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Mitigation of climate crisis from rice paddy field by tillage combination in central China

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Abstract
We have tested the tillage combination to study methods that help curtail the release of greenhouse gasses from rice paddy fields have had on the climate and contrasted the potential outcomes for rice production (Oryza sativa L.), no-tillage plus no fertilizer (NT0), conventional tillage plus no fertilizer (CT0), conventional tillage plus compound fertilizer (CTC), no-tillage plus compound fertilizer (NTC) by measuring ammonia volatilization and greenhouse gases emissions (GHG) from paddy fields for rice throughout the year of 2018 in the subtropical area of central China. The mean NH_3 volatilization in CT0 was 9.55% greater than that in NT0 by ($p>0.05$), and for NTC, it was 11.30% ($p>0.05$) lower than in CTC. In comparison to CT0, the mean CH_4 emission flux in NT0 was 1.12% ($p>0.05$) lower, but the mean CH_4 emission flux in CTC was 28.34% ($p>$ 0.05) higher than that in NTC. The mean N_2O emission flux in NT0 was 174.72% ($p<0.05$) lower than in CT0. The average flux of N_2O emission in CTC was 47.90% ($p>$ 0.05) greater than in NTC. We compared the IGWPs based on N_2O, CH_4, and CO_2 emission flux. CT0 had the lowest (non-significant) recorded amount at 12097.43KgCO_2.ha^{-1} of GWPs, which was only 397.5KgCO_2.ha^{-1} lower than that in NT0. CTC had the highest recorded amount at 20042.72KgCO_2.ha^{-1} of GWPs, which was 2292.53KgCO_2.ha^{-1} higher than that reported in NTC. NTC system to be the superior, sustainable method for mitigating the harmful effects of GHG emissions contributing to the climate crisis by way of rice production in rice paddy fields.

Keywords: Rice cultivation, Climate crisis, No-tillage, Conventional tillage, GHG, NH_3 volatilisation

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Introduction

The greenhouse effect is a process that happens naturally, but human activity's release of greenhouse gases (GHG) into the atmosphere may make it unpleasant. Globally, N_2O, CH_4, and CO_2 each comprise 5%, 15%, and 60% of the anthropogenic greenhouse gas effect (Rodhe, 1990). Since the

Industrial Revolution, these gases' significant increases in air concentrations have occurred. They are recurring annually by 0.3%, 1.1%, and 0.5%, respectively (IPCC, 2022). Some academics and decision-makers support NT agriculture as a successful strategy for reducing the climate crisis. (Soussana, 2017; Baveye, 2018). The century's end predicted the average world temperature to rise by around 1.8 °C in 2025 and by 3.8 °C if the GHG emissions keep increasing at the current rate (IPCC, 2001). An excess of 30% of the world's rough rice comes from China, which is produced globally, making it the world's largest rice producer (IRRI, 2004). Marshy land releases CH4, a principal GHG, with an estimated GWP on a mass basis that is 25 times more than CO_2 over a 100-year time horizon (http://www.ipcc.ch/). Over the past few decades, global worry has already resulted from increased atmospheric methane concentration. Wetland paddy fields emit between 10 and 20 per cent of all methane emissions, or between 50 to 100 Tg $^{-year}$. Biotic and abiotic elements influence methane emission from rice fields, including the development stage of rice, soil properties, soil temperature, and methane oxidation during production and transfer to the atmospheric environment (Kumaraswamy et al., 2000; Rath et al., 1999; Yang and Chang, 1997 and 1998). In the first 15 cm of the soil, Schutz et al. (1989) discovered a link between soil temperature and emissions of CH_4. According to Li and Lin (1993), soil water content greatly influences CH_4 emissions by having a sturdy influence on the action of methanogenic bacteria through its impact on the redox potential. Soil characteristics such as organic matter, textures, bulk density, concentrations, infiltration rates, porosities, and soil-microbial densities also influenced methane emissions. N_2O has a lower atmospheric concentration than CO_2, yet it has a 298-fold greater global warming potential (GWP) than CO_2. It contributes 5% to the overall GHG impact (http://www.ipcc.ch/), but 60% of N_2O emissions are related to agriculture. N_2O production can be directly impacted by changes in the nitrification and denitrification rates in the soil by controlling agricultural water use and applying fertilizer (Xiong et al., 2007). Like CH4, differing soil types compaction how much N_2O is created and released from paddy soil. (Mitra et al., 2002a; Wang et al., 1999).

N losses and the mass amount of ammonium volatilization (NH_3) that occurs from inefficient N fertilizer application to rice, but it remains an essential avenue for loss of N due to the flooding of rice paddies. As causes of NH_3 volatilization, Song et al. (2004) cited variations in water management, fertilization techniques, soil microbial activity, and other factors. Through air transit and deposition, the volatilization of NH_3 causes N loads to be released into the environment. Continuous and excessive N loading eutrophicates the environment, which might have various ecosystem-wide effects (Vitousek et al., 1997; Emmett, 2007). Therefore, research into the variables influencing ammonia volatilization from paddy soil and the development of sensible fertilization procedures are crucial to lessen the harmful environmental effects of applying fertilizer.

No-tillage systems that use direct mulch crop residues (DMC) typically result in higher N_2O emissions and lower CO_2 and CH_4 emissions because of C fixation. Therefore, effective mitigation is only conceivable if DMCs significantly impact lowering the GWP as measured using the GHG fluxes (Six et al., 2002). Only a few studies have investigated this issue (Six et al., 2002; Mummey et al., 1998). Effects of N_2O, CH_4, CO_2, and NH_3 volatilization for the same paddy soil over four months are presented in this work, along with providing an evaluation of tilled versus no-tilled systems. The article is among the earliest to report the above fluxes, concentrations, and no-till management profiles from a fertilized subtropical location. Thus, the following were the primary goals of this research: (i) to assess CO_2, CH_4, and N_2O emissions from conventional (CT) and no-tillage (NT) systems of rice farming (to keep wetland conditions suitable for rice cultivation, several fields are prepared by puddling) in rice fields; (ii) to determine whether tillage may affect NH_3 volatilization; (iii) to assess the GWPs of the CT systems and the NT systems using CO_2, CH_4, and N_2O emission.

Material and Methods

Site details and soil characteristics

The Experimental Farm is the test location in Dafashi Town, Hubei Province of China, at 29.55°N latitude and 116.33°E longitude, 22 meters above sea level. Having a 16.8 °C yearly average temperature and 1357.6 –1535.7mm of precipitation, this area experiences a soggy mid-subtropical monsoon environment, with the maximal of the rain falling between mid-April and August-last. Water logogenic paddy soil, a clayey, silty soil derived from yellow quaternary sediment, makes up the soil in rice fields. The plow layer and pan have 20 and 10 cm thicknesses, respectively. The location's main soil qualities are listed below (0–20 cm soil depth): pH, 6.47; attainable P, 3.86 mg-^{kg}; accessible K, 113 mg^{-kg}; total N, 3.87 g^{-kg}; organic C, 18.45 g^{-kg}; NO_3^-–N, 4.49 mg^{-kg}; NH4$^+$–N, 2.48 mg^{-kg}; total P, 0.77 g^{-kg}; tangible K, 113 mg^{-kg}; soil bulk density, 1.48 g^{-cm3}. The plough layer and pan have 20 and 10 cm thicknesses, respectively.

The prevalent local medium *Liangyoupeijiu* was the variety of rice (*Oryza sativa* L.) donated by the MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Researches of the Yangtze River, Huazhong Agricultural University, China. The experimental field used a rape-rice rotation planting strategy, in which rape was planted without any tilling from October to May of the following year, 30 years ago, and direct seeding of rice under tilling circumstances from May first week to October last week of each year. Starting in 2006, no-till conditions were used to produce rice and rapeseed.

Designed experiments

Three replications of 45 m^2 each were used in the experiment, each with one of the following treatments: no-tillage plus no fertilizer (NT0), conventional tillage plus no fertilizer (CT0), conventional tillage plus compound fertilizer (CTC) and no-tillage plus compound fertilizer (NTC). Each plot has four compartments of 120 cm wide and five trenches 30 cm deep and 20 cm wide. On June 3, 22 kg/ha of rice seeds were planted, and on October 11, they were harvested. Standard fertilizer rates of 210kg N/ha, 135kg P_2O_5/ha, and 240kg K_2O/ha were used. June 1, compound fertilizers containing 40% nitrogen were broadcast. On June 15, July 15, and August 6, respectively, three doses of urea with an excess of 60% of N-fertilizers were used. Phosphorus fertilizers and potassium were also used as base fertilizers on June 1, following the standard rate (Table 1). As soon as the trenches were not floodwater, irrigation was carried out. All management and agronomic procedures for the four experimental treatments were the same, and the techniques were adopted from the PhD research (Ahmad, 2009).

Sampling and measuring of gases

Ammonia (NH_3) volatilization

The continuous airflow enclosure approach was utilized to measure the volatilization rate of ammonia. The chamber's depth in the ground allows for adjustment of the vol. of the NH_3 volatilization room (20 cm in diameter). A pump with a predetermined air exchange rate of 2 volume$^{-minute}$ based on the space size used for volatilization. (Tian et al.,1998). The two observational chambers were installed in an irrigation water-filled basin. Every morning and in the afternoon, we twice tested the ammonia volatilization rate at 1-hour intervals, documenting any variations for four months before finally harvesting. To remove any discrepancies in circumstances between the chambers' inside and exterior, the air was constantly flowing for each measurement at an hourly interval. The rate of ammonia volatilization was measured twice after the first week of applying base fertilizer, once just after the first top-dress with two days between measurements, once after the second top-dress with two days between measurements, once after the third top-dress with two days between measurements, and once after the average one-week interval. Each plot had samples collected from three replications.

Carbon dioxide (CO_2) emission flux

Using Parkinson's soil respiration method (1981), which involved placing a cylinder chamber on the soil with a 30 cm height and 20 cm diameter, we could estimate soil CO_2 flux. We did this by observing how quickly the CO_2 concentration increased inside the chamber.

Table-1: Each treatment of 22 kg/ha rice seed was broadcast on 2 June 2018 and fertilized for a different duration.

Treatment	▼Basal/ June 1	Topdress-1/ June15	Topdress-2/ July 15	Topdress-3/ August 6
NTC	81 kg.N^{-ha} + 135 kg $P_2O_5^{-ha}$ + 240 kg K_2O^{-ha}.	43 kg. N^{-ha} as urea	43 kg. N^{-ha} as urea	43 kg. N^{-ha} as urea
CTC	81 kg.N^{-ha} + 135 kg $P_2O_5^{-ha}$ + 240 kg K_2O^{-ha}.	43 kg. N^{-ha} as urea	43 kg. N^{-ha} as urea	43 kg. N^{-ha} as urea

Note: ▼In both treatments, the extra 60% N fertilizer was equally divided and applied to topdress-1, 2, and 3 as urea.

A portable photosynthetic analyzer, the LI-6400 (Li-Cor Inc., Lincoln, NE), was used to monitor the CO_2 flow at the soil's surface from June 4 to October 10. Every sample was taken at intervals of one hour. Every plot was sampled three times, and the average of the three readings was used to calculate the CO2 flow from that plot. The initial week following basal fertilizer application saw CO_2 flux rates measured in two-day intervals and similar intervals following the first top dress, the second in two weeks, the third in a week, and later, after roughly one week.

Fluxes of N_2O and CH_4 emissions

CH_4 and N_2O were sampled using the static chamber technique using 58×58×120 - cm metal steel chests (Crill et al., 1988). Each sampling chamber contained six rice seedling hills. Gas samples of CH_4 and N_2O were started on June 4 and stopped on October 10. Initial gas samples were collected before and following subsequent top dresses 1, 2, and 3, as well as following basal fertilization by two days. Following topdress-3, samples were collected on average every two weeks. Each sample was separated into three equal parts at 9-minute intervals. Precisely, to measure CH_4 and N_2O, a Gas Chromatograph meter (Shimadzu GC-14B) was utilized. Temperature controls were set for the injector of a column detector at 55 °C, 110 °C, and 220 °C, respectively. It was kept at the same flow rate at 40 ml^{-min} while the carrier gas, N_2, was utilised to measure N_2O. Temperatures of 60 °C, 120 °C, and 280 °C were set for the column, injector, and detector.

Using the Zheng et al. (1998) equation, the flow of gas emission was based on the variation in gas concentration: $F = \rho h\ (dC/dt)\ 273\ (273 + T)^{-1}$,

where F denotes gas emission flux (mg/m/h), ρ denotes gas density in normal conditions, h denotes the chamber's height above the ground (m), C denotes the concentration of the ratio of gas mixing (mg^{-m3}), and T is the chamber's average air temperature. Total gas emissions were computed by combining daily and cumulative gas discharges throughout the research period. For each period, accretive gas emissions were calculated as the average of the results from the previous two sample days plus the total number of days without sampling plus one (Singh et al.,1996).

Statistical analysis

The differences between treatments were evaluated using SPSS 19 for Windows paired sample t-test methodology. When there were substantial differences, LSD tests were applied. The data's median and standard deviation are displayed in the tables.

Results

Seasonal changes in CO_2 emission rates from various rice tillage systems

Total rice growth time was 128 days, of which 65 days were spent in the vegetative stage, 35 days in the reproductive stage, and 28 days in the ripening stage. The CO_2 emission flux surged three days after the broadcast began and remained high. It grew rapidly 15 days before harvesting but quickly fell the month before and gradually slowed down in the final week. In NT0, the average CO_2 emission flow was 6.21 ± 0.52 $g.m^{-2}.d^{-1}$,which was 1.78 % higher than CT0 ($p > 0.05$). In CTC, it was 6.41 ± 0.60 $g.m^{-2}.d^{-1}$, 5.58% lower than NTC ($p > 0.05$). In NTC, it was 8.93% higher than NT0; in CTC, it was 5.02% higher than CT0 ($p > 0.05$).

Table 2 displays CO_2 emissions during different rice growth periods under various treatments. In 2018, CO_2 emissions from NT0 and CT0 during rice growth were 7624.45 and 7639.95 kg/ha, respectively. In this instance, the emission flow was only 1.02 ($p > 0.05$) times CT0. On the other hand, the amount of CO_2 emission from NTC was 8230.95 kg/ha and 7849.75 kg/ha from CTC, which was only 1.04 ($p > 0.05$) times CTC. NT0 and NTC were 7624.45 kg/ha and 8230.95 kg/ha, meaning emission was 1.079 ($p > 0.05$) times NT0. CT0 and CTC, CO_2 emission was 7639.95 kg/ha and 7849.75 kg/ha, which indicates emission was 1.027 ($p > 0.05$) times of CT0.

Seasonal changes in CH_4 emission rates from various rice tillage systems

After flooding, CH_4 emission flux increased and was preserved at a relatively high caliber in NT0, CT0, NTC, and CTC, where previously it was lower. NT0 and CT0 show a roughly similar trend before rice harvesting. However, after the first top-dress to two weeks before harvesting, NTC and CTC CH_4 emission flux showed a higher variability and kept a high level. In all treatments, CH_4 emission flux decreased rapidly before two weeks of harvest, with NT0 recording the lowest level while rice grew. The average flow of CH_4 emissions for NT0 was 5.33 ± 0.94 $mg.\ m^{-2}.\ h^{-1}$, which was 1.12% and 83.95% lower compared to CT0 and NTC ($p < 0.05$).

On the other hand, CT0 was 5.39 ± 0.39 mg. m^{-2}. h^{-1} was 133.48 % less than CTC ($p < 0.05$). The average amount of CTC was 12.59 ± 1.04 mg. m^{-2}.h^{-1} was 28.34% higher than NTC ($p<0.05$). Table 2 shows that the amount of CH_4 emission from NT0 and NTC were 18904.42 mg. m^{-2} and 33656.18 mg. m^{-2} ($p < 0.05$), respectively. This was 1.78 times as much compared to NT0. CT0 and CTC were 16571.4mg.m^{-2} and 43519.40mg.m^{-2} ($p < 0.05$) was 2.63 times higher than those from CT0. On the other hand, NTC and CTC emission flux was 33656.18mg.m^{-2} and 43519.40mg.$m^{-2,}$ respectively, which was 1.29 ($p > 0.05$) times of NTC. However, the result, NT0 and CT0 shows that NT0, CH_4 emission flux was 1.14 ($p >0.05$) times of CT0.

Table-2. The overall sum of CO_2, CH_4, N_2O emission and NH_3 volatilization during growth period of rice (June 3 ~ October 9, 2018) in different tillage

Gases with unit	Treatment			
	NT0	CT0	NTC	CTC
(CO_2) kg CO_2/ha	7624.45a	7639.95a	8230.95a	7849.75a
(CH_4) mg CH_4/m^2	18904.42a	16571.41a	33656.18b	43519.40c
(N_2O) mg N_2O/m^2	48.36a	105.58b	370.87c	440.64d
(NH_3) kg N/ha	10736.37a	13003.4a	49715.3b	42751.4b

At the 5% level, there are no significant differences between a group of common letters.

Seasonal variation in amounts of N_2O emission from various rice tillage techniques

N_2O emission was high for NTC and CTC but low for NT0 and CT0 before July 15. From July 15 to harvesting time, the N_2O emission for NT0, CT0, and NTC was low except for the relatively high CTC. The mean N_2O emission flux in NT0 was 11.72 ± 7.69 ug. m^{-2}.h^{-1}, was 174.72 % puisne than CT0 ($p < 0.05$) and 799.40 % puisne than NTC ($p < 0.05$). For CT0, it was 32.21±9.35 ug. m^{-2}.h^{-1}; that was 384.20% puisne than CTC ($p < 0.05$). However, the N_2O emission flux was 155.96±8.95 ug.m^{-2}.h^{-1} in CTC and 47.90 % upper ($p < 0.05$) than NTC. Table 2 shows that N_2O released from NT0 and NTC was 48.36 mg.m^{-2} and 370.87 mg.m^{-2} respectively, which NTC 7.66 ($p < 0.05$) times NT0. CT0 and CTC were 105.58 mg.m^{-2} and 440.64mg.m^{-2} N_2O emission flux, which was 4.17 ($p < 0.05$) times than those of CT0. On the other hand, NT0 and CT0 were 48.36 mg.m^{-2} and 105.58 mg.$m^{-2,}$ respectively, in which CT0 and N_2O emission flux were 2.18 ($p < 0.05$) times NT0. However, the NTC and CTC emission flux was 370.87 mg.m^{-2} and 440.64 mg.m^{-2} respectively, which were 1.18 times NTC ($p< 0.05$).

Seasonal variations in NH_3 volatilization rates resulting from various rice tillage systems

Volatilization of NH_3 in NTC and CTC peaked during the first week following broadcasting, remained moderate during flooding, and then fell sharply to its lowest levels two weeks before harvesting. NH_3 volatilization patterns in NT0 and CT0 followed a similar trend. The mean NH_3 volatilization flux in NT0 was 10.13±3.15 g.m-^{2}.d^{-1}, which was 9.55 % lower than CT0 ($p> 0.05$) and 410.72 % lower than NTC ($p< 0.05$) in 2008. On the other hand, CT0 was 11.09±3.47 g.m^{-2}.d^{-1}, which was 318 % lower than CTC ($p< 0.05$). However, the NH_3 volatilization flux was 51.71±3.59 g.m^{-2}.d^{-1} in NTC was (not significantly) 11.30 % higher than CTC ($p> 0.05$). Table 2 displays the NH_3 volatilization throughout various rice growth phases in various treatments in 2018. The total N lost through NH_3 volatilization of NTC was 49715.3 kg. $N^{-ha,}$ which were 4.63 ($p< 0.05$), 3.82 ($p< 0.05$), and 1.16 ($p> 0.05$) times of those NT0, CT0, and CTC, respectively. On the other hand, whole N losses via NH_3 emission in the CTC was 42751.4 kg. N^{-ha}, was 3.28 ($p< 0.05$) and 3.98 ($p< 0.05$) times of those CT0 and NT0, respectively. It is also viewable that the result CT0 N losses NH_3 volatilization was 13003.4 kg. $N^{-ha,}$ which was 1.21($p> 0.05$) times of NT0.

Discussion

CO_2 emission

Due to the tight relationship between CO_2 emissions and the ability to physically access microbial turnover, from microorganisms and extracellular enzymes to organic matter, emissions of CO_2 may be exploited as markers of the effects of agricultural practices and the soil ecosystem. Moldboard/disking of soil disturbance is an increase in CO_2 flux, which results in rougher surfaces and more significant voids (Ball et al., 1999; Amundson and Biardeau, 2018), due to two key reasons: integrating and mixing wastes, which encourages microbial activity, and loosening and inverting the soil, which allows for quick CO_2 loss and O_2 entry (Bhattacharyya et al., 2008). As a result of the ZT (zero tillage / no-tillage) system's implementation, a new ecosystem is developed and a potential alternative for carbon sequestration in agricultural soils in Brazil's different regions (Maiaa et al., 2022). Higher sequestration of SOC is one of its defining traits (Dick et al., 1991), improved soil-aggregation (Lal et al., 1994), and a more even ordination of pore sizes (Bhattacharyya et al., 2006) ZT may result in lower total porosity than tillage because to higher soil bulk density. However, macropores and bio pores are left untouched between peds (Unger and Fulton, 1990). ZT typically has significant transmission and storage pores (Shang et al., 2021). According to careful research, tillage disturbs pore continuity and reduces water infiltration (Shukla et al., 2003), while others claim there has been no modification or rate reduction (Azevedo et al., 1998; Ankeny et al., 1990).

In our silty clay loam paddy soil, the total CO_2 emission flux CT0 was higher than NT0 (Table 3). In comparison to no-till systems, several investigations have revealed that tilled soils emit more CO_2 (Reicosky et al., 1997; Reicosky, 2002). As shown in Table 1, after basal fertilization of one week CO_2 emission flux of CTC was higher than NTC. The following reason could explain it. Due to the tillage process, CTC soil was highly fragile. It had shattered internal air spaces, which led to a decrease in intermolecular space, a reduction in transmission and storage pores, and a quick CO_2 loss and oxygen entry rate under aerobic conditions. At the same time, NTC plots contain higher moisture for her previous residual effect. When we drained the paddy field, the CO_2 emission flux first came down and increased again in all cases. July and August this time was the highest temperature in Hubei, China. These significant elements impact respiration and moisture content. All depths showed a favourable relationship between soil temperature and CO_2 flux of soil, although the 4 cm and 8 cm depths showed the strongest correlation (Jacob et al., 2008). However, at this time, the CO_2 emission flux NTC was greater than CTC. Due to the fertilizer application and draining of the field, NTC's uppermost soil layer's biological activity reached a vigorous condition.

CH_4 emission

The research on the various factors affecting CH_4 emission flux is substantial. For example, irrigation, liming, nitrogen fertilization, and tillage can all impact the extent the CH_4 can sink in arid soils, frequently in opposite directions (Weier, 1999; Mosier et al., 1996). Methane emissions are affected by land usage, rice variety, and fertilizer use (Guo and Zhou, 2007). In the experiment after the basal fertilizers application and rice seed broadcast first two weeks in the aerobic condition of paddy field, no significant amount of CH_4 emission occurred in the treatment of NT0, CT0, CTC, and NTC even though relatively NT0>CT0 and NTC>CTC. It may be due to the higher moisture content of NT0 and NTC field's where methanogenic bacteria are more active than CT0 and CTC fields. In paddy fields, microbes produce methane (Denardin et al., 2019). Since methanogenic bacteria are inactive in dry soil, CH_4 emissions in dry environments are often minimal. The most negligible CH4 emissions were by direct sowing on dry soil (Ko and Kang, 2000). Additionally, dry land soils have a limited capacity to absorb CH_4. As a result, dryland farming is anticipated to have little impact on methane emissions (Guo and Zhou, 2007). CH_4 emission flux CTC and NTC increased rapidly from July to August. July and August are the hottest months in Hubei, China; methanogen numbers rise as soil temperatures steadily raise, so throughout the growing season for rice, June and July had the highest methanogen numbers and CH_4 emissions. NT0 and CT0 did not show any higher CH_4 emissions (Table-3). This can be explained as there was no vigorous rice growth due to the improper/or lack of applications of fertilizer. Guo and Zhou, 2007 explained that the CH_4 from the earth takes up space in the plant roots followed by release via its stomata into the atmosphere; for this case, NTC had lower emission flux than CTC. This may be because the NTC plots' uppermost layer of soil was not disturbed; as a result, compared to tilled plots, there is reduced overall porosity. According to reports, methane emission is additionally affected by the soil characteristics like texture, porosity, bulk density, organic matter, and infiltration rate (Stephen et al., 2019; Bouwman, 1990). In our experiment, we explained that compared to traditional tillage management, no-tillage management reduces the percentage of big pores by volume and increases the volume fraction of tiny pores. CH_4 emission from rice paddies also can be due to process because of a concentration differential; water-air and soil-water interactions both allow gas to diffuse. CTC generally had a significantly higher CH_4 emission flux than NTC due to the tillage operation.

N_2O emission

Estimates of tillage practice's impact on N_2O emissions are uncertain (Chatskikh and Olesen, 2007; Li et al. 2008). Compared to typical tillage soils, no-tillage soils have been shown to emit more N_2O, according to specific research (Vinten et al., 2002; Cusser et al., 2020) because there is more soil moisture, air-filled porosity, and less soil gas diffusivity, have the most significant impacts on emissions of N_2O, after applying fertilizer. However, other investigations have found no change between conventional and NT systems (Choudhary et al., 2002) or the CT-tilled soils' enhanced N_2O emissions (Passianoto et al., 2003). Large volumes of N_2O are emitted from the rice paddy before the very stage of inundation of fields and the dry time following crop maturation. On the other hand, rice fields release nearly no N_2O when the rice plant is in its flooding stage (Huang and Chen, 1999; Li et al. 2009). Moreover, higher variability was observed shortly after each fertilization (Metay et al., 2007).

In our investigation, the first two weeks saw more significant N_2O emission fluxes. The rice plant's small size and ineffective root system for absorbing applied N may be the cause. A higher amount of release of N_2O occurred in the initial stages of inorganic N of denitrification and nitrification (Holtgrieve et al., 2006; Panek et al., 2000). In addition, NTC had greater soil organic carbon levels, which can facilitate denitrification (Rochette et al., 2000); this more significant N_2O trend came from NTC than that of CTC in the first two weeks. Additionally, applied N fertilizers in the NTC did not mix with the soil during the first two weeks, leaving the moisture of the fertilizer exposed to air and sunshine and easily nitrified. That is, N_2O emission was higher in NTC than in CTC. However, when rice field was flooded, N_2O emission was lowered, thus causing little variability between NTC and CTC. However, N_2O emission in CTC kept relatively higher could result from the rapid water absorption in CTC; in CTC, the soil was more fragile due to the tillage operations. Thus, N_2O emission from N fertilizer by nitrification is higher in CTC than in NTC. Low N_2O emission recorded in NT0 and CT0 in the rice growing period may be because the soil was silty clay loam, and no fertilizer was applied. In mineral soils, no-tillage generally increases N_2O emissions (Ball et al., 1999; Jacinthe and Dick, 1997). Although both CT0 and NT0 had low N_2O emission, CT0 had 2.18 times higher than NT0, this is due to oxygen availability in the soil caused by tillage operations that encourage nitrogen mineralization and increase nitrification's ability to produce nitrous oxide. NT0, CT0, NTC, and CTC's low N_2O production one month before rice harvest because the absence of fertilizer application could be to blame, decreased temperature, and water content changes in the soil directly affecting denitrification rates and nitrification. Before harvesting the rice at the one-month interval, NT0, CT0, NTC, and CTC levels showed similar trends with low variability. This may be due to a lack of fertilizer application, alongside lower temperature fluctuations in the soil's water content that impact the nitrification and denitrification rates, which in turn impact the formation of N_2O (Table-3). Therefore, there are discrepancies between the results of mathematical modelling on the NT's impact on soil N_2O emissions, and there is currently no explanation for the significant interstice variability of this effect.

Table-3. GWP of the NT0, CT0, NTC, and CTC a system of cultivation based on CH_4, N_2O and CO_2

Treatment	CH_4-based GWPs, kg. CO_2. ha^{-1}	N_2O-based GWPs, kg. CO_2. ha^{-1}	GWPs of CO_2, kg. CO_2. ha^{-1}	Integrated GWPs kg. CO_2. ha^{-1}
NT0	4726.1	144.13	7624.7	12494.93
CT0	4142.85	314.63	7639.95	12097.43
NTC	8414.04	1105.2	8230.95	17750.19
CTC	10879.85	1313.12	7849.75	20042.72

Volatilization of NH_3

One of the key routes for the loss of nitrogen using flooded rice is the seasonal variation in NH_3 flux from rice fields for the four treatments. However, the loss of N from N fertilizer implicated in rice via NH_3 volatilization differs (Cai et al., 2002; Song et al., 2004) as a cause of variations of fertilization techniques, water management, soil microbial activity, and other factors. Ammonia fluxes were extremely high for the first two days following each application of N fertilizer. The highest NH_3 volatilization was observed after the basal application of 40% N fertiliser. At the time, the field was in aerobic condition. Hong et al. (2007) demonstrated that the various degrees and types of fertilizer used have significantly impacted NH_3 emissions from rice fields. In NTC fields, NH_3 volatilization was higher than in CTC fields because the air and sunshine were immediately exposed to the fertilizer (urea) that was used and therefore could volatilize very quickly. Additionally, rice plants' early-stage root systems did not absorb applied N. However, after paddy fields were flooded, the CTC field had higher NH_3 volatilisation than the NTC field. Hong et al., 2007, observed that higher NH_4^+ concentration in floodwater causes a more significant NH_3 emission. Our study also recorded higher NH_3 volatilization CTC than in NTC plots after flooding the paddy field. This can be explained by the applied N (urea) in the CTC plot of the flooded paddy fields being rapidly mixed with total soil NH_4^+-N (2.43 mg/kg). NH_4^+ concentration of the ploughed layer increased, causing high NH_3 volatilization plots. Just before one month of harvesting, the NTC shows great volatilization to CTC, this may be because of the soil's propensity to operate as a pH buffer and a cation exchanger, affecting urease activity levels, availability of moisture, the texture of the soil, the presence of plants or plant leftovers, and the rate of nitrification. The whole rice growing period NT0 and CT0 plots show lower NH_3 volatilization. NT0, NH_3 volatilization lesser than CT0. This is because NT0 plots had no fertiliser applied. In addition, it contained higher microbial activity and higher soil moisture. According to several studies, soil with zero tillage has a more significant bulk density than soil that has been tilled (Blanco and Ruis, 2018; Bajpai and Tripathi, 2000).

Estimates of global warming potentials

The global warming potentials (GWPs) were used to convert gaseous emissions to CO_2 equivalents. The idea of GWP was created to contrast a gas's capacity and atmospherically store heat compared to CO_2, derived from dividing the bulk of the object by the GWP coefficient. To reduce GHG emissions from agricultural soils and their negative impact on global warming, it is necessary to introduce agricultural practices that would facilitate sustainable land management (Ahmad et al., 2009; Valujeva et al., 2020). A gas's GWP coefficient describes how well it can trap heat in the amount of CO_2. The N_2O and CH_4 have GWPs coefficients that are 298 and 25 respectively, based on a period of 100 years when considering that the GWP of CO2 is assumed as 1. (IPCC, https://en.wikipedia.org/wiki/IPCC_Sixth_Assessment_Report, 2022). To evaluate the system's role in contributing to the global warming-climate crisis regarding CH_4, N_2O, and CO_2 emission, the greenhouse gas partition coefficient (GWPs) of the NT0, CT0, NTC, and CTC cultivation system (Table3) is regarded to be an integrative criterion.

CO_2: As per Table 3, kg CO_2.ha^{-1} daily fluxed decreased in the following order: NTC 381.2 > CTC 209.8 > CT0 15.25 > NT0. In addition NTC 591 >CT0; NTC 606.25 > NT0 and CTC 225.05 > NT0.

CH_4: CH_4 emission measured in terms of kg CO_2.ha^{-1} were also found to decrease (Table 3) in the following order CTC 2465.8 > NTC 3687.94 > NT0 583.25 > CT0. It was noticeable that CTC 6153.75 >NT0, CTC 6737 > CT0 and NTC 4271.19 > CT0.

N_2O: It was observed that N_2O emission from four cultivation types produced kg CO_2.ha^{-1} daily fluxed, as shown in Table 3, were found to decries in the following order CTC 207.92 > NTC 790.57 > CT0 170.5 > NT0. This can be presented as CTC 998.49 > CT0, CTC 1168.99 > NT0, and NTC 961.07 > NT0.

Table-4. The Δ represents the difference of the integrated GWPs kg.CO_2.ha^{-1}

CTC > NTC	NTC >NT0	NT0 > CT0	CTC > NT0	CTC >CT0	NTC > CT0
2292.53Δ	5255.26Δ	397.5Δ	7547.79Δ	7945.29Δ	5652.76Δ

Moreover, the Integrated GWPs kg.CO_2.ha^{-1} daily fluxed (Table 4) were found to decrease in the following order: CTC 12.91% > NTC 42.05% > NT0 3.28% > CT0. We also keenly calculated that CTC 60.40% > NT0, CTC 65.67% > CT0, and NTC 46.72% > CT0, respectively.

Conclusion

The findings of this study make it clear that compared to CTC farming systems, NTC farming systems show to minimise integrated GWPs (CO_2 + CH_4 + N_2O) and reduce the overall dimension of N_2O and CH_4 from rice paddies. According to these projections, the NTC cultivation technique is a valuable method for cutting N volatilization and integration of GWPs (CO_2 + CH_4 + N_2O) from rice paddy fields in central China (a major hub of rice production for the globe), which will help to mitigate global warming and climate crisis. To effectively address the global climate crisis issue from any agricultural field, more research is required to fully understand and compare how various tillage practices interact with GHG emissions from silty clay loam or any other kind of soil in any part of the world.

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Li C: Experimentation, methodology assessment, data collection, statistical analysis and interpretation.
Ahmad S: Conceived idea, literature review, research design, data interpretation, manuscript writing and final approval.
Cao C: Provided research materials and conducted trials at different places and critiquing important intellectual content.