Impact of expanded production of biofuels on non-CO_2 GHG emissions

A note prepared for California Air Resource Board

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March 22, 2013

This note describes introduction of non-carbon dioxide (non-CO_2) greenhouse gas (GHG) emissions into GTAP-BIO model and provides illustrative analysis of the effects of expanded production of US corn ethanol on sectoral, regional and global non-CO_2 emissions. GTAP non-CO_2 version 7 data base (Rose et al. 2010), containing detailed information on global emissions in 2004, is linked to the current version of the GTAP-BIO model with the same base year (Taheripour et al. 2011). The emissions data include nitrous oxide (N_2O), methane (CH_4) and fourteen fluorinated gases (F-gases). For each region, the emissions dataset provides disaggregated source-level non-CO_2 emissions for each economic sector and regional household. Furthermore, the sector emissions are tied to emissions drivers: factor inputs (endowments), intermediate inputs, or output. Household non-CO_2 emissions are tied to energy use.

Non-CO_2 GHG emissions data

Figure 1 shows sectoral breakdown of global non-CO_2 emissions. More than half of all non-CO_2 emissions are related to agricultural activities. Global ruminant livestock sector is the largest emitter of anthropogenic non-CO_2 gases.

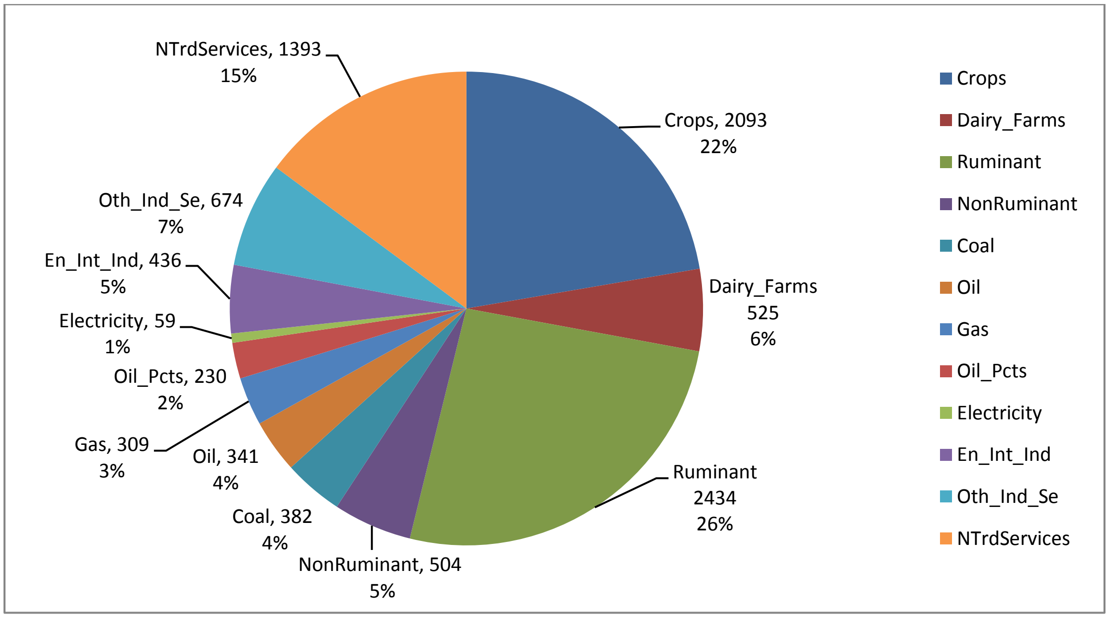

Figure 1 Global non-CO2 GHG emissions by sector, $MtCO_2eq$

Livestock production makes a significant contribution to agricultural emissions in all regions, and China[1] and Sub Saharan Africa are the largest contributors of global non-CO_2 emissions from agriculture (Figure 2). These two regions are also the largest contributors of global non-CO_2 emissions from the livestock sectors, and the ruminant meat sector in Sub Saharan Africa is single largest agricultural source of non-CO_2 emissions globally.

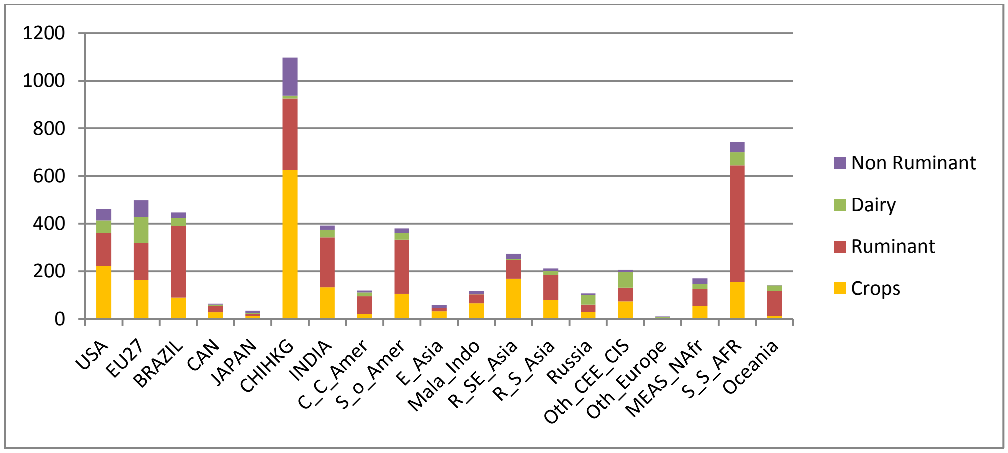

Figure 2 Non-CO_2 GHG emissions by agricultural sector and region, MtCO2eq

A detailed breakdown of non-CO_2 emissions from crop sectors by region is provided in Figure 3. Paddy rice and fruits and vegetables (OthAgri) sectors are large contributors of non-CO_2 in many regions. Oilseeds sectors are significant source of non-CO_2 emissions in Brazil and Other South America (S_o_Amer). Coarse grain sectors are important emitters in US, EU27 and Sub-Saharan Africa (S_S_Africa).

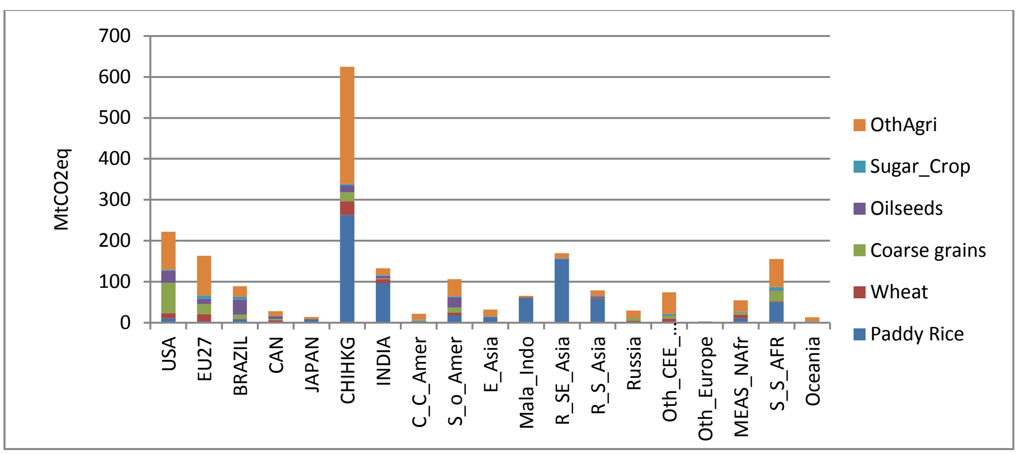

Figure 3 Non-CO_2 GHG emissions by crop sector and region, $MtCO_2eq$

[1] China region in the model is denoted by CHIHKG and includes China and Hong Kong.

Figures 4-6 identify specific categories of emissions within largest emitters (paddy rice, fruits and vegetables, coarse grains and oilseeds). In paddy rice production most of non-CO_2 emissions are methane from paddy rice land. Nitrous oxide emissions from fertilizer application are noticeable in China and Rest of South Asia (Figure 4). In coarse grains, oilseeds, and fruits and vegetables sectors most of non-CO_2 emissions are nitrous oxide emissions from fertilizer application (Figures 5 and 6).

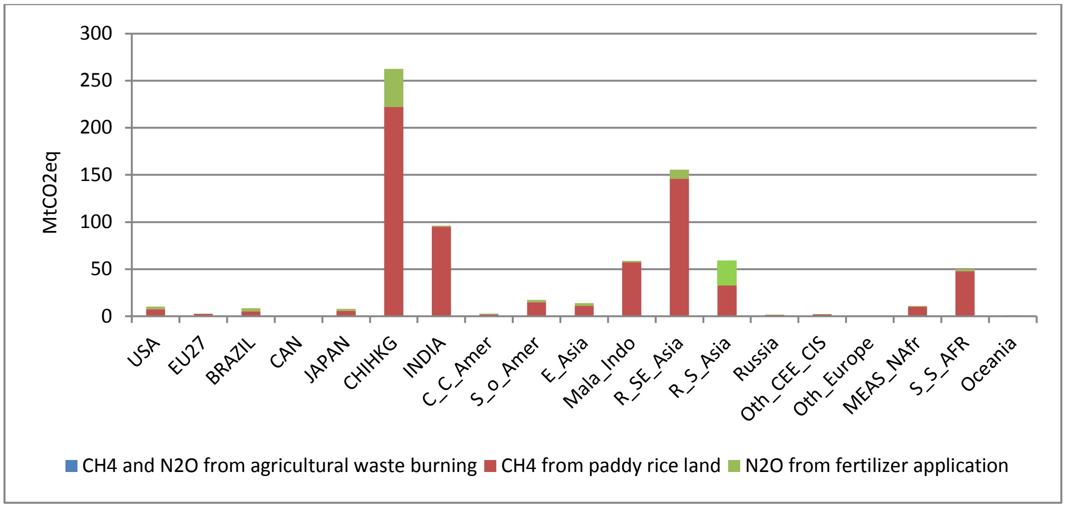

Figure 4 Non-CO_2 GHG emissions from paddy rice production by driver and region, $MtCO_2eq$

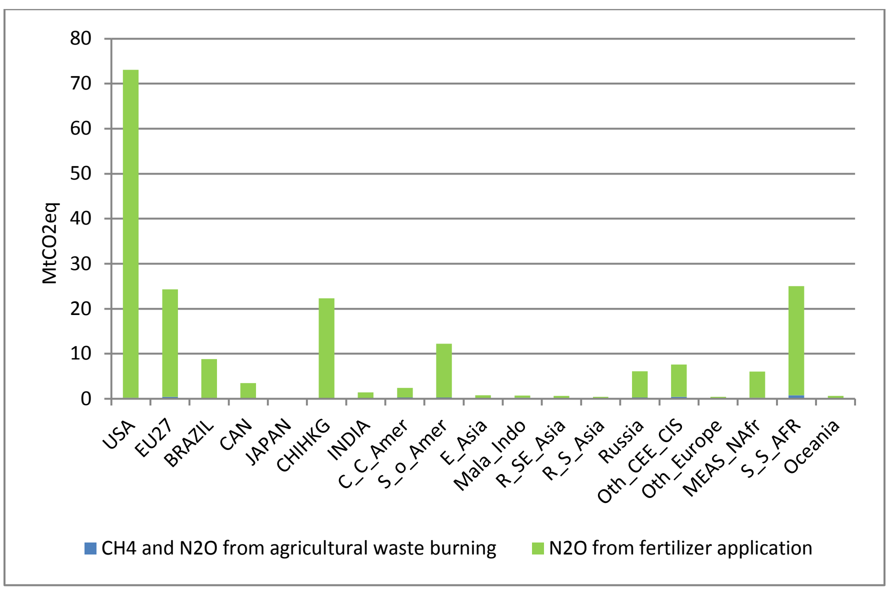

Figure 5 Non-CO_2 GHG emissions from sorghum and other coarse grains production by driver and region, $MtCO_2eq$

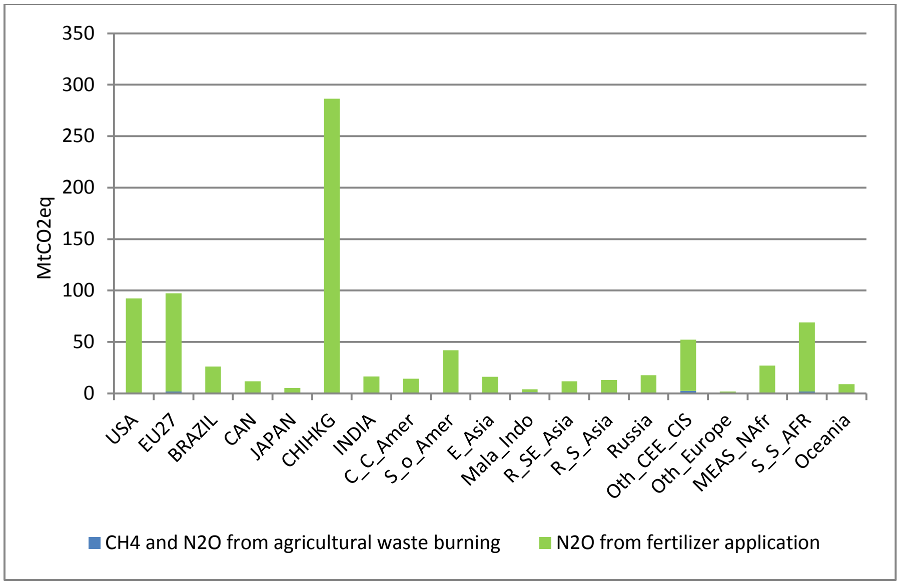

Figure 6 Non-CO_2 GHG emissions from fruit and vegetables production by driver and region, MtCO2eq

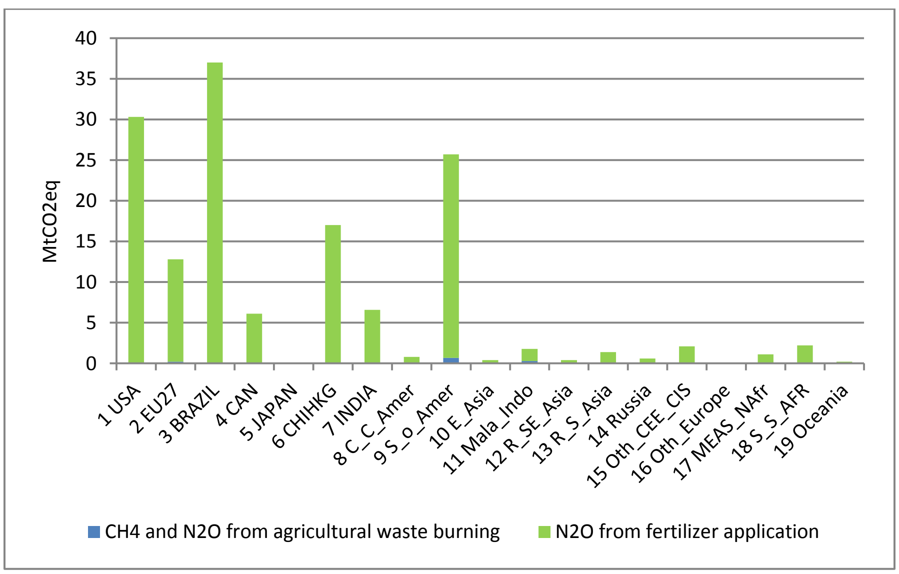

Figure 7 Non-CO_2 GHG emissions from oilseeds (soybeans, oil palm, rapeseeds, other oilseeds) production by driver and region, $MtCO_2eq$

Livestock production is the world's largest source of CH_4 emissions, most of which is derived from fermentative digestion by ruminant animals. Manure handling and storage is a significant source of both CH_4 and N_2O emissions. The GHG contributions vary considerably between livestock sectors and regions according to animal physiology, agro-climatic conditions, quality of feed resources, manure management practices, and degree of land intensification. Figure 8 identifies specific categories of emissions within three livestock sectors (ruminant, dairy and non-ruminants).

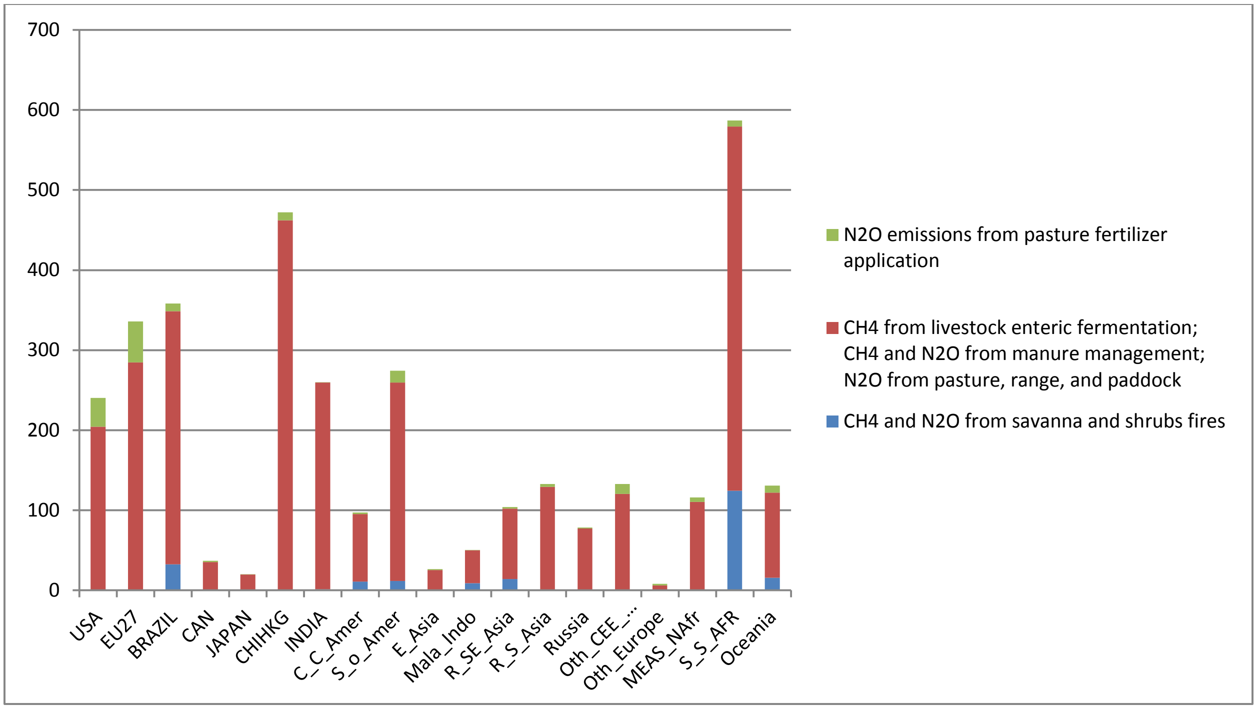

Figure 8 Non-CO_2 emissions from livestock production by emission category and region, $MtCO_2eq$

One category of emissions related to livestock introduced into the model is emissions from cropland-pasture. In current version of GTAP-BIO, cropland-pasture sector is a *fictitious* activity that uses cropland as an input, and does not use any other inputs. The cropland-pasture sector produces "cropland-pasture output". This cropland-pasture output is used as an input into ruminant meat production and dairy production. The cropland-pasture input is treated as a separate from pasture land input and competes with pasture land input within livestock sectors production structure .

Cropland-pasture sector is introduced in US and Brazil by splitting land endowment of ruminant meat sector between new ruminant meat and cropland-pasture sectors. Emissions from savanna and shrubs fires related to ruminant meat production are present in Brazil, but not US (Rose et al. 2010). Rose and Lee (2009) identify land endowment as a driver behind these emissions in ruminant meat production. Thus, in the construction of non-CO_2 emissions data for GTAP-BIO, CH4 and N2O emissions from savanna and shrubs fires in ruminant meat sector in Brazil are separated into emissions from land in cropland-pasture sector (16 $MtCO_2eq$) and emissions from land in new ruminant meat sector (32 $MtCO_2eq$), in proportion to land endowments used in these sectors.

Introducing non-CO_2 emissions into GTAP-BIO model

To track changes in non-CO_2 emissions within the GTAP-BIO model, emissions are tied to specific drivers: factor inputs (endowments), intermediate inputs, or output (table 1).

Table 1 Mapping between emission category and emission driver (adopted from Rose and Lee, 2009)

Emission category	Emission driver
CH4 and N2O from agricultural waste burning	Sector output
CH4 from paddy rice land	Paddy rice harvested area
N2O from fertilizer application	En_Int_Ind input (include GTAP “crp” input, which, in turn, includes fertilizers)
CH4 from livestock enteric fermentation; CH4 and N2O from manure management; N2O from pasture, range, and paddock	Livestock capital
CH4 and N2O from savanna and shrubs fires	Land employed in livestock sector

Illustrative analysis of the effects of the expanded production of US corn ethanol on land use related emissions

In this illustrative example, US corn ethanol production is increased from 3.41 billion gallons per year (bg/y), observed in 2004, to15 bg/y. Economy wide changes in non-CO_2 emissions in this experiment are shown in table 2. Globally, non-CO_2 emissions increase by 8 $MtCO_2eq$. Most of the increase is observed in US (7.71 $MtCO_2eq$). Large increase in non-CO_2 emissions (14 $MtCO_2eq$) is observed in coarse grains production in US due to yield intensification and increased use of fertilizers. The increase is partially offset by reduction in non-CO_2 emissions in other sectors, most notably in fruits and vegetables (OthAgri) and energy intensive sectors. In fruit and vegetables, reduction in emissions from fertilizer application is driven by the reduction in output of this sector. In energy intensive sectors, where non-CO_2 emissions are tied to output, their reduction is directly driven by output reduction in these sectors. Changes in land use related non-CO_2 emissions (calculated as a sum of changes in emissions from agricultural sectors) is 11.6 $MtCO_2eq$.

Table 2 Changes in non-CO_2 emissions due to increased production of US corn ethanol by11.59 bg/y, $MtCO_2eq$

Sector	USA	EU27	CHIHKG	INDIA	MEAS_NAfr	S_S_AFR	Oceania	Other regions	Global
Paddy_Rice	-0.43	0.03	-0.37	-0.05	-0.04	0.10	0.00	-0.28	-1.03
Wheat	-0.60	0.10	0.15	0.02	0.07	0.03	0.01	0.16	-0.07
Sorghum	0.17	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.20
Oth_CrGr	14.20	0.00	0.13	0.00	0.05	0.00	0.01	0.15	14.54
Soybeans	-0.85	0.00	0.03	0.00	0.00	0.00	0.00	0.48	-0.34
palmf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Rapeseed	-0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.03	0.05
Oth_Oilseeds	-0.06	0.04	0.03	0.01	0.01	0.01	0.00	0.08	0.12
Sugar_Crop	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.05	-0.05
OthAgri	-1.90	0.19	0.43	0.03	0.04	0.22	0.02	0.57	-0.41
Dairy_Farms	-0.01	0.04	0.01	0.03	-0.02	-0.04	0.01	-0.10	-0.08
Ruminant	-0.28	0.15	0.10	0.22	-0.03	-0.69	0.18	-0.39	-0.74
NonRuminant	-0.35	0.04	-0.02	0.01	-0.06	-0.06	0.01	-0.01	-0.43
Cropland pasture								-0.19	-0.19
Energy and energy intensive sectors	-1.84	0.09	0.24	0.10	-0.43	-0.41	0.02	-0.67	-2.90
Private consumption	-0.32	0.04	0.01	0.00	0.00	0.00	0.00	0.01	-0.26
Total	7.71	0.73	0.75	0.38	-0.40	-0.84	0.27	-0.17	8.43

Changes in land use related emissions include CO_2 emissions from land cover change and changes in non-CO_2 emissions from agricultural activities. Using recently developed AEZ and region specific emission factors (Plevin et al. 2011), one time discharge of CO_2 emissions from land cover change in this experiment amount to 580 teragrams of CO_2 emissions, or 580 $MtCO_2$. If divided by 30 years of production, then it is about 19 $MtCO_2$ per year. Together with changes in non-CO_2 land use related emissions, total land use related emissions increase due to expanded US ethanol production is about 30 $MtCO_2eq$ per year.

References

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