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M.M. Mekonnen
M. Pahlow
M.M. Aldaya
E. Zarate
A.Y. Hoekstra

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Water Footprint Assessment for Latin America and the Caribbean

An analysis of the sustainability, efficiency and equitability of water consumption and pollution

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WATER FOOTPRINT ASSESSMENT FOR LATIN AMERICA AND THE CARIBBEAN: AN ANALYSIS OF THE SUSTAINABILITY, EFFICIENCY AND EQUITABILITY OF WATER CONSUMPTION AND POLLUTION

M.M. MEKONNEN[1]

M. PAHLOW[1]

M.M. ALDAYA[2]

E. ZARATE[3]

A.Y. HOEKSTRA[1,*]

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[1] Twente Water Centre, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands.

[2] United Nations Environment Programme, Sustainable Consumption and Production Branch, Integrated Resources Management Unit, 75441 Paris CEDEX 09, France.

[3] Good Stuff International, 3533 Bowil, Switzerland.

*Corresponding author: Arjen Y. Hoekstra, e-mail: a.y.hoekstra@utwente.nl

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Contents

Summary

The Latin America and Caribbean (LAC) region is relatively well endowed with water, yet the water resources are spatially and temporally unevenly distributed and millions of people still lack access to safe drinking water and proper sanitation systems due to lack of proper governance and infrastructure. Export of water-intensive commodities to the rest of the word is quickly increasing. The paper quantifies the green, blue and grey water footprint (WF) within LAC, and assesses the sustainability, efficiency and equity of water use in the region.

The total WF of production in LAC in the period 1996-2005 was 1,162 billion m^3/y (87% green, 5% blue and 8% grey). Crop production contributed 71%, followed by grazing (23%). Maize and soybean contributed 18% each to the crop-related WF. About 21% of the WF within LAC is related to production for export. The gross virtual water export of LAC to the rest of the world was 277 billion m^3/y, with the largest contribution coming from soybean exports. Vegetables have the highest economic return per unit of water consumed (0.86 \$/m^3). Cereals and oil crops, accounting for the largest share (55%) of the total water consumption in crop production, have relatively low economic water productivities (0.08 \$/m^3).

The average WF of consumption in LAC was about 1,769 m^3/y per capita, which is about 28% above the global average. Consumption of agricultural products accounts for the largest share (93%), followed by domestic water supply (4.5%) and consumption of industrial products (2.4%).

Severe blue water scarcity was observed mainly in Mexico, in parts of Central America, along parts of the western and northern coasts of South America, in northeast Brazil and large parts of Argentina. Three of the 77 river basins studied in the region are facing year-round severe water scarcity and 26 basins experience severe water scarcity at least one month per year. In addition, in parts of Mexico, Central America, and along the coast of South America the nitrogen and phosphorous assimilation capacity of the rivers has been fully consumed.

The expansion of pasture and export-oriented industrial agriculture has become the main driver of forest and savannah removal in various parts of LAC. The conversion of natural ecosystems to agricultural lands is the most important driver of biodiversity loss and ecosystem degradation in the region. The combined agricultural and forest area in the region accounts for 85% of the total land area. Given that the remaining area is in part built-up area and barren land, additional land for agriculture is limited. Efficient use of the green water resources in existing rain-fed agriculture, rather than expanding agricultural lands, is crucial to increase production and conserve biodiversity at the same time. Besides, the combination of significant undernourishment levels in the region and increasing areas and water volumes used for producing export commodities, raises questions on the fairness of land and water allocation in the region from a final consumer point of view, particularly when considering the allocation of land and water for domestic versus export purposes.

1. Introduction

Latin America and the Caribbean (LAC) comprises 33 sovereign countries, recognised in the Community of Latin American and Caribbean States (CELAC, 2013), plus a number of islands which are small dependent territories. The sovereign countries cover an area of 20.5 million km^2 (15.2% of the world's total land surface) and had a population of 609 million inhabitants in the year 2012 (8.6% of the world population) (World Bank, 2014). The actual total renewable water resources of LAC are about 18.5 billion m^3/y, which corresponds to 34% of the world resources (FAO, 2014a). LAC is therefore relatively well endowed with water resources. However, there are important regional differences. While countries like Guyana and Suriname had, in the year 2012, total renewable water resources of 318×10^3 and 228×10^3 m^3/capita/y, respectively, other countries, such as the Bahamas, Barbados and Saint Kitts and Nevis, have values as low as 57, 291 and 444 m^3/capita/y, respectively (FAO, 2014a). Generally, water resources are mainly located in the inland parts of the region, and still, inland LAC has substantial geographic and temporal variations as well.

In 2011 agriculture accounted for 68% of the total freshwater withdrawal in LAC, whereas the industrial and domestic sectors accounted for 11% and 21% respectively (World Bank, 2014). According to FAO (2012), much of the remaining unexploited arable land in the world is located in LAC and Sub-Saharan Africa. The relative abundance of water and remaining arable land in combination with global trade liberalization, have boosted LAC as an agricultural commodities exporter to the world market. Agricultural production increased by more than 50% from 2000 to 2012, with Brazil expanding production by more than 70%. Most food produced in LAC comes from rain-fed agriculture, which represents 87% of the total cropland area (Rockström et al., 2007). The irrigation potential for the region is estimated at 77.8 million hectares, with most of the regional irrigation potential (66%) localised in four countries: Argentina, Brazil, Mexico and Peru (UNCTAD, 2011).

Agricultural developments in LAC are desirable in order to improve the economic and social conditions of the region and increase food production for both LAC and the world, which in turn can contribute to alleviate pressures on the world's freshwater resources and food security. However, this must be done in a sustainable way, dealing with both changes in production processes and consumption behaviour (Godfray et al., 2010; Vanham et al., 2013). Challenges include substantial differences in climate within the region, different levels of economic development within and between countries, vast social inequalities, lack of appropriate accounting systems and transparency, and deficiencies in public administration and institutions that make implementation of policies challenging. River basin managers should have accurate data on actual water availability per basin, taking into account basic human needs, environmental water requirements and the basin's ability to assimilate pollution.

To plan sustainable water allocation and use, water managers need data and tools capable of informing them in a comprehensive way. In this paper, we carry out a Water Footprint Assessment (WFA) to provide comprehensive insight regarding the state of freshwater appropriation in LAC river basins and the sustainability thereof. The goal of the paper is to understand current water allocation and pollution in LAC, assess the environmental sustainability, economic efficiency and social equity of water use in the region and identify future challenges.

We analyse the water footprint (WF) related to agricultural and industrial production and domestic water supply in the region, as well as virtual water trade with the rest of the world. We evaluate the environmental sustainability of the WF by comparing the blue WF to blue water availability per river basin, by evaluating the increasing use of land and green water resources for agriculture at the expense of natural vegetated areas, and by comparing grey WFs related to nitrogen and phosphorus to the assimilation capacity per river basin. We assess the efficiency of water use in LAC by comparing actual WFs of crop production to WF benchmarks, by analysing economic water productivity of different crops and by estimating the export earnings per unit of water appropriated for production for export. Subsequently, we assess the equitability of water use within the LAC region by analysing the differences in the WFs of consumers across the different countries in the region in relation to undernourishment. Finally, we discuss future challenges and potential response strategies, as well as limitations of this study.

2. Method and data

Green, blue and grey WFs have been estimated following the calculation framework as set out in *The Water Footprint Assessment Manual* (Hoekstra et al., 2011). The blue and green WFs refer to water resources consumption (appropriation of ground/surface water and rainwater, respectively). The grey WF refers to the volume of water pollution, focusing thereby on nitrogen in this study.

The WF of production within a nation or geographic region is defined as the total freshwater volume consumed or polluted within the territory of the nation or region as a result of different economic activities (domestic water supply, agricultural and industrial production). In the current study, the LAC region includes the 33 countries recognized by CELAC plus 6 other island states recognized by FAO. Data on WFs of crop production in LAC were taken from Mekonnen and Hoekstra (2011a), who estimated the global WF of crop production with a crop water use model at a 5 by 5 arc minute spatial resolution. The WFs of grazing and animal water supply per country were taken from Mekonnen and Hoekstra (2012). The national level data were mapped at 5 by 5 arc minute spatial resolution using the global livestock density obtained from FAO (2013a).

Gross virtual-water flows are calculated by multiplying, per product, the trade volume with the WF per ton of product in the exporting nation. LAC's virtual water import and export related to trade in agricultural and industrial products were taken from Mekonnen and Hoekstra (2011b).

In order to assess environmental sustainability of the WFs, we compared – per catchment – the blue WF to blue water availability (Hoekstra et al., 2012) and the nitrogen- and phosphorus-related grey WFs to available assimilation capacity (Liu et al., 2012). Furthermore, we analysed the limitations to green water resources availability by looking at the conflict between increasing use of land and green water resources for agriculture and biodiversity conservation. Water use efficiency in the region was analysed by considering economic water productivities of crops, calculated by dividing the producer price (US$/ton) by the WF of the product (m^3/ton), per product category. Data on producer price per crop were obtained from FAO (2014c). Additionally, we calculated the economic return of exported products by dividing the export value (US$/y) by the WF of the product (m^3/y). Data on export values of agricultural and industrial products were taken ITC (2007). We used the WF benchmarks for crop production from Mekonnen and Hoekstra (2014) to identify the potential for water productivity increases per crop. Equity of water allocation was studied by comparing the average WF per capita across countries within the region and by correlating the WF per capita and the proportion of undernourished people per country.

3. The green, blue and grey water footprint of production

The total WF of national production in LAC in the period 1996-2005 was 1,162 billion m^3/y (87% green, 5% blue and 8% grey). Crop production contributed most (71%) to this total, followed by grazing (23%), domestic water supply (4%), industrial production (2%) and animal water supply (1%) (Table 1). The contribution of different crops to the total WF related to crop production is shown in Figure 1. Maize and soybean contribute 18% each, followed by sugarcane (11%), fodder crops (7%) and coffee (7%). Wheat and rice are the other major crops, each having a 5% share of the total crop-related WF. Rice and sugar cane account for the largest share of the blue WF related to crop production, each accounting for 19%, followed by maize (6%) and wheat (5%). The WF of production per country is listed in Appendix I.

On average, 21% of the WF of production in LAC (246 billion m^3/y) is not for domestic consumption, but for export (Table 1). In the agricultural sector, 22% of the total WF relates to production for export; in the industrial sector this is 16%. The largest share (97%) of the WF for total export comes from green water.

Table 1. Water footprint of production in Latin America and the Caribbean in the period 1996-2005.

	Water footprint of agricultural production			Water footprint of industrial production	Water footprint of domestic water supply	Total
	Related to crop production	Related to grazing	Related to animal water supply			
Water footprint of production (billion m^3/y)						
Green	739	269	–	–	–	1,008
Blue	43.9	–	7.18	1.37	5.05	57.5
Grey	44.4	–	–	16.4	35.8	96.7
Total	827	269	7.18	17.8	40.9	1,162
Water footprint for export (billion m^3/y)						
Green	------------- 236 -----------------------			–	–	236
Blue	------------- 3.5 -----------------------			0.16	0	3.7
Grey	------------- 4.0 -----------------------			2.68	0	6.7
Total	------------- 243 -----------------------			2.84	0	246
Water footprint for export (% of total)						
Green	------------- 23% -----------------------			–	–	23%
Blue	------------- 7% -----------------------			11%	0%	6%
Grey	------------- 9% -----------------------			16%	0%	7%
Total	----------- 22% ----------------------			16%	0%	21%

Data source: Mekonnen and Hoekstra (2011b).

Brazil is the country with the largest total WF within its territory, accounting for 41% of LAC's total WF. The other major countries are Argentina (16%) and Mexico (13%). In terms of the blue WF, Mexico comes out at the top with 29% of the total blue WF, followed by Brazil (24%), Argentina (10%) and Peru (8%).

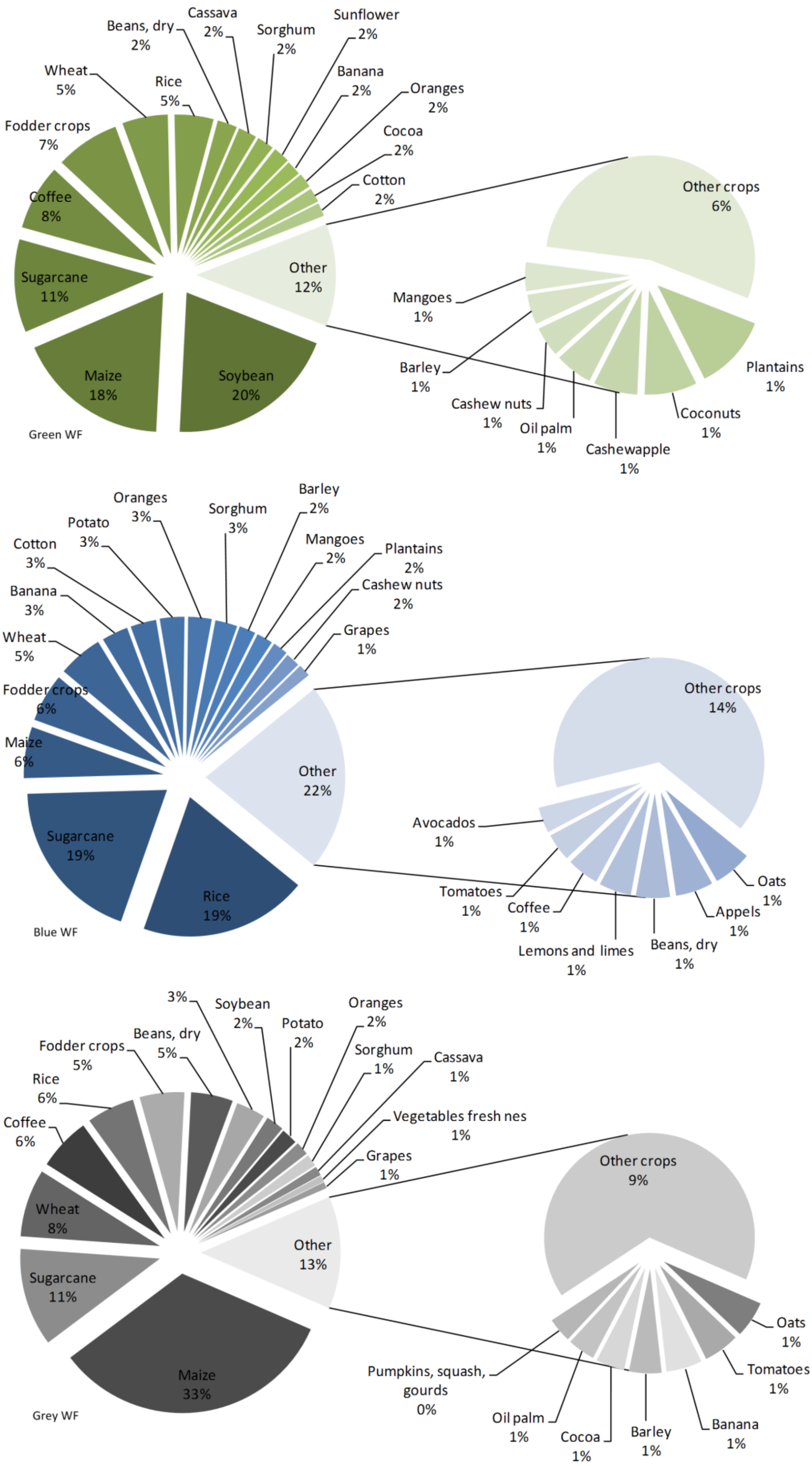

Figure 1.Contribution of different crops to the total green, blue and grey water footprint related to crop production in LAC (1996-2005). Data source: Mekonnen and Hoekstra (2011a).

The spatial distribution of the green, blue, grey and total WF of production in LAC is shown in Figure 2. The WF in the twenty major river basins in LAC is presented in Table 2. The Parana basin has the largest WF with 336 billion m^3/y (19% of the total WF). Other river basins with a significant share of the total WF are Amazon (73 billion m^3/y), Salado (52 billion m^3/y), Uruguay (48 billion m^3/y), Magdalena (36 billion m^3/y), and Tocantins (34 billion m^3/y). About 50% of the total WF of production in LAC is located in these six river basins. The largest blue WF in LAC is also found in the Parana basin (10% of the blue WF within LAC). The Amazon, Santiago and Uruguay are the river basins with a large blue WF, each contributing 4% of the total blue WF of production.

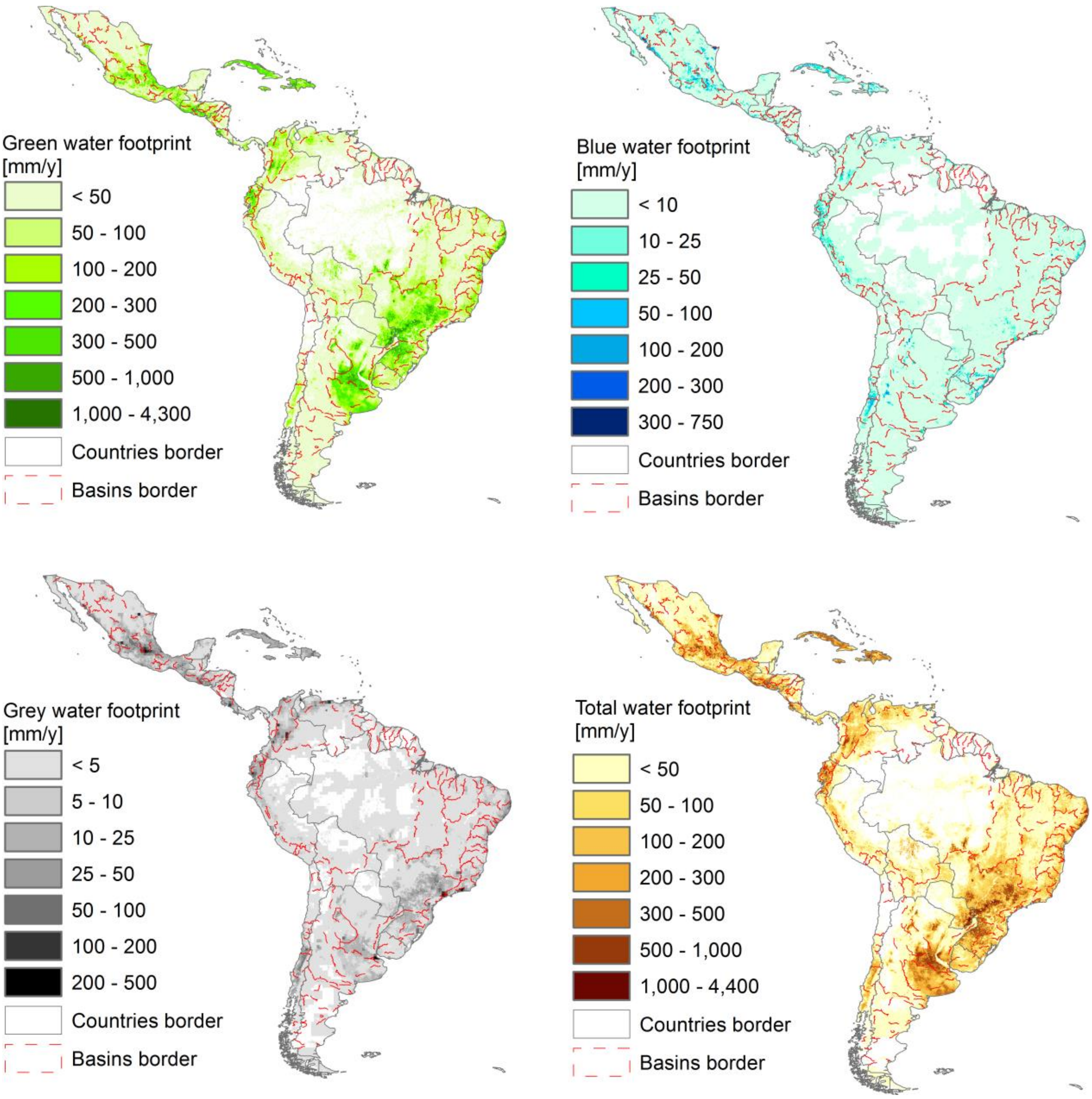

Figure 2.The green, blue, grey and total water footprints within Latin America & Caribbean (1996-2005). The data are shown in mm/y on a 5 by 5 arc minute grid. Data source: Mekonnen and Hoekstra (2011b).

Table 2. The top-20 river basins with the largest total water footprint of production in LAC (1996-2005).

Basin name	Basin area (km^2)[a]	Countries in the basin	Water footprint of production (million m^3/y)[b]		
			Green	Blue	Grey
Parana	2640000	Brazil; Bolivia; Paraguay; Argentina	315,142	5,587	15,616
Amazon	5880000	Colombia; Venezuela; Guyana; Suriname; French Guiana; Ecuador; Peru; Brazil; Bolivia	66,553	2,566	3,692
Salado	266000	Argentina	50,566	299	1,541
Uruguay	266000	Brazil; Uruguay; Argentina	44,069	2,050	1,737
Magdalena	261000	Colombia	29,596	1,672	4,500
Tocantins	775000	Brazil	32,169	532	1,057
Sao Francisco	629000	Brazil	24,689	1,379	2,102
Orinoco	952000	Colombia; Venezuela; Brazil	23,363	1,111	2,744
Santiago	126000	Mexico	14,757	2,164	3,917
Lake Mar Chiquita	154000	Argentina	16,386	588	1,017
Grisalva	128000	Mexico; Guatemala	13,458	283	1,911
Rio Jacui	70800	Brazil	12,308	747	632
Panuco	83000	Mexico	9,031	1,528	2,996
Daule &Vinces	42000	Ecuador	9,538	963	1,062
Parnaiba	337000	Brazil	7,616	240	678
Doce	86100	Brazil	7,016	238	567
Lempa	18100	Guatemala; Honduras; El Salvador	4,756	93	634
Papaloapan	39900	Mexico	4,538	169	701
Negro (Uruguay)	70800	Brazil; Uruguay	4,692	269	99
Esmeraldas	19800	Ecuador	3,968	253	644

Sources: [a] GRDC (2007); [b] Own elaboration based on Mekonnen and Hoekstra (2011b).

4. Virtual water flows

LAC's gross virtual water export to the rest of the world related to agricultural and industrial products was 277 billion m^3/y (88% green, 6% blue and 6% grey) in the period 1996-2005 (Table 3). The virtual water export was dominated by five major products contributing a little over three quarters of the total virtual water export from LAC to the rest of the world (Table 8). Soybean accounts for the largest share of virtual water export (36%), followed by coffee (14%), cotton (10%), livestock products (10%) and sugarcane (8%). The water footprint of these major export products was dominantly based on rainwater: soybean (99% green water), coffee (94%), cotton (62%), livestock products (92%) and sugarcane (87%). In total terms, LAC is a net virtual water exporter, with an average net virtual water export of 112 billion m^3/y over the period 1996-2005 (Table 3). The net export refers to green water only: LAC's net green virtual water export was 141 billion m^3/y. Regarding blue and grey water, LAC had net virtual water import: 16 and 12 billion m^3/y, respectively.

Table 3. LAC's virtual water trade balance (billion m^3/y). Period 1996-2005.

Products	Gross virtual water import			Gross virtual water export			Net virtual water import			
	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Total
Related to crop products	88	30	17	220	14	8.8	-131	16	8.0	-107
Related to animal products	16	1.3	1.1	26	1.8	0.37	-9.8	-0.43	0.75	-9.5
Related to industrial products		1.0	9.7		0.60	6.3	0.00	0.44	3.4	3.9
Total	104	33	28	245	16	15	-141	16	12	-112

Source: Own elaboration based on Mekonnen and Hoekstra (2011b).

The gross virtual water import by LAC from the rest of the world related to import of agricultural and industrial products was 165 billion m^3/y (63% green, 20% blue and 17% grey). The largest share of the virtual water import relates to import of cotton products (42%) (mainly from the US and Pakistan), followed by wheat (12%) (mainly from the US and Canada) and livestock products (11%) (mainly from the US). About 54% of the total virtual water imports goes to Mexico. It accounted for about 50% of the total virtual water import to LAC related to crop, 83% related to livestock, and 47% related to industrial products.

The major destinations of LAC's virtual water exports were the US (22%), China (8%), Germany (6%), Netherlands (5%), Italy (5%), and Spain, France and Russia 4% each (Appendix II). The virtual water trade balance of countries trading with LAC together with the gross virtual water flows to and from LAC are shown in Figure 3.

The international virtual water flows within LAC are small compared to the exchanges with the rest of the world. Most of the virtual water flows are related to crop products (88%). Virtual water flows related to trade in animal and industrial products contribute 9% and 3%, respectively. The virtual water flows within LAC are dominantly green water (88%), while blue and grey water contribute 5% and 7%, respectively (Table 4).

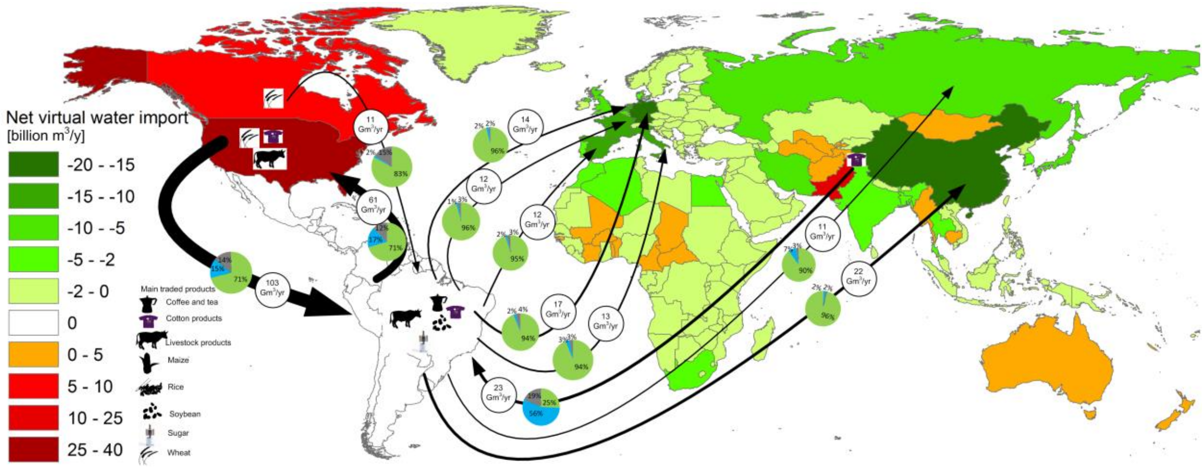

Figure 3.Global map showing countries with net virtual water import related to import of agricultural and industrial products from LAC (green) and countries with net virtual water export due to agricultural and industrial exports to LAC (red) over the period 1996-2005. Only the biggest gross virtual water flows (> 10 billion m^3/y) are shown. Data source: Mekonnen and Hoekstra (2011b).

Table 4. International virtual water flows within the LAC region (billion m^3/y).

Product	Green	Blue	Grey	Total
Related to crop products	48	2.3	2.4	52
Related to animal products	4.7	0.34	0.08	5.1
Related to industrial products	–	0.14	1.6	1.7
Total	52	2.7	4.1	59

Source: Own elaboration based on Mekonnen and Hoekstra (2011b).

5. Environmental sustainability of the WF in the region

5.1. Blue water footprint versus blue water availability

The expansion of irrigation in the LAC region, at an average annual rate of 250,000 hectares over the past five decades, reflects the economic importance of blue water resources in the region (World Water Forum, 2012). The total area equipped for irrigation in LAC is 15 million ha (cf. world total: 308 million ha) and the area actually irrigated is 12 million ha (cf. world total: 255 million ha) (FAO, 2014b). Areas of high irrigation density are located along the western coasts of Mexico and Peru, in central Chile, and in the growing areas along the border between Brazil and Uruguay. In addition, numerous other, smaller irrigation areas are spread across the LAC region. Areas predominantly irrigated with groundwater are found in a strip of about 500 km width and 2,500 km length in Brazil and in the north-eastern part of Argentina. In most regions of Southern America irrigation mainly depends on surface water. No water from nonconventional sources is used for irrigation (Siebert et al., 2013).

Figure 4 shows the annual average monthly blue water scarcity in the LAC region at 30×30 arc minute resolution level, using data of Hoekstra and Mekonnen (2011) for the ten-year period 1996-2005. Blue water scarcity is here defined as the ratio of the total blue WF to the blue water availability, thereby accounting for environmental flow requirements (Hoekstra et al., 2011; 2012). The blue WF exceeds blue water availability mainly in Mexico, but also in parts of Central America, along the west coast of South America (Peru, Chile), along the north coast (Venezuela), in the northeast of Brazil and in the southern part of South America (Argentina).

A detailed analysis of the monthly data shows that three of the 77 river basins are facing year-round severe water scarcity. Those are the Yaqui River Basin in north-western Mexico (76,000 km^2, 651,000 people), the Loa River Basin, the main water course in the Atacama Desert in northern Chile (50,000 km^2, 196,000 people) and the Conception River Basin in northern Mexico (26,000 km^2, 193,000 people). In addition, 26 basins experience severe water scarcity at least one month per year (2,660,247 km^2, 82 million people).

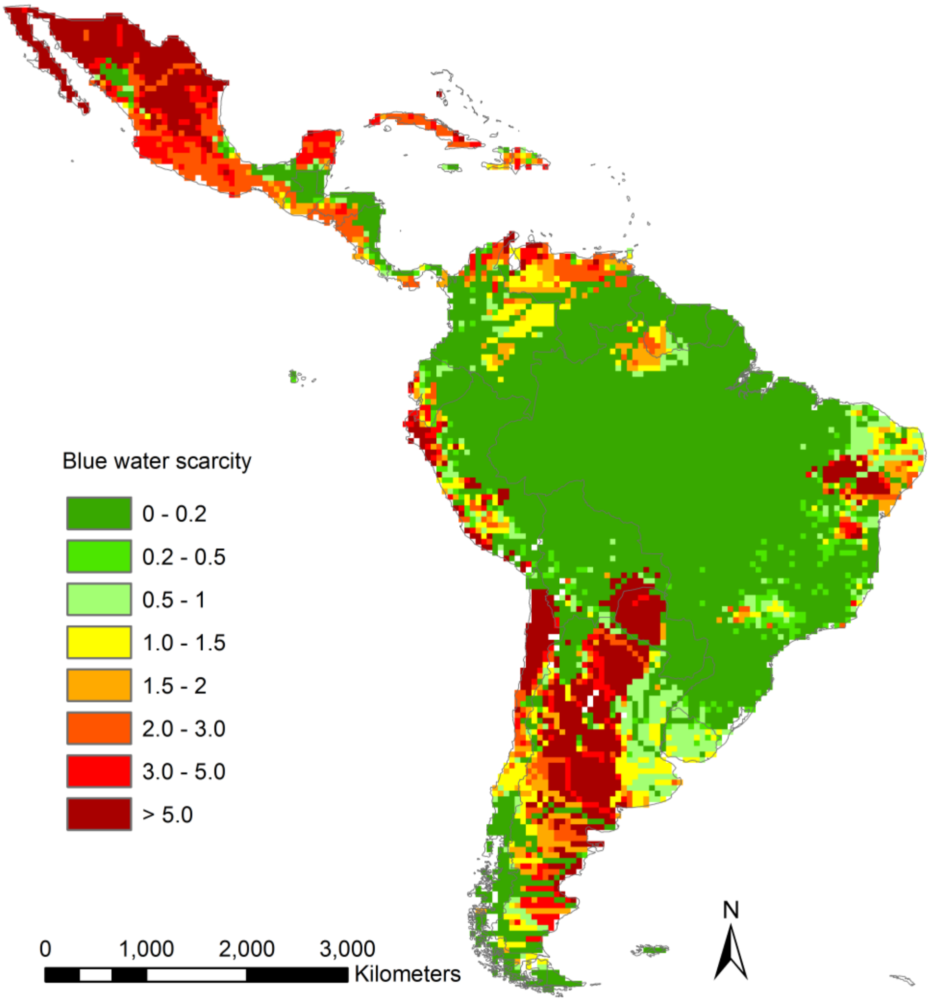

Figure 4. Annual average monthly blue water scarcity in Latin America and the Caribbean estimated at a resolution level of 30×30 arc minute grid cells. Low blue water scarcity corresponds to green colours (<1.0), moderate to yellow (1.0-1.5), significant to orange (1.5-2.0) and severe to red (>2.0).

Even though a large share of the blue WF of production in LAC is in the basins of the Parana (8%), Amazon (4%), Uruguay (4%) and Magdalena (3%), blue water scarcity in these basins is low throughout the year. Table 5 presents the ten river basins that have a share of blue WF above or equal to 0.4% and experience severe water scarcity at least one month in a year. For each river basin the major products (agricultural, industrial or domestic) are listed, based on their share of the total blue WF in each river basin.

The Santiago river basin (located in Mexico) not only has the largest blue WF, but also experiences severe water scarcity for five months in a year and moderate scarcity in one month. The Panuco river basin (also located in Mexico) is the second basin with a significant share of the blue WF and experiences a similar scarcity level. The major activities contributing to the blue WF in the basins of Santiago and Panuco are wheat, fodder crops, barley and maize, in competition with domestic water supply. The Colorado basin, located in Argentina and Chile, also has a large share of the blue WF and experiences severe scarcity for one and significant scarcity for two months in a year. Grapes and fodder crops are the major products contributing to the blue WF of that basin.

Table 5.The blue water scarcity and contribution of major products in ten priority basins (1996-2005).

River basin	Percentage of the total blue water footprint of production in LAC located in this basin[a]	Number of months per year that a basin faces moderate, significant or severe water scarcity[b]			Products with significant contribution to the blue water footprint in the basin (% contribution)[a]
		Moderate	Significant	Severe	
Santiago (Mexico)	3.8%	1	0	5	Wheat-18%, Fodder crops-15%, Barley-13%, Domestic-12%, Maize-11%, Other perennials-15%
Panuco (Mexico)	2.7%	1	0	4	Fodder crops-19%, Domestic-17%, Sugarcane-13%, Barley-10%, Maize-6%, Wheat-6%, Citrus fruits-5%, Other perennials-16%
Colorado (Argentina, Chile)	2.6%	0	2	1	Grapes-38%, Fodder crops-10%, Other perennials-25%, Other annuals-19%
Rapel (Chile)	1.1%	1	0	2	Maize-27%, Rice-10%, Sugar Beets-6%, Wheat-15%, Other annuals-14%, Other perennials-18%
Lake Mar Chiquita (Argentina)	1.0%	1	1	4	Sugarcane-20%, Domestic-10%, Wheat-9%, Cotton-8%, Fodder crops-8%, Soybeans-8%, Maize-6%, Citrus fruits-5%, Other annuals-11%, Other perennials-7%
Yaqui (US and Mexico)	0.8%	0	0	12	Wheat-53%, Maize-11%, Fodder crops-8%, Other annuals-10%, Other perennials-6%
Jaguaribe (Brazil)	0.6%	1	1	3	Fodder crops-22%, Sugarcane-5%, Other perennials-58%
Fuerte (Mexico)	0.5%	2	0	3	Sugarcane-19%, Potatoes-11%,Wheat-11%, Pulses-9%, Maize-6%, Other annuals-18%, Other perennials-13%
Negro (Uruguay)	0.5%	0	0	1	Rice-97%
Chira (Peru)	0.4%	0	2	5	Rice-26%, Maize-16%, Citrus fruits-9%, Sugarcane-9%, Cotton-6%, Other perennials-17%, Other annuals-8%

Sources: [a] Own elaboration based on Mekonnen and Hoekstra (2011b); [b] Hoekstra et al. (2012).

5.2. Limitations to land and green water resources availability

LAC is producing and supplying more and more food to other parts of the world using rainwater. Many parts of the region have abundant green water resources, which suggest that there is room for expansion of rain-fed agriculture. However, this ‘abundance of green water’ is misleading, because a great part of the green water resources in the region is attached to forested lands. Claiming new land and associated green water resources for agriculture will be at the expense of natural vegetation. The economy of LAC is highly dependent on its rich biodiversity, yet it is increasingly under threat from human activities. Although there are numerous biodiversity policies and measures in the region, collectively they do not effectively conserve its biological resources (UNEP, 2010).

Across the region, the agricultural sector makes significant contributions to GDP, export revenues, employment, and rural livelihoods. Argentina’s and Brazil’s growing shares of international agricultural markets are explained by the enormous growth in soybean production and exports from both countries between 1995 and

2011. During that period, soybean production increased by 198% in Brazil and by 287% in Argentina, while soybean exports increased by 329% in Brazil and 980% in Argentina (FAO, 2012). Soybean export has a share of 36% of the total virtual water export from LAC to other countries of the world. The green WF of soybean production amounts to 99%. With an abundance of green water and hence favorable conditions for excellent agricultural production, in some of the basins in those countries blue water scarcity is low throughout the year. But it is important to note that drastic land-use changes are occurring in the region, which generally take place with little or no planning (Chico et al., 2014).

The land area in Central America, the Caribbean and South America is 249 million ha, 23 million ha and 1,781 million ha, respectively. The area devoted to agriculture is 52% of the total land area in the Caribbean, 51% in Central America and 33% in South America. Forests take up 29% in the Caribbean, 36% in Central America and 51% in South America (Table 6). This shows that expansion of the agricultural sector has limits with respect to land availability. There is a trade-off between biodiversity conservation and food production. It must also be considered that some areas are difficult to use for agricultural production, such as high mountains or deserts.

Table 6. Land use in the LAC region (average values for 1996-2005 in million ha) (FAO, 2014c).

	Central America	Caribbean	South America
Region area	249	23	1,781
Land area	245	23	1,757
Agricultural area[a]	124	12	578
Inland water	3.4	0.76	24
Forest area	89	6.5	902
Other land[b]	32	4.4	277

[a] Agricultural area is the sum of areas under (a) arable land - land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years); (b) permanent crops; and (c) permanent meadows and pastures - land used permanently (five years or more).

[b] Other land is the land not classified as agricultural land and forest area. It includes built-up and related land, barren land, other wooded land, etc.

From the perspective of biodiversity conservation a certain area of the total region needs to be reserved for natural vegetation. As a result, also the green water resources associated with this land will be reserved for nature and not be available for agriculture. Myers (1979) suggested that at least 10%, and perhaps as much as 20%, of tropical moist forest needs to preserve biodiversity. The 10% conservation target is an arbitrary value, but one that has gained considerable popularity, without evidence of biological substance or conservation merit (Svancara et al., 2005). In 2002, it was used as global 2010 biodiversity target in the Convention on Biological Diversity (Bertzky et al., 2012). Svancara et al. (2005) show that proposed protection percentages in conservation assessments (30.6 percent ± 4.5 percent) and threshold analyses (41.6 percent ± 7.7 percent) are significantly greater than average policy-negotiated values (13.3 percent ± 2.7 percent). While the regions of Central America, the Caribbean and South America meet the 2010 conservation target of 10% protected terrestrial area (according to FAO (2014c) – 11.7% was protected in the Caribbean in 2010, 14.4% in Central America and 21.6% in South America – it must be questioned whether this is sufficient to conserve biodiversity. Figure 5 shows that in all LAC countries except Venezuela the biodiversity hotspot area was larger than the protected area in the year 2004. According to Butchart et al. (2010), the rate of biodiversity loss in the world does not slow down, despite increasing efforts and some local successes.

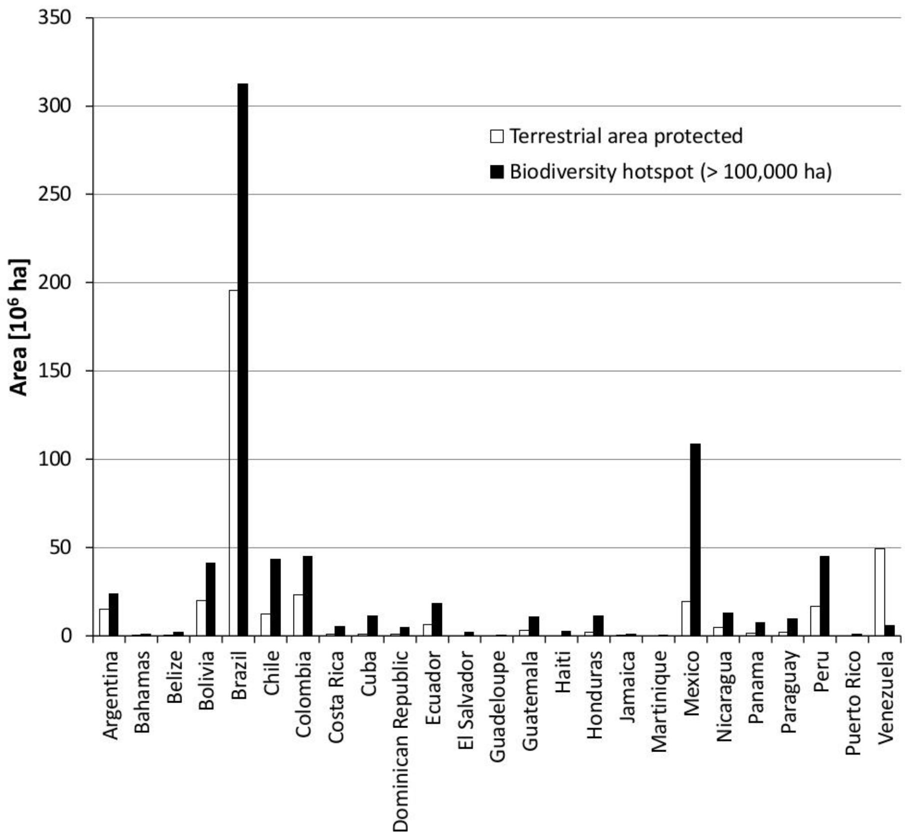

Figure 5. Protected terrestrial areas (Bertzky et al., 2012) and biodiversity hotspot areas (Mittermeier et al., 2005) in LAC. The area protected in the year 2004 is shown in order to allow for a comparison with Conservation International's 2004 Hotspot Revisited Analysis (Mittermeier et al., 2005). A region must meet two strict criteria to be considered a hotspot: it must contain at least 1,500 species of vascular plants (> 0.5% of the world's total) as endemics, and it has to have lost at least 70% of its original habitat (Myers et al., 2000).

In 2010, in response to the continued loss of biodiversity, the Parties of the Convention on Biological Diversity adopted the Strategic Plan for Biodiversity 2011-2020, known as the Aichi Biodiversity Targets (Convention on Biological Diversity, 2014a) whereby Target 11 states that "at least 17% of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes". According to Svancara et al. (2005), specific regional targets should be informed by conservation planning processes that are based simultaneously on the biological needs of species, communities, and ecosystems. Such efforts must include the development of national and region-specific targets, action plans and strategies to enforce their successful implementation. In line with this, Brazil is striving for 30% protection of the Amazon area, 17% of the other terrestrial biomes and 10% of coastal and marine areas (Convention on Biological Diversity, 2014b).

Globally, South America suffered the largest net loss of forests between 2000 and 2010 – about 4.0 million ha/y; decreasing after a peak in the period 2000–2005. The average net loss of forest was 4.2 million ha/y in the 1990s, 4.4 million ha/y in the period 2000–2005, and 3.6 million ha/y in the period 2005–2010. The regional figures primarily reflect the developments in Brazil, which accounts for 60% of the forest area in this region (FAO, 2010). In the period 2000–2010, three of the ten countries with the largest annual net loss of forest area globally are in the LAC region: Brazil -2,642,000 ha/y, or -0.49%, Bolivia with -290,000 ha/y or -0.49% and Venezuela with -288,000 ha/y or -0.60%.

Extensive grazing is one of the main causes of the rapid deforestation in the tropical rainforests of the region and will continue to expand mostly at the expense of forest cover (Figure 6). Although there are substantial differences among countries, both concerning the spatial patterns of deforestation and the substitution trends between land uses, nearly two-thirds of the deforested land will be converted to pasture (Wassenaar et al., 2007).

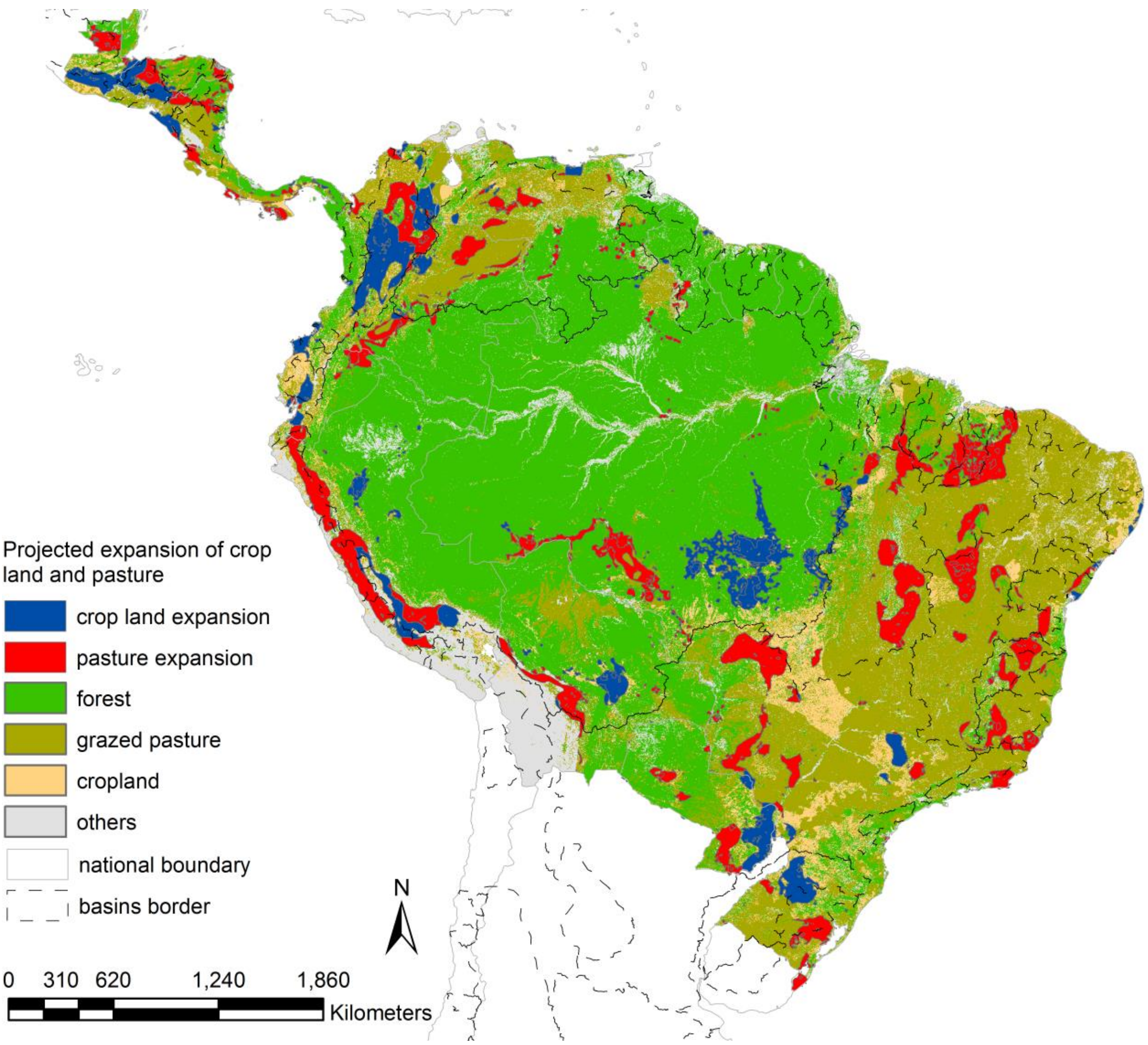

Figure 6. Expansion of cropland and pasture to forested area in South and Central America. Data source: FAO (2013b).

Export-oriented industrial agriculture has become another main driver of South American forest and savannah removal. A large share of the deforested area is dedicated to large-scale production of soybeans and other feed crops driven by the sharp increase in global demand for livestock products (FAO, 2006, Smaling et al., 2008). This increased demand for feed, combined with other factors, has triggered increased production and exports of soybean and other feed crops from Latin America, leading to extensive deforestation. The soybean and other feed crops are mainly exported to China and the European Union (Zarate et al., 2014).

The conversion of natural ecosystems into grazing lands and cropland is currently the most important driver of biodiversity loss and ecosystem degradation in the LAC region (FAO, 2010). The destruction of large areas of tropic forests as well as of wooded grasslands of the Cerrado in South America due to unsustainable agricultural practices is of major concern (Bovarnick et al., 2010; UNEP, 2010). Given the need to protect remaining natural areas, there is little room for expansion of rain-fed agriculture. Also outside the forested lands there is little room for expansion. In the period 1996-2005, the combined agricultural and forest area accounted for 87% of the total land area in Central America, 81% in the Caribbean, and 84% in South America. Given that the remaining area is in part built-up area and barren land, additional land for agriculture is limited. Efficient use of the existing agricultural lands and associated green water resources is therefore crucial to increase total production. As pointed out by Molden et al. (2007), water productivities and yields in rain-fed agriculture can often be substantially improved through better management practices.

5.3. Grey water footprint versus assimilation capacity

Pollution from nutrients is identified as one of the five main pressures on biodiversity in Latin America, which presents a generally rising trend (UNEP, 2010). Anthropogenic pollution due to nitrogen (N) and phosphorus (P) in LAC has been investigated here using the water pollution level (WPL) as defined by Hoekstra et al. (2011). WPL is the ratio of the total grey WF in an area (typically a watershed, catchment or river basin) to the runoff from the area. WPL values exceeding 1.0 imply that ambient water quality standards are violated. In large parts of LAC, WPLs for N and P are close to or higher than 1.0. In parts of Mexico, Central America, and along many regions of the coast of South America the pollution assimilation capacity of the rivers has been fully consumed (Figure 7). Particularly high WPL levels are found in Mexico and in the south cone of Latin America.

Water pollution is partly related to lack of water treatment infrastructure and governance in the water sector. Although there is infrastructure to treat about 35%, only 20% of wastewater is effectively treated in LAC (Mejia, 2014).) More than 70% of sewage is discharged into the nearest water bodies without any treatment, causing alarming water pollution problems (FAO, 2012). In most river basins, the untreated wastewater from the domestic and industrial sectors accounts for the largest share of the total N-related grey WF (Table 7). Throughout the LAC region, river basins and aquatic habitats are used as sinks for garbage, mining effluent, and industrial and agricultural waste. The region's heaviest polluter is Brazil - the country with the most abundant water resources. Smaling et al. (2008) mention "massive use of pesticides" in the agricultural sector in Brazil. While large investments in wastewater treatment have been planned for large LAC cities such as Buenos Aires, Mexico City, Bogota, Lima, and São Paulo, they have been delayed for many years because of the lack of strong institutions and policy frameworks that are hindering effective implementation (Mejia, 2014).

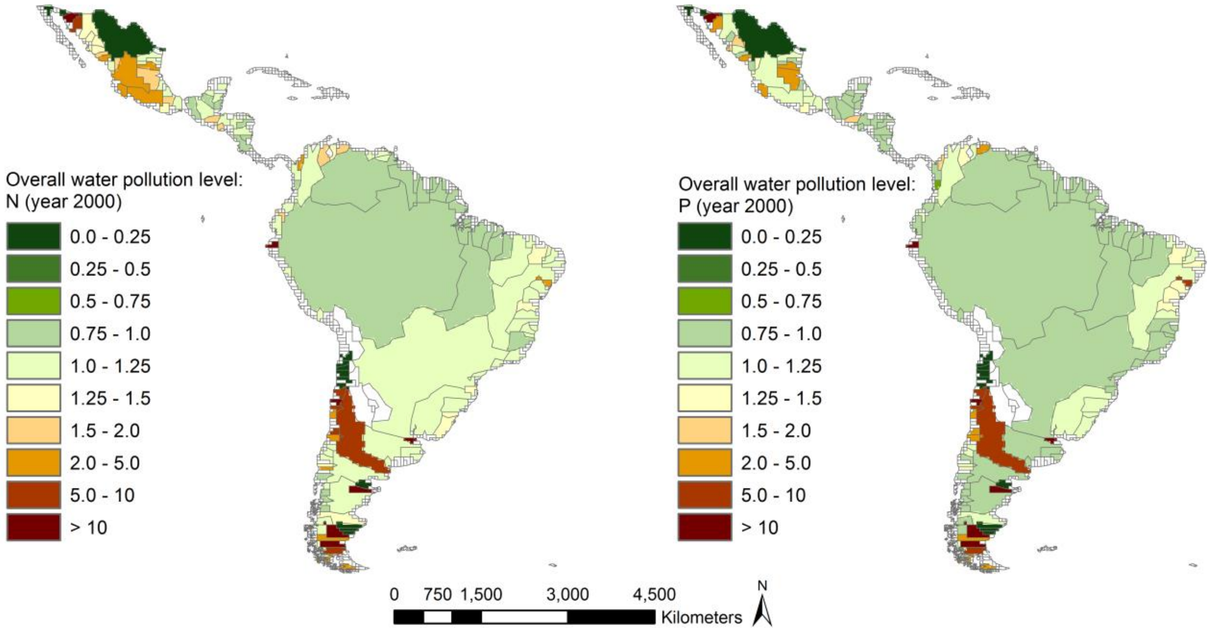

Figure 7. Water pollution level for nitrogen (N) and phosphorus (P) per river basin in the LAC region (year 2000). Data source: Liu et al. (2012).

Table 7. The nitrogen-related water pollution level (WPL) and contribution of major sectors in twelve priority basins (1996-2005).

Basin name	Percentage of the total N-related grey WF in LAC located in this basin[a]	N-related WPL[b]	Products with significant contribution to the N-related grey WF in the basin (% contribution)[a]
Parana	16.1%	1.14	Domestic-22%, Maize-18%, Industrial-17%, Sugar cane-16%, Wheat-6%
Magdalena	4.7%	1.19	Domestic-69%, Coffee-12%, Industrial-5%, Rice-5%
Santiago	4.1%	2.06	Domestic-42%, Maize-34%, Industrial-12%
Amazonas	3.8%	0.94	Domestic-29%, Industrial-17%, Maize-13%, Rice-8%
Panuco	3.1%	1.83	Domestic-54%, Maize-20%, Industrial-16%
Orinoco	2.8%	0.95	Domestic-58%, Coffee-12%, Industrial-8%, Rice-7%, Maize-7%
Sao Francisco	2.2%	1.11	Domestic-29%, Industrial-25%, Maize-14%, Cotton-8%, Dry beans-7%, Sugar cane-5%
Grisalva	2.0%	1.04	Maize-54%, Domestic-21%, Industrial-8%, Sugar cane-6%
Uruguay	1.8%	1.02	Maize-31%, Domestic-15%, Rice-13%, Industrial-12%, Wheat-10%, Soybeans-5%
Salado	1.6%	1.36	Wheat-28%, Maize-27%, Fodder crops-19%, Domestic-9%
Daule & Vinces	1.1%	1.11	Domestic-53%, Industrial-24%, Maize-8%, Rice-7%
Tocantins	1.1%	0.96	Domestic-22%, Industrial-19%, Cotton-17%, Maize-16%, Rice-11%

Sources: [a] Own elaboration based on Mekonnen and Hoekstra (2011b); [b] Liu et al. (2012).

6. Water use efficiency in the region

Total green and blue WFs and economic water productivity (US$/m^3) per crop category are shown in Figure 8. Vegetables (mainly tomatoes, chilli & peppers and carrots) have the highest economic return per unit of water consumed (0.86 $/m^3). Tobacco and natural rubber have the second largest economic water productivity, followed by roots & tubers, which are key to prosperity in several countries of the region. Cereals and oil crops, accounting for the largest share of crop-related water consumption in the region (about 55%), have an economic water productivity of about 0.08 $/m^3.

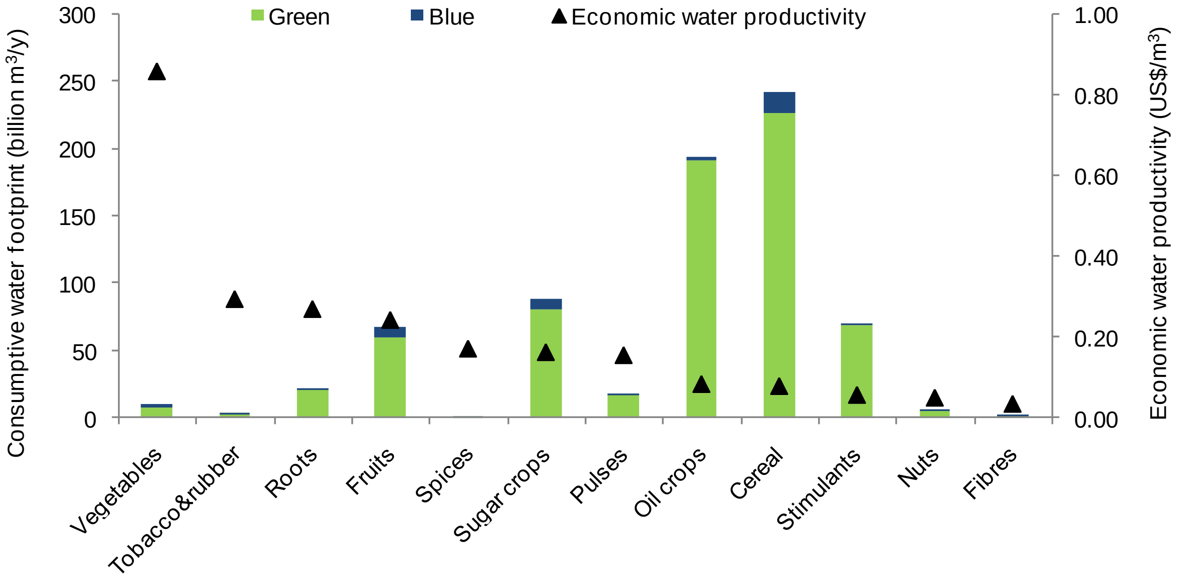

Figure 8. Green and blue water footprints and economic water productivity of major crop categories in LAC (1996-2005). Data source: water footprints from Mekonnen and Hoekstra (2011a).

LAC's total earnings related to export of agricultural and industrial products were US$ 315 billion per year (Table 8), with an associated economic water productivity of about 1.14 US$/m^3. Export gains associated with industrial products contributed about 79% to the total export earnings, with an average water productivity of 36 US$/m^3. Among the agricultural export products, cotton has the highest return per unit of water used (0.58 US$/m^3), followed by livestock products (0.20 US$/m^3), sugarcane and coffee (0.15 US$/m^3 each). Soybeans have a very modest economic revenue of 0.12 US$/m^3. Reallocation of water may improve the economic value of water use, but for further reaching conclusions on optimal crop choices, obviously other factors than water have to be taken into account.

By comparing the WF of crops in LAC with global benchmark values from Mekonnen and Hoekstra (2014) we are able to identify the potential for increasing water productivities per crop. Figure 9 shows a comparison of the (production-weighted) average green-blue and grey WFs (m^3/ton) of different crops in LAC to the global benchmark values at the best 25th percentile of production. Most of the average crop WFs in the region are larger than the global benchmark values. This should be an incentive for the LAC countries to improve their water productivities in both rain-fed and irrigated agriculture. If all countries in LAC would reduce the green-blue WF of crop production to the level of the best 25th percentile of current global production, the water saving in LAC crop production would be about 37% compared to the reference water consumption. Furthermore, if every LAC country would reduce the nitrogen-related grey WFs in crop production to the level of the best 25th percentile of current global production, water pollution related to crop production in LAC would be reduced by 44% compared to the current situation.

Table 8.Top-10 products that account for large shares of LAC virtual water exports, export earnings and water productivity (1996-2005).

Product	Virtual water export (billion m^3/y)[a]				Export value (billion US$/y)[b]	Economic value (US$/$m^3$)[c]
	Green	Blue	Grey	Total		
Soybeans	98	0.14	0.68	99	12	0.12
Coffee	37	0.23	2.1	39	6.0	0.15
Cotton	18	8.6	2.4	29	17	0.58
Livestock products	26	1.7	0.37	28	5.7	0.20
Sugarcane	19	1.9	0.89	22	3.4	0.15
Maize	9.1	0.10	0.75	10	1.0	0.10
Sunflower seed	8.4	0.03	0.09	9	0.86	0.10
Industrial products	0.0	0.60	6.3	7	250	36
Cocoa beans	6.6	0.00	0.09	7	0.40	0.06
Wheat	5.4	0.21	0.39	6	0.43	0.07
Other crops	18	2.7	1.4	22	19	0.87
Total	245	16	15	277	315	1.14

Sources:[a] Own elaboration based on Mekonnen and Hoekstra (2011b); [b] ITC (2007); [c] Own elaboration.

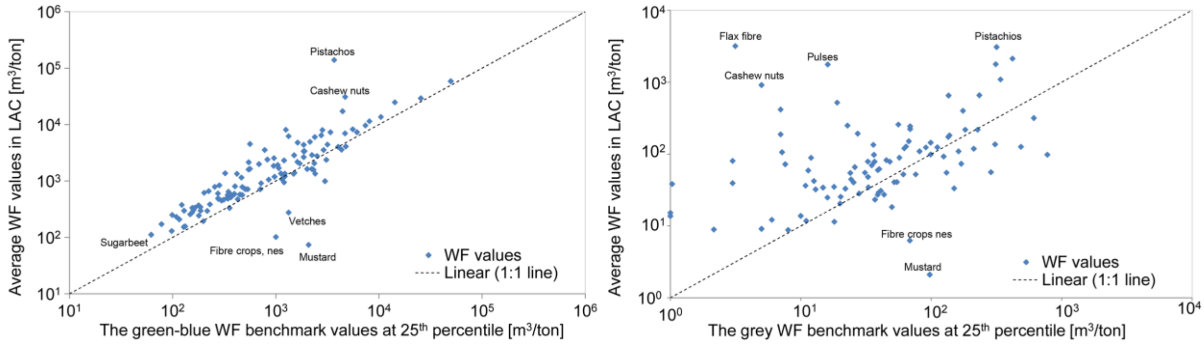

Figure 9. Distribution of the average green-blue (left) and grey (right) water footprint of different crops in LAC against the global benchmark values for best 25th percentile of production. Period 1996-2005. Data sources: water footprints from Mekonnen and Hoekstra (2011a) and benchmark values from Mekonnen and Hoekstra (2014).

7. Equity of water allocation in the region

The average WF of consumption in the LAC region was about 1,769 m^3/y per capita (83% green, 6% blue and 11% grey) over the period 1996-2005. The WF mostly comes from the consumption of agricultural products, which accounts for about 93% of the total WF. Domestic water supply and consumption of industrial products contribute 4.5% and 2.4%, respectively. Animal products account for the largest share (54%) of the WF related to consumption of agricultural products; cereal products account for 18%. The WF per capita in LAC is 28% above the global average WF, due to the combination of relatively high per capita consumption levels (particularly of meat) and larger WFs per ton of products consumed.

The WF of consumption ranges from 912 m^3/y per capita in Nicaragua to 3,468 m^3/y per capita in Bolivia (Figure 10). The large WF in Bolivia is mainly due to the relatively low water productivities of the livestock sector in the country, i.e. large WFs per ton of product consumed. The per capita consumption of meat in Bolivia is 0.8 times the LAC average, but the WF per ton of meat is four times the LAC average. The small per capita WFs in Nicaragua and Guatemala are the result of both the low level of consumption and the smaller WF per ton of the consumed products. The per capita consumption of meat in Nicaragua is about one third of the LAC average and the WF per ton of meat is about 0.6 times the LAC average.

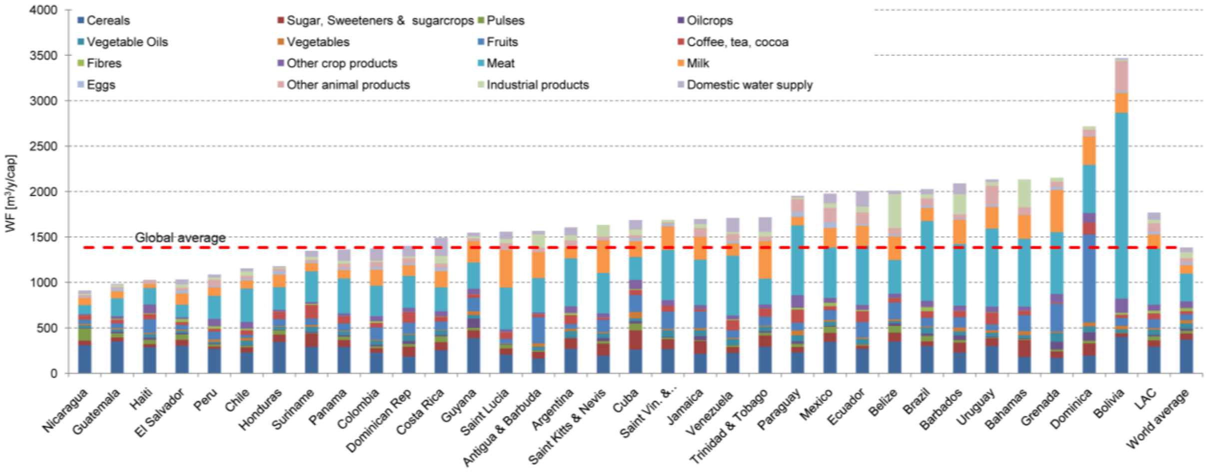

Figure 10. Water footprint of national consumption for LAC countries, shown by product category (1996-2005). Data source: Hoekstra and Mekonnen (2012).

In order to assess the fairness of water allocation in the region, it would have been interesting to look at the WF variations within countries, but due to a lack of data we were not able to assess the WFs of different communities within a county. In order to address this limitation, we used the proportion of undernourished population as a proxy of the equity of water allocation within a country. Figure 11 shows the WF related to consumption of agricultural products and the proportion of undernourished population. Although there is no strong correlation between the size of the national WF per capita and the proportion of the undernourished population, countries with smaller average per capita WF tend to have a larger proportion of undernourished people. Since the WF of national consumption is a function of the volume of consumption and the WF per unit of the commodities consumed, a country with a large WF (e.g. Bolivia) may still have a relatively large proportion of undernourished people.

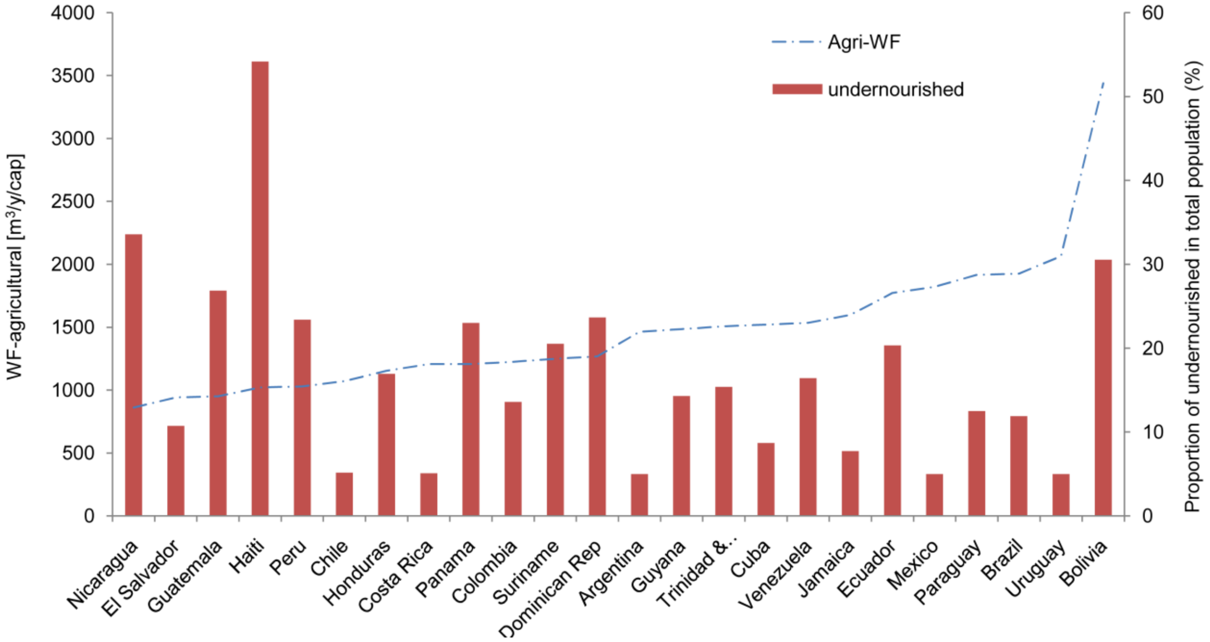

Figure 11. Water footprint related to consumption of agricultural products and proportion of population undernourished for LAC countries. Data sources: water footprints from Hoekstra and Mekonnen (2012) and undernourishment data from FAO (2013c).

The inequitable allocation of the limited water resources of the region to final consumers, combined with the increasing volumes of water used for producing export commodities, will not be sustainable in the long run. As discussed in the previous section, countries need to raise their water productivities in order to produce more with the limited available resources, so that there is more to share. In addition, however, one may need to explore the idea of "fair water footprint shares per community" as proposed by Hoekstra (2013).

8. Discussion and conclusion

This is the first comprehensive study on WF and virtual water trade in the LAC region. The study shows that the total WF of national production in LAC in the period 1996-2005 was 1,162 billion m^3/y. Crop production contributed 71%, followed by grazing (23%). The crops contributing most are maize, soybean, sugarcane, fodder crops and coffee. About 21% of the WF within the region is related to production for export. The gross virtual water export of LAC to the rest of the world related to agricultural and industrial products was 277 billion m^3/y. About 78% of this total virtual water export is related to export of soybean, coffee, cotton, livestock products and sugarcane. Most of the virtual water export was destined to the EU (36%), the US (22%) and China (8%). Vegetables (mainly tomatoes, chilli & peppers and carrots) have the highest economic return per unit of water consumed (0.86 $/m^3$). Cereals and oil crops, accounting for the largest share of the total green and blue WF (about 55%) related to crop production, give much lower economic returns.

Severe blue water scarcity was observed mainly in Mexico, in parts of Central America, along parts of the western and northern coasts of South America, in northeast Brazil and large parts of Argentina. Three of the 77 river basins studied are facing year-round severe water scarcity. In addition, 26 basins experience severe water scarcity at least one month per year. Nutrient related pollution is identified as a main pressure on biodiversity in the region. In large parts of LAC the water pollution level for nitrogen and phosphorus is close to or higher than 1.0. Particularly high WPL levels are found in Mexico and in the southern half of Latin America.

The expansion of pasture and export-oriented industrial agriculture have become the main driver of forest and savannah removal and biodiversity loss in various regions in LAC. The combined agricultural and forest area of LAC region account for 85% of the total land area. Given that the remaining area is in part built-up area and barren land, additional land for agriculture is limited. Efficient use of the available green water resources in existing agricultural areas is hence crucial. Furthermore, making more efficient use of green water in rain-fed agriculture can lessen the need for irrigated agriculture in the water-scarce parts of the region and thus contribute to the reduction of blue water scarcity in these water-short areas.

There is ample room for improvement in water productivity and yields in rain-fed agriculture, which represents 87% of the cropland (Molden et al., 2007; Rockström et al., 2007). According to FAO (2012), Argentina was able to double its agricultural yields in ten years while reducing the area under cultivation by 37% by adopting a number of practices including the use of hybrid technologies, conservation tillage, direct planting and fertilization. For Brazil it has been estimated that through improved agricultural practices, the rotation of soybean and pasture and the restoration and cultivation of degraded pastures, considerable increase in productivity can be reached (Smaling et al., 2008). Improvement in agricultural practices and water management must come along with technical support to small farmers, engagement of river basin managers and policy makers, and good quality data at the river basin level.

The study shows that allocation of water in the region is rather inequitable from a consumer point of view. The average per capita WF of the region is 28% larger than the global average and varies greatly, from 912 m^3/y per capita in Nicaragua to 3,468 m^3/y per capita in Bolivia. The LAC region shows significant levels of undernourishment, although there is abundant water and food production in the region. This calls for action that leads to more equitable allocation of water and food within societies.

The results indicate that in particular the production of specific crops (including sugarcane, rice, maize, wheat and fodder crops), untreated wastewater from households and industries, grazing by livestock and production for export are responsible for localized unsustainable situations in the region, such as water scarcity, water pollution and loss of natural habitats and biodiversity. Local water accounting and assessments – considering the environmental needs – are crucial to develop adequate response strategies. Sustainable water management and protection of the environment in Latin America and the Caribbean will not be achieved unless water and land resources are accounted and assessed comprehensively in the future. Mechanisms need to be adopted that constrain the exploitation of land and water resources within environmental thresholds and agricultural practices need to be developed that lead to more value (economic, environmental and social) per drop.

References

Bertzky, B., Corrigan, C., Kemsey, J., Kenney, S., Ravilious, C., Besançon, C. and Burgess, N. (2012) Protected Planet Report 2012: Tracking progress towards global targets for protected areas. IUCN, Gland, Switzerland and UNEP-WCMC, Cambridge, UK.

Bovarnick, A., Alpizar, F. and Schnell, C. (eds.) (2010). The importance of biodiversity and ecosystems in economic growth and equity in Latin America and the Caribbean: An economic valuation of ecosystems. United Nations Development Programme, New York, USA.

Butchart, S.H.M., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E. M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.-C. and Watson, R. (2010) Global biodiversity: Indicators of recent declines, Science 328(5982): 1164-1168.

CELAC (2013) Community of Latin American and Caribbean States. http://www.celac.gob.ve (last accessed 18 December 2013)

Chico, D., Aldaya, M.M., Flachsbarth, I. and Garrido, G. (2014) Virtual water trade, food security and sustainability: lessons from Latin America and Spain. In Martinez-Santos, P., Aldaya, M.M and Llamas, R. (Eds.): Integrated Water Resources Management in the 21st Century: Revisiting the paradigm, CRC Press, Leiden, The Netherlands, pp. 75-98.

Convention on Biological Diversity (2014a) Aichi Biodiversity Targets. https://www.cbd.int/sp/targets/ (last accessed 27 May 2014)

Convention on Biological Diversity (2014b) National Biodiversity Strategies and Action Plans (NBSAPs) https://www.cbd.int/nbsap/targets/default.shtml (last accessed 27 May 2014)

FAO (2006) Cattle ranching and deforestation, FAO Livestock Policy Brief No. 3, Food and Agriculture Organization, Rome, Italy.

FAO (2010) Global forest resources assessment 2010, FAO Forestry Paper 163, Food and Agriculture Organization, Rome, Italy.

FAO (2012) The outlook for agriculture and rural development in the Americas: A perspective on Latin America and the Caribbean 2013, ECLAC, FAO, IICA – Food and Agriculture Organization, Santiago, Chile.

FAO (2013a) Gridded Livestock of the World, Food and Agriculture Organization, Rome, Italy, http://www.fao.org/geonetwork/ (last accessed: 10 November 2013)

FAO (2013b) Land use in the Neotropics, Food and Agriculture Organization, Rome, Italy, http://www.fao.org/geonetwork/srv/en/main.home (last accessed: 18 December 2013)

FAO (2013c) Food security indicators, Food and Agriculture Organization, Rome, Italy, http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/ (last accessed: 30 April 2014)

FAO (2014a) AQUASTAT country database Food and Agriculture Organization, Rome, Italy http://www.fao.org/nr/water/aquastat/main/index.stm (last accessed 17 January 2014)

FAO (2014b) Global map of irrigation areas, Food and Agriculture Organization, Rome, Italy, http://www.fao.org/nr/water/aquastat/irrigationmap/index.stm, (last accessed: 1 January 2014)

FAO (2014c) FAOSTAT database, Food and Agriculture Organization, Rome, Italy, http://faostat.fao.org (last accessed: 30 April 2014).

Godfray, H. C. J., Beddington, J. R., Crute,, I. R., Haddad, L., Lawrence, D., Muir, J. F. Pretty, J., Robinson, S., Thomas, S.M. and Toulmin, C. (2010) Food security: the challenge of feeding 9 billion people, Science, 327: 812–818.

GRDC (2007) Major River Basins of the World, Global Runoff Data Centre, Federal Institute of Hydrology, Koblenz, Germany, available at: http://grdc.bafg.de (last accessed: 18 December 2013).

Hoekstra, A.Y. (2013) The water footprint of modern consumer society, Routledge, London, UK.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2011) The water footprint assessment manual: Setting the global standard, Earthscan, London, UK.

Hoekstra, A.Y. and Mekonnen, M.M. (2011) Global water scarcity: monthly blue water footprint compared to blue water availability for the world's major river basins, Value of Water Research Report Series No.53, UNESCO-IHE, Delft, the Netherlands.

Hoekstra, A.Y. and Mekonnen, M.M. (2012) The water footprint of humanity, Proceedings of the National Academy of Sciences, 109(9): 3232−3237.

Hoekstra, A.Y., Mekonnen, M.M., Chapagain, A.K., Mathews, R.E. and Richter, B.D. (2012) Global monthly water scarcity: Blue water footprints versus blue water availability, PLoS ONE 7(2): e32688.

ITC (2007) Statistics for International Trade Analysis (SITA) version 1996–2005 in SITC [DVD-ROM]. International Trade Centre, Geneva, Switzerland.

Liu, C., Kroeze, C., Hoekstra, A.Y. and Gerbens-Leenes, W. (2012) Past and future trends in grey water footprints of anthropogenic nitrogen and phosphorus inputs to major world rivers, Ecological Indicators, 18: 42-49.

Mittermeier, R.A., Gil, P.R., Hoffman, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. and da Fonseca, G.A.B. (2005) Hotspots revisited - Earth's biologically richest and most endangered terrestrial ecoregions, University of Chicago Press, Chicago, USA.

Mejia, A. (2014) Water scarcity in Latin America and the Caribbean - myths and reality. In Garrido, A. and M. Shechter (Eds.): Water for the Americas: Challenges and opportunities, Routledge, Oxford, UK.

Mekonnen, M.M. and Hoekstra, A.Y. (2011a) The green, blue and grey water footprint of crops and derived crop products, Hydrol. Earth Syst. Sc. 15(5): 1577-1600.

Mekonnen, M.M. and Hoekstra, A.Y. (2011b) National water footprint accounts: the green, blue and grey water footprint of production and consumption, Value of Water Research Report Series No.50, UNESCO-IHE, Delft, the Netherlands.

Mekonnen, M.M. and Hoekstra, A.Y. (2012) A global assessment of the water footprint of farm animal products, Ecosystems, 15(3): 401−415.

Mekonnen, M.M. and Hoekstra, A.Y. (2014) Water footprint benchmarks for crop production: A first global assessment, Ecological Indicators, 46: 214-223.

Molden, D., Oweis, T.Y., Steduto, P., Kijne, J.W., Hanjra, M.A., Bindraban, P.S., Bouman, B.A.M., Cook, S., Erenstein, O., Farahani, H., Hachum, A., Hoogeveen, J., Mahoo, H., Nangia, V., Peden, D., Sikka, A., Silva, P., Turral, H.U.A. and Zwart, S. (2007) Pathways for increasing agricultural water productivity. In Molden, D. (ed.). Water for food, water for life: A Comprehensive Assessment of Water Management in Agriculture. London, UK: Earthscan; Colombo, Sri Lanka: IWMI, pp. 279-310.

Myers N. (1979) The sinking ark: A new look at the problem of disappearing species, Pergamon Press, Oxford, UK.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonsenca, G.A.B. and Kent, J. (2000) Biodiversity hotspots for conservation priorities, Nature, 403: 853–858.

Rockström, J., Hatibu, N., Oweis, T. Y., Wani, S., Barron, J., Bruggeman, A., Farahani, J., Karlberg, L. and Qiang, Z. (2007) Managing water in rainfed agriculture. In Molden, D. (ed.). Water for food, water for life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan, London, UK & IWMI, Colombo, Sri Lanka, pp. 315-352.

Siebert, S., Henrich, V., Frenken, K. and Burke, J. (2013) Update of the global map of irrigation areas to version 5. Project report, FAO, Rome, Italy.

Smaling, E.M.A., Roscoe, R., Lesschen, J.P., Bouwman, A.F. and Comunello, E. (2008) From forest to waste: Assessment of the Brazilian soybean chain, using nitrogen as a marker, Agriculture, Ecosystems & Environment, 128(3): 185-197.

Svancara, L.K., Brannon, R., Scott, J.M., Groves, C.R., Noss, R.F. and Pressey, R.L. (2005) Policy-driven versus evidence-based conservation: A review of political targets and biological needs. BioScience, 55(11): 989-995.

UNCTAD (2011) Water for Food: Innovative water management technologies for food security and poverty alleviation. UNCTAD Current Studies on Science, Technology and Innovation No. 4., United Nations Conference on Trade and Development, New York, USA.

UNEP (2010) Latin America and the Caribbean Environment Outlook: GEO LAC 3. UNEP, Panamá City, Panamá.

Vanham, D., Hoekstra, A.Y. and Bidoglio, G. (2013) Potential water saving through changes in European diets. Environment International 61: 45–56.

Wassenaar, T., Gerber, P., Verburg, P.H., Rosales, M., Ibrahim, M. and Steinfeld, H. (2007) Projecting land use changes in the Neotropics: The geography of pasture expansion into forest, Global Environmental Change, 17(1): 86-104.

World Bank (2014) World DataBank - World Development Indicators, The World Bank, Washington, D.C., USA http://databank.worldbank.org/data/home.aspx (last accessed 27 May 2014)

World Water Forum (2012) Americas' Water Agenda: Targets, Solutions and the Paths to Improving Water Resources Management. 6th World Water Forum, February 2012, Marseille, France.

Zarate, E., Aldaya, M., Chico, D., Pahlow, M., Flachsbarth, I., Franco, G., Zhang, G., Garrido, A., Kuroiwa, J., Pascale-Palhares, J.C and Arévalo, D. (2014) Water and agriculture, In: Willaarts, B.A., Garrido, A., Llamas, M.R. (eds.), Water for Food and Wellbeing in Latin America and the Caribbean. Social and Environmental Implications for a Globalized Economy. Routledge, Oxford and New York, pp. 177-212.

Appendix I. The water footprint of national production (million m^3/y)

Country	Water footprint of crop production			Water footprint of grazing	Water footprint of animal water supply	Water footprint of industrial production		Water footprint of domestic water supply		Total water footprint		
	Green	Blue	Grey	Green	Blue	Blue	Grey	Blue	Grey	Green	Blue	Grey
Antigua and Barbuda	21	0.09	0.00	18	0.44	0.05	0.95	0.30	2.7	39	0.9	3.7
Argentina	157605	4306	4958	18589	773	138	1508	491	2724	176194	5708	9189
Bahamas	53	0.00	0.00	2.0	0.49	0.00	0.00	0.00	0.00	55	0.49	0.00
Barbados	136	0.54	6.6	20	1.1	2.0	38	3.0	27	156	6.6	72
Bolivia	12552	389	90	19007	189	5.0	64	18	130	31559	601	284
Brazil	303743	8934	15917	132223	3158	533	7487	1202	8526	435966	13826	31930
Belize	664	6.1	80	12	1.6	5.5	89	1.0	8.3	677	14	177
Cayman Islands	1.9	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	1.9	0.02	0.00
Chile	6510	2374	2981	2633	123	158	534	142	373	9143	2797	3888
Colombia	31779	1338	1979	18394	486	20	380	539	4851	50173	2384	7210
Costa Rica	4420	291	310	991	35	23	427	79	701	5412	428	1437
Cuba	18577	1823	629	2010	102	50	581	156	993	20587	2130	2204
Dominica	215	0.00	1.9	14	0.33	0.00	0.00	0.00	0.00	229	0.33	1.9
Dominican Republic	5877	1017	0.00	2511	62	3.0	50	109	907	8389	1191	957
Ecuador	15277	2057	603	11167	129	45	855	212	1908	26444	2443	3366
El Salvador	4702	66	401	500	26	10	190	32	288	5202	134	879
French Guiana	107	6.5	0.00	5.9	0.41	0.00	0.00	0.00	0.00	113	6.9	0.00
Grenada	129	0.29	0.00	3.8	0.28	0.00	0.00	0.00	0.00	133	0.6	0.00
Guadeloupe	296	8.4	0.00	43	1.4	0.00	0.00	0.00	0.00	338	10	0.00
Guatemala	12360	299	777	888	52	14	157	13	96	13248	378	1030

Country	Water footprint of crop production			Water footprint of grazing	Water footprint of animal water supply	Water footprint of industrial production		Water footprint of domestic water supply		Total water footprint		
	Green	Blue	Grey	Green	Blue	Blue	Grey	Blue	Grey	Green	Blue	Grey
Guyana	1592	249	98	41	5	0.5	10	3.0	27	1632	257	135
Haiti	5849	187	0	1581	50	0.5	10	5.0	45	7430	243	55
Honduras	6447	122	442	1126	48	5.0	95	7.0	63	7573	182	600
Jamaica	1849	59	31	307	12	3.5	67	14	126	2156	89	224
Martinique	295	13	0.00	34	0.93	0.00	0.00	0.00	0.00	329	14	0.00
Mexico	83105	13885	11382	25916	995	215	2649	1359	9022	109021	16453	23053
Montserrat	2.4	0.00	0.00	11	0.21	0.00	0.00	0.00	0.00	14	0.21	0.00
Nicaragua	4896	147	133	982	63	1.5	29	19	171	5877	230	333
Panama	1930	54	147	626	31	2.0	17	55	314	2556	141	478
Paraguay	29977	135	540	2868	176	2.0	32	10	83	32845	323	655
Peru	11399	4096	1800	6641	188	102	501	168	721	18040	4553	3022
Puerto Rico	559	13	0.0	323	9.4	0.00	0.00	0.0	0.0	882	22	0.0
Saint Kitts and Nevis	54	0.01	0.06	2.4	0.19	0.00	0.00	0.0	0.0	56	0.2	0.1
Saint Lucia	3.6	0.01	0.00	12	0.54	0.00	0.00	1.3	11	15	1.8	11
Saint Vincent and the Grenadines	122	0.00	0.00	6.2	0.39	0.00	0.00	0.0	0.0	128	0.4	0.0
Suriname	275	73	28	15	2.7	1.0	19	3.0	27	290	80	74
Trinidad and Tobago	453	8.7	17	29	3.9	4.0	57	21	184	482	38	257
Uruguay	3932	698	234	7572	180	2.0	38	8	72	11504	888	344
Venezuela	11340	1239	854	12001	277	30	561	381	3429	23341	1926	4844
LAC total	739103	43895	44441	269123	7183	1373	16444	5052	35829	1008227	57503	96714

Source: Mekonnen and Hoekstra (2011b).

Appendix II. Top-10 gross virtual water exporters to and importers from LAC (billion m^3/y) (1996-2005)

Country	Top-10 gross virtual water exporters to LAC			
	Green	Blue	Grey	Total
USA	73	16	14	102
Pakistan	6.0	13	4.3	23
Canada	9.0	0.18	1.7	11
China	1.6	0.35	2.0	4.0
India	1.3	0.36	0.46	2.2
Thailand	1.1	0.06	0.49	1.6
Indonesia	1.5	0.00	0.09	1.6
Spain	0.60	0.76	0.14	1.5
Australia	1.0	0.07	0.07	1.2
Korea, Rep.	0.55	0.33	0.25	1.1
Others	9.0	2.0	3.8	15
LAC total	104	33	28	165

Country	Top-10 gross virtual water importers from LAC			
	Green	Blue	Grey	Total
USA	43	10	7.6	61
China	21	0.47	0.40	22
Germany	16	0.31	0.71	17
Netherlands	13	0.24	0.34	14
Italy	13	0.44	0.37	13
Spain	12	0.20	0.40	12
France	11	0.17	0.32	12
Russia	10	0.80	0.27	11
Japan	7.9	0.28	0.61	8.8
UK	7.7	0.31	0.40	8.4
Others	91	2.7	4.0	98
LAC total	245	16	15	277

Source: Mekonnen and Hoekstra (2011b).

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UNESCO-IHE
P.O. Box 3015
2601 DA Delft
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