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Investigation of Energy Consumption in Agriculture Sector of Iran and their Effect on Air Pollution and Social Cost

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Abstract: The aims of this study are investigation of consumption, intensity and efficiency of fossil fuels and electricity energy in Iran's agriculture sector and emission of GHG and air pollutants and their social (damage) costs. Data used in this study were obtained from ministry of energy and central bank of Iron in 1997- 2007. Input energy of fossil fuel and electricity in agriculture increased from 265.1 to 411.2 PJ in this period. Results show that the efficiency of using of fuels and electricity has not increased and increasing of social costs of GHG and air pollutants emission has been more than added value of agriculture sector. So, it is necessary that by increasing of technology level and replacement of age-old and depreciated machineries and equipments, appropriate management and increasing efficiency of fuel and electricity energy in macro level will cause decreasing negative effects of energy consumption.

Key words: Electricity, fossil fuel, greenhouse gas

INTRODUCTION

Energy plays a major role in providing vital services, which are necessary for human survival and growth of civilization. It has a significant role in national development process and supports all big and small activities. In fact, per capita energy consumption is an index of growth of any nation in all forms (Singh, 2002). Energy is a kind of strategic resource and an important substantial basis for economic increase and social development (Richardson, 2006; Shao and Chuc, 2008). The global economy has depended largely upon fossil energy such as coal, petroleum, and natural gas. These energy sources have been consumed throughout the world, seriously degrading the Earth's environment (Shao and Chuc, 2008; Dickmann, 2006). There are many immediate adverse effects to the environment such as greenhouse gases and pollutants emissions from the burning of fossil fuels (Li *et al*., 2009). Environmental problems growing dramatically caused by significant increase of consumption of fossil fuel energy and greenhouse gas emissions. Fossil fuel burning causes a significant pollution of CO_2, SO_2, NO_x and other gases (Kalogirou, 2004). They have very bad influence on environment such as acid rain, air pollution, destruction of ozone layer and land and global earth warming (Haralambopulos and Spilanis, 1997). At current rates of emission, the accumulation of Greenhouse Gases (GHG) in the upper atmosphere is expected to elevate average global surface temperature by approximately 0.3-2.5 in the next 50 years and 1.4-5.8ºC in the next century (Zelek and Shively, 2003). It is now well understood that air pollution produces significant adverse health effects in the general public and over the past 60 years, there have been on-going efforts to reduce the emitted pollutants and their resulting health effects (Hopke, 2009). Because of political economy condition and environment crisis in Iran, in ranking Environment Sustainability Index (ESI), it is graded 132 among 146 country and from 100 score, scored 39.8 (Anonymous, 2005). In Iran, the cost of air pollution was 1.6% of GDP (1810 million US$) and cost of environmental degradation is about 8.8% (10000 million US$) of Iran's GDP (World Bonk, 2005) and estimated will receive to 10.9% GDP in 2019 (Shafie-Pour Motlagh *et al*., 2005). Also, cost of emission of CO_2 is 1.36% GDP of Iran (World Bank, 2005).

Agriculture is the most important sector to provide foodstuffs and similar other sector on the increase depended sources such electricity, fuel, natural gas and other sours (Karkacier *et al*., 2006) that causing environment damage (Demirbas, 2003). Fast worldwide population growth leads to a quickly increasing energy demand. To maintain the standard of living in industrialized countries and to improve the situation in developing countries, energy consumption cannot be avoided and energy can be used much more efficiently (Bolatturk, 2008; Ucar and Balo, 2009). Also, environment problems and air pollution are global issue. Therefore studying the negative impacts of GHG and air pollution emission from agriculture sector is essential. The aims of this study are investigation of intensity and efficiency of energy sources in Iran's agriculture sector and its effects on air pollution and social cost (damage cost).

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MATERIALS AND METHODS

In this study, consumption of petrol, kerosene, gasoil (fossil fuels) and electricity in agriculture sector of Iran and economic damages of GHG and air pollutants include CH, CO, SO_3, CO_2, NO_x, SO_2, and SPM resulting of their consuming from 1997 up to 2007 was investigated. Data used in this study were collected from the ministry of energy (Anonymous, 2008b) and central bank of Iran (Anonymous, 2008a, 2009) in 2008-2009.

Geometric mean of consumption growth rate has used for evaluating and predicting of consumption of fossil fuels (Zar, 1984).

$$\overline{M} = \sqrt[i]{d_1 * d_2 * d_3 * \ldots * d_i} \quad (1)$$

$$d_i = \frac{q_i}{q_{i-1}} \quad (2)$$

$\overline{M}$ is geometric mean of consumption growth rate and d is growth's rate of fuel consumption in different years (Eq. 2) and q_i is fuel consumption in year of i.

Electricity consumption in agriculture sector has increased heavily and it has been about 3 times during 10 years. This increase is mainly resulting of electricity consumption for pumping water (Anonymous, 2008b). For considering of consumption tendency of fossil fuels and electricity in agriculture, their equivalent energy was used (Table 1).

The total energy of fossil fuel and electricity consumption in agriculture sector was accounted by Eq. (3).

$$E = \frac{\sum_j k_j q_j + 1000 k_e e}{10^6} \quad (3)$$

E is equal to total consumption of fossil fuels and electricity energy in agriculture sector in quantity of PJ per year, k_j is energy equivalent of j fuel in quantity of MJ/L, q_j is amount of consumption of j fuel in quantity of 1000 liters, e is amount of consuming electricity in quantity of million kWh and k_e is equal to 12 MJ/kWh.

For accounting of GHG and air pollutants emission, emissions factore of GHG and air pollutants in lieu of each unit of fuels consumption in agriculture sector was accounted on the data of ministry of energy (Table 2). The quantity of gases and air pollutants to be emission of fossil fuels in agriculture sector was accounted by Eq. (4).

$$P_{iz} = \sum \frac{c_{zj} q_{ij}}{1000} \quad (4)$$

Table 1: Energy values for various energy sources

Energy source	Unit	Energy equivalent (MJ/unit)	Reference
Diesel fuel	Liter	47.8	(Kitani, 1999)
Petrol	Liter	46.3	(Kitani, 1999)
Kerosene	Liter	50.19	(Parikh and Syed, 1988)
Electricity	kWh	12	(Kitani, 1999)

P_{iz} is the emission's quantity of z gas or air pollutant in i year (ton), c_{jz} is the emission of f gas or air pollutant in lieu of each unit of j fuel (emission factor) (g/L), q_{ij} is consuming of j fuel in i year in quantity of 1000 liter.

There are so many losses in generation, transmission and distribution of electricity that must be considered. These losses include of internal consumption of power plants, transmission and distribution of electricity. Because data are in basis of consumption of electricity, changing coefficient of consumption electricity to its production equivalent was used in different years (Eq. 5).

$$b_i = 1 + \frac{L_i}{100} \quad (5)$$

b_i is changing coefficient of consuming electricity to its generation equivalent in i year and is the total percentage of losses.

Equation 6 was used for accounting of emission GHG and air pollutants from consumption of electricity in agriculture.

$$P_{iz} = \sum h_{iz} b_i e_i \quad (6)$$

h_{iz} is emission factor of GHG and air pollutants of z in lieu of each unit of electricity's generation (g/kWh) in i year, is the amount of electricity consumption in i year and as changing coefficient of electricity consumption to its generative equivalent in i year.

Destruction cost (social cost) is the cost that pollutant causes destruction of ecosystem, damage to structures and people's health. In other word, destruction cost is a cost that evaluates destructive effects of a pollutants or activity on farming crops, ecosystem, material and health of human being and most of time is a cost that isn't considered in finishing praise. There is need to quantitative effect of pollutants and activities in environment (humanity and natural) for accounting of destruction costs (Anonymous, 2007a). Social cost in Iran in compare with Europe is very much because of low rainfall and low average of wind (Shafie-Pour *et al.*, 2005) the social (destruction) cost of each ton emission of GHG and air pollutants was accounted on data of ministry of energy (Table 3).

Equation 7 was used for accounting of total social cost of GHG and air pollutants emission from agriculture sector.

Table 2: Emission factor in lieu of each unit of fuels (g/L)

fuels	NO_x	SO_2	CO_2	SO_3	CO	CH	SPM
Gasoil	16	16.4	2646.995	0.1	3.5	11	7
Kerosene	0.498	2.403	2415.614	nugatory	0.7676	nugatory	nugatory
Petrol	13.503	1.497	2320.917	nugatory	350.12	62.94	1.28

Table 3: Social cost of GHG and air pollutants (k Rial[1] per ton)

NO_x	SO_2	CO_2	SO_3	CO	CH	SPM
5580.1	16972.5	27.8996	-	1748.4	1748.946	39989.6

[1]: 9942 IRR = 1 American Dollars (Anonymous, 2009)

$$C = \frac{\sum m_z g_z}{10^6} \qquad (7)$$

C is social cost, m_z is social cost of each ton emission of z GHG or air pollutant and p_z is quantity of z air pollutant emission.

Added value of agriculture sector has growing procedure in this period but it is not show that this increase has been accompanied with increase of efficiency of energy consumption. So, $R_{A/E}$, $R_{A/C}$ and $R_{C/E}$ indicators was determined for accurate evaluation of energy consumption of fossil fuels and electricity and GHG and air pollutant emission of them.

$$R_{A/E} = \frac{r_{AV}}{r_E} \qquad (8)$$

$$R_{A/C} = \frac{r_{AV}}{r_{CS}} \qquad (9)$$

$$R_{C/E} = \frac{r_{CS}}{r_E} \qquad (10)$$

r_{AV} is annual growing rate of added value of agriculture sector, r_E is annual growing rate of fossil fuels and electricity energy consumption in agriculture sector and r_{CS} is annul growing rate of social costs of GHG and air pollutants emission from fossil fuels and electricity from agriculture.

RESULTS AND DISCUSSION

Average of growth rate of gasoil consumption calculated 1.02615 that it will expected gasoil consumption in agriculture will reach more than 5×10^9 l up to 2012 with this grow rate. Petrol consumption almost had decreeing trend that average of growth rate of it was accounted 0.95284. Consumption of petrol is predicted by this rate about 9140×10^3 l in 2012. The average of consuming growth rate of kerosene obtained 0.8564984 and it will expected that with this rate, the consumption of kerosene will decrease to 1773×10^3 l up to 2012.

In studying period mathematic model of electricity consumption in agriculture sector is according to Eq. (3).

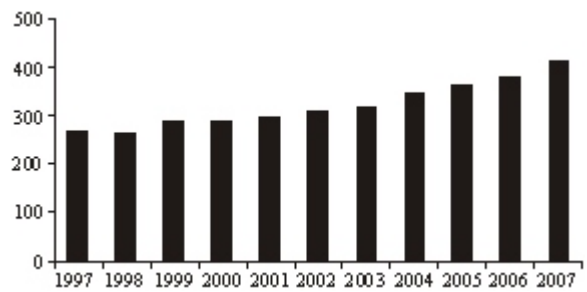

Fig. 1: Consumption of fossil fuels and electricity energy in agriculture sector (PJ)

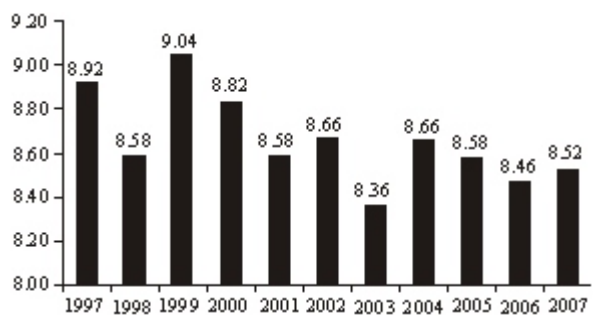

Fig. 2: Share of agriculture sector of total fossil fuels and electricity energy consumption in Iran (%)

$$Y = 129.6\ x + 3374 \qquad (12)$$

Y is the electricity consumption in quality of million kWh and x is year in base year of 1997. Correlation coefficient (R) is equal to 0.987 and is meaningful in level of 1%. According to this equation, it is predicted that electricity consumption in agriculture will reach to 22800 million kWh in 2012.

Energy equivalence of fossil fuels and electricity consumption in agriculture sector had growing trend in studying period and reached from 265.1 PJ in 1996 to 411.2 PJ in 2008 (Fig. 1) but share of fossil fuels and electricity energy consumption in agriculture to total energy consumption of it, in addition to oscillation was going to decrease (Fig. 2).

There is meaningless different in emission factor of pollutants and GHG in lieu of fuel consumption in different years in agriculture sector of Iran (Table 2) that

Table 4: GHG and air pollutants emission of fossil fuels consumption in agriculture (ton)

Year	NO_x	SO_2	CO_2	SO_3	CO	CH	SPM
1997	65206.13	67291.55	11570878.53	405.27	136652.9	45493.57	28387.47
1998	64034.71	65795.16	10959525.86	398.8	72600.54	44563.59	27929.96
1999	67457.99	69264.01	11569372.37	419.62	81904.25	47436.26	29395.57
2000	62519.41	64141.31	10685331.77	388.8	70938.18	4388.04	27238.86
2001	60678.02	62303.61	10462111.49	377.08	83186.64	42670.60	26419.58
2002	58651.84	60280.71	10120146.94	364.82	80129.49	41021.74	25555.86
2003	55262.71	56628.2	9362991.76	343.77	50433.59	38803.88	24084.29
2004	58959.59	60410.96	9942445.67	367.05	45895.78	41265.84	25711.94
2005	58959.59	59541.13	9801868.01	361.76	45668.75	40747.62	25342.50
2006	59898.24	61369.73	10083003.61	373.00	43660.36	41876.13	26127.17
2007	66601.21	68184.50	11109783.70	415.08	32515.42	46449.62	29071.42

Table 5: GHG and air pollutants emission of electricity consumption in agriculture (ton)

Year	NO_x	SO_2	CO_2	SO_3	CO	CH	SPM
1997	6378.37	18931.56	3797032	291.76	6.76	237.49	759.98
1998	6706.04	20406.56	4060582	317.28	7.21	245.17	793.19
1999	7737.92	22969.41	4582154	342.10	8.15	309.52	838.95
2000	8897.24	26885.14	5415518	425.52	9.67	375.82	1044.46
2001	10562.74	31177.82	6227032	477.10	11.10	421.62	1275.96
2002	13040.91	38638.41	7713097	577.92	13.76	509.12	1568.65
2003	14658.04	43057.99	8642405	558.99	15.53	512.41	1599.34
2004	15457.73	40158.95	9570379	450.06	17.31	484.68	1575.20
2005	16399.88	33655.74	11031300	194.54	19.45	583.63	1945.42
2006	18007.55	12779.94	11690281	250.39	20.87	646.85	2044.89
2007	19994.45	18317.06	12806355	335.48	22.37	738.05	2415.44

show that efficiency of fossil fuels consumption has not change by entrance of new machines and technologies (Anonymous, 2007b).

The GHG and air pollutants emission of fossil fuels and electricity has shown respectively in the Table 4 and 5. Decrease in emission of gases like SO_2 and SO_3 from electricity consumption from 2003 up to 2007 for intense decrease of emission factor of these gases is in lieu of each kWh of generative electricity of Iran. Changing of factor emission of GHG and air pollutants in lieu of each kWh production in different years causes irregular trend of other gases emission by existence of regular increasing of electricity consumption in agriculture sector. The total trend of emission indicator of SPM and NO_x gases is going to decrease. Emission of CO_2 was increased by existence of decrease in consuming of gasoil in 1998-2001 and decreasing trend of petrol and kerosene consumption because of too much increase of electricity consumption in agriculture to decrease of fossil fuels consumption. Decreasing of CO and CH emission was for reason of decreasing in petrol consumption and more emission factor of these gases in lieu of each consuming liter of petrol than gasoil and electricity. Decrease of SO_3 and SO_2 gases is for intense decrease of their emission factor of productive electricity in ending years of studying period. Decrease of NO_x gas emission was for decreasing of its emission factor of electricity and decreasing petrol and kerosene consumption. Because of decreasing trend of emission factor of SO_2, NO_x and SPM pollutant in lieu of productive electricity unit (especially 2005) and also their too much social cost, total social cost of gases emission from electricity consumption in agriculture have

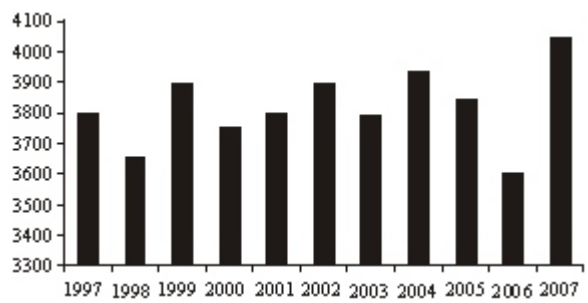

Fig. 3: Social cost of GHG and air pollutants emission of consuming fossil fuel and electricity in agriculture (milliard Iranian Rial, 1USD = 8910 IRR (Anonymous, 2009))

decreased (Fig. 3) whereas emission factor of gases and pollutants of productive electricity was fixed, social cost would increased considerably.

$R_{A/E}$ has almost fixed process in during of study period (Table 6). In this period, consumption of other input like breeder seed, fertilizers, modern machines and technology in farming, gardening, animal husbandry and fishing have increased (Anonymous, 2007b) which by considering of these inputs, it is predicted that agriculture productions and added value of agriculture sector increase in lieu of fossil fuels and electricity. This affair shows lack of efficiency and optimum using of fossil fuels and electricity in agriculture sector.

$R_{A/C}$ had fixed trend totally. For decreasing of gases emission factor and air pollutants in lieu of each unit of generative electricity and consequently decrease of total

Table 6: Indicator of efficiency

Year	$R_{A/E}$	$R_{A/C}$	$R_{C/E}$
1998	1,0135	1.0501	0.9582
1999	1.0292	1.0370	0.9925
2000	0.9271	0.9634	0.9623
2001	1.006	1.0203	0.9857
2002	0.9233	0.9531	0.9678
2003	1.0931	1.1449	0.9547
2004	0.9835	1.0319	0.9530
2005	0.9733	1.0453	0.9312
2006	1.0438	1.1670	0.8944
2007	0.9596	0.9323	1.0292

social cost in lieu of each unit of consuming energy in studying period, this indicator must have increased (increasing of agriculture value added must have been more than increasing cost of social cost of GHG and air pollutants emission of this sector). By considering fixed emission indicator of GHG and air pollutants emission from generative electricity, this indicator would have decreased that show increasing of social cost of GHG emission and air pollutants from agriculture sector is more than added value of this sector. Trend of $R_{C/E}$ was fixed statistically (there is no meaningful difference between its amount statistically). Because of decrease of emission factor of pollutants in studying period, this indicator shows that increase of social cost of pollutants emission is more than increase of energy consumption. In this case, energy doesn't use efficient and economic (indicator of $R_{A/E}$). Fossil fuels use more for generation of power in agriculture machinery in farms, gardens, animal husbandries, farming fixed equipment and fishing boats. Also, electricity and fossil fuels use for producing heat in animal husbandries (Anonymous, 2007a, b). So, increasing of efficiency of agricultural machinery and equipments and power generator engines and using of technology and proper method in macro levels are factors that decrease fuel consumption and emission indicators of GHG and air pollutants of their consumption which cause decrease of emission and social cost of GHG and air pollutants. Electricity consumption is used for pumping of irrigation water. Using of proper irrigation method, increasing of irrigation efficiency, suitable irrigation canals and pumping stations with high efficiency can decrease consumption of electricity energy.

CONCLUSION

In this study, intensity and exploitation of fossil fuels and electricity consumption in agriculture sector of Iran and GHG and air pollutants emission and environment destruction cost of their, evaluated. Data were collected of ministry of energy and central bank of Iran in 1997- 2007. In studying period, share of energy consumption of fossil fuels and electricity in agriculture sector to total consumption of their in Iran, decreased but for increasing of energy consumption in Iran, its energy increased from 265.1 in 1997 to 411.2 PJ in 2007. Growth rate of energy consumption and GHG and air pollutants emission of fossil fuels and electricity in agriculture sector was been more than added value of this sector and shows that energy of fossil fuels and electricity doesn't use effectively and efficiency of using energy has not increased by entrance of new technology. Also, if gases emission factor of generative electricity was fixed, pollutants emission and their social cost must have increased considerably. It is expected by existent trend, GHG and air pollutants emission will increase. So, increase of technology level and replacement of age-old and depreciated machineries and equipments, correct management and increasing efficiency of fuels and electricity energy in macro level can decrease negative effects of energy consumption such environment pollution, acid rain and social cost. In fact, efficiency use of fossil fuels and electricity energy will decrease GHG and air pollutants emission and their social costs.

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