**Effect of tillage practices on greenhouse gas emissions and global warming potential**

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**Abstract:**

As the issue of global warming has grown in prominence in recent years, it is necessary to look for management strategies that can effectively reduce greenhouse gas emissions in agricultural systems, such as tillage practices. The selection of a tillage system is crucial since it directly affects crop yield, water management, and soil properties, as well as greenhouse gas emissions such as carbon dioxide, methane, and nitrous oxide, all of which contribute to global warming. The effects of tillage practices on greenhouse gas emissions, which significantly contribute to global warming, were discussed in this review based on the most recent studies published in specialized global journals. The reviewed studies were carried out under the influence of various variables including tillage practices, tillage depth, experiment year, duration, site and season, soil texture, grown crop, precipitation, ambient temperature, amount and type of residues, and measurement depth. Tillage practices, weed incorporation, and residue retention significantly impacted greenhouse gas emissions, soil organic carbon, and carbon sequestration, and thus on global warming potential, according to the findings of the reviewed studies. Among tillage practices, no-tillage has been shown to have the lowest greenhouse gas emissions therefore, it was found that most studies suggest a preference for no-tillage in terms of mitigating global warming. Nonetheless, crop stubble incorporation combined with conventional tillage at a moderate depth could significantly reduce net global warming potential. The threat of global warming could be mitigated quickly if no-tillage with weed and residue retention is widely adopted.

KEYWORDS: *Crop effects; Crop residue; Methane; Nitrous oxide; Plowing; Rice stubble; Soil organic carbon; Weed retention;*

**1. Introduction**

In an effort to mitigate the effects of global warming, 195 countries agreed in Paris at the end of 2015 to reduce greenhouse gas emissions in order to keep global temperature increases under 2 degrees Celsius (Anderson et al., 2016; Jacobs, 2016; Urpelainen and Van de Graaf, 2017).

Carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) are three greenhouse gases (GHG) that directly contribute to global warming (Voigt et al., 2016; Vinasco, 2021). They absorb infrared light and decrease transparency to thermal radiation from the Earth's surface (Antille et al., 2015; Berquist et al., 2020; Zhukov and Gushcha, 2020). However, CO2 is the most abundant and accounts for the majority (65%) of world emissions (Bhattacharyya et al., 2021; Rodas Zuluaga et al., 2021) (Fig.1) Moreover, between 5% and 20% of the annual global emissions of CO2 are brought on by soil respiration (Xu, F., and Chang, H. (2022). Nitrous oxide (N2O) and methane (CH4) also contribute around 5 and 12% of global warming, respectively (Luo et al., 2013; Solomon et al.,2007). Emissions of greenhouse gases have grown considerably over the last two centuries, particularly since the industrial revolution due to increasing industrial and transportation activities related to the use of fossil energy sources and land use changes (Muñoz et al., 2010).

By 2050, the world population is expected to increase by more than 9 billion people (Sapkota et al., 2020; Roberts, 2011; United Nations, 2017) and food production will need to double in order to satisfy food demand (Ray et al., 2013; Van Dijk et al., 2021). This requires a shift to intensive agriculture, which increases greenhouse gas emissions and has a negative impact on the environment (Snyder et al., 2009; Frank et al., 2017). Agriculture has recently had a significant impact on greenhouse gas emissions (Smith et al., 2014) due to an increase in cultivated areas worldwide (Myhre et al., 2013), coming in second place after electricity and heat production (Fig. 2). Agricultural practices, for instance, account for around 6% of total greenhouse gas emissions in the United States (Greenhouse Gas Working Group, 2010; USEPA, 2011) and currently contributes 10% to 12% of total anthropogenic greenhouse gas emissions worldwide (Smith et al., 2007; Cole et al., 1997; Smith et al., 2007). On the other hand, agriculture may be beneficial when acting as a carbon dioxide sink by sequestering carbon in biomass and soil organic matter (Johnson et al., 2007; Lal, 2007 and 2013). So it is critical to work toward reducing greenhouse gas emissions during agricultural activities such as fertilization, tillage, crop rotation, and irrigation (Sainju et al., 2012). Net emissions of carbon dioxide (CO2) and nitrous oxide (N2O) from the soil surface are of particular relevance in temperate climate agricultural systems because they are key components of the net global warming potential (GWP) of farmed land (Robertson and Grace, 2004; Mosier et al., 2005; Adviento-Borbe, 2007; Peichl et al., 2009). Carbon dioxide emitted from the soil is one of the most significant greenhouse gases (Parkin and Kaspar, 2003), and it is a byproduct of the decomposition of organic waste and agricultural residues inside the soil, as well as plant respiration (Gong et al., 2021).

The global warming potential is the sum of total CO2 and N2O emissions converted into CO2 equivalents (Liebig et al., 2010; Liu et al., 2015; Ma et al., 2013). When estimating net global warming, soil C sequestration, greenhouse gas emissions from the soil, emissions from fuel used for farm activities, and fertilizer and seed production must all be included (Robertson et al., 2000; Thelen et al., 2010; Dendooven et al., 2012; Pratibha et a., 2015).

The selection of a tillage system is critical since it has a direct impact on crop production (Mamkagh 2009, 2018), water management and properties of the soil (Mamkagh et al., 2022 a,b), greenhouse gas fluxes and global warming (Li et al., 2022). Tillage, as a mechanical modification of the soil surface, is known to impact greenhouse gas (GHG) emissions such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), all of which contribute to global warming (Omonode et al., 2007; Ruan and Philip Robertson 2013; Mangalassery et al., 2014; Liu et al., 2019; Campbell et al., 2014). Conservation tillage practices have the potential to be more effective in lowering greenhouse gas emissions (Busari et al., 2015; Shah et al., 2016; Wang et al., 2019; Alhassan et al., 2021; Rahman et al., 2021). Several studies have shown that no-tillage produces fewer GHG emissions than conventional tillage (Balesdent et al., 2000; Yang and Kay 2001; Denef et al., 2004; Sainju et al., 2008; Almaraz et al., 2009; Huang et al., 2018;). However, no significant variations in carbon dioxide emissions were found in two studies conducted in New Zealand (Aslam et al., 2000) and the United States (Elder and Lal, 2008). No-tillage and minimum tillage practices have the potential to enhance nitrous oxide emissions (Liu et al., 2007; Rochette et al., 2008; Regina and Alakukku, 2010; Yao et al., 2009) while simultaneously reducing methane gas emissions (Guo et al., 2021). However, when used as the only tillage treatment for a long time (more than 30 years), the NT system emitted more greenhouse gases from the soil annually (Oorts et al., 2007). Furthermore, there have been reports that the carbon content of the soil does not necessarily change when no-tillage is used in humid conditions (Angers et al., 1997; VandenBygaart et al., 2003; Dolan et al., 2006) which means similar CO2 fluxes under both NT and CT (Fortin et al., 1996; Aslam et al., 2000).

On the other hand, when compared to a no-tillage system, conventional tillage can either have no effect (Jantalia et al., 2008), reduce (Robertson et al., 2000; Steinbach and Alvarez, 2006), or increase (Baggs et al., 2003; Ussiri et al., 2009) greenhouse gas emissions from soils. Despite conflicting results regarding the impact of the tillage practices on greenhouse gases (Omonode et al., 2011; Six et al., 2002; Baggs et al., 2003) intensive tillage may result in a steady decline in soil organic matter due to the rapid oxidation of soil carbon, which would reduce the soil's capacity to regulate the supply of water and nutrients to plants (Ghosh et al., 2018; Mehra et al., 2018; Meena et al., 2020). Some studies (Sanderman et al., 2017; Le Quéré et al., 2016; Teague et al., 2016; Pan et al., 2011; Zomer et al., 2017) have found that a significant portion (between 50% and 70%) of the soil carbon stock is lost during cultivation and tillage for the production of several crops.

Soil greenhouse gas emissions are the consequence of intricate interactions between climatic factors and various soil properties (Ussiri et al., 2009). In soils, GHGs are produced through microbial activity, root respiration, chemical processes, and heterotrophic respiration of soil fauna and fungi (Chapuis-Lardy et al., 2007; Oertel et al., 2016; Adamczyk et a., 2021; Sae-Tun et al., 2022). Climate and climatological parameters, as well as land-use management data, are crucial since the amount of greenhouse gas emitted is heavily influenced by soil temperature, soil water content, nutrient availability, air pressure, and pH value (Ludwig et al., 2001; Reth et al., 2005). So reduced greenhouse gas emissions and increased soil carbon sequestration are urgently needed to slow global warming (Meisterling et al., 2009, Shang et al., 2011; Jia et al., 2012; Zhang et al., 2016; Yoro and Daramola, 2020).

 The increasing importance of the global warming issue in recent years, the existence of contradictory findings in a number of studies regarding the impact of tillage practices on greenhouse gas emissions as an important agricultural activity, and the lack of a comprehensive review on the topic were the impetus for this review. For the aforementioned considerations, a comprehensive literature searches for the main relevant works exclusively on the effects of tillage practices on greenhouse gas emissions and global warming potential that were conducted in the last years (from 2012 to 2022) was conducted. Furthermore, the goal of this review is to shed light on the impact of tillage practices on greenhouse gas emissions, which significantly contribute to global warming, as well as to determine the best method of tillage to reduce the possibility of global warming.

**2. Tillage effects**

**2.1. Winter plowing with the incorporation of rice stubble**

Under the cropping regime of double-cropping rice, an investigation into the effects of tillage and residue on the sequestration of soil organic carbon, methane emissions, nitrous oxide emissions, and net global warming potential was carried out in China (Yang et al., 2018).

When rice stubble was retained in the soil, winter plowing significantly increased SOC content and sequestration of SOC compared to spring plowing. Significant CH4 emissions were recorded throughout the early and late rice seasons. Seasonal CH4 emissions varied significantly over the years but were greatly affected by variations in field management techniques. Over the three winter-fallow seasons, winter tillage increased mean CH4 emissions by 24% compared to spring tillage.

The seasonal N2O emissions varied greatly with the field management and year but were not strongly affected by their interactions. When compared to spring tillage, winter tillage increased average N2O emissions by 54-83%. Rice stubble incorporation into the soil during tillage significantly reduced seasonal N2O emissions by up to 52% depending on the amount of stubble used.

To determine the impact of tillage on the sequestration of SOC and the emissions of CH4 and N2O from the double rice-cropping systems on carbon footprint, and net global warming potential a three-year field experiment began in 2013 in China, where the cropping regime was double rice-cropping systems and the location has a subtropical humid environment with an annual average air temperature of 17.5 o C and precipitation of 1587 mm (Shang et al., 2021). No-tillage (NT), reduced tillage (RT) with a rotary harrow to a depth of 10 cm, and conventional tillage (CT) with a moldboard plow to a depth of 20 cm followed by a rotary harrow were used before planting rice.

The total seasonal CH4 emissions differed significantly with tillage year and their interactions in the early rice growing season. The cumulative CH4 fluxes in reduced tillage increased by 6.8% - 41.6% throughout the three early rice seasons, while they fell by 5.7% -60.1% in no-tillage compared to conventional tillage. Annual CH4 emissions increased significantly under conventional tillage and reduced tillage, respectively, by 45.6% and 63.9% when compared to no-tillage. The amount of organic carbon in rice paddy fields in this study had a significant impact on CH4 production. The majority of the net potential for global warming is attributed to CH4 emissions from double rice cropping systems. It was much higher under conventional and reduced tillage than under no-tillage.

One of the study's key findings is that conventional tillage at a moderate depth, combined with rice stubble incorporation into the soil, has the potential to reduce net global warming potential.

**2.2. Tillage and crop effects**

Guardia et al. (2016) conducted a field experiment to assess the impact of two crops and three long-term tillage systems on greenhouse gas emissions and the potential for global warming. The global warming potential, expressed in CO2-equivalents, was assessed using cumulative soil N2O and CH4 emissions. The findings demonstrated that no-tillage significantly enhanced the topsoil's dissolved organic carbon content compared to the minimum and conventional tillage. The dissolved organic carbon content in no-tillage was 46% and 18% greater than in conventional and minimum tillage, respectively, for the whole cropping season. No-tillage also improved soil organic carbon and carbon sequestration in the 0-7.5 cm and 0-30 cm layers, respectively.

A strong interaction between tillage and crop impacts was observed in N2O cumulative emissions. The equilibrium between nitrogen dioxide generation and consumption by denitrifiers, according to the authors, might explain this strong interaction.

In terms of crop effect, the barley field produced more nitrous oxide emissions than the vetch field when no-tillage was applied. This result was attributed to denitrifying conditions in non-tilled soils.

As for methane (CH4) emissions, no significant differences were found between tillage and crop treatments. According to the authors, this was explained by the possibility of the soil maintaining a low moisture content throughout the experiment and the no significant improvement in soil porosity under no-tillage, which could have been caused by the high sand content of the soil.

The net global warming potential estimates in this study showed no-tillage and vetch cultivation as the most sustainable alternatives among tillage and crop factors. The comparison of net global warming potential components revealed that C sequestration, farm inputs, and operations had a greater influence than nitrous oxide fluxes. In comparison to the tillage treatments, no-tillage had the highest C sequestration rate and the lowest net global warming potential value. The effect of long-term tillage treatments on N2O emissions in rainfed agroecosystems is significantly affected by the interaction with crops (winter cereal or forage legume).

**2.3. With weed cover mulching**

Yagioka et al. (2015) investigated the effects of conventional (rotary tiller) and no-tillage tillage with weed cover, as well as two organic fertilizer application modes, on greenhouse gas fluxes, soil carbon sequestration, net global warming potential, and nitrate leaching in a fallow field with native weeds. The main crop, pumpkin was grown, along with mixed crops of okra, bell peppers, and eggplant.

The main results of this research work show the following:

* After converting to no-tillage with weed cover mulching, soil carbon content, and methane uptake increased yearly at the soil surface.
* Retention of weeds increased the amount of organic matter in the soil in a no-tillage system.
* Nitrous oxide emissions were greater immediately after weed mowing in no-tillage with weed-cover mulching, but there was no significant influence after that in the long run.
* The difference between initial and final soil organic carbon was higher in no-tillage with weed-cover mulching than in conventional tillage, indicating that no-tillage with weed-cover mulching has a lower net global warming potential than conventional tillage.
* Nitrate leaching was lower in no-tillage with weed-cover mulching than in conventional tillage at different soil depths.
* By improving yearly CH4 uptake and soil carbon sequestration, no-tillage with weed cover mulching aids in minimizing nitrate leaching and net global warming from the agroecosystem.
* The threat of global warming might be mitigated quickly after using no-tillage with weed cover mulching on a large scale, and this technology could be used on abandoned agricultural land.

The study's key finding is that no-tillage with weed cover is a viable alternative organic farming technique with low environmental impact that should be used by small farmers who have abandoned agricultural land in marginal areas.

**2.4. With residue management**

To evaluate the impact of conventional and no-tillage and crop residue management on greenhouse gas fluxes and the potential for global warming Dendooven et al. (2012) began a long-term rain-fed experiment in the semi-arid, subtropical highlands in Mexico.

In comparison to conventional tillage, the study's findings showed that no-tillage had a significant impact on the carbon content in the 0-60 cm layer when crop residue was retained on the soil. However, when the crop residue was removed, no such effect was noticed, and the C content in conventional tillage and no-tillage was the same. According to the authors, this might be attributed to several factors, including increased soil water content, which enhanced microbial activity, and the application of N fertilizer, which promoted organic matter mineralization. In this experiment, CH4 fluxes were modest and varied, with no obvious pattern emerging. Tillage with residue management had no significant effect on CH4 fluxes. The fluxes of N2O were affected by soil temperature, water content, and CO2 emissions. They were not affected by tillage when the residue was left on the field. When the crop residues were removed, they were significantly lower in no-tillage than in conventional tillage. Lower temperatures, improved soil structure, and less compact soils in no-tillage compared to conventional tillage may explain the decrease in N2O emissions.

The global warming potential of greenhouse gases was highest for conventional tillage and crop residue retention, while it was lowest for no-tillage and crop residue removal. This demonstrates that conservation agriculture can be an important tool for reducing agriculture's global warming potential in many parts of the world, including the central highlands of Mexico.

No-tillage and crop residue removal, according to the authors, is not always the best option for all farmers because they can degrade soil quality and produce lower yields than when residue is left on the crop.

**2.5. With and without residue retention.**

Chen et al. (2021) investigated the impact of no-till, rotary tillage, plowing, and various methods of incorporating rice residue into the soil on greenhouse gas fluxes and the potential for global warming. Throughout the experiment, it was found that the type of tillage had a significant effect on the contents of soil organic carbon (SOC). Over two seasons of rice cultivation, CH4 emissions were found to rise after planting, peak during the aeration stage, and then gradually fall to zero at harvest for all treatments. However, the annual mean of CH4 emissions ranged from 637.84 to 825.88 kg ha -1 yr -1 during the two years of measurements.The annual mean of CH4 emissions was found to be low when compared to the findings of other studies, such as those of Shang et al., (2011) and Jiang et al., (2006). This trend could be attributed to differences in soil properties as well as other local and environmental factors. CH4 fluxes in no-tillage were lower when compared to plowing. This could be attributed to variations in the physical environment, and that is consistent with the findings of Zhang et al (2013).

No-tillage produced slightly higher N2O emissions than plowing and rotary tilling. This could be due to soil compaction (Smith et al., 2000) and higher soil water content, which resulted in a higher denitrification rate (Jiang et al., 2006). Despite this, the authors state that more research is needed to understand the dynamics and quantification of NO2 emissions under various tillage practices.

Taking all tillage treatments, the net global warming potential values were 8711.91, 14705.76, and 14083.60 kg CO2 - eq ha -1 yr -1, for no-tillage, rotary tillage and plowing respectively, indicating that they were all sources of greenhouse gas emissions. The global warming potential of methane emissions was about 80%, indirect emissions from agriculture inputs were about 20%, and N2O emissions were about 2%.

**2.6. With rye crop cover**

A long-term experiment was conducted in Japan to investigate the potential of no-tillage for mitigating global warming potential (Gong et al., 2021).

It was discovered in this study that fields plowed with moldboard plows and cultivated with rye crops emitted less methane. This could be due to the lower water-filled pore space and soil bulk density noted with moldboard plowing, which would have increased the diffusion of atmospheric CH4 into the soil and enhanced soil CH4 oxidation. No-tillage was discovered to produce significantly more annual N2O emissions than moldboard plowing. In terms of cover crops, no-tillage with hairy vetch resulted in higher annual N2O emissions than moldboard plowing with hairy vetch and rye. This outcome might be linked to no-tillage because of the increased soil bulk density and water content, which promote the soil anaerobic environment and result in denitrification.

It was also shown that no-tillage significantly increased soil organic carbon (SOC) stock compared to moldboard plowing in the 0-2.5 cm, 0-7.5 cm, 0-15 cm, and 0-30 cm soil layers. However, crop cover had no significant impact on soil organic carbon stock. This could be attributed to the fact that no-tillage treatment increased surface soil organic carbon stock by maintaining high surface soil coverage (mainly with cover crops) and forming stable micro-aggregates (Abolanle et al., 2015; Higashi et al., 2014; Six et al., 2000). When compared to treatments with moldboard plowing, treatments with no-tillage had much higher net CO2 retention. This might be due to the soil developing stable micro-aggregates as a result of maintaining high surface soil covering during no-tillage.

It is concluded herein that no-tillage with cover crop systems, particularly with rye cover, had reduced net GWP and operated as a net sink for yield-scaled GWP and can maintain long-term crop yield in organic soybean fields in humid subtropical conditions.

**3. Factors that may influence GHG emissions and global warming potential during tillage operations**

The reviewed studies were conducted under the influence of various variables, including tillage practices, tillage depth in conventional and reduced tillage, experiment year, duration, site and season, soil texture, grown crop, precipitation, ambient temperature, amount and type of residues, and measurement depth. Most of these variables may have the potential to influence greenhouse gas emissions and consequently global warming. The current review of studies on the impact of tillage on greenhouse gas emissions and thus global warming obtained from the websites of Web of Science, Google Scholar, Scopus (Elsevier), and ResearchGate indicates the following:

* N2O emissions varied greatly depending on field management, experiment year, and season. Rice stubble incorporation into the soil during tillage significantly reduced seasonal N2O emissions by up to 52% depending on the amount of stubble used (Yang et al., 2018).
* Tillage methods had significant effects on the emissions of N2O (Shang et al., 2021).
* A strong interaction between tillage and crop impacts was observed in cumulative N2O. According to the authors, the equilibrium between nitrogen dioxide generation and consumption by denitrifiers might explain this strong interaction (Guardia et al., 2016).
* Nitrous oxide emissions can be influenced by the type of crop grown. For instance, when no-tillage was used, the barley field produced more nitrous oxide emissions than the vetch field. This result was attributed to denitrifying conditions in non-tilled soils (Guardia et al., 2016).
* When the residue was left on the field, neither conventional tillage nor no-tillage had an impact on N2O. When the crop residues were removed the next year, N2O was significantly lower in no-tillage than in conventional tillage (Dendooven et al.,2012).
* No-tillage produced slightly higher N2O emissions in the long run than plowing and rotary tilling. This could be due to soil compaction and higher soil water content, which resulted in a higher denitrification rate (Chen et al., 2021).
* In terms of cover crops, no-tillage with hairy vetch resulted in higher annual N2O emissions than moldboard plowing with hairy vetch and rye. This outcome might be linked to no-tillage because of the increased soil bulk density and water content, which promote the soil anaerobic environment and result in denitrification (Gong et al., 2021).
* CH4 emissions varied significantly over the years and were greatly affected by variations in field management (Yang et al., 2018).
* The total seasonal CH4 emissions differed significantly with tillage and year and their interactions in the early rice growing season (Shang et al., 2021).
* In the tillage-crop interactions, there were no significant differences in methane (CH4) emissions. This was explained by the possibility of the soil maintaining a low moisture content throughout the experiment and the insignificant improvement in soil porosity under no-tillage, which could have been caused by the high sand content of the soil (Guardia et al., 2016).
* After converting to no-tillage with weed cover mulching, soil carbon content and methane uptake increased yearly at the soil surface. According to the researchers, the retention of weeds increased the amount of organic matter in the soil in no-tillage systems, which increased the soil's air-filled porosity and decreased its bulk density. As a result, these changes could be the cause of the increase in soil carbon content and methane uptake (Yagioka et al., 2015).
* CH4 emissions were shown to rise after planting, peak during the aeration stage, and then gradually fall to zero at harvest. When compared to plowing these fluxes in no-tillage were lower. This can be attributable to variations in the soil’s physical environment (Chen et al. (2021)).
* Annual CH4 emissions increased significantly under conventional tillage and reduced tillage (Shang et al., 2021)
* When crop type is considered, moldboard plowing with rye produces the lowest annual amount of methane (CH4) emissions, while no-tillage with hairy vetch produces the highest annual amount. This could be due to the lower water-filled pore space and soil bulk density noted with moldboard plowing and rye, which would have increased the diffusion of atmospheric CH4 into the soil and enhanced soil CH4 oxidation (Gong et al., 2021).
* Tillage practices can have an impact on soil organic carbon (SOC) (Shang et al., 2021). The difference between initial and final SOC was greater in no-tillage with weed cover than in conventional tillage (Yagioka et al., 2015).
* No-tillage also improved carbon sequestration (Guardia et al., 2016)
* Crop cover had no significant impact on soil organic carbon (SOC) stock. No-tillage significantly increased soil organic carbon (SOC) stock compared to moldboard plowing. This could be attributed to the fact that no-tillage treatment increased surface soil organic carbon stock by maintaining high surface soil coverage (mainly with cover crops) and forming stable micro-aggregates (Gong et al., 2021).
* In the absence of crop residue management, tillage did not affect CO2 fluxes. In both conventional and no-tillage systems, residue removal significantly reduced these fluxes. This might be attributed to the increased soil water content, which could enhance microbial activity and promote organic matter mineralization (Dendooven et al.,2012).
* When compared to treatments with moldboard plowing, treatments with no-tillage had much higher net CO2 retention. This might be due to the soil developing stable micro-aggregates as a result of maintaining high surface soil covering during no-tillage (Gong et al., 2021).
* Winter tillage with stubble incorporation reduced net GWP by up to 78% depending on the amount of stubble used (Yang et al., 2018).
* The majority of the net potential for global warming is attributed to CH4 emissions from double rice cropping systems, these emissions were much greater with conventional and reduced tillage than with no-tillage (Shang et al., 2021).
* No-tillage had the lowest net global warming potential value. Among tillage and crop factors, the net global warming potential estimates revealed that no-tillage and vetch were the most sustainable alternatives (Guardia et al., 2016).
* When combined with weed or crop cover, no-tillage has a lower net global warming potential than conventional tillage (Yagioka et al., 2015 and Chen et al., 2021).
* By improving yearly CH4 uptake and soil carbon sequestration, no-tillage with weed cover mulching aids in minimizing nitrate leaching and net global warming from the agroecosystem. This might be because the improved soil physics caused by continuous no-tillage with weeds contributed to greater CH4 absorption (Yagioka et al., 2015).
* The global warming potential of greenhouse gases was highest for conventional tillage and crop residue retention, while it was lowest for no-tillage and crop residue removal (Dendooven et al.,2012).
* No-tillage with cover crop systems, particularly with rye cover, had reduced net GWP and operated as a net sink for yield-scaled GWP.
* Conventional tillage at a moderate depth combined with rice stubble incorporation could reduce net global warming potential (Yang et al., 2018).

**4. Conclusions**

Most reviewed studies suggest a preference for no-tillage in terms of reducing greenhouse gas emissions and mitigating global warming.The threat of global warming might be swiftly lessened by the widespread adoption of no-tillage with weed or crop cover mulching, and this strategy is ideal for abandoned agricultural land all over the world. This method is a viable alternative organic farming technique with low environmental consequences that can be used by farmers worldwide. No-tillage is not the best option when crop residue is removed because it can degrade soil quality and result in lower yields than when residue is retained. The findings show that net GWP can be reduced under no-tillage with the incorporation of stubble, weed, or crop residue. Among tillage practices, no-tillage had the lowest net global warming potential value. Conventional tillage at a moderate depth combined with rice stubble incorporation with soil can aid in reducing net global warming potential. In some reviewed studies, net GWP estimates revealed that no-tillage with vetch crop cultivation was the most sustainable option among tillage and cropping factors. By improving CH4 uptake and soil carbon sequestration, no-tillage with weed or crop residue retention aids in minimizing nitrate leaching and net global warming from the agroecosystem. Based on this review, further research on the impacts of conventional tillage and no-tillage on greenhouse gas emissions under the influence of various variables is required to fully understand the impact of tillage methods on global warming potential.

**Author Contributions**

All authors (Mamkagh, A.; AL-Zyoud, F. and Al-Atiyat, R.) searched in the literature, wrote, reviewed, and approved the final version of the manuscript equally.

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