Intensive agriculture is practiced worldwide to meet the huge food demand of rapidly growing population. This leads to environmental consequences like soil and water quality deterioration and greenhouse gases (GHGs) emission. Nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4) are the major long-lived greenhouse gases (GHGs) that are emitted from agricultural soils including both anthropogenic activities and natural process [1], [2]. About 60-80% of the annual anthropogenic N_2O and CH_4 emissions are estimated from agricultural lands [3]. Agriculture contributes to GHGs emissions mostly due to enteric fermentation (CH_4), addition of chemical fertilizers (N_2O), and soil tillage (CO_2) [4]. Nitrous oxide is a key greenhouse gas with half-life of 114 years in the atmosphere posing 298-fold higher potential for global warming than carbon dioxide [5]. Atmospheric N_2O has risen steadily from approximately 290 ppb in 1940 [6] to 334 ppb in 2021 [7]. Application of inorganic nitrogenous fertilizers is the main reason of increased agricultural N_2O emission, and the emission becomes higher when it is escorted by rainfall or irrigation [8]. Moreover, the readily available nitrogen substrates for microbial processes and high volatile nature of inorganic nitrogen fertilizers are the cause of increased N_2O emission [9], [10]. Nitrous oxide in soil is mostly produced due to the nitrification and denitrification processes [11], [12]. These processes occur naturally in soil when inorganic nitrogen (NH_4^+ and NO_3^-) substrates become available for the microbes [13], [14]. According to the Indian Ministry of Chemicals and Fertilizer, an average of 500 lakhs metric tonnes of fertilisers are used in India each year, out of which 2/3 are nitrogenous fertilisers [15]. However, the emission could be reduced, or agriculture induced global warming could be mitigated by actively managing the inorganic fertilizer uses and other agricultural procedures.

It is well accepted that organic farming is a sustainable option to maintain soil-plant ecological relationship and to reduce GHGs emission from agricultural lands. It emphasises on use of organic fertilizers for enhancing soil properties, nutrient cycling and crop health to mitigate climate change [16]. However, to meet the demand of organic fertilizer is a huge challenge. In this regard, use of biochar prepared from agricultural waste is achieving significant attention in recent time. Different organic feedstocks such as agricultural and garden wastes, plant-based feedstocks, animal litters, algae, and other solid wastes, etc. are used for biochar preparation [17]. India generates approximately 500 Mt of agro-waste every year and production of biochar using this huge waste will be a sustainable environment-friendly approach

[18], [19]. The unique features of biochar such as high carbon content, pH, large specific surface area, high adsorption potential and water retention capacity, and high recalcitrance potential to microbial degradation make it a potential amendment for soil application [20], [21]. Biochar improves soil microbial diversity, physico-chemical properties and nutrient status that boost crop production [22]. Several studies documented proficiency of biochar in climate change mitigation by reducing GHGs emission from agroecosystems [23], [24], [25]. Moreover, it offers prospects to sequester carbon for considerably longer times than raw biomass or solid waste [26]. The larger specific surface area of biochar contributes to profuse microbial growth by enhancing natural soil respiration rate [27]. Biochar application decreases the availability of environmental pollutants in soil by forming complexes and thereby reduce their hazard in food chain [28], [29]. Infiltration of water in landfill covers and slopes can also be managed by application of biochar [30], [31]. Furthermore, biochar is an alternative source of clean energy due to lower sulphur content and higher calorific value [32]. However, some of the research studies documented damaging effects of biochars on soil health and increased GHGs emission from agricultural soils [33], [34], [35]. These contrasting results of using biochar as soil amendment may be due to the properties of both biochar. Since, the role of biochar is governed by its specific properties [36] which relies on the characteristics of feedstock, production temperatures as well as the method [37], [38]. Several methods are used to produce biochar namely pyrolysis, gasification, conventional char production, hydrothermal treatment, torrefaction, carbonization and flash carbonization [39]. The production temperature determines the yield and physico-chemical properties of biochar [40]. Generally, biochar produced at lower temperature (below 350°C) has low recalcitrance and are found to be less effective as a soil amendment [41]. Whereas studies have shown that advanced and sustainable biochar can be produced over a prolonged temperature treatment (between 400 and 700°C) of several hours [42], [43]. Additionally, higher production temperature of biochar enables better recalcitrance of carbon with greater pH, EC, specific surface area and nutrient availability. This increases the possibility of their use for improving soil quality and crop growth [44], [45]. Similarly, carbon and nutrient composition of biochar depends on the specific characteristics of the feedstocks. Higher carbon and lesser nutrient composition were documented in hard wood derived biochar, while agro-waste based biochar displayed contrasting results [46]. Thus, according to the differences in cellulose,

hemicelluloses, lignin and elemental contents in feedstocks, and production temperature and methods, the characteristic of produced biochar varies [47], [48].

Influence of feedstocks and different production methods on biochar properties and their role as soil amendment were studied earlier. However, field experiment using biochar as amendment on North-eastern Indian soil is hardly been addressed. Moreover, most of the locally available feedstocks for biochar production remain unused due to the unavailability of production facility. Whereas, studies on conventional low-cost biochar production method are not getting adequate importance.

Assam is the largest tea producing state of India (51.77 million kg during January-April 2021, according to tea board of India) and tea pruning litter is one of the major agro-waste of the state. Additionally, Assam is rich in wood timber production, and good quantity of woodchips are produced from wood-based industries. However, documentation regarding use of these locally available feedstock in biochar production are scanty. Therefore, a research initiative was undertaken to produce biochar using tea pruning litter and mixed wood chips under different production technologies i.e., pyrolyser, gasifier and conventional methods. Present study investigates the physico-chemical properties of the produced biochars. Moreover, the study explores current understanding and knowledge gaps of biochar application as a tool to reduce N_2O and CO_2 emissions and impacts of biochar on crop yield and soil quality in acidic sandy loam soils of Assam.

Hypothesis of the study:

- Biochars produced from some commonly available feedstocks (tea pruning litters, and mixed wood chips) with different production techniques (gasification, pyrolysis and conventional methods) will exhibit different characteristics.
- Screening of proper feedstock and production technology for biochar can reduce the use of chemical fertilizers, improve crop growth, soil property and mitigate GHGs emission from agroecosystems.

Objective of the study:

1. To study the characteristics of biochars produced from different feedstocks and methodologies.
2. To investigate the impact of biochar application on soil properties and crop health.
3. To estimate the impact of biochar application on emission of GHGs (N_2O, CO_2) from agroecosystems.

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