EFFECTS OF AGRICULTURE ON CLIMATE CHANGE: A CROSS COUNTRY STUDY OF FACTORS AFFECTING CARBON EMISSIONS

Krishna Prasad Pant (PhD)[1]

ABSTRACT

Agriculture affects atmosphere by releasing green house gases and get affected in turn, from climate change. This paper reviews the literature on both the aspects and test empirically that what affects emissions of carbon dioxide to the atmosphere. Data on carbon emissions, energy consumption and agriculture related national level variables are obtained for 120 countries from the World Bank's Green Data Book. Multiple linear regression analysis revealed that agricultural land, irrigation, forest area, biomass energy, and energy use efficiency negatively affect the Carbon dioxide emission. But, fertilizer use and per capita energy use affect it positively. The analysis confirms that the people in rich countries are more responsible for carbon emission than the people in poor countries. It recommends for cross subsidization for low external input agriculture, particularly for organic farming in poor countries.

Key words: agriculture, carbon emissions, climate change, energy consumption, GHGs

BACKGROUND

Climate change is realized as the greatest threat to the living beings on the earth affecting widely from tropical to arctic regions and from sea to land and atmosphere. Though the climate on the earth is changing naturally in its slow pace, the increased rate of climate change due to anthropogenic factors is of grave concern. The climate change is mainly attributed to industrial revolution and large amount consumption of fossil fuels. Agriculture that comprises crop and livestock also emits green house gases aggravating the problem. In addition, the climate change affects agriculture adversely, and the agricultural practices need to be modified to reduce the problem of climate change. The paper empirically analyses the factors affecting emission of the main green house gas, carbon dioxide, using cross-country data on emissions and agricultural variables like agriculture land, fertilizers and irrigation.

The discussion starts with issues of climate change and its relations to the agriculture sector. The second section deals with the methodology followed and the third section presents the test of hypothesis by comparing mean differences. The fourth section delineates the factors affecting the carbon dioxide emission and finally the fifth section concludes with some recommendations.

ISSUES OF CLIMATE CHANGE

The climate change is attributed to the change in the composition of the global atmosphere that increases mean temperature that affects the ecology in the earth and ocean. The change in the composition of the atmosphere is caused directly and indirectly by various human activities in addition to natural climate variability over time. The energy from the sun

1 Senior Program Officer, National Agriculture Research and Development Fund, Nepal, kppant@yahoo.com

reaching the earth is balanced by the energy that the earth emits back to space. The cloud of greenhouse gases (GHGs) like water vapour, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) trap some of the solar energy that the earth releases to space (Robertson *et al.*, 2000). Such GHGs have effects like a greenhouse on the earth's atmosphere and the temperature of the earth increases.

Since 1750, the atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased by approximately 31 percent, 151 percent and 17 percent respectively. Current rates of increase per year are 0.5 percent for carbon dioxide, 0.6 percent for methane and 0.3 percent for nitrous oxide (IPCC, 2001). Human activities increase the GHG levels in the atmosphere by introducing new sources or removing natural sinks[1] such as forests. A balance between sources and sinks determines the levels of greenhouse gases in the atmosphere.

Aiming at stabilizing GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, members of United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 produced international environmental treaty named United Nations Framework Convention on Climate Change (UNFCCC)[2]. The treaty has set no limits on GHG emissions for individual nations and contained no enforcement provisions. Kyoto Protocol[3] under the treaty sets mandatory emission limits for industrialized countries as specified under Annex one countries[4] of the Protocol. Developing countries like Nepal are not expected to implement their commitments under the Convention unless developed countries supply enough funding and technology. For such countries, reduction in GHG emission has lower priority than economic and social development and poverty alleviation program. As the developing countries have less capacity to adapt than do their wealthier neighbors, they lose more from the effects of global warming on agriculture than do industrial countries. We can use green sector opportunities of the country to trap GHGs if enough funding and technology are provided by the industrial countries. The opportunity in forestry sub-sector is better known whereas that of agriculture sub-sector is still illusive.

The challenges of how to respond to climate change and ensure sustainable development are currently high on the political agenda among the world's leading nations (Olsen, 2007). Gleneagles meeting (2005) of Group of Eight countries confessed the seriousness of the issue and linked challenges in tackling climate change, promoting clean energy and achieving sustainable development (Blair *et al.*, 2005). The UN Climate Conference (2007) in Bali agreed to pursue negotiations toward a new international agreement by 2009 to succeed the Kyoto Protocol. The new negotiations can set the stage for meaningful international abatement

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[1] Sources are processes or activities that release greenhouse gases; sinks are processes, activities or mechanisms that remove greenhouse gases.

[2] The FCCC was opened for signature on May 9, 1992. It entered into force on March 21, 1994. The stated objective is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a low enough level to prevent dangerous anthropogenic interference with the climate system.

[3] The Kyoto Protocol came into effect on February 16, 2005.

[4] Signatories to the UNFCCC are split into three groups: Annex I, Annex II and developing countries. Industrialized countries are under Annex I and agree to reduce their emissions (particularly CO2) to target levels below their 1990 emissions levels. If they cannot do so, they must buy emission credits or invest in conservation. Annex II countries have to provide financial resources for the developing countries and consist of the OECD members. Developing countries have no immediate restrictions.

measures in the post-Kyoto period (Cline, 2008). However, knowledge is not enough to develop practical and efficient measures to address the problem of climate change.

There is a need to further strengthen the knowledge base on the emerging challenge of climate change and adaptation. To date, most work on climate change has been on knowledge development with a major focus on the water resource sector, including water-induced disaster management. Work in other key sectors, such as human health, forestry and biodiversity and agriculture, is only just starting (World Bank, 2007a). Nepal's greenhouse gas emissions are extremely small in global terms. The Initial National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) showed that its total greenhouse gas emission in 1994/95 was equivalent to 39,306 giga grams of carbon dioxide. Land use change and the forestry sector were the main sources of CO_2. The energy sector is the second largest emitter of greenhouse gases (MoPE, 2004), whereas the contribution of agriculture sector is very low.

While Nepal's contribution to GHG emissions is small, it will face a significant challenge in responding to the effects and impacts of climate variability, climate change, and extreme weather events. There was an average increase in the mean annual temperature of earth surface by 0.06°C per year between 1977 and 1994 (World Bank, 2007a). Such rapid increase in the temperature may have affected agricultural production in the country, we have not yet conducted a specific research on this regards. Such study is, however, beyond the scope of this paper. It is not counter intuitive to think that with predicted increases in temperatures and changes in rainfall patterns, there will be significant negative impacts on ecosystems and people's livelihoods. Specifically, there will be negative impacts on public health, forestry and biodiversity, agriculture and water resources (MoPE, 2004). As the agriculture is concerned with the food security and livelihood of the majority of the people in developing countries and under developed countries, this sector deserves immediate attention for making it environment friendly.

INTER-LINKAGES BETWEEN AGRICULTURE AND CLIMATE CHANGE

Agriculture emits GHGs and can trap them as well. The major gases emitted by agriculture are carbon dioxide, methane and nitrous oxide. The amount of sources and sinks of these gases depends on land use and management of soils, crops, manures, livestock and energy. In agriculture, the majority of on-farm carbon dioxide emissions come from fuel combustion for heating farm buildings and machinery, intensive tillage regimes, and summer fallow when soil organic matter is decomposing. Similarly, the primary on-farm sources of methane emissions include enteric fermentation from ruminant livestock like cattle, sheep and goats, anaerobic respiration of organisms in riparian areas, and manure storage systems like stockpiled solid or liquid storage (Takle and Hofstrand, 2008). Likewise, the primary on-farm sources of nitrous oxide emissions involve soil nitrogen management like wet soils containing nitrogen-fixing plants like alfalfa or pulses and application of manure and nitrogenous fertilizers.

On one hand, the agriculture aggravates the problem of climate change by emitting different GHGs and also gets affected from the climate change. On the other hand, it offers an opportunity for sequestering such gases from the atmosphere mitigating, though partly, the problem of climate change.

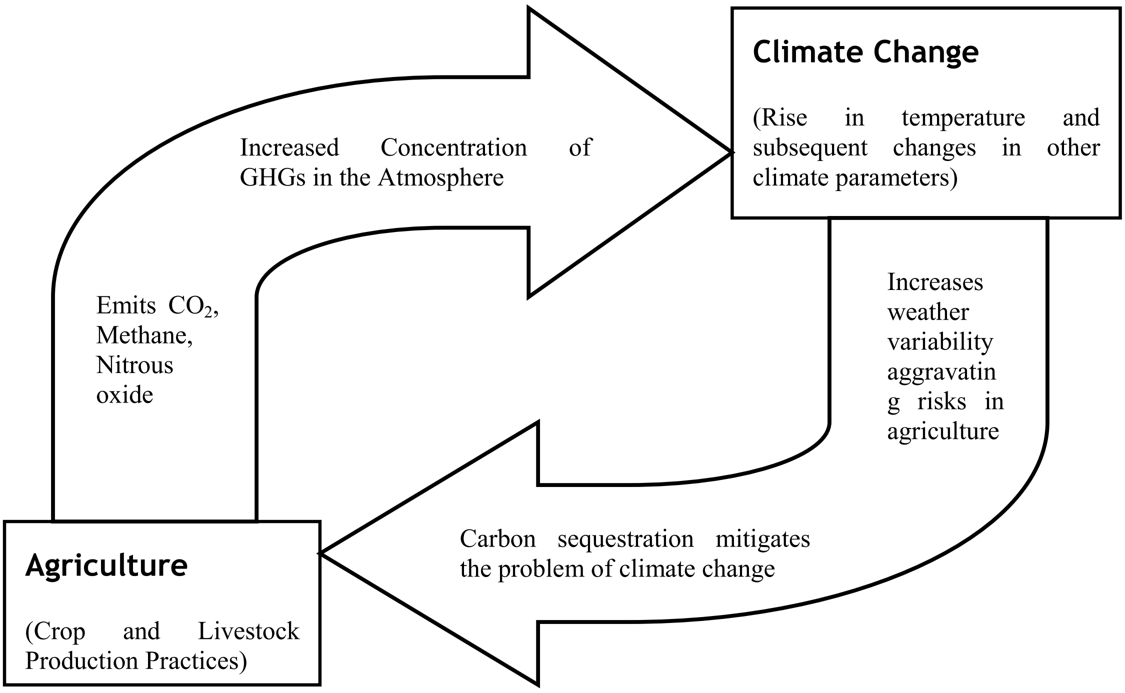

Figure 1: Inter-linkages between agriculture and climate change

Green House Gas Emissions from Agriculture

Agricultural greenhouse gas emissions come from soil and manure management, enteric fermentation and fossil fuels consumption. Agricultural soil management accounts for about 60 percent of the total emissions of nitrous oxide from the agricultural sector. The large increase in the use of nitrogenous fertilizer for the production of high nitrogen consuming crops has increased the emissions of nitrous oxide. Efficient use of nitrogenous fertilizer can reduce nitrous oxide emissions (Takle and Hofstrand, 2008). Ruminant animals are the major emitters of methane. Enteric fermentation in digestive process of animals produces methane. Feed quality and feed intake influence the level of methane emissions. Similarly, manure management also affects methane emissions. Methane is produced by the anaerobic decomposition of manure. Dairy cattle and swine contribute about 85 percent of the methane emissions (Takle and Hofstrand, 2008). When rice is grown with no oxygen, the soil organic matter decomposes under anaerobic conditions and produces methane that escapes into the atmosphere. Carbon dioxide from fossil fuel consumption is another source of GHG. The use of fossil fuels in agricultural production also emits green house gases from agriculture.

Effects of Climate Change on Agriculture

Agriculture is likely to get affected positively and negatively by the climate change. Negative effects are feared to be larger than the positive effects. Some studies have been conducted for evaluating the potential effects of climate change on agriculture in global level (Kane *et al.*, 1992; Rosenzweig and Parry, 1994; Darwin *et al.*, 1995), regional level (Adams *et al.*, 1990;, Adams *et al.*, 1993; Mendelsohn *et al.*, 1994) and farm level (Kaiser *et al.*, 1993; Easterling *et al.*, 1993). Some others are conducted in the effects of climate change on crop yields (Andresen and Dale, 1989; Dixon *et al.*, 1994; Kaufmann and Snell, 1997; Wu, 1996). Increased temperature during growing season can reduce yields, because crops speed through their physiological development producing less grain. Faster plant growth and modifications of water and nutrient budgets in the farm (Long, 1991) will render existing farming technology unsuitable. Change in crop physiology will make traditional practices inappropriate.

The higher temperature also increases the process of evapo-transpiration and decreases soil moisture availability. Because global warming is likely to increase rainfall, the net impact of higher temperature on water availability is a race between higher evapo-transpiration and higher precipitation. As the precipitation is not regular, the race will be won by higher evapo-transpiration (Cline, 2008). Rainfed agriculture, mostly practiced by the poor, is likely to get affected adversely by the climate change.

Higher concentration of CO_2 and carbon fertilization (increased availability of the carbon to the crops) increase plant photosynthesis and thus crop yields (Rosenzweig and Hillel, 1998; Kimball, 1983). Enhanced photosynthesis can increase the yield of C3 crops such as wheat, rice and soybean, but not of the C4 crops such as sugarcane and maize (Cline, 2008). Moreover, increase in the temperature and changes in precipitation pattern have potential to affect crop yields (Reilly *et al*., 2001). But this can either be positive or negative. Chang (2002) estimates crop-yield response models and finds negative effects associated with some climate changes. Physical effects of temperature rise on crop yield are feared more damaging in tropical and subtropical countries than in the temperate countries.

Initial National Communication of Nepal to the UNFCCC notes that there will be growing negative impacts on ecosystems and people's livelihoods with predicted increases in temperatures and changes in rainfall patterns in the future (MoPE 2004). Nepal's agricultural sector is highly dependent on weather, particularly on rainfall. Given the low productivity increase of the last few years compared to population growth, climate change is likely to have serious consequences for the agriculture. Most of the population is directly dependent on a few crops for food such as rice, maize and wheat. The predicted decrease in precipitation from November to April would adversely affect the winter and spring crops, threatening food security. Higher temperatures, increased evapo-transpiration and decreased winter precipitation may bring about more droughts in Nepal (Alam and Regmi, 2004). Increased water evaporation and evapo-transpiration may also mean that crops will require more water through irrigation.

The major effects of climate change can be summarized as increase in temperature, weather variability, evapo-tranpiration and uncertainty of precipitation. This will affect both crop and livestock production technologies particularly choice of variety/breed, sowing time, disease/pest management and water management.

Mitigation of Climate Change by Agriculture

We are searching for effective approaches to improve energy efficiency and minimize GHG emissions from agriculture sector. Improved livestock farming can reduce GHG emissions through improved livestock feeding and manure management. Carbon sequestration in crops, pastures and trees and trapping carbon is soil can reduce atmospheric carbon. Similarly, substituting fossil fuels with renewable energy in crop and livestock production can reduce GHG emissions. Thus, the agriculture can reduce atmospheric greenhouse gases.

Soil organic carbon (SOC) pool is the largest among terrestrial pools and the restoration of SOC pool in arable lands represents a potential sink for atmospheric CO_2 (Jarecki *et al.*, 2005). Restorative management of SOC includes using organic manures, adopting legume-based crop rotations and converting plough till to conservation till system. When land is ploughed, soil carbon gets oxidized and become atmospheric carbon dioxide (Takle and Hofstrand, 2008). Minimum till farming practices provide a great potential for the future sequestration of atmospheric carbon and building soil organic matter while also minimizing soil erosion and reducing production costs. However, the carbon trapped in the soil is reversible and it gets released to the atmosphere after some years.

Restoration of SOC in arable lands represents a potential sink for atmospheric CO_2 (Lal and Kimble, 1997). Strategies for SOC restoration by adoption of recommended management practices include conversion from conventional tillage to reduced tillage, increasing cropping intensity by eliminating summer fallows, using highly diverse crop rotation, introducing forage legumes and grass mixtures in the rotation cycle, increasing crop production and increasing carbon input into the soil (Lal *et al.*, 1998; Lal, 1999; Desjardins *et al.*, 2001; Hao *et al.*, 2002). The potential to sequester carbon varies considerably between crop type, crop rotation and the amount of fertilizer necessary for crop growth.

Sequestration of the carbon in biomasses like woodlot through improved forest management practices and trapping the carbon in agricultural soils are two major sinks for the carbon. Growing trees sequester large amounts of carbon dioxide from the atmosphere through photosynthesis. The soil is a great storehouse of carbon in the form of organic matter. There are several opportunities like sequestering carbon in agricultural soils by reducing tillage, reducing nitrous oxide emissions through more efficient use of nitrogenous fertilizer, developing viable technologies for creating such fertilizers, capturing methane emissions from anaerobic manure handling facilities (such as biogas) and substituting renewable fuels for fossil fuels (Takle and Hofstrand, 2008). Soil management practices like crop rotations, tillage and fertilizer management affect the level of carbon dioxide in the soil (Martens and Frankenberger, 1992; Nyamangara *et al.*, 1999; Martens, 2000b). Crop characteristics like species, productivity, canopy structure, root physiology and root function and pattern affect soil organic carbon (Chan and Heenan, 1996). Change in farming practices to the emission reducing ones can offer great potential to reduce the problem of climate change.

Crop residue management can have a substantial influence on SOC concentration (Follett, 2001; Franzluebbers, 2002; Hulugalle and Cooper, 1994; Unger, 1997; Kushwaha *et al.*, 2001). Maize residue has high carbon to nitrogen (C:N) ratio, and high SOC concentrations (Martens, 2000a). There is not a direct relationship between legumes and SOC concentration. The low quantity of residues from soybean does not promote SOC concentration (Martens, 2000a; Martens, 2000b). Enhanced crop rotation for several years increases SOC concentration (West and Post, 2002). After 30 years of crop rotations, annual SOC gains ranged from 60 to 220 kg per ha per year for fields in Canada (Campbell *et al.*, 2000). Nutrient management through fertilization and manure application generally increases SOC concentration (Haynes and Naidu, 1998; Schjonning *et al.*, 2002; Munkholm *et al.*, 2002; Hao *et al.*, 2002). Manure application increases SOC concentration (Martens and Frankenberger, 1992; Haynes and Naidu, 1998; Nyamangara *et al.*,1999; Aoyama *et al.*, 2000). Long-term manure applications and incorporation of crop residues in the soil increase SOC (Whalen and Chang, 2002). Burning crop residues is clearly a climate unfriendly practice.

Reduced and no-till systems have higher SOC concentrations compared with conventional tillage practices (Salinas Garcia *et al.*, 1997). Conservation tillage reduces biomass mineralization, decreases oxygen availability and increases SOC concentration (Martens, 2000b). Soil erosion resulting from soil mismanagement results in loss of SOC (Lal, 2003b). Management practices such as reduced tillage and increased carbon inputs through residue management and manuring improve soil structure, reduce erosion and carbon loss through mineralization and CO_2 emissions (Hao *et al.*, 2002; Lal, 2003a; Lal, 2003b). Bronick and Lal (2005) suggest that the combination of conservation tillage, increasing carbon inputs and increasing the complexity of the agricultural system combining different crops and animals improves carbon aggregation and SOC concentration. Improved management practices such as reduced tillage, manure application, mulching, composting, summer and winter fallowing, crop rotations and agro-forestry (Lal *et al.*, 1999; Bruce *et al.*, 1998) as well as changes in land use, including the conversion of degraded croplands to grasslands or pasture, increase the rate of CO_2 uptake from the atmosphere.

The paper addresses the first part of the problem, the green house gas emissions from agriculture, by assessing the factors affecting emission of per capita CO_2 from different countries on the earth.

METHODOLOGY

For empirical testing, some pertinent hypotheses are proposed first and data sources are analyzed for the purpose. Then the analytical frameworks are discussed briefly before going to the results and discussions.

HYPOTHESES

Following nine general hypotheses (Table 1) are tested empirically using the test of mean differences and multiple linear regression models.

Table 1: Hypotheses tested

SN	Hypotheses	Method of testing
1	A person in a rich country emits more carbon dioxide to the atmosphere than a person in a poor country.	Test of mean difference
2	Higher the proportion of land under agriculture less is the emission of carbon dioxide.	Multiple regression
3	Higher the proportion of the arable land irrigated higher is the emission of CO_2.	Multiple regression
4	Higher the dose of fertilizer application higher is the emission of CO_2.	Multiple regression
5	Higher the population pressure on agricultural land higher is the CO_2 emission.	Multiple regression
6	Larger is the proportion of forest area in the country the smaller will be the CO_2 emissions.	Multiple regression
7	Larger the contribution of biomass on the total energy consumption larger will be the amount of CO_2 emission.	Multiple regression
8	Higher is the per capita consumption of energy (deflated by the latitude of the country) higher will be the emission of CO_2.	Multiple regression
9	Higher the energy use efficiency in the country lower will be the emission of CO_2.	Multiple regression

DATA AND SOURCES

A country is taken as the unit of analysis. Country-wise data on carbon dioxide emissions and other important variables are taken for 120 countries from the World Bank (2007b). For rest of the countries in the world, data on one or the other variables included in the study are missing. The emissions include the carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

ANALYTICAL FRAMEWORK

Statistical and econometric analyses are conducted to test the hypotheses. Summary statistics of study variables and explanatory variables are generated statistically. To test the mean difference of the CO_2 emissions in the poor and rich countries difference of variances was tested first using group variance comparison test. Based on the equality or inequality of the variances, the mean difference is tested using group mean comparison test.

The effects of explanatory variables to the emission of CO_2 (hypotheses 2 to 9) are tested with a linear multiple regression model.

$$C = b0 + b1L + b2I + b3F + b4Pb5Lf + b6Bb7E + b8Ee + u$$

C Carbon dioxide emissions per capita

L Agricultural land

I Irrigation

F Fertilizer use

P Population pressure on agricultural land

Lf Forest area

B Biomass energy

E Energy use per capita deflated by the latitude

Ee Energy use efficiency

b0, b1, etc. are parameters to be estimated

u random term

The functional form, the linear equation is used based on the logic of linear effects at the mean level, strength of the equation being estimated and the logical validity of the coefficients estimated.

CARBON DIOXIDE EMISSIONS IN RICH AND POOR COUNTRIES

Emission statistics from 120 countries show that average per capita emission of CO_2 is 5.23 tons per year ranging from a zero to 33.4 tons (Table 2). The minimum per capita emission is in the poorest quartile whereas the highest per capita emission is in the richest quartile (see Annex I). The per capita mean emission of CO_2 is less than one ton (0.67 ton) per year in poorest quartile and 2.58 tons in the second quartile countries. It is 6.00 tons in the third quartile countries whereas a person in the richest quartile country on an average emits over 11 tons of carbon dioxide per year.

Table 2: Carbon Dioxide Emission of Countries by Income Quartile (tons per capita)

Gross National Income Quartile	N	Mean	SD	Minimum	p25	p50	p75	Maximum
1 Poorest countries	27	0.67	0.92	0.0	0.2	0.4	0.9	4.8
2	33	2.58	2.35	0.2	1.0	1.4	3.5	10.7
3	29	6.00	4.59	0.9	3.1	5.4	7.9	22.1
4 Richest countries	31	11.31	6.83	3.5	7.7	9.6	11.4	33.4
Total	120	5.23	5.90	0.0	0.9	3.5	7.95	33.4

Source: Compiled from World Bank, 2007b.

The zero order correlation between per capita gross national income and per capita carbon dioxide emission is 0.60, and it is highly significant (p = 0.000). It means richer country residents are more responsible for green house gas emissions and climate change than the poor country residents. This conclusion is further verified by the test of hypothesis of mean difference.

The test of mean differences with unequal variances is found to be highly significant and that leads to rejection of null hypothesis of equal per capita emission in rich and poor countries (Table 3). Out of the 120 countries under analysis countries under first two income quartiles are taken as rich and rest as the poor. Adopting an alternate hypothesis, it can safely be inferred that the people in richer countries emit more carbon dioxide than the people in the poor countries.

Table 3: Test of differences in per capita carbon emission between poor and rich countries

Group	N	Mean	Standard Error	Standard Deviation	Test of mean difference for unequal variance	Test of difference in variance
Rich countries	60	8.740	0.826	6.396	t= 8.08	F observed = 9.53 (p=0.000)
Poor countries	60	1.723	0.267	2.072	(p=0.000)	
Combined	120	5.232	0.539	5.901		

Source: Compiled from World Bank, 2007b.

FACTORS AFFECTING THE CARBON DIOXIDE EMISSIONS

The factors affecting the carbon dioxide emissions in different countries are assessed using linear multiple regression taking the emission data as the dependent variable regressed over agricultural, forestry and energy variables. Before going to the actual modeling of the empirical relations the summary statistics of the explanatory variables are discussed (Table

4). The agricultural land in the sample countries are taken as the percent of the total geographic areas. Nearly 42 percent of the totals geographical areas are under the agricultural uses, on an average. Nearly 21 percent of the crop area is irrigated. Average fertilizer consumption is 165 kg per ha with highest of 2,555 kg/ha in Iceland and the second highest of 2,418 kg/ha in Singapore. The lowest use of chemical fertilizer is recorded 0.4 kg per ha in Namibia and 0.5 kg/ha in Congo Republic and Angola. The fertilizer consumption in Nepal is reported to be 37.8 kg/ha of arable land.

Population pressure on agricultural land is another issue that deserves some discussions. The average population pressure is 3.24 persons per ha ranging from 0.05 persons/ha in Australia to 19.31 persons/ha in Oman. The population pressure on agriculture land in Nepal is 9.69 persons per ha that is higher than that in India (4.89 per ha) and China (7.66 per ha).

On an average 28 percent of the geographical areas are under the forest. The statistics report no forest area in Oman and very little area (0.1 percent) in Libya and Egypt. The highest area under forest is in Gabon (84.5 percent of geographic area) followed by Finland (73.9 percent). In Nepal 25 percent of the total geographic area is reported under the forest defined as natural or planted tree stands. However, our national data reports nearly 39 percent of the total geographic area under the forest jurisdiction.

Table 4: Summary statistics of explanatory variables

SN	Variable	Unit	N	Mean	Standard Deviation	Minimum	Maximum
1	Agricultural land	% of geographical area	118	41.84	20.92	1.00	85.00
2	Irrigation	% of crop land	116	20.51	23.71	0.10	99.90
3	Fertilizer use	kg/ha	120	165.24	334.78	4.00	2,555.00
4	Population pressure on agricultural land	person/ha of agricultural land	120	3.24	3.67	0.00	19.31
5	Forest area	% of geographical area	120	28.43	19.94	0.00	84.50
6	Biomass energy	% of energy use	115	21.86	27.29	0.00	92.50
7	Energy use per capita deflated by the latitude	kg of oil equivalent per capita divided by average latitude of the country	119	139.97	428.02	6.76	4,404.38
8	Energy use efficiency	GDP $ per kg of oil equivalent	117	5.02	2.36	0.80	10.90

Source: Compiled from World Bank, 2007b

Another difference among the countries is energy consumption. Nearly 22 percent of the average energy consumption comes from biomass. Some countries (Armenia, Azerbaijan, Israel, Jordan, Saudi Arabia, Syrian Arab Republic and United Arab emirates) use no biomass energy. However, Congo Democratic Republic (92.5 percent) and Tanzania (91.6 percent) depend heavily on the biomass for their energy supply. Nepal draws nearly 87 percent of total energy consumed from the biomass sources.

Energy use per capita is measured in terms of kilogram of oil equivalents (kgoe). Energy consumption depends on lifestyle and climatic conditions. To neutralize the effects of climatic conditions on energy consumption the per capita energy consumption is deflated by the average latitude of the country. Such deflated energy consumption per capita is 140 kg of oil equivalent per capita ranging from 6.76 kg (Bangladesh) and 4,404.00 kg (Singapore). It is 12 kg of oil equivalent in Nepal.

Another issue to discuss is that how efficiently the energy is being utilized. We measure the energy efficiency in an economy in terms of GDP produced per kg oil equivalent of energy consumption. Higher the GDP per unit of energy use the more energy-efficient is the economy. It would be ideal to use the disaggregated energy consumption for production only. But, such disaggregated data are not available. The average energy efficiency is US$ 5.02 per kg of oil equivalent. The least energy efficient country is Uzbekistan ($ 0.8 /kg of oil equivalent) followed by Tanzania ($1.3/kgoe), and Trinidad and Tobago ($1.3/kgoe). The most energy efficient countries are Colombia and Peru ($ 10.9/kgoe). Energy efficiency in Nepal is medium ($ 4.00/kgoe).

Based on the multiple linear regression analysis agricultural land, irrigation, forest area, biomass energy, and energy use efficiency negatively and significantly affected the CO_2 emission. Fertilizer use, and energy use per capita deflated by the latitude affected it positively and significantly. More specifically, the linear multiple regression using these explanatory variables shows that the countries with larger proportions of land under agriculture and forestry emit less CO_2 per capita as compared to those countries with smaller proportion of agricultural and forest areas (Table 5). One percent increase in agricultural land decreases per capita CO_2 emission by 0.048 metric tons. Similarly, one percent increase in area under forest decreases per capita CO_2 emissions by 0.049 metric tons. Agriculture and forest enterprises require less fossil fuel as compared to industrial sector; they are more climate friendly. Irrigation of crop land decreases the release of CO_2 to the atmosphere. Though the irrigation consumes some fuels, it reduces the flaring of CO_2 from the land. One percent (of the crop area) increase in irrigated land decreases per capita CO_2 emission by 0.085 metric tons. Dependency on biomass fuel reduces per capita emission of CO_2. One percent increase in the contribution of biomass on energy consumption in the country reduces per capita CO_2 emissions by 0.114 metric tons. Energy use efficiency (measured as gross domestic production per unit of energy use) also matters for CO_2 emissions. One United State Dollar increase in GDP per unit of energy (kg of oil equivalent) decreases per capita CO_2 emissions by 0.608 metric tons. This is because, higher the energy use efficiency lesser fuels to consume and low level of emissions. The equation estimated is statistically significant and explains 50 percent of the variation on the per capita CO_2 emissions.

Higher the energy use per capita higher is the CO_2 emission per capita. This is because of the release of CO_2 from the energy sources particularly that from fossil fuels. One kilogram increase in per ha use of the chemical fertilizers increases per capita emission of the CO_2 by six kilogram. This is because the production and transportation of the chemical fertilizers consume fossil fuels that release the carbon dioxide to the atmosphere. Increased use of chemical fertilizer also decreases the soil organic carbon by accelerating mineralization of SOC. Increase in the fertilizer consumption in agriculture increases the problem of global warming. This is the reason why low external input sustainable agriculture is being emphasized in many countries. As many farms in Nepal use very little fertilizers and many farms do not use them at all, this practice should be attributed as the climate friendly agriculture. Such farms deserves cross subsidization from carbon releasing activities within the country or from other countries that will compensate lower productivity of the low external input agriculture and promotes the climate friendly agricultural practices. Support for organic farming is one approach for harvesting such double dividends of climate protection and farmers wellbeing.

Table 5: Effects of agriculture on carbon dioxide emissions

	Explanatory variables	Coefficient	Standard Error	t	P>|t|	95% Confidence Interval	
1	Agricultural land	-0.048*	0.025	-1.940	0.055	-0.097	0.001
2	Irrigation	-0.085***	0.023	-3.740	0.000	-0.131	-0.040
3	Fertilizer use	0.006*	0.003	1.740	0.085	0.001	0.013
4	Population pressure on agricultural land	0.178	0.144	1.230	0.220	-0.108	0.463
5	Forest area	-0.049*	0.027	-1.800	0.074	-0.103	0.005
6	Biomass energy	-0.114***	0.018	-6.380	0.000	-0.149	-0.078
7	Energy use per capita deflated by the latitude	0.005**	0.003	1.980	0.050	0.000	0.011
8	Energy use efficiency	-0.608***	0.181	-3.350	0.001	-0.968	-0.248
9	Constant	13.772***	2.009	6.850	0.000	9.785	17.760
	Number of observation	106				R^2	0.501
	F(8, 97)	12.150				Adjusted R^2	0.459
	P > F	0.000				Root MSE	3.967

Note: n <120, due to some missing data.

CONCLUSIONS

Climate change affects crop and livestock production practices and yields. Negative effects are projected to be more prominent than the positive effects. Agriculture emits and traps green house gases. Farm practices can be modified to reduce emissions and to sequester the green house gases. The agricultural practices to reduce emissions should be pragmatic and cost-effective. The emissions reductions should be sector wide covering crop and livestock production, food processing enterprises, farm yard manure management, composting of crop residues, agro-forestry and pasture management.

Average per capita carbon dioxide emission of 120 countries is over five tons per year. The emission is directly related to per capita income. Richer country residents are more responsible for green house gas emissions and climate change than the poor country residents.

Linear multiple regression analysis shows that the countries with larger proportions of land under agriculture and forestry emit less carbon per capita as compared to those countries with smaller areas under agriculture and forest. As agriculture and forest enterprises require less fossil fuel, agriculture-dominating countries are more climate friendly than the others. Irrigation also decreases the release of carbon to the atmosphere. Thus, energy used for irrigation should not be blamed for carbon emission. Similarly, dependency on biomass fuel reduces per capita emission of carbon. Higher the energy use efficiency lower is the carbon emissions.

Higher the energy use per capita higher is the carbon emission. Energy intensive lifestyle can be attributed for climate change. Use of fertilizers is also contributive to the climate change. We need to emphasize low external input agriculture particularly organic farming. Such low or no fertilizer farming shall be subsidized to the tune of social benefits of emission reduction from such practices. People in high-income countries with higher carbon emission rate should buy organic products from less developed countries to promote such practices. The pricing of such organic vegetable should include the external benefits of reducing carbon dioxide emissions so that high-income people pay for their higher emission of the green house gases.

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Annex I: Summary Statistics of Per Capita Gross National Income (US $) by Income quartile

Quartile	1	2	3	4	
Country	Bangladesh, Benin, Congo Democratic Republic, Congo Republic, Cote d'Ivore, Ethiopia, Ghana, Haiti, India, Kenya, Kyrgyz Republic, Moldova, Mozambique, Nepal, Nicaragua, Nigeria, Pakistan, Senegal, Sudan, Tajikistan, Tanzania, Togo, Uzbekistan, Vietnam, Yemen Rep, Zambia and Zimbabwe	Albania, Algeria, Angola, Armenia, Azerbaijan, Belarus, Bolivia, Herzegovina, Cameroon, China, Colombia, Dominican Republic, Ecuador, Egypt, El Salvador, Georgia, Guatemala, Honduras, Indonesia, Iran, Jordan, Kazakhstan, Macedonia FYR, Morocco, Namibia, Paraguay, Peru, Philippines, Sri Lanka, Syrian Arab Republic, Thailand, Tunisia and Ukraine	Argentina, Botswana, Brazil, Bulgaria, Chile, Costa Rica, Croatia, Czech Republic, Estonia, Gabon, Hungary, Jamaica, Latvia, Lebanon, Libya, Lithuania, Malaysia, Mexico, Oman, Panama, Poland, Romania, Russian Federation, Serbia & Montenegro, South Africa, Trinidad and Tobago, Turkey, Uruguay and Venezuela	Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea Democratic Republic, Korea Republic, Kuwait, Netherlands, New Zealand, Norway, Portugal, Saudi Arabia, Singapore, Slovenia, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom and United States	Total
N	27	33	29	31	120
mean	531.85	2001.82	6007.93	32806.67	10410.5
sd	226.6	710.12	2242.87	12004.83	14530.97
min	120	1000	3220	12510	120
p25	350	1320	4470	23950	1040
p50	510	2290	5010	33860	2990
p75	690	2650	7210	39340	12510
max	950	2990	11220	60890	60890

Source: Compiled from The World Bank, 2007b