

Original Research Article

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Emission of Methane from Dead Trees / Snags of Tropical and Sub-Tropical Forest Ecoregions

A. Muthu Kumar^{1*}, R. Ezhumalai², A. K. Pandey³ and M. Srinivasa Rao⁴

¹Department of Forest Protection, Institute of Wood Science and Technology, 18th Cross, Malleshwaram, Bangalore - 560003, Karnataka, India

²Department of Timber Mechanics, Forest Research Institute, Dehradun, India

³Alkem Health Science Ltd., Sikkim, India

⁴Chief General Manager (Planning), FDCM, Maharashtra, India

*Corresponding author

ABSTRACT

Methane emission from various sources of biosphere contributes to the global warming/climate change related problems. Methane release from standing dead or age old trees, a new-fangled source for emission of CH₄, was investigated. The experiment was carried out in tropical and sub-tropical forest ecoregions of Western Ghats of India. A standardized protocol was formulated for sampling and analysis of the gas samples collected from dead/decay trees. Based on our standardized protocol maximum and minimum emission of CH₄ concentration was recorded. The result confirms that dead trees in forests release significant quantity of methane and henceforth could be another source contributing to global warming. Our data suggest that the average methane emission from dead trees of Rosewood (*Dalbergia latifolia*) was 1949.89 ppm, Matti (*Terminalia tomentosa*) was 4630.36 ppm, Teak (*Tectona grandis*) was 1561.92 ppm and Shisham (*Dalbergia sisso*) was 3059.45 ppm.

Keywords

Methane flux,
Decay trees;
Tropical forests;
Western Ghats;
Global warming

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Introduction

Methane (CH₄) is the second most important anthropogenic greenhouse gas. Methane plays an important role in the chemical and radioactive balances in the Earth's atmosphere,

predominant source of water vapour (Jones and Pyle, 1984), and is the primary sink for chlorine radicals (Cicerone and Ordmland, 1988). The global warming potential (GWP) of CH₄ is 28 over a time horizon of 100 years (Myhre *et al.*, 2013). Methane is

released into the atmosphere, from both anthropogenic and natural sources (Patra *et al.*, 2011; Kirschke *et al.*, 2013). The present day concentration of CH₄ (~ 1800 ppb) is unprecedented over at least the past 800,000 years (Loulergue *et al.*, 2008).

Measurements of CH₄ in air bubbles trapped in Antarctic and Greenland ice sheets suggest that after a very slow increase (average rate of ~ 0.04 ppb yr⁻¹) during pre-industrial time (1-1750 AD), CH₄ concentration have increased rapidly (average rate of ~4 ppb yr⁻¹ during 1750-1990 AD) until the early 1990s (Rasmussen and Khalil, 1984; Etheridge *et al.*, 1998; Nakazawa *et al.*, 1993; MacFarling Meure *et al.*, 2006). The rapid rise of CH₄ levels paused in the 1990s (Dlugokencky *et al.*, 2003) and resumed strong growth starting in 2007 (Rigby *et al.*, 2008; Dlugokencky *et al.*, 2009).

Early in 2006, Keppler *et al.*, (2006) reported measurements that implied plants produced methane in aerobic condition, and that the fluxes were approx. 10–45% of the total global methane source. This implies either that the classical methanogenic pathway operates under aerobic conditions or has gone undetected in plants. A novel phenomenon has been found in some bacteria, where methane is a byproduct of methylphosphonate decomposition (Karl *et al.*, 2008).

Forest is the world's most important and most valuable renewable natural resource and also repositories of terrestrial biodiversity. This resource is facing serious threats due to abiotic and biotic stresses resulting from urban expansion, infrastructure development and agriculture and global warming (Bawa and Dayanandan, 1998).

In the forest, decay trees may be significant new source of methane that contribute to climate change, said Kristofer Covey,

researcher at Yale School of Forestry and Environment Studies. The study was carried out at Yale Myers Forest in northeastern Connecticut.

According to the Covey *et al.*, (2012) methane concentration release from decay trees were as high as 80,000 times ambient levels and found average levels of 15,000 parts per million inside trees.

The report of Covey *et al.*, (2012) concluded methane release from tropical dead forest has to be studied for understanding the comprehensive release of methane from various sources of this world. We had worked in tropical and sub-tropical forests from the state of Karnataka, India for understanding methane flux contribution.

Materials and Methods

Selection of study area

Five different location of Karnataka state where selected based on agro climatic zones *viz.*, Northern dry zone (Dharwad), Coastal zone (Kundapura Forest Division), Southern transition zone (Kudremukh National Park), Hilly zone (Ponnampet) and Eastern dry zone (Institute of Wood Science and Technology - IWST Campus).

Selection of trees

The selected tree species include dead trees / snags standing at different sampling locations as mentioned above at 2.1. The tree species we had encountered during our study were *Poeciloneuron indicum* (Balige), *Elaeocarpus tuberculatus* (Kunge Mara), *Carallia brachiata* (Andipunar), *Dalbergia sissoo* (Indian Rosewood), *Terminalia tomentosa* (Matthi), *Tectona grandis* (Teakwood), *Dalbergia sissoo* (Shisham) and *Anogeissus latifolia* (Dindiga).

Sampling methods

The gas samples were collected based on the methodology adopted by Covey *et al.*, (2012), which includes;

Trees were drilled at chest height (1.3 m) with 5/16" drill bit and immediately plugged with a stopper of appropriate size.

After that 50 ml syringe was inserted through the stopper into the cavity to remove 50 ml trunk gas from each tree and store into a vacuum sealed sample vials for GC analysis.

Steps standardized for trunk gas sampling in our study

Trees were drilled horizontally at chest height to mid portion of the trunk with a 12 mm drill bit and immediately plugged with a 14 mm stopper.

Incubation period: 2hrs / 4hrs / 6hrs / 12hrs / 24hrs.

A 20ml gas syringe was inserted through the stopper into the cavity to remove 20 ml of trunk gas from each tree.

Then trunk gas samples were stored into an anaerobic gas chromatography vials for further laboratory analysis.

Gas Chromatography (GC) analysis of collected methane sample

The trunk gas methane concentration was analyzed by a gas chromatography with FID (flame ionization detector). The gas concentrations were represented in ppm. The procedure for GC analysis is described below.

Prepare the standard samples for calibration and set the parameters

Oven temperature = 60° C

FID temperature = 350° C

Carrier gas pressure = 4kg (N₂), 2kg (O₂), 2kg (He)

After set the parameter, GC was calibrated by inject standard samples containing varying concentrations of the compound to be analyzed and creating a calibration curve

Then trunk gas sample was injected into the carrier gas stream by inserting the needle of a special expensive syringe through a heavy wall rubber septum of gas sample vials.

After all the peaks attained stop the run and get results

The retention time for methane was near to 1.2 min. The methane peak usually comes of within a few minutes after CO peak. Peak area counts for each sample and compared with a calibration standard curve

After that calculate the calibration factor from standard, the amount of Methane (percent) in each sample calculate based on the calibration factor of standard

Observation and calculation of GC data

Statistical Analysis

SALSTAT 2 software was used for understanding the distribution of methane flux for all the selected tree species and their comparison using plot box and whisker graph.

Results and Discussion

Tree species and geographical location

The selected dead trees were old ranging between 80-90 year's approximately, and the species involved were *Poeciloneuron indicum* (Balige), *Elaeocarpus tuberculatus* (Kunge

Mara), *Carallia brachiata* (Andipunar), *Dalbergia sissoo* (Indian Rosewood), *Terminalia tomentosa* (Matthi), *Tectona grandis* (Teakwood), *Dalbergia sissoo* (Shisham) and *Anogeissus latifolia* (Dindiga). The geographical locations are as follows (Tab. No.1).

The dead trees were selected based on visual tree assessment or symptoms expressed by the trees. Only dead trees were selected, partially dead trees were ignored. We had identified 10 numbers of dead trees of *Poeciloneuron indicum* and *Elaecarpus tuberculatus* from Kudremukh National Park for trunk sampling. The gas samples were collected from the trunk of the dead trees as suggested by Covey *et al.*, (2012). The Gas Chromatography analysis of the samples from Kudremukh National Park revealed negative results, hence Covey method was modified, standardized and adopted (Materials & Methods 2.4). Later, standardized method of trunk gas sampling was carried out at IWST Campus. Since the selected tree species was completely dead and only the snag was present, species identification was not possible. The species *Carallia brachiata*, was selected for the study purpose from Kundapura Forest Division spread along three different ranges *viz* Kundapura range, Sanker Narayana range, and Hebri range. The selected trees were completely dead. From hilly zone, we selected Ponnampet of Kodagu district for our study purpose, where we noticed age old *Dalbergia sissoo* and *Terminalia tomentosa* found to be stressed followed by decline. In our study the northern part of Karnataka was represented by the forest areas of Dharwad. Here we found different tree species of *Tectona grandis*, *Terminalia tomentosa*, *Dalbergia sissoo* and *Anogeissus latifolia* which were found dried and dead (Tab. No. 2). The selected trees for this study fall under

different agroclimatic zones and they were almost dead due to interchangeable predisposing, inciting, and contributing factors.

Gas Chromatography and Statistical Analysis

The gas samples were analyzed using Gas Chromatography (Mayura Analytical Pvt. Ltd, Bangalore) as per the procedure stated in Materials and Methods 2.5. The distribution of methane flux of dead trees from IWST Campus was 78690 ppm with an incubation period of 24 hours, while the lowest emission was recorded as 20 ppm with an incubation period of 2 hours (Fig. No.1).

The highest emission of CH₄ was recorded in *Carallia brachiata* which was 38602 ppm (24 hours) and lowest was 277.985 ppm (2 hours). The methane flux data of *Carallia brachiata* was experimented during summer and winter season (Fig. No. 2 and 3).

Dalbergia sissoo from Ponnampet was recorded with highest CH₄ emission of 5373 ppm (24 hours) and the lowest emission recorded was 84.08 ppm (2 hours), while in *Terminalia tomentosa* the highest CH₄ emission observed was 34540 ppm (24 hours) and the lowest recorded 432 ppm (2 hours) (Fig. No. 4 and 5).

Tectona grandis from Dharwad region was recorded with maximum CH₄ emission of 3456 ppm (24 hours) and the lowest emission recorded was 334.1 ppm (2 hours). The trees of *Anogeissus latifolia* showed a maximum CH₄ release of 9422 ppm (24 hours) and the lowest emission recorded was 1.449 ppm (2 hours). *Terminalia tomentosa* located at Dharwad emitted highest CH₄ emission of 10120 ppm (24 hours) and the lowest emission recorded was 175.7 ppm (2 hours).

Table.1 Geographical locations and tree species

S. No.	Name of the tree species	Locations
1.	<i>Poeciloneuron indicum</i> and <i>Elaecarpus tuberculatus</i>	Kudremukh National Park
2.	<i>Carallia brachiata</i>	Kundapura Forest Division
3.	<i>Dalbergia sissoo</i> and <i>Terminalia tomentosa</i>	Ponnampet
4.	<i>Tectona grandis</i> , <i>Terminalia tomentosa</i> , <i>Dalbergia sissoo</i> and <i>Anogeissus latifolia</i>	Dharwad

Table.2 Characteristics and sample collection details from dead trees

Latitude	Longitude	Tree Species	Number of dead tree	Canopy height (m)	Sampling height (m)	Gas quantity taken (ml)
Kudremukh National Park Forest region						
13°07'46.24"N	75°16'06.79"E	<i>Poeciloneuron indicum</i>	3	29	1.5	20
		<i>Elaecarpus tuberculatus</i>	7			
IWST Campus Forest region						
13°00'40.33"N	77°34'12.72"E	-	10	30	1.5	20
Kundapura Forest Division Forest region						
13°00'40.33"N	77°34'12.72"E	<i>Carallia brachiata</i>	26	35	1.5	20
Ponnampet Forest region						
12°08'56.60" N	75°56'25.86" E	<i>Dalbergia sissoo</i>	19	32	1.5	20
		<i>Terminalia tomentosa</i>	23	35	1.5	20
Dharwad Forest region						
15.3778° N	75.2479° E	<i>Tectona</i>	5	36	1.5	20
		<i>Dalbergia sissoo</i>	9	30	1.5	20
		<i>Terminalia tomentosa</i>	5	30	1.5	20
		<i>Anogeissus latifolia</i>	11	31	1.5	20

Fig.1 Gas Chromatography data plotted showing distribution of methane flux in trees at IWST Campus

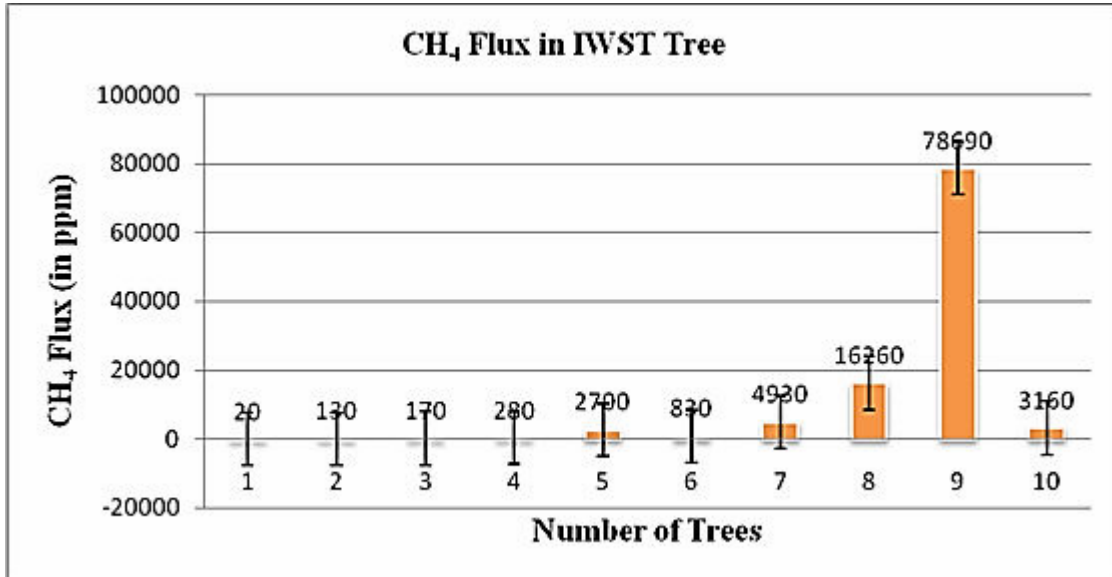


Fig.2 Gas Chromatography data plotted showing distribution of methane flux in *Carallia brachiata* during summer

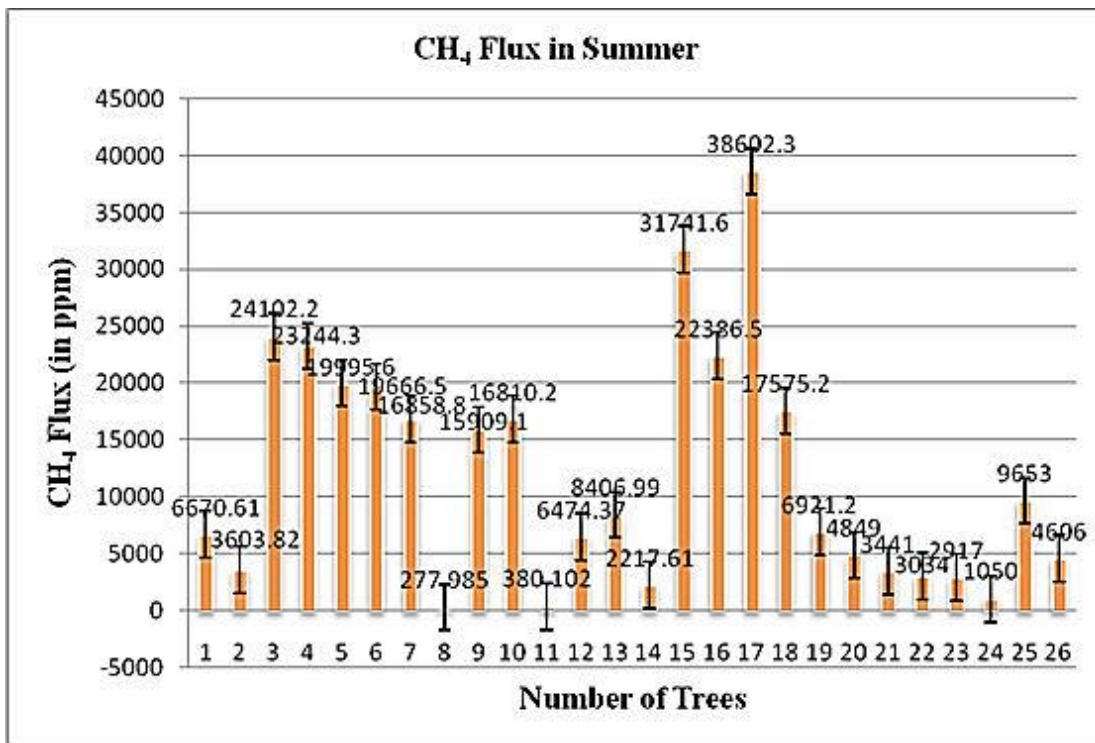


Fig.3 Gas Chromatography data plotted showing distribution of methane flux in *Carallia brachiata* during winter

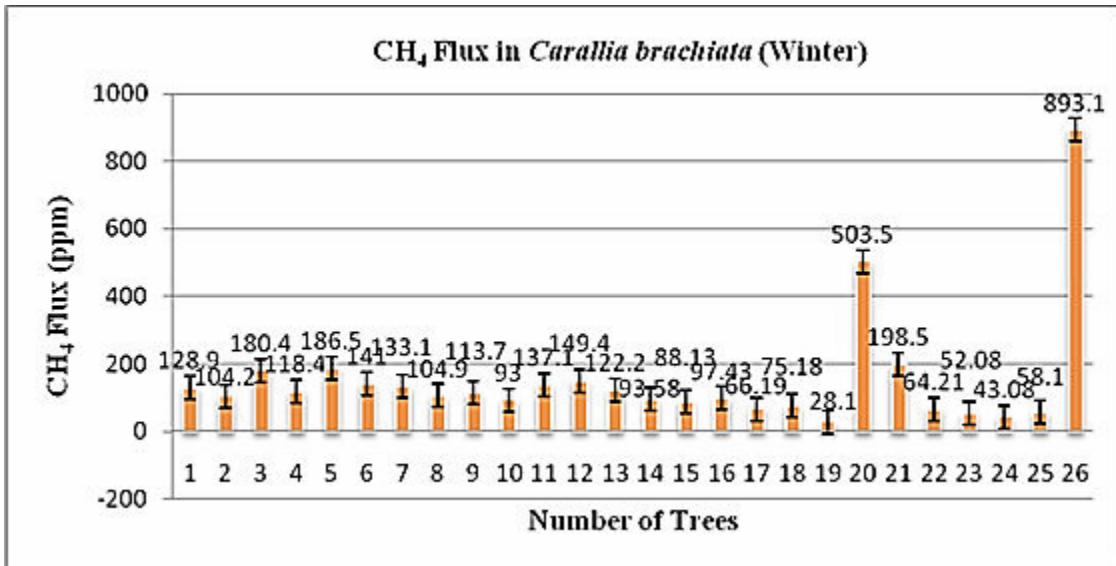


Fig.4 Gas Chromatography data plotted showing distribution of methane flux in *Dalbergia sissoo*

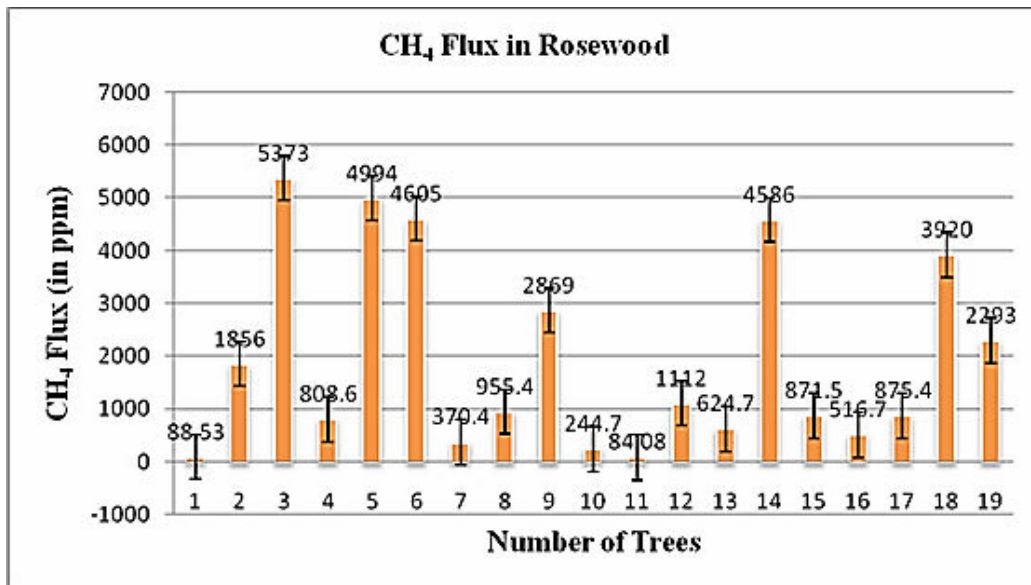


Fig.5 Gas Chromatography data plotted showing distribution of methane flux in *Terminalia tomentosa*

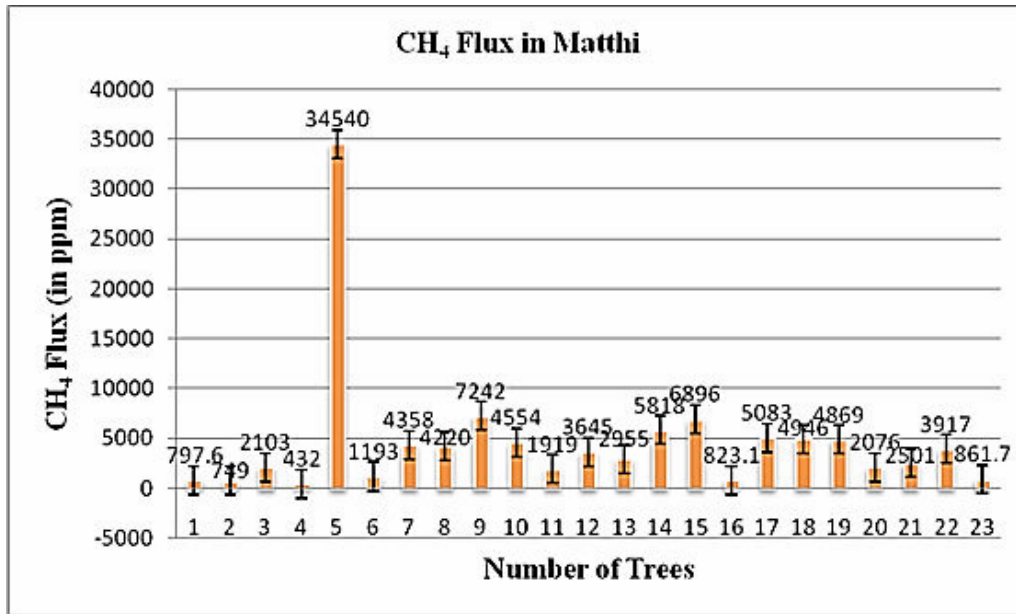
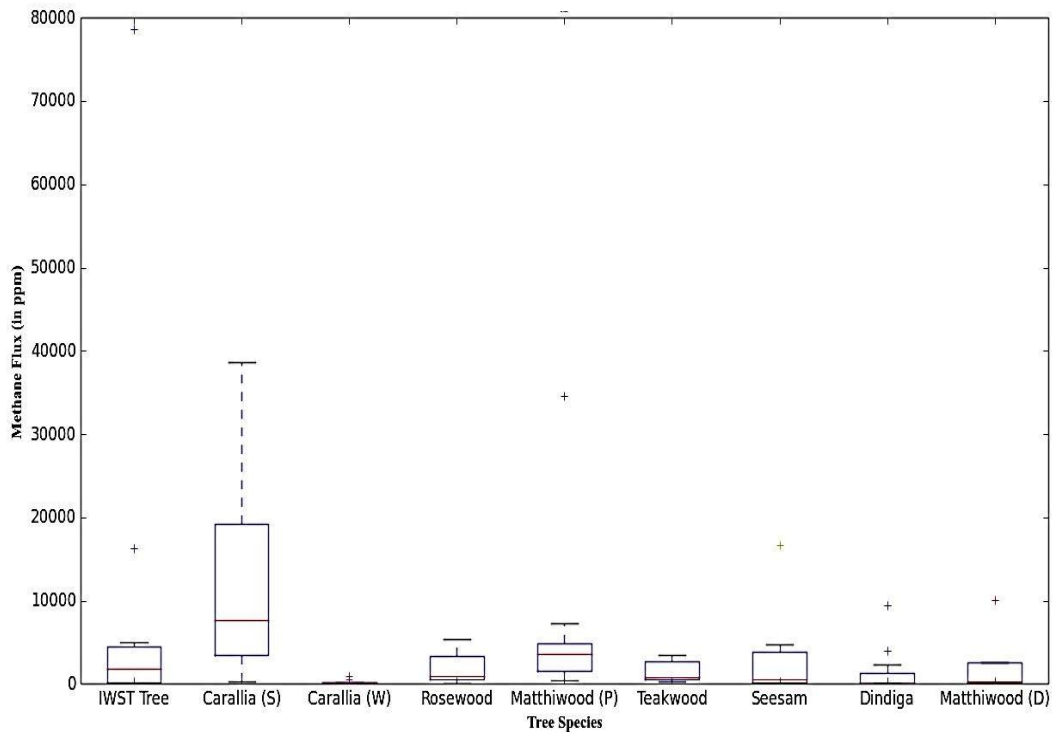


Fig.6 Box and whisker plot showing distribution of methane flux between species



The GC analysis of *Dalbergia sissoo* showed the highest CH₄ emission observed was 16680 ppm (24 hours) and the lowest emission recorded was 1.677 ppm (2 hours).

Box and whisker Plot

Box plot is a convenient way of graphically depicting groups of numerical data through their quartiles. Box plots may also have lines extending from the boxes (whiskers) indicating variability outside the upper and lower quartiles. Box and whisker plot showing distribution of methane flux from species to species. CH₄ emission in the dead trees of *Carallia brachiata* species displayed a strong seasonal variation (Fig. No. 6). Box plots are non-parametric, they display variation in samples of a statistical population. The spacing between the different parts of the box indicates the degree of dispersion (spread) and skewness in the data.

Various methods have been reported for quantification of CH₄ emission from tree sources. Terazawa *et al.*, (2007) used a steel chamber that was placed on the tree stem and gas samples were extracted from the chamber in intervals of 10 to 60 min and the CH₄ contents of the gas samples were measured to extrapolate CH₄ flux. The first experimental research paper published in the field of anaerobic CH₄ emission in dead trees by Covey *et al.*, (2012), where he argued that CH₄ flux could be extrapolated from concentrations of CH₄ measured in core samples especially on trees with uneven bark, this technique is much similar than measuring fluxes. Henceforth, careful considerations were taken at each step of the process ensuring reliable results as an outcome during our modified methodology for sampling gas from dead trees. Some of the factors that determine the quantity of methane were depth of the drill and incubation period. When the incubation

period increases the quantity of methane estimated was also the highest. It is now six years (the period of this study – 2018) since Covey *et al.*, (2012) reported anaerobic CH₄ emission from dead tree. Our data suggest that dead trees in the forest contribute significantly to global CH₄ emission. The CH₄ concentration from six tree species *viz.*, *Carallia brachiata*, *Dalbergia sissoo*, *Terminalia tomentosa*, *Tectona grandis*, *Dalbergia sissoo* and *Anogeissus latifolia* from different agro climatic zones of Karnataka were estimated. The maximum mean CH₄ flux of 11976.73 ppm was observed in *Carallia brachiata*, while the minimum of 1470.77 ppm was observed in *Anogeissus latifolia*. Therefore in addition to existing facts, it is once again proven that dead trees in forests are significant producers of CH₄ gas. The present work was executed in tropical and sub-tropical forests of India. Our standardized method for CH₄ gas extraction from dead trees was found effective. In connection to present change in climate pattern and subsequent effect on forest health, similar studies could be minimum significance in global warming prediction.

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