole environment and lessen its ability to withstand disruption. Many plant species rely on large areas of forest for their regeneration and cannot successfully breed in mosaic or destructed areas (Curran and Leighton 2000). These forests not only ensure the plant biodiversity, but in addition they give a portion of the main appropriate habitat for wildlife in their particular regions (Joppa et al. 2008).

12.5.2. Drivers of Deforestation

Despite the fact that there is general acknowledgment that conversion of land for farming purpose is responsible for a major portion of deforestation throughout the world but the elements that drive the conversion of forest into agricultural lands are less clear. Academic argument has extended from basic, single driver theories, such as over population or poverty is considered as the main reason of land use change to more difficult models that list mixtures of market-based clarifications and other socio-economic issues. Econometric models and observational studies are frequently used to clarify the blend of components that drive deforestation with an end goal to plan better strategies that will slow forest loss while lightening to the basic reasons of encroachment into forest regions. A review of the literature (i.e. Allen and Barnes 1985; Angelsen and Kaimowitz 2001; Barbier and Burgess 2001; Lambin et al. 2001; Geist and Lambin 2001, 2002; Achard et al. 2002; Fearnside 2005) shows that there are three noteworthy classes of deforestation drivers in the tropics e.g. financial, institutional, and socio economic factors.

12.5.2.1. Socio Economic Factor

i. Population Growth: In developing regions increasing population is considered as a major factor of deforestation for agriculture (Lambin et al. 2001; Allen and Barnes 1985). Though, the point that over population effectively describes clearing of forests is not as vigorous as earlier believed. For instance, scientists normally point that deforestation in tropics to growing populations of fluctuating farmers, despite the point that latest FAO data describes that moving growers responsible for only 5% of land conversion in tropics (Chomitz et al. 2007).

According to some scientists there is a direct relationship between increasing population and deforestation at the state level, nevertheless studies disclose that increasing populations that move into forested regions and successively clear the forested land are determined to do so because of a host of several other issues that comprises construction of buildings, fertile soils, occupation chances and remoteness to markets (Angelsen and Kaimowitz 1999). Over population is known as an autonomous feature to describe clearing of forests in many areas around the world fails to explain for the composite social and economic situation driving population development in these areas. The reasons of clearing forests for farming cannot be assumed without precise understanding of the interactions among local peoples and the climate of that area (Fairhead and Leach 2008).

Additionally latest effort emphases less on the effects of increasing population and in spite tries to describe land conversion trends as they narrate to diverse population types. Jorgenson and Burns (2007) studied the patterns of population growth, migration ways and financial improvement in both urban and rural areas to attract differences between the location of population growth and the effects on forest cover. Their outcomes show that increasing rural population does accelerate the deforestation whereas increase in urban population really have a little impact on clearing of forests for farming as subsistence villagers move to urban areas for work. Other work on increasing population and forest degradation recommends that the area of population development is huge; the earlier individuals arriving in a frontier area have great influence on clearing of forests in a region than population development movement in previously populated zone (Pfaff 1996). These discoveries might be huge for forest policy, as they show the significance of spatial heterogeneity of population thickness, describing various rates of deforestation.

ii. Urbanization: For investigating the link among increasing rates of population and deforestation, urbanization and the association of human populations are very chief aspects.

While urban regions have a tendency to be more minimal and require less land, fluctuating urban regimes and utilization designs at last prompt a more prominent strain on pastoral expected assets. Furthermore, land conversions from urban zones

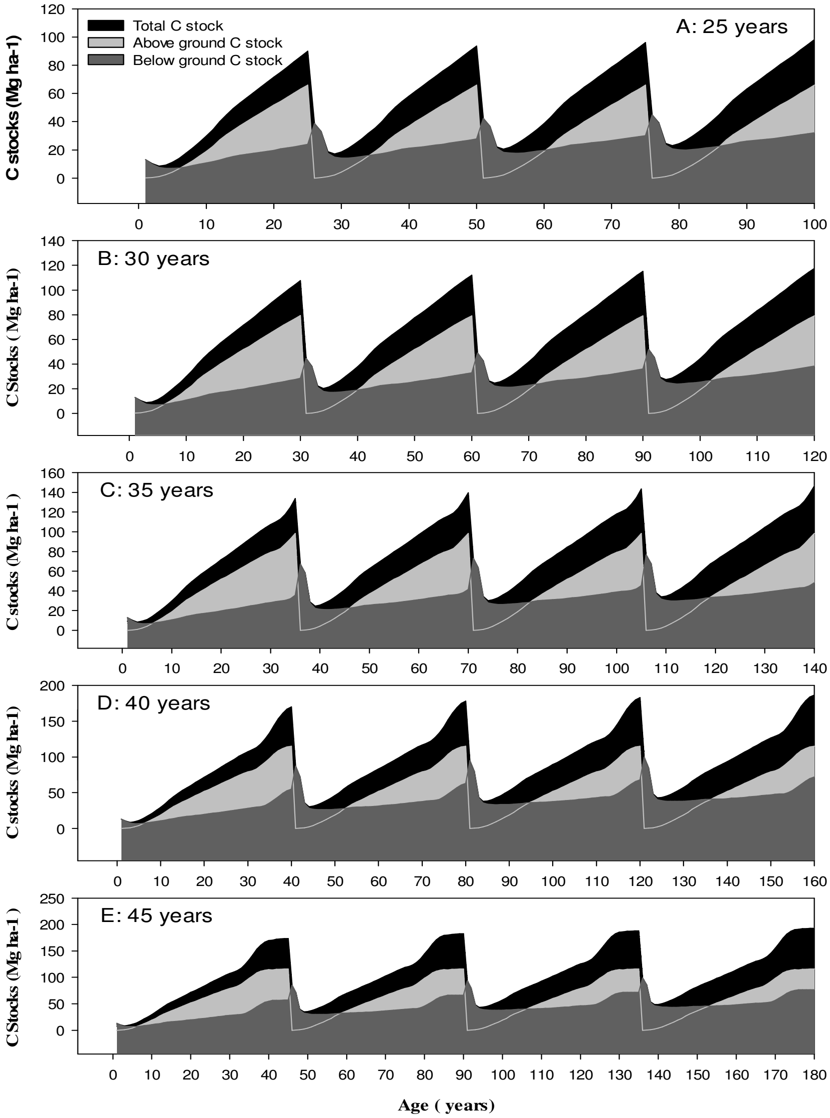

Fig.12.3 The Graphical output of C stocks Simulation from CO_2 Fix Model
Source: Nizami et al. *(2014)*

often enlarges into adjacent farming land, in this way pushing farming loads into forest lands (Lambin et al. 2003). Overall, the effects of urbanization ashore utilize change in forests should be concentrated more carefully in the native area.

Urbanization patterns lead to complex and non-straight input mechanisms that incorporate provincial infringement, the relocation of landless workers from urban regions back to rural zones, or desertion of farming lands that results in secondary growth (Jorgenson and Burns 2007).

iii. Poverty: According to some scholars similar to population, the poverty premise is also a key factor that is responsible for conversion of forested areas into agricultural areas around the world. The reason is that farmers of developing countries have a greater amount of a motivating force to deforest in the short period rather than waiting for longer time period to get more incomes from other land practices (Lambin et al. 2001; Angelsen and Kaimowitz 1999). Though, this perspective features a significant part of the deforestation that is happening for farming purposes in tropical areas to poor smallholders rather than to instead of to bigger industrial plantations, government-supported concessions or strategies to use the land on large sclae (Dove 1987, 1993; Angelsen 1995; Fearnside 2005).

A substitute perspective of the poverty theory resists that smallholders do clear a portion of the timberland for subsistence purposes, however they do not have the capital, work, and access to credit that is required to put resources into vast scale woodland clearing (Angelsen and Kaimowitz 1999). These results are in the line of finding of Chomitz et al. (2007) that forest clearing and conversion to expansive farming represents around 45% of area clearing in Asia and 30% in Latin America, while moving agriculture by smallholders represents roughly 5% of forests clearing.

iv. Economic Inequalities: Because of financial differences on a local and provincial scale, access to financial chances, equipment knowledge, and land contrasts across households and areas, which effects the trends of forest clearing. In the 1970s, for instance, subsidized credit for technology and organic inputs was mainly given to the farmers of Brazil at a large scale for soybean production (Kaimowitz and Smith 2001). Not astonishingly, the high product cost of soy and funded credit results in increase in land prices. It is not possible for small landholders to compete with large farmers for expensive machinery and chemical inputs for producing mechanized soy, resulted in land merging by big operators (Kaimowitz and Smith 2001). Results show that the production of soybean through the increase mechanization lead to the dis-placement of 11 farmers for each laborer utilized (Altieri and Bravo 2006).

v. Transportation: Roads are often appeared to be exceptionally related with an expansion in deforestation in most of the world forests, containing roads built for farming purposes (Angelsen and Kaimowitz 1999; Laurance et al. 2001) . Expanded infrastructure takes into consideration more prominent access to inner forests and to end markets for goods. In the literature, there is a general agreement that more access will result in less forest, roads are considered as nonstop facilitators of clearing of woods and additionally by-results of other monetary exercises causing deforestation previously (Lambin et al. 2003; Angelsen and Kaimowitz 1999).

While roads are thought to be an essential driver of deforestation in most tropical regions, there are some significant special cases. For instance, areas like West Kalimantan, Indonesia, with low population pressure from growth, don't demonstrate a solid relationship between the existence of cemented roads and pressure of forest clearing (Curran et al. 2004). Though, it is not identified whether this pattern is for short period of time or for long period of time. Roads have very important role in the landscape varies by geography and other components. In West Kalimantan, the high estimation of dipterocarp timber trees and the influence of the timber trade in the area have a much-grounded effect on clearing of forests as compared to existence of either roads or communities. Moreover, roads can advance connectivity between villages and nearby cities, in this way giving people employments that may diminish their need to clear forestland for money (Chomitz et al. 2007). Along these lines, even though roads are considered as an essential cause of deforestation in many parts of the world especially tropics result in change in their local effect.

vi. Technology: Increase in agricultural productivity because of local economy and skills have largely been related with both clearing of forests and evaded deforestation. While a few theories have been produced to investigate the causal connections amongst innovation and deforestation, two are very important. To begin with, the Borlaug theory attests that new higher-yielding innovations can increment agricultural production and benefit results in decrease in deforestation rate. (Angelsen and Kaimowitz 2001). In spite of the fact that this theory might be valid for worldwide food production, it has been demonstrated that commodity prices greaterly affect agricultural increase than innovative change at the local and regional levels, especially on forest frontiers. Second, the economic development theory suggests that expanded farming efficiency because of innovation will upgrade general financial advancement, ultimately lessen poverty decrease pressures on forests (Angelsen and Kaimowitz 2001).

With the passage of time advancements in agricultural technology reduce the deforestation rates, as demonstrated by the two theories. No doubt agricultural technology impacts on forest degradation depend upon several factors, comprising farmer features, the scale of selection, how the labor deal with new technology and the financial benefits of farming on the forest frontier (Lambin et al. 2003; Angelsen and Kaimowitz 2001). Those technologies which are very effective in reducing deforestation, results in high productivity and enable farmers to save capital and create employment opportunities. Although, the automation of agricultural growth has serious effects on land as it can be degraded because of soil erosion, compaction, and loss of fertility, ultimately increase the rate of land conversions.

12.5.2.2. Institutional Factors

i. Land Tenure: Property and land tenure rights are also known as essential factors responsible for conversion of forested land into agricultural land. There is a substantial literature on this issue (Dove 1987; Godoy et al. 1998; Angelsen and Kaimowitz 1999; Geist and Lambin 2001). Various Studies revealed that securing land tenure will lessen the deforestation to some extent, but not on complete basis (Angelsen and Kaimowitz 1999; Geist and Lambin 2001), particularly when governments have set up motivating forces to clear the forest. For a landowner, forest protection and preservation is a viable management choice, the financial advantages of keeping the forest in place must exceed the net present benefit of clearing the trees for farming purposes. In this way, several factors, for example, implementation and administration are responsible for the affiliation of deforestation and land tenure system.

ii) Institutions and Governance: Institutional components, for example, administration and political insecurity, add to deforestation in several ways. Basic decision making frameworks, ecological laws, and structure of property rights are extremely imperative parts of government that influence which groups are given concessions or are permitted to use natural resources of forests. However, in many countries of the world having substantial forest resources do not monitor and avoid clearing of forests in various regions where it is banned because of corruption and absence of administrative empowerment (Lambin et al. 2003).

Several protected regions in some countries are facing illegal felling of trees only because of absence of authorization. In the course of recent decades, developing countries have progressively accepted decentralization rules as a procedure to enhance governance and management of natural resources (Tacconi 2007). A study carried out by the World Bank, for instance, found that more than 80% of developing nations, having populations larger than five million were endeavoring to decentralize their administration structures (Silver 2003). Donor agencies and development organizations, such as the World Bank, The U.S. Agency for International Development (USAID), the International Monetary Fund, uphold decentralization as a method for expanding responsibility, straightforwardness, and vote based system in developing nations (McCarthy 2004). The prominence of decentralization approaches among important donor organizations and educational thinkers has brought about attempts by numerous developing countries with imperative forest assets to hand over control over forest resources from central to local governments. Local control over forest resources prompts enhanced resources resource governance, practically speaking, decentralization has prompted power battles over resources and misperception over designation of authorities (Ribot et al. 2006; Thorburn 2002).

12.5.2.3. Economic Factors

i. International Trade and Economic: Global business market, along with financial relaxation and association, also has molded land use patterns associated to farming. Economic liberalization laws and policies, for example, the regulation of commerce institutions and the expulsion of duties and exchange hindrances, have normally energized incremental area transformation for agricultural purposes. These approaches can change capital flows and interests in an area, prompting land use changes that may incorporate deforestation (Lambin et al. 2003). As governments keep on removing hindrances to trade and concentrate on exchange markets, people turn out to be progressively determined by business sector price variances. Therefore, conversion of forested land to farming develops more firmly connected to worldwide product markets.

ii. National Economic Policy: Financial growth and national safety are largely dependent on the National economic rules formulated by the authorities. Most of the time these policies are not be planned to consider subsequent influences on the forest Depending on the area, financial policies motivating clearing of forests for farming include credit strategies, subsidies for farming inputs and out-puts, tax collection plans, and agricultural price supports.

iii. Household and Local Economics: Decisions regarding the land use, at the household level, are specifically connected to nearby market access and variations in on-farm and off-farm incomes. At the point when greater market access and financial prospects develop, people will regularly react by amassed manufacture of valuable profitable and extending farming procedures (Lambin et al. 2003).

iv.Culture and Household-Level Decision Making: Land use decisions are made by individuals on daily basis considering social inclinations, accessible data, and cultural and financial desires (Lambin et al. 2003). The accumulation of these individual choices can interpret into wide deforestation and land use change. Deforestation rates can be lowered by providing appropriate incentives, results in conservation of forests. Impacted by the political economy, biophysical attributes of the area, and culture of a region, people will settle on judicious choices regarding what kind of land use they select to implement, differing from swidden farming and agro-silvopastoral systems to se vere monoculture farming and pasture (Lambin et al. 2003; Bebbington 1996). This procedure is imperative to consider when planning carbon capturing and sequestration encouragements, especially since exercises identified with carbon storage and sequestration will be one of frequent land use decisions accessible to landowners.

12.5.3. The Role of Climate Policy in Reducing Deforestation

One potential system for explaining deforestation has developed through the worldwide climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC). Policy incentives to reduce deforestation and forest degradation, or REDD, are being considered as part of a new climate agreement. Real advance was made in Cancun in November, 2010, and will keep on being arranged at the next meetings.

"REDD+" goes beyond deforestation and forest degradation and incorporates the part of protection, feasible administration of timberlands and improvement of forest carbon stocks. There are numerous issues that must be considered when outlining arrangements to protect forests either utilizing an asset or carbon markets. Since national, local and local-level would eventually regulate household REDD+ programs, execution challenges in developing world must be considered when assigning funds for REDD+. For governments that have feeble administrative requirement structures, it is hard to screen and implement behavior that preserves carbon stocks of standing forests. Correspondingly, for governments where dishonesty is a big problem, it might be hard to guarantee that REDD+ funding and benefits are impartially circulated to people who are decreasing deforestation on their properties or increasing carbon sequestration through reasonable land use practices.

Describing land tenure problems and financial inequities are essential components when instituting official capacity for REDD+. There must be other financial and incentives policies should be developed to manage forests and farming lands for carbon capturing and storage on appropriate basis, for farmers who do not have formal title to their land. It is not clear to date, whether farmers without ownership of land will have access to REDD+ funding or not. One solution may be to advance existing cooperatives and agriculturists' relationship to channel REDD+ assets to small farmers who keep their property forested or who build up agroforestry and silvopastoral systems to enhance carbon storage and sequestration. Cooperatives, agriculturists' affiliations and extension offices additionally could serve as a mechanism to give on REDD+ preparing on REDD+ and to help small farmers in acquiring payments to support reduced forest clearing and other economical land use performs. Though, clear land tenure does not generally prompt clear responsibility for carbon credits from trees and forests. The progress of actual laws and organizations that simplify land tenure and get profits from the sale of carbon credits at the local, provincial and national levels are important to advance decreased deforestation and consider for reasonable access to revenue generated by REDD+.

Since REDD+ policies and projects eventually will be directed by national governments, evaluations and changes of opposing government-drove strategies and projects that lead to across the board deforestation in nations additionally should happen before REDD+ can be a fruitful technique. National governments cannot stimulate forests preservation and restoration policies and programs at the same time (i.e., REDD+) whereas in the meantime give incentives for farming venture into forested zones (either directly or indirectly) by means of sponsorships and laws that promote and advance these practices.

12.6. Conclusions

Carbon cycling is dependent on several variables in forests and is considered as a very difficult process. General examples of stand carbon cycling are all inclusive, yet the temporal elements of these examples are extremely site particular. Subsequent conclusions are imperative to deliberate:

1) Succession results in more accumulation of carbon in forest stands. Most studies demonstrated that the most prominent rate of carbon take-up happens during the stem segregation stage, yet even mature stands sequester and store noteworthy amounts of carbon. Some latest studies ensure that this can be critical even for old forests, especially when such old stands illustrate important rations of large territories.
2) Decomposition of forest vegetation and soil organic matter results in release of carbon which cause disturbances in forest ecosystem. Future climatic conditions will assume a noteworthy part in carbon cycling in forest stands, similarly future forest stand conditions will impact the atmosphere.
3) Rainfall patterns and moisture regimes will shape the stand structure, its composition and production all over the globe. However, those changes will fluctuate extraordinarily with both site and timing.

4) The joined impacts of environmental change are being examined, however frequently there are too few factors being considered, making the worldwide utilization of results from these studies slightly doubtful. Zones of vulnerability in forests carbon science at the stand level give various chances to future research. A noteworthy region of uncertainty in present investigation is the long-term impact of changing atmospheres on woods ecosystems.

The four types of approaches assessed in this part depend on biomass measurement data, remote sensing data, CO_2 flux data (from eddy covariance) and CO_2 concentration data. They all show their own points of interest and inconveniences in assessing CO_2 flux and supplement each other in various ways. Inventory techniques measure biomass inside forests, and are classified by their long history and sufficient information attention (especially in developed countries). However, because of their low time resolution (years) and inconstant norms of estimation, Remote sensing strategies are most solid if remote sensing data is mutually utilized with forest carbon inventories and biological community models.

Though, deficient data restricted by remote sensing methods and uncertainties in the models need extra improvement strategy is progressed in its high precision and fine temporal determination (hours), and is a decent technique for direct estimation of CO_2 flux at the environment scale. Because of fewer numbers of observation sites and higher systematic biases, it is restricted for calculating carbon from forest stands. Inverse techniques are utilized at central to worldwide scales. They recover the quality of both anthropogenic and non-anthropogenic sources and sinks from atmospheric CO_2 amount data and transportation models. Carbon Tracker is considered as one of the best inverse model. In these inverse techniques, the data assimilation models are being enhanced for higher precision and better spatial determination. No single technique can meet the precision and determination necessities of all users. A nation, user or site will settle on a decision of strategy considering the specifics of the situation. To enhance progresses, the user is urged to attempt information correlation, coordinated effort and assimilation among various strategies (Heinsch et al. 2006; Gough et al. 2008). Such advancements ought to expand on a watchful synchrony among techniques. For instance, CO_2 spending estimations from forest stock and inventory depend on biomass aggregation, while CO_2 flux estimations reflect photosynthesis and respiration – generally a 1-year time lag will be found between these two results. Along with this a better and more complete perception system of CO_2 concentration is compulsory.

Decreasing emissions, and increasing storage, through enhances forest management and administration is an imperative procedure at present being discussed under REDD+.

The carbon capturing and storage limit of a particular forest fluctuate significantly relying upon the specific region, forest type, geophysical qualities, species creation and composition site degradation, land tenure, and human use.

1) To create and actualize satisfactory forest management methodologies, it is critical to understand that most are not reasonably oversaw, but rather exploited.
2) Applying stand-level land utilize depiction, harvest arrangements and planning lessened impact logging strategies can ensure significant effects on growing forest carbon.
3) More multifaceted silvicultural practices should be done to increase the carbon uptake and storage along with timber production. This approach will secure the recovery of the ancied species and the proceeded with vertical stratification of the stand, will build efficiency, and will advance the presence of the objective types of high monetary and carbon sequestration value.
4) For precise silvicultural methods proper forest management is very important.
5) If suitable silviculture is accomplished, forests will be stronger to the unpredictability of unsettling influence and environmental change, making them appropriate as stable long-term carbon sequestration and storage reservoirs.

Future research needs to move beyond reduced impact logging (RIL) and concentrate on how forested lands can be accomplished for carbon capturing and storage, along with water, biodiversity, and other ecological values. Still there is no technique has been developed to clarify financial drivers of forest clearing for cultivation across all regions of the world. The conditions that drive deforestation are privately based and rely on a number of factors that incorporate social, political, authentic, and land contemplations.

Policies are needed which must be multidimensional, historically-grounded, and should look at the fundamental reasons for financial variables, alongside bigger macroeconomic strategies and institutional plans that may influence local level land use choices to describe the deforestation in the world.

As REDD+ negotiations keep on considering the different ways carbon financing can be utilized to safeguard carbon captured in forests and to advance viable land utilize and supervision stratigies that improve carbon storage and sequestration, it is vital to consider what is by and large acknowledged fanincial drivers of tropical deforestation, as well as what is less well assumed:

1) Substantial factors responsible for deforestation are regularly context definite and are influenced by indigenous, administrative, financial, social, and biophysical factors that are molded by complex historical condition.
2) In different parts of the world the role of overpopulation and poverty has been considered as a major factor in deforestation is overstated.
3) Transportation foundation is unequivocally associated with deforestation. In this way, supporting national policies and laws results in reduction of pressure on forest development or necessitate better land use arrangement could be a compelling technique for diminishing deforestation along streets and roads.

4) Fluctuating product costs for agricultural crops, timber, and domesticated animals can specifically affect family unit basic leadership to deforest for farming or to keep up the forest.
5) Economic strategies at the national level including endowments and access to credit – can assume a key part in affecting deforestation for agriculture.

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