Bulgarian Journal of Agricultural Science, 24 (No 4) 2018, 537–553

Economic value of greenhouse gas emissions from crop production in Iran

Mohammad Ghorbani[1], Suren Kulshreshtha[2*], and Mohsen Jamali[1]
[1]*Department of Agricultural Economics, Agricultural College, P. O. Box: 91775-1163, Ferdowsi University of Mashhad, Mashhad, Iran*
[2]*Department of Agricultural and Resource Economics, University of Saskatchewan, Saskatoon, SK, Canada, S7N 5A8*
**E-mail:* suren.kulshreshtha@usask.ca

Abstract

Ghorbani, M., Kulshreshtha, S., & Jamali, M. (2018). Economic value of greenhouse gas emissions from crop production in Iran. *Bulgarian Journal of Agricultural Science*, *24*(4), 537–553

In this study, both the amount and value of greenhouse gas emissions from Iranian crop production are estimated. Both nitrous oxide and carbon dioxide emissions were included for the crop year 2011/12. Results showed that total emissions of nitrous oxide and carbon dioxide were, respectively, 25.471 and 777.714 tonnes per annum. Converted in value terms, these emissions create total environmental costs of more than $9 million annually. Results for different regions within Iran was also undertaken which suggested that the Khuzestan province in Iran is the largest producer of these greenhouse gases. But on a per acre basis, Alborz and Zanzin provinces are the higher producers of these gases. In all cases, use of nitrogenous fertilizers was the major source of these emissions. Proper use of such fertilizers is the major avenue to reduce greenhouse gas emissions from crop production in Iran. In addition, carbon sequestration is also an area that deserves a major attention, either through extension activities or through incentives (such as input taxes).

Keywords: greenhouse gas emissions model; economic value; marginal effect; environmental costs; spatial distribution; Iran

Introduction

Earth's atmosphere plays a key role in preventing the decrease of its temperature (Saleh et al., 2009), which supports the human life on the planet (Taqdisiyan and Minapour, 2003). In fact, one of the principal factors of environmental pollution and the main source of earth's climate and biodiversity changes is greenhouse gas (GHG) emissions from various sources, particularly agricultural sector (Ghorbani et al., 2009). Since 1800, greenhouse gases concentration has increased by 33% (Turner et al., 1995). Most climate scientists agree that under the condition of a doubling of GHG emissions, the average global temperatures would rise by 2-5°C in the next hundred years.

Based on recent experience, global warming could have serious consequences, particularly in terms of appearance of environmental problems, and enhancing natural disasters, such as storms, hurricanes, extreme forest fires, droughts, famines, floods, insect infestation, tides and ocean's horizontal flow, among others (Daftarian, 2009).

According to the IPCC, the global agricultural and forestry sectors combined are seen as the most important sectors in contributing to climate change mitigation (IPCC, 1996; Trumper et al., 2009). Globally, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), contribute 60%, 15% and 5%, respectively, to the anthropogenic greenhouse effect (Guo and Zhou, 2007). Productive and economic human activities, in particular, have been the main factors responsible for the increase of GHG into the atmosphere in recent years (Saleh et al., 2009). In essence, global warming and climate changes derive by human activities are the most serious environmental problems in this century that threaten human welfare (Jamalipour et al., 2015).

Agriculture sector is not only known as a major source of GHG, but also could play a role in sequestration and mitigation of GHGs, particularly carbon dioxide, ammonia, and nitric oxide (Motallebi et al., 2007). Gregorich et al. (2005) report that amount of GHG emissions in eastern Canada can be reduced by applying solid animal manures than using liquid animal manures and chemical N-fertilizers. Changing the cop mix can also have some impact on the level of these emissions. According to Zolghi et al. (2009) CO_2 emissions rice-fallow rotations was higher than the wheat-fallow or wheat-vegetables rotations.

As a result of the awareness of numerous environmental problems associated with global warming, it is imperative for governments to reduce these problems by new legislation and serious activities (Motallebi et al., 2007). A number of world nations have committed themselves to implementing the Paris Agreement. Under the Agreement, all countries must reduce their GHG emissions during the commitment period by specified amounts and target dates. Being a signatory to this Agreement, Iran is no exception. The long-term goal of the Agreement is to limit the increase in the global average temperature to well below 2°C above pre-industrial levels, and of pursuing efforts to limit this temperature increase to 1.5°C. It also includes the goal to increase the ability to adapt to the adverse impacts of climate change and to make finance flows consistent with a pathway towards low GHG emissions (European Parliament's Committee, 2016).

In order for Iran to develop appropriate policies for GHG mitigation, knowledge of GHG emissions from different sectors (particularly the agricultural sector since it is the largest emitter of CH_4 and N_2O) is a virtual necessity. The major objective of this study is to estimate these emissions from crop production in Iran, and evaluate their economic value.

Method of analysis

Production and consumption of agricultural (food and non-food) products generate all three GHGs, but those for CH_4 and N_2O are more prominent. Each of these gases is released from various farm level activities. Therefore, accounting for these emissions requires a system of relationship between level of farm activity and the resulting GHG emissions of individual gas. These activities are related to, among other things, fertilizers, chemicals and the burning of fossil fuels.

In this study a Greenhouse Gas Emission Model (GHGEM) was designed to compute the GHG emissions from selected various agricultural activities that are both directly and indirectly related to agricultural production. In addition, since various regions of Iran are different in terms of level of crop production as well as crop mix, analysis was undertaken first at a provincial (sub-national) level, and then aggregated to Iran as a whole. In this study, two main GHGs were included: N_2O and CO_2. The structure of GHGEM was designed as a linear and additive modular system, where each module estimated emissions from selected set of agricultural activities.

The GHGEM for the study mainly consisted of a Crop Production Module (CPM). This module computes all GHG emissions that are released from the production of crop. Natural emissions are produced from nitrogen-fixing crops, as they are able to convert nitrogen in the soil into usable nitrogen for the crop, however, in turn releasing some of that nitrogen into the atmosphere. Other natural sources of emissions occur from environmental cycles, such as the breaking down of soil organic matter (Klemmer, 2010).

The CPM includes four major activities related to crop production: Crop residues, Fertilizer, Fallow crops, and Soil carbon sequestration. These are the major sources of both N_2O and CO_2 emissions in Iran. Fertilizer is the largest contributor of N_2O emissions through atmospheric deposition and leaching. In addition to the direct GHG emissions from application of fertilizers under conventional production system, GHG emissions are also produced through production, storage and transportation of synthetic inputs (Klemmer, 2010). Crop residues refer to the things which are left in the field after the crops has been harvested, excluding plant roots. The break-down and decomposition of the crop residues is a cause of releasing back the N_2O emissions into the atmosphere. Sobool and Kulshreshtha (2005) discuss that "the amount of nitrogen fixed by a crop is not known for certain." However, they report that 45 percent of crops' total biomass is harvested, while the remaining 55 percent of biomass remains on the surface as crop residue. The amount of residues is directly related to management practices and the nitrogen content of the various crop types, as shown in Table 1, which was used to calculate total N_2O emissions.

All crops in Iran were included in the study, which resulted in seven categories: cereals, pulses, industrial crops, vegetables, vines, forages, and other crops. Cereals are the dominant crop type in Iran, comprising of 71% of total cropped area.

Estimation of emissions from crop residues

Total N_2O emissions from crop residues were related to the total area of a crop type in a region and the emissions coefficient for the crop type in the given region. The following equations (1 to 3) were used to determine total N_2O emissions for a region (equivalent to province in Iran ($N_2O\_TEM(c.r)_{CR}$):

Table 1
Farming activities related to greenhouse gas emissions

Emissions module	Activities	CO_2	CH_4	N_2O
Crop production	Crop residues			✓
	Fertilizer			✓
	Fallow crops			✓
	Soil carbon sequestration	✓		
Indirect crop and livestock production	Atmospheric sequestration – fertilizer			✓
	Atmospheric sequestration – manure			✓
	Nitrogen leaching – fertilizer			✓
	Nitrogen leaching – manure			✓
	Histosols			✓
	Human sewage			✓
On-farm energy use activities	On-farm transportation of crops	✓	✓	✓
	Stationary combustion for crops	✓	✓	✓
Farm inputs manufacturing	Fertilizer – domestic use	✓	✓	✓
	Fertilizer – exports	✓	✓	✓
	Fuel	✓	✓	✓
	Pesticides	✓	✓	✓
	Machinery and implements	✓	✓	✓
Off-farm transportation and storage	Transportation of crops	✓	✓	✓
	Storage of crops	✓	✓	✓

Source: Kulshreshtha et al. (2000)

$$N_2O\_TEM(c.r)_{CR} = AREA(c.r) * N_2O\_EC(c.r)_{CR,} \quad (1)$$

where, *AREA (c.r)* is area of crop type (c) in region (r), in ha, and $N_2O\_EC(c.r)$ is crop residue emission coefficient for nitrous oxide from crop type (c) in region (r), in tonnes (t) ha^{-1}.

Details on the estimation of emissions coefficients were based on IPCC (1996) (Houghton et al., 1997). The crop residue emission coefficient was estimated using equation (2):

$$N_2O\_EC\ (c.r)_{CR} = N\_CONT(c) * YIELD(c.r) * N_2O\_EF * {}^{44}/_{28} \quad (2)$$

where, *N_CONT(c)* is nitrogen content of crop type (c), in t ha^{-1}, *YIELD (c.r)* is yield for crop type (c) in region (r), in t ha^{-1} and N_2O_EF is nitrous oxide emissions factor (using a default value of 0.125 kg N_2O-N kg N^{-1}).

Nitrogen content (*N_CONT(c)*) of crop type (c) was estimated using equation (3), as shown below:

$$N\_CONT(c) = PROP\_BIOMSS(c) * CROP\_FACTOR(c) \quad (3)$$

where, *PROP_BIOMSS(c)* is proportion of crop type (c) that contains nitrogen and *CROP_FACTOR(c)* is quantity of nitrogen released from each specific crop type (c).

Estimation of emissions from fertilizer application

Greenhouse gases produced from application of chemical fertilizers to various crops is a major source of N_2O emissions. The total emissions from fertilizer ($N_2O\_TEM\ (c.r)_{FRTU}$) emissions were estimated at the provincial level using equation (4):

$$N_2O\_TEM\ (c.r)_{FRTU} = AREA\ (c.r) * N_2O\_EC\ (c.r)_{FRTU} \quad (4)$$

where, *AREA (c.r)* is area of crop type (c) in region (r), in ha, and $N_2O\_EC(c.r)_{FRTU}$ is N_2O emission coefficient from fertilizer use for crop type (c) in region (r), in t per ha.

The N_2O coefficient was based on the level of fertilizer applied to a crop and its N content, as shown in equation (5):

$$N_2O\_EC(c.r)_{FRTU} = QNTY(c.r) * N\_CONT(p)_{FRT} * {}^{44}/_{28} \quad (5)$$

where, *QNTY(c.r)* is quantity of fertilizer applied to crop (c) in region (r), in tonnes per ha and $N\_CONT(p)_{FRT}$ is the nitrogen content of fertilizer, in t per t of fertilizer.

Estimation of emissions from fallow lands

To estimate released N_2O from annual fallow lands, equation (6) was used:

$$N_2O\_FLW(c.r)_{CR} = AREA(c.r) * N_2O\_EC(c.r)_{FLW} \quad (5)$$

where, *AREA(c.r)* is area of crop type (c) in region (r) that is fallowed, in ha, and $N_2O\_EC(c.r)_{FLW}$ is N_2O emission coefficient from annual fallow for crop type (c) in region (r), in t per ha.

Estimation of carbon released from agricultural lands

Using carbon conversion factor to carbon dioxide (IPCC, 1996), the total amount of released CO_2 from Iran's crop lands ($CO_2\_SCS(c.r)_{CR}$) was estimated using equation (7):

$$CO_2\_SCS(c.r)_{CR} = AREA(c.r) * CO_2\_EC(c.r)_{SCS} * CON\_F_{C\_CO_2} \quad (6)$$

where, *AREA(c.r)* is area of crop type (c) in region (r), in ha, $CO_2\_EC(c.r)_{SCS}$ is C emission coefficient from firms for crop type (c) in region (r), in t per ha, and $CON\_F_{C\_CO_2}$ is conversion factor of Carbon to CO_2 (using a default value of 3.666) (Sobool and Kulshreshtha, 2005).

The CPM containing the above set of equations resulted in the total GHG emissions in various provinces in Iran. Using coefficients from other studies, a technique called Benefit Transfer, is generally recommended because of resources limitations and cost effective (Garrod and Willis, 1999).

A regional comparison of GHG emissions was made by classifying various provinces by scale of production and amount of GHG emissions. As well as, Analysis of Variance (Tukey Test) was used for comparing mean level of GHG emissions for different groups. The environmental costs of GHG emissions from cultivated crop area were also estimated.

All emissions were converted into carbon dioxide equivalent using the factors for Global Warming Potential (GWP) of each gas. In this study GWPs commonly accepted for international reporting were used, namely 1 for CO_2, 21 for CH_4 and 310 for N_2O (IPCC, 1996). This means that as a greenhouse gas on a mass basis, N_2O and CH_4 are 310 and 21 times more powerful than CO_2, respectively. Combined CO_2, CH_4 and N_2O, emissions are reported in t of CO_2 equivalents (CO_{2E}) (Desjardins et al., 2010).

Data for the study pertain to the crop year 2011/12, and were obtained from secondary sources (Office of the Statistics of the Ministry of Agricultural Jihad, 2014). All calculations were carried out using Microsoft Excel 2013 and SPSS 16.0.

Estimation of environmental cost of GHG emissions

Environmental costs are related to the damage of the environment. They include certain contingent liabilities, as the risk of having to decontaminate a site or having to pay compensation for damage to natural resources. Regardless of these problems, the evolution of social awareness towards environmental issues requires accurate calculations of costs (Tijani and Hamadi, 2013). Although a number of international studies have been done on GHG emission, environmental costs of these pollutants have not been considered clearly (Ghorbani and Motallebi, 2009). Performing a calculation of environmental costs of GHG emissions could have a big impact on agricultural sector's decision makers for providing urgent warning and environmental protection through necessary financial supports. Since there has not been a study on estimating the economic value of GHG emissions in Iran's crop lands, in this study a shadow price of N_2O and CO_2 gases were obtained from Ghorbani and Motallebi (2009). They have reported these values to be -1618.4 and -159.7 Rials. Adjusting these values for inflation over the period of six years resulted in a value of -3177.36 and -313.53 Rials, respectively, for N_2O and CO_2 gases and they were used in this study.

Results and Discussion

Estimated amount of GHG emissions

As noted above, cereals are the predominant type of crops in Iran, the amount of GHG emitted from them are presented in Table 2; the rest of the GHG emissions from the remaining six categories are included in the Appendix tables (A.1 to A.6). Table 2 records amount of N_2O emissions from crops' residues, using nitrogenous fertilizer, area under fallow and CO_2 releases from soil in Iran's cereals farms. The total amount of Iran's cereals cultivations is about 9.073 million hectare (ha), of which that in the Khuzestan province has the largest share (8.49 million ha).

Total N_2O emissions in Iran from cereal production were estimated at 12.443 tonnes, of which the highest proportion was as a result of fertilizer use (about 74% of total N_2O emissions), as shown in Table 2. The other N_2O emissions were from crop residues, which as noted above, are from that part of plant which is not removed from the land, is not eaten by livestock, and is not a part of plant root. According the results, although Yazd province has the highest of emission coefficient for N_2O emissions, but the highest amount of these emissions were released by Khozstan province (at 405 t). In terms of N_2O emissions from fertilizer application, some 9.204 t (equivalent to 2.95 Mt) of N_2O was emitted. Top emitting regions in Iran were Khozstan, followed by Kermanshah, and Fars provinces. Overall the use of nitrogen fertilizer by cereals farms generated 18.097 t of N_2O. The amount of estimated N_2O emissions from fallow lands showed that Khuzestan and Hormozgan provinces with pro-

Table 2
N_2O emissions (tonnes) from crop residues, nitrogen fertilizer application, area under fallow and CO_2 (tonnes) releases from soil in Iran's cereals farms

Provinces	Area (1000 ha)	Residues (t/ha)	N_2O emissions from residues (t)	N-fertilizer (kg/ha)	N_2O emissions from N-fertilizer (t)	N_2O emissions from fallow (t)	Total N_2O emissions (t)	CO_2 emissions (t)
Eastern Azerbaijan	502.87	0.11	92.6	787.7	441.3	7.0	540.865	30830.36
Western Azerbaijan	460.959	0.11	106.7	646.8	412.0	6.4	525.046	28290.10
Ardebil	474.827	0.10	148.1	627.3	357.6	6.6	512.305	29112.68
Isfahan	171.299	0.13	97.6	1302.5	234.1	2.4	334.136	10652.03
Alborz	22.76	0.07	15.9	304.5	26.5	0.32	42.716	1413.62
Ilam	154.982	0.07	30.1	439.5	128.3	2.1	160.554	9495.62
Bushehr	88.51	0.07	10.9	173.9	59.2	1.2	71.343	5402.59
Tehran	115.945	0.07	78.6	278.2	117.6	1.6	197.887	7181.63
Chaharmahal and Bakhtiari	97.062	0.06	25.5	398.8	88.5	1.3	115.294	5961.65
Southern Khorasan	68.693	0.08	16.4	205.3	52.5	1.0	69.874	4207.48
Khorasan Razavi	663.424	0.11	203.9	768.5	613.8	9.2	826.970	40787.15
Northern Khorasan	200.477	0.14	52.4	226.2	163.1	2.8	218.364	12293.74
Khozestan	848.591	0.12	404.6	684.3	1035.9	11.8	1452.357	52565.75
Zanjan	487.449	0.04	87.2	153.2	311.2	6.8	405.164	29765.80
Semnan	59.103	0.04	24.8	729.7	87.2	0.8	112.731	3672.70
Sistan and Baluchestan	107.697	0.09	35.2	443.5	122.4	1.5	159.104	6646.04
Fars	641.031	0.15	375.7	756.1	651.5	8.9	1036.121	39647.50
Qazvin	178.226	0.13	66.8	632.9	196.9	2.5	266.217	11001.35
Qom	30.221	0.05	15.1	457.7	56.4	0.4	71.881	1892.19
Kurdistan	567.192	0.08	86.2	159.4	422.7	7.9	516.785	34680.60
Kerman	155.565	0.06	64.8	652.5	243.8	2.2	310.668	9680.85
Kermanshah	627.617	0.13	196.6	789.4	674.3	8.7	879.672	38683.08
Kohgiluyeh and Boyerahmad	183.777	0.12	46.6	581.3	164.1	2.5	213.242	11282.73
Golestan	507.585	0.12	219.4	311.6	498.6	7.0	725.022	31298.51
Guilan	189.047	0.07	101.6	782.7	307.4	2.6	411.670	11798.58
Lorestan	318.584	0.11	85.4	341.2	265.0	4.4	354.769	19544.12
Mazandaran	298.324	0.09	206.0	844.1	473.4	4.1	683.571	18652.59
Markazi	279.141	0.07	57.2	1027.7	320.5	3.9	381.553	17195.12
Hormozgan	20.3	0.11	15.5	983.9	50.3	0.28	66.110	1288.85
Hamedan	517.724	0.12	123.2	576.0	550.6	7.2	680.890	31865.09
Yazd	34.951	0.15	22.0	1030.9	77.7	0.5	100.238	2205.45
Total	9073.933	952.64*	3112.6	5405.42**	9204.4	125.9	12443.121	558995.55

Source: Research findings *Total generated residues in all cultivated area (tonnes) **Aggregate of used fertilizer in all cultivated area (tonnes)

duction about 11.8 and 0.28 t, were the highest and lowest N_2O producers, respectively. In total, about 125.9 t of N_2O was released from cereal farms under fallow.

In general, soils in Iran are net emitters of carbon dioxide. The total emissions of CO_2 from cereal farms was estimated abound 558.996 t. Included here are the two top emitter of CO_2 being Khozestan and Khorashan Razavi provinces, with an emissions of 52.566 and 40.787 t annually.

Extending the analysis to all six types of farms in Iran, one obtains the total GHG emissions from crop production. In terms of CO_{2E} total emissions were estimated at 16.4 megatons (Mt), of which release of carbon from soils was estimated to be responsible for over half of the total (53% of total). This total was a result of 777 kilotons (kt) of N_2O and 8.7 Mt of CO_2 emissions (Table 3). The range of emissions was estimated from 54.018 to 1.354 t for Khuzestan and Hormozgan provinces, respectively. It should be noted that the Khuzestan province is the largest producers of both the GHGs in Iran. It produced about 11.67 percent of N_2O and 9.4 percent of CO_2 Iran's emissions (Figure 1).

Table 3
Total N_2O and CO_2 emissions (tonnes) from agronomy farms in Iran

Provinces	Area (1000 ha)	Residues (t/ha)	N_2O emissions from residues (t)	N-fertilizer (kg/ha)	N_2O emissions from N-fertilizer (t)	N_2O emissions from fallow (t)	Total N_2O emissions (t)	CO_2 emissions (t)	CO_2 equivalent (t)
Eastern Azerbaijan	739.535	1.163	258.26	3252.647	608.009	10.285	876.48	45085.40	316794.20
Western Azerbaijan	730.140	3.946	587.575	2592.914	644.431	10.129	1242.065	44503.43	429543.58
Ardebil	637.407	1.354	409.05	1222.17	410.824	8.856	2262.932	37312.09	738821.01
Isfahan	280.384	4.657	446.354	5467.27	409.659	3.916	859.94	17222.59	283803.99
Alborz	52.052	3.018	237.152	1266.13	33.387	0.726	271.201	3178.22	87250.53
Ilam	175.209	2.078	70.609	1008.62	140.896	2.375	213.994	10713.71	77051.85
Bushehr	113.243	4.435	161.204	1014.14	106.715	1.543	269.447	6892.45	90421.02
Tehran	171.406	2.111	415.317	1237.62	140.712	2.371	558.335	10522.47	183606.32
Chaharmahal and Bakhtiari	134.873	2.787	114.668	2474.27	153.628	1.817	270.066	8238.94	91959.40
Southern Khorasan	108.625	2.962	79.872	1029.94	80.728	1.552	162.091	6612.39	56860.60
Khorasan Razavi	935.395	2.523	859.412	3157.43	885.889	12.975	1758.399	57168.61	602272.30
Northern Khorasan	286.407	5.652	132.172	1442.27	214.809	3.988	352.775	17469.46	126829.71
Khozestan	1146.308	3.287	1868.291	2380.526	1144.897	15.927	3029.091	70498.27	1009516.48
Zanjan	591.642	1.659	187.377	900.08	369.421	8.247	565.038	36041.81	211203.59
Semnan	103.822	3.408	120.004	1574.795	126.785	1.417	248.252	6366.38	83324.50
Sistan and Baluchestan	189.760	2.726	335.577	1691.33	154.288	2.643	492.597	11589.14	164294.21
Fars	923.615	3.341	1341.61	4123.883	984.795	12.823	2339.24	56668.45	781832.85
Qazvin	274.738	5.563	436.841	2882.315	361.301	3.838	802.025	16814.74	265442.49
Qom	50.244	2.329	59.339	1285.37	64.396	0.678	124.463	3098.47	41682.00
Kurdistan	711.390	1.875	230.651	733.07	470.381	9.901	711.129	43365.87	263815.86
Kerman	324.223	1.312	271.018	3317.896	488.568	4.536	763.973	19839.62	256671.25
Kermanshah	858.111	6.480	456.164	3938.725	771.242	11.900	1239.404	52566.41	436781.65
Kohgiluyeh and Boyerahmad	203.298	2.538	77.247	2195.89	181.048	2.774	261.044	12458.23	93381.87
Golestan	699.133	2.035	415.426	1483.261	725.478	9.656	1150.556	42836.07	399508.43
Guilan	201.097	1.352	121.871	3003.406	319.304	2.775	443.931	12524.33	150142.94
Lorestan	548.983	2.668	322.543	2501.97	399.908	7.598	729.987	33421.57	259717.54
Mazandaran	412.536	2.150	549.139	3564.864	564.662	5.684	1119.419	25532.19	372552.08
Markazi	337.180	2.369	157.724	4541.834	388.765	4.701	551.205	20690.75	191564.30
Hormozgan	81.744	2.664	222.676	1877.67	97.607	1.133	321.531	4989.82	104664.43
Hamedan	650.865	2.404	465.783	3181.15	755.968	9.049	1230.654	39884.79	421387.53
Yazd	58.229	8.059	163.318	2852.1	85.114	0.823	249.347	3607.25	80904.82
Total	12,731.593	37,255.93*	11,574.244	33,233.58**	12,283.615	176.632	25,470.611	777,713.912	8,673,603.32

Source: Research findings *Total generated residues in all cultivated area (tonnes) **Aggregate of used fertilizer in all cultivated area (tonnes)

The GHG emissions from other crop productions (pulses, industrial crops, vegetables, vine crops, forage plants, and other crops) have been reported in appendix tables. Using these estimates along with those from cereals, total emissions of N_2O and CO_2 from crop production were developed. These estimates suggest that of the total GHG emissions in Iran from crop production was 8.67 Mt, over half of which were generated by cereals (Figure 2). Like the situation in cereal crops, Khuzestan province has the largest area under cultivation and therefore, has the highest emissions of N_2O and CO_2 gases. Although, the largest amount of residues has generated from Yazd's farms, the highest releases belong to Khuzestan province. In spite of the fact that Isfahan province has the most usage of nitrogen fertilizer, Khuzestan with 1.145 t is the highest producer of N_2O emissions from N-fertilizer applying.

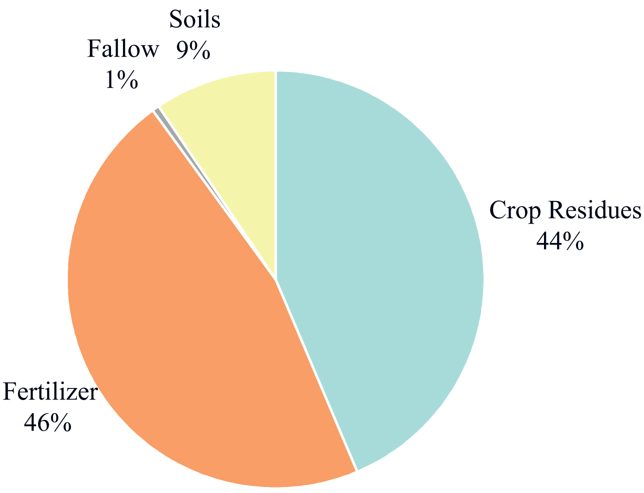

Fig. 1. Distribution of total GHG emissions from Iran's crop production

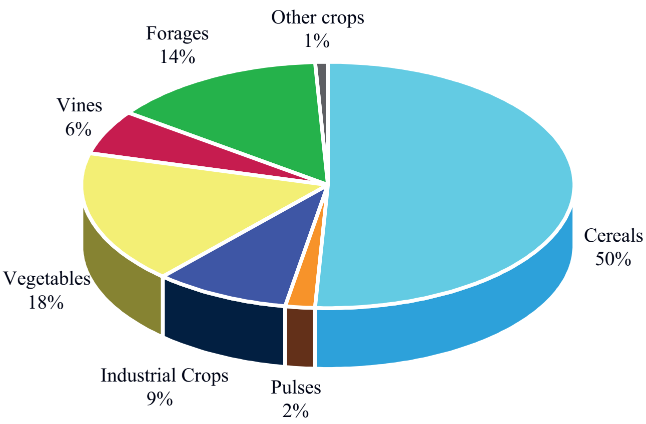

Fig. 2. Distribution of GHG emissions from Iran's crop production by product type

Comparison of GHG emissions on a per ha basis

In order to having an appropriate comparison among the findings, we have compared the various provinces of Iran in terms of GHG emissions per unit of area in Table 4 for both the gases – N_2O and CO_2. On average, one ha of land in Iran emits 2.27 t of N_2O and 61.16 t of CO_2. However, various provinces differ in their level of average emissions. The Alborz and Zanjan provinces with emissions of 5.21 and 0.96 t per ha, respectively, have the highest and lowest N_2O releases among all the 31 provinces. In addition, we found that Guilan and Ardebil provinces with 62.28 and 58.54 t per ha, respectively, were the highest and lowest emitters of CO_2. The variability among the provinces is determined by level of input use.

Table 4
Compare of GHG emissions in per unit area

Provinces	Area (1000 ha)	N_2O emissions ha^{-1} (t)	CO_2 emissions ha^{-1} (t)
Eastern Azerbaijan	739.535	1.19	60.96
Western Azerbaijan	730.140	1.70	60.95
Ardebil	637.407	3.55	58.54
Isfahan	280.384	3.07	61.43
Alborz	52.052	5.21	61.06
Ilam	175.209	1.22	61.15
Bushehr	113.243	2.38	60.86
Tehran	171.406	3.26	61.39
Chaharmahal and Bakhtiari	134.873	2.00	61.09
Southern Khorasan	108.625	1.49	60.87
Khorasan Razavi	935.395	1.88	61.12
Northern Khorasan	286.407	1.23	61.00
Khozestan	1146.308	2.64	61.50
Zanjan	591.642	0.96	60.92
Semnan	103.822	2.39	61.32
Sistan and Baluchestan	189.760	2.60	61.07
Fars	923.615	2.53	61.36
Qazvin	274.738	2.92	61.20
Qom	50.244	2.48	61.67
Kurdistan	711.390	1.00	60.96
Kerman	324.223	2.36	61.19
Kermanshah	858.111	1.44	61.26
Kohgiluyeh and Boyerahmad	203.298	1.28	61.28
Golestan	699.133	1.65	61.27
Guilan	201.097	2.21	62.28
Lorestan	548.983	1.33	60.88
Mazandaran	412.536	2.71	61.89
Markazi	337.180	1.63	61.36
Hormozgan	81.744	3.93	61.04
Hamedan	650.865	1.89	61.28
Yazd	58.229	4.28	61.95
Total	12731.593	2.27	61.16

Source: Research findings

Since not many other studies have addressed this issue, a comparison is not possible. The only similar study reported was by Kulshreshtha et al. (2005). Since the methodology of this study is similar to that of the Kulshreshtha et al. study, a comparison is valid. Results showed that the amount of emissions in Iran is higher than ones in Canada on a per unit area. Furthermore, the environmental costs value has not been investigated in previously studies, and therefore no comparison can be made.

Table 5
Environmental costs of N_2O and CO_2 emissions from agronomy farms in Iran

Provinces	Costs of N_2O emissions ($1000)	Costs of CO_2 emissions ($1000)	Total cost of GHG emissions ($1000)
Eastern Azerbaijan	80.722	409.734	490.456
Western Azerbaijan	114.391	404.445	518.836
Ardebil	208.410	339.091	547.501
Isfahan	79.198	156.518	235.716
Alborz	24.977	28.884	53.860
Ilam	19.708	97.366	117.074
Bushehr	24.815	62.638	87.454
Tehran	51.421	95.628	147.049
Chaharmahal and Bakhtiari	24.872	74.875	99.748
Southern Khorasan	14.928	60.093	75.021
Khorasan Razavi	161.944	519.546	681.490
Northern Khorasan	32.490	158.762	191.251
Khozestan	278.971	640.685	919.657
Zanjan	52.039	327.546	379.585
Semnan	22.863	57.857	80.721
Sistan and Baluchestan	45.367	105.322	150.689
Fars	215.438	515.001	730.438
Qazvin	73.864	152.812	226.676
Qom	11.463	28.159	39.622
Kurdistan	65.493	394.107	459.600
Kerman	70.360	180.302	250.662
Kermanshah	114.146	477.721	591.867
Kohgiluyeh and Boyerahmad	24.041	113.220	137.261
Golestan	105.963	389.292	495.256
Guilan	40.885	113.821	154.705
Lorestan	67.230	303.734	370.964
Mazandaran	103.096	232.036	335.131
Markazi	50.765	188.037	238.801
Hormozgan	29.612	45.347	74.959
Hamedan	113.340	362.471	475.811
Yazd	22.964	32.783	55.747
Total	2345.777	7067.832	9413.608

Source: Research findings

Table 6
Marginal effect and policy of increase in area under cultivation

Provinces	One hectare increase in scale of cultivation (1000 ha)	N_2O emissions (t/added ha)	CO_2 emissions (t/added ha)
Eastern Azerbaijan	739.536	0.0012	0.0610
Western Azerbaijan	730.141	0.0017	0.0610
Ardebil	637.408	0.0036	0.0585
Isfahan	280.385	0.0031	0.0614
Alborz	52.053	0.0052	0.0611
Ilam	175.21	0.0012	0.0611
Bushehr	113.244	0.0024	0.0609
Tehran	171.407	0.0033	0.0614
Chaharmahal and Bakhtiari	134.874	0.0020	0.0611
Southern Khorasan	108.626	0.0015	0.0609
Khorasan Razavi	935.396	0.0019	0.0611
Northern Khorasan	286.408	0.0012	0.0610
Khozestan	1146.309	0.0026	0.0615
Zanjan	591.643	0.0010	0.0609
Semnan	103.823	0.0024	0.0613
Sistan and Baluchestan	189.761	0.0026	0.0611
Fars	923.616	0.0025	0.0614
Qazvin	274.739	0.0029	0.0612
Qom	50.245	0.0025	0.0617
Kurdistan	711.391	0.0010	0.0610
Kerman	324.224	0.0024	0.0612
Kermanshah	858.112	0.0014	0.0613
Kohgiluyeh and Boyerahmad	203.299	0.0013	0.0613
Golestan	699.134	0.0016	0.0613
Guilan	201.098	0.0022	0.0623
Lorestan	548.984	0.0013	0.0609
Mazandaran	412.537	0.0027	0.0619
Markazi	337.181	0.0016	0.0614
Hormozgan	81.745	0.0039	0.0610
Hamedan	650.866	0.0019	0.0613
Yazd	58.23	0.0043	0.0619

Source: Research findings.

The environmental cost of GHG emissions

For the reported GHG emissions in Table 3, the economic cost to Iran was estimated for various provinces. All things considered, Khuzestan province, with the largest crop area, had the highest environmental cost among all the provinces estimated at $278.971 and $640.685 for N_2O and CO_2, respectively (Table 5). Similarly, the lowest environmental costs were estimated for the Qom province. For Iran as a whole, the total environmental cost is estimated at $9.413 million annually. It should be noted that these costs are relatively very small, since they make up 0.005 percent of GDP and 0.006 percent of country's total budget for the 2011-12 year. Moreover, these costs are still lower than the market value of these cultivable.

Table 7
Comparison of greenhouse gas emission based on production scale

Scale of production	Provinces	Share of provinces in group (%)	*Mean of emissions (t)
Small	Alborz, Ilam, Bushehr, Tehran, Chaharmahal and Bakhtiari, Southern Khorasan, Semnan, Sistan and Baluchestan, Qom, Kohgiluyeh and Boyerahmad, Guilan, Hormozgan, Yazd	13	8052.2[a]
Medium	Eastern Azerbaijan, Western Azerbaijan, Ardebil, Isfahan, Northern Khorasan, Zanjan, Qazvin, Kurdistan, Kerman, Golestan, Lorestan, Mazandaran, Markazi, Hamedan	56.5	32374.2[b]
Large	Khorasan Razavi, Khozestan, Fars, Kermanshah	30.5	61317.0[c]

Source: Research findings   *Non-common letters indicate significant differences between groups (P)

Table 8
Means comparison test of N_2O and CO_2 emissions of provinces

Emissions categories	Provinces	Share of provinces in group (%)	*Mean of emissions (t)
Low	Isfahan, Alborz, Ilam, Bushehr, Tehran, Chaharmahal and Bakhtiari, Southern Khorasan, Northern Khorasan, Semnan, Sistan and Baluchestan, Qazvin, Qom, Kohgiluyeh and Boyerahmad, Guilan, Hormozgan, Yazd	19.7	9887.48[a]
Medium	Eastern Azerbaijan, Western Azerbaijan, Ardebil, Zanjan, Kurdistan, Kerman, Golestan, Lorestan, Mazandaran, Markazi, Hamedan	49.8	36337.91[b]
High	Khorasan Razavi, Khozestan, Fars, Kermanshah	30.5	61316.97[c]

Source: Research findings   *Non-common letters indicate significant differences between groups (P)

Marginal effects

In order to reduce GHG emissions, the private or public sector would have to develop appropriate mitigation measures. To select the areas (provinces) with a higher reduction in emissions, comparison of their marginal emissions coefficient could be very helpful. In table 6, emissions associated with a single ha of crop land are presented. According to these estimates, an additional unit of land (1 ha) in Alborz province would emit 0.0052 t of N_2O and 0.0611 t of CO_2 for a total of 0.0663 t. Similar change in the Guilan province would yield a change of 0.0645 t. Based on our estimation, both Alborz and Guilan provinces have the highest marginal change in N2O and CO_2 emissions associated with increasing the cropped area by one ha.

Comparison of mean test

In order to compare all the Iranian provinces, we classified them into three categories based on scale of production: small (0-250 thousand ha), medium (250-800 thousand ha), and large (800-1200 thousand ha). As shown in Table 7, approximately 13 percent of provinces had small area, as against, 56.5 and 30.5 percent of provinces in medium and large scale groups, respectively. The mean of N_2O and CO_2 emissions of first groups is about 8052.2 t. The medium and large scale groups had an average GHG emissions of 32.374 and 61.317 t, respectively, which are 4 and

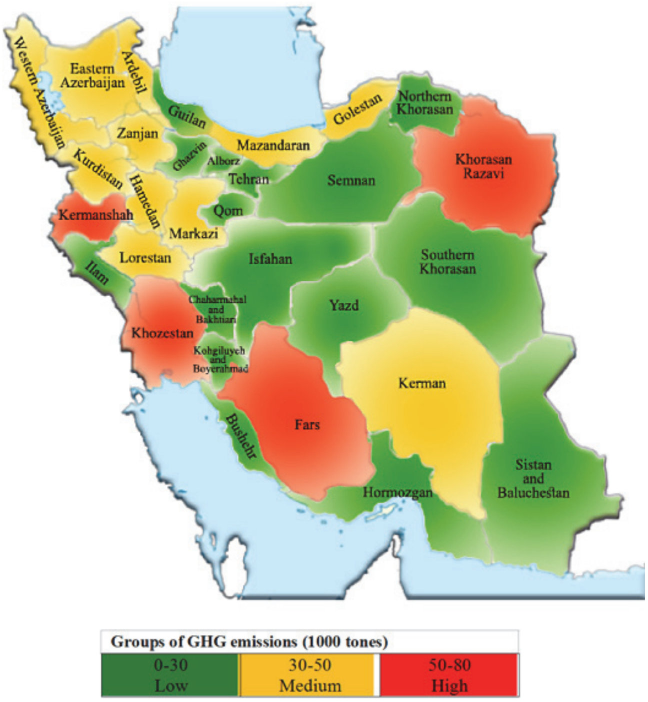

Fig. 3. Map of Iran showing GHG emissions by province

7.6-fold of small scale groups. Large scale group's mean emissions of N_2O and CO_2 are about 1.9-fold of medium scale group. Mean-comparison test confirms the existence of significant difference of GHG emissions among the three groups. In other words, this test shows that there is significant difference among the three groups at 5 percent level of significance.

We also compared provinces based on amount of GHG emissions (Table 8). The corresponding three categories were: low (0-20,000 t), medium (20,000-50,000 t), and high (50,000-80,000 t). According to these results, approximately 19.7 percent of provinces belong to the low emissions category with annually mean about 9888 t. Similarly, 49.8 and 30.5 percent of provinces belonged to the medium and large level of emissions, with average emissions of 36338 and 61317 t, respectively.

A map of various provinces and their position in three groups shows the location of these three categories of provinces (Fig. 3).

We used the Tukey Test for determining the existence (or nonexistence) of significant difference among different classified categories. These results showed that there is a significant difference among the classified groups' means at 5 percent level of significance. Also, the accuracy of classified emissions categories based on low, medium, and high emissions scenarios and the scenarios of small, medium, and large scale of productions have been validated.

Research findings also illustrate the provinces with large scale production of crops also have a larger amount of emissions relative to others. Nearly half provinces of country have medium emissions as medium as scale. It means that amount of GHG emissions have a close relation with size of area under cultivation.

Conclusion

Human society's life depends on maintaining the temperature range and removing the effect of greenhouse gas emissions (Signor and Cerri, 2013). Over the past years, some governments have considered action to cut back on GHG emissions. In order to take any action on this issue, knowledge of GHG emissions is needed. This study was taken with this view in mind but only included crop production in various provinces in Iran. A CPM was developed using IPCC emission coefficients crop year 2011/12 data obtained from the Ministry of Jihad Agriculture.

In addition, we divided the provinces into different classes based on the scale of production and emissions and evaluated their condition through Mean Comparison Test. Furthermore, we conducted the comparison of GHG emissions in per unit area, investigated marginal effect based on a change of one ha in crop area, and computed environmental costs of GHG emissions eventually.

According to the results, Khuzestan province is the largest producer of N_2O and CO_2 gases. Moreover, we estimated that for Iran as a whole, total N_2O and CO_2 emissions were nearly 25.471 and 777.715 t, respectively. Results show that among all provinces, Alborz and Zanjan provinces with 5.21 and 0.96 t, have the highest and lowest N_2O releases per ha. In contrast, we found that Guilan and Ardebil provinces with 62.28 and 58.54 t, are the highest and lowest producers of CO_2 in per ha, respectively. As a policy of increase in scale of cultivation, both of Alborz and Guilan provinces has the highest marginal effects of N_2O and CO_2 emissions. Eventually, Khuzestan province which is the largest producer of agronomy crops, has the highest environmental costs of GHG emissions among the other provinces. The total environmental costs of GHG emissions have estimated about $9.413 million.

Reduction of these emissions would require some action taken by governments and private bodies (mainly famers). The following measures are suggested to control or reduce the environmental pollution created by greenhouse gases:

- Developing the emissions reduction policies like carbon sequestration and applying the ways of absorbing carbon such as tree plantings around the farmland;
- Reforming the ways of agricultural inputs management, like managing the used N-fertilizers through recommended dosage to farmers;
- Imposing environmental tax (like Green Tax) on various levels of production and cultivation in order to compensate for the environmental costs; and
- Continuously applying the designed patterns to calculate the GHG emissions from crop production sub-sector of Iran.

References

Daftarian, M. (2009). Location and pattern use of clean energy for all life on earth by continuing to use coal gas. *New Energy Journal*, 2, 56-57.

Desjardins, R.L., Worth, D.E., Vergé, X.P.C., McConkey, B.G., Dyer, J.A., & Cerkowniak, D. (2010). Agricultural greenhouse gases. In: (Eilers, W., MacKay, R., Graham, L., and Lefebvre, A., editors), *Environmental sustainability of Canadian agriculture: Agri-environmental indicator report series – report #3. Agriculture and agri-food*, Canada, Ottawa, Ontario, pp. 110-117.

European Parliament's Committee (2016). Implementing the Paris Agreement – issues at stake in view of the COP 22 Climate Change Conference in Marrakesh. Policy Department A: Economic and Scientific Policy. http://www.europarl.europa.eu/supporting-analyses

Garrod, G., & Willis, K. G. (1999). *Economic valuation of the environment*. Cheltenham: Edward Elgar Publishing.

Ghorbani, M., Darijani, A., Kouchaki, A. R., & Motallebi, M. (2009). Estimation of environmental costs of greenhouse gases emission in Mashhad dairy farms. *Agricultural Economics and Development*, 17(66), 43-63.

Ghorbani, M., & Motallebi, M. (2009). The study on shadow price of greenhouse gases emission in Iran: case of dairy farms. *Research Journal of Environmental Sciences*, *3*(4), 466-475.

Gregorich, E. G., Rochette, P., VandenBygaart, A. J., & Angers, D. A. (2005). Greenhouse gas contributions of agricultural soils and potential mitigation practices in Eastern Canada. *Soil and Tillage Research*, *83*(1), 53-72.

Houghton, J. T., Meira Filho, L. G., Lim, B., Treanton, K., & Mamaty, I. (eds), (1997). Revised 1996 IPCC guidelines for national greenhouse gas inventories. Vols. 1–3. Hadley Centre Meteorological Office. United Kingdom**.**

IPCC (1996). Intergovernmental Panel on Climate Change. Revised IPCC Guidelines for National Greenhouse Gas Inventories: Workbook. http://www.ipcc-nggip.iges.or.jp/public/gl/invs5c.htm.

Jamalipour, M., Ghorbani, M., & Koocheki, A. R. (2015). Estimating the economic value of greenhouse gases emissions of oilseeds in Iran. *Journal of Agricultural Economics and Development*, *29*(3), 224-241.

Jianping, G., & Chaodong, Z. (2007). Greenhouse gas emissions and mitigation measures in Chinese agroecosystems. *Agricultural and Forest Meteorology*, *142*(2-4), 270–277.

Klemmer, C. (2010). Environmental and Economic Evaluation of Conventional and Organic Production Systems in the Canadian Prairie Provinces. Master of science's Thesis. University of Saskatchewan.

Kulshreshtha, S., & Klemmer, C. (2011). Environmental and economic evaluation of conventional and organic production systems in the Canadian Prairie provinces. *Transactions on Ecology and the Environment*, *152*, 55-66.

Motallebi, M., Ghorbani, M., Danesh, Sh., Darijani, A., Koocheki, A. R., Danesh Mesgaran, M. (2007). Estimation and valuation of greenhouse gases in Khorasan razavi dairy farms and recognition of its influencing factors (case study Mashhad), Ms Thesis, University of Mashhad.

Office of Statistics of the Ministry of Agricultural Jihad (2014).

Saleh, A., Zohreh Shabani, Z., Sadat Barikani, H., & Yazdani, S. (2009). Assessment of causality between GDP and volume of greenhouse gases in Iran: carbon dioxide Murray's study. *Agricultural and Development Economics*, *7*(66), 19-41.

Signor, D., & Cerri, C. E. P. (2013). Nitrous oxide emissions in agricultural soils: a review. *Pesquisa Agropecuária Tropical*, *43*(3), 322-338.

Sobool, D., & Kulshreshtha, S. N. (2005). *Greenhouse Gas Emissions from Canadian Agriculture Model (2000): Technical Documentation*. Department of Agricultural Economics, University of Saskatchewan.

Taqdisiyan, H. & Minapour, S. (2003). Climate change, what we need to know. Office of the National Action Plan on Climate Change. Department of the Environment.

Tijani, A., & Hamadi, F. (2013). Quantifying and accounting for environmental costs by the avoidance cost's method: the case of a Tunisian firm. *Journal of Accounting and Auditing*, 1, 144-157.

Trumper, K., Berzky, M., Dickson, B., van der Heijden, G., Jenkins, M., & Manning, P. (2009). The natural fix? The role of ecosystems in climate mitigation. UNEP rapid response assessment. United Nations Environment Programme, Cambridge, UK.

Turner, A., Pierce, D., & Butman, A. (1995). *Environmental Economics*. University Press of Mashhad.

Zolghi, R., Landi, A., & Ameri Khah, H. (2009). Evaluation of the emission of greenhouse gases CO_2 and CH_4 from rice and wheat cultivated soils in Abteymor Area. *Journal of Environmental Studies*, *35*(49), 9-16.

Appendix:

Table A.1.

N_2O emission from crop residues, nitrogen fertilizer application, area under fallow and CO_2 releases from soil in Iran's pulses farms

Provinces	Area (1000 ha)	Residues (t/ha)	N_2O emissions from residues (t)	N-fertilizer (kg/ha)	N_2O emissions from N-fertilizer (t)	N_2O emissions from fallow (t)	Total N_2O emissions (t)	CO_2 emissions (t)
Eastern Azerbaijan	76.96	0.022	7.828	203.53	21.81	1.07	30.70	4635.49
Western Azerbaijan	82.44	0.023	6.202	227.54	20.52	1.14	27.87	4965.33
Ardebil	43.94	0.021	4.649	-	0.00	0.61	5.26	2646.35
Isfahan	6.22	0.048	1.736	396.26	8.26	0.09	10.09	374.65
Alborz	0.25	0.035	0.070	-	0.00	0.004	0.07	15.30
Ilam	8.27	0.062	1.309	19.90	0.71	0.11	2.14	497.89
Bushehr	0.02	0.009	0.004	-	0.00	0.0003	0.004	1.33
Tehran	0.43	0.022	0.039	-	0.00	0.01	0.05	26.14
Chaharmahal and Bakhtiari	5.38	0.031	1.328	329.87	5.65	0.07	7.05	323.87
Southern Khorasan	0.83	0.030	0.066	-	0.00	0.01	0.08	49.69
Khorasan Razavi	15.56	0.035	1.138	274.22	3.47	0.22	4.83	936.99
Northern Khorasan	20.42	0.018	2.393	22.43	1.41	0.28	4.08	1229.84
Khozestan	45.32	0.034	12.351	149.60	11.00	0.63	23.98	2729.83
Zanjan	35.94	0.064	3.776	173.93	12.50	0.50	16.77	2164.90
Semnan	5.29	0.017	0.600	242.40	4.74	0.07	5.42	318.75
Sistan and Baluchestan	2.62	0.048	0.580	25.00	0.06	0.04	0.68	157.99
Fars	57.38	0.046	16.578	301.90	62.18	0.80	79.56	3456.18
Qazvin	10.06	0.021	1.227	9.25	0.47	0.14	1.84	606.13
Qom	0.05	0.014	0.015	-	0.00	0.001	0.02	3.25
Kurdistan	76.37	0.022	4.596	35.79	1.82	1.06	7.48	4599.77
Kerman	3.13	0.032	0.473	179.86	0.87	0.04	1.39	188.47
Kermanshah	166.97	0.045	17.594	216.07	13.04	2.32	32.95	10057.08
Kohgiluyeh and Boyerahmad	6.35	0.038	1.097	249.80	3.84	0.09	5.02	382.18
Golestan	2.48	0.006	0.28	-	0.0	0.034	0.314	149.38
Guilan	4.12	0.042	0.951	256.90	3.55	0.06	4.56	248.10
Lorestan	172.12	0.041	22.533	251.85	53.17	2.39	78.09	10367.11
Mazandaran	2.09	0.056	0.838	146.47	0.48	0.03	1.34	126.13
Markazi	9.61	0.024	2.495	255.12	5.11	0.13	7.74	578.60
Hormozgan	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Hamedan	25.09	0.025	2.013	256.87	10.40	0.35	12.76	1511.43
Yazd	0.23	0.054	0.055	-	0.00	0.003	0.06	13.55
Total	885.94	31.12*	114.814	169.91**	245.06	12.302	372.198	53361.7

Source: Research findings   *Total generated residues in all cultivated area (tonnes)   **Aggregate of used fertilizer in all cultivated area (tonnes)

Table A.2.
N_2O emission from crop residues, nitrogen fertilizer application, area under fallow and CO_2 releases from soil in Iran's industrial crops farms

Provines	Area (1000 ha)	Residues (t/ha)	N_2O emissions from residues (t)	N-fertilizer (kg/ha)	N_2O emissions from N-fertilizer (t)	N_2O emissions from fallow (t)	Total N_2O emissions (t)	CO_2 emissions (t)
Eastern Azerbaijan	8.492	0.123	1.432	949.908	14.486	0.118	16.035	511.501
Western Azerbaijan	32.035	0.405	245.773	328.255	80.231	0.444	326.449	1929.572
Ardebil	24.487	0.064	10.101	172.380	11.214	0.340	21.654	1474.931
Isfahan	7.666	0.360	13.218	1133.86	22.490	0.106	35.814	461.748
Alborz	0.862	0.046	0.382	167.08	1.021	0.012	1.415	51.921
Ilam	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Bushehr	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Tehran	3.048	0.018	1.077	179.48	4.18	0.04	5.298	183.591
Chaharmahal and Bakhtiari	0.825	0.25	3.14	325.83	1.67	0.01	4.822	49.692
Southern Khorasan	13.158	0.202	10.506	605.78	23.149	0.182	33.837	792.549
Khorasan Razavi	70.217	0.319	130.674	527.5	117.252	0.974	248.899	4229.398
Northern Khorasan	25.894	0.279	15.479	771.09	38.393	0.359	54.231	1559.68
Khozestan	112.664	0.50	796.14	197.21	9.45	1.56	807.154	6786.118
Zanjan	0.004	0.015	0.001	78.25	0.002	0.0001	0.004	0.241
Semnan	13.084	0.389	20.304	318.675	18.015	0.181	38.501	788.092
Sistan and Baluchestan	2.57	0.028	0.497	207.7	1.380	0.036	1.913	154.799
Fars	41.662	0.352	78.332	909.405	71.15	0.578	150.059	2509.437
Qazvin	4.286	0.406	13.814	609.06	9.095	0.059	22.968	258.16
Qom	3.033	0.026	0.924	827.67	7.996	0.042	8.962	182.687
Kurdistan	3.407	0.473	5.555	196.87	0.462	0.047	6.064	205.215
Kerman	8.294	0.040	1.345	920.07	17.555	0.115	19.015	499.575
Kermanshah	17.412	0.698	125.170	788.695	37.471	0.241	162.882	1048.781
Kohgiluyeh and Boyerahmad	2.09	0.32	1.15	0.00	0.00	0.03	1.182	125.887
Golestan	115.443	0.069	37.546	400.408	172.973	1.601	212.120	6953.507
Guilan	1.099	0.019	0.42	198.78	1.67	0.02	2.101	66.2
Lorestan	6.545	0.33	31.51	547.67	12.82	0.09	44.428	394.226
Mazandaran	25.484	0.060	7.401	753.533	67.254	0.353	75.008	1534.984
Markazi	1.022	0.236	3.529	1099.826	2.555	0.014	6.098	61.55838
Hormozgan	4.8	0.064	1.776	136.66	0.68	0.067	2.521	289.12
Hamedan	5.756	0.51	34.77	713.86	12.25	0.08	47.104	346.703
Yazd	1.343	0.064	0.263	610.81	2.667	0.019	2.949	80.893
Total	556.68	158.92*	1592.23	265.34**	759.53	7.718	2359.478	33530.77

Source: Research findings *Total generated residues in all cultivated area (tonnes) **Aggregate of used fertilizer in all cultivated area (tonnes)

Table A.3.
N_2O emission from crop residues, nitrogen fertilizer application, area under fallow and CO_2 releases from soil in Iran's vegetables farms

Provinces	Area (1000 ha)	Residues (t/ha)	N_2O emissions from residues (t)	N-fertilizer (kg/ha)	N_2O emissions from N-fertilizer (t)	N_2O emissions from fallow (t)	Total N_2O emissions (t)	CO_2 emissions (t)
Eastern Azerbaijan	25.533	0.295	29.2	745.35	39.880	0.354	69.4	1537.94
Western Azerbaijan	11.073	1.062	59.0	757.458	16.583	0.154	75.7	666.96
Ardebil	26.894	0.493	143.7	421.04	41.552	0.373	1619.913	26.894
Isfahan	26.1845	1.268	107.8	1650.66	102.401	0.363	210.6	1577.18
Alborz	10.919	1.458	114.8	413.83	3.398	0.151	118.3	657.69
Ilam	0.954	0.609	2.6	183.33	0.244	0.013	2.8	57.46
Bushehr	19.1348	2.340	126.2	519.04	43.533	0.265	170.0	1152.55
Tehran	17.734	0.815	117.7	483.34	8.396	0.246	126.3	1068.18
Chaharmahal and Bakhtiari	5.3	0.701	26.6	783.84	31.451	0.073	58.1	319.24
Southern Khorasan	1.01662	1.082	1.3	-	0.000	0.014	1.3	61.23
Khorasan Razavi	27.145	0.931	130.8	709.02	44.958	0.376	176.2	1635.03
Northern Khorasan	6.71029	3.099	33.8	370.95	6.347	0.093	40.3	404.18
Khozestan	74.533	0.935	335.0	778.883	41.976	1.033	378.0	4489.36
Zanjan	23.222	0.523	65.8	425.48	22.170	0.322	88.3	1398.74
Semnan	6.782	1.926	21.0	-	0.000	0.094	21.1	408.50
Sistan and Baluchestan	13.318	0.632	39.0	860.89	8.898	0.185	48.1	802.19
Fars	50.275	1.215	312.4	1011.795	103.392	0.697	416.5	3028.23
Qazvin	12.61253	2.037	64.9	398.66	33.752	0.175	98.8	759.69
Qom	1.425	0.575	8.2	-	0.000	0.020	8.3	85.83
Kurdistan	16.028	0.773	74.3	268.82	28.995	0.222	103.6	965.42
Kerman	41.828	0.158	26.3	915.338	88.016	0.580	114.9	2519.44
Kermanshah	8.838	2.346	68.9	804.34	20.677	0.123	89.7	532.34
Kohgiluyeh and Boyerahmad	0.775	0.743	2.0	409.09	0.859	0.011	2.8	46.68
Golestan	15.501	1.027	72.6	366.05	12.346	0.215	85.1	933.68
Guilan	2.885	0.257	3.3	1007.828	1.618	0.040	4.9	173.77
Lorestan	21.344	1.085	91.6	798.02	20.745	0.296	112.6	1285.62
Mazandaran	30.897	0.521	90.9	705.64	12.212	0.428	103.5	1861.03
Markazi	0.524	0.905	2.1	1219.6	1.433	0.007	3.6	31.56
Hormozgan	41.68	0.726	145.3	345.73	32.547	0.578	178.5	2510.52
Hamedan	35.115	0.792	195.1	643.29	65.708	0.487	261.3	2115.09
Yazd	3.184	3.743	16.1	721.55	2.491	0.044	18.6	191.78
Total	579.3647	549.96*	2528.3	403.72**	836.5756	8.033	4807.113	33304.004

Source: Research findings   *Total generated residues in all cultivated area (tonnes)   **Aggregate of used fertilizer in all cultivated area (tonnes)

Table A.4.
N_2O emission from crop residues, nitrogen fertilizer application, area under fallow and CO_2 releases from soil in Iran's vine crops farms

Provinces	Area (1000 ha)	Residues (t/ha)	N_2O emissions from residues (t)	N-fertilizer (kg/ha)	N_2O emissions from N-fertilizer (t)	N_2O emissions from fallow (t)	Total N_2O emissions (t)	CO_2 emissions (t)
Eastern Azerbaijan	5.228	0.227	3.8	453.745	6.294	0.072	10.2	314.90
Western Azerbaijan	6.1928	1.834	21.5	362.703	4.215	0.086	25.8	373.01
Ardebil	0.005	0.119	0.0	-	0.000	0.00	0.0	0.30
Isfahan	4.8058	1.981	19.8	838.56	6.840	0.067	26.7	289.47
Alborz	1.235	0.855	6.1	360.00	1.980	0.017	8.1	74.39
Ilam	9.018	0.716	32.2	365.89	11.642	0.125	44.0	543.18
Bushehr	5.176	1.468	23.4	321.2	3.982	0.072	27.4	311.77
Tehran	2.299	0.660	9.5	176.75	2.514	0.032	12.0	138.48
Chaharmahal and Bakhtiari	0.089	0.637	0.3	428.56	0.288	0.001	0.6	5.36
Southern Khorasan	4.86514	1.079	7.0	167.27	3.364	0.067	10.4	293.04
Khorasan Razavi	61.541	0.523	150.6	651.97	45.973	0.853	197.4	3706.81
Northern Khorasan	3.86461	1.75	4.6	22.44	0.243	0.054	4.9	232.78
Khozestan	35.193	0.758	140.8	469.503	42.955	0.488	184.2	2119.79
Zanjan	0.333	0.551	0.8	-	0.000	0.005	0.8	20.06
Semnan	6.572	0.468	21.4	-	0.000	0.091	21.5	395.85
Sistan and Baluchestan	26.322	0.576	95.4	130.89	19.275	0.365	115	1585.46
Fars	38.242	0.945	195.1	755.04	68.533	0.53	264.2	2303.44
Qazvin	7.87502	2.197	38.6	530.00	6.206	0.109	44.9	474.34
Qom	2.113	0.517	5.8	-	0.0	0.03	5.8	127.27
Kurdistan	4.518	0.383	10.7	-	0.0	0.063	10.8	272.13
Kerman	51.05	0.514	70.0	532.913	98.208	0.708	168.9	3074.91
Kermanshah	9.682	3.054	20.0	544.345	10.163	0.134	30.3	583.18
Kohgiluyeh and Boyerahmad	4.09	0.786	17.6	813.77	8.584	0.057	26.2	246.35
Golestan	19.818	0.481	21.9	212.03	10.807	0.275	33	1193.7
Guilan	3.883	0.713	15.5	636.419	5.061	0.054	20.6	233.89
Lorestan	13.17	0.558	50.7	358.69	33.351	0.183	84.3	793.27
Mazandaran	1.725	0.465	7.8	423.189	2.276	0.024	10.1	103.9
Markazi	2.547	0.593	5.1	745.265	2.570	0.035	7.7	153.41
Hormozgan	13.394	0.745	52.2	335.53	13.594	0.186	66	806.76
Hamedan	3.972	0.408	15.9	686.43	10.556	0.055	26.5	239.25
Yazd	4.34396	3.102	62.9	488.84	2.256	0.06	65.2	261.65
Total	353.1623	290.37*	1127.00	167.71**	421.7296	4.896	1553.5	21272.1

Source: Research findings *Total generated residues in all cultivated area (tonnes) **Aggregate of used fertilizer in all cultivated area (tonnes)

Table A.5.
N_2O emission from crop residues, nitrogen fertilizer application, area under fallow and CO_2 releases from soil in Iran's forage farms

Provinces	Area (1000 ha)	Residues (t/ha)	N_2O emissions from residues (t)	N-fertilizer (kg/ha)	N_2O emissions from N-fertilizer (t)	N_2O emissions from fallow (t)	Total N_2O emissions (t)	CO_2 emissions (Tt
Eastern Azerbaijan	115.726	0.377	122.6	112.414	84.239	1.605	208.4	6970.55
Western Azerbaijan	96.59	0.503	141.2	76.985	50.608	1.34	193.2	5817.93
Ardebil	62.664	0.538	100.8	1.45	0.458	0.87	102.1	3774.46
Isfahan	61.881	0.785	202.3	145.43	35.568	0.86	238.7	3727.29
Alborz	16.026	0.554	99.9	20.72	0.488	0.22	100.6	965.3
Ilam	1.974	0.347	4.3	-	0	0.027	4.4	118.9
Bushehr	0.402	0.548	0.7	-	0	0.006	0.7	24.21
Tehran	31.95	0.526	208.4	119.85	8.022	0.443	216.8	1924.45
Chaharmahal and Bakhtiari	25.997	0.655	55.8	207.37	26.069	0.36	82.2	1565.88
Southern Khorasan	16.132	0.485	44.3	51.59	1.715	0.224	46.2	971.68
Khorasan Razavi	72.265	0.602	241	226.22	60.436	1.002	302.5	4352.76
Northern Khorasan	25.92	0.339	21.9	29.16	5.316	0.36	27.6	1561.25
Khozestan	30.007	0.94	179.4	101.03	3.616	0.416	183.4	1807.42
Zanjan	44.653	0.385	29.7	69.22	23.549	0.62	53.9	2689.6
Semnan	11.801	0.562	31.8	284.02	16.83	0.164	48.8	710.81
Sistan and Baluchestan	27.748	1.211	138.7	23.35	2.275	0.385	141.4	1671.35
Fars	92.817	0.572	360.9	65.393	22.573	1.287	384.7	5590.67
Qazvin	55.393	0.757	249.6	479.365	104.169	0.77	354.6	3336.5
Qom	13.337	0.696	28.7	-	0	0.185	28.9	803.33
Kurdistan	41.677	0.136	49	72.19	16.404	0.58	66	2510.34
Kerman	57.176	0.499	106.8	117.215	40.119	0.793	147.7	3443.9
Kermanshah	23.686	0.171	25.2	572.795	8.936	0.33	34.4	1426.68
Kohgiluyeh and Boyerahmad	6.148	0.472	8.7	141.93	3.665	0.085	12.4	370.31
Golestan	17.464	0.328	62.1	-	0	0.242	62.3	1051.91
Guilan	0.063	0.251	0.1	120.779	0.005	0.001	0.1	3.79
Lorestan	17.22	0.544	40.8	204.54	14.822	0.24	55.8	1037.22
Mazandaran	53.294	0.836	234.5	509.462	8.034	0.74	243.2	3210.07
Markazi	44.286	0.527	87.3	194.323	56.597	0.614	144.5	2667.49
Hormozgan	1.02	0.533	2.6	75.85	0.487	0.014	3.1	61.44
Hamedan	60.909	0.529	93.9	304.7	106.454	0.845	201.2	3668.75
Yazd	12.912	0.924	61.5	-	0	0.18	61.7	777.73
Total	1139.138	637.02*	3034.5	181.84**	701.454	15.795	3751.5	68613.97

Source: Research findings *Total generated residues in all cultivated area (tonnes) **Aggregate of used fertilizer in all cultivated area (tonnes)

Table A.6.
N_2O emission from crop residues, nitrogen fertilizer application, area under fallow and CO_2 releases from soil in Iran's other crops farms

Provinces	Area (1000 ha)	Residues (t/ha)	N_2O emissions from residues (t)	N-fertilizer (kg/ha)	N_2O emissions from N-fertilizer (t)	N_2O emissions from fallow (t)	Total N_2O emissions (t)	CO_2 emissions (t)
Eastern Azerbaijan	4.726	0.008	0.8	-	0	0.065	0.880	284.66
Western Azerbaijan	40.85	0.009	7.2	193.173	60.27	0.56	68.0	2460.58
Ardebil	4.59	0.02	1.7	-	0	0.06	1.7	276.47
Isfahan	2.328	0.08	3.9	-	0	0.03	3.9	140.22
Alborz	0	0	0	-	0	0.00	0	0
Ilam	0.011	0.3	0.1	-	0	0.0002	0.1	0.66
Bushehr	0	0	0	-	0	0.00	0	0
Tehran	0	0	0	-	0	0.00	0	0
Chaharmahal and Bakhtiari	0.22	0.45	2.0	-	0	0.003	2.0	13.25
Southern Khorasan	3.93	0.004	0.3	-	0	0.05	0.4	236.71
Khorasan Razavi	25.243	0.002	1.3	-	0	0.35	1.6	1520.46
Northern Khorasan	3.121	0.026	1.6	-	0	0.04	3.3	187.98
Khozestan	0	0	0	-	0	0.00	0	0
Zanjan	0.041	0.08	0.1	-	0	0.0006	0.1	2.47
Semnan	1.19	0.006	0.1	-	0	0.016	0.2	71.67
Sistan and Baluchestan	9.485	0.14	26.2	-	0	0.13	26.4	571.31
Fars	2.208	0.06	2.6	324.25	5.47	0.03	8.1	132.99
Qazvin	6.285	0.01	1.9	223.08	10.7	0.087	12.7	378.56
Qom	0.065	0.45	0.6	-	0	0.0009	0.6	3.91
Kurdistan	2.198	0.0075	0.3	-	0	0.03	0.4	132.4
Kerman	7.18	0.009	1.3	-	0	0.099	1.4	432.47
Kermanshah	3.906	0.035	2.7	223.08	6.65	0.054	9.5	235.27
Kohgiluyeh and Boyerahmad	0.068	0.06	0.1	-	0	0.0009	0.2	4.09
Golestan	20.842	0.004	1.6	193.173	30.75	0.23	32.7	1255.9
Guilan	0	0	0	-	0	0.00	0	0
Lorestan	0	0	0	-	0	0.00	0	0
Mazandaran	0.722	0.12	1.7	182.47	1.006	0.01	2.7	43.48
Markazi	0.05	0.013	0.0	-	0	0.0007	0.014	3.01
Hormozgan	0.55	0.48	5.3	-	0	0.0076	5.3	33.13
Hamedan	2.299	0.019	0.9	-	0	0.032	0.9	138.47
Yazd	1.265	0.022	0.5	-	0	0.017	0.6	76.19
Total	143.373	3.3*	64.8	15.04**	114.87	1.988	183.69	8635.82

Source: Research findings   *Total generated residues in all cultivated area (tonnes)   **Aggregate of used fertilizer in all cultivated area (tonnes)