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REPORT ON GLOBAL WARMING AND ASSOCIATED IMPACTS

(PHASE I)

TATA ENERGY RESEARCH INSTITUTE
NEW DELHI

REPORT ON GLOBAL WARMING AND ASSOCIATED IMPACTS

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Tata Energy Research Institute
New Delhi

PREFACE

This report represents the first formal output provided by the Tata Energy Research Institute to the Ministry of Environment and Forests from the project entitled "Professional and Analytical Support on Global Warming and Climate Change". Prior to this report, TERI was privileged to be associated with the technical preparation for and providing support to the International Conference of Select Developing Countries on Global Environmental Issues, organised by the Ministry.

Global negotiations and discussions are likely to intensify in the next few years, as the positions of specific countries and groups become clearer and the impacts of speciic agreements or decisions become better known and quantified. Several countries of the world, particularly the industrialised nations have mobilised a vast array of researchers and institutions to help them in producing analytical work required for current discussions, such as the work of the Inter-governmental Panel for Climate Change (IPCC). In fact, in several cases, governments appear to be going even further and orchestrating the opinions and analyses of specific experts to support positions that appear politicaly preferable to governments themselves. The Ministry of Environment and Forests, while taking the step of setting up an Expert Advisory Committee to advise on global environmental matters, has also awarded this project to TERI to provide regular and wide analytical advice to the Ministry.

In preparation of this report, TERI has mobilised a large number of researchers within the Institute and has recruited professionals where necessary to work exclusively on the activities that have resulted in the submission of this report. The primary authors of each of the chapters in this report are mentioned in the contents, but an equal number of researchers have assisted in various ways by performing portions of the work required for analysis of the problems covered, and for producing this report itself. TERI would very much look forward to comments and feedback from the Ministry so that specific areas of emphasis could be taken in hand for the third report which would be submitted in about a year from now. Meanwhile, work is already in hand for preparation and submission of the second report due towards the end of this year.

Finally, my colleagues and I are deeply appreciative of the opportunity provided to us by the Ministry for working closely on an area of vital importance to this country.

R.K. Pachauri
Director
Tata Energy Research Institute

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FOREST BIOMASS BURNING IN INDIA

O.N. Kaul

INTRODUCTION

There seems to be growing scientific evidence that increasing atmospheric concentration of "Greenhouse Gases" (GHGs) will alter the global climate, thus threatening global security, the world economy and the natural environment. Various human activities are now increasing the concentration of greenhouse gases in the earth's atmosphere, thereby intensifying the "Greenhouse Effect" and causing "Global Warming". It has been estimated (Ahuja, 1989) that 22,718 Tg of CO_2 (1 Tg = 1 Teragram = 10^{12} gm), 1,102 Tg of CO, 350 Tg of CH_4, 5.0 Tg of NO_2 and 1.77 Tg of Chloroflourocarbons (CFCs), with 20% uncertainity, are being emitted annually, into the earth's atmosphere, globaly, from anthropogenic sources and 4% of these emissions originate from India excluding any contribution that may occur from tropospheric O_3 and some other trace gases like NO_x. This contribution could rise with increasing developmental activities in the country.

The contribution of various GHGs and policy sectors to global warming indicate (UNEP, 1989) that rising concentrations of atmospheric CO_2 are likely to be responsible for about 50% of global warming over the next several decades, the other half being due to other GHGs (CFCs, CH_4, O_3, N_2O, etc in that order). As regards the contribution of various policy sectors to global warming the greatest potential is from energy (49%) and industrial (24%) sectors but more than one-quarter (27%) of potential warming is from biological sectors of forestry and agriculture;

forestry contributing about 14% through forest biomass burning and deforestation.

Biomass burning results in the emission of all the four inorganic GHGs, namely, CO_2, CH_4, CO , and N_2O, the emissions of CO_2 contributing to greenhouse warming only to the extent that these emissions are in excess of that fixed in photosynthesis. Of the global emissions of various GHGs, from anthropogenic sources, mentioned in Para 1, 61% CO, 16% CH_4 and 44% N_2O is attributed to biomass burning for energy and non-energy related sources (Ahuja, 1989). Further, it is estimated that 6,800 Tg of biomass (dry matter) is burnt annually, world-wide, (Crutzen et al, 1979) of which about 496 Tg (7.3% of global) is burnt in India. Accordingly, the emissions of various GHGs like CO, CH_4, N_2O, from India, as Tg per year have been calculated to be of the order of 48.5, 4.1, and 0.2 respectively (Ahuja, 1989). These emissions have to be taken with necessary reservations as they are fraught with major uncertainities and externalities due to lack of information, data, and statistics on various aspects of biomass burning like areas burnt, biomass densities, fractions of biomass burnt, burning efficiencies etc., but all the same they are a pointer in the right direction, for taking any effective action that may be necessary.

An attempt has been made in the present paper to identify the various sources/activities of forest biomass burning in India, and thereby estimate the various types of forest biomass burnt annually, in recent years, in the context of estimation of emissions of GHGs. The estimates mentioned in this paper are at best only indicative of the nature and extent of the problem due to extreme paucity of information and data on the subject and uncertainity of certain parameters. As such they have to be taken with due reservations. Much better information and statistics are needed to make these estimates more realistic and dependable.

TERRESTRIAL BIOMASS AND CARBON FLUXES

The influence of terrestrial biomass on the atmospheric carbon cycle is potentially very large, though very difficult to estimate. With about 700 Pg (1 Pg = 1 Petagram = 10^{15} gm) present in the atmosphere as CO_2, 600 to 1000 Pg in the land biota and a world-wide carbon detritus pool estimated to be in the range of 700-3,000 Pg (Seiler and Crutzen, 1980) or even more (Table 1, Houghton and Woodwell, 1989), it is clear that carbon shifts in land biota and detritus pools can result in important changes of CO_2 in the atmosphere.

Table 1. Major carbon reservoirs of the World

Reservoir	Size of Reservoir (10^9 Metric tons)
World Vegetation	560
World Soils	1,500
Atmosphere	735
Oceans	36,000
Fossil Fuel Reserves	5,000 to 10,000

Some recent studies have shown that global terrestrial biomass is decreasing with time, mostly due to deforestation in tropical and subtropical regions, so that the biosphere, currently, is acting as a large net source of atmospheric CO_2. The release of CO_2 into the atmosphere has been estimated in recent years by several authors using different pathways and methods, which are, unfortunately, often not well documented and clear (Seiler, and Crutzen, 1980). It is also clear that there exist major discrepancies in the published net and gross carbon fluxes between the oceans, the biosphere and the atmosphere.

The reported net releases vary widely ranging from 0.5 Pg C to more than 8 Pg C per year, to which should be added the net input of 5.6 Pg C per year from burning of fossil fuels to get the total input of CO_2 into the atmosphere (Seiler and Crutzen, 1980). A recent estimate of annual carbon fluxes is given in Table 2 (Houghton and Woodwell, 1989) which indicates a net gain of 3.00 billion tonnes of carbon as CO_2 by the atmosphere, as a result of various removals and emissions.

Table 2. Annual carbon fluxes

Source	Removals of Carbon from atmosphere as CO_2 (10^9 Metric tons)	Emissions of Carbon into atmospher as CO_2 (10^9 Metric tons)
Photosynthesis	100	-
Respiration by plants	-	30
Soil respiration	-	50
Fossil fuel burning	-	5
Deforestation	-	2
Physicochemical processes at the sea surface	104	100
Total	204	207
Net gain to atmosphere ----- 3.0 billion tonnes		

SOURCES OF FOREST BIOMASS BURNING

The various sources/activities of <u>forest</u> <u>biomass</u> burning identified in the context of emission of GHGs are as follows:

- Fuelwood
- Shifting cultivation
- Forest fires
    - Unregulated fires
    - Prescribed burning
        - Natural regeneration
        - Protection fires
        - Plantations
- Forest encroachments
- Forest area lost
- Burning of grasses in forests
- Burning of forest litter

The above sources/activities identified are briefly discussed hereafter.

Fuelwood

In common with many developing countries, India, consumes energy in various forms ranging from electricity obtained from nuclear fuels to agriculture waste and animal dung. The most important commercial sources of energy are coal, oil and electricity;the details regarding production and consumption of these forms of energy being regularly recorded by the concerned agencies. The production and consumption data of the most significant sources of non-commercial energy sources (fuelwood, agricultural waste, and animal dung) are very scanty (except the recorded production from Government forests) and are derived by computations based on the quantity of energy required in the households, population growth, economic development and such other factors influencing the consumption of these forms of energy.

A considerable amount of forest biomass, in India, is annually burnt as fuelwood, the proportion of fuelwood, agriculture waste and animal dung in the total non-commercial energy sector being estimated to be 65%, 20% and 15% respectively (Anon., 1979). While the recorded removals from Government forests supply only a fraction of the fuelwood consumed in the country (about 25%), the bulk of the fuelwood supply comes from the so called "Unrecorded Sources" which include supply from private lands, gardens, trees around houses, shifting cultivation areas and the like. However, a large quantity of fuelwood is collected from the nearby forests, by the local population, as a matter of right and this removal does not find a record anywhere. Similarly, there is a lot of pilferage (illicit removal) from the nearby forests which meets a large part of the fuelwood needs of the neighbouring population and such removals also go unrecorded. In fact, most of the fuelwood being used in the rural areas is collected mainly from the nearby forests and people collect fuelwood from distant forests only when no firewood is available nearby.

Based mainly on per capita consumption, population growth, economic development as well as the availability of alternative sources of energy, various estimates of consumption/demand projections of fuelwood in India have been made by different agencies (Table 3) from time to time for the period 1953-54 to 2004-2005. While the figures in Table 3 generally indicate a substantial rise in the requirement of fuelwood in the country by the year 2000 and 2005, there is a great variation in the estimates projected in these studies. For example, the National Commission on Agriculture indicated the requirement for fuelwood in India for the years 1980, 1985 and 2000 as 123, 134.7 and 150 million tonnes (Anon., 1976). The report of the Working Group on Energy Policy has projected the demands of fuelwood as 139.7, 138.7, 134 and 111.9 million tonnes for the years 1982-83, 1987-88, 1992-93

Table 3. Consumption/Demand projections of fuelwood

Year	Estimates of Consumption/Demand Projections (Million Tonnes)						
	(5) (8) (13) (15) (30)	(4)	(12)	(15)	(18)	(14)	(34)
1953-54	86.3						
1960-61	99.6						
1965-66	109.3						
1970-71	117.9						
1975-76	133.1						
1980		123.0					
1982-83	139.7						
1985		134.7	120-130				
1987				157.0			
1987-88	138.7						
1991					306.5		
1992-93	134.0						
1996					342.8		
1999-2000						191.6	
2000		150.0					
2000-01	111.9						
2001					383.6		256.7
2004-05			300-330				

Note : Figures in brackets on top of each column indicate the references of the estimates.

and 2000-01 (Anon., 1979), the demand showing a decreasing trend because of the presumed availability of alternative sources of energy. A recent study of the Planning Commission (Anon., 1989) has placed the demand projections of fuelwood at 306.5, 342.8 and 383.6 million tonnes for the years 1991, 1996 and 2001. However, the Seventh Five Year Plan document of the Planning Commission has estimated the fuelwood requirement of 191.60 million tonnes for 1999-2000 (Anon., 1987). The Advisory Board for Energy has forcast the demand for fuelwood in the country as 300-330 million tonnes in 2005 (Anon., 1985 a).

With such large variations in consumption/demand projections of fuelwood presented in Table 3, it becomes necessary that these estimates are reconciled before a final set of figures is adopted for the present study. It is also to be noted that the fuelwood consumption in the country is going to rise, in the foreseeble future, atleast in the rural sector, due to the present energy crises and the difficulty of alternative sources of energy being available more freely and cheaply. Plant biomass would, therefore, remain a major source of energy in the near future.

In order, therefore, to obtain any dependable estimates of consumption/demand projections of fuelwood for different years, eight observations of consumption/demand projections in Table 3 (these observations were considered to be more realistic for various reasons including past consumptions) were plotted against the corresponding years and a regression worked out. The consumption/demand projections for different years were then calculated using the regression equation:

$$Y = -4268.58 + 2.228 \times X$$

where Y is the consumption/demand projection in million tonnes and X is the year of consumption/demand projection. The values so obtained are set out in Table 4 (Col.2) and range from 82.70 million tonnes in 1953 to 154 million tonnes in 1985, 187.42 million tonnes in the year 2000 and 198.56 million tonnes in 2005. These values of consumption/demand projections appear to be reasonably correct looking at past consumptions and the rate of growth and have been adopted in the present study.

Table 4 (Col.3) also indicates the quantity of fuelwood available for burning, on a dry weight basis, in different years from 1953 to 2005. The values range from 74.43 million tonnes in 1953 to 138.60 million tonnes in 1985, 168.69 million tonnes in the year 2000 and 178.70 million tonnes in 2005.

Table 4. Consumption/Demand patterns of fuelwood

Year	Consumption/Demand Projections (Million Tonnes)	Dry Weight (Million Tonnes)	Fuelwood Burnt (Million Tonnes)
(1)	(2)	(3)	(4)
1953	82.70	74.43	66.99
1960	98.30	88.47	79.62
1965	109.44	98.49	88.64
1970	120.58	108.54	97.69
1975	131.72	118.55	106.69
1980	142.86	128.57	115.71
1985	154.00	138.60	124.74
1990	165.14	148.63	133.77
1995	176.28	158.65	142.79
2000	187.42	168.69	151.82
2005	198.56	178.70	160.83

Notes: 1) Figures in Col.2 are those obtained from the regression equation.

2) Figures in Col.3 are dry weights of the figures in Col.2 which are on air dry basis having an average moisture content of 10%.

3) Figures in Col.4 are based on the assumption that the overall burning efficiency of fuelwood is 90%.

Though burning of fuelwood is almost complete, as a first approximation an overall burning efficiency of 90% could be assumed. The actual quantity of wood, therefore, burnt annually as fuel, in different years, is shown in Col. 4 of Table 4, the remaining quantity being left as Charcoal. In terms of million tonnes of fuelwood burnt/ to be burnt annually, in different years, the values respectively are 66.99, 124.74, 151.82 and 160.83 for the years 1953, 1985, 2000 and 2005.

Shifting cultivation

Shifting Cultivation (or Jhumming, as the practice is commonly known in India), a legacy from the neolithic period is practised in about 16 states of the country (being most prevelant in the seven Northeastern states and Orissa), with very deep roots and very wide ramifications, as the tribal group system of cultural and ethenic mores is typical of the area and has resisted change for a very long time. It is rooted in the cultural ethos of the tribal societies, and although their traditional economy has evolved to some extent, the constraints imposed by the environment and the increasing population combined with shrinking resources have invariably led to short term adaptations with possibilities of disaster in the long run.

In its simplest form the practice consists of clearing a forest area of its vegetation during the winter months of November - December and allowing the cut vegetation to dry up till March - April of the following year, when it is burnt *in situ* after making a fire line around the Jhum plot. This is followed by raising of agricultural crops in mixtures which are harvested sequentially as the crop matures. The Jhumed plot is then abandoned, and the cultivator moves to another plot during the next winter season for Jhumming, allowing the previous plot to regenerate to be Jhumed again after keeping it fallow for some years.

While clearing the land for Jhumming, the cultivator slashes down the undergrowth, bamboos and smaller trees, while larger trees may often be left behind, along with stumps of smaller trees due to difficulties of extraction because of the high labour input involved or to speed up fallow regeneration or provide shade to the crops grown. These larger trees may, therefore, remain on the Jhum plot through successive Jhum cycles till they are burnt in a Jhum operation or are extracted by the cultivator . In certain cases the slashing of vegetation may be partial in that the undergrowth is completely cut down and the very sparsely distributed trees may merely be topped along with their branches so that they are able to recuperate quickly during the fallow period when the second-growth vegetation comes up. Depending on the accessibility of the area, some timber, bamboos and fuelwood may be extracted by the cultivator, while clearing the plot for Jhumming, for his personal consumption and/or for export outside the village for monetary returns.

Adequate data about the extent of forest area affected by shifting cultivation or the annual area put under this practice are not available, in the absence of any regular surveys and transitory nature of the practice, except for very rough estimates mostly based on small samples and intellegent guesses. The earlier estimate (1956) places the annual area involved in shifting cultivation at 0.542 million ha and the number of tribal families affected at 529 thousand, with a population of 2.645 million (Kaith, 1958) or a mean family size of five. The later estimates made by various agencies, from time to time, are set in Tables 5.1, 5.2 and 5.3 and are discussed hereafter.

Tables 5.1, 5.2, and 5.3 present the extent of shifting cultivation, respectively, on an all India basis, for the Northeastern states (7 states) of the country and for Northeastern states and Orissa state together. It is observed that, on an all India basis (Table 5.1), the total area affected by shifting cultivation has increased by 81.2% (from 2.710 to 4.912 million ha) during the period 1956 to 1984-85. Correspondingly the annual area under this practice has also gone up from 0.542 to 1.000 million ha (84.5%) in the same period. The total population involved has increased by 17.6% from (2,645 to 3,110 thousand) for the period 1956 to 1983 with a corresponding increase in the number of familie, from 529 to 622 thousand (17.6%). As a result the area cultivated per family has also risen by 56.9%, form 1.02 to 1.60 ha between 1956 and 1983. In this analysis certain observations in Table 5.1 (Col.2), regarding the total area affected by shifting cultivation in different years have been excluded, for obvious reasons, particularly for the years 1977 and 1984.

The position with regard to extent of Jhumming in the Northeastern states, where it is most prevelant, is shown in Table 5.2 . While there are certain inconsistancies with regard to the estimates of total area affected by shifting cultivation, as well as the annual area under this practice (Cols. 2 and 3), made by various agencies for different years (these inconsistancies are bound to occur as the estimates are not based on any actual surveys but on rough intelligent guesses), generally, both the total area affected by shifting cultivation and the annual area have increased during the period 1956 to 1984-85. The annual area has increased by 41.8% from 0.273 to 0.387 million ha (Col. 3), while the total area affected has risen from 1.365 to nearly two million ha (46.5%) during the same period (Col. 2). Increasing trends are also observed in the total population involved in Jhumming as also the number of families (Cols. 5 and 6). While the total population has gone up from 1,249 to

Table 5.1. Extent of shifting cultivation in India: (All India)

Estimates for the Year	Total Area Affected by Shifting Cultivation (Million Hectares)	Annual Area Under Shifting Cultivation (Million Hectares)	Col (3) as % of Col (2)	Total Population Involved (000)	No. of Families Involved (000)	Mean Family Size	Area Cultivated per Family (HA)	No. Of Communities Practising Shifting Cultivation	Reference
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1956	(2.710)	0.542	20.0	2,645	529	5	1.02	109	(25)
1960-61	2.705	0.541	20.0	2,589	(518)	-	1.04	-	(2)
1977	9.470	-	-	-	-	-	-	-	(21)
1983	4.357	0.996	22.9	(3,110)	622	-	1.60	-	(9)
1984	6.770	0.990	14.6	-	-	-	-	-	(10)
1984-85	4.912	1.000	20.4	-	-	-	-	-	(17)

Note: (1) Figures in brackets are calculated values taking a mean family size of 5.
(2) Figures in brackets under Col.2 are calculated values taking a Jhum cycle of 5 years.

2,215 thousand (73.3% increase) during the years 1956 to 1983, the total number of families (Col.6) has increased by 77.2% (250 to 443 thousand) during the same period. The area cultivated per family (Col.8) seems to be almost constant, if not decreased (1956 to 1983), being around one hectare per family, even though there has been a population increase. This could be possible because of the land constraint and the fact that a number of schemes are presently in operation in the Northeastern states to wean away the people from this practice.

As Jhumming is also extensively practised in Orissa, Table 5.3 indicates the extent of this practice in the Northeastern states and Orissa together. Excluding the data for the years 1977 and 1984, an increasing trend is observed in the total area affected by shifting cultivation (Col. 2), annual area jhumed (Col. 3), total population and number of families involved (Cols. 5 and 6) and the area cultivated per family (Col.8), during the period 1956 to 1983 and 1984-85 ; the respective percentage increases being of the order of 110.2, 117.8 ,29.8, 29.8 and 66.7.

Table 5.2. Extent of shifting cultivation in India: (North-eastern States)

Estimates for the Year	Total Area Affected by Shifting Cultivation	Annual Area Under Shifting Cultivation	Col (3) as % of Col (2)	Total Population Involved (000)	No. of Families Involved (000)	Mean Family Size	Area Cultivated per Family (HA)	No. Of Communities Practising Shifting Cultivation	Reference
	Million Hectares								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1956	(1.365)	0.273	20.0	1,249	250	5	1.09	22	(25)
1960-61	1.360	0.272	20.0	1,258	(252)	-	1.08	-	(2)
1971	2.695	0.457	16.9	(2,125)	425	-	1.08	-	(31)
1974	2.696	0.455	16.8	(2,125)	425	-	1.07	-	(24)
1975	2.696	0.456	16.8	-	-	-	-	-	(3)
1975	7.341	-	-	-	-	-	-	-	(19)
1976	2.696	0.455	16.8	(2,460)	492	-	0.92	-	(4)
1977	7.341	-	-	-	-	-	-	-	(21)
1983	1.352	0.387	28.6	(2,215)	443	-	0.88	-	(9)
1984	2.800	0.416	14.9	-		-	-	-	(10)
1984	6.285	-	-	-	-	-	-	-	(19)
1984-85	1.908	0.387	20.3	-	-	-	-	-	(17)

Note: (1) Figures in brackets are calculated values taking a mean family size of 5.
(2) Figures in brackets under Col.2 are calculated values taking a Jhum cycle of 5 years.

The above percentage increases are significant, to be taken note of, when compared to percentage increases (mentioned earlier) on an all India basis and for the Northeastern states only, to indicate the substantial contribution of Orissa to Jhumming. For example, while the annual area under shifting cultivation, during the period 1956 to 1984-85, has increased by 84.5% and 41.8%, respectively, on an all India basis and for the Northeastern states, there has been a rise of 117.8% for the Northeastern states and Orissa put together. The same is the case with regard to the annual area affected by Jhumming as well as the area cultivated per family.

The data presented in Table 6, on the annual extent of and total area affected by shifting cultivation for the period 1956 to 1984-85, on an all India basis, Northeastern states and Northeastern states and Orissa together is also striking as far as the contribution of Orissa state is concerned. Of the One million ha (Col.2) under shifting cultivation in the country, in 1984-85, Northeastern states and Orissa together account for 91.7% of the area and the balance (8.3%)is contributed by the other eight states. Out of the 91.7% area under Jhumming in Northeastern states and Orissa, the Northeastern states account for only 38.7%, the remaining (53.0%) being contributed by Orissa, which is substantial. The same is the case with regard to the total

Table 5.3. Extent of shifting cultivation in India : (North-eastern states & Orissa)

Estimates for the Year	Total Area Affected by Shifting Cultivation	Annual Area Under Shifting Cultivation	Col (3) as % of Col (2)	Total Population Involved (000)	No. of Families Involved (000)	Mean Family Size	Area Cultivated per Family (HA)	No. Of Communities Practising Shifting Cultivation	Reference
	Million Hectares								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1958	(2.165)	0.433	20.0	2,249	450	5	0.98	42	(25)
1960-61	2.160	0.432	20.0	2,194	(439)	-	0.98	-	(2)
1977	9.000	-	-	-	-	-	-	-	(21)
1983	4.000	0.917	22.9	(2,920)	584	-	1.60	-	(9)
1984	6.509	0.946	14.5	-	-	-	-	-	(10)
1984-85	4.556	0.917	20.1	-	-	-	-	-	(17)

Note: (1) Figures in brackets are calculated values taking a mean family size of 5.
(2) Figures in brackets under Col.2 are calculated values taking a Jhum cycle of 5 years.

Table 6. Annual extent of shifting cultivation

Estimates for the Year	Annual Area Under Shifting Cultivation (Million Hectares)			Col (3) As % Of Col (2)	Col (4) As % Of Col (2)	Total Area Affected by Shifting Cultivation (Million Hectares)			Col (8) As % Of Col (7)	Col (9) As % Of Col (7)
	ALL INDIA	NE STATES	NE STATES & ORISSA			ALL INDIA	NE STATES	NE STATES & ORISSA		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1956	0.542	0.273	0.433	50.4	79.9	2.710	1.365	2.165	50.4	79.9
1960-61	0.541	0.272	0.432	50.3	79.8	2.705	1.360	2.160	50.3	79.8
1983	0.996	0.387	0.917	38.9	92.1	4.357	1.352	4.000	31.1	91.8
1984	0.990	0.416	0.946	42.0	95.6	6.770	2.800	6.509	41.4	96.2
1984-85	1.000	0.387	0.917	38.7	91.7	4.912	1.908	4.556	38.8	92.8

Note: NE states means Northeastern states.

area affected by this practice. The position being similar for other years also as far as the annual area and total area affected are concerned.

A perusal of Col.4 of Tables 5.1,5.2 and 5.3 shows that the total area affected by shifting cultivation, in a particular year, is generally five times the annual area (around 20%), which implies a disturbing shortening of the Jhum cycle (crop-fellow cycle) to 5 years only. It has been reported that this cycle, about 50 to 60 years back, was in the range of 30-40 years (Anon., 1976) or 20-30 years (ICAR, 1983). Table 7 sets the Jhum cycles for various states of the country, in the last four decades, as reported by different agencies, though locally the cycle may be as short as 3-6 years (ICAR, 1983) or even 2-3 years (Kaul, 1980), which precludes the necessary flexibility to allow the natural processes of recuperation to repair these damaged ecosystems. A Jhum cycle of 5 years has been adopted for the present study. This period is also reported by the Forest Survey of India in their surveys conducted in the Northeastern states (Anon., 1988).

While a large quantity of vegetation may be burnt annually in shifting agriculture, data on the total biomass burnt due to this practice are presently not available for India. Any estimates, therefore, made in this regard would only be educated guesses to be depended upon with caution. Most of the total area affected by Jhumming is under fallow regeneration and as mentioned earlier, about 20% of this area is annually cleared for cultivation. The land annually cleared for cultivation, having gone through several Jhum cycles earlier, is covered with second-growth vegetation and some older tree growth left over from earlier Jhumes. This second growth vegetation is mainly dominated by bamboos (and a few tree species) which continue to remain on the site as a pyric subclimax due to repeated cycles of Jhumming (burning). No new forest land is, however, allowed for Jhumming since 1980 with the passage of the Forest (Conservation) Act which prohibits diversion of forest land to non-forest uses.

Studies carried out on secondary succession, biomass, litter production and productivity in forest areas after Jhumming (Ramakrishnan and Toky, 1981 quoted by ICAR, 1983) indicate that the total inventory of the aboveground biomass increased linearly with age attaining a maximum value of 147.59 tonnes/ha (7.38 tonnes/ha/annum) in a 20 year fallow. The rate of accumulation of biomass increased upto 15 years of secondary growth reaching a maximum of 8.95 tonnes/ha/year and declined in a 20 year fallow.

Table 7. Shifting cultivation (Jhuming) cycle by states

State	Jhuming Cycle (Years)				
	(24)	(2)	(4)	(9)	(10)
	(A) Northeastern States				
Arunachal Pradesh	-	5	1-17	3-10	4
Assam	3-7	5	5-10	2-10	7
Manipur	15-20	5	6-8	4-7	6
Meghalaya	-	5	4-5	5-7	6
Mizoram	-	5	4-5	3-4	8
Nagaland	-	5	6-15	4-9	9
Tripura	8-10	5	4-5	5-9	8
	(B) Other States				
Andhra Pradesh	-	5	-	3	6
Bihar	8-10	5	-	5-8	6
Karnataka	-	5	-	-	-
Kerala	-	5	-	-	6
Madhya Pradesh	20 : 10-15 : 15-20 :	5	-	10-15	6
Maharashtra	2-3 : 16 :	5	-	-	-
Orissa	6-7	5	-	5-14	7
Tamil Nadu	3-6 : 6-8 : 2-3 :	5	-	-	-

Note: Figures in brackets on top of columns indicate the references.

Assuming a Jhum cycle of 5 years and adopting the above mentioned rates of accumulation of biomass (7.38 and 8.95 tonnes/ha/annum respectively at ages 20 and 15 years), the rate of accumulation of biomass at age 5 years comes to 3 tonnes/ha/annum through graphics. The total aboveground biomass at 5 years would, therefore, be of the order of 15 tonnes/ha. In another study, (carried out in Meghalaya), however, the total aboveground standing biomass in a 5 year second growth Jhum fallow is reported as 23 tonnes/ha (Toky and Ramakrishnan, 1983).

Forest Survey of India has been conducting a survey of forest resources of the Northeastern states for sometime past and some reports on the inventory of these states have already been published. Taking the inventory figures from these reports for second growth Jhum fallows (predominantly bamboo areas) for the states of Assam and Nagaland (Anon., 1982,1988), it has been estimated that the average total per ha aboveground biomass, on a dry weight basis, works out to 65.72 tonnes of which 20.72 tonnes is bamboo and 45.00 tonnes as tree biomass, bamboo biomass constituting 31.51% of the total aboveground biomass (Table 8).

Table 8. Aboveground biomass in Jhum areas

State	Aboveground Biomass (Tonnes/Ha Dry wt.) Tree Species	Bamboos	Total
Assam (Muli Bamboo areas)	43.68	11.69	55.37
Assam (Hill Jati Bamboo areas)	49.00	28.80	77.80
Nagaland	42.54	31.96	74.50
Weighted Average	45.00	20.72	65.72

Bamboo Biomass as % of total aboveground biomass = 31.51

There are, however, some major drawbacks in the data presented in Table 8. Firstly, that the age of the fallows is not known, though the sampled area is very large, and covers all age classes of Jhum fallow from 1 to 5 years and in some cases older Jhum fallows also. Secondly, a standing aboveground biomass of 65.72 tonnes/ha, of which tree species constitute 45 tonnes (68.49%) is much more than expected in a 5 years old second-growth Jhum fallow. It is, therefore, very clear that the tree biomass is from the older trees left over in the earlier successive Jhum cycles (this has been mentioned earlier also). It would thus be prudent to exclude the tree biomass from our calculations of biomass available for burning and take into account only the bamboo biomass of 20.72 tonnes/ha, plus the incremental biomass of the older trees.

Averaging the three values of per ha aboveground biomass (15, 23 and 20.72 tonnes) obtained from three sources quoted earlier, the average aboveground biomass/ha in Jhum fallows comes to 19.57 tonnes (or 20 tonnes). Giving an allowance of 3 tonnes/ha for the incremental biomass of older trees, the average aboveground biomass/ha in Jhum fallows would be of the order of 23 tonnes, which looks fairly reasonable and has been adopted for this study. This incremental biomass of 3 tonnes has been calculated on the assumption that the average annual wood production of Indian forests is 0.7 m^3/ha/year (Anon., 1987 a).

Accordingly, the aboveground biomass in areas put under shifting cultivation, annually, on an all India basis, during the period 1956 to 1985 is shown in Table 9 Col. 3, being of the order of 12.47, 12.44, 22.91, 22.77 and 23.00 million tonnes respectively for these five years.

Table 9. Total aboveground biomass

Estimates for the Year	Annual Area Under shifting Cultivation (Million Ha)	Aboveground Biomass (Million Tonnes)	Biomass Burnt (Million Tonnes)
(1)	(2)	(3)	(4)
1956	0.542	12.47	4.99
1960	0.541	12.44	4.98
1983	0.996	22.91	9.16
1984	0.990	22.77	9.10
1985	1.000	23.00	9.20

The fate of the standing biomass in Jhum areas is rather uncertain, both from the point of view of burning as well as utilisation. It has already been mentioned earlier that the larger trees on a Jhum may not be cleared and burnt for various reasons and that some biomass may be extracted for personal consumption and/or sale for monetary gains. As such the entire standing biomass on a Jhum plot is not cut and burnt. Further, because of climatic factor like high humidity and relatively short dry season in the shifting cultivation areas of the country, only part of the biomass gets burnt in the Jhum operation. Generally, however, bamboos, undergrowth, grasses and smaller trees get burnt along with dead organic matter on the forest floor (dealt with subsequently). It would, therefore, be a good guess to adopt a burning efficiency of 40% and accordingly, the quantity of biomass burnt, annually, for the period 1956 to

1985 in shifting cultivation areas is shown in Table 9 (Col.4), which ranges from 4.99 (1956) to 9.20 (1985) million tonnes.

Forest fires

Forest fires are one of the most potent source of damage to forests causing loss of standing crop and productive capacity of the soil/forest and destroying natural regeneration, protective, recreational and scenic values of the forest and wildlife. However, the ecological role of fires may be significant in that, much of natural regeneration in the country owes its existence to the burning of forests though lot of regeneration may be destroyed in the process.

Regulated or controlled burning is a very useful tool in forestry practices for the accomplishment of certain specific purposes. For example, the natural regeneration of teak (*Tectona grandis*), and sal (*Shorea robusta*), in their more moister regions of natural occurrence is intimately associated with controlled fires, which keep down the shrubs and weeds and reduce the depth of litter thus exposing the mineral soil to create the necessary seed bed conditions for germination and establishment of seedlings of the desired species. Delibrate and controlled burning is a regular feature in chir (*Pinus roxburghii*) forests to prevent occurrence of more destructive and accidental fires in the hot weather.

There are three types of forest fires most prevelant, namely, Ground Fires, Surface Fires and Crown Fires. Ground fires occur in the humus and peaty layers beneath the litter in undecomposed portion of forest floor with intense heat but practically no flame. Such fires are rather rare, and have been recorded occasionally in high level Himalayan fir and spruce forests. Surface fires, occur on or near the ground in the litter, ground cover, brushwood and reproduction and are the most common type in all fire-prone forests of the country. Crown fires, occur in the crowns of trees, consuming foliage and usually killing the trees and are met frequently in low level coniferous forests, in the Siwaliks, and the Himalayas. In India, there is a definite dry hot season before the monsoon, during which period most of the fires occur, even the wetter forests being prone to fire damage during this season.

There are three main causes of forest fires, i.e., natural, unintentional/accidental by man, and deliberate/intentional/incendiary due to man. Natural fires occur mostly due to lightning, rolling stones and rubbing of bamboos with each other. Unintentional/accidental fires occur due to careless throwing of match-sticks and burning cigarettes, carrying of naked fire by people passing through the forests and spread of fire from labour camps and recreation/picnic spots. Deliberate/intentional fires would include annual burning of fire lines in the forests or burning of slash for raising new plantations. Most of the forest fires can, however, be traced to the deliberate action of the local villagers who set fire to the forests for inducing luscious growth of grass for better grazing, and catching wild animals. Fires are also caused by local population for collection of minor forest products like honey, mahua (Madhuca longifolia),etc.

Unregulated fires: There are no statistics available, in India, on the occurrence of forest fires and the damage caused by such fires in terms of area and biomass burnt and the monetary losses caused, except for some very parfunctory attempts made in the past (Table 10). Even in these attempts, it appears that all the fires have not been reported and the information contained in Table 10 pertains to some significant fires only.

Table 10 shows the annual estimated record of reported forest fires in India with regard to the number of fires, area burnt and the damage caused by these fires in terms of monetary value for the period 1960-61 to 1987-88. Though no pattern is emerging from the figures presented in the table, it speaks of the dearth in collecting and collating data on forest fires in the country.

In the absence of any statistics on biomass burnt in these fires, an attempt has been made to calculate the quantity of aboveground tree biomass burnt from the monetary values in Table 10 (Col. 4). Adopting an average stumpage value of Rs. 1,500/- per m^3 of standing crop (which would be correct on an average basis looking at the number of species involved and their stumpage value), the calculated aboveground tree standing biomass for different periods, in m^3, is shown in Table 11 (Col. 3), in tonnes (air dry) in Col. 4 and on oven dry weight basis (in tonnes) in Col. 5. In arriving at figures in Cols. 4 and 5 it is assumed that one m^3 weighs 750 Kg (air dry) at 10% moisture content. Apart from the fact that there is an increasing trend in biomass burning in unregulated fires from 1985-86 to 1987-88, no other conclusions are possible from the scanty data in Table 11.

Allowing a burning efficiency of 30%, (as all the material does not get burnt and such fires are promptly attended to by the respective Forest Departments), the actual biomass burnt in unregulated fires varies from nearly 3,000 tonnes (Oven dry) in 1985-86 to over 9,000 tonnes in 1987-88.

Prescribed burning: Reference has already been made to the ecological role of forest fires in the form of Controlled Burning (regulated burning/prescribed burning) earlier. There are three main forms of controlled burning generally in vogue in the country, namely,controlled burning for natural

Table 10. Annual estimated record of reported forest fires in India

Estimates for the Period	Average Annual			Reference	Mid-point Year of the Period
	No.Of Fires	Area Burnt (000 Ha)	Damage Value (Million Rs)		
(1)	(2)	(3)	(4)	(5)	(6)
1960-61 to 1964-65	6407	534.0	0.201	(4)	1962
1968-69 to 1972-73	3424	258.9	94.393	(4),(22)	1970
1968-69 to 1977-78	1905	NR	NR	(29)	1972
1980-81 to 1984-85	3570	114.5	1.4	(15)	1982
1985-86	NR	985.8	21.987	(33)	1985
1986-87	NR	975.0	26.973	(33)	1986
1987-88	NR	1034.3	67.897	(33)	1987
1987-88	NR	54634.0**	NR	(28),(15)	1987

Note: (1) NR - Not reported.
(2) ** - Area subject to repeated annual ground fires.

regeneration, for protection (burning of fire lines) and for raising of new plantations. These are discussed hereafter.

(A) Natural regeneration: Controlled burning for purposes of natural regeneration is associated mainly with three species, i.e., teak, sal and chir. The total forest area in the country under these three species, respectively, is of the order of 9.77, 12.00 and 0.89 million ha (Anon., 1980). Based on the rotations of these species - teak, 60 years; sal, 100 years; and chir, 120 years - it is assumed that 2% of the area under teak (0.20 million ha), 1% of the area under sal (0.72 million ha), and 4% of the area under chir (0.04 million ha), giving a total of 0.36 million ha, is subject to annual burning for the purposes of natural regeneration.

As prescribed burning for purposes of regeneration is controlled and consists mostly of ground fires carried out during winter months, the material burnt is usually litter lying on the forest floor, grasses, shrubs and other undergrowth. These are being dealt with subsequently, as to the amount of actual biomass burnt in such fires.

(B) Protection fires: The Forest Departments of the various states carry out annual burning of fire lines, in the forests of the country, as a measure of protection against any unregulated fires which may cause damage to the forests. There is absolutely no information available as to the extent

Table 11. Aboveground biomass burnt

Estimates for the Year	Annual Monetary Loss (Million Rs.)	Aboveground Biomass m^3	Aboveground Biomass Air Dry Wt. (Tonnes)	Aboveground Biomass Dry Wt. (Tonnes)	Biomass Burnt (Tonnes)	Mid-point Year of the Period
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1960-61 to 1964-65	0.201	134	100	90	27	1962
1968-69 to 1972-73	94.393	62,929	47,196	42,476	12,743	1970
1980-81 to 1984-85	1.400	934	700	630	189	1982
1985-86	21.987	14,658	10,994	9,895	2,968	1985
1986-87	26.973	17,982	13,486	12,137	3,641	1986
1987-88	67.897	45,265	33,949	30,554	9,166	1987

Notes: (1) Figures in Col. 2 are from Table 10, Col.4
(2) Figures in Cols. 4 and 5 are based on one m^3 weighing 750 Kg, air dry, at 10% moisture content.

of fire lines burnt annually, in India, and much less on the quantity of biomass burnt in such fires. It would, however, be safe to assume that about 1% of the total forest area of the country (75.18 million ha - Anon., 1987, 1987 a, 1989 a) is under fire lines which would account for an area of about 0.752 million ha, being burnt annually.

Burning of fire lines being in the nature of controlled ground fires carried out during the cold season, the materials burnt usually consist of litter on the forest floor, grasses, shrubs and other undergrowth. These have been dealt with subsequently in terms of the actual biomass burnt.

(C) Plantations: It is customery to give a good hot burn, during the winter season, in all plantations areas prior to their sowing/planting in the succeeding planting season. After all the utilisable materials (timber, fuelwood, etc.) have been extracted from the area, the remaining small material and other debris is allowed to dry, when, later it is collected in heaps and burnt. This cleans up the area to facilitate various planting operations and keeps the area relatively free of weeds atleast for sometime.

While reasonably accurate statistics on the areas planted annually are available, there is no record of the biomass burnt in such fires, though these fires are essentially in the nature of ground fires where mostly litter, grasses, small material and other undergrowth gets burnt.

Table 12 shows the area afforested during the successive Five Year Plans from 1951 to 1986 (Anon., 1987), indicating that a total of 11.478 million ha have been planted during this period, with an increasing rate of afforestation from 0.052 million ha (1951 - 1956) to 1.762 million ha (1986-87). The average annual area afforested has also risen from 0.0104 million ha during the period 1951 - 56 to 1.762 million ha in 1986-87. It must, however, be mentioned here that of the total area afforested annually, over 50% is planted under various development programmes of farm forestry, agro-forestry etc. where plantation areas are not burnt prior to planting operations. Consequently the planting areas subject to pre-planting burning would get reduced and is shown in Col. 4 of Table 12.

As only litter, grasses, small material and other undergrowth gets burnt in these controlled prescribed fires, the amount of biomass burnt is being dealt with subsequently.

Forest encroachment

Attempts to encroach upon Government forest lands for cultivation has been a regular feature since independance till before the enforcement of the Forest (Conservation) Act, in 1980, which prohibits diversion of any forest land for non-forest purposes. With the growth of population, the demand for land for agriculture also increased with the

Table 12. Progressive afforestation through successive plan periods

Period/ Year	Total Area Afforested (Million Ha)	Av. Annual Area Afforested (Million Ha)	Annual Area Subject to Burning (Million Ha)	Mid-point Year of the period
(1)	(2)	(3)	(4)	(5)
1951-56	0.052	0.0104	0.0052	1953
1956-61	0.311	0.0622	0.0311	1958
1961-66	0.583	0.1166	0.0583	1963
1966-69	0.453	0.1510	0.0755	1967
1969-74	0.714	0.1428	0.0714	1971
1974-79	1.221	0.2442	0.1221	1976
1979-80	0.222	0.2220	0.1110	1979
1980-85	4.650	0.9300	0.4650	1982
1985-86	1.510	1.5100	0.7550	1985
1986-87	1.762	1.7620	0.8810	1986
Total	11.478			

result that as many as 2.623 million ha of forest lands were officially diverted for agriculture during the period 1951 - 1980, in addition to many hectares of un-occupied non-forest Government lands, (Anon., 1987 a).

Encroachments on Government forest lands are generally made by people who live in the vicinity of the forest or forest dwellers as they are popularly known. Forest dwellers are mostly tribals who prefer forest lands for cultivation for two reasons. Firstly, forest lands are taken to be more fertile than other un-occupied Government lands and secondly, these lands are in the vicinity of their habitations. Owning agricultureal lands not only satisfies the tribal's economic and social needs but also his emotional feelings.

Forest encroachments could be considered a form of shifting cultivation, practised by the local population who encroach upon forest lands for cultivation, with the difference that once the cultivator has cleared and burnt the land for growing agriculture crops, he takes to permanent agriculture on the same plot of land rather than move from one plot to another as done in the case of Jhumming. So the land once occupied by the cultivator is lost to forests and remains permanently under agriculture.

It has been estimated that nearly 700,633 ha of forest land were under encroachment since 1951 to 1982 (Anon., 1987); the average annual forest area under encroachment being of the order of 21,895 ha (21,900 ha).

Though a large quantity of vegetative growth may be burnt in the areas encroached annually, for permanent agriculture, there is no information presently available as to the amount of biomass burnt in such encroachments. However, taking foret encroachments to be a form of shifting cultivation, it is assumed that the aboveground biomass in these encroached areas would be of the same order as for the jhummed plots, i.e., 23 tonnes/ha. Accordingly, the total biomass available for burning, annually, would be 503,700 (21,900 X 23) tonnes.

As in shifting agriculture, so also in case of encroachments, only a part of the biomass gets burnt and generally, bamboos, grasses, undergrowth and smaller trees get burnt along with dead organic matter lying on the forest floor (dealt with subsequently). A burning efficiency of 40% (as in the case of Jhumming) has, therefore, been adopted, and accordingly the total biomass actually burnt, annually, is of the order of 201,480 tonnes.

A part from the GHGs emissions that may be caused as a result of burning in such encroachment areas, these areas are permanently lost as forest carbon sinks unlike shifting agriculture, where forest regrowth is allowed to come in after one year of Jhumming. How far this loss of vegetative carbon sinks is compensated by the new plantations that are being raised, annually, in the country is hard to predict, at this stage.

Forest area lost

The future demands of various goods and services on our forest ecosystems would primarily be influenced by the increase in population and economic growth though in case of fuelwood consumption, urbanisation, availability of alternative fuels more freely and cheaply and the energy crises would continue to have a significant effect. The impact of dynamic population growth arises the need for increased resources and the competition for land becoming more intense, resulting in the detrimental effect of population increase on these ecosystems.

Table 13.1 indicates the forest area lost for various purposes during the period 1952 to 1980 (prior to the passage of Forest (Conservation) Act, 1980) while Table 13.2 shows the extent of diversion of forest land for non-forestry purposes from 1980 to 1987 (Anon., 1987). It will be observed that the forest area lost for different purposes during the period 1952 to 1980 (Table 13.1) is the tune of 4.328 million ha, with 0.155 million ha having been lost annually, on an average. The largest forest area (2.623 million ha or over 60% of the total) has been lost to agriculture and the balance to other uses.

The total forest area diverted for non-forest uses from 1952 -1987 is of the order of 4,442,809.41 ha (4.443 million ha) (Tables 13.1 and 13.2) which accounts for a yearly average area of 0.127 million ha having been diverted for non-forestry purposes during this period. There have, however, been no official diversions for agricultural purposes after 1980 when the Forest (Conservation) Act was passed. It has also been reported that an area of 0.19 million ha has been deforested during the period 1981-83 to 1985-87 amounting to an annual loss of 47,500 ha (Anon., 1989).

It must be mentioned here that generally, in all cases of diversion of forest lands for non-forestry uses, all usable materials in the form of timber, poles, firewood etc. are extracted from the area prior to the land being put to such non-forestry purpose for which it was diverted. Consequently, there is very little biomass left in the area and as a rule, these areas are not burnt prior to their non-forestry use except, may be, in case of agriculture where the land has to be free of all debris etc. In such cases, burning would be confined to grasses, shrubs and other undergrowh, besides litter on the forest floor. This is being dealt with subsequently under litter burning, as to the amount of actual biomass burnt in such fires.

The most significant effect of the diversion of forest lands for non-forest uses, is actually the reduction of forest Carbon sinks, rather than emission of any GHGs into the atmosphere except for agriculture where the diverted forest area may be burnt for preparing the land for agriculture crops. Once forest areas are diverted for non-forestry uses like the ones mentioned in Table 13.1, there is a permanent reduction in the forest carbon sinks. How far the carbon balance is maintained by raising of new plantations, annually, in the country could only be guessed.

Table 13.1. Forest area lost for various purposes from 1952 to 1980

S.No.	Purpose	Area Lost (Million Ha)	Av. Annual Area Lost (Million Ha)
(1)	(2)	(3)	(4)
1.	Agricultural activities	2.623	0.094
2.	Submergence due to river valley projects	0.502	0.018
3.	Industries and townships	0.134	0.005
4.	Transmission lines,roads etc	0.061	0.002
5.	Miscellaneous uses	1.008	0.036
	Total	4.328	0.155

Table 13.2: Forest area diverted for non-forestry uses from 1980 to 1987

Year	Forest Land Diverted (Ha)
1980	Nil
1981	2,672.04
1982	3,246.54
1983	5,702.01
1984	7,837.59
1985	10,608.07
1986	11,963.11
1987	72,780.05
Total	114,809.41

Burning of grass in forests

Reference has already been made to the burning of grasses in forest and plantation areas due to shifting cultivation; unregulated fires; prescribed burning in natural regeneration areas, protection fires and in plantations; forest encroachments and forest areas diverted for agriculture. The areas annually burnt in different periods for the above sources/activities of forest biomass burning have also been mentioned earlier.

It has been reported that the productivity of grass in forest areas is generally higher than in other grass producing areas (barran and uncultivated land, permanent pastures and grazing land, culturable wastelands and fallow lands) and that the production of dry grass generally varies from 0.5 to 6.0 tonnes/ha/year; the average grass yield from forest areas and other grass producing areas being taken to be about 3 and 1.5 tonnes/ha/year respectively (Anon., 1985).

Adopting an average annual yield of 3 tonnes/ha for forest areas, the aboveground grass biomass in the areas annually burnt with regard to the various sources/activities of forest biomass burning (shifting cultivation etc) is given in Table 14 (Col. 3).

Allowing a burning efficiency of 40% for shifting cultivation areas, encroachment areas and forest land diverted for agricultural purposes; 30% for areas burnt in unregulated fires; and 50% for areas where burning is prescribed (natural regeneration, protection fires and plantations); the aboveground grass biomass actually burnt in these areas is indicated in Table 14 (Col. 4).

With increasing area under shifting agriculture, unregulated fires and plantations, the aboveground grass biomass actually burnt has increased from 0.650 to 1.200 million tonnes (1956-1985); from 0.481 to 0.931 million tonnes (1962-1987) and from 0.008 to 1.322 million tonnes (1953-1986), respectively, for the above mentioned three activities of forest biomass burning. As the area burnt, under natural regeneration, protection fires, encroachments and forest lands diverted for agriculture, is assumed to be constant, the aboveground grass biomass actually burnt has also remained static, being to tune of 0.540, 1.128, 0.026 and 0.113 million tonnes, respectively.

Table 14. Aboveground grass biomass

Year	Annual Area Burnt (Million Ha)	Aboveground Grass Biomass (Million Tonnes Dry Wt.)	Biomass Burnt (Million tonnes)
(1)	(2)	(3)	(4)
		(A) Shifting Cultivation	
1956	0.542	1.626	0.650
1960	0.541	1.623	0.649
1983	0.996	2.988	1.195
1984	0.990	2.970	1.188
1985	1.000	3.000	1.200
		(B) Unregulated Fires	
1962	0.534	1.602	0.481
1970	0.259	0.777	0.233
1982	0.114	0.342	0.103
1985	0.986	2.958	0.887
1987	1.034	3.102	0.931
		(C) Natural Regeneration Areas	
Annual	0.360	1.080	0.540
		(D) Protection Fires	
Annual	0.752	2.256	1.128

		(E) Plantations	
1953	0.0052	0.016	0.008
1963	0.0583	0.175	0.088
1976	0.1221	0.366	0.183
1982	0.4650	1.395	0.698
1986	0.8810	2.643	1.322
		(F) Encroachments	
Annual (1951-1980)	0.0219	0.066	0.026
		(G) Forest Area Diverted to Agriculture	
Annual (1952-1980)	0.094	0.282	0.113

Burning of forest litter

Burning of forest litter in forest and plantation areas due to different sources/activities of forest biomass burning (shifting cultivation; unregulated fires; prescribed burning in natural regeneration areas, protection of forests from fire damage and in plantations; encroachment of forest lands, and forest areas diverted for agriculture) has already been referred to earlier. The areas annually burnt in different periods for the sources/activities just mentioned have also been reported earlier.

The position with regard to data on biomass, productivity and litter production in Indian Forests is no better than many other tropical countries, in that very little data exist on the subject and whatever is available is rather fragmentary. Data are, however, available in the form of yield and volume tables for a large number of species (both for natural forests and plantations). It is only during the last two decades that studies of limited nature on biomass, productivity, litter production and nutrient cycling in the various forest ecosystems of the country, both in natural forests and plantations, have been taken up. Kaul (1973), has made a comprehensive review of these studies upto 1973, though some studies have been undertaken thereafter also.

A literature review of the various studies carried out on litter production in Indian forests, indicates that, on an average litter production in tropical deciduous forests of the country is of the order of 7,000 Kg (7 tonnes)/ha/annum, (Kaul, 1973), the rate of decomposition of litter being very fast, it being difficult to demonstrate the presence of a humus layer.

Assuming an average annual litter production of 7 tonnes/ha, the litter biomass in the areas annually burnt due to various sources/activities of forest biomass burning (shifting cultivation etc) is given in Table 15 (Col. 3).

Adopting a burning efficiency of 40% for shifting cultivation areas, forest areas encroached, and forest lands diverted for agriculture; 30% for areas burnt in unregulated fires; and 50% for prescribed burning areas (natural regeneration, protection fires and plantations); the litter biomass actually burnt in these areas is shown in Table 15 (Col. 4).

As in the case of grass burning, the litter biomass actually burnt has also increased with increasing area under shifting cultivation, unregulated fires and plantations, the increase being, respectively, from 1.518 to 2.800 million tonnes (1956-1985); from 1.121 to 2.171 million tonnes (1962-1987); and from 0.018 to 3.083 tonnes between 1953 and 1986. The actual litter biomass burnt in the areas burnt under natural regeneration, protection fires, encroachments and forest lands diverted to agriculture has remained constant for obvious reasons of the annually burnt areas remaining the same.

Table 15. Litter production

Year	Annual Area Burnt (Million Ha)	Litter Biomass (Million Tonnes Dry Wt.)	Litter Burnt (Million tonnes)
(1)	(2)	(3)	(4)
		(A) Shifting Cultivation	
1956	0.542	3.794	1.518
1960	0.541	3.787	1.515
1983	0.996	6.972	2.788
1984	0.990	6.930	2.772
1985	1.000	7.000	2.800
		(B) Unregulated Fires	
1962	0.534	3.738	1.121
1970	0.259	1.813	0.544
1982	0.114	0.798	0.239
1985	0.986	6.902	2.071
1987	1.034	7.238	2.171
		(C) Natural Regeneration Areas	
Annual	0.360	2.520	1.260

	(D) Protection Fires		
Annual	0.752	5.264	2.632
	(E) Plantations		
1953	0.0052	0.0364	0.018
1963	0.0583	0.4095	0.205
1976	0.1221	0.8547	0.427
1982	0.4650	3.2550	1.625
1986	0.8810	6.1670	3.083
	(F) Encroachments		
Annual (1951-1980)	0.0219	0.1533	0.061
	(G) Forest Area Diverted to Agriculture		
Annual (1952-1980)	0.094	0.658	0.263

Conclusions

Summarising the results obtained for individual sources/activities of forest biomass burning (presented in earlier tables), an attempt has been made to arrive at the total quantity of forest biomass actually burnt in the country during 1980s (1985-1987) due to various sources/activities of forest biomass burning in India. The results are presented in Table 16.

Table 16. Total quantity of biomass burnt annually during 1985-87

Source/Activity	Biomass burnt annually during 1985-87 (Million Tonnes)
(A) <u>Tree Biomass Burnt</u>	
Fuelwood	124.740
Shifting cultivation	9.200
Unregulated fires	0.009
Prescribed burning	-
Encroachments	0.202
Forest areas diverted for agriculture	-
(B) Burning of grasses	5.260
(C) Burning of litter	12.270
Total	151.681
Carbon = 151.681 X 0.45 =	68.26 Million tonnes

It is observed (Table 16) that a total of 151.681 million tonnes of forest biomass (dry weight) was burnt annually during the period 1985-1987, the major contribution of 88.44% (134.151 million tonnes) being from tree biomass, followed by burning of litter (12.270 million tonnes - 8.09%) and grasses (5.260 million tonnes - 3.47%). The total amount of carbon involved for emission of GHGs would be to the tune of 68.26 (151.681 X 0.45) million tonnes.

The above estimates are of best only indicative of the nature and extent of the problems created by forest biomass burning with regard to emission of GHGs and have to be taken with due care, in view of the extreme paucity of data and uncertainities involved. As more and adequate statistics and data are made available, more realistic and dependable estimates could be concluded.

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