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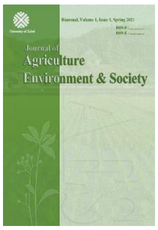

Effects of different cotton tillage methods on N_2O and NH_3 emissions in a cotton-wheat rotation

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ABSTRACT

Conventional tillage methods result in resource waste and the release of greenhouse gases into the environment. An experiment with a randomized complete block design and three treatments in four replications was conducted at Darab Agricultural Research Station for five years to determine the effects of different tillage methods on nitrous oxide (N_2O) and ammonia (NH_3) emissions in cotton-wheat rotation. Direct farming (no tillage), low tillage, and conventional wheat-cotton tillage (control) were used as treatments. Following wheat harvesting in the direct and low tillage treatments, 30% (weight) of wheat residues were dispersed on the field. Within two years, N_2O and NH_3 emissions from the cotton-wheat field were estimated using the DNDC 9.5 model. Data from the first three years of the study was used to validate the model. The results of model validation revealed that the model performed well in simulating the soil environment as well as N_2O and NH_3 emissions. The simulation results revealed that the highest and lowest N_2O emission rates occurred in conventional and no-tillage treatments, with a significant difference. After five years of experimentation, average annual N_2O emissions were 4.40, 2.80, and 2.14 kg N ha^{-1} y^{-1} for conventional, low, and no-tillage treatments, respectively. According to the simulation results, peak NH_3 emission from soil occurred on the fifth day after fertilization in all three treatments. The overall findings of this study indicated that the use of no-tillage methods is more advantageous than other cotton culture treatments in cotton-wheat rotation under similar conditions as in the current study.

1. Introduction

Environmental issues have received increasing attention in recent years. Different economic sectors are interested in evaluating the effects of their activities on increasing environmental awareness. Agriculture is one of the most important economic sectors that has important effects on the environment (Charles et al., 2017). Increasing mechanization, improving production methods, widespread application of fertilizers and pesticides, and improvements in animal husbandry during the 20th century have contributed to the increase in production. Today, energy consumption in the agricultural sector has increased as a result of population growth, reduced arable land, and improved welfare levels. Intensive use of chemical fertilizers, pesticides, agricultural machinery, electrical energy, and natural resources is needed to provide food for the growing population (Fittton et al., 2017). Meanwhile, fossil resources are limited, so it is imperative to preserve these resources for future generations of human beings through proper and high-efficiency consumption. On the other hand, intensive use of land sources causes environmental problems. Agriculture is the main source of several important environmental pollutants (Franqueville et al., 2018). According to the Kyoto Treaty (1997), agricultural development with high-efficiency energy consumption can be effective in reducing greenhouse gas emissions from agricultural activities. Optimum use of resources in agriculture reduces environmental problems, prevents the degradation of natural resources, and expands sustainable agriculture (Deng et al., 2018).

Agriculture is a well-known and substantial source of greenhouse gas emissions (Bareau et al., 2017). The

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concentration of atmospheric nitrous oxide (N_2O) has risen by 20% since 1750 AD (Ciais et al., 2013). Nitrogenous fertilizer application and agronomic operations account for 78% of N_2O emissions in the United States (UNEP, 2013). Agricultural activities account for 90% of the total anthropogenic NH_3 emissions in Canada, and NH_3 emissions have increased by 23% since 1990 due to increasing fertilizer use in agriculture and animal husbandry (Congreves et al., 2016).

The complexity of the relationships governing biogeochemical cycles and their importance leads to the application of predictive models to study the impacts of climate change and land use on the emission rates of greenhouse gases and changes in soil characteristics to discover the truth (Li et al., 2009). The study of the carbon and nitrogen cycles and their effects on global climate allows for the use of models to inspect the amount of greenhouse gas emissions into the atmosphere and investigate options for reducing agriculture's role in climate change. The DNDC (DeNitrification-DeComposition) model provides satisfactory results in simulations of carbon and nitrogen cycles and greenhouse gas emissions from agricultural lands. This model is written using the C^{++} programming language and includes two main modules. The first module can simulate crop growth and carbon and nitrogen cycles in the soil using three sub-models of soil climate, crop growth, and soil degradation (Uzoma et al., 2015). The second module can simulate the biochemical processes associated with soil environmental factors using nitrification, denitrification, and fermentation sub-models. The DNDC divides soil carbon stocks into four parts: plant residues, plant biomass, active humus, and inactive humus. In the next step, carbon stocks are divided into three sub-sections, *viz*., highly unstable, unstable, and resistant, based on the differences in carbon to nitrogen ratios and decomposition rates (Li, 1994, 1995). This model utilizes the classical laws of physics, chemistry, and biology in conjunction with empirical equations derived from laboratory studies to determine the soil-plant biogeochemical parameters (Giltrap et al., 2010).

Inputs required for the DNDC model implementation include the study site (including geographical coordinates), daily meteorological information (minimum and maximum temperatures, precipitation, wind speed, solar radiation, and relative humidity), soil physical properties (texture, soil water content at the field capacity point and permanent wilting, apparent soil weight, soil reaction, soil hydraulic conductivity, and soil mineral nitrogen and organic carbon contents), and management operations (crop rotation, tillage operations, details of chemical and organic fertilizer applications, planting and harvesting dates, and irrigation methods). Plant growth and yield, allocation of plant biomass to leaves, stems, roots, and seeds, nitrification and denitrification, soil temperature and moisture profiles, soil carbon reservoirs and fluxes, soil nitrogen reservoirs and fluxes, nitrate leaching, and the emissions of carbon dioxide (CO_2), methane (CH_4), ammonia (NH_3), nitric oxide (NO), and nitrous oxide (N_2O) from plant-soil systems are simulated and modeled at the end of each day by running the DNDC model. The DNDC also simulates and provides an annual report for the system based on the annual crop yield as well as carbon, nitrogen, and water reservoirs and fluxes (Li, 2000).

Agricultural activities, such as plowing and management of crop residues, play an important role in determining the crop yield and/or greenhouse gas emissions (Pandey et al., 2012; Liu et al., 2014). Many researchers have investigated the effects of plowing and tillage operations on the emissions of greenhouse gases. Pandey et al. (2013), for instance, examined the effects of different tillage methods on wheat-rice rotation in India and reported that conventional plowing for both plants increased greenhouse gas emissions in addition to increasing wheat yield. In another study, the same authors (Pandey et al., 2012) found that tillage reduction could reduce the release of CH_4, N_2O, and crop yield.

Soil tillage and management of residues can change the dynamics of carbon (C) and nitrogen (N), resulting in significant changes in greenhouse gas emissions and crop yields (Smith et al., 2011; Li et al., 2010). Experiments in China for 50 years showed that increasing farm residues reduced greenhouse gas emissions during the growing season (Song et al., 2019). Agriculture is expected to have a lower effect on N_2O emissions through the application of irrigation and fertilization management methods (Mielenz et al., 2016). West and Marland (2002) reported that average carbon emissions for soybean production in conventional tillage, low-tillage, and no-tillage systems were reported as 168, 146, and 137 kg ha^{-1}, respectively (West and Marland, 2002). Organic carbon and total nitrogen were uppermost in the no-tillage system, followed by the low-tillage system, with the least amount in the conventional tillage system. This was attributed to increasing enzymatic activity in the no-tillage system due to less soil disturbance (Mohammadi et al. 2012). Researchers reported more N_2O emissions for conventional tillage compared to low or no tillage applications. However, Rochette et al. (2008) observed increased emissions of nitrogen oxides from soils compressed by tillage, particularly in loamy soils. Zhang et al. (2015) experimented with different effects of tillage and residue management on greenhouse gas emissions in China. They reported that although CH_4 and N_2O emissions were not significantly different in various treatments during the wheat growth season, CH_4 emission rates were significantly different between treatments in the rice growing season. Also, the interaction effect of tillage and residue management was significant on greenhouse gas emissions, but had no significant impacts on wheat and rice yields.

It is known that denitrification and N_2O production increase with rising water-filled pore space (WFPS). Maximum N_2O emission is achieved at WFPS values above 70%, and maximum denitrification occurs at soil saturation (Liang et al., 2018). Some studies have shown that N_2O emission rates in conventional tillage and no-tillage systems are controlled by the soil water content (Boeckx et al., 2011; Almaraz et al. 2009), but the positive or negative effects of tillage on N_2O emission are largely dependent on soil texture and atmospheric conditions

(Fang et al., 2015). Almaraz et al. (2009) studied soy plants in Canada and found that N_2O emission decreased from a maximum of 18.1 mg m^{-2} day^{-1} in conventional tillage to 7.4 mg m^{-2} day^{-1} in a no-tillage system. They also reported that increasing soybean N_2 fixation in a no-tillage system might reduce CO_2 and N_2O emissions compared to conventional plowing. Existing field studies, however, do not clearly illustrate the effects of tillage or management of residues and/or the interaction of these two methods on greenhouse gas emissions (Bayer et al., 2014).

Considering the cost of direct measurements and the high error of point measurements, a cost-effective method is necessary to determine optimal soil management practices and their effects on atmospheric carbon sequestration and greenhouse gas emissions reduction using simulation models with proven capability. This issue is important in assessing carbon output and the role of agricultural soils in the formation and emission of greenhouse gases and the development of sustainable agriculture. Accordingly, this research aimed to evaluate the impacts of different tillage systems on N_2O greenhouse gas emissions in cotton-wheat rotation using the DNDC model.

2. Materials and methods

2.1. The study area and experimental design

This study was conducted at the Hassan Abad Agricultural Research Station of Darab, which is affiliated with the Fars Agriculture and Natural Resources Research Center (57° 54′ E and 29° 28′ N, with 1107 m above sea level) and is located 230 km south-east of Shiraz, in a warm-dry climate with long-term rainfall (285 mm). The soil specification of the study site is presented in Table 1. The soil texture was loamy, and the studied land had been fallow for three years before the experiment onset.

Table 1. Soil physicochemical characteristics in the study site

Depth (cm)	EC (dS m^{-1})	pH	O.C. (%)	N (mg kg^{-1})	Ab. P	Ab. K	Silt	Clay	Sand	Soil texture
0-15	1.7	7.8	0.58	22	5.9	149	47.5	17.1	35.4	Loam
15-30	0.76	7.8	0.52	24	4.7	97	46.1	19.1	34.8	Loam

This experiment aimed to determine the effects of different tillage methods on greenhouse gas emissions in cotton cultivation in a completely randomized block design with three treatments in four replications during five crop years (2012–2017). The research treatments included direct (no-tillage) wheat-cotton cultivation, low-tillage wheat-cotton, and conventional tillage of wheat-cotton as a control. The dimension of each experimental plot was 180 m^2 (30 m long and 6 m wide). Each wheat plot consisted of 40 planting rows cultivated with inter-line and on-line spacing of 15 cm and 2 cm, respectively, in the last week of November in all 5 years. Wheat was harvested with a special experimental combine and 30% (weight) of wheat residues were dispersed in the field at conservational tillage treatments (low and no tillage). In cotton cultivation, each plot included eight planting rows with an inter-line and on-line spacing of 70 cm and 20 cm, respectively, in the last week of April in all five years.

In direct farming (no-tillage), no tillage operations were done before planting, and the plants were cultivated with one movement of a direct planter (Semeato, model SHM 11/13, Brazil) in the field. A compound tiller (Mark Puttinger, Austria) was used in the low-tillage method. Wheat and cotton were cultivated by a grain drill and a row-planter, respectively. In the conventional method, soil tillage was carried out by moldboard and disk plows, and wheat and cotton were cultured with a line-planter and a row-planter, respectively.

All stages of cotton production were performed according to the instructions of the Iranian Cotton Institute. The farm was irrigated using a siphon in such a way that the height of water behind the siphons was constant and at a similar level for all siphons. Similar irrigation durations were considered for all treatments. The amounts of fertilizers were determined based on the soil test results in all 5 years. Levels of fertilizer use were similar in wheat and cotton fields, and all superphosphate fertilizer (30 kg ha^{-1} of P_2O_5), potassium nitrate (44 kg ha^{-1} of K_2O), and one-third of urea fertilizer (60 kg ha^{-1} of pure N) were applied to the plots by the planter at the cultivation time. The rest of the urea fertilizer was spread as top-dress in the field in two steps (after thinning and after flowering). For weed control on cotton farms, Treflan herbicide (4 L ha^{-1}) was used as pre-culture together with the first irrigation. In addition, manual weeding was carried out at two stages, one in the four-leaf stage along with thinning (40 days after planting) and the other in the pre-flowering stage.

In the cotton field, after full opening of the bolls at the end of the growth season, cotton seed per plot was harvested in separate sacks and weighed with a digital scale to determine the cotton yield. At harvest time, the cotton biomass was calculated by cutting the plants from the soil surface and drying them in an oven at 70 °C for 48 h.

Average soil water content during the experimental period was measured using a TFA max-min thermometer (IP67, Germany). To calculate WFPS (%) (Paul, 2007), soil water content was measured as volumetric water content (VWC) in m^3 m^{-3}.

$$\mathrm{WFPS} = \frac{\mathrm{VWC}}{1 - BD/PD} \times 100\% \qquad \text{Eq.1}$$

Soil bulk density (BD) was 0.83 g cm^{-3} at a depth of 5 cm, and a particle density (PD) of 2.65 g cm^{-3} was considered in this study. Meteorological data was obtained from the weather station in Hasanabad, Darab.

2.2. Measurement of N_2O and NH_3 emissions

The N_2O and NH_3 emission rates were estimated by placing a cap on the soil at weekly intervals. In this method, each cap was inserted into the soil (2 cm) and N_2O and NH_3 fluxes were sampled in a Plexiglas chamber after 30 minutes. The samples were then transferred to the laboratory to determine the N_2O content through gas chromatography (GC) (Model 14a-Shimatzu, Japan). Ammonia emission rates were also measured using the Bentech ammonia assay (GM8806, China). The emission of gases was simulated by the DNDC 9.5 model.

2.3. Statistical evaluation of simulation results

The predictive power of the model was evaluated using the normalized root mean square errors (RMSEn) and error regression coefficients of actual values against predicted values. RMSEn was calculated using Equation 2 (Rinaldi et al., 2003).

$$\mathrm{RMSE_n} = 100\ \Big(\sum_{I=1}^{n} (P_i - O_i)^2 / n\Big)^{0.5} / O_{mean} \qquad \text{Eq. 2}$$

In this equation, P_i and O_i are, respectively, the predicted and actual values, n is the real number of actual measurements of the plant components, and O_{mean} is the actual mean value. RMSEn is expressed as a percentage difference between the predicted and actual values. By definition, RMSE values of < 10%, 10-20%, 20- 30%, and >30% indicate excellent, good, moderate, and weak estimations of the model's predictive power (Rinaldy et al., 2001). Excel software was used for fitting the equations and statistical calculations.

2.4. Model calibration

To design a model, it is necessary to have a rather complete understanding of the processes, mathematical equations, and algorithms describing the processes, since most biogeochemical models need to adapt and adjust the parameters controlling processes (e.g., N_2O and CO_2 generation, leaching, soil moisture storage, etc.). Model regulation or calibration involves the parameters for model coordination and compatibility in producing such data as gas emissions or the original system specimen. In other words, the calibration aims to minimize the difference between the predicted and observed output, and this may be done by accurate measurement of parameters or with optimization methods. There is usually a special relationship between the general model form and the physical system studied through the model parameters, which determines the accuracy of parametric values for a certain proportion between the model output and the measured output.

In this study, the model was calibrated by test and error (manual method). In this method, the included measurable parameters were soil temperature and moisture, as well as cotton biomass and yield. Unknown parameters were estimated as preliminary estimates. Then, the model was run and its output was compared with that observed in the original sample. In this study, data from the first three years of research was used to calibrate the model.

3. Results and discussion

3.1. Soil temperature and moisture

Figure 1 shows the simulated and observed values of average daily soil temperatures at a depth of 5 cm in the three treatments from April 2013 to March 2016. Temporal patterns and simulated values were consistent with field measurements. A linear correlation coefficient (R^2) of 0.97 was obtained for the simulated values against the observed average daily temperatures with a slope of 1.0 ($p<0.01$) and an RMSE value of 10.13% (Table 2).

Table 2. Statistics of simulated DNDC variables in comparison to observed values

Variables	Linear regression				RMSE (%)	n
	Intercept	Slope	R^2	p		
Cotton biomass (Mg ha^{-1})	0	1.06	0.92	≤0.01	26.81	84
Cotton yield (Mg ha^{-1})	0	0.78	0.70	≤0.01	10.51	36
Daily emission of NH_3 (Kg $ha^{-1}d^{-1}$)	0	1.22	0.77	≤0.01	74.73	14
Yearly emission of NO_3 (Kg ha^{-1} yr^{-1})	0	1.24	0.95	≤0.01	18.45	12

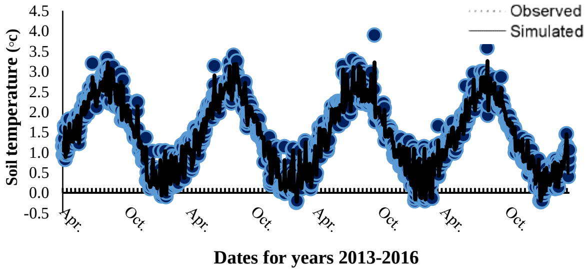

Figure 1. Average daily soil temperature (0-5 cm) observed and simulated from 2013-2016

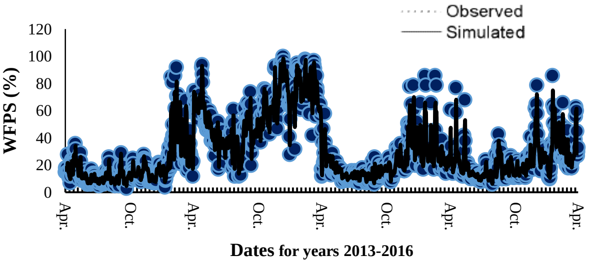

Figure 2. Average daily moisture content in the soil porosity (0-5 cm) observed and simulated from 2013-2016

In addition to the conditioning rate, WFPS (%) also shows the availability of water (Paul, 2007). The best soil conditions for maximum N_2O release occurred at temperatures ranging from 10 to 20 °C, with water filling 60–80% of the WFPS. In warm-dry and cold-wet conditions (beyond the optimum range), the N_2O emission rate from the soil is very slow (Liang et al., 2018). As shown in Figure 2, the model prediction included temporal changes and soil moisture values measured at a depth of 0–5 cm in most cases, although there were some differences in some values. A linear correlation (R^2) of 0.92 was obtained for the simulated values versus the observed mean daily moisture with a slope of 1.04 ($P<0.01$). The RMSE was calculated as 34.57% (Table 2).

3.2. Shoot biomass changes and yield

Simulated changes in shoot biomass for wheat and cotton were generally close to field observations (Figure

3). According to our findings, wheat shoot biomass was very low in winter, but it increased dramatically after the onset of spring, while it rose in cotton with a steady gradient during the plant's growth. This model successfully simulated this dynamic. The linear regression showed an R^2 of 0.92 with a slope of 1.06 for the simulation of the cotton shoot biomass versus the observations ($p<0.01$) indicating a good agreement. An RMSE of 81.86% was obtained from the simulation results (Table 2). Figure 4 compares the simulated and observed cotton yields in the three treatments between 2013 and 2017. The linear regression shows a good agreement between the simulated and observed yields with an R^2 of 0.70, a slope of 0.78 ($p<0.01$), and an RMSE value of 51.5% (Table 2). The simulation results of the 5-year consecutive yields for the treatments (Figure 5) indicate that the tillage methods for cotton cultivation led to average yields of 3.26, 3.10, and 2.88 mg C ha^{-1} in conventional, low, and no tillage treatments, respectively.

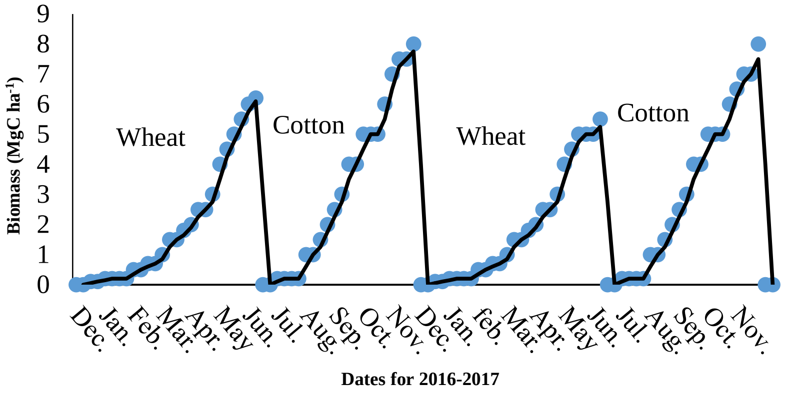

Figure 3. Average biomass observed and simulated in the wheat-cotton rotation from December 2016 to December 2017

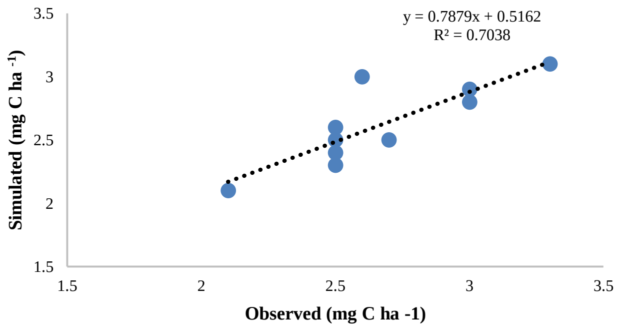

Figure 4. Correlation between observed and simulated average yields of cotton during the 5-year study

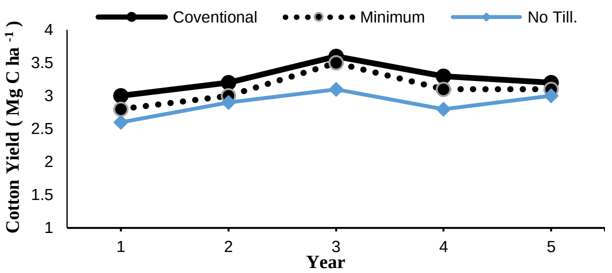

Figure 5. Comparison of cotton yields in different tillage treatments during five years of study

3.3. NH_3 emission from soil

Figure 6 displays the daily and cumulative NH_3 emissions from soil identified and simulated in the days following nitrogen fertilizer application in the conventional tillage treatment. According to the figure, the pattern of changes in the simulated fluxes corresponds to the observed values. However model simulation showed an increasing peak flux on day 5 after fertilization, with a slight flux in the initial three days. Despite these differences, the model simulation obtained an NH_3 cumulative emission of 3.76 kg N ha^{-1} resulting from fertilization operations, which was approximately 4% higher than the observed value (3.60 kg N ha^{-1}). Linear regression of simulated against observed daily emission of NH_3 showed values of 0.77 and 1.22 ($p<0.01$) for R^2 and slope, respectively, with an RMSE value of 74.73% (Table 2).

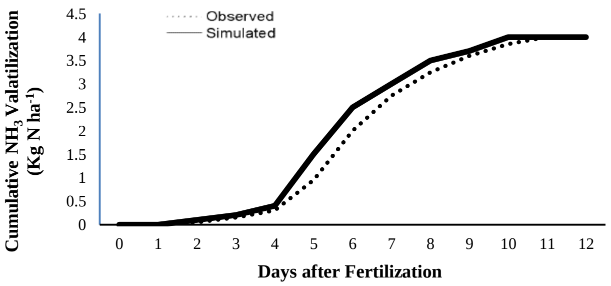

Figure 6. The observed and simulated daily (a) and cumulative (b) NH_3 emissions

3.4. N_2O emission from soil

Figure 7 exhibits the simulated and observed emissions of N_2O for the conventional and no -tillage treatments from October 2015 to October 2016. Daily N_2O emissions were very variable every year. The highest values were usually observed after fertilization, irrigation (especially after fertilizer use), and heavy rainfall. CO_2 emission from the soil depends on the soil temperature, while N_2O emission shows a strong correlation with rainfall (Almaraz et al., 2009). Compared to the observed fluxes, the DNDC model generally showed the temporal pattern of N_2O daily fluxes, although there were some differences in some N_2O peak emissions.

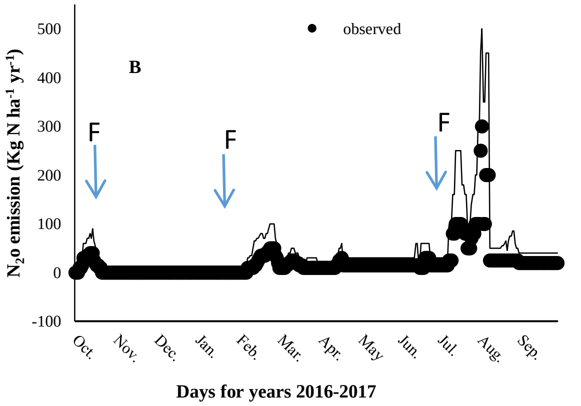

Figure 7. The observed and simulated daily N_2O fluxes in no-tillage (A) and conventional tillage (B) treatments (F is the fertilization time).

In the three tillage treatments, the annual observed emission rate of N_2O varied from 2.9 to 57.5 kg N ha^{-1}, with an average of 3.70 kg (Figure 8). In accordance with the observations, model simulations for the annual N_2O emission varied from 2.67 to 6.95 kg N ha^{-1} with a mean value of 4.24 kg in different tillage treatments. A comparison of linear regression between simulated and observed N_2O emissions in different treatments revealed an R^2 of 0.95 with a significant slope ($p<0.01$) of 1.24. An RMSE value of 19.45% was obtained for the simulated N_2O emission (Table 2). According to the above results, the simulated and observed yearly N_2O emissions were compatible and stable despite a wide range of management practices. This implies that the model simulation could accurately estimate the effects of various management practices on the emission of this gas.

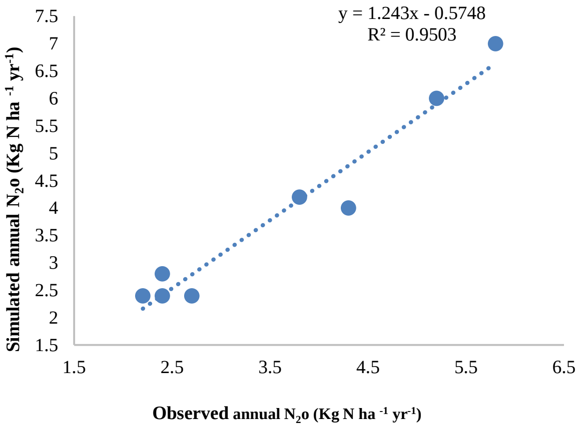

Figure 8. Annual cumulative distribution observed and simulated by N_2O

The N_2O emission rate in conventional tillage, with an annual average of 4.41%, was higher in all studied years than those in low and no tillage treatments, with annual averages of 2.00 and 2.14 kg N ha^{-1}, respectively (Figure 9). The annual release of this gas in all the three treatments showed high variations, with a CV of 25–28% for N_2O between different years.

The results of many studies are available on the use of conservational farming to reduce emissions of greenhouse gases from the soil, but these reports are very contradictory.

In a study, the use of conventional farming in maize fields had no effect on CO_2 and N_2O emissions compared to conservational farming (Johnson and Barbour, 2010). In other studies, conventional agriculture reduced N_2O emission from the soil (Dendooven et al., 2012; Singh et al., 2008), or the application of field conservational farming stimulated N_2O emission through new N inputs in the plant biomass (Baggs et al., 2003; Harrison et al., 2002).

The conventional tillage led to the highest N_2O emission from the soil in the cotton field (4.4 kg N ha^{-1}) and zero tillage (2.1 kg N ha^{-1}) (Figure 10). It seems that after rainfall and irrigation, the residues mixed with soil upon plowing in conventional tillage were degraded more rapidly, nitrogen released for denitrification and N_2O production was more accessible than in the conservational tillage method. Under conservational farming , N_2O emissions from the soil can decrease (Dendooven et al., 2012), increase (Baggs et al., 2003; Ussiri and Lal, 2009), or remain unchanged (Elmi et al., 2003; Jantalia et al., 2008; Omonode et al., 2007; Smith et al., 2011).

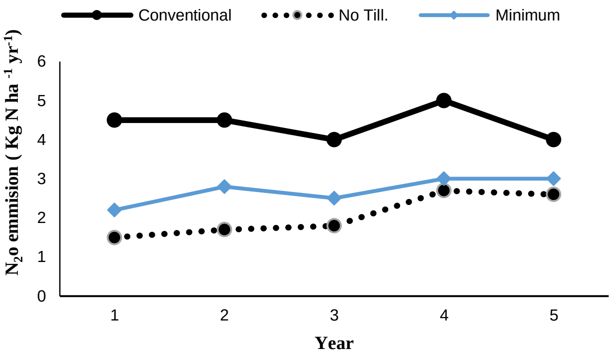

Figure 9. The simulated N_2O emission rates in different tillage treatments in five years of study

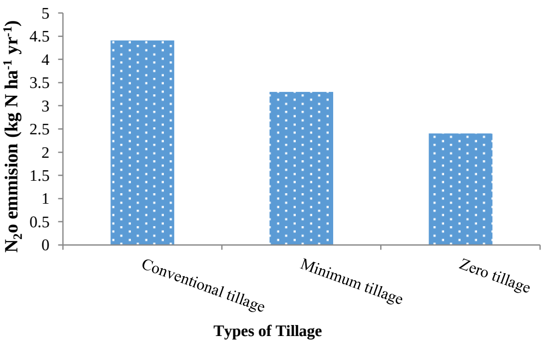

Figure 10. Annual N_2O emissions in different methods of cotton field tillage

The results of some researchers were also consistent with ours. Spie et al. (2011) and Almaraz et al. (2009) reported significant differences between conventional and low tillage methods, so that reduction of plowing reduced N_2O emissions in all studied scenarios. Grant et al. (2004) also reported that a change in farm management from conventional tillage to zero -plowing resulted in a decrease of about 17% in the mean weight of N_2O emission during their entire 30-year study period in Canada.

4. Conclusion

The DNDC model was tested and applied based on validation with limited variables of observations for agricultural systems in many countries (Giltrap et al., 2010). In this study, this model was validated through model simulation using measurements of soil moisture and temperature, crop growth and yield, and NH_3 and N_2O emissions under different field tillage treatments in the wheat-cotton rotation. Despite the differences in daily simulations, validation results revealed that the model worked well in simulating the soil environment and the emission of gases.

In the Darab area of Fars Province, both surface dispersion of the base manure and tillage operations are carried out on a single day. The DNDC model runs daily. In the model, tillage occurs before fertilization, meaning that if fertilization and tillage are set up to be performed on a single day, the fertilizer is not incorporated into the soil. This will greatly reduce NH_3 emission and, as a result, other processes in the nitrogen cycle (Cai et al., 2003). To solve this problem, the soil tillage date can be simply determined one day after fertilization (as in this study). With continued rainfall and initial fertilizer application to cotton, N_2O emissions were elevated in the spring. The emission was higher in the second than in the first year, and was greater in conventional than in conservational tillage, which seems to be due to the faster mineralization of residues in conventional than in conservational tillage treatment in which residues remain on the soil surface. The soil temperature in the no-tillage system was 1 °C lower on average than in the other tillage treatments. In all measurements, the no-tillage system had an average moisture content of 1-3% higher than conventional and low -tillage operations.

Overall, the results showed that tillage systems had significant effects on nitrogen gas emissions from cotton fields, with a reduction in the no-tillage method. It seems that preservation of wheat residues in conservational farming treatments (low and no tillage methods) in the cotton field could have a reducing effect on N_2O and NH_3 emissions from the soil.

It can be concluded that in addition to reducing N_2O and NH_3 pollutant emissions, conservation plowing in wheat-cotton rotation in Darab is economically justifiable due to fuel, time, production costs, machinery depreciation, soil erosion, human resources, and so on. Altogether, the present study considers tillage reduction as an essential element in improving the studied traits. As the no-tillage treatment in the cotton field was more favorable than the other treatments for cotton growing in wheat- cotton rotation, it can be recommended in the same conditions as the present study.

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