INTRODUCTION
1. INTRODUCTION

The radiatively important atmospheric trace gases such as water vapor (OH), carbon dioxide (CO$_2$), methane (CH$_4$), carbon monoxide (CO), nitrous oxide (N$_2$O), nitric oxide (NO), ozone and xenobiotic chlorofluorocarbons are responsible for global warming. These gases absorb the outgoing thermal radiation, emitted by the cooling of earth’s surface in the infrared range of electromagnetic spectrum, to maintain a favourable temperature in the atmosphere. Increase in the emission of these anthropogenically emitted gases due to population pressure, intensive agriculture, rapid industrialization and other human related activities are anticipated to result in a steady increase in global warming. Current researches worldwide are directed towards understanding the source-sink relationship of different greenhouse gases in order to stabilize or lower the concentration of these gases in the earth’s atmosphere. CH$_4$ is one of the gases, which directly affects the tropospheric chemistry and forms a part of highly interactive chemical system that largely determines the background concentration of the hydroxyl radical, which is the most important oxidizing gas in the troposphere (Crutzen, 1995).

Agriculture is considered to be one of the major anthropogenic sources of atmospheric greenhouse gases. Its important task of providing food for a steadily increasing world population is reflected in the increase of damage to the environment as exemplified by the global rise in concentrations of CH$_4$, CO$_2$ and nitrogen oxides (NO and N$_2$O). According World Resource Institute, Washington DC, USA 1990, Indian contribution of CH$_4$ from all sources (flooded paddy fields, wet lands, ruminants, animal husbandry, termites and landfills etc.) is 12% of global CH$_4$ production. Flooded paddy is
considered to be one of the most important sources of anthropogenic CH₄ (Houghton et al., 1996). CH₄ emission from paddy is governed by a complex set of parameters, viz. soil type, pH, redox potential, temperature, water regime, fertilizer, sulphate content, paddy cultivars and cultural practices followed in paddy cultivation (Neue et al., 1997). Both organic and inorganic fertilizers can influence CH₄ production and emission (Minami, 1995). However, the effect of urea and other N fertilizers on methonogenesis is not clearly understood and the explanations given on this are often contradictory. Thus, urea fertilization promoted CH₄ emission in some soils and inhibited it in others, depending upon the soil physical characteristics (Wang et al., 1993). In a paddy-based cropping system, lowland paddy is normally rotated with upland crops such as wheat, oilseeds, pulses and vegetables. Such crop rotation with an upland crop preceding paddy, reduces not only phytotoxic effects of continuous flooding, but also CH₄ emission from paddy besides increasing overall productivity (Neue et al., 1997). The following literature review is concerned with the significance of CH₄ as the greenhouse gas and its role in global warming, the sources and sinks of CH₄ and the production, oxidation and the emission of CH₄ from flooded paddy fields. In addition, factors affecting CH₄ production and its emission and relevant mitigation strategies to reduce CH₄ emission from wetland paddy fields are also reviewed.

1.1. Rice

Oryza sativa L. a semi aquatic annual cereal, is grown in more than 100 countries (planted in 11% of the world's cultivated land), in a wide range of climatic, soil and hydrological regimes—from a wet tropical to semi-arid and warm temperate regions, from heavy clay to poor sandy soils and from a prolonged period of flooding in deep water to
dry areas on hilly slopes. Geographically rice is grown between 53°N latitude and 40°S longitude and from sea level to an altitude over 3000 meters (Bor Luh, 1994).

1.2. World scenario in rice production

Rice is the world's single most important crop and staple diet for more than a third of the world's population. 90% of the world's total rice is produced and consumed in Asia, where, about 60% of the earth's population live (Gurudev Kush, 1994) supplying 75% or more of the calorie requirement and almost 50% of the protein requirement. India, China and Indonesia are the leading rice producing countries, with India and China accounting for 50% of the world's supply of rice. A complicating factor in the human geography of rice producing areas is the rapid population growth and the resulting increased pressure on the already strained food producing resources.

1.3. Indian scenario in rice production

Archeological records reveal that rice has been cultivated in India since 9/8th millennia B.C. India occupies first position in area with 42.4 million hectares (31%) out of total cultivable area of around 143 million hectares and such a large area is not witnessed in any of the rice growing countries. In India, rice is cultivated mostly during the wet season, coinciding with the period of active monsoon rains. However, in some south and southeast regions of the country, two to three rice crops are harvested in a year by extending cultivation to the dry season with the help of irrigation. Regarding production, India is in second position with 112.5 million tonnes (42%). Apart from providing employment to the largest mass of rural population (70%), rice earns foreign exchange to the tune of Rs.1790 crores.
The success or failure of rice crop is pivotal to the quality of individual life of major segments of world’s population as well as to the political and economic stability of large regions. The socio economic importance of rice combined with urban growth and the requirement of cost-effective monitoring of the rice crop has led these countries to investigate methods to augment traditional land based monitoring with data obtained through space born sensors.

1.4. Remote sensing in crops

Space born remote sensing in the visible, infrared and microwave bands of the electromagnetic spectrum using modern automatic interactive data handling techniques, has shown its effectiveness as a monitoring technique. Assessment of vegetation using remotely sensed data requires understanding of the spectral behavior of vegetation in different parts of the electromagnetic spectrum. Such an understanding of the spectral response helps in interpretation of data collected by various sensors. The identification of agricultural crops is based on the spectral reflectance characteristics of the different crop types. This reflectance however is a function of a number of factors such as phenology, which again depends on the weather situation of a particular year on other growing conditions like soil fertility or on management practices. Another factor relevant for crop identification is the similarity of reflectance values of different crop types. A careful selection of the satellite data acquisition date is necessary, which makes use of different phonological dynamics of the crops in question, provided the crop calendar of the various crops existing in the area is known.
1.5. Remote sensing in rice Production

Remote sensing has potential to provide information on many factors related to rice production worldwide. Although production and yield statistics are available, data from many areas, especially those where access is difficult, is open to question. Moreover, because of differences in sampling methods, comparisons of production figures among different areas may not be valid. When compared with the number of investigations on wheat and maize, the number of remote sensing investigations on rice is meager; thus it is suggested that rice crop has presented investigators with a great array of problems both technical (example: cloud cover during monsoon season) and logistical. The reasons are of much higher diversity in growing conditions as well as yield, sensitivity of spectral indices to water background particularly in areas where the rice canopy is poor. If successfully applied, remote sensing of biomass can be important in global predictive estimates of grain production.

1.6. Need for Present Study

The mechanism for CH₄ emission consists of its formation in flooded soils and its transport through paddy plants to the atmosphere. The Intergovernmental Panel on Climate Change (IPCC, 1996) reported that paddy fields contribute about one-eighth of the globally generated CH₄. There is an urgent need to understand and measure the CH₄ emission in greater detail because in order to manage the wetland paddy fields through suitable soil-water-crop management practices for reduction of CH₄ flux.

The uncertainty in this estimate is caused by lack of flux measurements, gaps in the knowledge of the process of methanogenesis and lacunae in the geographic database of the harvested area of the various paddy eco-systems, soil types and soil-water-crop
management practices. The use of straw and compost stimulate soil reduction and methanogenesis, while the application of sulphate containing fertilizers (such as ammonium sulphate) may have reducing effect. Specific agronomic practices such as adapting levels, application mode and time of fertilization (including chemical as well as organic fertilizers), water management and varieties would be influencing the CH₄ emissions from flooded paddy fields. Flooded paddy soils with dry fallow periods between paddy growing seasons and fields that are likely to dry up during the cultivation period, are emanating less CH₄ (Neue et al., 1990). Heavy textured soils with high content of montmorillonite clays and high content of organic carbon will produce high rates of CH₄ formation. In leached tropical and other soils with ferritic, gibbsitic, ferruginous or hydrous oxide mineralogy, the methane production is not high if the dry fallow periods are followed in the crop rotation. So Kerala state was also selected so as to facilitate the study on methane production in lateritic, peat and acid sulphate soils and Kerala is only the state in India where peat and acid sulphate soils are found.

The Intergovernmental Panel on Climate Change (IPCC, 1996) estimated that it would require about 15-20% reduction in the total CH₄ emission in order to stabilize the global concentration of atmospheric CH₄ at today's level. Accurate estimates of emissions from the sources are difficult to arrive at, primarily due to the lack of extensive experimental data and several other factors, which control emission fluxes. There is an urgent need to generate more information on methanogenesis in paddy soils, for developing eco-friendly and economically viable mitigation technologies for tropical paddies.
Venkataratnam et al., (2003) have shown that Remote sensing data from IRS-1C and 1D satellites having three sensors Viz., PAN, LISS-III and WiFS sensors with 5.8, 23.5 and 188 metres of spatial resolution, respectively, could be used to estimate the paddy acreages at village, district, and state level. Soil map can be superimposed on the paddy growing areas, so that the CH₄ flux can be determined for each major soil unit. Such work is the unique one, which is integrating the CH₄ fluxes from different locations and acreages of paddy crop that are obtained from remote sensing data. This report describes the methodology adopted for estimation of regional CH₄ flux from paddy fields in Andhra Pradesh state in India.

The experiment was also conducted in different soil units of Kerala state as the western ghats receives not only the earliest rains but also highest rainfall in the country and the soils are of acid saline influenced by high tidal waves in addition to lateritic soils. Thus the studying the methane flux measurement, in such varying pedological conditions gives us an impetus in this specific research project resulting in the generation of data base on methane flux as such widely varying agro-pedo-climatological conditions hitherto not available. Hence the present study was conducted on lateritic (Pattambhi), acid sulphate (Known as Pokkali soils near Ernakulam) and kari (peat) soils (near Moncompu) with the following objectives.

Objectives of present study

1. Measurement of methane flux from broad paddy soil units as a function of diurnal and seasonal fluctuations and studying the inter-seasonal variations in both Andhra Pradesh and Kerala.
Estimation of seasonal integrated methane flux from paddy fields from different broad soil units based on paddy acreage derived from Remote sensing data and random sampling of CH₄ flux.

Studying the methane flux emissions from different paddy varieties including early maturing, medium duration, late maturing, hybrid and high yielding.

Development of relationships between spectral reflectance and methane flux as influenced by different growth stages.