AGRICULTURAL POLICY REPORTS
MAY 2017

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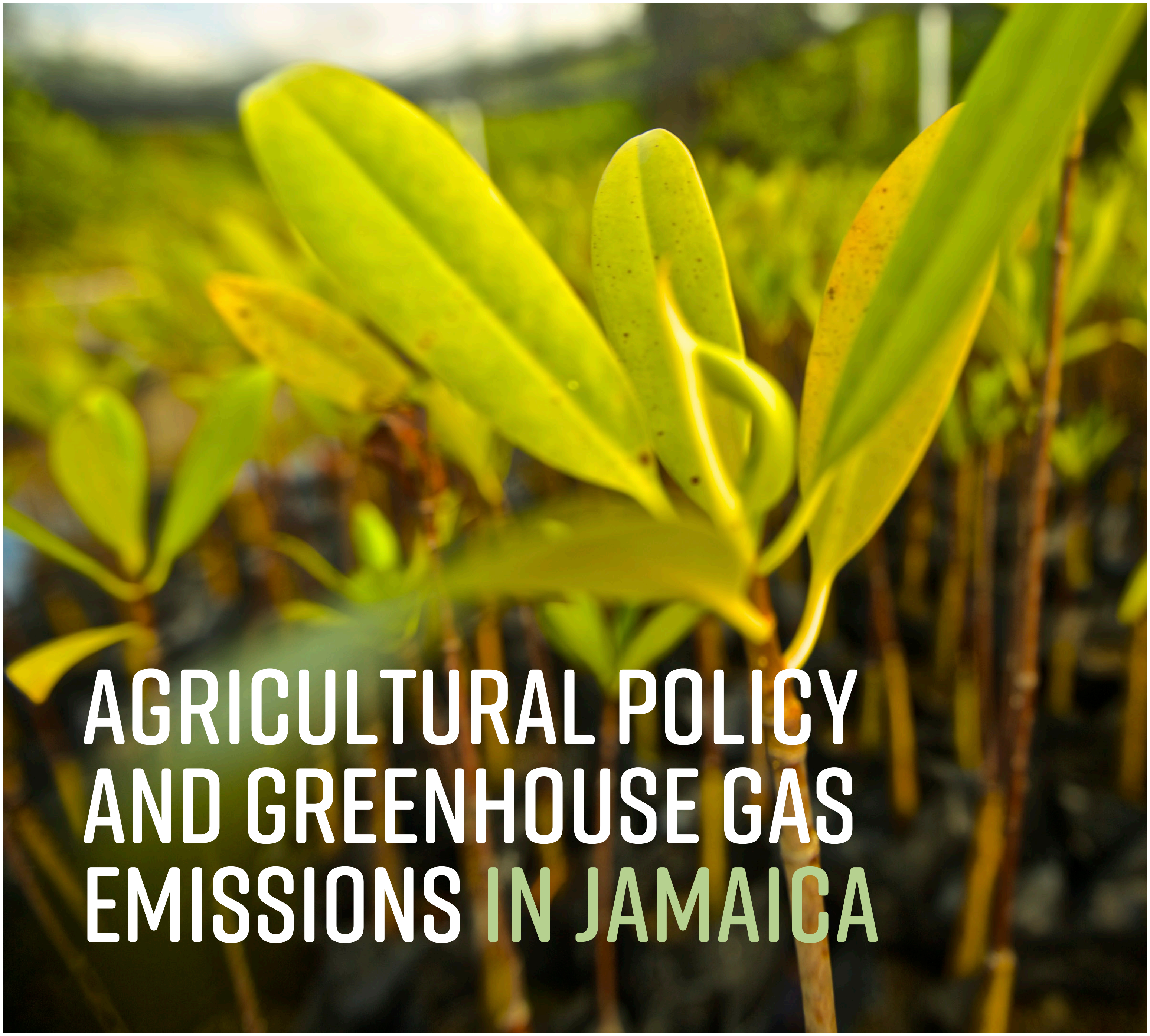

AGRICULTURAL POLICY AND GREENHOUSE GAS EMISSIONS IN JAMAICA

IDB

Cataloging-in-Publication data provided by the Inter-American Development Bank Felipe Herrera Library.
Agricultural policy and greenhouse gas emissions in Jamaica.
Tim Josling, Gerard Alleng, Carmine Paolo De Salvo, Rachel Boyce, Anaitée Mills, Sara Valero.
p. cm. — (IDB Monograph ; 529)
Includes bibliographic references.
1. Agriculture and state-Jamaica. 2. Greenhouse gas mitigation-Jamaica. 3. Agricultural pollution-Jamaica. I. Josling, Tim, 1940- II. Alleng, Gerard P. III. De Salvo, Carmine Paolo. IV. Boyce, Rachel. V. Mills, Anaitée. VI. Valero, Sara. VII. Inter-American Development Bank. Environment, Rural Development and Disaster Risk Management Division. VIII. Series.
IDB-MG-529

Authors: Tim Josling, Gerard P. Alleng, Carmine Paolo De Salvo, Rachel Boyce, Anaitée Mills, and Sara Valero.
Keywords: Climate Change, Greenhouse Gas Emissions, Agriculture, Public Policy, Agricultural Policy.
JEL Codes: O54 Latin America; Q01 Sustainable Development; Q15 Agriculture and Environment; Q18 Agricultural Policy; Q54 Global Warming; Q58 Government Policy.

Published May 2017
Design and Layout: Elena Sampedro | elena@lacasagrafica.com
Photo credits: IADB Photo Library
Series of Publications on Monitoring Agricultural Policy

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ACKNOWLEDGMENTS

The authors would like to thank those who participated in a presentation of the initial results in Kingston, Jamaica, in June 2016, and in subsequent discussions of the paper at UC Davis, California State University Fresno, and Texas A&M University. In addition, the authors would like to thank David Blandford, Olga Shik, Pedro Martel and Joseph Milewski for their comments on the manuscript, which improved the quality of the document. The authors are grateful to Rajiv Ebanks, Yolanda Valle Porrua, and Juan Jose Egas for providing logistical and editorial support. None of these people should be held responsible for the content of this paper.

ABSTRACT

This document presents the results of a study that combines data on the emission of greenhouse gasses (GHG measured in CO_2 equivalents) from farming activities with the incidence of policy incentives (transfers to the farming sector as measured in the Agrimonitor database) for Jamaican agriculture. The report's objective is to look at Jamaican agricultural policy from the viewpoint of greenhouse gas emissions in the context of attempts to ensure consistency among policy objectives and nationally established targets related to the current climate change discourse. Specifically: Are the products that contribute the most to GHG emissions also those that receive the most protection? Or are the incentives emerging from policy in line with GHG emission mitigation objectives?

LIST OF ABBREVIATIONS

ACE | Agricultural Carbon Equivalent

CO_2E | Carbon Dioxide Equivalent

GHG | Greenhouse Gas

GOJ | Government of Jamaica

INDC | Intended Nationally Determined Contributions

IPCC | Intergovernmental Panel on Climate Change

NSV | Net Social Value

PCST | Producer Commodity Specific Transfers

PSE | Producer Support Estimate

UN | United Nations

UNFCCC | United Nations Framework Convention on Climate Change

VoP | Value of Production, or Production Value

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INTRODUCTION

The Government of Jamaica (GOJ) has an obligation to communicate greenhouse gas (GHG) emission levels to the United Nations (UN), under the provisions of the UN Framework Convention on Climate Change (UNFCCC). The first such communication took place in 2000, with a second communication in 2011. A study conducted for the third National Communication brings the data up to 2012 **(Aether, 2015)**. In this context, the farming sector's contribution to the "inventory" of Jamaican GHG emissions is of interest in the debate on ways to mitigate such emissions, and will become even more significant as comprehensive attempts are made to reduce GHG emissions in the economy.

The Paris Climate Change Agreement of December 2015 (COP 21) called for "Intended Nationally Determined Contributions" (INDC) to be defined by signatories. INDC levels for the countries of the Caribbean are reported in a recent IICA study (IICA, 2016). All but one of the Caribbean countries have included agriculture as a relevant sector in terms of GHG emissions and potential for GHG reductions. Jamaica's participation in this global effort will require some adjustments, including to its agriculture sector.[1]

AGRICULTURAL DEVELOPMENT IN JAMAICA IS IMPORTANT TO THE COUNTRY'S ECONOMIC AND SOCIAL FABRIC.

At the same time, agricultural development in Jamaica is important to the country's economic and social fabric. The FAO and IDB conducted several studies to assess policy's contribution to agricultural development; the first one measured producer support estimates (PSEs) for the sector, following the methodology used by the OECD in its monitoring of the agricultural policies of its members (IDB/FAO, 2012). This information has been updated to 2014 in the current report and is contained in the **IDB Agrimonitor database**, which covers many of the countries of Latin America and the Caribbean (IDB, 2016).[2]

An additional study, looked at agriculture taxation in Jamaica and calculated the benefits provided to the sector through the tax code (FAO, 2012). And a third study examined the question of the vulnerability of Jamaican agriculture to extreme weather events (IDB/FAO, 2013). Though not limited to events linked to climate change, the results emphasize that Jamaica is a high weather-risk country and that the agricultural sector is particularly vulnerable. This study builds on the analysis of the earlier studies and brings together the information necessary to assess consistency among objectives. In particular, it focuses on GHG emissions from the agricultural sector, an issue not covered in the study of the impact of climate change on the agricultural sector. It also attempts to bring prior analyses of policy incentives up to date by using the most recent data available.

THOUGH NOT LIMITED TO EVENTS LINKED TO CLIMATE CHANGE, THE RESULTS EMPHASIZE THAT JAMAICA IS A HIGH WEATHER-RISK COUNTRY AND THAT THE AGRICULTURAL SECTOR IS PARTICULARLY VULNERABLE.

The Aether study and the Agrimonitor database provide a welcome opportunity to address the question of the link between, on the one hand, commodity policies that provide support for particular sectors, and on the other, the environmental impact of those sectors as measured by their contribution to GHG emissions. The matching of GHG emission data with policy support is not precise, as emissions are dependent on farming practices and other conditions that can vary, and the policy incidence depends on the market conditions as well as the details of policy administration. But the result of the comparison presented in this study provides a starting point for more detailed research into the links between farm and climate change policy.

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[1] Jamaica is not an Annex 1 country under the current climate change agreement and therefore has not so far been required to undertake reductions. However, the nature of the INDC targets are "voluntarily mandatory" in that by signing and ratifying the agreement, the countries concerned commit to their targets.

[2] For more detail on the Agrimonitor database see http://www.iadb.org/en/topics/agriculture/agrimonitor/agrimonitor-pse-agricultural-policy-monitoring-system,8025.html

DATA AND METHODS

The data on GHG emissions was combined with the policy transfer data in a way that focused on the correspondence between commodity policy indicators and climate change measures. Some assumptions were required to make the mapping possible that involved allocating various activities responsible for GHG emissions to individual commodities. The most important of these assumptions are:

1. THE EMISSIONS DATA FROM THE AETHER STUDY cover direct GHG release from the farming activity itself. The farms' use of fuel is also captured along with corresponding data from other sectors (energy, transportation, etc.) in the Jamaica inventory. The focus in the Aether report is on direct emissions from livestock and from crop cultivation. In this study, we attempt to include the GHG emissions from farm use of fuel and energy inputs based on additional information found in other parts of the Aether data files. This requires some additional assumptions about the nature of fuel and energy use per crop. (Additional details on the methods used are given in Annex B.)

2. SEQUESTRATION OF GHG BY AGRICULTURAL PRODUCTS

is not measured in the Aether study. The positive contribution of crops —in particular tree crops— due to GHG absorption needs to be included in the accounting in order to take into consideration this key aspect of land use. In the UN inventory the category of GHG accounting known as Land Use and Land Use Change and Forestry was calculated but was not specifically included in the agricultural inventory. Sequestration estimates were recorded in the Aether database under the heading "changes from forestry to other uses." However, in the absence of data on sequestration by agricultural crops such as coffee and sugar, some preliminary estimates are incorporated into our study to close this informational gap.[3]

3. DIFFERENT SETS OF CROPS AND LIVESTOCK ACTIVITIES

were included in the Aether study and the FAO/IDB estimates in the Agrimonitor database. Aether groups 56 crops into 13 categories, along with eight livestock sectors. Some crops such as cocoa are not considered separately in that commodity list. The Agrimonitor database identifies 10 crops, including cocoa, and five livestock types. It does not provide separate support estimates for pulses, condiments, plantain, tubers, or sorrel, though there is a category for "other products." On the livestock side, Agrimonitor does not include support estimates for turkeys, horses, mules, sheep, or rabbits. More significantly, goats are not included in the Agrimonitor database (there are no specific goat sector policies) whereas Aether includes them as a class of livestock that is important in the Jamaican livestock sector. In our study, the emphasis is on those products that are included in the Agrimonitor database and account for about 70 percent of the value of production in Jamaica. The mapping of the two data sets is described below.

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[3] The sequestration issue remains a cloudy one as far as measurement and reporting of GHG emissions. Different countries use different sequestration measures when reporting to the UNFCCC. The UNFCCC does not fully incorporate these data, explaining that "since the communicated amounts by the Parties to the Convention in many cases did not include data on emissions by source and removals by sinks from land use, land-use change and forestry, or when included these emissions by source and removals by sink were estimated using different methodologies, these data were not included."

GHG EMISSIONS

The Aether study collected data on the types of emissions that are shown in Table 1. The magnitude of these emissions was calculated by estimating the use (in Gigagrams) of GHG emitting products such as nitrogen fertilizer (synthetic nitrogen and urea) and limestone, and taking into account hectares of organic farming. The IPCC emissions factors were used to convert these quantities into estimated N_2O emissions —both direct and indirect— from managed soils. Similarly, CO_2 emissions from liming, N_2O emissions from urea, and corresponding GHG emissions from rice cultivation and biomass burning were derived. Adding up the GHG estimates for these different types of activity and converting them to the CO_2 equivalent enabled Aether to come up with an estimate of the GHG emissions from soils (and by implication the crops grown in those soils).

THE MAGNITUDE OF THESE EMISSIONS WAS CALCULATED BY ESTIMATING THE USE OF GHG EMITTING PRODUCTS, AND TAKING INTO ACCOUNT HECTARES OF ORGANIC FARMING.

The contribution of individual crops to the total is not calculated in the Aether report though it includes data on hectarage and production for many crops.[4] The data on hectarage is used in the Aether study to estimate land for three different crop types: nitrogen-fixing crops (such as dry beans), non-nitrogen fixing grain crops (such as corn and rice), and roots and tubers (such as potatoes). These groups were designed to correspond to emission factors identified in the IPCC guidelines (2006). We used this information in our study to check assumptions on the use of fertilizer needed to estimate GHG emissions from individual commodities.

TABLE 1: LIST OF CATEGORIES AND EMISSIONS (GASES) ESTIMATED IN THE AETHER STUDY

Source: Aether (2015), page 1.

SOILS
• DIRECT EMISSIONS FROM MANAGED SOILS: N_2O (SYNTHETIC/ORGANIC/GRAZING ANIMALS/CROP RESIDUES)
• INDIRECT EMISSIONS FROM MANAGED SOILS: N_2O (SOIL DEPOSITIONS/LEACHING, RUNOFF)
• LIMING: CO_2
• UREA APPLICATION: N_2O
• RICE CULTIVATION: CH_4
• BIOMASS BURNING: CO / NO_X / N_2O / CH_4 / NMVOC
• INDIRECT GHG: NO_X / NMVOC

LIVESTOCK
• ENTERIC FERMENTATION: CH_4
• MANURE MANAGEMENT: CH_4 / N_2O
• INDIRECT EMISSIONS FROM MANURE MANAGEMENT: NMVOC / NO_X / CO

The calculations for livestock emissions are given in much more detail in the Aether study. The population numbers are given for the major types of livestock, based on government sources. The emission factors were again drawn from the IPCC Guidelines (IPCC 2006). The calculations for livestock emissions by livestock category are dominated by N20 from manure management and CH_4 from enteric fermentation.[5]

[4] Aether uses the 2006 IPCC Guidelines, both Tier 1 and Tier 2 methods, depending on the availability of data. For emission coefficients the study takes an average of North American and Latin American (intensive and extensive) assumptions.

[5] Enteric fermentation refers to the release of methane from the fermentation of feed as a part of the normal digestive process of ruminants. Some methane is released by anaerobic management of manure. N_2O is released in the breakdown of nitrogen in manure and urine.

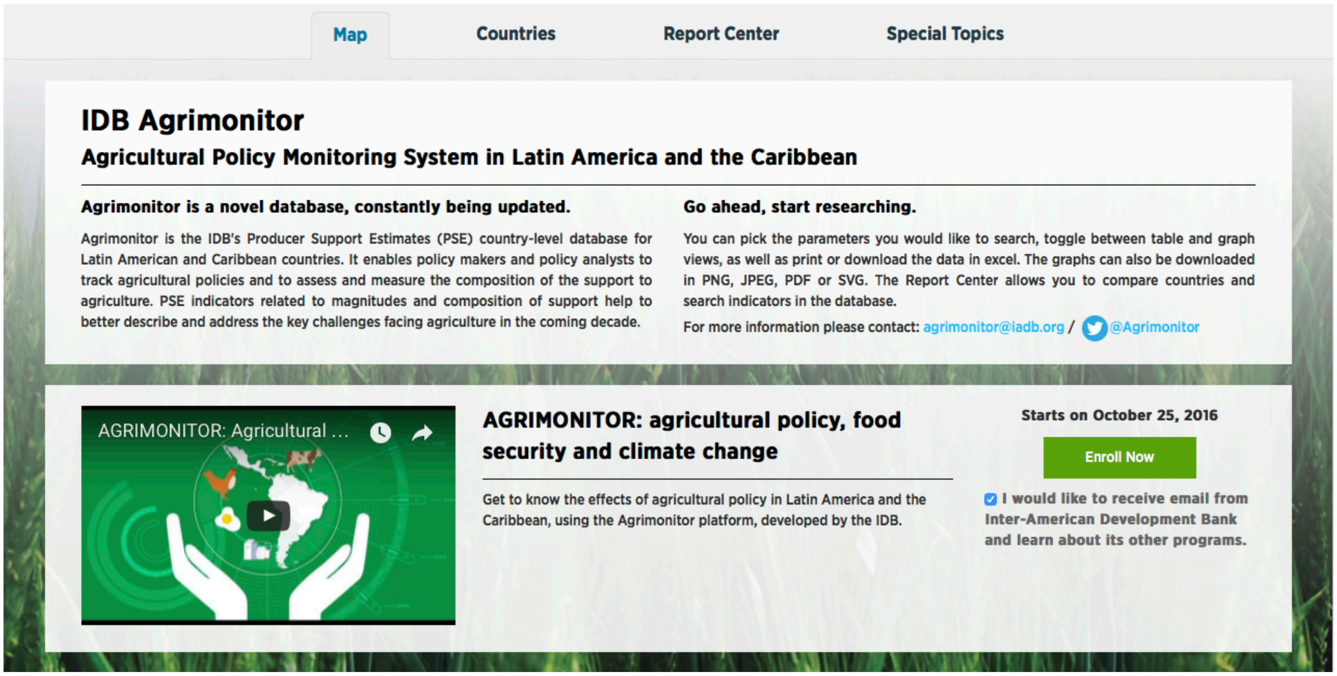
The 2006-2014 emissions average based on the various categories of activity noted above as estimated in the Aether study are given in Table 2 (annual figures are shown in Annex Table 3). The total GHG emissions from agriculture for 2012 were estimated at 4,336 Gg CO_2 equivalent. The average for the period 2006 to 2014 as shown was 3,765 Gg CO_2 equivalent.[6] Of the various contributions to this total, N_2O from manure management accounts for 43 percent of total crop and livestock emissions. Other major contributions came from N_2O emissions from organic fertilizer and soil leaching.

TABLE 2: **GHG EMISSIONS IDENTIFIED IN AETHER REPORT**

			AVE 2006-2014
SYNTHETIC N FERTILIZER		Gg NO_2/yr, CO_2 e	35.7
ORGANIC N FERTILIZER		Gg NO_2/yr, CO_2 e	1,390.7
CROP RESIDUES		Gg NO_2/yr, CO_2 e	6.6
DRAINED/MANAGED ORGANIC SOILS		Gg NO_2/yr, CO_2 e	64.4
INDIRECT N_2O EMISSIONS:	SOILS DEPOSITION	Gg NO_2/yr, CO_2 e	4.1
	SOILS LEACHING/RUNOFF	Gg NO_2/yr, CO_2 e	459.5
EMISSIONS OF CO_2 FROM LIME		Gg CO_2	0.2
EMISSIONS OF CO_2 FROM UREA APPLICATION		Gg CO_2	1.5
EMISSIONS OF CH_4 FROM RICE CULTIVATION		Gg CH_4/yr, CO_2 e	0.2
EMISSIONS OF CH_4 FROM FIELD BURNING		Gg CH_4/yr, CO_2 e	6.0
EMISSIONS OF N_2O FROM FIELD BURNING		Gg NO_2/yr, CO_2 e	1.9
TOTAL		**Gg CO_2 e**	**1,970.9**
GHG EMISSIONS FROM LIVESTOCK:	GRAZING ANIMALS	Gg NO_2/yr, CO_2 e	304.3
	ENTERIC FERMENTATION (CH_4)	Gg CH_4/yr CO_2 eq	139.9
	MANURE MANAGEMENT (CH_4)	Gg CH_4/yr CO_2 eq	106.9
	MANURE MANAGEMENT (N_2O)	Gg NO_2/yr, CO_2 e	1,613.7
TOTAL		**Gg CO_2 e**	**2,104.5**
TOTAL CROPS AND LIVESTOCK		**Gg CO_2 e**	**4,075.4**

[6] This total was obtained by adding each of the individual emission categories in the Aether study. The FAO GHG database indicates a total emission of only 904 Gg CO_2e on average for Jamaican agriculture over the period 1990-2012, the total falling from 1,063 Gg in 2003 to 636 Gg in 2012 (FAO, 2014).

ALLOCATION OF EMISSIONS TO AGRIMONITOR COMMODITIES



The GHG emissions were allocated to the commodities identified in the Agrimonitor database using the information updated to 2014.

Allocation of the total emissions estimated for soil management (direct and indirect N_2O emissions from fertilizer and crop residues) required several steps. The Aether study provides a breakdown of the land area and production (harvested weight) from Ministry of Agriculture and Fisheries data but not of GHG emissions by individual commodities. To map them to policy incentives, assumptions had to be made as to each commodity's individual contribution to total emissions. The Aether data on area per commodity harvested are grouped under 13 headings. Allocating GHG emissions by individual commodity required emissions to first be allocated to these groupings. The mapping of these groups to the Agrimonitor commodities is provided in Table 3. This mapping is then used to estimate soil management emissions per commodity in the Agrimonitor data by scaling it according to the share of that commodity in the Aether group (Annex B gives an example of this calculation.)[7]

THE AETHER STUDY PROVIDES A BREAKDOWN OF THE LAND AREA AND PRODUCTION (HARVESTED WEIGHT) FROM MINISTRY OF AGRICULTURE AND FISHERIES DATA BUT NOT OF GHG EMISSIONS BY INDIVIDUAL COMMODITIES.

The Aether data spreadsheets do provide an estimate of emissions from fuels used in farming activities associated with agricultural commodities. This data is not broken down by specific activity, such as land preparation; fertilizing and weed control; and harvesting.

TABLE 3: **CORRESPONDENCE BETWEEN AETHER AND AGRIMONITOR SECTORS**

AETHER CATEGORIES		INDIVIDUAL COMMODITIES	AGRIMONITOR COMMODITIES
CROP CATEGORIES	PULSES	–	(NONE)
	VEGETABLES	TOMATO	TOMATOES
	CONDIMENTS	–	(NONE)
	FRUITS	PINEAPPLE	PINEAPPLE
	CEREALS:	HYBRID CORN	CORN
	CEREALS:	ORDINARY CORN	CORN
	CEREALS:	SWEET CORN	CORN
	PLANTAIN	–	(NONE)
	POTATOES:	IRISH POTATO	(NONE)
	POTATOES:	SWEET POTATO	SWEET POTATO
	YAMS	VARIOUS TYPES	YAMS
	TUBERS (OTHER)	–	(NONE)
	SORREL	–	(NONE)
	SUGAR CANE	–	SUGAR (REFINED)
	BANANA	–	BANANAS
	COFFEE	–	COFFEE
	(NONE)	–	COCOA
	(NONE)	–	ORANGES
	(NONE)	–	OTHER PRODUCTS
LIVESTOCK CATEGORIES	CATTLE:	DAIRY	MILK
	CATTLE:	OTHER	BEEF
	POULTRY:	BROILER	POULTRY
	POULTRY:	LAYER	EGGS
	POULTRY:	OTHER (TURKEY, ETC)	(NONE)
	GOATS	–	(NONE)
	HORSES	–	(NONE)
	MULES AND ASSES	–	(NONE)
	PIGS	–	PIGMEAT
	SHEEP	–	(NONE)
	RABBIT	–	(NONE)

In addition, many crops require some first stage processing and transportation to get them to market. Each of these activities use fuel and energy, and thus a full inventory for agriculture would include the GHG emissions from these processes.[8] In the absence of information with this level of detail, we calculated fuel use in field operations, harvesting, and processing (Annex B describes how we did this). As far as energy use, national totals were scaled down to match the agriculture's approximate share of total use of energy in the Jamaican economy.

The Aether report's livestock categories match more conveniently with the sector breakdowns in the Agrimonitor database. Enteric fermentation estimates can thus be used with minimal reallocation. Direct and indirect manure management and animal grazing emissions can likewise be allocated to the livestock sectors. Aether's emissions estimates for the different livestock groups are placed on the worksheets according to Agrimonitor livestock product. Livestock emission levels are thus based on Aether, with little need for modification.

TABLE 4: **GHG EMISSIONS BY AGRIMONITOR CATEGORIES OF PRODUCTS**

		AVE 2006-2014
CORN	Gg CO_2 e	10.4
SUGAR	Gg CO_2 e	762.9
BANANAS	Gg CO_2 e	244.4
COFFEE	Gg CO_2 e	146.2
COCOA	Gg CO_2 e	22.7
ORANGES	Gg CO_2 e	18.0
PINEAPPLE	Gg CO_2 e	13.1
TOMATOES	Gg CO_2 e	12.6
SWEET POTATO	Gg CO_2 e	70.2
YAMS	Gg CO_2 e	215.4
MILK	Gg CO_2 e	98.0
BEEF	Gg CO_2 e	386.8
PIGMEAT	Gg CO_2 e	174.8
POULTRY	Gg CO_2 e	1,505.4
EGGS	Gg CO_2 e	41.3
OTHER PRODUCTS	Gg CO_2 e	109.2
TOTAL	Gg CO_2 e	**3,831.2**

GHG emissions according to the Agrimonitor product categories are shown in Table 4. Total GHG emissions under the two different product groupings are within range of each other: 3,765 Gg CO_2e in the case of the Aether groups and 3,831 Gg CO_2e for the Agrimonitor categories.

Once included in the worksheets based on the Agrimonitor commodities, comparison with policy transfers is straightforward, using the Agrimonitor database's Producer Commodity Specific Transfers (PCST) indicator. This indicator measures the transfers that are specific to a particular commodity and thus provide direct incentives to produce that crop or animal product.

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[7] The inclusion of an "other products" category in the Agrimonitor database picks up some of the commodities that are included in Aether but not separated out in Agrimonitor.

[8] The data sent to the UNFCCC includes fuel and energy as separate sectors. Allocation to various farming activities is not necessary under the IPCC guidelines for the inventory. The Aether spreadsheets contain detailed allocations for fuels used in sugar and in "agriculture, forestry, and fisheries" production. Assumptions were made to scale this back to fuels used in agricultural product activities.

COMPARISON AMONG SECTORS

The contributions to total agriculture GHG emissions of the sectors identified in the Agrimonitor database are detailed in Table 5. The first three columns of the table indicate the average annual share of the value of output, share of commodity-specific support, and share of the GHG emissions for 2006-2014 (Annex Tables 1, 2, and 4 list the annual values of these variables).

The share of total production value (column 1) shows that three products are dominant: poultry, yams, and sugar, along with a composite group of "other products" which mainly includes vegetables, pulses, and condiments. Over one quarter of the value of Jamaican agricultural production comes from the poultry (broiler) sector. The share of total transfers by sector (column 2) reflects policy priorities. Single commodity transfers by sector vary significantly in Jamaica and appear unrelated to production value. The sugar sector's share of transfers, for instance, is four times its share of production value. The poultry sector receives an overwhelming share of the transfers, as reported elsewhere (FAO/IDB, 2012). As several commodities have negative transfers (usually because farm prices are well below the reference prices

THREE PRODUCTS ARE DOMINANT: POULTRY, YAMS, AND SUGAR, ALONG WITH A COMPOSITE GROUP OF "OTHER PRODUCTS" WHICH MAINLY INCLUDES VEGETABLES, PULSES, AND CONDIMENTS.

for those commodities) total support to the poultry sector from commodity-specific policies is greater than the net total for the whole sector.

Are the sectors that account for most of the value of output also those with greatest GHG emissions (column 3)? The relationship is certainly not direct, as some products that have a low profile in terms of the production value still contribute significantly to GHG emissions. Bananas account for less than 3 percent of production value, but the sector accounts for 6 percent of GHG emissions. The poultry sector is responsible for almost 40 percent of the GHG emissions, exceeding its high share of total production value (26 percent).[9] Due to the significance of enteric fermentation by ruminants, the beef sector appears responsible for 10 percent of the total agriculture GHG emissions, though it only contributes 3 percent of the value of output.

TABLE 5: **SHARE OF AGRIMONITOR COMMODITIES IN SUPPORT AND EMISSIONS, 2006-2014**

Source: Author's calculations based on Agrimonitor and Aether.

SOILS	VALUE OF OUTPUT (VOP)	SINGLE COMMODITY TRANSFER (PSCT)	GREENHOUSE GAS EMISSIONS (GHG)	AGRICULTURAL CARBON EMISSIONS (ACE)	NET OUTPUT VALUE (VOP-SCT-ACE)
CORN	0.79%	5.14%	0.27%	0.24%	0.15%
SUGAR	8.25%	31.91%	19.91%	16.50%	4.05%
BANANAS	2.89%	3.23%	6.38%	4.22%	2.75%
COFFEE	1.34%	-12.52%	3.82%	2.30%	3.43%
COCOA	0.22%	-0.38%	0.59%	0.17%	0.32%
ORANGES	1.36%	-9.34%	0.47%	0.35%	3.09%
PINEAPPLE	2.07%	-4.88%	0.34%	0.28%	3.26%
TOMATOES	3.09%	-0.13%	0.33%	0.29%	3.76%
SWEET POTATO	3.72%	-19.87%	1.83%	1.55%	7.52%
YAMS	12.14%	-12.43%	5.62%	4.76%	16.43%
MILK	0.80%	0.36%	2.56%	21.42%	-0.43%
BEEF	2.71%	-0.20%	10.10%	8.19%	2.82%
PIGMEAT	2.56%	-11.04%	4.56%	3.64%	4.61%
POULTRY	26.43%	141.66%	39.29%	32.84%	8.12%
EGGS	2.67%	0.93%	1.08%	0.88%	3.06%
OTHER PRODUCTS	28.96%	-12.43%	2.85%	2.40%	37.06%
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Another sector that contributes significantly to GHG emissions is sugarcane, which accounts for about 19 percent of total GHG emissions but contributes only 8 percent of the total value of agricultural output. Coffee and bananas also contribute significantly to GHG emissions. Sweet potatoes and yams, pineapples and other products (mostly vegetables) contribute less to GHG emissions than would be expected according to their share in the value of production. The implications for policy are discussed below.

The importance of accounting for crop sequestration was mentioned above. Measurements of GHG emissions associated with agricultural activities should take into account the carbon stored in growing plants, soil, and organic matter (carbon sinks). Again, because consistent and comprehensive data is not available, sequestration amounts for crops were estimated using limited studies on individual tree crops.[10] Sequestration amounts are included in the calculations in the next section on the cost of agricultural carbon emissions by crop, as ignoring these benefits would skew the estimates against tree crop and sugar cane production.[11]

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[9] The high GHG emissions from the poultry sector mainly come from manure management. This illustrates the importance of soil management as a way of reducing GHG emissions. Poultry production is a relatively efficient way of converting grain-based feed into protein. Evidence from the FAO suggests that this gives poultry an advantage over other livestock products in terms of GHG emissions per unit of protein produced (Gerber, et al. 2013). But much hinges on the type of waste management employed by the sector.

[10] Annual crops also sequester carbon, but it is largely released after harvest and therefore is not relevant for GHG accounting on an annual basis. The use of plant material as fertilizer is included in the GHG inventory under soil management.

[11] In the case of sugar cane, another important assumption needs to be made. The use of bagasse (a by-product from the sugar mills) as a source of fuel is an important part of the sugar economy. The burning of bagasse releases greenhouse gasses, but the amount of CO_2 emitted is generally less than the CO_2 absorbed by the sugar cane during the growing stage. The tables below thus assume that use of bagasse as a fuel in agriculture does not make a net GHG emission contribution. In broader terms, as a biofuel, bagasse contributes to reducing fossil fuel use.

COSTING EMISSIONS

The goal of this report is to analyze GHG emission estimates alongside the incentives provided by agricultural (commodity) policy. In order to do these, we use a common unit: money. That is, the monetary value of GHG emissions and the monetary value of transfers based on commodity output. **This requires that we estimate a carbon price so the cost of GHG emissions can be compared to the cost of financial transfers to the producers of particular commodities.**

WE USE A COMMON UNIT: MONEY. THE MONETARY VALUE OF GHG EMISSIONS AND THE MONETARY VALUE OF TRANSFERS BASED ON COMMODITY OUTPUT.

There is no carbon price, in the sense of an observable market price applicable globally. However, at least 44 countries now have carbon markets in which permits for CO_2 emissions are traded on exchanges. Thus, we can propose a cost for CO_2 emissions by either assuming the Jamaican agricultural sector has to purchase such permits in a carbon marketplace or that the government taxes the sector to offset the cost of carbon emissions. In either case, it is straightforward to apply a price to carbon emissions to arrive at a financial equivalent of GHG emissions. The price chosen for a unit of CO_2 or equivalent is a key assumption. The figure underlying the tables presented here is US$10 per metric ton of carbon dioxide. The price on the carbon markets in countries in the region is somewhat lower than this ($5 per ton in Chile and up to $4 in Mexico). However, the carbon price tends to be much higher in other regions: $62 in Switzerland and $16 in France and the UK (IMF sources).[12]

The unit used here to represent this financial equivalent is called the agricultural carbon equivalent (ACE), expressed as a value in local currency. The GHG emission data is thus expressed in terms of J$ and modified to account for sequestration. Commodities' share of the total ACE is indicated in Table 5 (column 4) for 2006-2014. (The annual values are provided in Annex Table 5). The shares are broadly comparable to those of the GHG emissions, as in most cases, the sequestration adjustment is not large. However, some products such as sugar cane, bananas, coffee, and cocoa contribute less to the ACE than to GHG emissions due to carbon sequestration, which offsets some of the cost of GHG emissions.

[12] The distinction must be made between the carbon price in Jamaica that would encourage a reduction in the emissions identified in the INDC (i.e. the internal carbon price) and the price that if adopted by all countries would achieve a reduction in global warming of a target amount (the external carbon price). The latter is discussed in Kossoy, et al, 2015. Had the Paris accord chosen to regulate GHG emissions through a global carbon price then the two prices would be similar.

NET VALUATION OF COMMODITIES

Putting GHG emissions in a monetary unit allows for an interesting comparison between GHG costs and the value of farm output. For example, we can look at the production value minus the carbon emission cost (ACE). The result only marginally changes the sector ranking. Poultry still dominates, with about 26 percent of total production value net of externalities, the same as for current total production value. Sugar cane also appears to contribute about 8 percent to the agricultural economy even when the cost of emissions is considered. Similarly, yams account for about 12 percent of the value of output whether or not the ACE is taken into account. The ACE is relatively small when compared to the value of production.

WE CAN LOOK AT THE PRODUCTION VALUE MINUS THE CARBON EMISSION COST (ACE). THE RESULT ONLY MARGINALLY CHANGES THE SECTOR RANKING.

These relative shares are illustrated in Figures 1 and 2 on the following page. Figure 1 shows the average share of production by commodity for 2006-2014, while Figure 2 shows the share when the costs of GHG emissions is included. (Annual numbers are provided in Annex Table A6.)

FIGURE 1: **SHARES IN VALUE OF PRODUCTION, AVERAGE 2006-2014**

COCOA	0.2%
CORN	0.8%
MILK	0.8%
COFFEE	1.3%
ORANGES	1.4%
PINEAPPLE	2.1%
PIGMEAT	2.6%
EGGS	2.7%
BEEF	2.7%
BANANAS	2.9%
TOMATOES	3.1%
SWEET POTATO	3.7%
SUGAR	8.2%
YAMS	12.1%
POULTRY	26.4%
OTHER PRODUCTS	29.0%

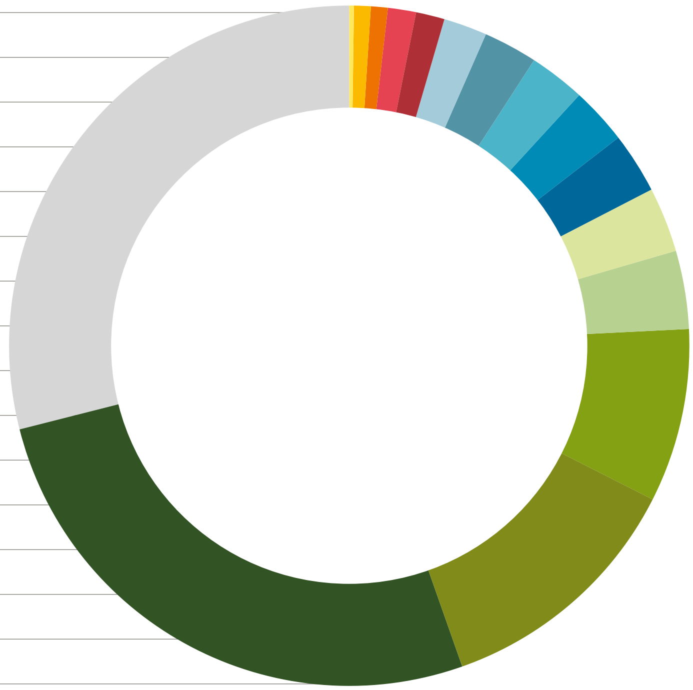
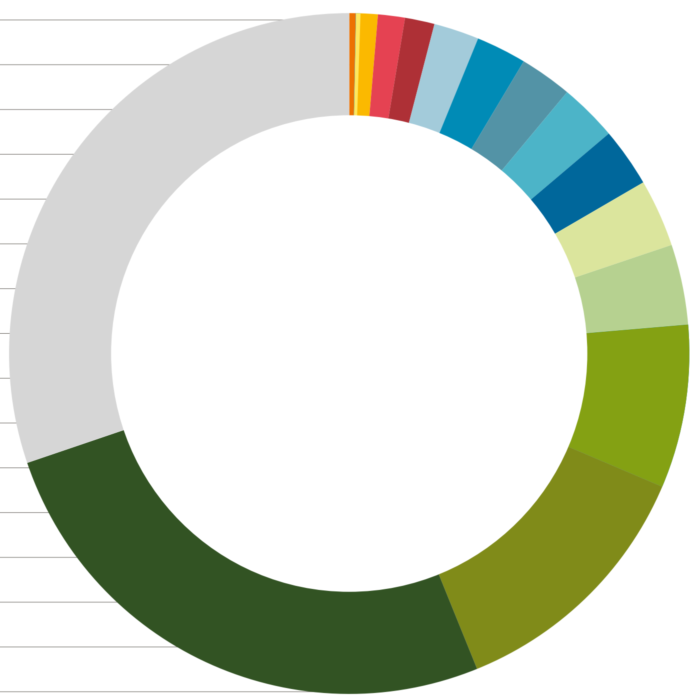


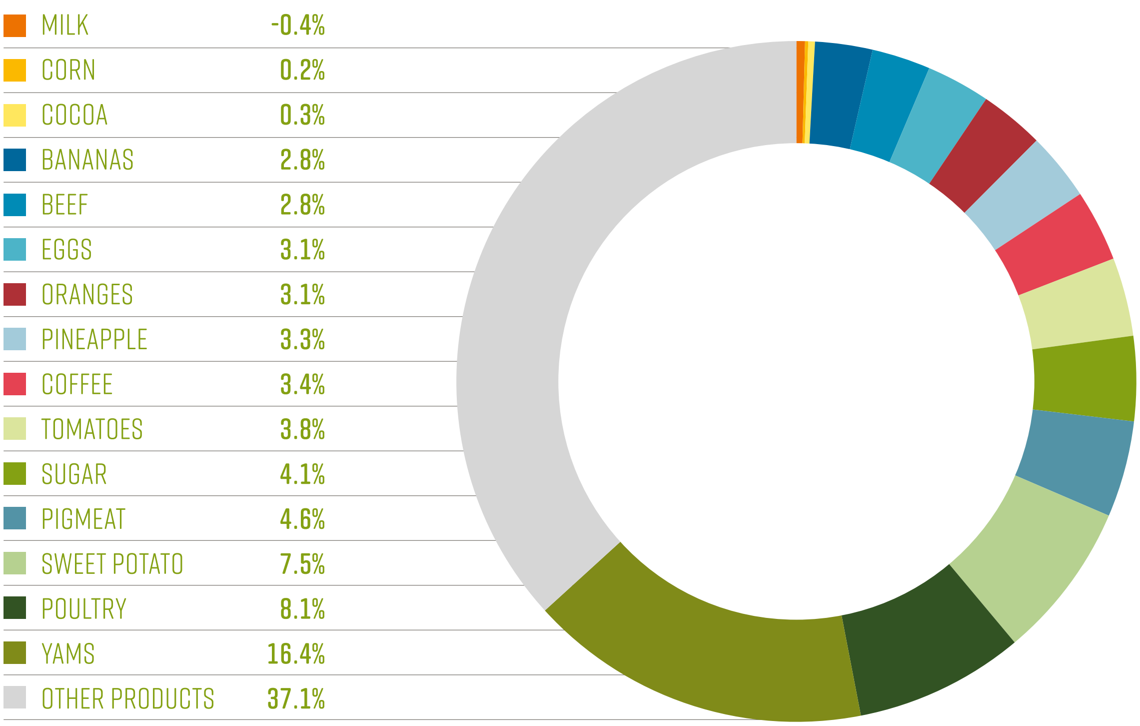
FIGURE 2: **SHARES IN VALUE NET OF ACE (2006-2014)**

MILK	-0.3%
COCOA	0.2%
CORN	0.8%
COFFEE	1.3%
ORANGES	1.4%
PINEAPPLE	2.2%
BEEF	2.4%
PIGMEAT	2.5%
EGGS	2.8%
BANANAS	2.8%
TOMATOES	3.2%
SWEET POTATO	3.8%
SUGAR	7.8%
YAMS	12.5%
POULTRY	26.1%
OTHER PRODUCTS	30.4%



To link GHG emissions with agricultural policy, we must take the further step of subtracting the combined GHG emission impact (ACE) and transfers from commodity-specific policy (SCT) from the total production value. The results of this calculation are shown in Figure 3, with the annual data provided in Annex Table 7. The result is the total production value net of both the cost of carbon emissions and transfers through agricultural policy. What this essentially calculates is the total production value (assuming no change in hectarage or cattle numbers) if producers had to pay for the GHG emissions and were obliged to forgo the transfers through the commodity-specific programs, which is a rough approximation of the value of output at world prices with a carbon tax offsetting GHG externalities. This in turn gives a partial estimate of the net social value (NSV) of the sector's output from the sector.[13]

FIGURE 3: **SHARES IN VALUE NET OF ACE AND SCT (2006-2014)**



Estimating the positive contribution of the Jamaican agricultural sector to the economy (VoP-SCT-ACE) tells a significantly different story about the importance of various crops and livestock products when these adjustments are made. Crops with relatively little support (or in several cases negative support) and a low ACE value turn out to make a more significant contribution to the net benefits of the agricultural sector. Those with significant support and high levels of GHG emissions make up a smaller share of the sector's net benefit.

CROPS WITH RELATIVELY LITTLE SUPPORT (OR IN SEVERAL CASES NEGATIVE SUPPORT) AND A LOW ACE VALUE TURN OUT TO MAKE A MORE SIGNIFICANT CONTRIBUTION TO THE NET BENEFITS OF THE AGRICULTURAL SECTOR.

The NSV of the poultry sector is among the most revealing results. The poultry subsector's contribution to the NSV of the agricultural sector is only 8.1 percent, compared to 26 percent before the impact of policy is considered. The NSV of sugar cane is 4.1 percent, compared to 8 percent before policy transfers are taken into account. Beef contributes less than 3 percent to production NSV. However, sweet potatoes contribute 7.5 percent of total NSV (compared to less than 4 percent of the gross production value). Yams (16%) and other products (37%) are also more significant when GHG emissions and policy transfers are considered. This latter category consists mainly of vegetables and other annual crops that have no or only limited price support policies, use less inorganic fertilizer, and have no issues with manure management.

[13] A full NSV calculation would have to take account of all external costs and benefits from the sector besides GHG emissions and policy actions.

INTERPRETATION OF RESULTS

The main objective of combining GHG emission data with data on policy transfers is to measure to what extent the transfers encourage or reduce GHG emissions. If the transfers encourage sectors with high GHG emissions, then it would seem climate change and agricultural policies are at cross-purposes. The dominance of the poultry sector, for instance, is in part due to commodity policy transfers (in this case, through high tariffs). This encourages a sector that is responsible for a considerable amount of GHG emissions, suggesting that the policies producing transfers from consumers to poultry producers of poultry may not be entirely consistent with the need to reduce GHG emissions.

Any relationship between sectors that receive significant support and those with high GHG emissions is of interest in the context of reaching the INDC targets. Thus, poultry and sugar stand out as sectors that receive both much of the support from farm policies and contribute significantly to GHG emissions. The connection, however, must be handled with care. With crops, for example, high support levels can encourage production, thereby elevating

POULTRY AND SUGAR STAND OUT AS SECTORS THAT RECEIVE BOTH MUCH OF THE SUPPORT FROM FARM POLICIES AND CONTRIBUTE SIGNIFICANTLY TO GHG EMISSIONS.

GHG emissions. But some commodities have higher emissions per hectare than others, so policy transfers that encourage production of a commodity with a lower per hectare GHG emission would actually reduce GHG emissions.[14]

GHG emissions per hectare are detailed in Table 6, column 1. The table shows that sugar cane has the highest per-hectare GHG emissions, followed by bananas and yams. It would appear that switching hectares away from sugar production would reduce GHG emissions. However, when the sequestration benefits are accounted for and the carbon price converted to J$ (i.e. the ACE), the per-hectare comparison comes out different (column 2). Here, cocoa, bananas, and coffee have a higher per-hectare ACE, with sweet potatoes, yams, and sugar falling back in the ranking.

For livestock, we are better off comparing the total ACE (in J$) rather than per-ton or per-hectare ACE (column 3).

TABLE 6: **GHG AND ACE PER UNIT BY COMMODITY, 2006-2014 AVERAGE**

Source: Author's calculations based on Agrimonitor and Aether.

SOILS	GHG EMISSIONS MET. TONS CO_2E/HA	AGRICULTURAL CARBON EMISSIONS: J$/HA	J$ MN	ACE AS PERCENT OF VOP (%)	VOP-SCT/ ACE RATIO
CORN	8.3	3,539	9.6	2.5%	9
SUGAR	524.4	11,516	663.6	9.6%	8
BANANAS	138.1	27,671	169.8	2.3%	29
COFFEE	89.2	21,982	92.5	1.5%	119
COCOA	15.5	36,476	6.9	23.9%	10
ORANGES	15.5	4,753	13.9	0.7%	308
PINEAPPLE	8.5	5,409	11.2	0.5%	175
TOMATOES	9.2	4,472	11.7	0.4%	369
SWEET POTATO	43.2	17,220	62.2	1.6%	69
YAMS	134.3	11,908	191.3	1.5%	63
MILK	–	–	854.1	202.3%	0
BEEF	–	–	332.9	15.6%	6
PIGMEAT	–	–	146.5	17.1%	9
POULTRY	–	–	1,323.3	3.6%	8
EGGS	–	–	35.4	1.2%	57
OTHER PRODUCTS	–	–	96.7	0.2%	395

Poultry accounts for J$1.3 billion of total livestock production; milk contributes J$854 million; and beef, J$332 million. This emphasizes the significant environmental burden of milk and beef due to enteric fermentation, and of poultry due to manure management.

A further way to measure the connection between agricultural policy and GHG emissions, shown in Table 6 (column 4), is to calculate the percentage of total production value that is offset by the ACE. Milk appears to have very high environmental costs (200 percent) relative to the value of production. The ACE costs of beef and pigmeat are also a significant proportion of their production value. By contrast, the ACE for poultry is equivalent to only about 3 percent of the market value of the product. The ACE for field crops such as tomatoes, potatoes, and yams and tree crops such as bananas and coffee is generally equivalent to only a small share of the value of production. Thus, this measurement would tend to suggest that a policy to reduce GHG emissions might focus on only a handful of commodities.

Production value, however, includes the transfers generated through commodity policy. One more step is needed to arrive at the relative value of sectors net of emissions costs. To remove the effect of policy, we can compare the "social" value of production (as defined above) with the ACE. The final column in Table 6 shows the ratio between the production value net of policy transfers (VoP-SCT) and the ACE. Tomatoes, oranges, "other products," pineapples, and coffee appear to have highly favorable ratios, indicating the greatest value (net of transfers) per unit of environmental cost. Sugar, corn, and cocoa have much lower ratios of net value to the cost of GHG emissions. The ratio for livestock appears to be uniformly relatively low: the social value of output is only 8 times the ACE in the case of poultry and there appears to be no net benefit from milk production once emission costs and transfers are accounted for. This underscores that minimizing ACE is not automatically a sound policy choice: If GHG emissions are already being limited, then one should get the best value possible subject to this constraint.

MINIMIZING ACE IS NOT AUTOMATICALLY A SOUND POLICY CHOICE: IF GHG EMISSIONS ARE ALREADY BEING LIMITED, THEN ONE SHOULD GET THE BEST VALUE POSSIBLE SUBJECT TO THIS CONSTRAINT.

[14] A complete solution to this measurement issue would be to use a multi-market model of Jamaican agriculture that includes cross-elasticities of supply. This would require input from databases such as Agrimonitor but involve considerable additional modeling. Unfortunately, the more realistic the model, the more parameter assumptions and model structure decisions would be needed, so the additional precision of the results may come at the cost of credibility.

POLICY IMPLICATIONS

What implications might these results have for policy makers? As the GOJ implements its INDC commitment to curb emissions of GHG it has a range of agricultural policy actions from which to choose. One would be to reduce the transfers to the highest GHG-emitting sectors —such as poultry, sugar, and beef (Table 6, column 3). The cost of GHG emissions in terms of ACE suggests that milk could also be added to that list (column 4). If the main objective of policy is to meet the INDC targets, then such an approach has merit. But the sectors in question produce goods for sale to consumers.

If one allows for a mix of objectives that include farm policy as well as GHG emission mitigation, then another option would be to reduce support to sectors with a high ACE to production value ratio (essentially, livestock products), as this would ensure that GHG emissions reduction was being achieved at the lowest cost in terms of farm output. This would involve constraints on production of milk, cocoa, beef, pigmeat and sugar (but not poultry), which have the highest ratio of ACE to VoP (Table 6, column 5), although these production values include the incidence of policy transfers.

A strategy to combine farm policy changes and GHG emission reductions (a "two birds with one stone" approach) would be to focus on commodities with both high emissions and high protection. The candidates are listed in Table 6, column 6. Livestock products (except eggs) have a low ratio of output net of transfers to the cost of GHG emissions. The same is true of sugar, corn, and cocoa. Reducing support to these sectors would also lean toward reducing price distortions in agricultural markets and mitigating GHG emissions to meet the Jamaican INDC goals.

A STRATEGY TO COMBINE FARM POLICY CHANGES AND GHG EMISSION REDUCTIONS (A "TWO BIRDS WITH ONE STONE" APPROACH) WOULD BE TO FOCUS ON COMMODITIES WITH BOTH HIGH EMISSIONS AND HIGH PROTECTION.

Alternatively, one could increase support for sectors with a high ratio of the value of output *net of support* to the cost of carbon emissions. Candidates here would include oranges, tomatoes, coffee, pineapple, and "other products" (mainly vegetables and condiments). The estimates given here point potential policy efforts to coordinate price incentives with greenhouse gas emission reduction.

An alternative approach, or one that could be considered complementary to price policy changes, would be to locate the source of the GHG emissions and attempt to change the management techniques used in the high-emitting sectors. Manure management is one area that may need to be addressed, either with regulation or financial incentives (taxes or subsidies). The use of GHG emission offsets would fit with this approach, as improved management practices would be encouraged by private incentives. Thus, the results shown here may be most useful in guiding policy towards solutions regarding crop and livestock husbandry. Commodity-level policy may help, but changes in farming practices could be a very useful complementary step.

The report has focused on GHG emissions in the context of attempts to mitigate climate change at the global level. The extent to which Jamaica participates in such mitigation will depend on national policy decisions that are beyond the considerations of agricultural policy. No amount of mitigation in Jamaica alone is likely to have any measurable impact on Jamaica or its agricultural sector: the vulnerability of Jamaica and its agriculture sector to climate change depends on the actions of other countries. Similarly, the issue of carbon leakage (shifting production abroad where higher GHG emissions are possible) is less relevant to Jamaica's decision on GHG reduction, as its agricultural policy is unlikely to have any significant impact on GHG emissions in other countries. However, the actions taken by Jamaica in connection with its INDC obligations could have a considerable impact on the agricultural sector. Thus, to some extent, the significance of GHG reductions is separate from the Jamaican agriculture sector's vulnerability to climate change, although in the context of policy decisions, the link between GHG emissions and policy incentives is significant.

NO AMOUNT OF MITIGATION IN JAMAICA ALONE IS LIKELY TO HAVE ANY MEASURABLE IMPACT ON JAMAICA OR ITS AGRICULTURAL SECTOR: THE VULNERABILITY OF JAMAICA AND ITS AGRICULTURE SECTOR TO CLIMATE CHANGE DEPENDS ON THE ACTIONS OF OTHER COUNTRIES.

There is an even more important link between mitigation and adaptation policies relating to climate change that could be crucial for policy-makers. Given the compelling case for Jamaican policy to develop a strategy for adapting to climate change, the more such a strategy is consistent with mitigation efforts, the more mutually supportive the two separate policy goals will be. Efforts to increase the resilience of agriculture in the face of climate variability could go hand in hand with the changes necessary to meet mitigation goals. Resilience can also be related to policy transfers. Attempts to make Jamaican agriculture more sustainable could in this way be coupled with a reduction in GHG emissions. The next step could therefore be to use tools such as Agrimonitor to assess the range of policies that are being used that might impact adaptation and resilience. This report has discussed the link between policy incentives and GHG emissions: The compatibility of Jamaican agricultural policy with climate change adaptation needs to be further explored.

ANNEX A: TABLES WITH ANNUAL VALUES OF DATA AND CALCULATIONS REPORTED IN TEXT

ANNEX A. TABLE A1

VALUE OF PRODUCTION, 2006-2014

	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVERAGE 2006-14
CORN	221	247	354	471	647	933	863	964	890	621
SUGAR	3,595	4,349	4,378	4,044	4,208	6,434	9,948	9,284	11,865	6,456
BANANAS	2,700	1,970	1,434	2,322	2,361	2,053	2,616	2,051	2,843	2,261
COFFEE	1,553	1,260	1,287	1,164	802	855	758	856	896	1,048
COCOA	38	218	148	162	200	81	279	199	231	173
ORANGES	1,003	1,219	1,057	975	845	1,084	1,257	1,066	1,069	1,064
PINEAPPLE	1,097	944	1,262	1,640	1,970	1,796	1,968	2,011	1,882	1,619
TOMATOES	1,436	1,809	1,945	2,013	3,030	2,618	2,583	3,308	2,995	2,415
SWEET POTATO	1,770	1,555	2,206	2,737	2,926	3,548	3,398	4,091	3,949	2,909
YAMS	6,055	5,191	8,191	10,611	8,538	10,575	10,067	13,032	13,272	9,503
MILK	339	408	586	649	607	668	765	770	841	626
BEEF	1,717	1,706	1,918	1,953	1,969	2,216	2,351	2,759	2,480	2,119
PIGMEAT	767	912	1,307	1,439	1,684	2,899	3,137	3,123	2,781	2,006
POULTRY	14,582	17,764	16,904	18,300	19,380	21,344	22,896	25,273	29,727	20,686
EGGS	1,963	1,533	1,513	1,713	1,590	2,292	2,908	2,847	2,472	2,092
OTHER PRODUCTS	18,215	18,787	25,640	33,420	33,555	16,873	16,455	21,025	19,991	22,662
TOTAL	**57,051**	**59,873**	**70,129**	**83,610**	**84,311**	**76,268**	**82,248**	**92,661**	**98,184**	**78,259**

Source: Agrimonitor
Unit: million J$

ANNEX A. TABLE A2

SINGLE COMMODITY TRANSFER (SCT), BY COMMODITY

	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVERAGE 2006-14
CORN	172.9	114.7	326.9	194.3	588.2	859.6	734.7	821.0	809.0	513.5
SUGAR	696.2	1,015.1	1,267.0	2,388.7	3,300.9	4,903.5	6,704.9	5,288.1	3,112.9	3,186.4
BANANAS	907.9	649.8	279.3	293.3	219.7	(59.6)	385.9	207.2	22.4	322.9
COFFEE	(1,145.8)	(996.0)	(1,191.2)	(1,690.6)	(1,223.4)	(1,196.4)	(1,070.3)	(1,404.1)	(1,335.4)	(1,250.4)
COCOA	(48.9)	(103.3)	(31.4)	9.5	(75.9)	(26.8)	(58.8)	78.7	(88.4)	(38.4)
ORANGES	(1,197.0)	(1,354.5)	(1,793.7)	(447.0)	(415.5)	(426.8)	(724.8)	(666.9)	(1,370.5)	(933.0)
PINEAPPLE	226.9	141.4	(20.0)	(146.2)	(123.4)	(473.3)	(1,158.2)	(1,471.8)	(1,362.7)	(487.5)
TOMATOES	(793.1)	440.6	301.4	(418.7)	462.3	(387.8)	(601.3)	188.3	693.0	(12.8)
SWEET POTATO	(208.1)	(527.5)	(846.6)	(2,503.3)	(4,441.3)	(2,086.7)	(1,802.7)	(3,338.9)	(2,095.4)	(1,983.4)
YAMS	518.1	(352.1)	(572.8)	(1,554.4)	273.4	(657.5)	(2,324.4)	(4,290.3)	(2,211.5)	(1,241.3)
MILK	48.9	92.7	34.3	209.2	44.0	23.6	118.2	(31.7)	(217.3)	35.8
BEEF	75.9	492.4	533.1	200.1	411.7	101.5	(318.6)	(707.3)	(971.8)	(20.3)
PIGMEAT	(431.3)	(267.2)	(1,499.5)	(1,517.6)	(1,423.4)	(125.6)	(990.4)	(2,278.8)	(1,389.1)	(1,102.5)
POULTRY	10,284.6	11,341.5	10,671.2	10,809.2	13,296.8	15,801.8	16,435.1	17,724.5	20,928.5	14,143.7
EGGS	566.7	306.3	(103.1)	(293.8)	(222.6)	25.4	(124.8)	613.6	65.2	92.5
OTHER PRODUCTS	518.1	(352.1)	(572.8)	(1,554.4)	273.4	(657.5)	(2,324.4)	(4,290.3)	(2,211.5)	(1,241.3)
TOTAL	**10,191.9**	**10,641.8**	**6,782.3**	**3,978.3**	**10,945.0**	**15,617.4**	**12,880.1**	**6,441.6**	**12,377.6**	**9,984.0**

Source: Agrimonitor
Unit: million J$

ANNEX A. TABLE A3 (A)

GHG EMISSIONS FROM CROP CULTIVATION

	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVERAGE 2006-14
SYNTHETIC N FERTILIZER Gg N_2O/yr, CO_2 e	26.71	23.7	31.36	20.21	34.71	23.6	53.78	53.78	53.78	35.7
ORGANIC N FERTILIZER Gg N_2O/yr, CO_2 e	821.84	1,122.67	1,635.03	1,590.92	1,590.93	1,007.43	1,582.58	1,582.58	1,582.58	1,390.7
CROP RESIDUES Gg N_2O/yr, CO_2 e	6.18	6.13	5.57	6.26	6.42	7.2	7.31	7.31	7.31	6.6
DRAINED/MANAGED ORGANIC SOILS Gg N_2O/yr, CO_2 e	64.42	64.42	64.42	64.42	64.42	64.42	64.42	64.42	64.42	64.4
INDIRECT N_2O **EMISSIONS**										
SOILS DEPOSITION Gg N_2O/yr, CO_2 e	2.94	2.74	3.7	2.57	4.03	2.7	5.93	5.93	5.93	4.1
SOILS LEACHING/RUNOFF Gg N_2O/yr, CO_2 e	289.58	381.06	535.3	517.31	518.41	337.59	518.77	518.77	518.77	459.5
EMISSIONS OF CO_2 FROM LIME Gg CO_2	0.01	0.01	0.01	0.01	0.03	0.47	0.35	0.35	0.35	0.2
EMISSIONS OF CO_2 FROM UREA APPLICATION Gg CO_2	1.06	2,098	1.6	0.73	1.07	0.84	2.15	2.15	2.15	1.5
EMISSIONS OF CH_4 FROM RICE CULTIVATION Gg CH_4/yr, CO_2 e	0.01	0.13	0.18	0.22	0.33	0.26	0.36	0.36	0.36	0.2
EMISSIONS OF CH_4 FROM FIELD BURNING Gg CH_4/yr, CO_2 e	6.32	6.49	6.3	5.52	5.61	5.88	5.92	5.92	5.92	6.0
EMISSIONS OF N_2O FROM FIELD BURNING Gg N_2O/yr, CO_2 e	1.95	2	1.95	1.71	1.8	1.82	1.83	1.83	1.83	1.9
TOTAL Gg CO_2 e	**1,221.02**	**1,611.45**	**2,285.42**	**2,209.88**	**2,227.76**	**1,452.21**	**2,243.40**	**2,243.40**	**2,243.40**	**1,970.9**

ANNEX A. TABLE A3 (B)

GHG EMISSIONS FROM LIVESTOCK

	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVERAGE 2006-14
GRAZING ANIMALS Gg N_2O/yr CO_2 e	328.9	345.89	335.31	315.33	296.1	267.02	283.35	283.35	283.35	304
ENTERIC FERMENTATION (CH_4) Gg CH_4/yr CO_2 eq	136.15	143.24	139.11	135	130.86	126.75	149.47	149.47	149.47	140
MANURE MANAGEMENT (CH_4) Gg CH_4/yr CO_2 eq	101.77	111.84	119.62	114.91	111.21	94.38	102.89	102.89	102.89	107
MANURE MANAGEMENT (N_2O) Gg/yr CO_2 eq	939.66	1,275.32	1,904.01	1,857.12	1,863.82	1,162.11	1,840.55	1,840.55	1,840.55	1,614
TOTAL Gg CO_2 e	**1,506.48**	**1,876.29**	**2,498.05**	**2,422.36**	**2,401.99**	**1,650.26**	**2,376.26**	**2,376.26**	**2,376.26**	**2,164.9**

TOTAL CROPS AND LIVESTOCK Gg CO_2 e	**2.727,50**	**3,487.74**	**4,783.47**	**4,632.24**	**4,629.75**	**3,102.47**	**4,619.66**	**4,619.66**	**4,619.66**	**4,135.79**

Source: Agrimonitor

ANNEX A. TABLE A4

GHG EMISSIONS BY AGRIMONITOR SECTOR

	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVERAGE 2006-14
CORN	8.0	7.0	9.2	5.9	10.1	6.9	15.7	15.3	15.3	10
SUGAR	516.7	711.1	1,035.8	849.9	853.6	534.1	798.3	783.1	783.1	763
BANANAS	135.6	184.1	267.1	264.0	267.3	167.9	261.1	326.2	326.2	244
COFFEE	88.7	121.7	171.6	169.3	166.7	105.8	164.0	164.1	164.1	146
COCOA	15.4	19.5	26.1	25.2	25.2	17.1	25.2	25.2	25.2	23
ORANGES	12.8	18.5	25.1	24.3	22.4	13.6	16.8	14.2	14.2	18
PINEAPPLE	7.9	9.6	14.9	15.6	16.2	9.9	14.9	14.6	14.6	13
TOMATOES	8.4	9.4	13.3	13.2	13.0	10.2	15.5	15.1	15.1	13
SWEET POTATO	42.3	56.1	85.7	82.7	78.5	52.1	80.7	76.7	76.7	70
YAMS	131.4	169.9	235.6	243.7	256.5	161.8	249.4	245.1	245.1	215
MILK	103.0	82.8	90.1	95.8	101.4	104.8	101.3	101.3	101.3	98
BEEF	400.8	442.4	421.4	392.5	364.6	328.9	376.8	376.8	376.8	387
PIGMEAT	199.5	222.0	205.9	189.8	173.7	157.6	141.5	141.5	141.5	175
POULTRY	803.3	1,129.1	1,780.7	1,744.2	1,762.3	1,058.9	1,756.6	1,756.6	1,756.6	1,505
EGGS	37.0	49.4	45.8	42.3	38.7	35.2	41.1	41.1	41.1	41
OTHER PRODUCTS	67.7	78.3	109.3	115.9	114.6	89.6	133.3	137.0	137.0	109
TOTAL	**2,579**	**3,311**	**4,538**	**4,274**	**4,265**	**2,854**	**4,192**	**4,234**	**4,234**	**3,831**

Source: Agrimonitor
GHG emissions: Gg CO_2 e

ANNEX A. TABLE A5

MONETARY VALUE OF AGRICULTURAL CARBON EMISSIONS (ACE), BY COMMODITY

	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVERAGE 2006-14
CORN	5	5	7	6	9	6	14	16	18	10
SUGAR	345	497	761	758	752	466	717	797	880	664
BANANAS	62	97	163	185	177	96	181	270	299	170
COFFEE	23	38	96	101	111	61	120	135	148	93
COCOA	9	2	7	8	8	1	8	9	10	7
ORANGES	7	11	17	20	18	10	14	13	14	14
PINEAPPLE	5	6	11	13	14	8	13	14	16	11
TOMATOES	6	7	10	12	12	10	15	16	18	12
SWEET POTATO	28	39	63	74	70	46	73	79	87	62
YAMS	88	119	174	218	227	142	225	251	277	191
MILK	687	580	666	859	897	913	912	1,033	1,140	854
BEEF	267	309	311	352	322	287	340	384	424	333
PIGMEAT	132	153	150	168	152	136	126	143	158	146
POULTRY	531	782	1,300	1,546	1,542	914	1,565	1,773	1,957	1,323
EGGS	24	34	34	38	34	30	37	42	46	35
OTHER PRODUCTS	45	54	80	103	100	77	119	139	153	97
TOTAL	**2,265**	**2,735**	**3,850**	**4,461**	**4,445**	**3,203**	**4,479**	**5,113**	**5,643**	**4,022**

Source: Agrimonitor
Unit: million J$

ANNEX A. TABLE A6

VALUE OF PRODUCTION - VALUE OF EXTERNALITIES (ACE)	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVERAGE 2006-14
CORN	215	242	347	465	638	927	849	948	872	612
SUGAR	3,250	3,853	3,617	3,286	3,456	5,967	9,231	8,488	10,985	5,792
BANANAS	2,638	1,873	1,271	2,137	2,184	1,957	2,436	1,781	2,544	2,091
COFFEE	1,530	1,221	1,191	1,062	691	794	638	722	748	955
COCOA	29	216	141	154	192	80	271	190	221	166
ORANGES	995	1,208	1,040	955	827	1,073	1,243	1,053	1,054	1,050
PINEAPPLE	1,092	938	1,251	1,626	1,956	1,787	1,955	1,996	1,867	1,608
TOMATOES	1,430	1,803	1,934	2,001	3,018	2,609	2,568	3,292	2,977	2,404
SWEET POTATO	1,741	1,516	2,143	2,662	2,857	3,502	3,325	4,012	3,863	2,847
YAMS	5,966	5,071	8,017	10,392	8,311	10,432	9,841	12,781	12,995	9,312
MILK	-347	-172	-80	-210	-290	-244	-147	-263	-299	-228
BEEF	1,450	1,397	1,607	1,602	1,646	1,929	2,012	2,375	2,056	1,786
PIGMEAT	636	759	1,156	1,270	1,532	2,763	3,011	2,981	2,624	1,859
POULTRY	14,052	16,982	15,603	16,754	17,838	20,430	21,331	23,500	27,770	19,362
EGGS	1,938	1,499	1,479	1,676	1,556	2,261	2,871	2,806	2,426	2,057
OTHER PRODUCTS	18,170	18,733	25,560	33,317	33,454	16,796	16,336	20,886	19,838	22,566
TOTAL	**54,786**	**57,137**	**66,279**	**79,149**	**79,867**	**73,065**	**77,770**	**87,548**	**92,540**	**74,238**

Carbon price for ACE calculations:
10 US$ per metric ton CO_2 equivalent

Source: Agrimonitor
Unit: million J$

ANNEX A. TABLE A7

VALUE OF PRODUCTION NET OF ACE AND SCT

	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVERAGE 2006-14
CORN	42	128	21	271	50	68	114	127	63	98
SUGAR	2,554	2,837	2,350	897	155	1,064	2,526	3,200	7,872	2,606
BANANAS	1,730	1,223	992	1,843	1,964	2,017	2,050	1,573	2,522	1,768
COFFEE	2,676	2,217	2,382	2,753	1,915	1,991	1,708	2,126	2,083	2,206
COCOA	78	319	172	144	268	107	329	112	309	204
ORANGES	2,192	2,563	2,834	1,402	1,242	1,500	1,968	1,720	2,425	1,983
PINEAPPLE	865	796	1,271	1,772	2,079	2,261	3,113	3,468	3,229	2,095
TOMATOES	2,223	1,362	1,633	2,419	2,556	2,997	3,170	3,104	2,284	2,416
SWEET POTATO	1,949	2,043	2,990	5,166	7,298	5,589	5,128	7,351	5,958	4,830
YAMS	5,448	5,424	8,590	11,947	8,038	11,090	12,166	17,072	15,207	10,553
MILK	(396)	(265)	(114)	(420)	(334)	(268)	(266)	(232)	(82)	-264
BEEF	1,374	905	1,074	1,402	1,235	1,827	2,330	3,082	3,027	1,806
PIGMEAT	1,067	1,026	2,656	2,788	2,955	2,889	4,002	5,259	4,013	2,962
POULTRY	3,767	5,641	4,932	5,945	4,541	4,629	4,896	5,776	6,842	5,219
EGGS	1,371	1,193	1,582	1,970	1,778	2,236	2,996	2,192	2,361	1,964
OTHER PRODUCTS	17,652	19,085	26,133	34,872	33,181	17,453	18,660	25,177	22,049	23,807
TOTAL	**44,594**	**46,496**	**59,497**	**75,171**	**68,922**	**57,448**	**64,889**	**81,106**	**80,163**	**64,254**

Carbon price for ACE calculations:
10 US$ per metric ton CO_2 equivalent

Source: Agrimonitor
Unit: million J$

ANNEX B: ADDITIONAL DETAILS ON MATCHING AETHER GHG EMISSIONS ESTIMATES TO AGRIMONITOR POLICY MEASUREMENTS

To move from the data presented in the Aether report to estimated GHG emissions from the various commodities included in the Agrimonitor database, some additional assumptions were required. This annex gives two examples that show the steps needed. The examples are for the emissions from synthetic nitrogen fertilizer and fuel oil in field operations, both used in corn production.

The Aether report estimates the total emissions from the agricultural use of synthetic nitrogen fertilizer at 26.71 Gg/yr CO_2e. The same report includes the number of hectares under cultivation of cereals. The assumption that is needed to link this to the Agrimonitor commodities is the share of synthetic nitrogen fertilizer used on cereals. The assumption is that 30 percent of such fertilizer is used in the cereal sector. This number is chosen to reflect the fact that many crops in Jamaica are produced using organic fertilizer or add to soil nitrogen naturally. Other crops that are assumed to use some synthetic nitrogen fertilizer include yams, vegetables, potatoes, and condiments. Having allocated this portion of synthetic nitrogen use to cereals, the proportion allotted to corn is based on the share of corn in cereal hectarage (in this case 100 percent). The result is an attribution of 8.01 Gg/yr CO_2e in corn production.

EXAMPLE 1: **CORN 2006, CALCULATION OF EMISSIONS FROM SYNTHETIC N FERTILIZER**

Total Emissions from Synthetic N Fertilizer	26.71 Gg/yr CO_2e	Aether
Cereals	1,542 Ha under cultivation	Aether
Allocation of Synthetic N Fertilizer emissions to cereals	30% allocated to cereals	Assumption
Corn area	1,541 Ha	Aether
Share of corn in cereals	1.0 share	Calculation
Emissions from Synthetic N Fertilizer attributed to corn	8.01 Gg/yr CO_2e	Calculation

A second example illustrates the allocation of fuel and energy to individual crop sectors. The Aether report estimates fuel use for the agricultural sector, and further allocating it to field operations, harvesting, and processing requires additional assumptions. This example shows the steps involved in estimating the use of fuel oil (one of four fuels identified) in field operations.

Total emissions from the use of fuel oil in the agricultural sector was reported as 119 Mg/yr CO_2e. The share of total emissions from fuel oil use in agriculture associated with field operations was assumed to be 75 percent, based on a judgment on the main use of fuel oil in agriculture. Thus, the total emissions from the use of fuel oil in field operations is 142 Mg/yr CO_2e. A further assumption is that fuel oil use in field operations are basically determined by the hectarage. As the corn sector represents 2.4 percent of harvested area, the use of fuel oil in corn field operations is calculated as 3.34 Mg/yr CO_2e.

EXAMPLE 2: **CORN 2006, CALCULATION OF EMISSIONS FROM FUEL OIL USE IN FIELD OPERATIONSFERTILIZER**

Total Emissions from Fuel Oil use in agriculture	119 Mg/yr CO_2e	Aether
Share used in field operations	75%	Assumption
Emissions from fuel oil use	142 Mg/yr CO_2e	Calculation
Hectares in Agriculture	65,205 Ha	Aether
Corn area	1,541 Ha	Aether
Share of corn hectarage	2.4%	Calculation
Emissions from corn use of fuel oil in field operations	3.34 Mg/yr CO_2e	Calculation

The estimates reported in this paper would be improved by the collection of more data on the use of fertilizer and on other soil management activities connected to the production of particular products. Similarly, the allocation of fuel and energy by activity could be improved by replacing broad assumptions with collected data.

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