CHAPTER 2

REVIEW OF LITERATURE
CHAPTER-II

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2.1: INTRODUCTION:

The literature for the study has been reviewed considering two aspects that are i) status of sacred groves and ii) carbon sequestration at global and regional levels with reference to the aim and objectives of research topic. The methods and highlighted studies have been reviewed mainly for above ground biomass, below ground biomass and soil organic carbon (SOC) as the major carbon pools for terrestrial carbon inventories and floristic diversity of sacred groves.

2.2: GLOBAL SCENARIO OF SACRED GROVES:

Certain protected vegetation areas (forest patches) are preserved on religious ground known as sacred groves, Deo-Rahats or Deo-Rais. These groves have been protected due to local people’s belief and folklores associated with deity.

These forest patches are preserved for a very long period of time, probably for centuries. Sacred groves are a very ancient and widespread phenomenon in the old world cultures. Literature search about sacred groves has been made in Greek and Sanskrit classics. Such preserved forest patches have been reported from different parts of the world like Ghana, Nigeria, Mexico, China, Syria and Turkey, wherein there are areas where the tribal live and practice shifting cultivation. However, it appears that they are entirely unknown to the New World.

Sacred groves were a feature of the mythological landscape and the cult practice of Old Europe. Sacred groves were prominently in many Asian and African mythologies and cultures, most notably in India, Japan, West Africa, and Anatolia. In Syria, some sacred groves are believed to have been made during Assyrian times. The most famous sacred grove in mainland Greece was the oak grove at Dodona. Outside the walls of Athens, the site of the Academy was a sacred grove of olive trees, still recalled in the phrase "the groves of Academe." The last
extermination of sacred groves was carried out in the lands of present-day Lithuania after its Christianization in 1387 and Samogitia in 1413. A sacred grove is known as alka(s) in Lithuanian.

Sacred groves feature prominently in Scandinavian mythology. The most famous sacred grove of Northern Europe was at the Temple at Uppsala in Old Uppsala, where every tree was considered sacred - described by Adam of Bremen. According to Adam of Bremen, in Scandinavia, pagan kings sacrificed nine males of each species at the sacred groves every ninth year. The pagan Germanic tribes also performed tree-worship and had the concept of sacred groves. It is thought that the idea of sacred trees like the Thor's Oak might have led to the concept of the present day Christmas tree.

The Celts used sacred groves, called nemeton in Gaulish, for performing ritual animal and human sacrifices and other rituals, based on Celtic mythology. The deity involved was usually Nemetona - a Celtic goddess. Druids oversaw such rituals. Existence of such groves have been found in Germany, Switzerland, Czech Republic and Hungary in Central Europe, in many sites of ancient Gaul in France, as well as England and Northern Ireland. Sacred grove remains had been plentiful up until the 3rd century BC, when the Romans attacked and conquered Gaul. One of the most well-known nemeton sites is that in the Nevet forest near Locronan in Bretagne, France. Gournay-sur-Aronde (Gournay-on-Aronde), a village in the Oise department of France, also houses the remains of a nemeton. Nemetons were often fenced off by enclosures, as indicated by the German term Viereckschanze - meaning a quadrangular space surrounded by a ditch enclosed by wooden palisades.

In the West Africa, the Osun-Osogbo Sacred Grove, containing dense forests, is located just outside the city of Osogbo, and is regarded as one of the last virgin high forests in Nigeria. It is dedicated to the fertility god in Yoruba mythology, and is dotted with shrines and sculptures. Suzanne Wenger, an Austrian artist, has helped revive the grove. The grove was designated as an UNESCO World Heritage Site in 2005.

The Sacred groves are also reported from Ghana and the Buoyem Sacred Grove is one of Ghana's most famous sacred groves. Many other sacred groves are present in the Techiman Municipal District and nearby districts of the Brong Ahafo Region. They provide a refuge for
wildlife which has been exterminated in nearby areas, and one of the groves houses 20,000 fruit bats in underground caves of the grove. The capital of the historical Ghana Empire El-Ghaba contained a sacred grove for performing religious rites of the Soninke people. Other sacred groves in Ghana include sacred groves along the coastal savannahs of Ghana. Many sacred groves in Ghana are now under federal protection like the Anweam Sacred Grove in the Esukawkaw Forest Reserve. Other well-known sacred groves in Ghana include the Malshegu Sacred Grove in Northern Ghana, one of the last remaining closed canopy forests in the savannah regions, and the Jachie Sacred Grove.

In Japan, the sacred groves are reported from almost all regions of the country. These sacred groves are typically associated with Shinto and Shrines. The Cryptomeria tree is venerated in Shinto practice is considered sacred. Among the sacred groves associated with such Jinjas or Shinto shrines are the shrine at Atsutaku, Nagoya, one of the most important Shinto shrines in Japan, and the Kashima Shrine is now protected as part of the Kashima Wildlife Preservation Area on account of its varied avifauna and trees (the grove houses over 800 species of trees). The Utaki sacred sites (often with associated burial grounds) at Okinawa are based on Ryukyuan religion and usually are associated with town or kami-asagi-regions dedicated to the gods, where people are forbidden. Sacred groves are often present in such places as in Gusukus, which are fortified areas containing sacred sites within. The Seifa-Utaki consisting of a triangular cavern formed by gigantic rocks was designated as a UNESCO World Heritage Site in 2003, contains a sacred grove with rare, indigenous trees like the Kubanoki (a kind of palm) and the Yabunikkei (the wild cinnamon, Cinnamomum japonicum). Direct access to the grove is forbidden. (http://www.Shodhganga.inflibhet.ac.in/bifstream/10603/---/08-chapter%202.pdf.)

2.3: INDIAN SCENARIO OF SACRED GROVES:

In India, as in other countries of the world, many communities practice different forms of worship of nature. One such significant tradition of nature worship was that of providing protection to patches of forests designated as sacred groves dedicated to deities or ancestral spirits. These groves were protected by local communities, usually through customary taboos
and sanctions with cultural and ecological implications. It is the expression of the relationship of man with the divine or with nature (Hughes & Chandran, 1998). The ecosystem level concept of the „sacred grove” of the original pre-Vedic inhabitants of India was extended by the Vedic migrants down to „species” level on one extreme of the scale and to the level of the „landscape” on the other extreme (Ramakrishnan, 1996).

In India, the sacred groves were reported earlier from the Himalayas, North-east India, highlands of Bihar, Orissa, Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu and Kerala. Earlier workers have studied floristic and ethno botanical aspects of sacred groves and provided detailed scientific account of the sacred groves in India (Gadgil & Vartak, 1975, 1976, 1981; Chandran et al., 1998; Malhotra, 1998; Malhotra & Das, 1997; Malhotra et al., 2001).

At present, the known presence and pattern of distribution of sacred groves in Chattisgarh, Jharkhand, Orissa, Uttaranchal, Madhya Pradesh and West Bengal for which detailed inventories are not available. The number of Sacred groves in India is likely to be between 100,000 and 150,000 (Pandey, 2000). According to Gokhale et al. (1998), the total area of sacred groves in India would be about 33,000 ha which comes to 0.01 percent of the total area of the country. But the actual area of the 4,415 sacred groves reported so far cover more than 42,000 ha. Hence, it may not be possible to come up with a reasonable estimate based on the present reports. Maximum number of sacred groves has been reported from Himachal Pradesh, Kerala, Maharashtra and Karnataka (Malhotra et al., 2000). The deities of the groves in Mysore and Kerala are snake gods rather and the mother goddesses as in Maharashtra. Aravalli hills in Rajasthan have groves dedicated to a mother goddess Jogmaya. Total number of sacred groves reported from India is 13,720.

In Western Maharashtra the sacred groves were reported for the first time from Lonavala, in Bombay presidency by Gammie (1903). Further inventories made by Gadgil and Vartak (1973, 1983) from Maharashtra. Botany Department of Maharashtra Association for the cultivation of science research institute (renamed as Agharkar research Institute) initiated survey for floristic studies of sacred groves in Western Ghat region of Maharashtra (Annonymceae 1983-1986). About 59 sacred groves from very high rainfall zone with lateritic
soils and transition zone with average rainfall 1950-2000 mm were submerged along with their flora. It includes Western hilly parts of Pune, Satara, Kolhapur and Eastern hilly parts of Sindhudurga district (Deshmukh, 1999). Sacred groves are basically useful for conserving diversity of natural wealth and ethno botanical knowledge associated with local inhabitants/tribal because of rituals, beliefs and taboos. Survey of deities from Pune region and their cultural association was made by Nipunage et al (1991). The tribal people in Western Ghat of Maharashtra are maintaining these groves under all odds and disasters (Kumbhojkar et al., 1996). Burman (1991) conducted survey in four villages of Ambegaon Taluka, Dist-Pune and recorded observations on deities, clans, cultural and social relationship with sacred groves in Mahadeo Koli tribe.

Sacred groves from Pune district are surveyed for multidimensional aspects by several workers. Detailed floristic account of submerged sacred groves in Panshet and Varasgaon dam sites were recorded by Vartak and Gadgil (1981), Tetali and Gunale (1990), Kulkarni and Kumbhojkar (1999). Threat to medicinal plants in Pune district was reported by Upadhye et.al (2004). Gadgil and Vartak (1981) made inventory of sacred groves from Maharashtra state in general and recorded 11 sacred groves from Bhor Taluka. Waghmare et.al (2006) recorded 14 sacred groves from Parinche Valley of Pune district for their cultural and ecological point of view. Kulkarni and Sindikar (2005) made plant diversity evaluation of Shirkai sacred groves situated at village Shirkoli from Bhor Taluka. Kulkarni and Nipunage (2009) reported floristic diversity and ecological evaluation of Dhup-rahát sacred grove situated in Bhor region of Pune district. This sacred grove is specially known as Dhup-Rahat due to magnificent trees of Dhup i.e. canarium strictum Roxb. Sacred groves from Bhor Taluka are under control of Devasthan committees and that are monitored by forest department, Maharashtra Government. The sacred groves are under threat because of anthropogenic pressure and development activities like construction of Bhatghar, Nira Devghar and Gunjawani Dams.

A survey of sacred groves from Ambegaon Taluka of Pune district was made by Nipunage and Kulkarni (2011) and floristic diversity as well as status of natural regeneration of plant species from 34 sacred groves belonging to 20 remote villages was recorded. They reported that 19 sacred groves are submerged under Kukadi and Chaskaman irrigation projects.
in Ambegaon Taluka of Pune district. The remaining sacred groves are out of submerged area and are still protected by Mahadeokoli tribe. The groves create microclimate which permits regeneration and sustains of biotic species not usually found in the surroundings (Kumbhojkar et al., 1996). Forest department of Maharashtra state has interested in conserving sacred groves (Deshmukh, 1999). The government has planted *Acrocarpus fraxinifolius* wt. and *Eucalyptus* sp. in Mahadevache ban having an area of 10.00 ha in the village Rajpur.

A survey of sacred groves from Bhor region of Pune district was made and floristic diversity as well as status of plant species was recorded by Kulkarni et al. (2010). The most important justification for nature conservation is that it provides an insurance policy for the future. The sacred groves in Bhor Taluka are in the range 0.02 to 10.00 ha in area. The sacred groves with lofty trees, shrubs and giant lianas are peculiar features of natural ecosystem (Vartak and Kumbhojkar 1985, Vartak et al., 1986).

### 2.4: CARBON SEQUESTRATION - GLOBAL SCENARIO:

Terrestrial carbon sequestration is the net removal of CO$_2$ from the atmosphere or avoidance of CO$_2$, carbon dioxide emissions from terrestrial ecosystems into the atmosphere. The process of removal includes CO$_2$ uptake from the atmosphere by chlorophyllous plants through photosynthesis. The carbon is stored in the form of plant biomass (in the trunks, branches, leaves and roots of the plants) and as soil organic carbon (SOC) in the soil (IPCC 2000).

Over the past years, policy makers have experienced number of different ways to mitigate the effects of rising greenhouse gas concentrations. The emphasis has been given on carbon stocks in forests because these ecosystems are major terrestrial sinks for carbon. The terrestrial ecosystem acts as a natural store of carbon, contributing approximately 80% of terrestrial above ground, and 40% of terrestrial below ground carbon storage (Kirschbaum, 1996). There is an urgent need for effective CO$_2$ emission reductions could be satisfied more cheaply through available sequestration technologies than by an immediate transition to nuclear, wind or solar energy (Lackner, 2003). Trees are a terrestrial carbon sink and managed forests can sequester carbon in biomass and soil (Houghton et.al. 1998). Trees are regarded as
Carbon Sequestration Potentials of Selected Sacred Groves from Bhor Tahsil, Dist. Pune, Maharashtra.

sinks for CO₂ by fixing carbon through photosynthesis and storing excess carbon as biomass. The net long term CO₂ source/sink dynamics of forests changes through time as trees grow, die, and decay (Moulton and Richards, 1990).

Jobbagy and Jackson (2000) showed that forest ecosystems capture and store more than 80% of all terrestrial above-ground C and more than 70% of all soil organic C. The annual CO₂ exchange between forests and the atmosphere via photosynthesis and respiration is 7 times the anthropogenic C emission. Terrestrial ecosystems influence the concentrations of GHGs to the atmosphere (Lal, 2004) as it works both sinks and sources. Greenhouse gases are constantly entering and leaving the atmosphere.

Green plants and trees uptake CO₂ from the atmosphere and combines it with H₂O through photosynthesis and produce simple sugars and more stable carbohydrates. Thus, trees capture and store atmospheric CO₂ in vegetation, soils and biomass products through photosynthesis. Carbohydrates become the building blocks and energy supply for almost all of life on Earth. Eventually, when plants and animal die, CO₂ returns to the atmosphere (Rosenbaum et. al., 2004). The terrestrial greenery plays an important role in global carbon sequestration. It has been estimated that 1146 Gt C is stored within the 4.17b ha of tropical, temperate and boreal forest areas, about one-third of which is stored in forest vegetation (IPCC, 2000).

Biomass estimation is the first step to know atmospheric carbon harvest through the forest. The diameter at breast height (DBH) relationship to biomass is well formulated (Kira and Ogava, 1971; Meeuwig and Cooper., 1978; Chojnachy, 1986). Traditionally biomass was estimated using harvest of the tree (Grier and Logan, 1977; Grier and Milne, 1981; Chaturvedi and Singh, 1983). Westlake (1963) showed that the biomass is having a direct relationship with the amount of carbon present in different parts of the tree i.e. 47% of the total dry biomass. The expansion of forest areas and maturing of forest stands are the basis of their function as atmospheric carbon sinks (Delcourt and Harris, 1980).

Tropical deforestation has been responsible in part for the increasing concentration of CO₂ in the atmosphere (Houghton et.al., 1990). Estimates of net release of carbon (C) at the global level are highly uncertain, ranging from 0.4-1.6 Gt (10⁹t or 10¹⁵g) of C/year (Detwiler
and hall, 1988) to 1.1-3.6 Gt C/year (Houghton, 1991). The atmospheric CO$_2$ concentration is currently rising by 4% per decade (Jo and Mcpherson, 2001). Increasing levels of CO$_2$ and other carbon containing gases will result in temperature rise by 1.4 to 5.8°C during next century (Bhadwal and Singh, 2002). An increase in temperature by 1°C will likely to limit in tolerance of species particularly the polar ones (Dobson et al., 1989).

Carbon is a basic element of life. Approximately 50% of the mass of animals/ plants is composed of carbon. It occurs in various forms and is cycled between several biotic and abiotic pools including oceans, terrestrial biota and atmosphere (Skole et al., 1995). Trees are important sinks for atmospheric carbon since 50% of their standing biomass is carbon itself (Ravindranath et al., 1997).

Increasing CO$_2$ may favors Net Primary Production (NPP) as well as increase water use efficiently of trees. However, trees may adapt to changing CO$_2$ concentrations and the effect may diminish soon (Magnani et al., 1988). Another factor influencing the carbon sequestration is the rise in the temperature. Higher temperature accelerates enzymatic processes and therefore biomass accumulation, unless other factors are limiting. Increasing temperature may also increase annual NPP by lengthening the growing season (Hasenauer and Monserud, 1997).

Grier and Milne, (1981) observed that in Pinus edulis – Juniperus monosperma woodland of north central Arizona, the biomass and NPP volume of 350 years old stands were higher than that of 90 years old stands. This clearly indicates, older the vegetation more is the biomass and high carbon sequestration.

Although oceans store greater amount of carbon than terrestrial ecosystems, man’s ability to manage terrestrial ecosystem is greater and is likely to have a greater mitigation effect. Therefore protection of developed forests is of great significance in mitigation measures (Bhadwal and Singh, 2002).

Anderson and Spencer (1991) found out carbon sequestration through forestry is based on two premises. First, that carbon dioxide is an atmospheric gas that circulates globally; therefore to remove greenhouse gases (GHGs) from the atmosphere will be equally effective at local or regional level. Second, green plants utilize CO$_2$ through the process of photosynthesis forming sugars and other organic compounds. Perennial plants store carbon in their wood and
other tissues and through its decomposition it may be released to the atmosphere as carbon dioxide, or it may be incorporated into the soil as organic matter.

Plant tissues vary in their carbon content (Chan, 1982). Stems and fruits have more carbon per gram than do leaves, but generally have an average concentration of 45-47% carbon. Thus, the amount of carbon stored in trees can be calculated by knowing the amount of biomass or living plant tissue. Gucinski et.al, (1995) showed that among the different terrestrial ecosystems, conifer forests are major carbon reservoirs. Their contribution to climate change mitigation is known both by their ability to uptake carbon dioxide from the atmosphere through photosynthesis as for the big storing capacity in biotic and abiotic components.

Rosillo-Calle et.al, (2006) indicated that ground methods refer to methods involving deployment of field personnel on the ground for survey and can produce accurate and detailed data. On the other hand, the methods are often time consuming, expensive and demand skilled personnel, especially in remote areas and harsh terrains. Thus, these methods are suitable for smaller areas.

Root biomass measurement is complex, time consuming and expensive. Root biomass is not measured in most land based projects. The alternative methods such as default root to shoot ratio and biomass equation are adopted. Root biomass is normally within a small range of proportion of root to shoot proportion of above-ground biomass. A review by Cairns et.al (1997) covering more than 160 studies from tropical, temperate and boreal forests estimated a mean root to shoot ratio of 0.26 with a range of 0.182-0.3. Thus, it may be practical to use a mean default value of 0.26 for estimating the root biomass.

Carbon sequestration through forestry is based on two processes; firstly carbon dioxide is an atmospheric gas which circulates globally. Secondly, green plants trap atmospheric CO$_2$ in the process of photosynthesis and utilize it for making carbohydrates (sugar) and other organic compounds required for growth and metabolism (Anderson and Spencer 1991). The increasing trend to change the land use patterns will result into lower value of carbon sinks (Dixon et al, 1994b). Conversion to agricultural land and pasture, logging operations and urbanization are some of the main pressures on forestry (World Resources Institute, 1990 (http://www.wri.org/)). The forests play a double role in relation to carbon sinks (Houghton...
Firstly forests prevent the emission of carbon by decomposition of its biomass. Secondly deforestation contributes to 30% of the current global emissions.

Reduction in rates of deforestation, introduction of techniques for controlled logging and fire prevention are some of the measures known to reduce carbon emissions. It has been estimated that 15 million hectares of tropical forests are logged yearly throughout the world (Singh, 1993), and the majority of logging operations in tropical countries are considered unsustainable and damaging (Poore, 1989). Role of forestry mitigation measurements is likely to have developmental processes in economies from developing countries (Mendis and Gowen, 1994).

Dixon et al, 1994 highlighted that terrestrial ecosystems play an important role in the global carbon cycle, serving as both carbon sinks and sources (Schimel, 1995). Approximately half of the organic carbon (C) stored in these ecosystems is sequestrated by forest. Plantation of trees has been considered a method for reducing atmospheric CO₂ because trees sequester CO₂ and store carbon in their biomass through the process of assimilation (Trexler, 1991).

Increase in soil respiration would increase the CO₂ emissions from forest ecosystems. In order to mitigate climate change more carbon should be sequestered in forest ecosystems and strategies for an adapted forest management are to be sought (Brown et al, 1996).

Urban vegetation influences the air pollution through two major processes: (1) cooling of the ambient temperature and hence slowing the smog formation process and (2) dry deposition of air pollutants (both gaseous and particulate) can be removed from the air. Plants directly remove pollutant gases through leaf stomata (Smith, 1984; Fowler, 1985). Nowak (1994a) worked on the urban forest in Chicago and showed that through dry deposition trees on an average remove about 0.002% (0.34g/m²/year) of CO, 0.8% (1.24g/m²/year) of NO₂, 0.3% (1.09g/m²/year) of SO₂, 0.3% (3.07g/m²/year) of O₃, and 0.4% (2.83g/m²/year) PM₁₀ pollutants from air.

Data for the rate of carbon sequestration by trees are inadequate due to relatively new area of research. However, Nowak (1994b) analyzed the carbon sequestration by individual trees as a function of tree diameter measured at breast height (DBH). Estimating the
environmental benefits of urban trees is particularly important in strengthening the green cover as part of aesthetic and ecological considerations (Wolf, 2004 and Schwab, 2009).

Reducing CO$_2$ in urban areas further helps to mitigate the impacts of climate change (McHale et al., 2007; McPherson et al., 1999; Nowak and Crane, 2002). Green cover reduces CO$_2$ level from the atmosphere and can be used for C storage and mitigation (Nowak, 1994; McPherson, 1998; Jo, 2002). Urban forest soils store large amounts of organic C before it releases into atmosphere (Pouyat et al., 2002 and Pouyat et al., 2006). In addition, urban forests decrease the demand of electricity for building cooling by shading and evaporate by transpiration in the summer and thereby reduce the heating effects.

There has been an increasing interest in quantification of C storage and sequestration by urban forests in both developing and developed countries (Brack, 2002; Jo, 2002; Yang et al., 2005; Gratani and Varone, 2006; Myeong et al., 2006; Stoffberg et al., 2010 and Zhao et al., 2010). These studies greatly expand our understanding on the role of urban forests in C storage and sequestration. Such studies are done in the United States (Rowntree and Nowak, 1991; Nowak, 1993; Nowak, 1994; Jo and McPherson, 1995; McPherson et al., 1997; McPherson et al., 1999; McPherson, 1998; Myeong et al., 2006; McHale et al., 2007; and McHale et al., 2009).

The 2000 IPCC Second Assessment Report showed that the technical potential for carbon sequestration via forestry activities ranged from 55-76 Pg C for the period from 1995 to 2050 (Brown et al., 1996). Technical potential of LULUCF options suggests that the total global potential for afforestation and reforestation activities between 1995 and 2050 will average between 1.1-1.6 Pg C per year, of which 70 percent will be in tropical forests (Schlamadinger and Karjalainen, 2000).

**2.5: CLIMATE CHANGE IMPACTS IN ASIA:**

Prediction of the third Assessment Report of IPCC indicates that the area-averaged annual mean temperature rise would be $3^\circ$C in the decade of the 2050s and about $5^\circ$C in the decade of the 2080s over the land regions of Asia as a result of future increase in atmospheric concentration of greenhouse gases (Lal et al., 2001a). The rise in surface air temperature was
projected to be most pronounced over boreal Asia in all seasons. An enhanced hydrological cycle and increase in area-averaged annual mean rainfall over Asia were projected. Rise in annual and winter mean precipitation would be highest in boreal Asia; as a consequence, the annual run-off of major Siberian Rivers would increase significantly. A decline in summer precipitation was likely over the central parts of arid and semi-arid Asia leading to expansion of deserts and periodic severe water stress conditions. Increased rainfall intensity, particularly during the summer and monsoon, could increase flood-prone areas in temperate and tropical Asia (IPCC, 2007). Inter-annual, Inter-seasonal and Spatial variability in rainfall trend has been observed during past few decades throughout the Asia. Decreased trends annual mean rainfall have been observed in Russia, North-East and North China, Coastal Beds and arid plains of Pakistan, parts of north-east India, Philippines, Indonesia and some areas of Japan. Annual mean rainfall exhibits increasing trends in western China, Changjiang Valley and the south-eastern coast of China, Arabian Peninsula, Bangladesh and along the western coast of Philippines. 0.68°C increase per century, increasing trends in annual mean temperature, warming more pronounced during post monsoon and winter. Increase in extreme rains in north-west during summer monsoon in recent decades, and lower number of rainy days along east coast were reported by Kripalani et al (1996), Lal et al (1996), Lal et al (2001), Singh and Sontakke, (2002), and Lal, (2003).

2.6: INDIA’S FOSSIL FUEL EMISSIONS:

India’s total emissions (CO2) from fossil fuels consumption and cement production have more than doubled since 1992. Fossil fuel emissions in India continue to result largely from coal burning with India being the world’s third largest producer of coal. Coal contributed 87% of the emissions in 1950 and 71% in 2007, at the same time, the oil fraction increased from 11% to 20%. India’s 2007 total fossil fuel CO2 emissions rose 7.2% over the 2006 level to nearly 440 million metric tons of carbon. From 1952 to 2007, India experienced dramatic growth in fossil fuel (CO2) emissions averaging 5.7% per year and becoming the world’s third largest fossil fuel (CO2) emitting country. Indian emissions data reveal little there was impact of the oil price increase that affected emissions in the United States and Western Europe so
dramatically in the late 1970s and early 1980s. With the world’s second largest population and over 1.1 billion people, India’s per capita emission rate for 2007 of 0.39 metric tonnes of carbon was well below the global average (1.25) and the smallest per capita rate of any country with fossil-fuel (CO₂) emissions exceeding 50 million metric tonnes of carbon (http://cdiac.ornl.gov/).

2.7: NATIONAL SCENARIO:

India is making a valuable contribution to the Kyoto Protocol since August 2002, and one of the objectives of agreement was to fulfill prerequisites for implementation of Clean Development Mechanism (CDM) projects, in accordance with national sustainable priorities. Further, India is considered as one of the very attractive countries after China, regarding the implementation of CDM projects.

At present CO₂ capture and storage (CCS) is not a priority in India because, the UNFCCC and Kyoto Protocol, have not given out gas emission reduction targets (Shakley and Verma, 2008). However, Rai (1984), have shown that there are growing activities to bring additional land under forest. Further efforts have been undertaken to protect existing vegetation, particularly along Western Ghats and to bring various management practices to increase green covers.

Negi et al. (1988); and Rawat and Singh (1988) considered destructive method, which involved felling of trees, impractical for biomass estimation in view of increasing environmental problems. Tiwari (1992) developed non-destructive method of biomass estimation in forest of Siwalik Hills (India). The method involved taking a cylindrical wood sample instead of cutting entire tree. Roy and Ravan (1994) have developed biomass equations for dominant species in Madhav National Park (M.P), using non-destructive approach. Dabas and Bhatia (1996) have compared the plantation growth rates of tropical and temperate forest and indicated that growth is faster in tropical and subtropical areas than temperate areas. Murali and Bhatt (2005) have developed biomass equations for broad forest types in India.

Lugo et al., (1992) and Singh et al., (1985) concluded that tropical forests are sinks of atmospheric carbon. Lal and Singh (2001) have estimated carbon sequestration of Indian forest
using historic database prepared by forest survey of India (FSI). Bhadwal and Singh (2002) estimated net carbon sequestration by different forest of India. They used Land Use and Carbon Sequestration (LUCS) model which takes several parameters into consideration for estimating carbon sequestration including population, fuel wood demand, wood for permanent uses and forest harvesting.

Mitra (1992) has shown estimations of anthropogenic GHG emission inventories in India. Warran and Patwardhan (2001) estimated the carbon sequestration potential of trees within Pune city limits to be 15000 tonnes per year. Sharma, et al, (2006), concluded that the GHG emissions in the years 1990, 1994 and 2000 increased from 988 to 1228 to 1484 million tonnes respectively and the compounded annual growth rate of these emissions between 1990 and 2000 has been 4.2 percent. Emissions from the industrial sector registered the highest rate of growth per annum within this period.

Maryam and Ahmed (2010) have prepared the land use change map and showed that 5985.6 hectares of farms, 15508.749 hectares of pasture and 254.337 hectares of orchards have changed to urban land use. This land use change prevented 126290.7 Mg C from sequestration, which was equal to 463065.9 Mg CO₂ released to atmosphere. With regarding to the pollutants and combustion of fossil fuel, its magnitude can reach to several times greater.

The potential for carbon sequestering through forestry in India has been estimated and shown to be significant enough to offset 25-50% of national carbon emission (Ravindranath et al., 1995). Ravindranath et al., (1997) estimated the standing biomass (as above and below ground biomass) in India to be 8375 million tonnes for the year 1986, of which the carbon storage would be 4178 million tonnes.

Project-specific process may reduce the CO₂ emission. First, it is difficult to predict the future. Secondly, under clean Development Mechanism, project managers have strong incentives to overstate the decline in carbon stocks. Thirdly, baseline setting requires some assumptions about regional and national land use related programmes and policies (Chomitz, 1998). Finally, project-specific baselines have high transaction costs (Watson et al., 2000).

The first available estimates for forest carbon stocks (biomass and soil) for the year 1986 are in the range of 8.58 to 9.57 Gt C (Haripriya, 2003; Chhabra and Dadhwal, 2004).
Ravindranath, *et al.*, (1997) concluded that contrary to many developed countries, we do not have carbon inventories and databank to monitor and enhance carbon sequestration potential of different forests.

In India, attempts were made to assess carbon sequestration studies at macro level, mostly with the available data. No attempt has been made so far to assess the biomass soil carbon sequestration at micro-level. Such kind of micro level study is essential for sustainable forest management, especially in a country like India (Chaturvedi and Khanna, 1982).

India as a large developing country is known for its diverse forest ecosystems and mega biodiversity. It ranks 10th amongst the most forested nations of the world (FAO, 2000) with 23.4 percent (76.87 million ha) of its geographical area under forest and tree cover (FSI, 2008).

The carbon sequestration potential of sacred groves of India and Maharashtra state has not been studied so far. The present study deals with carbon sequestration potential of sacred groves namely i) Somjaichi Rai at the village Nandghur ii) Moulidevichi Rai at the village Varvand iii) Nivgunjaichi Rai at the village Nivgun and iv) Umberjaichi Rai at the village Parhar, Taluka - Bhor Dist-Pune, Maharashtra, India.