*Water, Sustainability and Agriculture Module*

Unit 2 > Activity 2.2b

**Analysis of Individual Water Footprints and Footprints of Nations**

Activity by Robert Turner – 2016

Summary

This document provides context, learning objectives, and guidance for Activity 2.2b – Analysis of Individual Water Footprints and Footprints of Nations. The handout to be distributed to the students follows the guidance. This Activity is designed to take place over 1.5 class periods where the class is assumed to last one hour.

Context

In lieu of a 20 minute Power Point overview, this activity is designed to enhance the critical thinking, numeracy, and communication skills of the students and help them develop a better understanding of the calculation and application of water footprints. It impresses upon them the great variability of national water footprints per person and how the water footprint of many regions exceeds the natural supply within their basin. Student analysis of water footprint data provides the basis for a discussion on whether water footprints should be more tightly controlled for the sake of international equity, ecosystem requirements, and long term water sustainability.

Learning Goals

Participation in Activity 2.2b is designed to help students advance in achievement of the following module learning goals:

1. Students will be able to explain how variability in water availability and current water use and management practices threaten ecological integrity, human health, security and agricultural production.
2. Students will be able to explain what goes into the calculation of virtual water amounts and water footprints and the application of these concepts.

Participation in Activity 2.2b will also help students advance in achievement of the following unit specific learning objectives:

* 1. Explain how water footprints are calculated and differentiate between internal and external water footprints.
  2. Differentiate between green, blue and grey water in water footprint analysis.

1. Interpret individual and national water footprint data and explain how water footprints relate to water scarcity, water degradation, and water-related equity and sustainability.
2. Demonstrate improved ability to analyze and evaluate complex quantitative information.
3. Demonstrate facility in working with student partners in equitable and inclusive collaboration.

Activity 2.2b Instructions for Instructors (~1.5 hours, 30 minutes at the end of class 1 and 1 hour during class 2)

A. To prepare for Activity 2.2b, students should have already completed Activity 2.2a, which consists of a reading and homework assignment. They should come to class with printed out results of their individual water footprint quizzes. They will be submitting those results for a grade as well as sharing them with each other in class.

B. Print out the following worksheet (pages 3 -14 in this document) for every student in class.

C. When you are ready to start this activity (after completing the virtual water debate), explain the goals and general progression of the activity to the students. Emphasize that they will be working in small groups to complete and submit one worksheet per group. Then break them up into groups of 4-5 and distribute the handout. Have them read the beginning of the handout and start the activity.

D. Part 1 of the activity should take approximately 15 minutes. When all groups have completed Part 1 of the activity, have a whole class discussion of the results for another 15 minutes.

E. Completion of Part 1 of the worksheet should take you to the end of the class. If it doesn’t, have them work through Part 2.

F. At the end of the first class period, have students submit their homework assignment.

G. At the beginning of class (or hour) 2, have the students reconvene in the same groups they were working in previously.

H. Get them started on Part 2 of the activity if they haven’t already worked through it. Part 2 should take approximately 5 minutes. Advise them to continue to Part 3 when they complete Part 2. Part 3 should take about 15 minutes. Advise students to take a break after completing Part 3.

I. While students are working on parts 2 and 3, circulate from group to group to make sure they get reasonable answers to the questions in these parts.

J. After the short break, have students work through Part 4. This should take about 10 minutes.

K. Have students continue through Part 5. This should take about 15 minutes.

L. Use the final 15 minutes of class to discuss student responses to Parts 4 and 5 of the activity. Make sure to leave time to address the last question that deals with whether we should establish some sort of maximum national per capita water footprint.

M. Collect the group worksheets.

A bibliography of references for Activity 2.2b can be found in the handout for the students.

**Group Work -** **Analysis of Individual Water Footprints and Footprints of Nations**

In preparation for this class you have been asked to read about water footprints and have calculated your individual water footprint in a few ways. This series of activities is designed to help you further assess how water footprints are calculated and why they matter.

Work through the series of activities and questions in your small group. The last page of this handout is an answer sheet to fill in. You will turn in your collective answers (one answer sheet per group) for credit. Your first task is to identify someone in your group who will fill out the sheet you will submit for the group. Then move on through the following activities.

**Part 1 – Sharing Individual Water Footprints**

Taking turns with everyone in your group, share with each other the water footprint quiz results you got for the homework assignment. Then address the following questions. Summarize your responses on the answer sheet provided.

1. How did your water footprints change by switching from the quick calculator to the extended calculator?
2. Each of you was asked to change some input into the extended calculator. What had the most influence on your water footprint?
3. Of the initial best estimates, what was the lowest individual water footprint among your group? What was the highest individual water footprint among your group?
4. What caused the differences in the high and low water footprints of your group?

When your group has completed Part 1, let the instructor know. When all groups have completed part 1, we will engage in an entire class discussion of the results. If you are done before the discussion, forge on to Part 2.

**Part 2 – Fundamentals of Water Footprints**

Come to a shared understanding on the following questions.

1. What is the difference between the Blue Water and Green Water components of water footprints?
2. What does the Grey Water component of water footprints represent?
3. What is the difference between the internal and external components of a national water footprint?

**Part 3 – Variability in National Water Footprints**

Review the following tables and figures and use them to answer the following questions.

1. What are the top 4 countries in terms of total water footprint in Mm3/yr (million cubic meters/year)? In other words, who uses the most water?

**Table 1: Selected Water Footprints of National Consumption per Country (Mm3/yr)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Period 1996 - 2005 | |  |  |  |  |  |  |  |
| Country |  | | | | | **Total** | Ratio external / total water footprint (%) |
| Internal WF | External WF | Total WF by Source | | | Int + Ext |
| All sources | All Sources | Green | Blue | Grey | All Shades |
| Bahamas | 61 | 592 | 475 | 51 | 127 | **653** | 90.6 |
| Belgium | 2,134 | 17,498 | 12,645 | 1,479 | 5,509 | **19,632** | 89.1 |
| Bermuda | 1 | 188 | 108 | 15 | 66 | **189** | 99.5 |
| Brazil | 322,574 | 32,799 | 316,326 | 12,342 | 26,706 | **355,374** | 9.2 |
| China | 1,231,579 | 136,425 | 894,705 | 150,011 | 323,287 | **1,368,004** | 10.0 |
| France | 55,879 | 50,253 | 80,443 | 8,036 | 17,653 | **106,132** | 47.3 |
| Germany | 36,593 | 80,558 | 86,518 | 6,993 | 23,641 | **117,151** | 68.8 |
| Iceland | 68 | 527 | 419 | 38 | 139 | **595** | 88.5 |
| India | 1,115,676 | 28,929 | 744,190 | 230,110 | 170,305 | **1,144,605** | 2.5 |
| Indonesia | 208,896 | 23,343 | 192,785 | 15,119 | 24,335 | **232,239** | 10.1 |
| Italy | 52,082 | 80,384 | 98,962 | 11,086 | 22,419 | **132,466** | 60.7 |
| Japan | 40,396 | 134,384 | 127,927 | 11,531 | 35,321 | **174,779** | 76.9 |
| Jordan | 1,181 | 7,136 | 6,140 | 1,235 | 941 | **8,316** | 85.8 |
| Korea, Republic | 16,578 | 59,092 | 59,686 | 5,170 | 10,813 | **75,670** | 78.1 |
| Mexico | 113,481 | 83,944 | 149,827 | 18,981 | 28,617 | **197,425** | 42.5 |
| Netherlands | 1,263 | 22,110 | 16,838 | 2,055 | 4,480 | **23,373** | 94.6 |
| Nigeria | 149,281 | 8,055 | 150,863 | 3,025 | 3,448 | **157,336** | 5.1 |
| Pakistan | 166,942 | 32,487 | 108,941 | 63,188 | 27,301 | **199,429** | 16.3 |
| Russian Federation | 236,989 | 33,502 | 226,265 | 13,872 | 30,354 | **270,490** | 12.4 |
| Saint Lucia | 21 | 224 | 189 | 19 | 37 | **246** | 91.3 |
| Spain | 57,350 | 43,170 | 73,600 | 13,116 | 13,803 | **100,520** | 42.9 |
| UK | 18,478 | 56,168 | 54,323 | 5,498 | 14,825 | **74,646** | 75.2 |
| USA | 655,061 | 166,292 | 568,763 | 69,024 | 183,566 | **821,354** | 20.2 |
| World | 6,676,713 | 1,848,351 | 6,249,537 | 943,325 | 1,332,202 | **8,525,064** | 21.7 |

After: Mekonnen, M.M. and Hoekstra, A.Y. (2011).

1. What are the top 4 countries in terms of grey water footprint? In other words, which countries are polluting the most water?
2. What are the top 4 countries in terms of external water footprint? In other words, who receives the most via imports and is exerting the greatest pressure on water resources of other nations?
3. What are the top 4 countries in terms of ratio of external water footprint to total water footprint? In other words, which countries are the most dependent on external sources for their water needs?

These gross numbers only tell part of the story. Naturally, the largest countries in terms of population (China and India) should be expected to have large water footprints. How does the picture change if we control for population size, emphasizing the influence of culture and economy? Check out Table 2.

**Table 2: Selected Per Capita Water Footprints of National Consumption per Country**

(Top 9 and Bottom 9 Countries with > 1 million citizens, plus World Average)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Period 1996 - 2005 | |  |  |  | |  | | |  | |  | | |  |  | | |  | |  |
| Rank by Total Per Capita WF | Country | Population in thousands (add 3 zeros) | **Per Capita Water Footprint Breakdown by Percent** | | | | | | | | | | **Per Capita WF Totals** (m3/yr/cap) | | | | | |
| agricultural | | industrial | | domestic | green | | blue | | grey | Internal | | | External | **Total WF** | |
| production | | production | | Consump. |  | |  | |  | all sources | | | all sources | all sources | |
| 1 | Mongolia | 2,409 | 97.9 | | 1.1 | | 1.0 | 93.4 | | 2.4 | | 3.2 | 1,444 | | | 2,331 | **3,775** | |
| 2 | Niger | 11,272 | 99.7 | | 0.0 | | 0.2 | 96.9 | | 2.5 | | 0.4 | 3,429 | | | 90 | **3,519** | |
| 3 | Bolivia | 8,409 | 99.2 | | 0.3 | | 0.5 | 96.9 | | 1.7 | | 0.9 | 3,141 | | | 327 | **3,468** | |
| 5 | United Arab Emirates | 3,330 | 84.3 | | 9.7 | | 5.9 | 61.3 | | 17.6 | | 15.2 | 761 | | | 2,375 | **3,136** | |
| 8 | USA | 288,958 | 84.3 | | 11.7 | | 3.9 | 69.2 | | 7.6 | | 19.2 | 2,267 | | | 575 | **2,842** | |
| 10 | Mauritania | 2,648 | 97.1 | | 0.6 | | 2.2 | 89.6 | | 6.4 | | 1.8 | 1,408 | | | 1,157 | **2,565** | |
| 12 | Portugal | 10,278 | 94.0 | | 3.2 | | 2.8 | 74.0 | | 14.1 | | 9.1 | 1,004 | | | 1,501 | **2,505** | |
| 13 | Spain | 40,841 | 93.7 | | 4.8 | | 1.5 | 73.2 | | 12.6 | | 12.7 | 1,404 | | | 1,057 | **2,461** | |
| 14 | Serbia and Montenegro | 10,730 | 61.8 | | 35.1 | | 3.0 | 55.7 | | 3.3 | | 37.9 | 2,211 | | | 179 | **2,390** | |
| 110 | World Avg. | 6,154,564 | 91.5 | | 4.7 | | 3.8 | 73.3 | | 10.6 | | 12.3 | 1,085 | | | 300 | **1,385** | |
| 166 | Nicaragua | 5,125 | 94.4 | | 1.5 | | 4.1 | 86.3 | | 5.1 | | 4.5 | 767 | | | 146 | **912** | |
| 167 | Yemen | 18,502 | 97.9 | | 0.5 | | 1.6 | 69.1 | | 24.0 | | 5.3 | 219 | | | 682 | **901** | |
| 168 | Korea, Dem People Rep | 22,867 | 81.4 | | 9.8 | | 8.8 | 71.3 | | 8.9 | | 11.0 | 762 | | | 126 | **888** | |
| 169 | Gambia | 1,325 | 98.8 | | 0.6 | | 0.6 | 88.9 | | 6.1 | | 4.5 | 556 | | | 331 | **887** | |
| 170 | Rwanda | 7,736 | 99.2 | | 0.3 | | 0.6 | 97.4 | | 1.0 | | 1.1 | 784 | | | 37 | **821** | |
| 171 | Congo, Republic | 3,096 | 98.5 | | 0.2 | | 1.3 | 88.8 | | 6.9 | | 3.0 | 525 | | | 261 | **786** | |
| 172 | Bangladesh | 141,967 | 95.9 | | 0.5 | | 3.7 | 74.9 | | 10.0 | | 11.4 | 635 | | | 134 | **769** | |
| 174 | Burundi | 6,652 | 98.5 | | 0.5 | | 1.0 | 96.1 | | 2.2 | | 0.7 | 702 | | | 16 | **719** | |
| 175 | Congo, Dem Republic | 52,053 | 99.2 | | 0.1 | | 0.7 | 97.8 | | 0.9 | | 0.6 | 536 | | | 16 | **552** | |

1. So the U.S.A. is third in the world in terms of total water footprint, and number 1 in terms of total *external* water footprint, but “only” 8th in the world in terms of per capita footprint. Still, it is clear that we enjoy a rather water intensive lifestyle. What are 3 reasons for countries to have a higher than average per capita water footprint?
2. Have a look at the per capita water footprint breakdown by percent in Table 2. Note the different ratios of water use for agricultural products vs. industrial products vs. domestic consumption. What are the ramifications of these different ratios?
   1. How does this constrain the opportunities for people in the bottom six countries vs. the United States?
   2. How does a high ratio of industrial use appear to influence the grey water component of the footprint?

A country like the Unites States is large, with quite a bit of regional variability in water use. Figure 1 below shows this variability in total water footprint via color intensity.



Figure 1. The global blue (top map) and grey (bottom map) water footprint of US citizens related to the consumption of crop and animal products (1996-2005). From Mekonnen and Hoekstra (2011).

1. Where within the United States is our water footprint most evident?
2. Where outside of the United States is *our* water footprint most evident?

Table 3 below shows the top contributing drainage basins to the U.S.A. water footprint. Note that this is just a partial list. The full list features river basins from around the world. Indeed, the river basin that contributes the 11th most water resources to our water footprint is the Yangtze River basin in China.

16. The Columbia River Basin provides the second most water resources to our national water footprint of any basin, but it is dwarfed by the Mississippi River Basin. What are 2 reasons that the Mississippi River Basin provides an order of magnitude more to our water footprint than does the Columbia?

**Table 3.** **The Water Footprint of U.S. Consumption of Agricultural and Industrial Products, Specified Per Basin (Mm3/yr)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Drainage\* | Related to Consumption of Agricultural and Industrial Products | | | |
| Green | Blue | Grey | Total |
| Mississippi | 19,9010 | 14,844 | 40,505 | 254,359 |
| Columbia | 13,154 | 8,545 | 8,736 | 30,435 |
| St.Lawrence | 14,637 | 2,219 | 14,526 | 31,382 |
| Nelson | 16,932 | 648 | 5,156 | 22,737 |
| Colorado | 3,098 | 1,220 | 1,526 | 5,844 |
| Bravo | 2,248 | 1,116 | 1,051 | 4,415 |
| Brazos | 7,331 | 1,110 | 1,049 | 9,489 |
| Sacramento | 2,217 | 3,989 | 2,077 | 8,282 |
| San Joaquin | 3,076 | 3,767 | 2,144 | 8,987 |
| Colorado | 3,203 | 615 | 510 | 4,328 |
| Yangtze (China) | 360 | 236 | 3,102 | 3,697 |
| Fraser | 40 | 34.8 | 220 | 294 |
| Skagit | 33 | 3 | 23 | 59 |

From Mekonnen and Hoekstra (2011).

As the United States is a large virtual water *exporter*, other nations exert their water footprints in our territory. See Figure 2 for an example of the geographic variability in (part of) the external water footprint of Japan on the United States.



Figure 2. Grey water footprint of Japan between 1996 and 2005. From Mekonnen and Hoekstra (2011).

17. Why do we tolerate this water resource use and pollution in the United States for the needs of foreign countries?

**Part 4 – The Watery Impacts of Diet**

As you learned by taking the individual water footprint quiz, your diet has a significant impact on your water footprint. Table 4 below shows the global average variability in the water footprints of various food products.

**Table 4.** **The Water Footprint of Selected Food Products from Vegetable and Animal Origin**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | Water footprint per unit of nutritional value | | |
|  | Water footprint per ton (m3/ton) | | | | Calorie | Protein | Fat |
|  | Green | Blue | Grey | Total | (litre/kcal) | (litre/g protein) | (litre/g fat) |
| Sugar crops | 130 | 52 | 15 | 197 | 0.69 | 0 | 0 |
| Vegetables | 194 | 43 | 85 | 322 | 1.34 | 26 | 154 |
| Starchy roots | 327 | 16 | 43 | 387 | 0.47 | 31 | 226 |
| Fruits | 726 | 147 | 89 | 962 | 2.09 | 180 | 348 |
| Cereals | 1,232 | 228 | 184 | 1,644 | 0.51 | 21 | 112 |
| Oil crops | 2,023 | 220 | 121 | 2,364 | 0.81 | 16 | 11 |
| Pulses | 3,180 | 141 | 734 | 4,055 | 1.19 | 19 | 180 |
| Nuts | 7,016 | 1,367 | 680 | 9,063 | 3.63 | 139 | 47 |
| Milk | 863 | 86 | 72 | 1,020 | 1.82 | 31 | 33 |
| Eggs | 2,592 | 244 | 429 | 3,265 | 2.29 | 29 | 33 |
| Chicken | 3,545 | 313 | 467 | 4,325 | 3 | 34 | 43 |
| Butter | 4,695 | 465 | 393 | 5,553 | 0.72 | 0 | 6.4 |
| Pig meat | 4,907 | 459 | 622 | 5,988 | 2.15 | 57 | 23 |
| Sheep/goat meat | 8,253 | 457 | 53 | 8,763 | 4.25 | 63 | 54 |
| Bovine meat | 14,414 | 550 | 451 | 15,415 | 10.19 | 112 | 153 |

From Mekonnen and Hoekstra (2010).

Looking at Table 4, it is clear that beef has the largest footprint by a long shot. Interestingly, it does not have the biggest grey water footprint, nor is it the least efficient in terms of water use to protein gain (though 3rd least efficient isn’t much to crow about).

18. Should the water footprints of foods be included on their labels (or available via a mobile ap)? Survey the group and come to consensus. If you give a collective no, why not? If you give a collective yes, what impact do you expect (or hope) it might have on consumers?

The next two figures compare the water footprints of beef raised in different countries.

Figure 3. Comparison of the total water footprint of beef products from selected countries. Based on data from Mekonnen and Hoekstra (2010)

Figure 4. Comparison of the grey water footprint of beef products from selected countries. Based on data from Mekonnen and Hoekstra (2010)

19. Looking at Figure 3, the U.S.A. appear to be most water efficient in raising beef when compared to some other countries and the global average. But how does that upbeat assessment change when you look at Figure 4? What is the problem here?

20. Looking below at Table 5, how much water in Liters/day can be saved per day by eating a vegetarian diet where you receive the same kcal/day as from a meat diet?

**Table 5. The Water Footprint of Two Different Diets in Industrialized Countries**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Item** | **Meat Diet** | | | **Vegetarian Diet3** | | |
| **Kcal/day1** | **L/kcal2** | **L/day** | **Kcal/day1** | **L/kcal2** | **L/day** |
| **Animal origin** | **950** | **2.5** | **2,375** | **300** | **2.5** | **750** |
| **Vegetable origin** | **2,450** | **0.5** | **1,225** | **3,100** | **0.5** | **1,550** |
| **Total** | **3,400** |  | **3,600** | **3,400** |  | **2,300** |

1 The numbers are taken equal to the actual daily caloric intake of people in the period from 1997 to 1999 (FAO, 2011).

2 For each food category, a rough estimate has been made by taking the weighted average of the water footprints (L/kg) of the various products in the food category (from Hoekstra and Chapagain, 2008) divided by their respective caloric values (kcal/kg).

3 This example assumes that the vegetarian diet still contains dairy products.

From Hoekstra, AY (2012).

**Part 5 – Water Footprint Insights Into Global Water Scarcity**

Hoekstra et al., (2012) conducted a month by month water footprint analysis of 405 river basins that

“collectively account for 69 percent of global runoff, 75 percent of world irrigated area, and 65 percent of world population.” Figure 5 below displays the results of their analysis for the Murray River Basin in Australia.



Figure 5. Water scarcity over the year for the Murray River Basin in Australia (average for the period 1996–2005). Net available water – that is natural runoff minus environmental flow requirement – is shown in in the bottom color below the dashed line. From October until May, the blue water footprint exceeds net available water; in these months, the presumptive environmental flow requirement is not met. Starting in September, when the blue water footprint moves above the dashed line, water scarcity progresses from moderate to significant to severe as the shading gets darker. From Hoekstra AY, Mekonnen MM, Chapagain AK, Mathews RE, and Richter BD (2012).

21. For how many months of the year are the environmental flow requirements not met in the Murray River Basin? What do you think are some of the consequences of this?

22. What do you think controls the large variation throughout the year in the blue water footprint?

Review the following table to get a sense of how widespread water scarcity is in the world.

**Table 6. Number of basins and number of people facing low, moderate, significant and severe water scarcity during a given number of months per year**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Number of basins facing low, moderate, significant and severe water scarcity during *n* months per year | | | | Number of people (millions) facing low, moderate, significant and severe water scarcity during *n* months of the year | | | |
| Number of months per year (*n*) | Low Water Scarcity | Moderate Water Scarcity | Significant Water Scarcity | Severe Water Scarcity | Low Water Scarcity | Moderate Water Scarcity | Significant Water Scarcity | Severe Water Scarcity |
| 0 | 17 | 319 | 344 | 204 | 353 | 2,690 | 2,600 | 1,289 |
| 1 | 2 | 55 | 45 | 46 | 18.6 | 894 | 357 | 440 |
| 2 | 1 | 26 | 12 | 49 | 0.002 | 302 | 672 | 512 |
| 3 | 4 | 4 | 2 | 33 | 80 | 69 | 220 | 182 |
| 4 | 6 | 1 | 1 | 22 | 35 | 0.14 | 9.2 | 345 |
| 5 | 18 | 0 | 1 | 16 | 897 | 0 | 97.8 | 706 |
| 6 | 9 | 0 | 0 | 10 | 111 | 0 | 0 | 26 |
| 7 | 17 | 0 | 0 | 4 | 144 | 0 | 0 | 88 |
| 8 | 29 | 0 | 0 | 4 | 293 | 0 | 0 | 254 |
| 9 | 29 | 0 | 0 | 3 | 66.8 | 0 | 0 | 20 |
| 10 | 52 | 0 | 0 | 0 | 428 | 0 | 0 | 0 |
| 11 | 39 | 0 | 0 | 2 | 296 | 0 | 0 | 1.8 |
| 12 | 182 | 0 | 0 | 12 | 1,233 | 0 | 0 | 93 |
| Total | 405 | 405 | 405 | 405 | 3,956 | 3,956 | 3,956 | 3,956 |

From Hoekstra AY, Mekonnen MM, Chapagain AK, Mathews RE, and Richter BD (2012).

Hoekstra et al., (2012) classify blue water scarcity values into four levels:

* **low blue water scarcity**: the blue water footprint is lower than 20% of natural runoff and does not exceed blue water availability; river runoff is unmodified or slightly modified; presumed environmental flow requirements are not violated.
* **moderate blue water scarcity**: the blue water footprint is between 20 and 30% of natural runoff; runoff is moderately modified; environmental flow requirements are not met.
* **significant blue water scarcity**: the blue water footprint is between 30 and 40% of natural runoff; runoff is significantly modified; environmental flow requirements are not met.
* **severe water scarcity**. The monthly blue water footprint exceeds 40% of natural runoff; runoff is seriously modified; environmental flow requirements are not met.

23. According to Table 6, how many river basins and how many people are experiencing severe blue water scarcity throughout the *entire* year?

Hoekstra et al., (2012) state: “In 223 river basins (55% of the basins studied) with 2.72 billion inhabitants (69% of the total population living in the basins included in this study), the blue water footprint exceeds blue water availability during at least one month of the year. For 201 of these basins, with 2.67 billion inhabitants, there was severe water scarcity during at least one month of the year. In 35 river basins with 483 million people, there was severe water scarcity for at least half of the year.”

According to Hoekstra (2011), “about one billion people do not have sustainable access to an improved water source, while others water their gardens, wash their cars, fill their swimming pools and enjoy the availability of water for many other luxury purposes. In addition, many people consume a lot of meat, which significantly enlarges their water footprint. The average meat consumption in the U.S. for instance is 120 kg/yr, more than three times the world average. The water used to produce the feed for the animals that provide the meat for the rich cannot be used for other purposes, for example, to fulfill more basic needs of people who cannot afford to pay. What is a sustainable water footprint, given the seven billion inhabitants of the earth and the fact that the total water availability in the world is limited?”

Hoekstra (2011) further states the following: “Fairness and sustainability in water use require the establishment of both minimum water rights and maximum levels of water use.” Hmmm… If one accepts that a just and compassionate civilization will recognize a human *right* to some minimum amount of water and food, does this then “translate into a moral obligation of communities that have abundant water resources at their disposal toward communities with severely limited resources?”

24. Do we have a moral obligation to eliminate starvation and water stress in far distant lands? If so, what are the best ways to address these problems and *should that include establishing a cap on the U.S.A.’s “reasonable share of the globe’s water resources?*” If you don’t think we have that moral obligation, what lets us off the hook? Provide a thoughtful paragraph in response to these questions.

**Bibliography of References for Activity 2.2b**

1. Hoekstra, AY (2011). The Global Dimension of Water Governance: Why the River Basin Approach Is No Longer Sufficient and Why Cooperative Action at Global Level Is Needed. *Water*, 3: 21-46. <http://www.waterfootprint.org/Reports/Hoekstra-2011-Global-Dimension-of-Water-Governance.pdf>
2. Hoekstra, AY (2012). The Hidden Water Resource Use Behind Meat and Dairy. *Animal Frontiers*, 2(2): 3-8. <http://www.waterfootprint.org/Reports/Hoekstra-2012-Water-Meat-Dairy.pdf>
3. Hoekstra, AY and Mekonnen, MM (2012). The Water Footprint of Humanity. *Proceedings of the National Academy of Sciences of the United States of America*, 109(9): 3232-3237. <http://www.waterfootprint.org/Reports/Hoekstra-Mekonnen-2012-WaterFootprint-of-Humanity.pdf>
4. Hoekstra AY, Mekonnen MM, Chapagain AK, Mathews RE, and Richter BD (2012). Global Monthly Water Scarcity: Blue Water Footprints versus Blue Water Availability. *PLoS ONE,* 7(2): e32688. <http://www.waterfootprint.org/Reports/Hoekstra-et-al-2012-GlobalMonthlyWaterScarcity.pdf>
5. Mekonnen, MM and Hoekstra, AY (2010). The green, blue and grey water footprint of farm animals and animal products. Value of Water Research Report Series No. 48, UNESCO-IHE, Delft, the Netherlands. <http://www.waterfootprint.org/Reports/Report-48-WaterFootprint-AnimalProducts-Vol1.pdf>
6. Mekonnen, MM and Hoekstra, AY (2011). 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. <http://www.waterfootprint.org/Reports/Report50-NationalWaterFootprints-Vol1.pdf>

**Answer Sheet for** **Analysis of Individual Water Footprints and Footprints of Nations**

Up to 10 points for a complete answer sheet

Student Names:

* 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. What influenced your water footprints? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Lowest: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Highest: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Blue vs. Green? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Grey?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  2. Internal vs. External? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Top 4 Water Footprints? \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_
  2. Top 4 Grey Water Footprints? \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_
  3. Top 4 External Water Footprints? \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_
  4. Highest external to total WF Ratios? \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_
  5. Why high per capita WF? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. a. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* 1. Where in the U.S? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  2. Where outside of the U.S? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  3. Misssissippi vs. Columbia? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Labeling? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Liters/day
  3. \_\_\_\_\_\_\_ months. Consequences? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* 1. Blue footprint variability? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  2. \_\_\_\_\_\_\_\_\_\_ river basins. \_\_\_\_\_\_\_\_\_\_\_\_\_\_ billion people.
  3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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