Global Climate Change, Greenhouse Gases (GHGs) and Cultivated Plants

Küresel İklim Değişikliği, Sera Gazları ve Kültür Bitkileri

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Abstract: It was investigated the effect of global climate change and greenhouse gases on plants which were grouped as cultivated and related information was given. As known, agricultural sector is very sensitive to the global climate change, GHGs and their interactions. Especially, this formation is very effective on flora and fauna. On the other hand, agriculture is the second largest industrial contributor to the GHGs. It is likely to get affected positively and negatively by the climate change, but negative effects are feared to be than the positives. They contribute to unwanted effect(s) through the emission of Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_20), Chlorofluorocarbons (CFCs), etc. gases. Especially, from them CH_4 has the highest global warming potential that is about 300 times than the potential of CO_2, and about 20 times than that of the N_20. According to research findings, it is being informed that the average temperature of the Earth would be rise up to (1.4–5.8 ^{0}C) by 2100, and, various agricultural ecosystems (poly, mono and mixed) including agro-forestry, agro-silvo-pastoral systems, landscape, aquaculture, rangelands, wetlands and fallowlands, etc. many components will affect from this at various levels. Similarly, increases in concentration of CO_2 gase will increase plant growth and water use efficiency (WUE) or consumption, reduces grain filling and nutrient use-efficiency. The purpose of the paper is state of the relationships among global climate change, greenhouse gases (GHGs) and cultivated plants.

Key words: Global climate change, Glasshouse gases (GHGs), Cultivated plants.

Özet: Küresel iklim değişikliği ve sera gazlarının gruplandırılan kültür bitkilerine etkileri irdelenerek, bu konuda ilgili bilgiler verilmiştir. Bilindiği üzere, tarım sektörü, küresel iklim değişikliği ve sera gazları ile bunların etkileşimlerine karşı çok duyarlıdır ve özellikle bu oluşum flora ve fauna için çok etkilidir. Öte yandan, tarım, sera gazları (GHGs) açısından en büyük endüstriyel katılımcıdır ve bu oluşumun pozitif ya da negatif sonuçlarının olması olasıdır. Ancak, bu etkilerin pozitiflerinden çok negatiflerinden korkulmaktadır. Karbondioksit (CO_2), Metan (CH_4), Nitroz oksit (N_20), Kloroflorokarbonlar (CFCs) gibi gazların emisyonları, söz konusu oluşuma katkı vererek istenmeyen etkileri oluşturmaktadır. Özellikle bunlardan metan (CH_4) gazı, CO_2'den 300; H_20'dan da 20 kat daha yüksek küresel ısınma potansiyeline sahiptir. Araştırma bulgularına göre, 2100 yılına kadar (1.4-5.8 ^{o}C) yükseleceği tahmin edilen dünya ortalama sıcaklığından; aralarında (poli, mono ve karışık) olmak üzere ormancılık, agro-silvo-pastoral sistemler, peyzaj, su kültürleri (aquakültürler), çiftlikler, ıslak alanlar ve nadas alanları gibi pek çok tarımsal ekosistemin bundan değişik şekilde etkileneceği ifade edilmektedir. Benzer şekilde, CO_2 gazı derişimindeki artış bitki büyümesini ve su kullanma etkinliği ya da tüketimini artıracak tane dolumu ve besin maddesi etkinliğini azaltacaktır.

Anahtar Kelimeler: Küresel iklim değişikliği, Sera gazları (GHGs), Kültür bitkileri.

1.Introduction

During the last 8.000.000 years, the Earth's climate has generally been cooler than the present mean temperature by as much as 4 ^{o}C to 5^{o}C (Gates, 1990). "Climate" can affect agriculture in a variety of ways (with the some parameters such as temperature, radiation, rainfall, soil moisture and carbon dioxide concentration) are all important variables to determine agricultural productivity. "Global warming" refers to the increase of earth temperature due to the release of gases such as CO_2, CH_4, CFCs, N_2O, O_3, etc into the Earth's atmosphere (Singh et al. 1998; IPCC, 2007). These gases affect the interaction between the first and the second atmospheric layers (troposphere and stratosphere) by preventing the reflection of solar rays (Krupa, 1997). They cause a global climate climate forcing , i.e., an imposed perturbation of the Earth's energy balance with space (Hansen et al. 2000). There are lots of sign the global warming such melting glaciers and sea ice, sea-level rise, earlier flowering and ripening dates, longer growing seasons, coral reef(s) bleaching, migration of the plants and animals towards the poles, etc. is being estimated when the increase of air temperature between (2.0–6.3 °C) by 2100 in Europe (Fernandes et al., 2009) and in the world.

The climate change is attributed to the change in the composition of the global atmosphere that increases mean temperature that effects the ecology in the earth and ocean. Fuhrer (2003) reported

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that losses are predicted to be more intensive in some regions of the world, and that, if the earth's temperature increases by (1.4-5.8 °C) by 2100, as predicted, then yield loss will be greater. The temperature rise correlates with the increase in the content of greenhouse gases CO_2 and CH_4 (Zvarzin, 2001). Prior to the industrial revolution, the level of atmospheric CO_2 was 270 ppm. It has exceeded 355 ppm in modern times and it is expected to reach 600 ppm during the 21st century (Rogers et al.,1994) (Table 1 and Figure 1). In this paper, information of the effect of global climate change and greenhouse gases on cultivated plants was assessed.

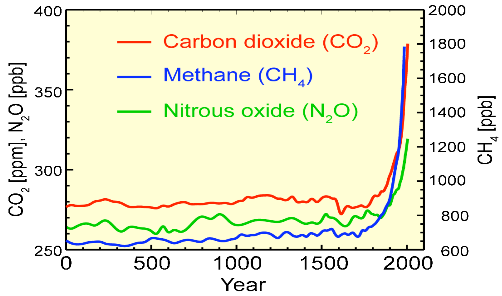

Figure 1. GHGs concentrations and global temperature changing within the last 2000 years (Di orcia, 2008).

The effects of CO_2 are most significant, since its overall contribution to global warming is 300 times bigger than other GHGs. The heat that stays trapped in the atmosphere causes the global temperature to increase. In addition to increases in CO_2, the annual percentage increase of CH_4 is 1%, the annual percentage increase of N_2O is 0.3% and tropospheric O_3 concentration also affects the situation (Krupa, 1997). Big masses of ice are melting in the poles, so biological diversity in the poles is being disappeared. Consequence of this unwanted developments, very large amounts of fresh water poured into the oceans and it sea level are being rised that this is predicted between (2.0-50.0 cm) (Olesen and Bindi, 2004). Agricultural GHGs emissions come from soil and manure management, enteric fermentation and fosil fuels consumption, and the main reasons for global warming are the automotive and petro-chemical industries, emissions from factories, planes and cars, iron and steel factories (Mei et al., 2007), refineries, rice paddies (Conrad, 2002) (Fig. 2).

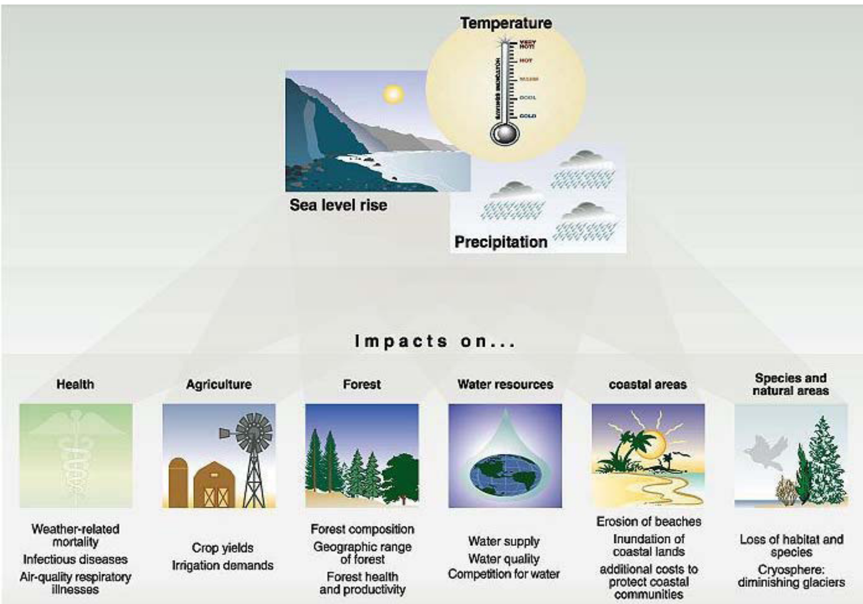

Figure 2. Illustration of potential global climate change impact (IPCC 2007).

2. Materials and Methods

Plants are grouped into three groups such as C_3, C_4 and CAM according to the stable carbon isotope which the first products acquired via photosynthesis are bound and the photosynthesis metabolism. The C_3 group includes trees, grain legumes, rice, small grain cereals, potato, vegetables; C_4 group includes coarse grain cereals, millet, sugar cane, and CAM (*Crassulacean Acid Metabolism*) plants (e.g. Pineapple) are not affected by temperature increases, as they are inherently high in water use efficiency, due to their ability to open their stomata at night to take in CO_2 (Ulukan, 2008). Increases in atmospheric CO_2 concentration can have a positive impact on plant yields by stimulating their photosynthetic activities and reducing the water amount loss via respiration. So, this carbon fertilization effect is strong for grain legumes, which have a lower rate of photosynthetic efficiency (Zhani and Zhuang, 2009) and their photosynthetic activity and net photosynthesis ratios increase; but, water use decreases when CO_2 concentration increases (Dhakhwa and Campbell, 1998) (Fig. 3).

C_3 and C_4 plants react differently to elevated CO_2 and other climatic factors. Recent research based on experiments with the free air concentration enrichment method suggests a much smaller CO_2 fertilization effect on yield for C_3 plants and little or no stimulation for C_4, in comparison with past estimates from studies conducted under enclosed test conditions (Zhai and Zhuang, 2009). In C_3 plants, which comprise the great majority of plant species, including important food crops such as wheat, rice, soybean and potatoes, CO_2 is exclusively assimilated through the abovementioned Calvin cycle. In contrast, C_4 plants, including the most productive crop species such as maize, sorghum and sugarcane, use a series of enzymes that initially combine CO_2 (HCO^-_3) with a three-carbon molecule (phosphoenolpyruvate, PEP), a four-carbon compound (DaMatta et al., 2009).

Despite there being a growing body of evidence suggesting that C_3 crops are likely to produce more harvestable products and that both C_3 and C_4 plants are likely to use less water with rising Atmospheric CO_2 in the absence of stressful conditions, large uncertainties remain about food production in a future scenario with global warming and altered regional patterns of precipitation. According to Fuhrer (2009), a more important effect of temperature operates via plant development with warming the start of active growth is advanced, plants develop faster, and the potential growing season is extended. Studies have indicated that global warming would have dramatic effects on the growth and development of field crops (Romanova, 2005); increasing CO_2 increases the water use activity with the growth, especially in grain legumes (Cutforth et al., 2007). C_3 plants have a lower water requirement compared with other crops such as maize or soybeans, as their growth period is short and occurs mainly during spring. Increased temperature during growing seasons can reduce yields, but effects at the leaf level (Fuhrer, 2009), because crops speed through their physiological development producing lees grain, faster plant growth and modifications of water and nutrient budgets will render existing farming technology unsuitable (Prasad, 2009), and, critical temperatures are between (35-40 ^oC) particularly when stress coincides with flowering because of damage to meiosis and polen growth, which inhibits setting of fruit and grain (Fuhrer, 2009). These metabolic events in plants depend on mean temperature, the interaction between water stress and CO_2 (Table 1), and the interaction between ozone and a range of environmental variables. Studies have indicated that the sensitivity of C_3 photosynthesis to temperature declines as plants become limited by CO_2, much like the patterns exhibited by the C_4 plants (Ward et al., 2008). CO_2 accelerates photosynthesis and its concentration is increasing, the productivity of C_3 plants will not drop (generally) it will increase by 36% (Uzmen, 2007) -compared with 35-80% in the grain legumes (Ziska et al. 2001). According to the findings of a satellite-imagery study, there can be shift ranging between five days to three weeks in the cultivation period of various plant species (Cuthford et al., 2007).

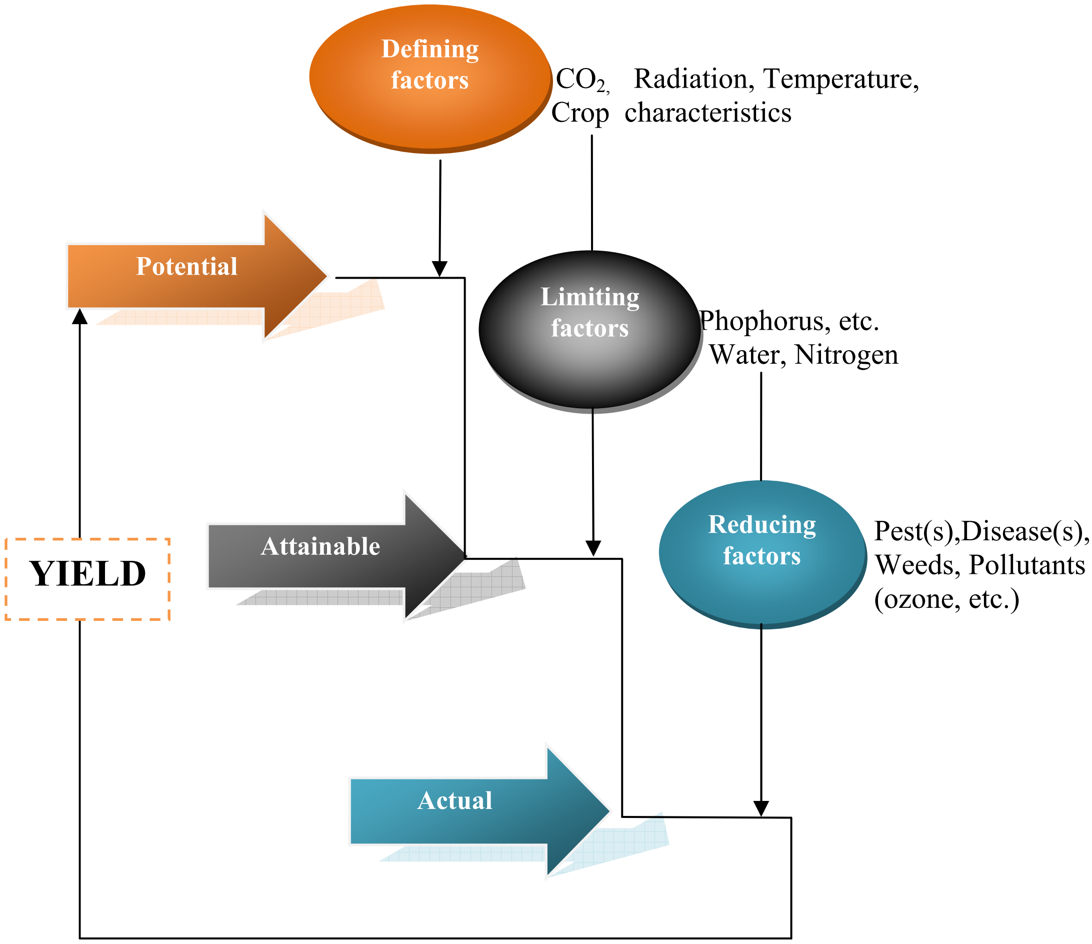

Figure 3. Crop production levels depending on defining, limiting and reducing factors (Modified from Fuhrer 2003).

Moreover, the anatomical effect of global warming on plants generally emerges with the increase of CO_2 concentration due to ambient temperature and also with the following interactions between: vitality of leaf and thickness, ramification and the length of the stem, life of the leaf and the thickness of leaf and length of the stem etc. Furthermore, it results in following: a shift in growth and development period of plants cultivated in the field; the closure of stoma and reduced water intake by increasing the number of chloroplasts in the cells (Mei et al. 2007); excessive development of green sections and, accordingly, seed productivity, due to an increase in the ratio of root/stem (e.g. cotton, carrot, soybean) and some changes happens in the morphology of some root and tuberous plants in the C_3 plants (esp. in potatoes and in grain legumes) over time (Romanova, 2005; Ulukan, 2008; 2009b) (Table 2).

Temperature has important phenological effects on plants and their responses such as time of decomposition, flowering (*anthesis*), N mineralization net photosynthesis, maintenance respiration, growth respiration, etc. (Norby and Luo, 2004). The higher temperature also increases the process of evapo-transpiration and decreases soil moisture availability. Higher CO_2 concentration leads to increased growth and transpiration rates in some plants; it lead to extension of the cultivation range of crops such as grain legumes, wheat, maize, soybean, potato, and this causes extra CO_2 reproduction, and this extra reproduction is brought into the use for them.

Table 1. Some agronomic characteristics of the world's 18 leading crops (Modified from Rötter and Geijn, 1999).

Crop	World (FAO 2008 [a]) Production (Mt)	Yield (Hg/Ha)	Origin	Plant Type	WUE Value [b]	Response/Sensitivity to CO_2 and Yield Change (%) [c]
Barley	158.0	27 766	West Asia	C_3	1.25-2.50	50-70
Beans, dry	20.4	7 286	S.& Cent. Amer.	C_3	1.40-3.30	(70)
Cassava	233.0	124 604	S.& Cent. Amer.	CAM	1.30-3.30	unknown
Coconuts	61.1	54 509	Africa, Asia	C_3	1.40-3.30	unknown
Cotton, seed	66.0	20 992	South America	C_3	1.40-3.30	40-90
Grapes	68.0	91 397	Asia	C_3	1.25-3.30	unknown
Maize	823.0	51 094	Cent. Amer.	C_4	2.90-6.70	30-55
Oats	25.8	22 751	W. Europe	C_3	1.25-2.5	40
Peanuts	38	15 535	South America	C_3	1.40-3.30	unknown
Peas, dry	16584	16 584	West & North Asia	C_3	unknown	(85)
Potatoes	314	172 676	South America	C_3	1.25-2.50	(50)
Rice, paddy	685	43 094	Asia, Africa	C_3	1.40-3.30	15-55
Rye	17.8	26 224	West Asia	C_3	1.25-2.50	unknown
Sorghum	66.0	14591	Africa	C_4	2.90-6.70	30-90
Soybeans	231.0	23841	East Asia?	C_3	1.40-3.30	7-40
Sugar cane	1,743	715 102	SothEast Asia, Aus.	C_4	1.25-6.66	unknown
Sweet Potatoes	110.0	134 666	South & Cent. Amer.	C_3	1.40-3.30	40-90
Wheat	690.0	30 861	Fertile Crescent	C_3	1.25-2.50	30-40

[a] URL-1, 2010 : http://faostat.fao.org (03.02.2010), [b] WUE : Water use efficiency (Dry mater based)
[c] : Response to 600-700 ppmv compared to 300-350 ppmv

Table 2. Effect of some global warming factors on the plant groups (Modified from Krupa, 1997; Dhakhawa and Campbell, 1998; Tubiello and Ewert, 2002).

Trait	**Elevated CO_2**	**Elevated UV-B**	**Elevated O_3**
Photosynthesis	Increase in C_3 up to 100%; less happens or not in C_4	Decrease in many C_3 and C_4	Decrease in many C_3 and C_4
Leaf Conductance	Decrease in C_3 and C_4	Most of them are not affected	Decrease in susceptible species and cultivars
Water Use Efficiency	Increase in C_3 and C_4	Increase in C_3 and C_4	Decrease in susceptibles
Leaf Area	More in C_3	Decrease in C_3 and C_4	Decrease in susceptibles
Leaf Thickness	Increase	Increase in most of them	Increase in susceptibles
Maturity Rate	Increase	Non affected	Decrease
Flowering	Happens early	Prevents or Stimulates	Flower and fruit number decreas, flowering delays
Dry Matter Prod. & Yield	Doubled (almost) in C_3 but it is unclear in C_4	Only "yield" decreased in most of them	Only "yield" decreased in most of them
Species & Cultivars	There is a big difference in C_3 and C_4	There is a great variance	There is a great variance
Susceptibility	Varied	Varied	Varied
Susc. to Drought Stress	Less susceptible	Less susceptible to UV-B; but more susceptible to water deficiency	Less susceptible to ozone; but more susceptible to water deficiency
Susc. to Mineral Stress	Less responses	Some of less, some of more susceptibles	Very susceptible to its damage

C_3 : Examples: Trees, Small Grain Cereals, Legumes, Cotton, Rice, Soybean, Potatoes
C_4 : Examples: Coarse Grain Cereals, Maize, Sugar cane, Sorghum, *Euphorbia*, *Amaranthus*
CO_2 : Carbon dioxide, UV-B : ultraviyolet (B) ray, O_3 : ozone

In this process, which can be analyzed as CO_2 fertilization in brief, metabolic rates will increase and plants will age more rapidly, since temperature and the length of the vegetation process are directly proportional and the shortening of the period between cultivation and harvest (Ulukan, 2009a). Studies have indicated that a 1°C increase in global temperature will lead to reduced productivity in some cultivated plants such as 7.0–124.0% in wheat (Fuhrer, 2009); –22.0-18.0% in soybean (Fuhrer, 2009); 1.0–3.8% in barley (Cline, 2008); 28.0% in potato (Fuhrer, 2003) and 17.0% in corn (Fig. 4).

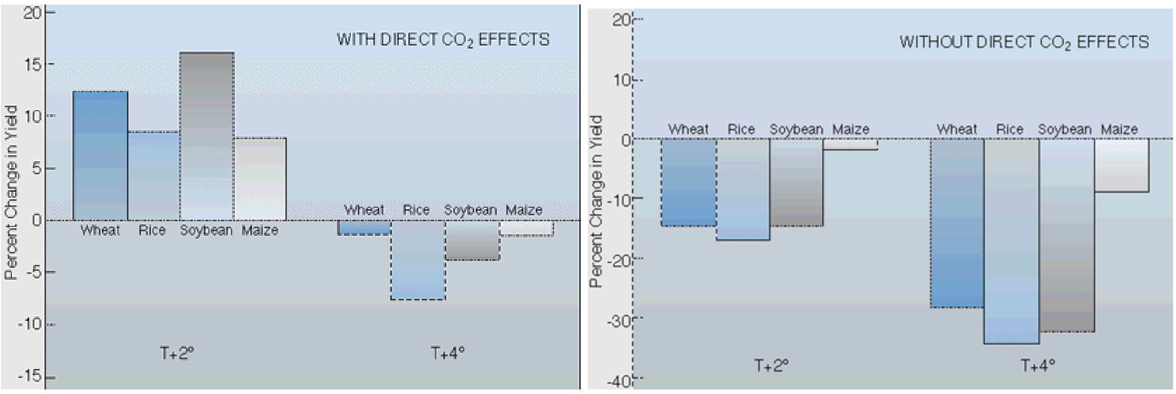

Figure 4. Estimated changes in world-averaged crop yields of four major cereal grains (wheat, rice, soybean (= C_3) and maize (= C_4)), as a result of increases of 2°C and 4°C in average global surface temperature, with and withouth direct CO_2 effects on plant growth and water use (Rosenzweigh and Hillel, 1995; Mengü vd. 2008), T= Temperature

Future climate change's possible impacts on (global) agriculture can be mentioned as fallow (Anonymous, 2010): a) In general, the report states that increases in the frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes; b) globally, the potential for food production is projected to increase in local mean temperature over a range of (1-3°C), but above this range, food production is projected to decrease; c) at lower latitudes, especially in the seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase risk of hunger; d) crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to(1-3°C) depending on the crop, and then decrease beyond that in some regions; e) with the virtually certain likelihood of warmer and more frequent hot days and nights, there are projected to be increased insect outbreaks impacting agriculture, forestry and ecosystems; f) adaptations such as altered cultivars and planting times allow low-and mid- to high-latitude cereal yields to be maintained at or above baseline yields for modest warming.

3. Results and Discussion

Global climate change and GHGs are an increasingly significant global challenge and its negative impacts have been already felt in some regions of the world. It is clear that elimination of the negative effects of global warming on field crops is nearly impossible; and the rational approach will be to develop means to minimize the effects. The most reasonable strategy will be to minimize agricultural factors effectively and fairly, without ignoring the causes of global warming. Therefore, agreements should be developed and adopted which include powers to regulate both CO_2 emissions and use of water resources according to 'the contribution to global climate change and GHGs'. Efficient use of nitrogenous fertilizer can reduce nitrous oxide emissions and ruminants are the major emitters of CH_4 (Prasad, 2009). Measures should be taken to reduce release resulting from excessive nitrogenous fertilization (N_2O). The use of artificial nitrogen fertilizer should be avoided, as far as possible. Crop rotation pattern(s) should be adopted which incorporate animal feed and edible legumes because of their ability to translocate (C) compounds to their storage organs (Ulukan, 2009b); alternative energy sources should be used; zero soil tillage techniques should be applied (Çakır vd. 2009); the sowing area of some field crops such as common wheat should be decreased but durum wheat and maize be increased (Thomson et al. 2005), organic agricultural techniques should be promoted, and organic material(s) should not predominantly be burned.

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