Chapter 1

INTRODUCTION
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The global environment is constantly changing and our planet is getting warmer at an unprecedented rate. The average temperature of the earth’s surface, currently at about 15°C, is controlled by the gaseous composition of the atmosphere. Radiatively active greenhouse gases in the atmosphere trap outgoing solar radiation which warms the earth. Important greenhouse gases in the atmosphere are water vapour (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), oxides of nitrogen (NOX), tropospheric ozone (O₃), carbon monoxide (CO) and chlorofluorocarbon (CFC). Amongst the greenhouse gases, CO₂ accounts for 60% of the global warming and thus attains enormous importance. The concentration of CO₂ in the atmosphere has increased from 280 parts per million by volume (ppmv) at the beginning of 18th century to the present day value of 366 ppmv (CDIAC, 2001). Major natural sources of these gases are terrestrial ecosystems, including world soils, biota, wetlands, and volcanic eruptions. Emission and re-absorption of these gases from natural ecosystem have been in equilibrium for millions of years. However, this balance has recently been disturbed by human activities. Consequently, atmospheric concentrations of several of these gases (e.g. CO₂, CH₄, and N₂O) have been increasing since the onset of the industrial revolution and more rapidly since the 1950s.

The latest report by the Intergovernmental Panel on Climate Change (IPCC) predicted a 1.4 – 5.8 ºC average increase in the global surface temperature over the period 1990 to 2100 (Houghton et al., 2001). It is assumed that increasing temperature will increase the decomposition rate of soil organic matter, which will increase the CO₂ in the atmosphere and enhance the greenhouse effect: a so-called feed forward cycle. Though this hypothesis is generally accepted, it is not clear to what extent the elevated temperatures would increase the decomposition rate, and how soil biological systems would adjust to a warmer environment. The estimates of future warming are greater than earlier projections, which is partly due to incorporation of a positive feedback. This feedback results from higher release of greenhouse gases from terrestrial ecosystems in response to climate warming. The feedback mechanism is usually based on the assumption that observed sensitivity of soil respiration to temperature under current climate condition would hold in a warmer climate. However, this assumption has not been carefully examined. The results of various experiments indicate that the temperature sensitivity of soil respiration decreases or acclimatizes under warming and that the acclimatization is greater at high temperatures. This acclimatization of soil
respiration to warming may therefore, weaken the positive feedback between the terrestrial carbon cycle and climate.

CO₂ emission from soil or CO₂ efflux popularly known as soil respiration is the release of carbon dioxide from the soil surface to the atmosphere. This is the most representative manifestation of the biological as well as chemical processes in the soil as it produces 75-80 Pg of CO₂-C annually (Raich & Potter 1995), which is more than 10 times of the current rate of fossil fuel burning (Marland et al., 2000). Soil respiration is an ecosystem process that releases carbon dioxide. It is among the least understood subjects in ecosystem ecology. Since it represents the second largest flux of carbon cycling between the atmosphere and terrestrial ecosystems, soil respiration also becomes relevant to climate change, carbon trading, and environmental policy. In short, soil respiration is nowadays a multidisciplinary subject that is of concern not only to soil scientists, microbiologist, and agronomists but also to atmospheric scientists, biogeochemists, carbon traders, and policy-makers.

The dominant terrestrial source of CO₂ is soil which is more than 11 times the current rate of fossil fuel combustion (Marland et al., 2000) and 10% of the atmosphere's CO₂ cycles through soil each year. This flux comprises 50-80% of ecosystem respiration (Davidson et al., 2000; Giardina and Ryan 2002) and consists of respiration from roots and associated mycorrhizae and from heterotrophic microbes using root exudates and recent and older organic material as an energy substrate (Wiant 1967, Anderson 1973). Instantaneous CO₂ flux rates range from near zero during winter to >10 µmol m² s⁻¹ for high productivity ecosystems during the growing season (Raich et al., 2002) and annual estimates range from less than 200 g C m² year⁻¹ in xeric systems to nearly 2000 g C m² year⁻¹ in wet temperate forests (Hibbard et al., 2005). Soil respiration has been shown to vary dramatically in temporal scales ranging from hours (Ekblad et al., 2005) to years (Raich et al., 2002) and in spatial scales ranging from meters (Tang and Baldocchi 2005) to regions (Reichstein et al., 2003). In addition, individual soil respiration measurements typically cover less than 0.25 m² and represent only a snapshot of a few minutes (Lavigne et al., 1997, Murthy et al., 2003). These two realities complicate the process of generating accurate large-area and long-term soil respiration estimates because, unlike many ecological processes, soil respiration has not been clearly linked to aboveground structural or functional patterns (Fahey et al., 2005) that are easily mapped with remote sensing (Reichstein et al., 2003, Tang et al., 2005a). Studies are beginning to explicitly characterize the scales and
drivers of this spatial and temporal variability and these results will undoubtedly contribute to the up-scaling of soil respiration.

As with many ecological processes, interest in soil respiration has shifted from addressing site-specific or treatment-related questions to characterizing respiration rates for large areas over long time periods (Underwood et al., 2005). Large-area and long-term estimates of soil respiration are needed to: (1) reduce uncertainties in landscape, regional and global carbon budgets (Law et al., 2002), (2) characterize the spatial and temporal dynamics in plant physiological processes, including belowground carbon allocation (Giardina and Ryan 2002), (3) facilitate direct comparisons with eddy-covariance measurements (Pypker and Fredeen 2002, Kutsch et al., 2005, Tang and Baldocchi 2005, Tang et al., 2005a), and (4) provide parameterization and validation for ecological simulation models (Chen et al., 2000, Soegaard et al., 2000, Tate et al., 2000).

Changes in agriculture practices can result in changes in both the pool size and turnover rates of soil organic matter. Jenkinson and Rayner (1977) identified different carbon pools ranging from a decomposable pool with a radiocarbon age of less than 1 year, biomass pool (radiocarbon age of 25.9 years) and chemically stabilized pool (radiocarbon age of 2565 years). The decomposable and the biomass pools of carbon constitute labile carbon, which decline faster and is restored faster than the non-labile carbon and, therefore, is a more sensitive indicator of carbon dynamics of the system. The atmospheric carbon pool is increasing by about 6.1 gigatons per year. The increased carbon dioxide in the atmosphere traps heat and can lead to global warming. The soil organic matter pool is currently losing about 1 to 2 gigatons of carbon per year to the atmospheric pool. About 60 gigatons of carbon enters the soil organic carbon sink each year as decaying biomass remains in the soil. About 61 to 62 gigatons of carbon are lost from this pool as soil organic matter is oxidized by the atmosphere.

The formation of carbonate carbon or soil inorganic carbon (SIC) is an important long term sink of atmospheric CO2 in soils of arid and semi-arid regions. However, it is improbable that any proposed change in irrigation water management and soil fertility management would have a significant impact on net global carbon fluxes from soil carbonates (Lal et al., 2000).

Several studies have shown that factors such as soil texture, temperature, moisture, pH, C (labile and non-labile components of soil organic matter), and N content of the soil influence CO2 production and emission from the soil (Wild Dung et
al., 1975). For root respiration, the source of C is photosynthates and its translocation to the root; while litter fall, root mortality, application of manures and crop residue provide carbon for microbial respiration in the soil.

Despite the progress reported by the scientists all over the globe, several gaps in our knowledge exist, particularly with reference to the information on the influence of land use, soil properties and climatic conditions on the emission of CO$_2$ from the soil, in Indogangetic Plain of India. The present study was therefore, undertaken to assess the seasonal variation of CO$_2$ efflux rate from different soil associations and land use/crop combination in part of Indo-Gangetic plain in India which covers 13% of the geographic area of the country. This study was conducted in 25 soil mapping units (SMU), spread over the districts of Saharanpur, Muzaffarnagar, Meerut, Baghpat, Ghaziabad and Haridwar; supporting forest, orchard, plantations and agricultural crops for a period of 24 months by collecting/generating in-situ and ex-situ data on monthly basis. The in-situ data included estimation of soil CO$_2$ emission rate and soil temperature from 77 points at 39 sites at an interval of one month. Simultaneously, the soil samples were collected every month, from all the points for estimation of soil moisture, organic carbon, redox potential and pH. The main aim of this study was to establish relationship between CO$_2$ emission rate and soil properties. The effort has been made to fulfil the following objective.

Objectives of the study:

1. To estimate CO$_2$ emission from the soils under different land uses.
2. To determine the important soil properties, viz., soil organic and inorganic carbon, nitrogen, moisture, temperature, texture, redox potential and pH.
3. To establish the relationship between CO$_2$ emission and soil properties.

Organisation of thesis:

This thesis has been presented in seven chapters.

Chapter 1: Reflects the light on introduction and objectives of the study.
Chapter 2: Reviews the literature pertinent to this work.
Chapter 3: Gives a description of the study area and the methodology adopted for carrying out field work, laboratory work and data interpretation.
Chapter 4: Focuses on the results and discussions.
Chapter 5: Covers the summary.
Chapter 6: Contains conclusions of the results.
Chapter 7: The thesis ends with this chapter, which includes bibliography (References) of the literature cited.