

# *Carbon Transport through International Commerce*



*Jeff Tschirley and Géraud Servin*  
*Global Terrestrial Observing System*  
*Food and Agriculture Organization of the United Nations*

This discussion paper represents a contribution to the project *Concerted Action CarboEurope-GHG* which is part of the CarboEurope Cluster

Published November 2004

## • Contents

• ABSTRACT	3
1. INTRODUCTION	4
2. DATA AVAILABILITY AND QUALITY	6
3. CONSIDERATIONS IN DATA ANALYSIS	8
4. ANALYSIS AND MAIN FINDINGS	9
4.1. Global carbon trade	9
4.2. Carbon trade in cereals exports	10
4.3. Global carbon net flow (exports minus imports) for 2000	11
4.4. Regional carbon net flow (exports minus imports) from 1989 to 2000	11
5. CONCLUSIONS AND RECOMMENDATIONS	13
6. REFERENCES	14
7. ANNEX 1: CROP CARBON RATIOS (IPCC, 1996)	16
8. ANNEX 2: TOP IMPORTERS AND EXPORTS OF CEREALS, PAPER AND WOOD PRODUCTS, 2000	17
9. ANNEX 3: EXPORT AND IMPORTS FROM REPORTER TO PARTNER, 2000 (COMTRADE, 2003)	18
10. ANNEX 4: COUNTRY GROUPINGS (COMTRADE, 2003)	19
11. ANNEX 5: SELECTED DEFINITIONS	20

- Abstract

Transfers of carbon in the form of imports and exports between regions are analysed using global data for agriculture and forest related products. An estimated 3.5 PgC are produced annually by agricultural crops, accounting for about 7 percent of the total NPP in terrestrial ecosystems. Of this amount approximately one-third represents harvested product of which about half is used for direct human consumption. Cereals, wood and paper products account for 3.8 percent of total global trade value. The UN ComTrade database and carbon conversion coefficients are used to transform export and import volumes in the three product groups into carbon equivalents for the period 1989 - 2000. North America and Europe have been net exporters of cereals. In turn, Asia, Africa and Other America are net carbon importers. Carbon commerce in the agriculture and forestry sectors are likely to remain a small portion of the total terrestrial carbon budget but may take on added importance in the context of emission trading schemes and national accounting processes. In 2000, cereal exports represented about 14 percent of the total carbon content in harvested cereal products and could reach 22 percent in 2030 based on recent projections.

## • Introduction

In 1997, national governments agreed to adopt the Kyoto Protocol to the UN Framework Convention on Climate Change as a legally binding framework to reduce emissions of greenhouse gases (GHG). Although a number of GHGs are relevant, carbon dioxide is of overriding interest due in part to its sequestration in living organic matter that can be managed to regulate eventual fluxes to the atmosphere. The Kyoto Protocol has a predominant focus on the role of forests in carbon sequestration but there is broad agreement in the science community on the need to understand the entire carbon cycle (Falkowski *et al.* 2000) – terrestrial, ocean and atmosphere - and use these components in complementary and synergistic ways.

A comprehensive and systematic approach to carbon accounting would provide countries with the accuracy and consistency they need to monitor and manage their carbon stocks in the context of national, regional and global efforts to mitigate and adapt to the effects of climate change. This would mean that in addition to forestry, there is need for satellite and *in situ* observational data for land uses such as cropland and grazing land, wetlands, and coastal areas in order that such information may be reflected in national, regional and global carbon budgets (FAO, 2002a, 2002b, 2003).

With the exception of the service sector, all international commercial trade involves a transfer of carbon. The value of all global exports in 2000 was \$6,186 billion of which mining was \$813 bn, manufacturing \$4,613 bn and agriculture \$558 bn (WTO, 2003). This paper focuses on transfers of carbon which takes place between regions in the form of imports and exports of agriculture and forest products such as cereals and wood pulp (see Annex 5). Although the economic dimension is significant, it is not addressed in this paper. Furthermore, this paper does not address the question of how credits (or debits) related to trade in products with carbon content could be applied in carbon accounting frameworks.

The inter-comparison of a number of global ecosystem models indicates that approximately 55 petagrams of carbon (PgC) is generated each year in the form of net primary production (NPP) in terrestrial ecosystems (GAIM, 1998). This takes place on a global land area of 13.4 million km<sup>2</sup> (FAOSTAT, 2003) consisting of forests and woodland, croplands, grasslands and other ecosystems. About 1.5 million km<sup>2</sup> is arable land in use at various levels of cropping intensity ranging from rainfed systems with low levels of external inputs to irrigated systems with high inputs.

An estimated 3.5 PgC are produced annually just by agricultural crops, accounting for about 7 percent of the total NPP in terrestrial ecosystems. Of this amount approximately one-third represents the harvested product of which about half is used for direct human consumption and half for animal consumption (Goudriaan, 2001).

Only a few investigations have used global agriculture datasets to assess production relative to transfers of crop material across regional or national boundaries:

Land use and cropland data were used to derive estimated long-term changes in global cropland area that were then validated against a satellite-derived potential vegetation data set (Ramankutty and Foley, 1999).

Crop production data for 16 major food products were used to estimate horizontal carbon transfers (through trade) in agriculture. The data were converted to carbon equivalents to arrive at an estimated "displacement" in excess of 1 PgC per year (Ciais *et al.*, 2001).

Agricultural production statistics for 1991 were used to estimate the NPP of arable land by using fixed crop-specific coefficients which included dry matter content, harvest index, root production, carbon- and nitrogen content (Goudriaan *et al.* 2001).

The most relevant data on international trade of forest products were undertaken in the work of Michie and Kin (1999) which analyses global trade flows of major forest products in six regions between 1983 and 1996 based on the UN ComTrade database. This comprehensive effort includes trade flow summaries and illustrated regional charts, maps and spreadsheets.

## • 2. Data availability and quality

The most relevant data on international trade of forest products were undertaken in the work of Michie and Kin (1999) which analyses global trade flows of major forest products in six regions between 1983 and 1996 based on the UN ComTrade database. This comprehensive effort includes trade flow summaries and illustrated regional charts, maps and spreadsheets.

With the partial exception of forest products, little attention has been given to analysing the quantities of carbon that flow annually between regions in the form of exports and imports. Potentially, a large number of items could be included. The UN Standard Industrial Trade Classification scheme (SITC, 1986) uses a global framework with ten categories for national export and import data (Table 1).

**Table 1:** *SITC framework for national export and import (SITC, 1986).*

Number	Category
0	Food and live animals
1	Beverages and tobacco
2	Crude materials, inedible, except fuels
3	Mineral fuels, lubricants and related materials
4	Animal and vegetable oils, fats and waxes
5	Chemical and related products
6	Manufactured good classified chiefly by material
7	Machinery and transport equipment
8	Miscellaneous manufactured articles
9	Commodities and transactions not classified elsewhere

Each category contains numerous sub-categories, most of them consisting of products which have carbon content. For example, category 0 contains 9 sub-categories that include meats, dairy products, fish, cereals, vegetables and fruit, sugars, harvested beverages, animal feeds and miscellaneous edible products. These are further broken into 344 sub-groups, some of which include products such as hides and skins, oil seeds and fruits, rubber, pulp and waste paper, fertilizers, and various kinds of agricultural machinery. Crude materials, fuels, chemicals, machinery and manufactured goods are other relevant categories.

Carbon conversion coefficients have not been developed for most of the products in the SITC framework. Although in many cases the carbon content may not be sufficiently great to justify their inclusion in an accounting framework, more analysis is needed to ascertain the potential magnitude of the carbon content, the significance of trade in these items and the viability of developing coefficients.

There are a wide variety of agriculture and forest products for which trade data are publicly available, measured in both quantity and value (Table 2). Of primary interest to the carbon science community are the volumes of carbon-based products that are transported through international commerce and their spatial and temporal distribution.

**Table 2:** Selected agriculture and forest product trade data availability (ComTrade, 2003).

Plant material	Woody material	Animals
Cereals	Pulp	Live animals
Roots and tubers	Cellulosic material	Meat products
Vegetables	Paper	Milk products
Live trees	Paper board	Fish and seafood
Coffee, tea, spices	Roundwood	Hides and skins
Oils, seeds, gums	Fibres and filaments	
Cotton	Wadding and weaving	

The primary sources for data related to commerce in agriculture and forestry are from the Food and Agriculture Organization of the United Nations (FAOSTAT, 2003) and the UN Statistical Division database for commercial trade (ComTrade, 2003). The ComTrade database has several advantages. Foremost is the ability to quickly extract, manipulate and display trade data in a variety of different ways. The agriculture and forest content is built primarily upon the statistical data collected and managed by FAO. It is further supplemented with data from the Organization for Economic Co-operation and Development (OECD) and selected other international sources, *inter alia*, the World Trade Organization (WTO) and the European Union (EU).

The most complete and reliable data at the global and continental levels are available only for the period since 1989. Longer time series could be helpful in projecting regional and global trends with better accuracy and temporal composition for individual crops and commodities. The ComTrade database does not aggregate trade quantities to higher levels such as the 2 digit group (represented by cereals, e.g. code 10) due to possible error arising from the use of different measurement units at the basic reporting level. Thus, estimates in this paper have been derived manually from the 4 digit groups (which includes wheat and rice, e.g. codes 1001 and 1006).

### • 3. Considerations in data analysis

Conversion rates for estimating carbon content of biomass rely primarily on the work the Intergovernmental Panel on Climate Change (IPCC) in its assessment reports. A conversion factor of 45 percent was used to estimate the net dry amount of carbon in agricultural crop that was made up of carbon. The figure of 48 percent may be more representative for the cereal group but would make little difference in the results (see Annex 1). For forests and wood products, a conversion factor of 50 percent was used.

The accuracy of the carbon conversion factors is also assumed to be applicable to all types of production systems. For example, countries that use high levels of external inputs such as fertilizers, pesticides and conventional energy tend to produce crops with the same “embodied” carbon content as lower income countries which use much lower inputs.

The embodied carbon contained in the cereal and wood products reflects only a portion of the total carbon consumed in producing, harvesting and transporting those same products. It is assumed that this additional carbon component, consisting of fossil fuels arising from indirect sources, are (or should be) captured in National Greenhouse Gas Inventories (NGHGI) as reflected in the suggested guidelines. While this additional carbon is probably not significant in calculating flows at the regional and global levels, the same may not necessarily be true at the national level where the performance of individual countries in managing and accounting for their carbon stock changes takes on added economic and political importance.

The UN ComTrade database is country-based and data are available only at the national level. For example, country A (i.e. reporter) will export cereals to country B (i.e. partner). However, this study focuses on the regional and global trade in carbon commerce. Therefore, the country statistics were aggregated to produce estimates for six regions: Africa, Asia, Europe, North America, Oceania and Other America (see Annex 3 for region definitions). The aggregation is done by breaking down the region to its underlying countries and then summing the returned results. This means that the total trade from a region to a partner may be less than the total flow as intra-regional exchanges are included. For example, exports and imports from North America to North America are mostly reflecting the trade existing between the U.S.A and Canada.

Discrepancies exist between reported exports and imports to and from the same countries and regions. At the global level the differences for all three commodity groups range from moderate (7 percent) for the cereals to large (30 percent) for the paper and wood products (Table 3). At the regional level there are discrepancies of several orders of magnitude. For example, the export of wood products from Africa to Asia is equivalent to 0.043 PgC while reported wood imports to Asia from Africa are only 0.002PgC (Annex 3). The reasons for such inconsistencies are not yet fully understood but may arise more from the differences existing between national reporting and accounting systems.

During data processing ComTrade estimates quantities (trade quantities and net weight in kg) at the 6-digit level (e.g. Durum wheat, code 100110) of the classification system and the 4-digit level (e.g. Wheat, code 1001). If in the aggregation of quantities there exists a conflict in the quantity unit of measure they follow the rule that “if the value associated with one quantity unit equals 75 percent or more of the total commodity value, then that quantity unit will be chosen as the unit of the given commodity and the remaining quantity will be estimated according to the proportion of its value.” A “not reported” quantity is treated in the same sense and the quantity unit left blank.

## • Analysis and main findings

Although a wide range of agriculture products could be analysed, this paper has concentrated on the cereals group, the wood and paper products groups and paper products (see Annex 5 for group definitions).

Cereals include all coarse grains as well as rice and wheat. At the regional and global levels, this group is clearly the dominant one both in economic value and total trade volume. The group components tend to be homogenous in terms of the carbon content of the harvested product which can range from 47-52 percent (Strehler and Stutzle, 1987).

These three groups represented approximately 3.8 percent of total global trade value and cereals represent 5.3 percent of the total trade value in agriculture products in 2000 (Table 4).

### 4.1. Global carbon trade

Based on ComTrade data, exports trade in cereals, and wood and paper products is estimated to be on the order of 0.370 PgC in the year 2000 (see Table 3). North America led in the export of cereals (0.049 PgC), Europe led in the export of paper and wood products (0.046 PgC and 0.071 PgC).

If cereals (i.e. small and coarse grains) represent 60 percent (0.735 PgC) of the total NPP of harvested agricultural crops (1.225 PgC) then the carbon in total cereal exports (0.105 PgC) represents 14.3 percent of the total carbon content in global harvested cereal products (Table 3). If we consider the total NPP of agricultural harvested and non-harvested crops (3.5 PgC) then cereals represent 5 percent of the total carbon content.

**Table 3: Carbon exports and imports by continent for 2000 (PgC).**

Commodity group	Reporter	Export (PgC)	Import (PgC)
Cereals (10)	Africa	0.000	0.011
	Asia	0.014	0.042
	Europe	0.029	0.024
	North America	0.049	0.003
	Oceania	0.001	0.000
	Other America	0.011	0.018
<b>Cereals (10) Total</b>		<b>0.105</b>	<b>0.098</b>
Paper products (47,48,49)	Africa	0.001	0.001
	Asia	0.009	0.023
	Europe	0.046	0.044
	North America	0.023	0.016
	Oceania	0.001	0.001
	Other America	0.007	0.034
<b>Paper products (47,48,49) Total</b>		<b>0.087</b>	<b>0.118</b>
Wood products (44,45,46)	Africa	0.060	0.011
	Asia	0.011	0.039
	Europe	0.071	0.055
	North America	0.023	0.019
	Oceania	0.004	0.000
	Other America	0.006	0.004
<b>Wood products (44,45,46) Total</b>		<b>0.178</b>	<b>0.129</b>
<b>Grand Total</b>		<b>0.370</b>	<b>0.345</b>

Globally, forests cover 3.9 million km<sup>2</sup> of which about 95 percent is natural forest and the remainder plantations (FAO. 2001). In total, forests contain an estimated 340 PgC in live and dead material, representing more than 55 percent of the global carbon stored in vegetation (Niles *et al.* 2002) and an estimated NPP of 45 PgC per year. From this base, exports of paper and wood products (0.265 PgC) represent a very small fraction (0.6 percent) of the carbon content in forest and woodland.

## 4.2. Carbon trade in cereals exports

North America, Europe, Asia and Other America are the main exporters of cereals representing 98 percent in volume and value (Table 4); North America and Europe account for three quarters of that trade. Data consistency was cross-checked by calculating the price of a kilogram of cereals. The price ranges from 0.113\$/kg (-12 percent) in Other America to 0.160\$/kg (+26 percent) for Asia from the world average of 0.127\$/kg, broadly conform to the weight volume figures.

**Table 4:** Volume and value of exports by continent for 2000.

Commodity group	Reporter	Net weight (billion kg)	%	Trade value (billion US\$)	%	Unit price (\$/kg)
Cereals (10)	Africa	0.9	0%	0.1	0%	<b>0.137</b>
	Asia	30.1	13%	4.8	16%	<b>0.160</b>
	Europe	65.4	28%	8.7	29%	<b>0.133</b>
	North America	108.6	47%	12.6	43%	<b>0.116</b>
	Oceania	3.2	1%	0.4	1%	<b>0.140</b>
	Other America	25.2	11%	2.8	10%	<b>0.113</b>
	<b>Cereals (10) Total</b>		<b>233.3</b>	<b>100%</b>	<b>29.5</b>	<b>100%</b>

In the year 2000, North America exported 0.049 PgC of cereals followed by Europe, Other America and Asia (Table 5). The three major flows are the exports from North America to Asia and Other America and intra-continental trade in Europe. These fluxes represent more than half (52 percent) of the global carbon flow in cereals. North America alone accounts for 40 percent of the total flow just in its exports to Asia and Other America.

**Table 5:** Carbon exports from region to region for 2000 (PgC)

Commodity group	Reporter	Partner						Grand Total	
		Africa	Asia	Europe	North America	Oceania	Other America		
Cereals (10)	Africa	0.000	0.000	0.000	0.000	0.000	0.000	<b>0.000</b>	
	Asia	0.002	0.009	0.002	0.000	0.000	0.000	<b>0.014</b>	
	Europe	0.004	0.006	<b>0.019</b>	0.000	0.000	0.000	<b>0.029</b>	
	North America	0.008	<b>0.023</b>	0.002	0.003	0.000	<b>0.013</b>	<b>0.049</b>	
	Oceania	0.000	0.001	0.000	0.000	0.000	0.000	<b>0.001</b>	
	Other America	0.002	0.002	0.001	0.000	0.000	0.006	<b>0.011</b>	
	<b>Cereals (10) Total</b>		<b>0.017</b>	<b>0.041</b>	<b>0.024</b>	<b>0.003</b>	<b>0.000</b>	<b>0.020</b>	<b>0.105</b>

**4.3 Global carbon net flow (exports minus imports) for 2000**

A central issue in agriculture and forest carbon commerce is the net position in which countries and regions find themselves in comparison to their total imports and exports. In 2000, North America was the largest net exporter of carbon for cereals (0.046 PgC) leading Europe and Oceania which are small net exporters with 0.006 and 0.001 PgC, respectively. On the other hand Asia, and Other America are clearly net carbon importers. Africa is a net carbon importer for cereals but becomes a net exporter of carbon when wood products are considered.

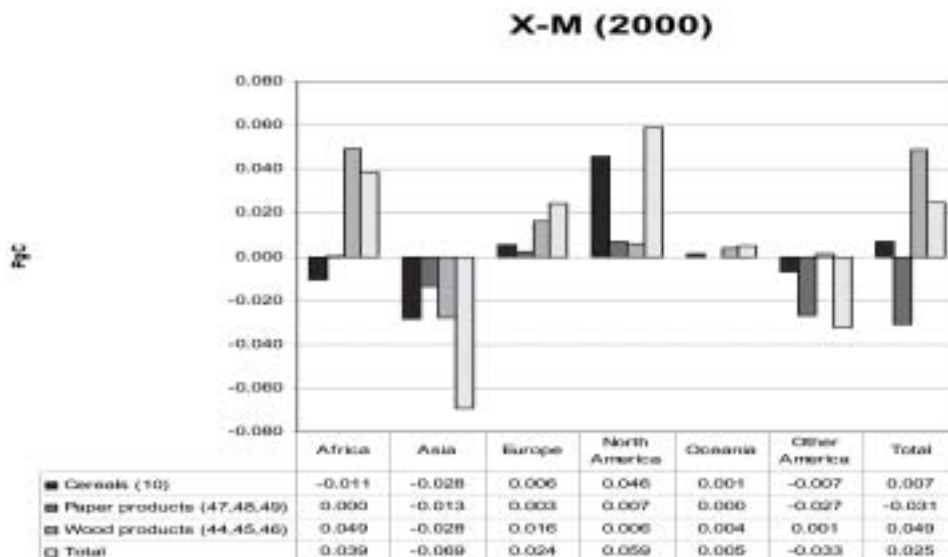


Figure 1: Net carbon flow for all regions (2000).

**4.4. Regional carbon net flow (exports minus imports) from 1989 to 2000**

Based on this assessment, North America and Europe have been net exporters of carbon since the first data sets in 1989 while Asia has been a net importer (Figures 2, 3 and 4). The trend since 1992 for North America (Figure 2) is stable with a net carbon export fluctuating between 0.040 and 0.050 PgC for cereals. Paper and wood products are also stable and less than 0.010 PgC.

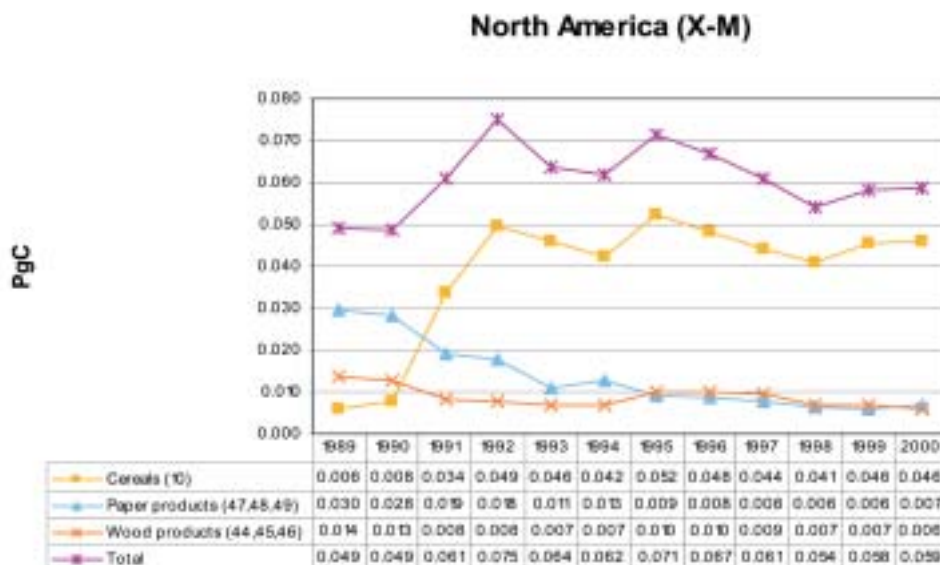


Figure 2: Net carbon flow (X-M) for North America (1989 to 2000)

In Europe (Figure 3) the net balances in cereals and paper products have been relatively stable since 1996. However, wood product balances have increased steadily since 1997 (0.001 PgC) through 2000 (0.016 PgC).

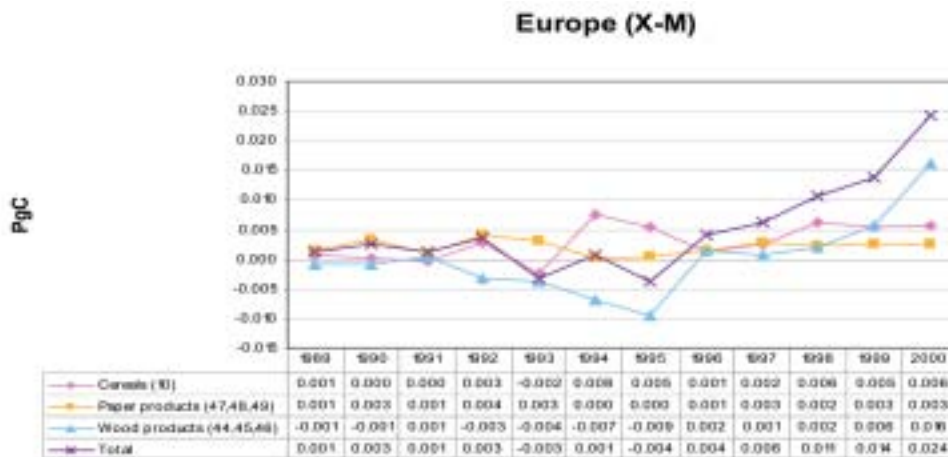


Figure 3: Net carbon flow (X-M) for Europe (1989 to 2000)

Except for 1999 when Asia changed from being a net wood importer to a net exporter, the data are stable for the period 1989-2000. Asia is a net importer of carbon for all three commodity groups.

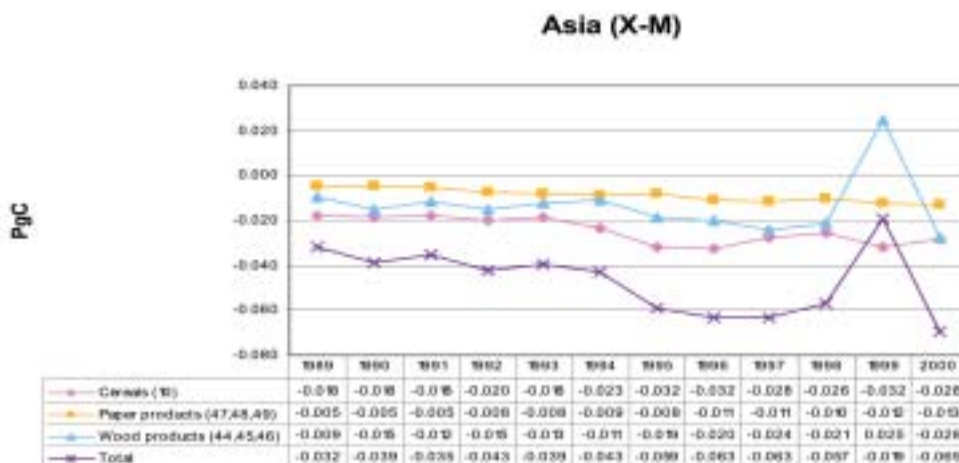


Figure 4: Net carbon flow (X-M) for Asia (1989 to 2000)

## • 5. Conclusions and recommendations

FAO projects that cereal exports will continue to grow for the foreseeable future as developing countries find it more efficient to import from lower cost producers for a portion of their overall food needs (FAO, 2003b). This implies (assuming constant climate change) that the present net exporting regions – North America and Europe – will further expand their present positions, possibly at growth rates exceeding 1 percent per annum. Global cereal production is projected to rise from 1.86 bn tons in 1999 to 2.83 bn tons in 2030 (FAO, 2003b). At that rate, exports of cereals would represent only 7.6 percent of the 2.1 PgC produced yearly by cereals in 2030 but a fifth (21.7 percent) of the harvested cereal product (0.735 PgC) assuming the same NPP.

Even under conditions of a steadily growing trade in carbon commerce for agriculture and forestry, the total amount of the transfers at the regional and global levels will remain almost insignificant (0.6 percent) when viewed in the light of the total terrestrial carbon budget (55 PgC). When viewed from a country-to-country perspective, carbon commerce takes on an added importance as calculation of the net position (carbon importer or carbon exporter) of the countries could have a more significant bearing on their reporting to the Conference of the Parties of the UN Framework Convention on Climate Change. Under such conditions it may be worthwhile to expand the analytical framework to include a wider variety of carbon-based products beyond the agriculture and forestry sectors to include manufactured goods, chemicals and other significant sectors.

Should a global emission trading system be implemented, the trade through commerce might be considered an element. It has been estimated that an emission trading system could price carbon at \$14-\$23 per ton (Brown, 1996), far above many of the prices (\$3-\$5 per ton) that have been used to date in various sequestration schemes. Higher prices could provide incentive for countries to assess potential carbon gains and losses with respect to their ongoing imports and exports.

This overview has provided an initial analysis of the magnitudes of carbon that enters the trade stream from the agriculture and forest sectors. Future efforts could provide deeper analysis through more complete and consistent data. In this regard, the following could be considered:

- Review the possible differences in carbon content that may arise from technology, ecology or crop type or variety.
- Assess current algorithms for calculating carbon content in different types of export crops, including grains, roots and tubers, meat, hides and skins, especially in the light of the technological package used, ecology or crop variety; and, consider extending such analysis to export other agriculture products.
- Further investigate the methods used to aggregate ComTrade data at the regional and global levels in order to undertake data assembly and develop reliable longer term historical data for carbon commerce.
- Clean the ComTrade data to ensure that quantity and value data are consistent.
- Assess the feasibility and architecture required to develop a global carbon commerce database to analyse annual carbon commerce through queries using economic and tonnage data. Among the outputs could be calculations of the direction and velocity of flows, net carbon gains and losses, country-to-country flows, as well as regional, continental and global exchanges on annual, decadal basis.
- Collaborate with the climate modelling community to achieve better spatial accounting for net carbon flows in commerce through improved data structure and definition of model requirements.

## • 6. References

- Brown, S. 1996. *Present and potential roles of forests in the global climate change debate*. Unasylva. vol. 185.
- Ciais, P. and T. Naegler, P. Peylin, A. Freibauer, P. Bousquet. 2001. *Horizontal displacement of carbon associated to agriculture and its impact on the atmospheric CO<sub>2</sub> distribution*. Sixth international carbon dioxide conference. Sendai, Japan. 1-5 October 2001.
- ComTrade. 2003. *Commercial trade database* <http://unstats.un.org/unsd/comtrade/> United Nations Statistical Office.
- Falkowski *et al.* 2000. *The global carbon cycle: A test of our knowledge of earth as a system*. Science. Vol. 290: 290-296.
- FAO. 1999. *Prevention of land degradation, enhancement of carbon sequestration and conservation of biodiversity through land use change and sustainable land management with a focus on Latin America and the Caribbean*. Food and Agriculture Organization of the United Nations. World Soil Resources report #86, 113 pp.
- FAO. 2001. *Global forest resources assessment 2000: Main report*. Food and Agriculture Organization of the United Nations. FAO Forestry paper #140, p. 5.
- FAO. 2002a. *Terrestrial carbon observations: The Ottawa assessment of requirements, status and next steps*. J.Cihlar ed. Food and Agriculture Organization of the United Nations. Environment & Natural Resources report #2, 96 pp. Isbn 92-5-104801-0. Issn 1684-8241.
- FAO 2002b. *Terrestrial carbon observations: The Rio de Janeiro recommendations for terrestrial and atmospheric measurements*. J.Cihlar et al ed. Food and Agriculture Organization of the United Nations. Environment & Natural Resources report #3, 42 pp. Isbn 92-5-104802-9. Issn 1684-8241.
- FAO 2003a. *Terrestrial carbon observations: The Frascati report on in situ carbon data and information*. J.Cihlar *et al.* ed. Food and Agriculture Organization of the United Nations. Environment & Natural Resources report #5, 120 pp. Isbn 92-104844-4. Issn 1684-8241.
- FAO. 2003b. *Agriculture towards 2015-2030*. J.Bruinsma, ed. Food and Agriculture Organization of the United Nations. In press.
- FAOSTAT. 2003. *FAO statistical database*. <http://apps.fao.org/default.htm>. Food and Agriculture Organization of the United Nations. Rome, Italy.
- GAIM. 1998. *Global net primary productivity*. Global analysis, integration and modelling, 1993-1997 report. 18 pp.
- Goudriaan J., J.J.R. Groot and P.W.J. Uithol. 2001. *Productivity of agro-ecosystems*. In: Terrestrial global productivity. Mooney and Roy eds. Academic press. pp. 301-313.
- Heath and Skogg. 2003. *Contribution of forest products to the global carbon budget*. US national report on sustainable forest management. (in draft).
- IPCC. 1996. *Greenhouse gas inventory reference manual*. Vol. 3, p. 4.75

Michie, B. and S. Kin. 1999. *A global study of regional trade flows of five groups of forest products*. World forest, society and environment research program. Helsinki.

Niles, John O., S. Brown, J. Pretty, A.S. Ball and J. Fay. 2002. *Potential carbon mitigation and income in developing countries from changes in use and management of agricultural and forest lands*. Philosophical transactions: Mathematical, physical and engineering sciences. Vol. 360, no. 1797, pp. 1621-1639.

Ramankutty, N. and J.A. Foley. 1999. *Estimating historical changes in global land cover: Croplands from 1700 to 1992*. Global biogeochemical cycles 13(4), pp. 997-1027.

Strehler, A. and W. Stutzle. 1987. *Biomass residues*. In: Hall, D.O. and Overend, R.P. (eds.) Biomass. Wiley and sons Ltd. Chichester, UK.

SITC. 1986. *Standard international trade classification*. United Nations Statistical papers, Series M, no.34/rev.3. Isbn 92-1-161265-9.

WTO. 2003. *Trade statistics*. <http://www.wto.org/stats> World Trade Organization, Geneva, Switzerland.

- 7. Annex 1: crop carbon ratios (IPCC, 1996).

Product	Residue/Crop Product	Dry matter Content (%)	Carbon Content (% dm)	Nitrogen-Carbon (N/C) ratio
Wheat	1.3	78-88	48.53	0.012
Barley	1.2	78-88	45.67	
Maize	1	30-50	47.09	0.02
Oats	1.3			
Rye	1.6			
Rice	1.4	78-88	41.44	0.014
Millet	1.4			0.016
Sorghum	1.4			0.02
Pulse				
Pea	1.5			
Bean	2.1			
Soya	2.1			0.05
Potatoes	0.4	30-60	42.26	
Feedbeet	0.3	10-20 <sup>1</sup>	40.72 <sup>1</sup>	
Sugarbeet	0.2	10-20 <sup>1</sup>	40.72 <sup>1</sup>	
Jerusalem artichoke	0.8			
Peanut	1			

*Table mainly based on Strahler and Stulze, 1987. Sugarbeet data from Ryan and Openshaw, 1991. Nitrogen content from Barnard and Kristoferson, 1985. Note: <sup>1</sup> Statistics are for beet leaves.*

- 8. Annex 2: Top importers and exports of cereals, paper and wood products, 2000

Cereals (10)	Paper products (47,48,49)			Wood products (44,45,46)				
	Trade value (billion \$)	% of total	Trade value (billion \$)	% of total	Trade value (billion \$)	% of total		
<b>Top exporters</b>								
USA	\$9.7	31%	Canada	\$18.6	15%	Canada	\$13.4	20%
France	\$4.0	13%	USA	\$16.3	13%	USA	\$6.4	10%
Canada	\$3.0	9%	Germany	\$12.4	10%	Indonesia	\$3.7	6%
Australia	\$2.9	9%	Finland	\$9.6	8%	Malaysia	\$3.5	5%
Argentina	\$2.4	8%	Sweden	\$7.0	6%	Germany	\$3.5	5%
Other reporters	\$9.3	30%	Other reporters	\$61.2	49%	Other reporters	\$35.6	54%
Total Export:	\$31.3	100%	Total Export:	\$125.1	100%	Total Export:	\$66.2	100%
<b>Top importers</b>								
Japan	\$3.7	12%	USA	\$20.0	16%	USA	\$17.0	23%
Mexico	\$1.6	5%	Germany	\$11.2	9%	Japan	\$11.6	16%
Rep. of Korea	\$1.5	5%	France	\$8.8	7%	Germany	\$4.7	6%
Iran	\$1.5	5%	United Kingdom	\$8.2	6%	United Kingdom	\$3.8	5%
Brazil	\$1.4	5%	China	\$6.6	5%	China	\$3.7	5%
Other reporters	\$21.1	68%	Other reporters	\$73.1	57%	Other reporters	\$33.5	45%
Total Import:	\$30.9	100%	Total Import:	\$127.9	100%	Total Import:	\$74.2	100%

• 9. Annex 3: Export and Imports from reporter to partner, 2000 (ComTrade, 2003).

Commodity group	Reporter	Africa		Asia		Europe		North America		Oceania		Other America		Grand Total
		Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	
Cereals (10)	Africa	0.000	0.000	0.000	0.002	0.000	0.004	0.000	0.004	0.000	0.000	0.000	0.001	0.011
	Asia	0.002	0.000	0.009	0.008	0.002	0.005	0.000	0.022	0.000	0.006	0.000	0.001	0.055
	Europe	0.004	0.000	0.006	0.002	0.019	0.018	0.000	0.002	0.000	0.000	0.000	0.001	0.053
	North America	0.008	0.000	0.023	0.000	0.002	0.000	0.003	0.003	0.000	0.000	0.013	0.000	0.052
	Oceania	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
	Other America	0.002	0.000	0.002	0.000	0.001	0.000	0.000	0.012	0.000	0.000	0.000	0.006	0.039
<b>Cereals (10) Total</b>		<b>0.017</b>	<b>0.000</b>	<b>0.041</b>	<b>0.012</b>	<b>0.024</b>	<b>0.027</b>	<b>0.003</b>	<b>0.042</b>	<b>0.000</b>	<b>0.006</b>	<b>0.020</b>	<b>0.010</b>	<b>0.203</b>
Paper products (47,48,49)	Africa	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
	Asia	0.000	0.000	0.008	0.007	0.000	0.005	0.001	0.003	0.000	0.001	0.000	0.001	0.032
	Europe	0.001	0.000	0.005	0.001	0.058	0.038	0.001	0.004	0.000	0.000	0.000	0.001	0.090
	North America	0.000	0.000	0.006	0.001	0.003	0.001	0.010	0.013	0.000	0.000	0.000	0.001	0.039
	Oceania	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
	Other America	0.000	0.000	0.001	0.001	0.001	0.001	0.003	0.029	0.000	0.000	0.000	0.001	0.040
<b>Paper products (47,48,49) Total</b>		<b>0.001</b>	<b>0.001</b>	<b>0.020</b>	<b>0.009</b>	<b>0.043</b>	<b>0.046</b>	<b>0.016</b>	<b>0.055</b>	<b>0.001</b>	<b>0.001</b>	<b>0.006</b>	<b>0.005</b>	<b>0.205</b>
Wood products (44,45,46)	Africa	0.003	0.010	0.043	0.000	0.014	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.071
	Asia	0.000	0.002	0.010	0.011	0.001	0.008	0.001	0.007	0.000	0.008	0.000	0.002	0.050
	Europe	0.001	0.002	0.010	0.001	0.059	0.050	0.001	0.001	0.000	0.000	0.000	0.002	0.227
	North America	0.000	0.000	0.006	0.000	0.001	0.000	0.017	0.013	0.000	0.000	0.001	0.001	0.044
	Oceania	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.005
	Other America	0.000	0.000	0.002	0.000	0.001	0.000	0.002	0.004	0.000	0.000	0.000	0.001	0.010
<b>Wood products (44,45,46) Total</b>		<b>0.005</b>	<b>0.014</b>	<b>0.075</b>	<b>0.013</b>	<b>0.076</b>	<b>0.059</b>	<b>0.020</b>	<b>0.030</b>	<b>0.001</b>	<b>0.008</b>	<b>0.001</b>	<b>0.005</b>	<b>0.307</b>
<b>Grand Total</b>		<b>0.023</b>	<b>0.015</b>	<b>0.136</b>	<b>0.035</b>	<b>0.143</b>	<b>0.133</b>	<b>0.039</b>	<b>0.127</b>	<b>0.002</b>	<b>0.016</b>	<b>0.027</b>	<b>0.020</b>	<b>0.715</b>

## • 10. Annex 4: country groupings (ComTrade, 2003)

**Africa:** Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Rep., Chad, Comoros, Congo, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, Saint Helena, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zambia, Zimbabwe.

**Asia:** Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei, Cambodia, China, Cyprus, East Timor, Georgia, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lao, Lebanon, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Palestinian Terr., Oman, Philippines, Qatar, Korea Rep., Korea Dem. People's Rep., Ryukyu Isd, Saudi Arabia, Singapore, Sri Lanka, Syria, Tajikistan, Thailand, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Viet Nam, Yemen.

**Europe:** Albania, Andorra, Austria, Belarus, Belgium, Belgium-Luxembourg, Bosnia Herzegovina, Bulgaria, Croatia, Czech Rep., Denmark, Estonia, Faeroe Isds, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russian federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, Yugoslavia.

**North America:** Bermuda, Canada, Greenland, Saint Pierre and Miquelon, USA.

**Oceania:** Australia, Christmas Isds, Cocos Isds, Cook Isds, Fiji, French Polynesia, Kiribati, Marshall Isds, Micronesia, N. Mariana Isds, Nauru, New Caledonia, New Zealand, Niue, Norfolk Isds, Oceania, Palau, Papua New Guinea, Pitcairn, Samoa, Solomon Isds, Tokelau, Tonga, Tuvalu, US misc. Pacific Isds, Vanuatu, Wallis and Futuna Isds.

**Other America:** Anguilla, Antigua and Barbuda, Antilles and Araba, Argentina, Bahamas, Barbados, Belize, Bolivia, Br. Antarctic Terr., Br. Virgin Isds, Brazil, Cayman Isds, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Rep., Ecuador, El Salvador, Falkland Isds (Malvinas), French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Neth., Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Isds, Uruguay, US Virgin Isds, Venezuela.

## • 11. Annex 5: Selected definitions

Cereals (ComTrade code 10) Composed of wheat and meslin, rye, barley, oats, maize, rice, grain sorghum, and buckwheat, millet and canary seed, other cereals.

Paper products (ComTrade codes 47, 48, 49) are composed of pulp of wood, fibrous cellulosic material, waste, etc., paper & paperboard, articles of pulp, paper and board, printed books, newspapers, pictures, etc.

Wood products (ComTrade codes 44, 45, 46) included wood and articles of wood, wood charcoal, cork and articles of cork, manufactures of plaiting material, basket-work, etc.

Primary crops (annual) Consisting of cereals, pulses, roots and tubers, sugar crops, oil bearing crops, fibre crops, vegetables, tobacco, fodder crops.

Primary crops (perennial) Fruits and berries; nuts; permanent oil bearing crops; spices, condiments, herbs; other permanents crops (e.g. cocoa, coffee, tea).