

Deforestation: Causes, Effects and Control Strategies

Sumit Chakravarty¹, S. K. Ghosh², C. P. Suresh²,
A. N. Dey¹ and Gopal Shukla³

¹Department of Forestry

²Pomology & Post Harvest Technology, Faculty of Horticulture
Uttar Banga Krishi Viswavidyalaya, Pundibari

³ICAR Research Complex for Eastern Region, Research Center, Plandu Ranchi
India

1. Introduction

The year 2011 is 'The International Year of Forests'. This designation has generated momentum bringing greater attention to the forests worldwide. Forests cover almost a third of the earth's land surface providing many environmental benefits including a major role in the hydrologic cycle, soil conservation, prevention of climate change and preservation of biodiversity (Sheram, 1993). Forest resources can provide long-term national economic benefits. For example, at least 145 countries of the world are currently involved in wood production (Anon., 1994_a). Sufficient evidence is available that the whole world is facing an environmental crisis on account of heavy deforestation. For years remorseless destruction of forests has been going on and we have not been able to comprehend the dimension until recently. Nobody knows exactly how much of the world's rainforests have already been destroyed and continue to be razed each year. Data is often imprecise and subject to differing interpretations. However, it is obvious that the area of tropical rainforest is diminishing and the rate of tropical rain forest destruction is escalating worldwide, despite increased environmental activism and awareness.

Deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development (van Kooten and Bulte, 2000). Deforestation is primarily a concern for the developing countries of the tropics (Myers, 1994) as it is shrinking areas of the tropical forests (Barraclough and Ghimire, 2000) causing loss of biodiversity and enhancing the greenhouse effect (Angelsen *et al.*, 1999). FAO considers a plantation of trees established primarily for timber production to be forest and therefore does not classify natural forest conversion to plantation as deforestation (but still records it as a loss of natural forests). However, FAO does not consider tree plantations that provide non-timber products to be forest although they do classify rubber plantations as forest. Forest degradation occurs when the ecosystem functions of the forest are degraded but where the area remains forested rather cleared (Anon., 2010).

Thirty per cent of the earth's land area or about 3.9 billion hectares is covered by forests. It was estimated that the original forest cover was approximately six billion hectares (Bryant *et*

al., 1997). The Russian Federation, Brazil, Canada, the United States of America and China were the most forest rich countries accounting to 53 per cent of the total forest area of the globe. Another 64 countries having a combined population of two billions was reported to have forest on less than ten per cent of their total land area and unfortunately ten of these countries have no forest at all. Among these countries 16 are such which had relatively substantial forest areas of more than one million hectares each and three of these countries namely Chad, the Islamic Republic of Iran and Mongolia each had more than ten million hectares of forest. The forest area remained fairly stable in North and Central America while it expanded in Europe during the past decade. Asian continent especially in India and China due to their large scale afforestation programme in the last decade registered a net gain in forest area. Conversely the South America, Africa and Oceania had registered the net annual loss of forest area (Anon., 2010; 2011a).

2. World deforestation

According to Professor Norman Myers, one of the foremost authorities on rates of deforestation in tropical forests, "the annual destruction rates seems set to accelerate further and could well double in another decade" (Myers, 1992). Mostly deforestation has occurred in the temperate and sub-tropical areas. Deforestation is no longer significant in the developed temperate countries now and in fact many temperate countries now are recording increases in forest area (Anon., 1990a; 2010). In most instances developed nations are located in temperate domains and developing nations in tropical domains. However deforestation was significantly less in tropical moist deciduous forest in 1990-2000 than 1980-1990 but using satellite imagery it was found that FAO overestimated deforestation of tropical rainforests by 23 per cent (Anon., 2001a, b). However the definition of what is and what is not forest remains controversial. The tropical rainforests capture most attention but 60 per cent of the deforestation that occurred in tropical forests during 1990-2010 was in moist deciduous and dry forests.

However extensive tropical deforestation is a relatively modern event that gained momentum in the 20th century and particularly in the last half of the 20th century. The FAO FRA 2001 and 2010 reports indicate considerable deforestation in the world during 1990-2010 but this was almost entirely confined to tropical regions (Anon., 2001a; 2010). A summary of deforestation during the decades 1990-2010 is given in tables 1 and 2. These tables show there was considerable deforestation in the world during 1990-2010 but this was almost entirely confined to tropical regions. Rowe *et al.* (1992) estimated that 15 per cent of the world's forest was converted to other land uses between 1850 and 1980. Deforestation occurred at the rate of 9.2 million hectares per annum from 1980-1990, 16 million hectares per annum from 1990-2000 and decreased to 13 million hectares per annum from 2000-2010. The net change in forest area during the last decade was estimated at -5.2 million hectares per year, the loss area equivalent to the size of Costa Rica or 140 km² of forest per day, was however lesser than that reported during 1990-2000 which was 8.3 million hectares per year equivalent to a loss of 0.20 per cent of the remaining forest area each year. The current annual net loss is 37 per cent lower than that in the 1990s and equals a loss of 0.13 per cent of the remaining forest area each year during this period. By contrast some smaller countries have very high losses per year and they are in risk of virtually losing all their forests within the next decade if current rates of

deforestation are maintained. Indeed some 31 countries do not even make the list because they have already removed most of their forests and even if that remain are seriously fragmented and degraded. The changes in area of forest by region and subregion are shown in table 1.

Region/subregion	1990-2000		2000-2010	
	1 000 ha/year	%	1 000 ha/year	%
Eastern and Southern Africa	-1841	-0.62	-1839	-0.66
Northern Africa	-590	-0.72	-41	-0.05
Western and Central Africa	-1637	-0.46	-1535	-0.46
Total Africa	-4067	-0.56	-3414	-0.49
East Asia	1762	0.81	2781	1.16
South and Southeast Asia	-2428	-0.77	-677	-0.23
Western and Central Asia	72	0.17	131	0.31
Total Asia	-595	-0.10	2235	0.39
Russian Federation (RF)	32	n.s.	-18	n.s.
Europe excluding RF	845	0.46	694	0.36
Total Europe	877	0.09	676	0.07
Caribbean	53	0.87	50	0.75
Central America	-374	-1.56	-248	-1.19
North America	32	n.s.	188	0.03
Total North and Central America	-289	-0.04	-10	0.00
Total Oceania	-41	-0.02	-700	-0.36
Total South America	-4213	-0.45	-3997	-0.45
World	-8327	-0.20	-5211	-0.13

Table 1. Annual change in forest area by region and subregion, 1990-2010
(Source: Anon., 2010)

South America with about four million hectares per year suffered the largest net loss of forests during the last decade followed by Africa with 3.4 million hectares annually and the least Oceania with seven lakh hectares annually. Oceania suffered mainly due to Australia where severe drought and forest fires from 2000 AD had exacerbated their loss. Both Brazil and Indonesia had the highest net loss of forest during the decade of 1990 but has significantly reduced their rate of loss after this decade. Brazil and Indonesia dominate accounting for almost 40 per cent of net forest loss over the decade of 1990s. Even though Brazil was the top deforesting country by area, the forests in Brazil are so extensive that this represents a loss of 0.4 per cent per year. The forest area in North and Central America remained stable during the past decade. The forest area in Europe continued to expand although at a slower rate of seven lakh hectare per year during the last decade than in the 1990s with nine lakh hectares per year. Asia lost some six lakh hectares annually during 1990s but gained more than 2.2 million hectares per year during the last decade. The ten countries with the largest net loss per year in the period 1990-2000 AD had a combined net loss of forest area of 7.9 million hectares per year. In the period 2000-2010 AD this was reduced to six million hectares per year as a result of reductions in Indonesia, Sudan, Brazil and Australia (table 1). There were 28 countries and areas which have an estimated net loss of one per cent or more of their forest area per year. The five countries with the largest

annual net loss for 2000-2010 AD were Comoros (-9.3 per cent), Togo (-5.1 per cent), Nigeria (-3.7 per cent), Mauritania (-2.7 per cent) and Uganda (-2.6 per cent). The area of other wooded land globally decreased by about 3.1 million hectares per year during 1990-2000 AD and by about 1.9 million hectares per year during the last decade. The area of other wooded land also decreased during the past two decades in Africa, Asia and South America.

Country	Annual change 1990-2000		Country	Annual change 1990-2000	
	1 000 ha/year	%		1 000 ha/year	%
Brazil	-2890	-0.51	Brazil	-2642	-0.49
Indonesia	-1914	-1.75	Australia	-562	-0.37
Sudan	-589	-0.80	Indonesia	-498	-0.51
Myanmar	-435	-1.17	Nigeria	-410	-3.67
Nigeria	-410	-2.68	Tanzania	-403	-1.13
Tanzania	-403	-1.02	Zimbabwe	-327	-1.88
Mexico	-354	-0.52	the Congo	-311	-0.20
Zimbabwe	-327	-1.58	Myanmar	-310	-0.93
Congo	-311	-0.20	Bolivia	-290	-0.49
Argentina	-293	-0.88	Venezuela	-288	-0.60
Total	-7926	-0.71	Total	-6040	-0.53

Table 2. Countries with largest annual net loss of forest area, 1990-2010 (Source: Anon., 2010)

3. The causes of deforestation

As Myers pointed out, "we still have half of all tropical forests that ever existed" (Myers, 1992). The struggle to save the world's rainforests and other forests continues and there is a growing worldwide concern about the issue. In order to save forests, we need to know why they are being destroyed. Distinguishing between the agents of deforestation and its causes is very important in order to understand the major determinants of deforestation. The agents of deforestation are those slash and burn farmers, commercial farmers, ranchers, loggers, firewood collectors, infra-structure developers and others who are cutting down the forests. Causes of deforestation are the forces that motivate the agents to clear the forests. However, most of the existing literature typically distinguishes between two levels of specific factors: direct and indirect causes of deforestation. Direct agents and causes of deforestation, also typically referred to as sources of deforestation, first level or proximate causes (Panayotou, 1990; Barbier *et al.*, 1994; Caviglia, 1999) are relatively easy to identify but the indirect causes which are usually the main drivers of deforestation are the ones that cause most disagreement and the ones that are hardest to quantify (Bhatnagar, 1991; Mather, 1991; Humphreys, 2006; Sands, R. 2005).

Similarly, Pearce and Brown (1994) identified two main forces affecting deforestation. They are:

- Competition between humans and other species for the remaining ecological niches on land and in coastal regions. This factor is substantially demonstrated by the conversion of forest land to other uses such as agriculture, infrastructure, urban development, industry and others.

- Failure in the working of the economic systems to reflect the true value of the environment. Basically, many of the functions of tropical forests are not marketed and as such are ignored in decision making. Additionally, decisions to convert tropical forests are themselves encouraged by fiscal and other incentives.

The former can be regarded as the direct and latter as indirect cause of deforestation.

3.1 Direct causes

3.1.1 Expansion of farming land

About 60 per cent of the clearing of tropical moist forests is for agricultural settlement (Myers, 1994; Anon., 1991) with logging and other reasons like roads, urbanization and Fuelwood accounting for the rest (Anon., 1994_b). Tropical forests are one of the last frontiers in the search for subsistence land for the most vulnerable people worldwide (Myers, 1992). Millions of people live on the tropical forest with less than a dollar a day where a third of a billion are estimated to be foreign settlers. However, as the land degrades people are forced to migrate, exploring new forest frontiers increasing deforestation (Wilkie *et al.*, 2000; Amor, 2008; Amor and Pfaff, 2008). Deforestation is proxied by the expansion of agricultural land. This is because agricultural land expansion is generally viewed as the main source of deforestation contributing around 60 per cent of total tropical deforestation.

Shifting agriculture also called slash and burn agriculture is the clearing of forested land for raising or growing the crops until the soil is exhausted of nutrients and/or the site is overtaken by weeds and then moving on to clear more forest. It is been often reported as the main agent of deforestation. Smallholder production in deforestation and the growing number of such producers notably shifting cultivators were the main cause of deforestation (Anon., 1990_b; *c*; Dick, 1991; Anon., 1992_a; *b*; Barbier *et al.*, 1993; Ascher, 1993; Dove, 1993; 1996; Dauvergne, 1994; Porter, 1994; Thiele, 1994; Anon., 1994_c; Angelsen, 1995; Ross, 1996). Mostly all reports indicate shifting agriculture as responsible for about one half of tropical deforestation and some put it up to two-thirds. Shifting agriculture was greatest in Asia (about 30 per cent) but only about 15 per cent over the whole tropical world. It appears that the proportion of direct conversion of forest to agriculture is increasing and the proportion of shifting agriculture is decreasing with time.

3.1.2 Forest and other plantations

Plantations are a positive benefit and should assist in reducing the rate of deforestation. The fact that plantations remove the timber pressure on natural forests does not translate eventually into less, but rather into more deforestation. Indeed, it is feared that agricultural expansion which is the main cause of deforestation in the tropics might replace forestry in the remaining natural forests (Anon., 2002; Cossalter and Pye-Smith, 2003; Anon., 2005). The impact of timber plantations could thus turn out to be quite detrimental to tropical forest ecosystems (Kartodihardjo and Supriono, 2000). Tree crops and rubber in particular plays a more important role in deforestation in Indonesia than subsistence-oriented shifting cultivation (Chomitz and Griffiths, 1996). Unfortunately about one-half of the plantations in the tropics are established on native forest cleared for the purpose. Moreover plantations can promote deforestation by constructing roads that improve access of the shifting cultivators and others to the forest frontier.

3.1.3 Logging and fuel wood

Logging does not necessarily cause deforestation. However, logging can seriously degrade forests (Putz *et al.*, 2001). Logging in Southeast Asia is more intensive and can be quite destructive. However, logging provides access roads to follow-on settlers and log scales can help finance the cost of clearing remaining trees and preparing land for planting of crops or pasture. Logging thus catalyzes deforestation (Chomitz *et al.*, 2007).

Fuelwood gathering is often concentrated in tropical dry forests and degraded forest areas (Repetto, 1988; 1990; Rowe *et al.*, 1992; Anon., 1994_a). Fuelwood is not usually the major cause of deforestation in the humid tropics although it can be in some populated regions with reduced forest area such as in the Philippines, Thailand and parts of Central America. Fuelwood gathering was considered to be the main cause of deforestation and forest degradation in El Salvador (Repetto, 1990). In the drier areas of tropics, Fuelwood gathering can be a major cause of deforestation and degradation.

3.1.4 Overgrazing

Overgrazing is more common in drier areas of the tropics where pastures degraded by overgrazing are subject to soil erosion. Stripping trees to provide fodder for grazing animals can also be a problem in some dry areas of the tropics but is probably not a major cause of deforestation. Clear cutting and overgrazing have turned large areas of Qinghai province in China into a desert. Overgrazing are causing large areas of grasslands north of Beijing and in Inner Mongolia and Qinghai province to turn into a desert. One man who lived in a village on the eastern edge of the Qinghai-Tibet plateau that was being swallowed up by sand told the New York Times, "The pasture here used to be so green and rich. But now the grass is disappearing and the sand is coming." Huge flocks of sheep and goats strip the land of vegetation. In Xillinggol Prefecture in Inner Mongolia, for example, the livestock population increased from 2 million in 1977 to 18 million in 2000, turning one third of the grassland area to desert. Unless something is done the entire prefecture could be uninhabitable by 2020. Overgrazing is exacerbated by sociological phenomena called "the tragedy of the common." People share land but raises animals for themselves and try to enrich them by rising as many as they can. This leads to more animals than the land can support. Grassland in Qinghai that can support 3.7 million sheep had 5.5 million sheep in 1997. Animals remove the vegetation and winds finished the job by blowing away the top soil, transforming grasslands into desert. When a herder was asked why he was grazing goats next to a sign that said "Protect vegetation, no grazing," he said, "The lands are too infertile to grow crops—herding is the only way for us to survive." (Hays, 2008 web page).

3.1.5 Fires

Fires are a major tool used in clearing the forest for shifting and permanent agriculture and for developing pastures. Fire is a good servant but has a poor master. Fire used responsibly can be a valuable tool in agricultural and forest management but if abused it can be a significant cause of deforestation (Repetto, 1988; Rowe *et al.*, 1992). Based on the data available from 118 countries representing 65 per cent of the global forest area, an average of 19.8 million hectares or one per cent of all forests were reported to be significantly affected

each year by forest fires (Anon., 2010). Deforestation due to road pavements in Brazil had also lead to higher incidences of forest fires (Carvalho *et al.*, 2001; Nepstad *et al.*, 2001).

3.1.6 Mining

Mining is very intensive and very destructive (Mather, 1991; Sands, 2005). The area of land involved is quite small and it is not seen as a major cause of primary deforestation. Mining is a lucrative activity promoting development booms which may attract population growth with consequent deforestation. The deforestation rate due to mining activities in Guyana from 2000 to 2008 increased 2.77 times according to an assessment by the World Wildlife Fund-Guianas (Staff, 2010). Similarly, in the Philippines, mining, along with logging, has been among the forces behind the country's loss of forest cover: from 17 million hectares in 1934 to just three million in 2003 or an 82 per cent decline (Docena, 2010). Nearly 2,000 hectares of tropical forest in the Municipality of Coahuayana in the State of Michoacán (south-western Mexico) will completely be destroyed by mining iron minerals planned by the Italo-Argentine mining company TERNIUM (Anonymous, 2008). Similarly, Nyamagari hills in Orissa India currently threatened by Vedanta Aluminum Corporation's plan to start bauxite mining will destroy 750 hectares of reserved forest (Griffiths and Hirvelä, 2008). Massive and unchecked mining of coal, iron ore and bauxite in Jharkhand, India has caused large scale deforestation and created a huge water scarcity (Anon., 2011_b). In return for US\$3.8 billion of investment, the agreements between the State government of Jharkhand, India and mining companies, there will be a massive land acquisition which will deforest no less than 57,000 hectares of forest and displace 9,615 families, many of them located in legally protected Scheduled Areas set aside for indigenous peoples in the State (Mullick and Griffiths, 2007). Moreover, Roads constructed to support the mining operations will open up the area to shifting agriculturists, permanent farmers, ranchers, land speculators and infrastructure developers. For instance the core of Brazil's Amazon development strategy were infra-structure development projects such as roads providing access to frontier regions, mining area and large hydroelectric reservoirs (Mahar, 1988; Fearnside and Barbosa, 1996; Carvalho *et al.*, 2002, 2004). The construction of roads, railways, bridges, and airports opens up the land to development and brings increasing numbers of peoples to the forest frontier. If wood is used as fuel in mining operations and it is sources from plantations established for the purpose, it can cause serious deforestation in the region. On the other hand, mining can be labour intensive and take labour away from clearing forest.

3.1.7 Urbanization/industrialization and infra-structure

Expanding cities and towns require land to establish the infrastructures necessary to support growing population which is done by clearing the forests (Mather, 1991; Sands, 2005). Tropical forests are a major target of infra-structure developments for oil exploitation, logging concessions or hydropower dam construction which inevitably conveys the expansion of the road network and the construction of roads in pristine areas (Kaimowitz and Angelsen, 1998). The construction of roads, railways, bridges, and airports opens up the land to development and brings increasing numbers of people to the forest frontier. Whether supported or not by the governmental programmes, these settlers have usually colonized the forest by using logging trails or new roads to access

the forest for subsistence land (Wilkie *et al.*, 2000; Amor, 2008; Amor and Pfaff, 2008). (Wilkie *et al.*, 2000; Amor, 2008; Amor and Pfaff, 2008). The development of these infrastructure projects are of worldwide concern, since tropical forest clearing accounts for roughly 20 per cent of anthropogenic carbon emissions destroying globally significant carbon sinks (Anon., 2001c) and around 21 per cent of tropical forests have been lost worldwide since 1980 (Bawa *et al.*, 2004).

3.1.8 Air pollution

Air pollution is associated with degradation of some European and North American forests. The syndrome is called "Waldsterben" or forest death. In 1982, eight per cent of all West German trees exhibited damage that rose to about 52 per cent by 1987 (Raloff, 1989) and half of the trees reported dying of Waldsterben in the Alps (Lean, 1990). High elevation forests show the earliest damage including forests in the north-east and central United States.

3.1.9 Wars and role of the military

It is well established that military operations caused deforestation during the Vietnam War and elsewhere (Mather, 1991; Sands, 2005). More recently, linkages have been documented between the civil war in Myanmar and the timber trade between Myanmar and Thailand. Myanmar regime sells timber to the Thais to finance its civil war against the Karen hill tribe. Forest destruction in El Salvador has resulted from war. Apart from military involvements in wars, the role of military in deforestation has been documented in Southeast Asia and South America (Mather, 1991; Sands, 2005). The authors also observed that role of powerful military in Brazilian politics are a major cause of Amazonian forest destruction.

3.1.10 Tourism

National parks and sanctuaries beyond doubt protect the forests, but uncautioned and improper opening of these areas to the public for tourism is damaging. Unfortunately, the national governments of tropical and sub-tropical countries adopt tourism for easy way of making money sacrificing the stringent management strategies. Further, many companies and resorts who advertise themselves as eco-tourist establishments are in fact exploiting the forests for profit. In Cape Tribulation, Australia, for example, the rain forest is being threatened by excessive tourism (Colchester and Lohmann, 1993). Similarly, in the Terai Duars of eastern India foothill Himalaya, eco-tourism is encouraged and we fear this is being done without developing adequate management plans. For instance, the Chilapatta Reserve Forest in this area is opened for eco-tourism for its ancient ruins deep in the forest and a tree species *Myristica longifolia* that exudes a blood like sap when injured. The site has become a popular eco-tourist destination because of the ruins and for this blood exuding tree. In the whole forest only eight individuals were found but two of the trees in the near vicinity of the ruins completely dried away due to repeated injuries caused to the plants by the curious tourists (Shukla, 2010). In fact, in the name of eco-tourism, infra-structure development is taking place mostly by the private players in these wilderness areas which are further detrimental in terms of attracting peoples other than tourists also, causing deforestation especially deep in the forest.

3.2 Indirect causes

The World Rainforest Movement's 'Emergency Call to Action for the forests and their Peoples' asserts that "deforestation is the inevitable result of the current social and economic policies being carried out in the name of development" (Anon., 1990_a). It is in the name of development that irrational and unscrupulous logging, cash crops, cattle ranching, large dams, colonisation schemes, the dispossession of peasants and indigenous peoples and promotion of tourism is carried out. Harrison Ngau, an indigenous tribesman from Sarawak, Malaysia and winner of the Goldman Environment Award in 1990 puts the cause of tropical deforestation like this, "the roots of the problem of deforestation and waste of resources are located in the industrialized countries where most of our resources such as tropical timber end up. The rich nations with one quarter of the world's population consume four fifth of the world's resources. It is the throw away culture of the industrialized countries now advertised in and forced on to the Third World countries that is leading to the throwing away of the world. Such so-called progress leads to destruction and despair" (Anon., 1990_a)! Such a development leads to overconsumption which is the basic underlying cause of deforestation.

3.2.1 Colonialism

Erstwhile colonies of the colonial powers like Britain, France, Spain or Portugal are now the Third World Countries or the developing nations mostly have the tropical rainforests except Australia and Hawaii were exploited for their natural resources and their indigenous people's rights destroyed by the colonial powers. All these countries have indigenous populations who had their own system of land management and/or ownership in place for thousands of years before the intervention of colonists from rich industrialized nations. Colonialism turned previously self-sufficient economies into zones of agriculture export production. This process continues even today in different form of exploitation and the situation is worsening (Colchester and Lohmann, 1993).

3.2.2 Exploitation by industrialized countries

Wealthy countries or the erstwhile colonial powers having deficit of their own natural resources are mainly sustaining on the resources of the financially poorer countries those are generally natural resource rich. Twenty per cent of the world's population is using 80 per cent of the world's resources. Unfortunately also the governments of these poor resource rich countries had generally adopted the same growth-syndrome as their western neighbours or their erstwhile colonial master giving emphasis on maximizing exports, revenues and exploiting their rich natural resources unsustainably for short-term gains. Moreover, corruption in government, the military and economic powers is well known. The problem is further worsened by the low price of the most Third World exports being realized in the international market (Colchester and Lohmann, 1993).

3.2.3 The debt burden

Pursuing the guided development agenda, the financially poorer countries are on a heavy international debt and now feeling the urgency of repaying these huge debts due to escalating interest rates. Such a situation compels these debt ridden poorer countries to

exploit their rich natural resources including their forests partly to earn foreign exchange for servicing their debts. For instance, construction of roads for logging operations in some South-east Asian countries was funded by Japanese aid which allowed the Japanese timber companies to exploit the forests of these countries. Understandably, these timber companies profitably exploited the forests while the South-east Asian countries were left owing Japan money for construction of their roads (Colchester and Lohmann, 1993).

3.2.4 Overpopulation and poverty

The role of population in deforestation is a contentious issue (Mather, 1991; Colchester and Lohmann, 1993; Cropper and Griffiths, 1994; Ehrhardt-Martinez, 1998; Sands, 2005). The impact of population density on deforestation has been a subject of controversy. Poverty and overpopulation are believed to be the main causes of forest loss according to the international agencies such as FAO and intergovernmental bodies. It is generally believed by these organizations that they can solve the problem by encouraging development and trying to reduce population growth. Conversely, the World Rainforest Movement and many other NGOs hold unrestrained development and the excessive consumption habits of rich industrialized countries directly responsible for most forest loss. However there is good evidence that rapid population growth is a major indirect and over-arching cause of deforestation. More people require more food and space which requires more land for agriculture and habitation. This in turn results in more clearing of forests. Arguably increasing population is the biggest challenge of all to achieve sustainable management of human life support systems and controlling population growth is perhaps the best single thing that can be done to promote sustainability. Overpopulation is not a problem exclusive to Third World countries. An individual in an industrialized country is likely to consume in the order of sixty times as much of the world's resources as a person in a poor country. The growing population in rich industrialized nations are therefore responsible for much of the exploitation of the earth and there is a clear link between the overconsumption in rich countries and deforestation in the tropics (Colchester and Lohmann, 1993).

Poverty and overpopulation are inextricably linked. Poverty, while undeniably responsible for much of the damage to rainforests, has to a large extent been brought about by the greed of the rich industrialized nations and the Third World elites who seek to emulate them. Development is often regarded as the solution to world poverty, seldom helps those whose need is greatest. Thus, it is often the cause rather than the cure for poverty. The claim that overpopulation is the cause of deforestation is used by many governments and aid agencies as an excuse for inaction. In tropical countries, pressure from human settlement comes about more from inequitable land distribution than from population pressure. Generally, most of the land is owned by small but powerful elite which displaces poor farmers into rainforest areas. So long as these elites maintain their grip on power, lasting land reform will be difficult to achieve (Colchester and Lohmann, 1993) and deforestation continues unabated. Therefore poverty is well considered to be an important underlying cause of forest conversion by small-scale farmers and naturally forest-dense areas are frequently associated with high levels of poverty (Chomitz *et al.*, 2007). The population also often lacks the finance necessary for investments to maintain the quality of soil or increase yields on the existing cleared land (Purnamasari, 2010). Deforestation is affected mainly by the uneven distribution of wealth. Shifting cultivators at the forest frontier are among the poorest and most marginalized sections of the population. They usually own no land and have little

capital. Consequently they have no option but to clear the virgin forest. Deforestation including clearing for agricultural activities is often the only option available for the livelihoods of farmers living in forested areas (Angelsen, 1999).

3.2.5 Transmigration and colonisation schemes

Transmigration of people to the forest frontier whether forced or voluntary due to development policy or dislocation from war is the major indirect cause of deforestation (Mather, 1991; Colchester and Lohmann, 1993; Sands, 2005). Moreover, governments and international aid agencies earlier believed that by encouraging colonisation and transmigration schemes into rainforest areas could alleviate poverty of the areas in the financially poorer countries. Such schemes have miserably failed but hurted the indigenous people and the environment. In Indonesia, the *Transmigrasi* Program of 1974 had caused annual deforestation of two lakh hectares (Colchester and Lohmann, 1993). Dispossessed and landless people bring increased population pressure to the forest frontier. Further, new migrants in the area increase demand for food and other agricultural products which can induce the farmers at the forest frontier to increase their agricultural production by expanding agricultural land by clearing the forests (Levang, 2002). Moreover, the new migrants may not care for conservation of the forests in their new home which further accelerates deforestation of the area.

3.2.6 Land rights, land tenure and inequitable land distribution and resources

Cultivators at the forest frontier often do not hold titles to land (absence of property rights) and are displaced by others who gain tenure over the land they occupy (Mather, 1991; Deacon, 1999; Sands, 2005). This means they have to clear more forest to survive. Poorly defined tenure is generally bad for people and forests (Chomitz *et al.*, 2007). In many countries government have nominal control of forests but are too weak to effectively regulate their use. This can lead to a tragedy of the commons where forest resources are degraded. In frontier areas deforestation is a common practice and legalized way of declaring claim to land and securing tenure (Schneider, 1995).

3.2.7 Economic causes - development/land conversion value, fiscal policies, markets and consumerism

The relationship between development and deforestation is complex and dynamic (Humphreys, 2006; Mather, 1991; Sands, 2005). One point of view is that development will increase land productivity and thereby reduce the need to clear forests to meet food requirements. Another is that development will produce further capital and incentive to expand and clear more forest. The former may be the case when constrained by a fixed food demand. The latter may be the case when food demand may not be satisfied owing to a continuing export market and rising internal population with rising levels of consumption. Profits from deforestation vary from less than a dollar to thousand dollars per hectare depending on location, technologies and land use systems (Chomitz *et al.*, 2007). It is also argued by the workers that richer farmers were better able to finance deforestation while a poor farmer can't afford to clear much forest. Conversely, through transfers, stronger credit markets and better opportunities for off-season employment can increase income as well as deforestation by small land holders. Moreover, land offering

higher rents encourage quicker deforestation. Higher prices for crops and lower prices for farm inputs also spur faster deforestation (Chomitz *et al.*, 2007). Wage increase can also stimulate deforestation (Barbier and Cox, 2004). Technological innovations make farming more profitable either prompting the expansion of farms into forest or attract new farmers to forest frontiers (Angelsen and Kaimowitz, 2001; Angelsen, 2006). Even when the increase in commodity price is only temporary, it tends to raise expectation about future prices, increasing the expected probability from land clearance and conversion to agriculture (Angelsen, 1995; Sunderlin *et al.*, 2000). Many development policies have failed because they have supported either wittingly or unwittingly the development of those who already have land, power, influence and political clout. This further alienates the rural poor and puts the pressure back on the forests.

Poor farm households or commercial loggers have little incentive to care about the environmental effects of their actions. Such unaccounted costs give rise to economic failures such as local market failures, policy failures and global appropriation failures (Panayotou, 1990). Market fails due to unregulated market economy which does not produce an optimal outcome. Prices generated by such market does not reflect the true social costs and benefits from resource use and convey misleading information about resource scarcity, providing inadequate incentives for management, efficient utilization and enhancement of natural resources. Policy failures or market distortions are result of misguided intervention or unsuccessful attempts to mitigate failures resulting in worse outcomes (Panayotou, 1990). For instance, lack of respect of traditional land rights make property rights to forest land uncertain and could encourage short-term exploitation of forests rather than long-term sustainable use. Further, global appropriation failures occur as in the case of tropical forests—the benefits of biodiversity conservation and the value of the genetic pool in developing new medicines, crops and pest control agents are poorly reflected in market allocations. For instance, it was argued that improved terms of trade for agricultural and forest product exports and higher real exchange rates make it more profitable to convert forests to other uses (Capistrano, 1994; Southgate, 1994; Kant and Redantz, 1997). The initial empirical analysis done by Scricieiu (2003) appears to confirm that tropical deforestation is caused by the drive for maximizing profits within the agricultural sector. Rampant consumerism by the developed countries frequently has been claimed as a major reason for tropical deforestation. The opening of tropical countries to the world commodity markets accelerated deforestation. The products include coffee, sugar, bananas, cotton and beef in Central America and oil palm, rubber and timber in Southeast Asia.

3.2.8 Undervaluing the forest

Forests gain value only when they are cleared for obtaining legal title through 'improvement' (Mather, 1991; Sands, 2005). The extraction of non-wood forest products has been suggested as a way to add value to the forest but it is not economical when compared to clearing options. If some means could be devised where those who benefit from the environmental values could pay the forest owners or agents of deforestation for them, then the option to not clear would become more competitive. Alternatively, if the national governments value the environmental benefits, it could apply a tax or disincentives to clear. However, even though maintenance of the environmental services is essential for sustained economic development, deforesting nations usually have more immediate goals and are unprepared to take this step.

3.2.9 Corruption and political cause

The FAO identified forest crime and corruption as one of the main causes of deforestation in its 2001 report and warned that immediate attention has to be given to illegal activities and corruption in the world's forests in many countries (Anon., 2001b). Illegal forest practices may include the approval of illegal contracts with private enterprises by forestry officers, illegal sale of harvesting permits, under-declaring volumes cut in public forest, underpricing of wood in concessions, harvesting of protected trees by commercial corporations, smuggling of forest products across borders and allowing illegal logging, processing forest raw materials without a license (Contreras-Hermosilla, 2000; 2001).

4. Effects of deforestation

4.1 Climate change

It is essential to distinguish between microclimates, regional climate and global climate while assessing the effects of forest on climate (Gupta *et al.*, 2005) especially the effect of tropical deforestation on climate (Dickinson, 1981). Deforestation can change the global change of energy not only through the micrometeorological processes but also by increasing the concentration of carbon dioxide in the atmosphere (Pinker, 1980) because carbon dioxide absorbs thermal infrared radiation in the atmosphere. Moreover deforestation can lead to increase in the albedo of the land surface and hence affects the radiation budget of the region (Charney, 1975; Rowntree, 1988; Gupta *et al.*, 2005). Deforestation affects wind flows, water vapour flows and absorption of solar energy thus clearly influencing local and global climate (Chomitz *et al.*, 2007). Deforestation on lowland plains moves cloud formation and rainfall to higher elevations (Lawton *et al.*, 2001). Deforestation disrupts normal weather patterns creating hotter and drier weather thus increasing drought and desertification, crop failures, melting of the polar ice caps, coastal flooding and displacement of major vegetation regimes. In the dry forest zones, land degradation has become an increasingly serious problem resulting in extreme cases in desertification (Dregne, 1983). Desertification is the consequence of extremes in climatic variation and unsustainable land use practices including overcutting of forest cover (Anon., 1994b).

Global warming or global change includes anthropogenically produced climatic and ecological problems such as recent apparent climatic temperature shifts and precipitation regimes in some areas, sea level rise, stratospheric ozone depletion, atmospheric pollution and forest decline. Tropical forests are shrinking at a rate of about five per cent per decade as forests are logged and cleared to supply local, regional, national and global markets for wood products, cattle, agricultural produce and biofuels (Anon., 2007; 2010). One of the most important ramifications of deforestation is its effect on the global atmosphere. Deforestation contributes to global warming which occurs from increased atmospheric concentrations of greenhouse gases (GHG) leading to net increase in the global mean temperature as the forests are primary terrestrial sink of carbon. Thus deforestation disrupts the global carbon cycle increasing the concentration of atmospheric carbon dioxide. Tropical deforestation is responsible for the emission of roughly two billion tonnes of carbon (as CO₂) to the atmosphere per year (Houghton, 2005). Release of the carbon dioxide due to global deforestation is equivalent to an estimated 25 per cent of emissions from combustion of fossil fuels (Asdrasko, 1990).

4.2 Water and soil resources loss and flooding

Deforestation also disrupts the global water cycle (Bruijnzeel, 2004). With removal of part of the forest, the area cannot hold as much water creating a drier climate. Water resources affected by deforestation include drinking water, fisheries and aquatic habitats, flood/drought control, waterways and dams affected by siltation, less appealing water-related recreation, and damage to crops and irrigation systems from erosion and turbidity (Anon., 1994_a; Bruijnzeel *et al.*, 2005). Urban water protection is potentially one of the most important services that forest provides (Chomitz *et al.*, 2007). Filtering and treating water is expensive. Forests can reduce the costs of doing so either actively by filtering runoff or passively by substituting for housing or farms that generate runoff (Dudley and Stolton, 2003). Deforestation can also result into watersheds that are no longer able to sustain and regulate water flows from rivers and streams. Once they are gone, too much water can result into downstream flooding, many of which have caused disasters in many parts of the world. This downstream flow causes soil erosion thus also silting of water courses, lakes and dams. Deforestation increases flooding mainly for two reasons. First, with a smaller 'tree fountain' effect, soils are more likely to be fully saturated with water. The 'sponge' fills up earlier in wet season, causing additional precipitation to run off and increasing flood risk. Second, deforestation often results in soil compaction unable to absorb rain. Locally, this causes a faster response of stream flows to rainfall and thus potential flash flooding (Chomitz *et al.*, 2007). Moreover deforestation also decrease dry season flows.

The long term effect of deforestation on the soil resource can be severe. Clearing the vegetative cover for slash and burn farming exposes the soil to the intensity of the tropical sun and torrential rains. Forest floors with their leaf litter and porous soils easily accommodate intense rainfall. The effects of deforestation on water availability, flash floods and dry season flows depend on what happens to these countervailing influences of infiltration and evapotranspiration- the sponge versus the fountain (Bruijnzeel, 2004). Deforestation and other land use changes have increased the proportion of the basin subject to erosion and so over the long run have contributed to siltation. Heavy siltation has raised the river bed increasing the risk of flooding especially in Yangtze river basin in China, the major river basins of humid tropics in East Asia and the Amazonian basin (Yin and Li, 2001; Bruijnzeel, 2004; Aylward, 2005, Bruijnzeel *et al.*, 2005; van Noordwijk *et al.*, 2006).

4.3 Decreased biodiversity, habitat loss and conflicts

Forests especially those in the tropics serve as storehouses of biodiversity and consequently deforestation, fragmentation and degradation destroys the biodiversity as a whole and habitat for migratory species including the endangered ones, some of which have still to be catalogued. Tropical forests support about two thirds of all known species and contain 65 per cent of the world's 10, 000 endangered species (Myers and Mittermeier, 2000). Retaining the biodiversity of the forested areas is like retaining a form of capital, until more research can establish the relative importance of various plants and animal species (Anon., 1994_a). According to the World Health Organization, about 80 per cent of the world's population relies for primary health care at least partially on traditional medicine. The biodiversity loss and associated large changes in forest cover could trigger abrupt, irreversible and harmful changes. These include regional climate change including feedback effects that could theoretically shift rainforests to savannas and the emergence of new pathogens as the growing trade in bushmeat increases contact between humans and animals (Anon., 2005).

Another negative effect of deforestation is increasing incidents of human-animal conflicts hitting hard the success of conservation in a way alienating the people's participation in conservation. Elephant habitat located at northern West Bengal in India is part of the Eastern Himalaya Biodiversity Hotspot which is characterized by a high degree of fragmentation. The heavy fragmentation of this habitat has resulted into an intense human-elephant conflict causing not only in loss of agricultural crops but also human and elephant lives. Mortality of about 50 persons and 20 elephants was reported due to these severe human-elephant conflicts from this hotspot area annually (Sukumar *et al.*, 2003; Mangave, 2004).

4.4 Economic losses

The tropical forests destroyed each year amounts to a loss in forest capital valued at US \$ 45 billion (Hansen, 1997). By destroying the forests, all potential future revenues and future employment that could be derived from their sustainable management for timber and non-timber products disappear.

4.5 Social consequences

Deforestation, in other words, is an expression of social injustice (Colchester and Lohmann, 1993). The social consequences of deforestation are many, often with devastating long-term impacts. For indigenous communities, the arrival of civilization usually means the destruction/change of their traditional life-style and the breakdown of their social institutions mostly with their displacement from their ancestral area. The intrusion of outsiders destroys traditional life styles, customs and religious beliefs which intensifies with infra-structure development like construction of roads which results into frontier expansion often with social and land conflicts (Schmink and Wood, 1992).

The most immediate social impact of deforestation occurs at the local level with the loss of ecological services provided by the forests. Forests afford humans valuable services such as erosion prevention, flood control, water treatment, fisheries protection and pollination-functions that are particularly important to the world's poorest people who rely on natural resources for their everyday survival. By destroying the forests we risk our own quality of life, gamble with the stability of climate and local weather, threaten the existence of other species and undermine the valuable services provided by biological diversity.

5. Strategies to reduce deforestation

Ways to reducing deforestation must go hand in hand with improving the welfare of cultivators at the forest frontier. Any policy that does without the other is unacceptable. There are no general solutions and strategies since these will vary with region and will change over time. All strategies require cooperation and goodwill. Effective implementation is essential including stakeholder participation, development of management plans, monitoring and enforcement. The strategies should be such that on one hand they should recognize the critical roles of national, state and municipal governments and on other hand empower the civil society and the private sector to take a pro-active role in reducing deforestation, often working in conjunction with government.

5.1 Reduce population growth and increase per capita incomes

Reduction of population growth is pivotal in reducing deforestation in the developing countries. Consequent of reduced population, increase in per capita income will occur as a consequence of increased incomes and literacy rates which will reduce pressure on the remaining forests for new human settlement and land use change.

5.2 Reducing emissions from deforestation and forest degradation

Many international organizations including the United Nations and the World Bank have begun to develop programmes to curb deforestation mainly through Reducing Emissions from Deforestation and Forest Degradation (REDD) which use direct monetary or other incentives to encourage developing countries to limit and/or roll back deforestation. Significant work is underway on tools for use in monitoring developing country adherence to their agreed REDDS targets (Chomitz *et al.*, 2007).

5.3 Increase the area and standard of management of protected areas

The provision of protected areas is fundamental in any attempt to conserve biodiversity (Myers, 1994; Myers and Mittermeier, 2000; Nepstad *et al.*, 2006). Protected areas alone, however, are not sufficient to conserve biodiversity. They should be considered alongside, and as part of, a wider strategy to conserve biodiversity. The minimum area of forest to be protected is generally considered to be 10 per cent of total forest area. It is reported that 12.4 per cent of the world's forest are located within protected areas. Tropical and temperate forests have the highest proportions of their forests in protected areas and boreal forests have the least. The Americas have the greatest proportion while Europe the least proportion of protected areas (Anon., 2010).

5.4 Increase the area of forest permanently reserved for timber production

The most serious impediment to sustainable forest management is the lack of dedicated forests specifically set aside for timber production. If the forest does not have a dedicated long-term tenure for timber production then there is no incentive to care for the long-term interests of the forest. FAO (2001) found that 89 per cent of forests in industrialized countries were under some form of management but only about six per cent were in developing countries. If 20 per cent could be set aside, not only could timber demand be sustainably met but buffer zones could be established to consolidate the protected areas. This would form a conservation estate that would be one of the largest and most important in the world (Anon., 2001_a).

5.5 Increase the perceived and actual value of forests

There are several ways of achieving increasing the perceived and actual value of forests. Governments can impose realistic prices on stumpage and forest rent and can invest in improving the sustainable productivity of the forest. National and international beneficiaries of the environmental services of forests have to pay for such services (Chomitz *et al.*, 2007). There has been some success in devising schemes to collect payments for environmental services like carbon sequestration, biodiversity conservation, catchment protection and

ecotourism. This success can further be more realized by integrating participatory mode of management with these collection schemes to ensure rights and tenure with equity in resource and benefit sharing for improving the livelihood of the rural poor who actually are the primary stakeholders of conservation and management.

5.6 Promote sustainable management

In order to promote sustainable forest management, it must be sustainable ecologically, economically and socially. Achieving ecological sustainability means that the ecological values of the forest must not be degraded and if possible they should be improved. This means that silviculture and management should not reduce biodiversity, soil erosion should be controlled, soil fertility should not be lost, water quality on and off site should be maintained and that forest health and vitality should be safeguarded. However, management for environmental services alone is not economically and socially sustainable. It will not happen until or unless the developing nations have reached a stage of development and affluence that they can accommodate the costs of doing so. Alternatively, the developed world must be prepared to meet all the costs (Chomitz *et al.*, 2007; Anon., 2010; 2011). There are vast areas of unused land as discussed earlier some of which is degraded and of low fertility. Technological advances are being made to bring this land back into production. This should be a major priority since a significant proportion of cleared tropical forest will eventually end up as degraded land of low fertility.

5.7 Encouraging substitutes

For all purposes where tropical or other timber is used, other woods or materials could be substituted. We can stop using timber and urge others to do the same. As long there is a market for wood products, trees will continue to be cut down. Labelling schemes, aimed at helping consumers to choose environmental friendly timbers are currently being discussed in many countries (Anon., 1990_d).

5.8 Increase area of forest plantation

Increasing the area of forest plantations by using vacant or unused lands and waste and marginal lands especially as road side, along railway tracts, on contours, avenues, boundaries and on land not suited for agricultural production should have a net positive benefit. Planting trees outside forest areas will reduce pressure on forests for timber, fodder and fuelwood demands. Moreover the deforested areas need to be reforested.

5.9 Strengthen government and non-government institutions and policies

Strong and stable government is essential to slow down the rate of deforestation. FAO (2010) considered that half of the current tropical deforestation could be stopped if the governments of deforesting countries were determined to do so (Anon., 2010). Environmental NGO's contribution towards conservation management has been enormous. They have the advantage over government organizations and large international organizations because they are not constrained by government to government bureaucracy and inertia. They are better equipped to bypass corruption and they are very effective at getting to the people at the frontier who are in most need.

5.10 Participatory forest management and rights

In frontier areas much of the forest is nominally owned by the state, but the reach of government and the rule of law are weak and property rights insecure. In order for forest management to succeed at the forest frontier, all parties with an interest in the fate of the forest should be communally involved in planning, management and profit sharing. But forest ownership and management rights are almost always restricted and restrictions on ownership and use define alternative tenure systems. The balance of rights can be tilted strongly toward society in the form of publicly owned strictly protected areas. State ownership and management can be retained but with sustainable timber extraction allowed. As of now much of the world's tropical forest are state owned but community participation in forest ownership and management needs to be encouraged with restrictions on extraction and conversion (Chomitz *et al.*, 2007). Land reform is essential in order to address the problem deforestation. However an enduring shift in favour of the peasants is also needed for such reforms to endure (Colchester and Lohmann, 1993). Moreover the rights of indigenous forest dwellers and others who depend on intact forests must be upheld. Therefore, the recognition of traditional laws of the indigenous peoples as indigenous rights will address the conflicts between customary and statutory laws and regulations related to forest ownership and natural resource use while ensuring conservation of forest resources by the indigenous communities. Central to this is the right to 'Prior Informed Consent', ensuring the indigenous communities to know what they are agreeing to. A means must be found to reconcile conservation and development by involving local/indigenous populations more closely in the decision-making process and by taking the interactions between 'societies' and forest resource more fully into account (Chakravarty *et al.*, 2008).

5.11 Support and reforms

Aid organizations like the World Bank have traditionally favoured spectacular large-scale development al projects. In all cases when such projects are proposed there has been a massive opposition from local people. Reducing the demand for southern-produced agribusiness crops and alleviating the pressure from externally-financed development projects and assistance is the essential first/primary step (Colchester and Lohmann, 1993). Campaigns opposing such developments and the campaigns to reform the large aid agencies which fund such schemes should be supported. Local campaigns against specific mining, dams, industrial and tourist developments should be supported. Further reform of the World Bank and other such organizations is largely the demand of time.

5.12 Increase investment in research, education and extension

Training and education of stakeholder's helps people understand how to prevent and reduce adverse environmental effects associated with deforestation and forestry activities and take appropriate action when possible. Research substantiates it and helps to understand the problem, its cause and mitigation. This arena is lagging behind for paucity of funds and investments encourages this arena. There is a lack of knowledge and information in the general community about forests and forestry. Forest managers and those developing forest policies need to be comprehensively educated and need to appreciate the complexity of the interacting ecological, economical, social, cultural and political factors involved.

5.13 Improve the information base and monitoring

Information on the global distribution of biodiversity and forest poverty is inadequate. Knowledge of how much forest, where it is and what it is composed of seems to be straightforward but surprisingly this most basic information is not always available. It is not possible to properly manage a forest ecosystem without first understanding it. New remote sensing technologies make it feasible and affordable to identify hotspots of deforestation. The international community could undertake monitoring efforts that would have immediate payoffs. A priority is to fund and coordinate basic monitoring on the rate, location and causes of global deforestation and forest poverty along with the impacts of project and policy interventions. Without this information, policy makers are flying blind and interest groups lack a solid basis for dialogue (Chomitz *et al.*, 2007).

5.14 Policy, legislative and regulatory measures-enforcement and compliance

A wide variety of policy statements and legislative and regulatory measures have been established to protect forests but need to be effectively enforced. New modifications/adjustments are of course needed for site specific conditions. Laws, policy and legislation should be such that they encourages local people and institutional participation in forestry management and conservation along with safeguarding indigenous people's traditional rights and tenure with rightful sharing of benefits. Many formal and informal enforcement/compliance mechanisms are used to prevent deforestation and environmental problems from forestry activities. These approaches include negotiation, warnings, cancelling work orders, notices of violation, fines, arrests and court action.

6. Conclusion

Economic globalization combined with the looming global land scarcity increases the complexity of future pathways of land use change. In a more interconnected world, agricultural intensification may cause more rather than less cropland expansion. The apparent tradeoff between forest and agriculture can be minimized through spatial management and the use of degraded or low competition lands (Lambin and Meyfroidt, 2011). This can be further addressed by community based forest management which builds on political goodwill and strong community institutions. New challenges from climate change require urgent action to explore and protect the local value of forests for livelihood even more. This is particularly true in the case of emerging activities undertaken as part of REDD+ activities where broad forest governance are aligned with it along with people's participation ensuring livelihood benefits of the people dependant on forests. These renewed activities will safeguard traditional ways of life and the environmentally important forest ecosystems of the world.

7. References

- Amor, D. 2008. *Road impact on deforestation and jaguar habitat loss in the Selva Maya*. Ph. D. dissertation. Ecology Department, Nicholas School of the Environment, Duke University.

- Amor, D. and Pfaff, A. 2008. *Early history of the impact of road investments on deforestation in the Mayan forest*. Working Paper, Nicholas School of the Environment and Sanford School of Public Policy, Duke University, Durham, NC, USA.
- Angelsen, A. 1995. Shifting cultivation and deforestation: a study from Indonesia. *World Development* 23: 1713-1729.
- Angelsen, A. 1999. Agricultural expansion and deforestation: modeling the impact of population, market forces and property rights. *Journal of Development Economics* 58: 185-218.
- Angelsen, A. 2006. *A stylized model of incentives to convert, maintain or establish forest*. Background Paper for World Bank Policy Research Report entitled "At Loggerheads: Agricultural Expansion, Poverty reduction and Environment in the tropical forests- 2007".
- Angelsen, A. and Kaimowitz, D. 2001. *Agricultural technologies and tropical deforestation*. CABI Publishing, Wallingford, United Kingdom.
- Angelsen, A.; Shitindi, E. F. K. and Aarrestad, J. 1999. Why do farmers expand their land into forests? Theories and evidence from Tanzania. *Environment and Development Economics* 4: 313-31.
- Anonymous. 1990_a. *The Forest Resources of the Temperate Zones, Vol. II*. FAO, Rome.
- Anonymous. 1990_b. *Situation and outlook of the Forestry Sector in Indonesia, Vol. 1: Issues, findings and opportunities*. Ministry of Forestry, Government of Indonesia; FAO, Jakarta.
- Anonymous. 1990_c. *Indonesia: sustainable development of forests, land and water*. The World Bank, Washington DC.
- Anonymous. 1990_d. *Rainforest destruction: causes, effects and false solutions*. World Rainforest Movement, Penang Malaysia.
- Anonymous. 1991. *The Forest Sector*. The World Bank, Washington DC.
- Anonymous. 1992_a. *Forest Products: Yearbook 1991*. FAO, Rome.
- Anonymous. 1992_b. *Violated Trust: Disregard for the Forests and Forests Laws of Indonesia*. The Indonesian Environmental Forum (WALHI), Jakarta Indonesia.
- Anonymous. 1994_a. *Deforestation Technical Support Package*. Third International Conference on Environment Enforcement, Oaxaca Mexico April 25-28, 1994. World Wildlife Fund; U. S. Environmental Protection Agency and U. S. Agency for International Development.
- Anonymous. 1994_b. *Breaking the logjam: obstacles to forestry policy reform in Indonesia and the United States*. World Resource Institute, Washington.
- Anonymous. 1994_c. *Indonesia: Environment and Development*. The World Bank, Washington DC.
- Anonymous, 2001_a. *Global Forest Resources Assessment 2000-Main Report*. FAO Forestry Paper 140. Rome, Italy.
- Anonymous. 2001_b. *State of the World's Forest 2001*. FAO, Rome Italy.
- Anonymous 2001_c. *Climate Change 2001: Synthesis Report. Contribution of working groups I, II, III to the 3rd assessment report of the IPCC*. IPCC, Cambridge University Press, Cambridge.
- Anonymous. 2002. *Forest certification and biodiversity: opposites or complements?* Discussion paper prepared for the GEF, International Tropical Timber Organization, Yokohama Japan.

- Anonymous. 2005. *Ecosystems and Human well-being: synthesis*. Millennium ecosystem Assessment. Island Press, Washington DC.
- Anonymous. 2007. Three Essential Strategies for Reducing Deforestation. Alianca da Terra, Amigos da Terra, Instituto Centro de Vida, IMAZON, Instituto de Pesquisa da Amazonia, Instituto Socio Ambiental, Nucleo de Estudos e Pratica Juridica Ambiental, Faculdade de Direito- Universidade Federal de Mato Grosso, Woods Hole Research Center and David and Lucile Packard Foundation.
- Anonymous. 2008. Mexico: Mining causes ecocide in Coahuayana, Michoacan. *WRM's bulletin* N° 136, November 2008.
- Anonymous, 2010. *Global Forest Resources Assessment, 2010-Main Report*. FAO Forestry Paper 163. Rome, Italy. 340p.
- Anonymous, 2011a. *State of the World's Forest*. FAO, Rome. 163p.
- Anonymous. 2011b. Mining, deforestation cause severe drought. March 5 *The Asian Age*, New Delhi.
- Ascher, W. 1993. *Political economy and problematic forestry policies in Indonesia: obstacles to incorporating sound economics and science*. The Center for Tropical Conservation, Duke University.
- Asdrasko, K. 1990. *Climate Change and Global Forests: Current Knowledge of Political Effects, Adaptation and Mitigation Options*. FAO, Rome.
- Aylward, B. 2005. Land use, hydrological function and economic valuation. In: *Forest, water and people in the humid tropics*, eds. Bonell, M. and Bruijnzeel, L. A. Cambridge University Press, Cambridge United Kingdom.
- Barbier, E. B. and Cox, M. 2004. An economic analysis of Shrimp farm expansion and mangrove conversion in Thailand. *Land Economics* 80: 389-407.
- Barbier, E. B.; Burgess, J. C. and Folke, C. 1994. *Paradise lost? The ecological economics of biodiversity*. Earthscan.
- Barbier, E. B.; Bockstael, N.; Burgess, J. C.; and Strand, I. 1993. *The timber trade and tropical deforestation in Indonesia*. LEEC Paper DP 93-01. Environmental Economics Centre, London.
- Barracough, S. and Ghimire, K. B. 2000. *Agricultural Expansion and Tropical Deforestation*. Earthscan.
- Bawa, K. S.; Nadkarni, N.; Lele, S.; Raven, P.; Janzen, A.; Lugo, A.; Ashton, P. and Lovejoy, T. 2004. Tropical ecosystems into the 21st Century. *Science* 306: 227-230.
- Bhatnagar, P. 1991. *The Problem of Afforestation in India*. International Book Distributors, Dehra Dun.
- Bruijnzeel, L. A. 2004. Hydrological functions of tropical forests: not seeing the soils for the trees? *Agriculture, Ecosystems and Environment* 104: 185-228.
- Bruijnzeel, L. A.; Bonell, M.; Gilmour, D. A. and Lamb, D. 2005. Forest, water and people in the humid tropics: an emerging view. In: *Forest, Water and People in the humid tropics*, eds. Bonell, M. and Bruijnzeel, L. A. Cambridge University Pres, Cambridge United Kingdom.
- Bryant, D.; Nielsen, D. and Tanglely, L. 1997. *The last frontier forests- Ecosystems and Economies on the Edge*. World Resource Institute, Washington DC.
- Capistrano, A. D. 1994. Tropical forest depletion and the changing macroeconomy 1967-85. In: *The Causes of Tropical of Tropical Deforestation. The economic and statistical analysis*

- of factors giving rise to the loss of the tropical forest*, eds. Brown, K. and Pearce, D. pp 65-85. UCL Press.
- Carvalho, G.; Barros, A. C.; Moutinho, P. and Nepstad, D. 2001. Sensitive development could protect Amazonia instead of destroying it. *Nature* 409: 131.
- Carvalho, G.; Moutinho, P.; Nepstad, D.; Mattos, L. and Santilli, M. 2004. An Amazon perspective on the forest-climate connection: opportunity for climate mitigation, conservation and development? *Environment, Development and Sustainability* 6: 163-174.
- Carvalho, G.; Nepstad, D.; McGrath, D.; Del Carmen Vera Diaz, M.; Suntilli, M. and Barros, A. C. 2002. Frontier expansion in the Amazon: balancing development and sustainability. *Environment* 44: 34-42.
- Caviglia, J. 1999. *Sustainable Agriculture in Brazil. Economic Development and Deforestation*. Edward Elgar.
- Chakravarty, S.; Shukla, G.; Malla, S. and Suresh, C. P. 2008. Farmer's rights in conserving plant biodiversity with special reference to North-east India. *Journal of Intellectual Property Rights* 13: 225-233.
- Charney, J. G. 1975. Dynamics of deserts and drought in the Sahel. *Quarterly Journal of Royal Meteorological Society* 101: 193-202.
- Chomitz, K. M. and Griffiths, C. 1996. *Deforestation, shifting cultivation and tree crops in Indonesia: nationwide patterns of smallholder agriculture at the forest frontier*. Research Project on Social and Environmental Consequences of Growth-Oriented Policies, Working Paper 4. World Bank, Washington DC.
- Chomitz, K. M.; Buys, P.; Luca, G. D.; Thomas, T. S. and Wertz-Kanounnikoff, S. 2007. *At loggerheads? Agricultural expansion, poverty reduction and environment in the tropical forests*. World Bank Policy Research Report. World Bank, Washington DC.
- Colchester, M. And Lohmann, L. 1993. *The Struggle for land and the fate of forest*. Zed books, London.
- Contreras-Hermosilla, A. 2000. *The underlying causes of forest decline*. CIFOR Occasional Paper No. 30. CIFOR, Bogor, Indonesia.
- Contreras-Hermosilla, A. 2001. Illegal activities and corruption in the forest sector. In: *State of the World's Forest 2001*, ed. FAO. Pp 76-89. FAO, Rome.
- Cossalter, C. and Pye-Smith, C. 2003. *Fast-wood forestry, myths and realities*. CIFOR, Bogor Indonesia.
- Cropper, M and Griffiths, C. 1994. The interaction of population growth and environmental quality. *American Economic Review* 84: 250-254.
- Dauvergne, P. 1994. The politics of deforestation in Indonesia. *Pacific Affairs* 66: 497-518.
- Deacon, R. T. 1999. Deforestation and ownership: evidence from historical accounts and contemporary data. *Land Economics* 75: 341-359.
- Dickinson, R. E. 1981. *Effects of tropical deforestation on climate*. In *blowing in the wind, deforestation and language implications*. *Studies in third world societies*, Publ. No. 14. Dept of Anthropology, College of William and Mary, Williamsburg Virginia. Pp 411-441.
- Dick., J. 1991. *Forest land use, forest use zonation and deforestation in Indonesia: a summary and interpretation of existing information*. Background paper to UNCED for the state

- Ministry for Population and Environment (KLH) and the Environmental Impact Management Agency (BAPEDAL).
- Docena, H. 2010. Philippines: Deforestation through mining subsidized by CDM project. *WRM's bulletin N° 161*, December 2010.
- Dove, M. R. 1993. Smallholder rubber and swidden agriculture in Borneo: a sustainable adaptation to the ecology and economy of the tropical forest. *Economic Botany* 47: 136-147.
- Dove, M. R. 1996. So far from power, so near to the forest: a structural analysis of gain and blame in tropical development. In: *Borneo in transition: people, forests, conservation and development*, eds. Padoch, C. and Peluso, N. L. Pp 41-58. Oxford University Press, Kuala Lumpur.
- Dregne, H. E. 1983. *Desertification of Arid lands*. Harwood Academia Publishers, London.
- Dudley, N. and Stolton, S. 2003. *Running Pure*. World Bank and WWF, Washington DC.
- Ehrhardt-Martinez, K. 1998. Social determinants of deforestation in developing countries: A cross-national study. *Social Forces* 77: 567-586.
- Fearnside, P. and Barbosa, R. 1996. The Cotingo dam as a test of Brazil's system for evaluating proposed developments in Amazonia. *Environmental Management* 20: 631-648.
- Griffiths, T. and Hirvelä, V. V. 2008. India: Illegal aluminum refinery in Tribal lands in Orissa. *WRM's bulletin N° 126*, January 2008.
- Gupta, A.; Thapliyal, P. K.; Pal, P. K. and Joshi, P. C. 2005. Impact of deforestation on Indian monsoon- A GCM sensitivity study. *Journal of Indian Geophysical Union* 9: 97-104.
- Hays, J. 2008. Deforestation and desertification in China.
<http://factsanddetails.com/china.php?itemid=389&catid=10&subcatid=66>
- Hansen, C. P. 1997. *Making available information on the conservation and utilization of forest genetic resources*. The FAO Worldwide Information System on Forest genetic resources.
- Houghton, R. A. 2005. Tropical deforestation as a source of greenhouse gas emissions. In: *Tropical deforestation and Climate change*, eds. Moutinho, P. and Schwartzman, S. Pp 13-20. Amazon Institute for Environmental Research, Belem Brazil.
- Humphreys, D. 2006. *Forest Politics*. Earthscan Publications Ltd., London.
- Kaimowitz, D. and Angelsen, A. 1998. *Economic models of tropical deforestation. A review*. Center for International Forestry Research, Bogor Indonesia.
- Kant, S. and Redantz, A. 1997. An econometric model of tropical deforestation. *Journal of Forestry Economics* 3: 51-86.
- Kartodihardjo, H. and Supriono, A. 2000. *The impact of sectoral development on natural forest conversion and degradation: the case of timber and tree crop plantations*. CIFOR Occasional Paper No. 26, Bogor Indonesia.
- Lambin, E. F. and Meyfroidt, P. 2011. Global land use change, economic globalization, and the looming land scarcity. *PNAS* 108: 3465-3472.
- Lawton, R. O.; Nair, U. S.; Pielke Sr., R. A. and Welch, R. M. 2001. Climatic impact of tropical lowland deforestation on nearby Montane Cloud Forests. *Science* 294: 584-587.
- Lean, G. 1990. *World Wildlife Fund Atlas of the Environment*. Prentice Hall, New York.

- Levang, P. 2002. People's dependencies on forests. In *Technical Report, Phase I 1997-2001. ITTO Project PD 12/97 Rev. 1 (F) - Forest, Science and Sustainability: the Bulungan model forest*, pp 109-130. CIFOR, Bogor Indonesia.
- Mahar, D. 1988. *Government policies and Deforestation in Brazil's Amazon region*. World Bank, Washington DC.
- Mangave, H. R. 2004. *A study of Elephant population and its habitats in the northern West Bengal, North East India*. M. Sc. Thesis, Bharathidasan University. Unpubl.
- Mather, A. S. 1991. *Global Forest Resources*. International Book Distributors, Dehra Dun.
- Mullick, B. and Griffiths, T. 2007. India: Indigenous movement in Jharkhand challenge plans for industrial development that threatens to destroy Adivasi forests, farmlands and way of life. *WRM's bulletin* N° 116, March 2007.
- Myers, N. 1992. *The Primary Source: Tropical Forests and Our Future*. Norton, New York.
- Myers, N. 1994. Tropical deforestation: rates and patterns. In: *The Causes of Tropical of Tropical Deforestation. The economic and statistical analysis of factors giving rise to the loss of the tropical forest*, eds. Brown, K. and Pearce, D. pp 27-40. UCL Press.
- Myers, N. and Mittermeier, R. A. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853-854.
- Nepstad, D. C.; Carvalho, G.; Barros, A. C.; Alencar, A.; Capobianco, J. P.; Bishop, J.; Moutinho, P.; Lefebvre, P.; Lopes Silva, Jr. U. and Prins, E. 2001. Road paving, fire regime and the future of Amazon forests. *Forest Ecology and Management* 154: 395-407.
- Nepstad, D. C.; Schwartzmann, S.; Bamberger, B.; Santilli, M.; Ray, D.; Schlesinger, P.; Lefebvre, P.; Alencar, A.; Prinz, E.; Fiske, G. and Rolla, A. 2006. Inhibition of Amazon deforestation and fire by parks and indigenous lands. *Conservation Biology* 20: 65-73.
- Panayotou, T. 1990. *The economics of environmental degradation: problems, causes and responses*, HIID Development discussion papers 335. Harvard University.
- Pearce, D. and Brown, K. 1994. Saving the world's tropical forests. In: *The Causes of Tropical of Tropical Deforestation. The economic and statistical analysis of factors giving rise to the loss of the tropical forest*, eds. Brown, K. and Pearce, D. pp 2-26. UCL Press.
- Pinker, R. 1980. The microclimate of a dry tropical forest. *Agricultural Meteorology* 22: 249-265.
- Porter, G. 1994. The environmental hazards of Asia Pacific development: the Southeast Asian Rainforests. *Current History* 93: 430-434.
- Purnamasari, R. S. 2010. Dynamics of small-scale deforestation in Indonesia: examining the effects of poverty and socio-economic development. *Unasyloa* 61: 14-20.
- Putz, F. E.; Blate, G. M.; Redford, K. H.; Fimbel, R. and Robinson, J. 2001. Tropical forest management and conservation of biodiversity: An overview. *Conservation Biology* 15: 7-20.
- Raloff, J. 1989. Where Acids Reign. *Science News* July 22. Pp 56-58.
- Repetto, R. 1988. *The forest for the trees? Government policies and the misuse of forest resources*. World Resource Institute, Washington DC.
- Repetto, R. 1990. *Deforestation in the Tropics*. Scientific American April, p. 37.

- Ross, 1996. Conditionality and logging reform in the tropics. In: *Institutions for Environmental Aid: Problems and Prospects*, eds. Keohane, R. O. and Leve, M. A. Pp 167-197. MIT Press, Cambridge Massachusetts.
- Rowe, R.; Sharma, N. P. and Bowder, J. 1992. Deforestation: problems, causes and concern. In: *Managing the world's forest: looking for balance between conservation and development*, ed. Sharma, N. P. Pp 33-46. Kendall/Hunt Publishing Company, Iowa.
- Rowntree, P. R. 1988. Review of General Circulation Models as a basis for predicting the effects of vegetation change on climate. In: *Forests, climate and hydrology, regional impacts*, eds. Reynolds, E. R. C. and Thompson, F. B., Pp 162-196. The United Nations University, Tokyo Japan.
- Sands, R. 2005. *Forestry in a Global Context*. CABI Publishing.
- Schmink, M. and Wood, C. 1992. *Contested Frontiers in Amazonia*. Columbia University Press, New York.
- Schneider, R. R. 1995. *Government and economy on the Amazon frontier*. Environment Paper 11. World Bank, Washington DC.
- Scrieciu, S. S. 2003. *Economic causes of tropical deforestation- a global empirical application*. Development Economics and Public Policy Working Paper 4. Institute of Development Policy and Management, University of Manchester.
- Sheram, K. 1993. *The Environmental Data Book*. The World Bank, Washington DC.
- Shukla, G. 2010. *Biomass production and vegetation analysis of Chilapatta Reserve Forest Ecosystem of West Bengal*. Ph. D. Thesis, Uttar Banga Krishi Viswavidyalaya, Pundibari. Unpublished.
- Southgate, D. 1994. Tropical deforestation and agricultural development in Latin America. In: *The Causes of Tropical of Tropical Deforestation. The economic and statistical analysis of factors giving rise to the loss of the tropical forest*, eds. Brown, K. and Pearce, D. pp 134-43. UCL Press.
- Staff, S. 2010. Mining deforestation nearly tripled between 2000-08. *Archives*, Wednesday October 13 2010.
- Sukumar, R.; Baskaran, N.; Dharmrajan, G.; Roy, M.; Suresh, H. S. and Narendran, K. 2003. *Study of the elephants in Buxa Tiger Reserve and adjoining areas in northern West Bengal and preparation of Conservation Action Plan. Final Report*. Center for Ecological Sciences, Indian Institute of Science, Bangalore.
- Sunderlin, W. D.; Resosudarmo, I. A. P.; Rianto, E. and Angelsen, A. 2000. *The effect of Indonesia's economic crisis on small farmers and natural forest cover in the outer islands*. CIFOR Occasional Paper No. 28 (E). CIFOR, Bogor Indonesia.
- Thiele, R. 1994. How to manage tropical forests: the case of Indonesia. *Intereconomics* 29: 184-193.
- Van Kooten, G. C. and Bulte, E. H. 2000. *The economics of nature: managing biological assets*. Blackwells.
- Van Noordwijk, M.; Agus, F.; Verbist, B.; Hairiah, K. and Tomich, T. P. 2006. Managing watershed services in ecoagriculture land-scapes. In: *The State-of-the-Art of Ecoagriculture*, eds. McNeely, J. A. and Scherr, S. J. Island Press, Washington DC.
- Wilkie, D.; Shaw, E.; Rotberg, F.; Morelli, G. and Auzels, P. 2000. Roads, development and conservation in the Congo Basin. *Conservation Biology* 14:1614-1622.

Yin, H. and Li, C. 2001. Human impacts on floods and flood disasters on the Yangtze River. *Geomorphology* 41: 105-109.

INTECH

INTECH



Global Perspectives on Sustainable Forest Management

Edited by Dr. Dr. Clement A. Okia

ISBN 978-953-51-0569-5

Hard cover, 300 pages

Publisher InTech

Published online 25, April, 2012

Published in print edition April, 2012

This book is dedicated to global perspectives on sustainable forest management. It focuses on a need to move away from purely protective management of forests to innovative approaches for multiple use and management of forest resources. The book is divided into two sections; the first section, with thirteen chapters deals with the forest management aspects while the second section, with five chapters is dedicated to forest utilization. This book will fill the existing gaps in the knowledge about emerging perspectives on sustainable forest management. It will be an interesting and helpful resource to managers, specialists and students in the field of forestry and natural resources management.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Sumit Chakravarty, S. K. Ghosh, C. P. Suresh, A. N. Dey and Gopal Shukla (2012). Deforestation: Causes, Effects and Control Strategies, Global Perspectives on Sustainable Forest Management, Dr. Dr. Clement A. Okia (Ed.), ISBN: 978-953-51-0569-5, InTech, Available from: <http://www.intechopen.com/books/global-perspectives-on-sustainable-forest-management/deforestation-causes-effects-and-control-strategies>

INTECH

open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821