THE WATER FOOTPRINT OF INDONESIAN PROVINCES RELATED TO THE CONSUMPTION OF CROP PRODUCTS

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Summary

Community welfare and food security in Indonesia partly depend on developments in the agricultural sector. This sector increasingly faces the problem of water scarcity caused by declining water resources and increasing competition over water with households and industries. To overcome these problems and to ensure stability, economic growth and food security, it has been recognised that the government has to reform the water policy in Indonesia. Water policies are most of the time based on the water withdrawal per sector. A useful addition to this are the concepts of water footprint and virtual water trade. The water footprint is an indicator of water use that looks at both direct and indirect water use. The water footprint of the people in a province is defined as the total amount of water that is used to produce the goods and services consumed by the inhabitants of the province. This water footprint is partly inside the province itself (the internal footprint) and partly presses somewhere else (external footprint). Virtual-water trade refers to the transfer of water in virtual form from one place to another as a result of product trade. Virtual water refers to the volume of freshwater embedded in a product, not in real but virtual sense; it refers to the water that was used to make the product. Quantitative information about the water footprint per province and interprovincial virtual water flows can feed a discussion on the role of trade in water resources management. The aim of this report is to quantify interprovincial virtual water flows related to trade in crop products and determine the water footprint related to the consumption of crop products per Indonesian province.

The study follows the method for calculating virtual water flows and water footprints as developed by Hoekstra and Chapagain (2007; 2008). The first step in the method is to calculate the water footprint of crops, which depends on crop water requirements, rainfall and irrigation. Crop water requirements depend on crop type and climate and can be supplied from either rainfall or irrigation water. The amount of rainwater that contributes to the evapotranspiration is called the green water use and will determine the green component of the water footprint of a crop. The amount of irrigation water that contributes to the evapotranspiration is called the blue water use and will determine the blue component of the water footprint of a crop. The last component that contributes to the water footprint of a crop is the grey component. This is the volume of water polluted, quantified as the amount of water required to dilute pollutants to an acceptable level. The second step is to calculate interprovincial virtual water flows, which result from crop trade between provinces. The flow will occur from provinces with surpluses to provinces with deficits. A surplus occurs when the consumption of a crop in a province is lower than the production of it. A deficit occurs when the consumption of a crop is higher than the production in a province. Finally, the water footprint of a province related to the consumption of crop products is the total amount of water used for the production of these products. This water can originate either from internal or external water resources. Data for the calculation have been taken mainly for the years 2000 till 2004.

The water footprints of crops largely vary among provinces. Rice produced on Java has the lowest water footprint of all rice in Indonesia. The green water component is relatively high for all crops; only for rice and soybeans the contribution of irrigation water is relatively high compared with other crops. The green component

gives the largest contribution to the water footprint related to the consumption of crop products. The interprovincial virtual water flows are primarily caused by trade in rice. The products cassava, coconut, bananas and coffee have the largest interprovincial water flows relative to the water use for production. The biggest amount of virtual water from provinces or countries goes to Java, a densely populated island where the production of crops is not sufficient to satisfy the total consumption. Sumatra has the largest contribution in the virtual water export.

The average water footprint in Indonesia insofar related to consumption of crop products is 1131 m^3/cap/yr, but there are large regional differences. The provincial water footprint varies between 859 and 1895 m^3/cap/yr. The average provincial water footprint consists for 84% of internal water resources. The remaining 16% comes from other provinces (14%) or countries (2%). All island groups except Java have a net export of water in virtual form. Java, the most water-scarce island, has a net virtual water import and the most significant external water footprint. This large external water footprint is releasing the water scarcity on this island.

There are two alternative routes to reduce the overall water footprint of Indonesia. On the one hand, it may be reduced by promoting wise crop trade between provinces – i.e. trade from places with high to places with low water efficiency. On the other hand, the water footprint can be reduced by improving water efficiency in those places that currently have relatively low efficiency, which equalises production efficiencies and thus reduces the need for imports and enhances the opportunities for exports. In any case, trade will remain necessary to supply food to the most densely populated areas where water scarcity is highest (Java).

1. Introduction

Agriculture is of great importance to Indonesia. The agricultural sector contributed only 11% to the GDP in 2002, but 44% of the labour force is working in this sector, making it the largest sector in terms of employment. Developments in the agricultural sector can lead to a reduction of poverty and the generation of broad-based economic growth (ADB, 2006). The sector has a strategic role concerning stability, economic growth and food security. To emphasize the important role of agriculture the Ministry of Agriculture (2006) developed the following vision for the years 2005-2025: realizing a competitive, fair and sustainable industrial agricultural system to guarantee food security and community welfare.

To develop the agricultural sector and achieve the abovementioned vision of the ministry, there are some challenges and problems to overcome. The sector faces an increasing demand for agricultural products, caused by an increasing population and hence a higher consumption. Water resources for agricultural activities are getting scarcer due to the impact of declining land and water resources. Moreover, competition over water is growing due to an increasing use of water for households and industries (Ministry of Agriculture, 2006). The water use is already highly constrained by unbalanced conditions of demands and the potential availability, particularly during the dry season. The water resources conditions in Indonesia have come to the stage where integrated action is needed to reverse the present trends of overconsumption, pollution and the increasing threat of drought and floods (World Water Council, 2003). Therefore, measures to ensure food security and community welfare must be taken by the government.

These measures are most often based on analysis of the water withdrawal in the domestic, agricultural and industrial sector. However, these indicators do not give information about the actual need of water by the people in a country in relation to their consumption. A useful addition to the water-withdrawal indicator are the indicators of ‘water footprint’ and ‘virtual water trade’. The water footprint is a consumption-based indicator of water use introduced seven years ago by Hoekstra (2003). This indicator shows the water use of inhabitants of a country or province in relation to their consumption pattern. It looks at both direct and indirect water use. The water footprint of the people in a province is defined as the total amount of water that is used to produce the goods and services consumed by the inhabitants of the province. This water footprint is partly inside the province itself (the internal footprint) and partly presses somewhere else (external footprint). Virtual-water trade refers to the transfer of water in virtual form from one place to another as a result of product trade. Virtual water refers to the volume of freshwater embedded in a product, not in real but virtual sense; it refers to the water that was used to make the product. Quantitative information about the water footprint per province and interprovincial virtual water flows can feed a discussion on the role of trade in water resources management.

The water footprint has already been calculated for different countries by Hoekstra and Chapagain (2007, 2008). Indonesia as a whole is also included in their study. Further research on a more detailed scale has already been done for some countries, such as China (Ma et al., 2006), India (Kampman et al., 2008), the Netherlands (Van Oel et al., 2008) and the UK (Chapagain and Orr, 2008). These national studies give a more detailed view of the

water flows, water use for crop production and water consumption by the population within a country than the global study of Hoekstra and Chapagain could do.

The aim of this report is to quantify interprovincial virtual water flows related to trade in crop products and determine the water footprint related to the consumption of crop products per Indonesian province. The water footprint will be calculated as an average for the years 2000 to 2004. The first part of the report is about the method (Chapter 2) and used data (Chapter 3). Thereafter the water footprint of crop products is presented (Chapter 4). Subsequently, interprovincial virtual water flows within Indonesia are shown in Chapter 5. The water footprint of Indonesian provinces related to crop products is presented in Chapter 6. Finally, in Chapter 7 conclusions are drawn.

2. Method

For the calculation of water footprints and virtual water flows, the methodology described in Hoekstra and Chapagain (2007, 2008) has been used. The water footprint of consumers can be divided into direct water use on the one hand and the consumption of agricultural and industrial products on the other hand. For this study only the consumption of agricultural products has been taken into account, because the direct water use and the consumption of industrial products account for only about 3% of the water footprint of Indonesia (Hoekstra and Chapagain, 2007).

Agricultural products can be divided in crops and livestock products. The focus in this study will be on crops. The first step in the calculation of the water footprint of a crop product is the determination of the evapotranspiration. The FAO Penman-Monteith method has been used to calculate the reference evapotranspiration, which is the evapotranspiration of reference grass in the situation with an abundance of water (Allen et al, 1998). Subsequently, the reference evapotranspiration is multiplied with a crop parameter, to calculate the evapotranspiration of a crop. The crop water requirement is the summation of this potential crop evapotranspiration over the growth period. The water footprint of a crop depends on the crop water requirement and the availability of water in the soil. This water can originate from either rainwater or irrigation. The water originating from rainfall that contributes to crop growth is called green water use. The green water use is the minimum of the potential crop evapotranspiration and the effective rainfall. The effective rainfall is the part of the rainwater that will be available in the soil for crop growth. Irrigation water that is used for crop growth is called blue water use. The blue water use is equal to the irrigation water requirement multiplied with the fraction of the total area of a crop that is irrigated. The irrigation water requirement is the potential crop evapotranspiration minus the green water use. Finally, the grey water footprint is the amount of water required to dilute pollutants to agreed acceptable levels. We have restricted the analysis to the effect of nitrates used as artificial fertilisers in agriculture. The grey water footprint is calculated as the amount of nitrate that has leached into the groundwater multiplied with a dilution factor. The amount of nitrate that has leached into the groundwater is equal to the amount of nitrate supplied to the field times the leaching factor. This leaching factor is the fraction of the total supplied amount of nitrate to the field that eventually leaches to the groundwater. The dilution factor is the inverse of the maximum acceptable level of nitrogen in the ambient water system. The total water footprint of a product is the sum of the green, blue and grey water footprint of a product. These components are calculated by dividing the water use of the concerning component by the yield.

The primary crops can be processed into other products. This will lead to a distribution of the water footprint of the crop over the processed products. The water footprint of a processed crop product is the water footprint of the primary crop multiplied with the value fraction and divided by the product fraction. The value fraction of a processed crop product is the value of that crop product divided by the total value of all crop products. The product fraction is the weight of the processed crop divided by the total weight of the primary crop.

Virtual water flows are the result of trade between regions. For the calculation of the virtual water flows between Indonesian provinces the methodology described in Ma et al. (2006) has been used. The method is based on surpluses and deficits in regions. If the production is larger than the consumption of a crop there is a surplus in a province. A deficit occurs when the consumption is larger than the production. Trade will occur from regions with surpluses to regions with deficits. In this study the assumption is made that trade will first start between provinces within an island group. After this first distribution trade will occur between the remaining provinces in Indonesia. Interprovincial virtual water flows are calculated by multiplying product trade volumes by the water footprints of the traded products.

The water footprint of a province consists of an internal and external part. The internal water footprint is defined as the annual volume of provincial water resources used to produce crops consumed by inhabitants of a province. The external water footprint is defined as the annual volume of water resources used in other countries or provinces to produce crops consumed by inhabitants of the province concerned (Hoekstra and Chapagain, 2007). The internal and external water footprints of a province are calculated following the accounting framework as shown in Figure 2.1. Re-export of virtual water from a province is assumed to be zero.

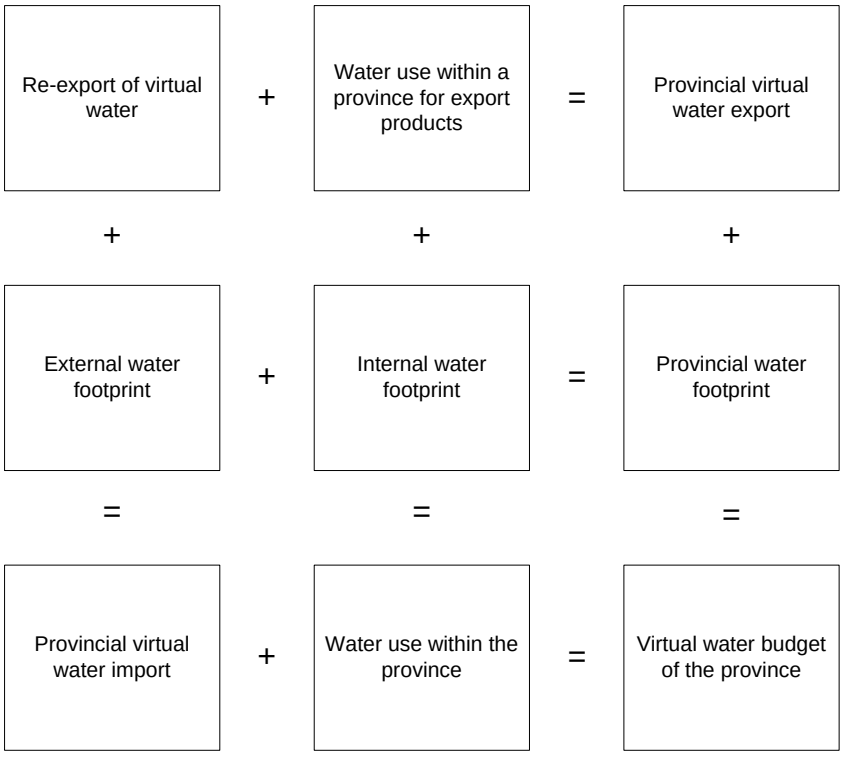


Figure 2.1. The accounting framework to calculate the water footprint, virtual water import and virtual water export of a province (based on Hoekstra and Chapagain, 2008).

3. Study area and data

3.1 Schematization of Indonesia

In the period considered in this study (2000-2004), Indonesia consisted of 30 provinces. These have been used as the basis of the analysis.

3.2 Crop selection

According to the FAOSTAT database (FAO, 2008a) more than 56 crops were cultivated in Indonesia in the period 2000-2004. For this study the most important crops have been selected, based on estimated and reported water use, production value and land use. For each crop the production quantity, production value and harvested area are derived from FAOSTAT. The averages over the period 2000-2004 have been used for the calculation. The water use of a crop has been estimated by multiplying the production quantity with the water footprint of the crop as estimated in an earlier study (Chapagain and Hoekstra, 2004). The criterion for selection is that a crop should contribute more than 1% of the total water use. If an excluded crop has a production value above 5% of the total crop production value or the land use exceeds 2% of the total crop land area, it will also be selected. This selection resulted in the following list of crops: rice, maize, cassava, soybeans, groundnuts, coconuts, oil palm, bananas, coffee and cocoa. The selected crops represent 86% of the total water use, 71% of the production value and 86% of the total agricultural land.

3.3 Data

3.3.1 Population

The population by province is taken from BPS (2008a). The data apply to the year 2000 and are shown in Appendix I.

3.3.2 Climatic parameters

The data for the calculation of the reference evapotranspiration and effective rainfall are taken from CLIMWAT (FAO, 2008b). In this database information is available from 33 weather stations across Indonesia. The data include humidity, mean maximum and mean minimum temperature, wind speed, daily sunshine, rainfall and location (altitude, latitude and longitude) of the weather station. The average data are given for each month in the year. The weather stations per province are listed in Appendix II.

CLIMWAT does not provide enough weather stations; in some provinces there are no weather stations or there are only data from one weather station available. To get a reliable value of the reference evapotranspiration and

effective rainfall in all provinces, supplementary data have been used. These data are available from Badan Meteorologi dan Geofisika (BMG), the national weather institute of Indonesia. Appendix II also lists the supplementary weather stations. The reference evapotranspiration and effective rainfall in a province have been estimated by taking averages of the weather stations from BMG and FAO in a province.

For the weather stations Belwan, Yogyakarta, Kendari, Mengalla, Tahuna and Telukbentung, no data about the sunshine hours are available. The sunshine hours of nearby located weather stations have been used as replacement. Furthermore, no weather stations are located in the province of Jambi. For Jambi the reference evapotranspiration is calculated as an average from the reference evapotranspiration in Riau and Sumatra Selatan, since those are the two nearest provinces.

3.3.3 Crop parameters

The crop parameter (K_c) is different per crop and changes over the crop development stages. The crop parameters have been taken from Allen et al. (1998) and Chapagain and Hoekstra (2004). The assumption has been made that a year has two seasons in Indonesia: a wet and a dry season. The wet season is from November till April and the dry season from May till October. In Appendix III the crop parameters and growing periods are listed.

3.3.4 Irrigated area fraction

Data about the irrigated area fraction of a crop in a province were not available, so assumptions had to be made. For every province data about land utilization, including the amount of wetland and dryland, are available (BPS, 2008b). Wetland is agricultural land that is irrigated, dryland is not irrigated and planted with seasonal crops. Estate crops like oil palm, coconut, banana, coffee and cocoa, do not belong to these categories. Irrigation of these crops is not common (FAO, 1999) and information about irrigation of these crops is not available.

To allocate the fraction of irrigated land over the seasonal crops in a province, the following method is applied. First of all, the irrigated area of rice is subtracted from the total wetland area. Information about the harvested area of wetland rice is taken from the Ministry of Agriculture (2008). Because it is possible to harvest rice at least two times a year, this area is divided by two. The surplus of land is distributed over the other crops based on the relative area of these remaining crops, including the crops that are not taken into account for this study. For rice the irrigated area fraction is determined by dividing the area of wetland rice by the total area of rice, the sum of the area of wetland and dryland rice. The irrigated area fraction per crop and province is given in Appendix IV.

For the provinces Maluku, Maluku Utara and Papua data about dryland and wetland area are not available. For rice, data on irrigated area fractions are available, but for the other crops the assumption is made that the irrigated area fraction is zero for these provinces.

3.3.5 Dilution water requirement

Data about fertilizer use have been taken from FAO (2008c; 2005). The data on fertilizer use per hectare are not specified by province; therefore it is assumed that fertilizer use is the same in every province. Because of differences in yields, the grey water footprint of a crop will vary between provinces. The fertilizer use per crop is shown in Appendix V. The leaching factor is assumed to be 10%, following Chapagain et al. (2006). The recommended maximum level of nitrogen has been taken as 10 mg/l, as recommended by EPA (2005) for nitrogen in drinking water and as applied also in Chapagain et al. (2006).

3.3.6 Production quantity and harvested area

The production quantity and harvested area are taken from the Ministry of Agriculture (2008). Data are taken from 2000 to 2004. The figures are compared with the figures from FAOSTAT (FAO, 2008a) and BPS (2008c). Because for some crops the data from the Ministry of Agriculture strongly differ with FAOSTAT en BPS, the numbers are corrected. This is the case for the production quantity of coconut and oil palm and the harvested area of oil palm, banana and cocoa. The production quantity of these crops in the database from the Ministry of Agriculture represents processed crops and not the primary crops. The high harvested areas of the perennial crops were caused by the fact that these crops can be harvested several times a year. Production quantities per crop and province are shown in Appendix VI; harvested areas are shown in Appendix VII.

3.3.7 Product and value fraction of processed crops

The product tree of a crop is taken from FAO (2008d). Product fractions are also derived from this source. The data about the product fractions are based on the years 1992 to 1996. For this study it is assumed that these data are still reliable and accurate. Value fractions are taken from Chapagain and Hoekstra (2004). Appendix VIII shows the product and value fractions of the crops.

3.3.8 Consumption

Consumption data have been taken from the national food balance sheet available in the FAOSTAT database (FAO, 2008a). This balance consists of domestic supply and domestic utilization. Domestic supply consists of production quantity, import quantity, stock change and export quantity. Domestic utilization is the sum of feed quantity, seed quantity, food manufacture, waste quantity, other uses quantity and food quantity. For these quantities we have taken the average for the years 2000 till 2003. The food balance is taken for the following products: rice (milled equivalent), maize, cassava, soybeans, groundnut (shelled equivalent), coconuts (incl. copra), palm kernels, soybean oil, groundnut oil, palm kernel oil, palm oil, coconut oil, bananas, coffee and cocoa beans. Appendix IX shows the Indonesian food balance per crop.

The consumption rate is based on the daily consumption per capita of protein by province. The data are derived from BPS (2008d) for the year 2005. The data about protein consumption by province are given in Appendix X. The diet is assumed to be equal in all provinces and is derived from the national food balance.

3.3.9 Virtual water import

The international virtual water flow coming into Indonesia is taken from Hoekstra and Mekonnen (2009). The virtual water import is an average for the years 2000 to 2003. The virtual water import of the products oil palm and coconut oil consists of the crude products and refined products. The virtual water import is shown in Appendix XI.

4. Water footprint of crops per province

The water use for production divided by the production determines the water footprint of a crop. The water footprints of the most important crops averaged for Indonesia are listed in Table 4.1. Cassava has the lowest water footprint of the crops considered, namely about 500 m^3/ton, and coffee the highest, about 22900 m^3/ton. In total terms, rice is the largest water user compared with the water use for other crops. This is caused by the high production quantity and the high water footprint per kilogram of rice produced. Rice is the most important crop in the diet of Indonesian people. The water footprint of the crops per province are shown in Appendix XII. The regional differences in the water footprint of crops are in some cases relatively large. These differences are caused by differences in climate and agricultural practice. Climate determines the evapotranspiration and thus influences the water footprint of crops. The average evapotranspiration varies within Indonesia between the 3.5 and 5.8 mm/day. Agricultural practice determines yields; a high crop yield results in relatively low water footprint of the crop.

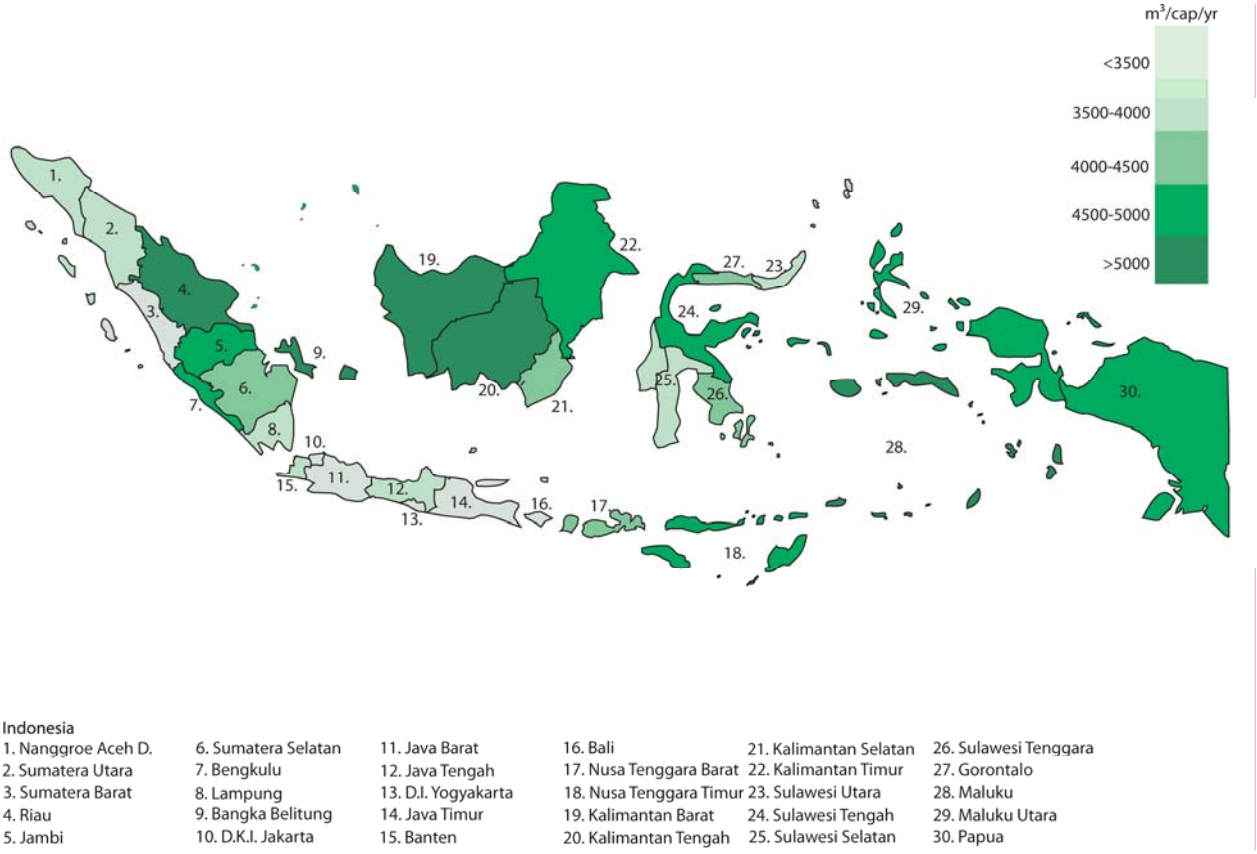
Table 4.1. The average green, blue and grey water footprint for primary crops in Indonesia (2000-2004).

	Water footprint [m^3/ton]			
	Green	Blue	Grey	Total
Rice	2527	735	212	3473
Maize	2395	75	13	2483
Cassava	487	8	19	514
Soybeans	1644	314	0	1958
Groundnut	2962	162	0	3124
Coconut	2881	0	16	2896
Oil palm	802	0	51	853
Banana	875	0	0	875
Coffee	21904	0	1003	22907
Cocoa	8895	0	519	9414

The green component has the largest contribution to the water footprint of crops. For rice, the green component contributes 73% to the total water footprint. The blue component is 21% for rice, 16% for soybean and 5% for groundnut; for the other crops the contribution of the blue component to the water footprint is marginal. Most crops are thus mainly grown with rainwater. Because blue water originates from groundwater or surface water, this component has a larger effect on the environment than the green water use. The crops rice, oil palm and cocoa have the largest grey component, because of the relatively large amount of fertilizer application. This component accounts for 6% of the water footprint for these crops. For some crops irrigation or fertilizer use is not common yet. Due to the increasing crop demand and spread of technology, this may become more common in the future, in which case the pressure on the blue water resources will increase.

Rice is an important and strategic crop in Indonesia. The water footprint of rice is about 3500 m^3/ton, but there are large differences between provinces as illustrated in Figure 4.2. 56% of the total rice production takes place on Java. Beside Java, large producing areas are Sulawesi Selatan and Sumatra Utara. In these provinces the water footprint of rice is about 3800 and 3900 m^3/ton respectively. This is higher than the average water

footprint of rice on Java, which is 2800 m^3/ton. The reason for the low water footprint of rice on Java is the combination of relatively high yields (5.3 ton/ha) and moderate evapotranspiration (4.6 mm/day). The other two regions do not have this combination of high yield and moderate evapotranspiration.



Indonesia

1. Nanggroe Aceh D.	6. Sumatera Selatan	11. Java Barat	16. Bali	21. Kalimantan Selatan	26. Sulawesi Tenggara
2. Sumatera Utara	7. Bengkulu	12. Java Tengah	17. Nusa Tenggara Barat	22. Kalimantan Timur	27. Gorontalo
3. Sumatera Barat	8. Lampung	13. D.I. Yogyakarta	18. Nusa Tenggara Timur	23. Sulawesi Utara	28. Maluku
4. Riau	9. Bangka Belitung	14. Java Timur	19. Kalimantan Barat	24. Sulawesi Tengah	29. Maluku Utara
5. Jambi	10. D.K.I. Jakarta	15. Banten	20. Kalimantan Tengah	25. Sulawesi Selatan	30. Papua

Figure 4.1. Water footprint related to rice production per province for the period 2000-2004.

5. Virtual water flows related to trade in crop products

5.1 Virtual water flows between provinces

The virtual water flows between provinces are shown in Appendix XIII. The province that has the largest virtual water outflow to other provinces is Sulawesi Selatan. This is mainly caused by the export of rice to other areas within Indonesia, most importantly Jakarta and the rest of Java. Other large exporting provinces are Kalimantan Selatan, Sumatera Barat and Nanggroe Aceh D. These provinces account for 82% of the total virtual water flow within Indonesia. These provinces have a large production and consequently a large surplus of one or more crops, so there is a large outflow of products to other provinces with deficits. The provinces that import most water in virtual form from other provinces are Jakarta, Java Barat, Riau and Banten. These provinces account for 55% of the total interprovincial virtual water import. Because of the high consumption quantity and/or the low production of crops, these provinces have a high virtual water import. The province Riau is a large exporting and a large importing province. This is caused by the fact that the surplus of certain crops is high and the deficit of other crops is relatively large. Riau imports a lot of rice and cassava and it has a large surplus of coconut and palm oil.

Figure 5.1 shows that the largest virtual water flows between provinces all go to Java. Java is an extremely densely populated island on which natural resources are not sufficient to feed all inhabitants. To release the pressure on the water resources on Java, water is imported in virtual form from provinces with a lower scarcity of water. This is in contrast with the situation in India and China, where studies have shown that virtual water is exported out of water-scarce regions, putting extra pressure on the water resources in these regions (Ma et al., 2006; Kampman et al., 2008).

5.2 International virtual water flows

The island group that exports most virtual water to other countries is Sumatra (Table 5.1). The large flow of virtual water out of Sumatra exists mainly of oil palm, coffee and coconut oil. Oil palm contributes more than 60% to the total virtual water export of Indonesia. Indonesia is the world's largest producer of oil palm and the largest part of the production is meant for the world market. Java is the only region in Indonesia with a net virtual water inflow (Table 5.1). In total, Indonesia exports more virtual water to other countries than it imports, resulting in a net outflow of virtual water from Indonesia.

5.3 Virtual water flows by product

Table 5.2 shows the interprovincial and international virtual water flows that can be associated with trade in various crops. Crops causing relatively large interprovincial flows of water are cassava, groundnuts, bananas and coffee. Bananas are the crop with by far the largest interprovincial water flow relative to the water use for production. Soybean is the product with the highest international import of virtual water. The crops with a relatively large amount of virtual water that will leave the country are oil palm, coffee, coconuts and cocoa.

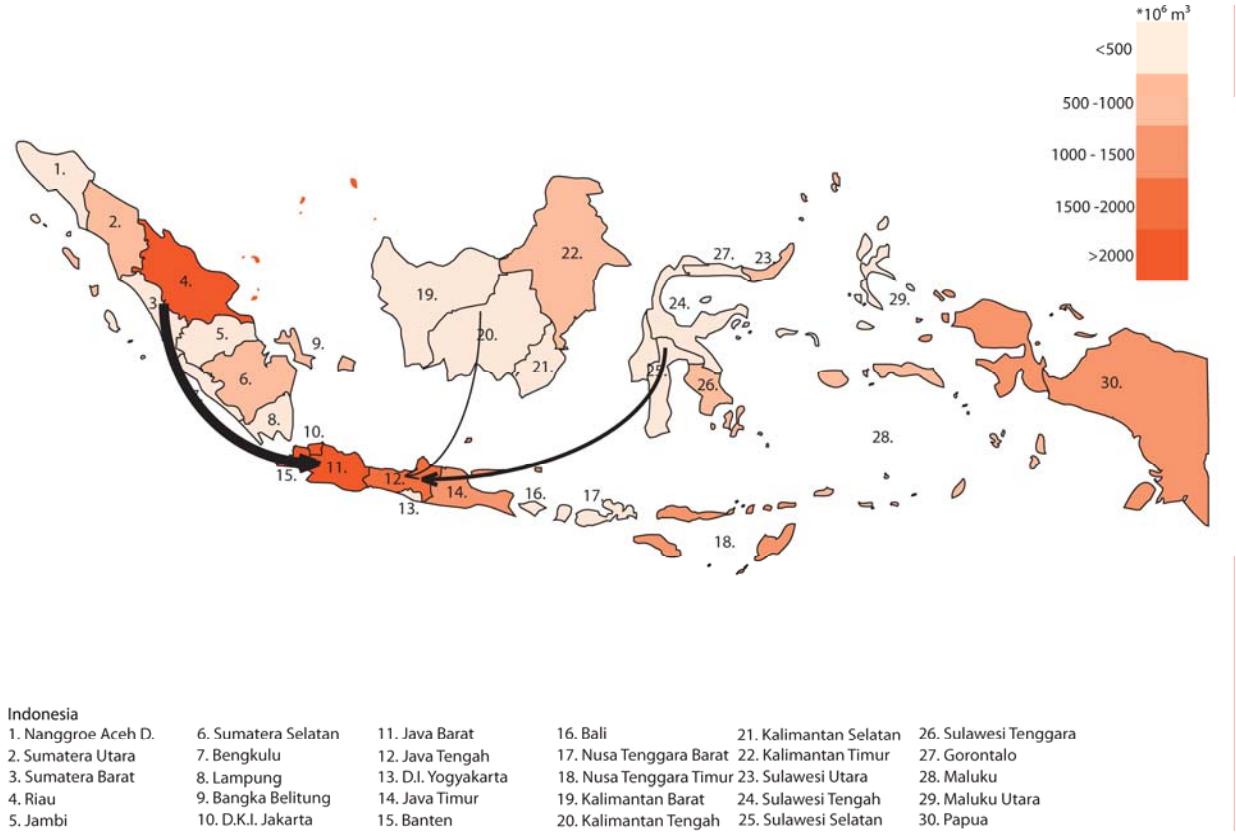


*Figure 5.1. Virtual water import per province with the largest net virtual water flows between island groups. Only the largest flows (>1000*10^6 m^3/yr) are shown.*

Table 5.1. International virtual water flow per island group as an average over the years 2000-2004.

	Water use for production[1] [10^9 m^3/yr]	International virtual water flows [10^6 m^3/yr]		
		Gross virtual water export	Gross virtual water import	Net virtual water export
Sumatra	116	28977	1320	27657
Java	124	1085	3089	-2003
Nusa Tenggara	18	1110	345	765
Kalimantan	32	5770	401	5369
Sulawesi	39	5492	379	5113
Maluku	4	970	153	816
Papua	2	249	156	93
Total	335	43653	5843	37809

[1]Water use refers here to the total crop production, including crops not used for food, but for feed, seed or other purposes (see food balance sheet).

Table 5.2. Water use for production, interprovincial virtual water flow and international virtual water flow per crop for Indonesia for the period 2000-2004. The primary and processed crops are combined.

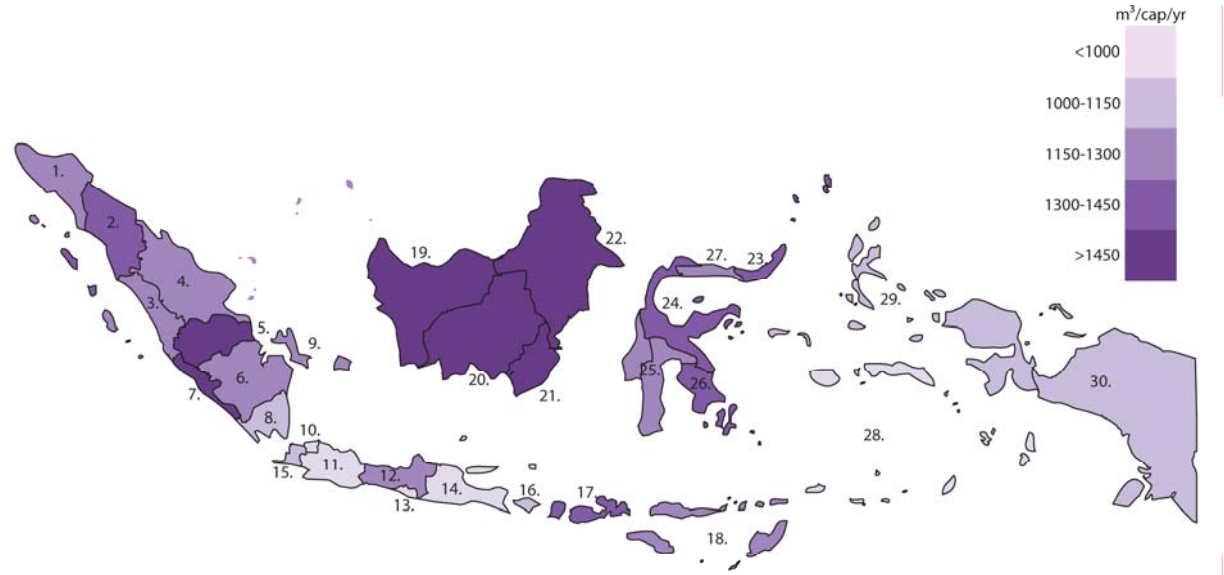
	Water use for production[1] [10^9 m^3/yr]	Interprovincial virtual water flow [10^9 m^3/yr]	International virtual water flow [10^9 m^3/yr]	
			Import	Export
Rice (milled equivalent)	182.0	13.8	1.8	0.0
Maize	25.3	3.2	0.2	0.1
Cassava	9.1	1.6	0.2	0.3
Soybeans	1.5	0.0	2.6	0.0
Groundnuts	2.4	0.5	0.4	0.0
Coconuts	47.3	3.7	0.0	8.6
Oil palm	44.1	4.3	0.0	24.0
Bananas	3.8	2.5	0.0	0.0
Coffee	14.5	2.5	0.1	7.0
Cocoa	5.3	0.2	0.5	3.5
Total	335.3	32.4	5.8	43.7

[1]Water use refers here to the total crop production, including crops not used for food, but for feed, seed or other purposes (see food balance sheet).

6. Water footprint of Indonesian provinces

The average water footprint related to the consumption of crop products in Indonesia is 1131 m^3/cap/yr. People in Kalimantan Tengah have the largest water footprint, 1895 m^3/cap/yr, and a person in Java Timur has the smallest water footprint, 859 m^3/cap/yr. A person in Jakarta relies the most on external water resources. Jakarta is a large urban area with only a small area suitable for agricultural purposes. This creates the dependency on water resources of other provinces and countries. Lampung has the highest use of internal water resources (98%). Lampung can fulfil its own needs for almost every crop, only for groundnuts and soybeans it has a small deficit. The provinces have an average internal water use of 84%, for the other 16% they rely on other provinces or countries. Table 6.1 shows the water footprint related to the consumption of crop products per Indonesian province.

Figure 6.1 visualizes the variation of the water footprint per capita over Indonesia. The water footprints of provinces on Java are relatively low and provinces on Kalimantan have a relatively high water footprint. The factors that determine the water footprint in general are: volume of consumption, consumption patterns, climate and agricultural practice (Hoekstra and Chapagain, 2007). Because in this study the consumption patterns have been assumed to be the same for each province, the differences in water footprints are caused by climate, agricultural practice and consumption quantity. Agricultural practice influences the yield and thus the water footprint of crop products. On Java the yields are high, the average consumption rate is just below average and the evapotranspiration rate is lower compared to other regions, which causes the low water footprint of the population on Java.



Indonesia

1. Nanggroe Aceh D.	6. Sumatera Selatan	11. Java Barat	16. Bali	21. Kalimantan Selatan	26. Sulawesi Tenggara
2. Sumatera Utara	7. Bengkulu	12. Java Tengah	17. Nusa Tenggara Barat	22. Kalimantan Timur	27. Gorontalo
3. Sumatera Barat	8. Lampung	13. D.I. Yogyakarta	18. Nusa Tenggara Timur	23. Sulawesi Utara	28. Maluku
4. Riau	9. Bangka Belitung	14. Java Timur	19. Kalimantan Barat	24. Sulawesi Tengah	29. Maluku Utara
5. Jambi	10. D.K.I. Jakarta	15. Banten	20. Kalimantan Tengah	25. Sulawesi Selatan	30. Papua

Figure 6.1. Water footprints of Indonesian provinces per capita related to crop products for the period 2000-2004.

Table 6.1. Water footprint related to the consumption of the selected crop products per capita for Indonesian provinces for the period 2000-2004.

	Provincial water footprint [m^3/cap/yr]			
	Internal	External		Total
		Other province	Other country	
Nanggroe Aceh D.	1171	69	4	1243
Sumatera Utara	1245	56	22	1323
Sumatera Barat	1131	71	24	1226
Riau	663	498	79	1240
Jambi	1288	158	38	1483
Sumatera Selatan	1143	98	30	1272
Bengkulu	1573	67	17	1657
Lampung	1113	5	19	1136
Bangka Belitung	360	732	115	1207
D.K.I. Jakarta	5	849	121	974
Java Barat	708	164	30	902
Java Tengah	1152	61	15	1228
D.I. Yogyakarta	875	101	11	986
Java Timur	815	42	2	859
Banten	789	287	55	1130
Bali	923	158	29	1110
Nusa Tenggara Barat	1332	96	6	1433
Nusa Tenggara Timur	865	354	58	1277
Kalimantan Barat	1639	74	26	1740
Kalimantan Tengah	1641	211	44	1895
Kalimantan Selatan	1337	97	26	1461
Kalimantan Timur	1096	334	56	1485
Sulawesi Utara	1021	267	47	1335
Sulawesi Tengah	1332	66	22	1420
Sulawesi Selatan	1249	35	14	1297
Sulawesi Tenggara	1089	276	50	1415
Gorontalo	905	242	36	1182
Maluku	360	544	80	984
Maluku Utara	569	442	72	1082
Papua Barat	475	503	70	1048
Indonesia	946	157	28	1131

The contribution of each separate crop to the average Indonesian water footprint is visualized in Figure 6.2. In the figure the primary and processed products of the root crop are combined. The figure shows that rice contributes 69% to the crop-related water footprint. This is caused by the relatively high water footprint per kilogram for rice, but mostly by the high consumption rate of rice in Indonesia. After rice, coconut and coconut oil have the largest contribution to the crop-related water footprint of an average Indonesian consumer.

The contribution of the green, blue and grey component to the water footprint related to the consumption of crop products is show in Figure 6.3. The green component has by far the largest contribution. The grey component is relatively small, but if the fertilizer use will increase in the future the contribution of this component will also increase.

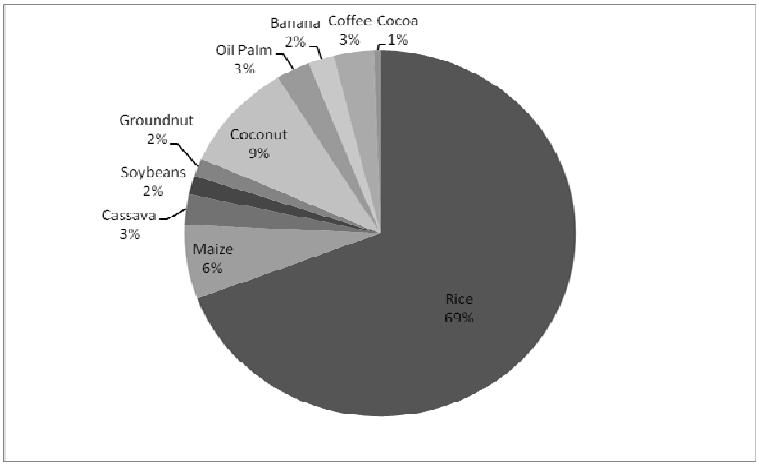


Figure 6.2. The contribution of crops to the total water footprint of Indonesia related to the consumption of crop products for the period 2000-2004.

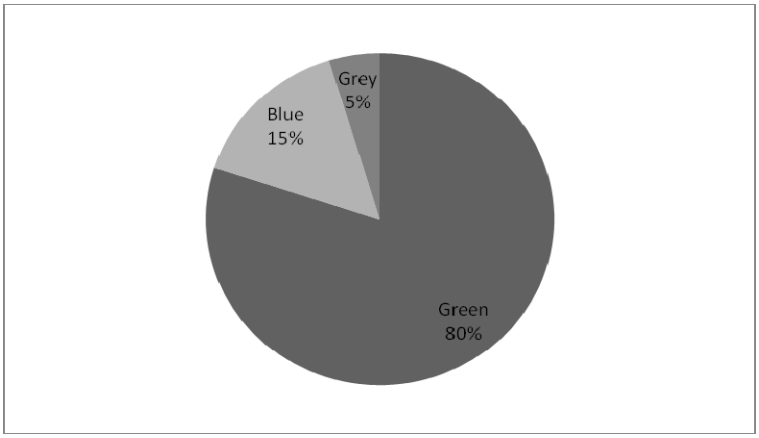


Figure 6.3. The contribution of the green, blue and grey component to the total water footprint of Indonesia related to the consumption of crop products for the period 2000-2004.

Figure 6.4 shows the virtual water trade balance and the water footprint for the island of Java and for Indonesia as a whole. The total virtual water import of Java is 15.6 billion m^3/yr, of which 12.5 billion m^3/yr comes from other islands (Appendix XIII) and 3.1 billion m^3/yr from other countries (Table 5.1). The total virtual water export from Java is 1.6 billion m^3/yr, of which 0.5 billion m^3/yr goes to other islands (Appendix XIII) and 1.1 billion m^3/yr to other countries (Table 5.1). The total water footprint of the Javanese population, insofar related to consumption of crop products, is 114 billion m^3/yr, 13% of which is external. Java thus depends on external water resources, most of which comes from other islands. As for Indonesia as a whole, the dependency on external water resources is minimal. On contrary, the country exports a significant amount of water in virtual form.

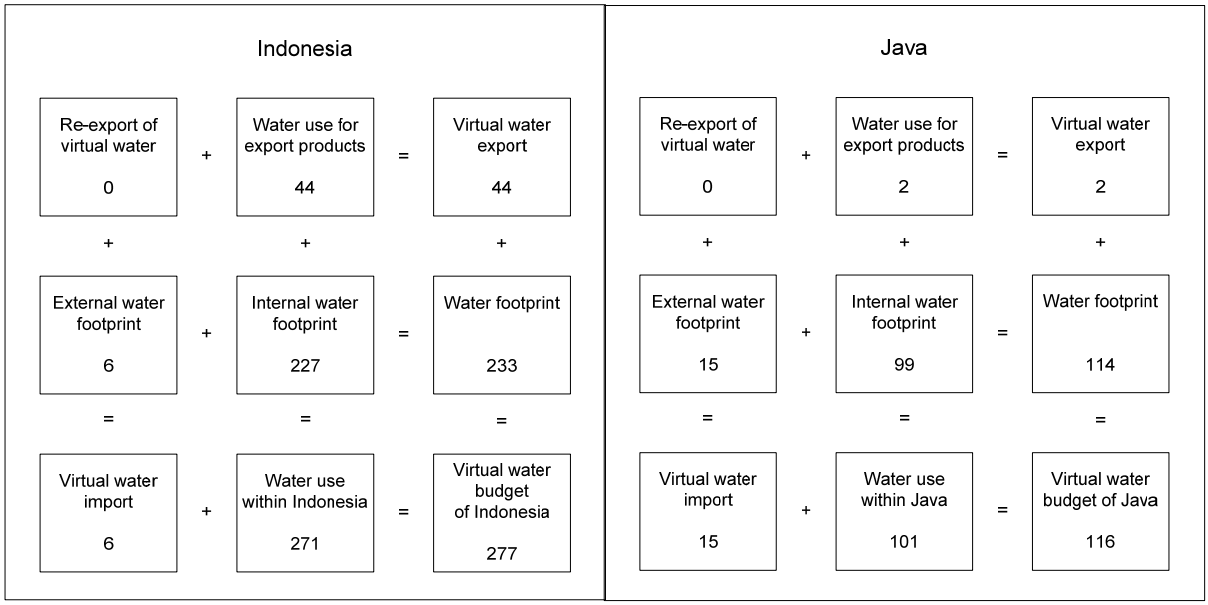


Figure 6.4. The virtual water trade balance and water footprint for Indonesia and the island of Java. The numbers refer to water volumes in 10^9 m^3/yr. The water use refers to the production for food only, not to the production for feed, seed and other uses.

7. Conclusions

The average water footprint related to the consumption of crop products in Indonesia is 1131 m^3/cap/yr, but there are large regional differences. The water footprint in Java Timur is the lowest, namely 859 m^3/cap/yr, and the highest water footprint can be found in Kalimantan Tengah, 1895 m^3/cap/yr. The factors that determine the water footprint are: volume of consumption, consumption patterns, climate and agricultural practice (Hoekstra and Chapagain, 2008). Because the consumption pattern is assumed the same in each province, the differences in water footprint are caused by climate, agricultural practice and consumption volume. The biggest contribution to the water footprint per capita is from rice. This is caused by the high consumption rate and the relatively high water footprint of rice.

The water footprint of crops varies within the country, there are large differences between provinces. For instance, of all large rice producing provinces, the provinces on Java and Bali have the lowest water footprint. The water footprint of one kilogram of rice produced on Java or Bali is almost half the amount of the water footprint of rice produced on Kalimantan, the Maluku islands or Papua.

The green water component has the largest contribution to the water footprint of crops in Indonesia. For most crops the blue water use is less than 10% of the total water footprint, only for rice and soybeans the blue water contribution is higher. The blue water use has a larger effect on the environment than the green water use, because this component is originating from groundwater or surface water. However, to ensure high yields and food security, irrigation water is required. The grey component is relatively low, it contributes to at most 6% of the water footprint of crops. If the use of fertilizers will increase in the future, this component will become a more important factor in the total water footprint of crop products in Indonesia.

The interprovincial virtual water flows are primarily caused by the trade in rice. The crops cassava, coconut, bananas and coffee have the largest interprovincial flow relative to the water use for production. Sulawesi Selatan has the largest contribution to the virtual water export to other provinces. The flow out of this province exists primarily of water virtually embedded in rice. Large importing provinces are Jakarta, Java Barat, Riau and Banten. The largest flow of net virtual water is from Sumatra to Java. Java, the most water-scarce island, has a net virtual water import and the most significant external water footprint, which does release the water scarcity on this island. Sumatra exports most virtual water to other countries. The large flow of virtual water out of Sumatra is mainly related to the products palm oil, coffee and coconut oil.

Provinces depend highly on internal water resources. On average 84% of the water footprint consists of internal water, the flow of virtual water between provinces is low. Because of the large variance between the water footprints of products in provinces, it is more efficient to produce crops in provinces where the water footprint of those particular products is low. When the pressure on the resources will increase and water will become scarcer, trade in virtual water can save water, reduce the pressure on the water resources and assure a high degree of food self-sufficiency within Indonesia. But to achieve this the agricultural sector needs to be reformed on the basis of water-efficient production and wise trade. There are two alternative routes. On the one hand, the overall

Indonesian water footprint may be reduced by promoting wise trade between provinces – i.e. trade from places with high to places with low water efficiency. On the other hand, the water footprint can be reduced by improving water efficiency in those places that currently have relatively low efficiency, which equalises production efficiencies and thus reduces the need for imports and enhances the opportunities for exports. In any case, trade will remain necessary to supply food to the most densely populated areas where water scarcity is highest (Java).

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Appendix I. Population per province in 2000

Province	Population [10^3]
Nanggroe Aceh D.	3931
Sumatera Utara	11650
Sumatera Barat	4249
Riau	4958
Jambi	2414
Sumatera Selatan	6900
Bengkulu	1567
Lampung	6741
Bangka Belitung	900
D.K.I. Jakarta	8389
Java Barat	35730
Java Tengah	31229
D.I. Yogyakarta	3122
Java Timur	34784
Banten	8099
Bali	3151
Nusa Tenggara Barat	4009
Nusa Tenggara Timur	3952
Kalimantan Barat	4034
Kalimantan Tengah	1857
Kalimantan Selatan	2985
Kalimantan Timur	2455
Sulawesi Utara	2012
Sulawesi Tengah	2218
Sulawesi Selatan	8060
Sulawesi Tenggara	1821
Gorontalo	835
Maluku	1206
Maluku Utara	785
Papua	2221
Indonesia	206265

Source: BPS (2008a)

Appendix II. Weather stations per province

Province	Weather stations
Nanggroe Aceh D.	Sabang, Banda Aceh
Sumatera Utara	Medan, Belawan
Sumatera Barat	Padang, Fort de Kock, Padang
Riau	Pakanbaru, Tarempa
Jambi	
Sumatera Selatan	Palembang
Bengkulu	Bengkulu
Lampung	Menggala, Telukbetung
Bangka Belitung	Pangkalpinang, Buluh Tumbang
D.K.I. Jakarta	Jakarta
Java Barat	Bandung, Bogor, Lembang, Rarahan, Tjipetir, Gunung-Rosa, Pangerango
Java Tengah	Semarang, Magelang, Tegal, Cilacap
D.I. Yogyakarta	Yogyakarta
Java Timur	Surabaya, Djember, Karanganjar, Pasuruan, Sawahan, Kawah-Idjen, Rogodjampi, Tosari, Tamansari
Banten	Curung-Budiarto, Serang
Bali	Den-Pasar
Nusa Tenggara Barat	Tambora, Bima
Nusa Tenggara Timur	Kupang, Waingapu
Kalimantan Barat	Pontianak, Sintang
Kalimantan Tengah	Palangkaraya, Pangkalan Bun
Kalimantan Selatan	Banjamarsin, Banjarbaru
Kalimantan Timur	Balikpapan, Tarakan
Sulawesi Utara	Manado, Tahuna
Sulawesi Tengah	Luwuk
Sulawesi Selatan	Ujung-Padang, Masamba, Majene
Sulawesi Tenggara	Kendari, Bau-bau, Poso
Gorontalo	Gorontalo
Maluku	Ambon, Amahai
Maluku Utara	Ternate
Papua	Jayapura, Biak-Mokmer, Manokwari, Sorong, Kaimana

Source: The underlined weather stations are from BMG (2008), the others are taken from FAO (2008b)

Appendix III. Crop parameters

Crop	Season	Date		Length of development stages[6] [days]					Crop coefficient[7]		
		Planted	Harvested	I	CD	MS	LS	Total	Kc ini	Kc mid	Kc end
Rice, paddy	Wet[1]	1-Nov	1-Apr	30	30	60	30	150	1.05	1.10	0.65
	Dry[1]	10-Apr	10-Sep	30	30	60	30	150	1.05	1.12	0.67
Maize	Wet[2]	10-Oct	15-Feb	20	35	40	30	125	0.30	1.08	0.48
	Dry[2]	10-Mar	15-Jul	20	35	40	30	125	0.30	1.10	0.50
Cassava	Wet[3]	1-Nov	1-Jun	20	40	90	60	210	0.30	0.99	0.39
Soybeans	Dry	1-Aug	25-Oct	15	15	40	15	85	0.40	1.08	0.43
Groundnuts	Wet[4]	10-Mar	1-Aug	35	45	35	25	140	0.40	0.97	0.52
Coconuts		15-Feb		120	60	180	5	365	0.95	1.00	1.00
Oil palm fruit		15-Feb		120	60	180	5	365	0.80	0.81	0.81
Bananas		1-Feb		120	60	180	5	365	1.00	1.05	0.95
Coffee			1-Aug	120	60	180	5	365	0.80	0.82	0.82
Cocoa beans			1-Nov[5]	120	60	180	5	365	0.90	0.91	0.91

[1] Source: IRRI (2008)

[2] Source: Swastika et al.(2004)

[3] Source: FAO (2008e)

[4] Source: Taufiq et al. (2007)

[5] Source: Wood and Lass (1989)

[6] Source: Allen et al. (1998); Chapagain and Hoekstra (2004)

[7] Source: Allen et al. (1998); Chapagain and Hoekstra (2004)

Appendix IV. Irrigated area fraction of crops per province

Province	Land type [10^3 ha][1]		Irrigated area fraction				
	Wetland	Dryland	Rice	Maize	Cassava	Soybeans	Groundnut
Nanggroe Aceh D.	367	799	0.99	0.20	0.20	0.20	0.20
Sumatera Utara	575	813	0.90	0.21	0.21	0.21	0.21
Sumatera Barat	238	525	0.98	0.06	0.06	0.06	0.06
Riau	120	709	0.86	0.08	0.08	0.08	0.08
Jambi	161	733	0.84	0.12	0.12	0.12	0.12
Sumatera Selatan	484	662	0.87	0.27	0.27	0.27	0.27
Bengkulu	77	263	0.83	0.11	0.11	0.11	0.11
Lampung	313	786	0.84	0.13	0.13	0.13	0.13
Bangka Belitung	4	161	0.37	0.02	0.02	0.02	0.02
D.K.I. Jakarta	2	3	1.00	0.29	0.29	0.29	0.29
Java Barat	918	809	0.95	0.11	0.11	0.11	0.11
Java Tengah	968	764	0.96	0.21	0.21	0.21	0.21
D.I. Yogyakarta	57	96	0.73	0.10	0.10	0.10	0.10
Java Timur	1096	1153	0.94	0.21	0.21	0.21	0.21
Banten	195	260	0.91	0.13	0.13	0.13	0.13
Bali	80	134	0.99	0.05	0.05	0.05	0.05
Nusa Tenggara Barat	226	246	0.87	0.28	0.28	0.28	0.28
Nusa Tenggara Timur	116	738	0.66	0.08	0.08	0.08	0.08
Kalimantan Barat	275	847	0.71	0.16	0.16	0.16	0.16
Kalimantan Tengah	164	970	0.58	0.10	0.10	0.10	0.10
Kalimantan Selatan	434	383	0.89	0.40	0.40	0.40	0.40
Kalimantan Timur	124	456	0.56	0.16	0.16	0.16	0.16
Sulawesi Utara	58	359	0.94	0.05	0.05	0.05	0.05
Sulawesi Tengah	118	703	0.97	0.04	0.04	0.04	0.04
Sulawesi Selatan	569	625	0.99	0.26	0.26	0.26	0.26
Sulawesi Tenggara	73	300	0.89	0.11	0.11	0.11	0.11
Gorontalo	27	175	0.97	0.05	0.05	0.05	0.05
Maluku			0.81				
Maluku Utara			0.86				
Papua			0.81				

[1] *Source: BPS (2008b)*

Appendix V. Fertilizer use per crop

Crop	Fertilized area [%]	Application of nitrate [kg N/ha]
Rice	90	105
Maize	80	5
Cassava	40	65
Soybeans	0	0
Groundnut	0	0
Coconut	15	45
Oil Palm	80	95
Banana	0	0
Coffee	70	70
Cocoa	70	95

Source: FAO (2008c) and FAO (2005)

Appendix VI. Production quantity of crops per province

Province	Production quantity [10^3 ton/yr] [1]				
	Rice	Maize	Cassava	Soybean	Groundnut
Nanggroe Aceh D.	1402	56	61	43	32
Sumatera Utara	3400	678	475	11	25
Sumatera Barat	1813	66	103	4	8
Riau	421	41	60	2	3
Jambi	568	27	56	4	2
Sumatera Selatan	1899	71	279	6	7
Bengkulu	390	49	86	2	6
Lampung	1999	1115	3865	11	12
Bangka Belitung	10	1	15	0	0
D.K.I. Jakarta	13	0	1	0	0
Java Barat	9650	427	1766	35	68
Java Tengah	8495	1727	3331	152	172
D.I. Yogyakarta	667	190	762	50	58
Java Timur	9061	3839	3963	326	196
Banten	1169	20	122	2	11
Bali	819	94	151	11	18
Nusa Tenggara Barat	1460	62	96	53	35
Nusa Tenggara Timur	480	579	865	3	14
Kalimantan Barat	981	52	201	2	2
Kalimantan Tengah	409	9	102	3	2
Kalimantan Selatan	1398	35	108	7	18
Kalimantan Timur	417	12	101	2	2
Sulawesi Utara	392	164	38	4	6
Sulawesi Tengah	657	52	55	2	5
Sulawesi Selatan	3888	634	539	26	49
Sulawesi Tenggara	308	78	193	2	8
Gorontalo	119	85	8	1	2
Maluku	28	8	230	2	4
Maluku Utara	15	1	27	0	0
Papua	73	7	50	6	5
Total	52403	10176	17713	771	775

Source: Provincial data from Ministry of Agriculture (2008), adjusted so the national totals are consistent to FAO (2008a)

Province	Production quantity [10^3 ton/yr]				
	Coconut	Oil Palm	Bananas	Coffee	Cocoa
Nanggroe Aceh D.	437	2245	36	45	11
Sumatera Utara	614	14665	68	44	49
Sumatera Barat	374	2671	43	21	7
Riau	2735	13108	34	2	2
Jambi	640	3831	13	5	0
Sumatera Selatan	161	4921	71	145	0
Bengkulu	42	618	12	62	2
Lampung	723	968	165	125	11
Bangka Belitung	36	641	3	0	0
D.K.I. Jakarta	0	6	2	0	0
Java Barat	515	76	1132	5	4
Java Tengah	1118	0	416	15	2
D.I. Yogyakarta	244	0	34	0	0
Java Timur	1326	0	631	45	15
Banten	296	0	130	2	1
Bali	390	0	79	21	5
Nusa Tenggara Barat	255	0	100	4	1
Nusa Tenggara Timur	302	0	118	15	6
Kalimantan Barat	286	140	66	4	2
Kalimantan Tengah	291	3225	13	2	0
Kalimantan Selatan	187	1300	36	2	0
Kalimantan Timur	198	840	32	6	19
Sulawesi Utara	1347	0	24	4	2
Sulawesi Tengah	978	665	36	6	74
Sulawesi Selatan	1009	350	111	43	226
Sulawesi Tenggara	177	886	28	4	87
Gorontalo	307	0	2	0	1
Maluku	364	0	3	1	4
Maluku Utara	900	0	33	1	12
Papua	73	420	878	4	15
Total	16327	51698	4348	635	564

Source: Provincial data from Ministry of Agriculture (2008), adjusted so the national totals are consistent to FAO (2008a)

Appendix VII. Harvested area of crops per province

Province	Harvested area [ha]				
	Rice	Maize	Cassava	Soybean	Groundnut
Nanggroe Aceh D.	337142	22198	4889	33196	8920
Sumatera Utara	813200	208990	38078	10687	22870
Sumatera Barat	406465	24934	8168	3031	7687
Riau	136260	18452	5273	2123	3866
Jambi	163643	10640	4493	2932	2094
Sumatera Selatan	564820	27425	22940	4671	6104
Bengkulu	108992	25037	6841	2485	5918
Lampung	488323	355281	287148	10326	10242
Bangka Belitung	6066	691	1807	3	406
D.K.I. Jakarta	2781	33	91		24
Java Barat	1878279	121562	93765	26500	68832
Java Tengah	1629020	537519	224082	105178	146077
D.I. Yogyakarta	134701	66469	58419	42493	62550
Java Timur	1708325	1132131	248656	258898	167965
Banten	346612	9509	11856	2874	11830
Bali	148218	32047	12310	8049	13790
Nusa Tenggara Barat	325533	30024	8151	65507	31038
Nusa Tenggara Timur	173572	258595	84153	3007	11932
Kalimantan Barat	357666	24451	14827	1550	1795
Kalimantan Tengah	178883	4487	9078	2432	2040
Kalimantan Selatan	432877	18644	7645	5550	14460
Kalimantan Timur	138836	6193	7392	2030	2447
Sulawesi Utara	90210	71333	4023	3327	5165
Sulawesi Tengah	175309	22010	4622	1942	5132
Sulawesi Selatan	816252	210010	40210	19328	39535
Sulawesi Tenggara	82533	35504	15498	2536	9457
Gorontalo	35667	49047	1043	1210	3223
Maluku	10900	5364	16816	1321	1672
Maluku Utara	15813	2856	10261	518	2167
Papua	23406	4405	4407	5385	5055
Total	11730306	3335840	1256942	629088	674291

Source: Ministry of Agriculture (2008)

Province	Harvested area [ha]				
	Coconut	Oil Palm	Bananas	Coffee	Cocoa
Nanggroe Aceh D.	116001	164633	3608	98401	11117
Sumatera Utara	139704	558592	10048	66360	30886
Sumatera Barat	88623	184988	3370	45380	6751
Riau	586347	885962	3535	10867	2375
Jambi	133231	246479	1688	27731	1008
Sumatera Selatan	50429	329208	10124	282139	192
Bengkulu	19829	83471	2068	118924	7384
Lampung	155844	96225	28663	173067	11694
Bangka Belitung	15077	79096	1629	86	152
D.K.I. Jakarta			106		
Java Barat	188082	5335	67803	14575	5718
Java Tengah	283563		54800	40131	3395
D.I. Yogyakarta	40578		2750	1787	1517
Java Timur	282803		43816	93705	15233
Banten	101983	8340	13781	8792	2257
Bali	72659		8917	38382	3677
Nusa Tenggara Barat	66546		3667	11884	1974
Nusa Tenggara Timur	162577		10239	66439	17746
Kalimantan Barat	108495	236807	4739	15858	4575
Kalimantan Tengah	68319	265559	1247	7138	494
Kalimantan Selatan	53908	114147	6176	6949	954
Kalimantan Timur	50474	113440	5979	16302	16806
Sulawesi Utara	255699		3367	8526	4081
Sulawesi Tengah	179301	31891	1378	19244	60263
Sulawesi Selatan	180754	9206	10424	94955	125359
Sulawesi Tenggara	51961	2715	1032	11496	68231
Gorontalo	59457		188	1127	2324
Maluku	93590		4762	5021	5501
Maluku Utara	172514		2790	5008	14823
Papua	35894	33752	2015	8565	13316
Total	3814242	3449848	314708	1298837	439801

Source: Ministry of Agriculture (2008)

Appendix VIII. Product and value fraction per crop

Root product	Processed product	Product fraction[1]	Value fraction[2]
Rice	Rice (Milled Equivalent)	0.65	1.00
Maize	-	1.00	1.00
Cassava	-	1.00	1.00
Soybean	Soybean Cake	0.80	0.66
Soybean	Soybean Oil	0.18	0.34
Groundnut with shell	Groundnut shelled	0.68	1.00
Groundnut shelled	Groundnut Oil	0.52	0.78
Coconuts	Copra	0.20	1.00
Copra	Coconut Oil	0.54	0.63
Oil Palm Fruit	Palm Oil	0.20	0.93
Oil Palm Fruit	Palmkernels	0.05	0.07
Palmkernels	Palmkernel Oil	0.45	0.42
Bananas	-	1.00	1.00
Coffee	-	1.00	1.00
Cocoa Beans	-	1.00	1.00

[1]*Source: FAO (2008d)*

[2]*Source: Chapagain and Hoekstra (2004)*

Appendix IX. National food balance per crop

Crop	Food balance items [10^3 ton/yr]										
	PR	IM	ST	EX	DO	FE	SE	FM	WA	OT	FO
Rice (milled equivalent)	34338	1375	108	7	35814	1376	307	0	2604	4	31524
Maize	9891	1237	0	42	11085	3250	96	0	625	30	7085
Cassava	17145	613	0	502	17257	343	0	0	2148	2459	12307
Soybeans	797	1243	0	2	2039	0	45	0	97	0	1897
Groundnuts (shelled equivalent)	907	138	0	10	1034	0	19	62	90	0	863
Coconuts – incl. copra	12090	39	0	283	11846	0	5	4751	1209	0	5881
Palmkernels	1942	1	15	6	1951	0	0	1951	0	0	0
Soybean oil	0	15	0	0	15	0	0	0	0	0	15
Groundnut oil	28	0	0	0	28	0	0	0	0	0	28
Palmkernel oil	868	3	0	640	232	0	0	0	0	0	232
Palm oil	8450	31	-75	6037	2369	0	0	0	0	681	1689
Coconut oil	789	2	-48	485	258	0	0	0	0	21	237
Bananas	4186	6	0	21	4171	0	0	0	419	0	3752
Coffee	650	11	0	328	334	0	0	0	26	0	308
Cocoa beans	434	33	-6	401	61	0	0	0	0	0	61

PR = production quantity. IM = import quantity. ST= stock variation. EX= export quantity. DO= domestic supply (=PR+IM+ST-EX). FE= feed quantity. SE= seed quantity. FM= food manufacture. WA= waste quantity. OT= other uses quantity and FO= food quantity

Source: FAO (2008a)

Appendix X. Daily consumption of protein per capita per province

Province	Protein intake [g/day][1]	Relative protein intake [%]
Nanggroe Aceh D.	55.2	96
Sumatera Utara	58.3	102
Sumatera Barat	57.8	101
Riau	58.2	102
Jambi	58.6	102
Sumatera Selatan	54.5	95
Bengkulu	54.0	94
Lampung	56.1	98
Bangka Belitung	62.6	109
D.K.I. Jakarta	62.0	108
Java Barat	58.6	102
Java Tengah	52.0	91
D.I. Yogyakarta	51.1	89
Java Timur	54.0	94
Banten	59.2	103
Bali	65.3	114
Nusa Tenggara Barat	58.2	102
Nusa Tenggara Timur	57.4	100
Kalimantan Barat	54.5	95
Kalimantan Tengah	58.2	102
Kalimantan Selatan	60.2	105
Kalimantan Timur	59.8	104
Sulawesi Utara	62.2	109
Sulawesi Tengah	56.5	99
Sulawesi Selatan	58.9	103
Sulawesi Tenggara	61.4	107
Gorontalo	55.2	96
Maluku	53.5	93
Maluku Utara	55.8	97
Papua	48.9	85
Indonesia	57.3	100

[1] *Source: BPS (2008d)*

Appendix XI. International virtual water import per crop

Crop	Virtual water import [10^3 m^3/yr]
Rice	1840000
Maize	215000
Cassava	172000
Soybeans	2590000
Groundnut (shelled)	383000
Coconut (copra)	1430
Groundnut oil	90
Palmkernel oil	10900
Palm oil	5930
Coconut oil	9260
Bananas	152
Coffee	82000
Cocoa beans	538000

Source: Hoekstra and Mekonnen (2009)

Appendix XII. Water footprint of crops per province

Province	Water footprint of crops [m^3/ton]											
	Rice				Maize				Cassava			
	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
Nanggroe Aceh D.	2361	1385	225	3972	2626	155	15	2797	484	26	21	531
Sumatera Utara	2771	903	229	3903	2371	96	13	2479	458	36	21	516
Sumatera Barat	2984	296	213	3493	2717	7	13	2738	574	0	21	595
Riau	3823	1501	305	5630	3579	83	18	3680	649	10	24	683
Jambi	3558	727	275	4560	3176	52	16	3244	632	1	23	656
Sumatera Selatan	3423	351	274	4049	3005	26	16	3048	574	0	22	596
Bengkulu	3635	889	264	4789	4473	59	21	4553	662	7	23	692
Lampung	1577	2035	232	3843	1663	164	13	1840	374	25	19	419
Bangka Belitung	5612	71	398	6081	3007	0	15	3022	603	0	23	626
D.K.I. Jakarta	2210	722	201	3133	3832	148	22	4001	578	3	22	603
Java Barat	2126	115	187	2428	1811	1	11	1823	370	0	17	387
Java Tengah	2621	1062	184	3866	3021	110	13	3144	635	1	18	653
D.I. Yogyakarta	2161	895	192	3248	2719	31	14	2764	619	0	20	640
Java Timur	1954	458	181	2593	2053	37	12	2102	416	0	17	433
Banten	1994	1332	205	3530	2618	112	15	2745	525	8	19	552
Bali	2096	411	175	2683	2924	10	15	2949	623	1	22	646
Nusa Tenggara Barat	2965	980	213	4159	4368	200	19	4587	748	1	23	773
Nusa Tenggara Timur	2559	1802	336	4697	2431	112	18	2560	613	9	25	647
Kalimantan Barat	5016	317	344	5677	3493	12	16	3521	558	0	20	578
Kalimantan Tengah	4867	1307	384	6558	5291	118	26	5434	714	5	23	741
Kalimantan Selatan	3578	200	292	4070	3673	0	21	3694	480	0	20	501
Kalimantan Timur	4445	0	308	4753	4112	0	21	4132	516	0	20	536
Sulawesi Utara	3060	436	219	3714	3827	7	18	3852	712	0	25	738
Sulawesi Tengah	2512	1969	250	4732	3038	45	17	3100	549	8	23	581
Sulawesi Selatan	2525	1026	205	3756	2841	95	13	2950	579	9	20	608
Sulawesi Tenggara	2582	1639	254	4475	3368	101	19	3488	510	9	20	540
Gorontalo	1952	1920	214	4086	2418	47	14	2479	541	12	24	577
Maluku	3821	855	344	5020	4146	0	24	4170	502	0	22	524
Maluku Utara	2802	1546	267	4615	4233	0	26	4259	568	0	22	590
Papua	4312	16	315	4643	4942	0	26	4968	609	0	24	633

Province	Water footprint of crops [m^3/ton]											
	Soybeans				Groundnuts				Coconut			
	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
Nanggroe Aceh D.	2139	155	0	2294	1134	114	0	1248	3098	0	18	3117
Sumatera Utara	3238	15	0	3253	4236	115	0	4350	3117	0	16	3133
Sumatera Barat	2780	0	0	2780	3828	7	0	3835	3556	0	16	3572
Riau	3150	63	0	3213	4900	166	0	5066	2963	0	15	2978
Jambi	2495	74	0	2569	3824	91	0	3915	2834	0	14	2848
Sumatera Selatan	2130	152	0	2283	3288	46	0	3335	4140	0	22	4161
Bengkulu	3360	105	0	3465	4646	74	0	4720	7091	0	32	7123
Lampung	1319	435	0	1753	2243	277	0	2520	1571	0	15	1586
Bangka Belitung	2914	0	0	2914	4166	0	0	4166	5841	0	27	5868
D.K.I. Jakarta					878	69	0	946				
Java Barat	2117	22	0	2139	2059	4	0	2062	3853	0	22	3874
Java Tengah	1558	418	0	1977	3561	328	0	3889	3733	0	17	3750
D.I. Yogyakarta	1515	110	0	1625	3167	108	0	3274	2144	0	12	2156
Java Timur	1381	262	0	1642	2587	128	0	2715	2090	0	13	2103
Banten	1111	279	0	1390	2685	190	0	2875	3430	0	23	3453
Bali	1168	52	0	1221	2813	5	0	2819	2244	0	12	2256
Nusa Tenggara Barat	2237	956	0	3193	3614	318	0	3932	3672	0	18	3690
Nusa Tenggara Timur	188	302	0	490	1398	154	0	1552	3962	0	37	3998
Kalimantan Barat	3048	23	0	3070	4312	14	0	4326	5462	0	24	5486
Kalimantan Tengah	2168	208	0	2376	3774	127	0	3901	2973	0	15	2988
Kalimantan Selatan	1834	321	0	2155	3234	0	0	3234	3510	0	19	3529
Kalimantan Timur	3007	8	0	3015	4124	0	0	4124	3820	0	18	3837
Sulawesi Utara	2352	40	0	2392	4082	15	0	4096	2752	0	13	2765
Sulawesi Tengah	1603	100	0	1703	3847	19	0	3866	1913	0	13	1926
Sulawesi Selatan	1428	446	0	1874	3205	250	0	3454	2511	0	13	2525
Sulawesi Tenggara	2019	344	0	2363	4344	161	0	4505	3217	0	21	3238
Gorontalo	1288	144	0	1433	3171	78	0	3249	1874	0	13	1888
Maluku	2297	0	0	2297	1527	0	0	1527	2985	0	17	3002
Maluku Utara	2429	0	0	2429	2231	0	0	2231	2179	0	13	2192
Papua	2582	0	0	2582	4147	0	0	4147	7105	0	35	7140

Province	Water footprint of crops [m^3/ton]											
	Oil palm				Banana				Coffee			
	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
Nanggroe Aceh D.	776	0	57	832	874	0	0	874	24094	0	1139	25233
Sumatera Utara	485	0	30	516	1463	0	0	1463	18350	0	740	19089
Sumatera Barat	841	0	50	891	1091	0	0	1091	28059	0	1067	29127
Riau	861	0	52	913	1185	0	0	1185	62231	0	2396	64628
Jambi	790	0	49	839	1448	0	0	1448	63743	0	2536	66279
Sumatera Selatan	718	0	49	768	1531	0	0	1531	22315	0	982	23297
Bengkulu	1613	0	92	1705	1830	0	0	1830	26036	0	953	26989
Lampung	689	0	74	763	786	0	0	786	9825	0	677	10502
Bangka Belitung	890	0	56	945	3058	0	0	3058	38435	0	1534	39969
D.K.I. Jakarta												
Java Barat	766	0	57	823	614	0	0	614	27016	0	1292	28308
Java Tengah					1514	0	0	1514	36262	0	1332	37594
D.I. Yogyakarta					796	0	0	796	50340	0	2295	52635
Java Timur					628	0	0	628	20611	0	1041	21652
Banten	625	0	51	676	667	0	0	667	36679	0	1906	38585
Bali					1075	0	0	1075	21597	0	965	22563
Nusa Tenggara Barat					498	0	0	498	34639	0	1344	35983
Nusa Tenggara Timur					588	0	0	588	28440	0	2077	30518
Kalimantan Barat	1006	0	58	1064	938	0	0	938	47667	0	1761	49427
Kalimantan Tengah	2159	0	131	2290	1021	0	0	1021	41582	0	1619	43200
Kalimantan Selatan	1304	0	95	1399	1620	0	0	1620	36604	0	1703	38307
Kalimantan Timur	1886	0	119	2006	1994	0	0	1994	34458	0	1391	35849
Sulawesi Utara					1472	0	0	1472	28154	0	1087	29241
Sulawesi Tengah	818	0	64	882	346	0	0	346	9778	0	490	10268
Sulawesi Selatan	154	0	10	164	923	0	0	923	28318	0	1169	29487
Sulawesi Tenggara	280	0	21	301	348	0	0	348	31599	0	1509	33107
Gorontalo					590	0	0	590	20255	0	1044	21299
Maluku					14782	0	0	14782	83426	0	3770	87196
Maluku Utara					742	0	0	742	80446	0	3556	84001
Papua	1006	0	67	1073	3242	0	0	3242	29554	0	1251	30805

Province	Water footprint of crops [m^3/ton]			
	Cocoa			
	Green	Blue	Grey	Total
Nanggroe Aceh D.	10361	0	635	10996
Sumatera Utara	8242	0	426	8667
Sumatera Barat	13549	0	630	14179
Riau	13760	0	690	14450
Jambi	31248	0	1575	32823
Sumatera Selatan	19102	0	1045	20148
Bengkulu	37351	0	1735	39086
Lampung	6865	0	642	7507
Bangka Belitung	43712	0	2140	45852
D.K.I. Jakarta				
Java Barat	14816	0	877	15693
Java Tengah	23332	0	1103	24435
D.I. Yogyakarta	53938	0	3180	57117
Java Timur	11792	0	753	12545
Banten	19979	0	1360	21339
Bali	8015	0	456	8471
Nusa Tenggara Barat	20783	0	1039	21822
Nusa Tenggara Timur	15929	0	1503	17432
Kalimantan Barat	38608	0	1761	40370
Kalimantan Tengah	102634	0	5128	107762
Kalimantan Selatan	46711	0	2704	49414
Kalimantan Timur	11895	0	583	12478
Sulawesi Utara	21588	0	1051	22638
Sulawesi Tengah	6756	0	453	7209
Sulawesi Selatan	7418	0	399	7817
Sulawesi Tenggara	7975	0	508	8483
Gorontalo	13956	0	974	14930
Maluku	13255	0	765	14020
Maluku Utara	14244	0	824	15068
Papua	12227	0	633	12860

Appendix XIII. Gross virtual water flows between provinces

Importing province of virtual water [10^6 m^3/yr]	Exporting province of virtual water [10^6 m^3/yr]														
	Nanggroe Aceh D.	Sumatera Utara	Sumatera Barat	Riau	Jambi	Sumatera Selatan	Bengkulu	Lampung	Bangka Belitung	D.K.I. Jakarta	Java Barat	Java Tengah	D.I. Yogyakarta	Java Timur	Banten
Nanggroe Aceh D.		20	0	0	1	2	0	123	1	0	0	1	0	2	0
Sumatera Utara	5		0	0	3	9	0	117	3	0	1	11	8	7	0
Sumatera Barat	2	22		0	0	1	0	127	0	0	0	4	3	5	0
Riau	458	361	657		1	242	26	493	0	0	0	8	6	8	0
Jambi	39	43	55	0		17	0	107	0	0	0	4	2	4	0
Sumatera Selatan	20	47	13	148	30		0	192	0	0	0	9	6	10	0
Bengkulu	3	3	2	26	5	0		14	0	0	0	0	0	0	0
Lampung	3	0	0	0	1	2	0		1	0	0	6	5	5	0
Bangka Belitung	125	97	180	7	2	66	7	122		0	0	2	1	2	0
D.K.I. Jakarta	214	189	267	305	71	183	55	154	5		184	2164	93	978	2
Java Barat	215	292	158	894	215	428	195	190	17	0		512	178	960	3
Java Tengah	102	202	80	329	90	263	114	85	13	0	69		6	0	0
D.I. Yogyakarta	15	23	14	27	8	34	15	13	1	0	12	48		15	0
Java Timur	62	206	68	365	95	129	42	30	15	0	28	0	3		0
Banten	72	74	80	86	23	102	39	56	3	0	33	685	57	463	
Bali	12	27	17	35	9	14	3	6	2	0	0	0	0	0	0
Nusa Tenggara Barat	6	25	7	40	11	12	3	2	2	0	0	0	0	0	0
Nusa Tenggara Timur	38	48	55	39	10	26	3	23	2	0	0	0	0	0	0
Kalimantan Barat	2	1	1	0	0	7	4	19	0	0	0	16	6	32	0
Kalimantan Tengah	2	1	1	0	0	6	3	9	0	0	0	9	3	20	0
Kalimantan Selatan	5	2	2	0	1	16	8	30	0	0	0	10	2	26	0
Kalimantan Timur	0	0	0	0	0	0	0	17	0	0	0	13	4	28	0
Sulawesi Utara	1	5	1	8	2	2	1	23	0	0	0	2	1	1	0
Sulawesi Tengah	0	0	0	0	0	0	0	19	0	0	8	12	3	1	2
Sulawesi Selatan	0	0	0	0	0	0	0	11	0	0	24	34	8	1	7
Sulawesi Tenggara	0	0	0	0	0	0	0	0	0	0	9	13	3	0	3
Gorontalo	0	2	1	3	1	1	0	9	0	0	0	1	0	0	0
Maluku	42	30	59	1	0	25	4	28	0	0	0	4	1	10	0
Maluku Utara	21	15	31	0	0	12	2	14	0	0	1	5	1	8	0
Papua	66	57	96	24	6	34	2	60	1	0	2	11	3	20	0
Total	1531	1793	1844	2336	587	1633	527	2093	65	0	372	3587	403	2606	19

Importing province of virtual water [10^6 m^3/yr]	Exporting province of virtual water [10^6 m^3/yr]															
	Bali	Nusa Tenggara Barat	Nusa Tenggara Timur	Kalimantan Barat	Kalimantan Tengah	Kalimantan Selatan	Kalimantan Timur	Sulawesi Utara	Sulawesi Tengah	Sulawesi Selatan	Sulawesi Tenggara	Gorontalo	Maluku	Maluku Utara	Papua	Total
Nanggroe Aceh D.	0	0	2	0	0	0	0	1	0	3	0	1	0	0	114	271
Sumatera Utara	1	13	3	0	0	0	0	0	0	5	0	0	0	1	467	655
Sumatera Barat	0	5	2	0	0	0	0	1	0	5	0	1	0	0	125	304
Riau	1	8	4	0	0	0	0	1	0	8	0	1	0	0	185	2469
Jambi	0	4	2	0	0	0	0	1	0	4	0	0	0	0	100	381
Sumatera Selatan	1	9	4	0	0	0	0	2	0	9	0	1	0	0	176	679
Bengkulu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	106
Lampung	1	7	0	0	0	0	0	0	0	3	0	0	0	0	0	33
Bangka Belitung	0	2	1	0	0	0	0	0	0	2	0	0	0	0	44	659
D.K.I. Jakarta	26	11	27	49	44	244	21	119	135	1294	11	18	33	65	164	7124
Java Barat	75	27	71	156	142	45	63	308	153	240	30	45	84	167	4	5866
Java Tengah	19	3	18	82	75	24	28	31	16	65	4	4	8	16	165	1912
D.I. Yogyakarta	2	0	2	7	7	8	2	0	2	37	0	0	0	0	21	316
Java Timur	7	2	7	93	85	27	32	25	13	21	2	4	7	14	65	1447
Banten	8	1	7	18	17	66	7	18	29	349	2	3	5	10	7	2321
Bali		172	105	10	9	14	3	0	4	57	0	0	0	0	0	497
Nusa Tenggara Barat	23		227	11	10	3	4	0	0	0	0	0	0	0	0	384
Nusa Tenggara Timur	0	795		11	10	54	4	0	17	266	0	0	0	0	0	1400
Kalimantan Barat	1	6	25		0	54	5	14	0	46	1	9	4	1	44	298
Kalimantan Tengah	1	3	16	0		194	4	9	0	30	0	6	2	1	72	391
Kalimantan Selatan	1	1	24	0	0		10	12	0	41	0	8	5	2	83	291
Kalimantan Timur	0	4	22	0	15	591		12	0	38	0	8	4	2	60	819
Sulawesi Utara	0	1	3	2	2	1	1		39	373	5	0	5	2	59	537
Sulawesi Tengah	0	1	2	0	1	1	0	10		37	4	7	4	2	30	146
Sulawesi Selatan	0	2	2	0	4	3	0	0	0		2	0	2	1	177	279
Sulawesi Tenggara	0	1	0	0	2	1	0	0	26	407		0	0	0	38	503
Gorontalo	0	0	1	1	1	0	0	0	13	124	2		2	1	38	202
Maluku	1	0	8	0	0	61	0	5	20	339	0	3		14	0	656
Maluku Utara	0	1	6	0	0	32	0	4	11	180	0	2	0		0	347
Papua	1	2	17	6	5	99	2	12	34	541	1	7	5	3		1117
Total	170	1081	610	446	429	1524	184	585	511	4522	67	127	170	303	2286	32411

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