Water Management for Rice Production in Thailand based on the Concept of Water Footprint

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Background of Water Footprint

World population growth:

Trends in global water use by sector

Source: UNEP (2008)

The grey band represents the difference between the amount of water extracted and that actually consumed. Water may be extracted, used, recycled (or returned to rivers or aquifers) and reused several times over. Consumption is final use of water, after which it can no longer be reused. That extractions have increased at a much faster rate is an indication of how much more intensively we can now exploit water. Only a fraction of water extracted is lost through evaporation.

Drought
Water pollution
Introduction of Water Footprint

WF introduced by Prof. Hoekstra (U of Twente) Dec. 2002
**Water Footprint**: An indicator of freshwater use, which considers in both direct and indirect water use of a consumer or producer.

- It refers water volume used,
- where the WF is located
- what source of water is used
- when the water is used.
Components of Water Footprint

WF of a consumer or producer

Direct water footprint
- Green water footprint
- Blue water footprint
- Grey water footprint

Indirect water footprint
- Green water footprint
- Blue water footprint
- Grey water footprint

Water withdrawal
Return flow

Water consumption

Green WF: Volume of rainwater consumed during the production = CWU_{green} / Y

Blue WF: Volume of surface and groundwater consumed as a result of the production of a good or service = CWU_{blue} / Y

Grey WF: Volume of freshwater required to assimilate the load of pollutants = (\alpha AR) / (C_{max} - C_{nat}) / Y

[Hoekstra et al., 2011]
What advantages of Water footprint? A strong tool for WM

• Improvement of water management (WM) by:
  – decreasing water demand: water saving in HH
  – improving the efficiency of water use (water recycle)

• Concentrate more about water depletion or pollution through imported products (water used, leaching)

• Awareness raising, policy formulation

Source: Schreier et al., 2007, Hoekstra et al. 2011
Sorts of WF

**Product**
(ΣWF process steps)
Ex. Rice, wheat, meat

**Consumer**
(ΣWF all products consumed)
Ex. Individual

**Community**
(ΣWF its members)
Ex. Provinces of Indonesia

**Within a geographically delineated area**
(ΣWF all processes in the area)
Ex. Guadiana River basin (Spain)

**Business**
(ΣWF final products produced)
Ex. Coca-Cola, Nestle

**National consumption**
(ΣWF its inhabitans)
Ex. Netherlands, Spain, India
Water labels

Elovena Oat Flake
(Raisio, Finland)
May 2009

Steam shower
Water footprint of products

1000 litres water → 1 litre milk

15400 litres water → 1 kg beef
Water footprint of products

- 1600 litres water for 1 kg wheat bread
- 2500 litres water for 1 kg rice

Source: http://www.waterfootprint.org
Table 5: WF and percolation per unit of paddy rice produced (m³/ton) in the 13 major rice-producing countries during 2000-2004

<table>
<thead>
<tr>
<th>Country</th>
<th>Water footprint</th>
<th>Percolation</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green</td>
<td>Blue</td>
<td>Grey</td>
<td>Total</td>
<td>Rain water</td>
<td>Irrigation water</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>367</td>
<td>487</td>
<td>117</td>
<td>971</td>
<td>338</td>
<td>448</td>
<td>785</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>1077</td>
<td>826</td>
<td>116</td>
<td>2020</td>
<td>794</td>
<td>609</td>
<td>1403</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Indonesia</td>
<td>583</td>
<td>487</td>
<td>118</td>
<td>1187</td>
<td>505</td>
<td>422</td>
<td>927</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bangladesh</td>
<td>549</td>
<td>577</td>
<td>103</td>
<td>1228</td>
<td>550</td>
<td>578</td>
<td>1128</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viet Nam</td>
<td>308</td>
<td>203</td>
<td>127</td>
<td>638</td>
<td>420</td>
<td>277</td>
<td>697</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>942</td>
<td>559</td>
<td>116</td>
<td>1617</td>
<td>787</td>
<td>467</td>
<td>1253</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myanmar</td>
<td>846</td>
<td>378</td>
<td>50</td>
<td>1274</td>
<td>763</td>
<td>341</td>
<td>1103</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>341</td>
<td>401</td>
<td>61</td>
<td>802</td>
<td>348</td>
<td>409</td>
<td>757</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philippines</td>
<td>844</td>
<td>423</td>
<td>78</td>
<td>1345</td>
<td>775</td>
<td>388</td>
<td>1163</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>791</td>
<td>670</td>
<td>61</td>
<td>1521</td>
<td>691</td>
<td>585</td>
<td>1276</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>227</td>
<td>835</td>
<td>101</td>
<td>1163</td>
<td>141</td>
<td>517</td>
<td>658</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Korea, Rep.</td>
<td>356</td>
<td>388</td>
<td>84</td>
<td>829</td>
<td>303</td>
<td>331</td>
<td>634</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>421</td>
<td>2364</td>
<td>88</td>
<td>2874</td>
<td>248</td>
<td>1394</td>
<td>1642</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Chapagain et al. (2010b)
### Statistics for the 13 largest rice producing countries during 2000-2004

<table>
<thead>
<tr>
<th>Country</th>
<th>Average production (ton/yr)*</th>
<th>Global share (%)*</th>
<th>Average area harvested (ha/yr)*</th>
<th>Average yield (ton/ha)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>177,657,605</td>
<td>30.0%</td>
<td>28,670,030</td>
<td>6.19</td>
</tr>
<tr>
<td>India</td>
<td>126,503,280</td>
<td>21.4%</td>
<td>43,057,460</td>
<td>2.93</td>
</tr>
<tr>
<td>Indonesia</td>
<td>52,014,913</td>
<td>8.8%</td>
<td>11,642,899</td>
<td>4.47</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>37,217,379</td>
<td>6.3%</td>
<td>10,641,271</td>
<td>3.50</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>33,960,560</td>
<td>5.7%</td>
<td>7,512,160</td>
<td>4.52</td>
</tr>
<tr>
<td>Thailand</td>
<td>26,800,046</td>
<td>4.5%</td>
<td>10,038,180</td>
<td>2.67</td>
</tr>
<tr>
<td>Myanmar</td>
<td>22,581,828</td>
<td>3.8%</td>
<td>6,431,364</td>
<td>3.51</td>
</tr>
<tr>
<td>Philippines</td>
<td>13,322,327</td>
<td>2.3%</td>
<td>4,056,577</td>
<td>3.28</td>
</tr>
<tr>
<td>Brazil</td>
<td>11,068,502</td>
<td>1.9%</td>
<td>3,371,562</td>
<td>3.28</td>
</tr>
<tr>
<td>Japan</td>
<td>10,989,200</td>
<td>1.9%</td>
<td>1,706,000</td>
<td>6.44</td>
</tr>
<tr>
<td>USA</td>
<td>9,520,015</td>
<td>1.6%</td>
<td>1,285,671</td>
<td>7.40</td>
</tr>
<tr>
<td>Pakistan</td>
<td>6,910,650</td>
<td>1.2%</td>
<td>2,339,200</td>
<td>2.95</td>
</tr>
<tr>
<td>Korea, Rep.</td>
<td>6,808,450</td>
<td>1.2%</td>
<td>1,045,173</td>
<td>6.51</td>
</tr>
<tr>
<td><strong>Sub total</strong></td>
<td><strong>535,354,755</strong></td>
<td><strong>90.5%</strong></td>
<td><strong>131,797,547</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Global total</strong></td>
<td><strong>591,751,209</strong></td>
<td><strong>100%</strong></td>
<td><strong>150,666,851</strong></td>
<td><strong>4.49</strong></td>
</tr>
</tbody>
</table>

* Source: FAO (2009).
** Average fertilizer use in rice cultivation. Source: IFA et al. (2002).
### Top-15 of countries with the largest WF of rice consumption during 2000-2004

<table>
<thead>
<tr>
<th>Country</th>
<th>Total water footprint (Mm³/yr)</th>
<th>Water footprint per capita (m³/cap/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green</td>
<td>Blue</td>
</tr>
<tr>
<td>India</td>
<td>133,494</td>
<td>102,425</td>
</tr>
<tr>
<td>China</td>
<td>65,154</td>
<td>86,050</td>
</tr>
<tr>
<td>Indonesia</td>
<td>31,097</td>
<td>26,005</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>20,560</td>
<td>21,574</td>
</tr>
<tr>
<td>Thailand</td>
<td>19,640</td>
<td>11,654</td>
</tr>
<tr>
<td>Myanmar</td>
<td>18,989</td>
<td>8,483</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>9,860</td>
<td>6,496</td>
</tr>
<tr>
<td>Philippines</td>
<td>11,736</td>
<td>6,020</td>
</tr>
<tr>
<td>Brazil</td>
<td>9,186</td>
<td>7,869</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2,480</td>
<td>13,935</td>
</tr>
<tr>
<td>Japan</td>
<td>4,084</td>
<td>4,923</td>
</tr>
<tr>
<td>USA</td>
<td>1,924</td>
<td>5,779</td>
</tr>
<tr>
<td>Egypt</td>
<td>3,467</td>
<td>3,203</td>
</tr>
<tr>
<td>Nigeria</td>
<td>3,478</td>
<td>3,005</td>
</tr>
<tr>
<td>Korea, R</td>
<td>2,491</td>
<td>2,732</td>
</tr>
</tbody>
</table>

Source: Chapagain et al. (2010b)
National water loss related to the net rice export of Thailand (1997–2001)

Water loss from rice export = -27,766 MCM/yr

Bhumiphol Dam
Storage capacity = 13,462 x 2 = 26,924 MCM

Source: Chapagain et al. (2006)
Options to reduce WF
Measure to reduce WF

- **Options for crop farmers to reduce their WF**
  - Reduce Green WF in crop growths
    - Increase land productivity (yield, kg/rai) by improving agricultural practice
    - Mulching of the soil (for reducing evaporation from soil surface)

Rice seeding transplanting in the black film and paper mulching treatment (Suwon, Korea)
Measure to reduce WF

- Reduce Blue WF in crop growths
  - Shift to an irrigation technique with lower evaporation loss e.g. pipe system, micro irrigation
  - Improve the irrigation schedule by optimizing timing and volumes of application

Water-Less Rice
Measure to reduce WF

– Reduce Grey WF in crop growths
  • Apply less or no chemicals (artificial fertilizers, pesticides) e.g. Organic farming
  • Apply fertilizers or compost in form that allows easy uptake (Need less leaching & runoff): ปัญหาด้าน
    ชีวภาพ
  • Optimize the timing and technique of adding chemicals (Need less leaching & runoff)
Measure to reduce WF

- Options for Gov. to reduce WF (national agri. policy)
  - Include the goal of sustainable use of available domestic WR in formulating national food security policy
  - Support investments in Irg. Systems & techniques that conserve water: Pipe system, Micro irrigation
  - Promote farmers to reduce the use of chemical fertilizers, pesticides, & insecticides
  - Promote WF reduction in Agri. e.g. awareness raising, subsidies for Irg. Techniques.

Source: Hoekstra et al. (2011)
Vacancy Postdoc Water Footprint

The University of Twente, in the Netherlands, is looking for a new postdoc to strengthen their water footprint research team. Deadline for application: June 30. Read more.

Direct and indirect use

People use lots of water for drinking, cooking and washing, but even more for producing things such as food, paper, cotton clothes, etc. The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.

International leaders support the Global Water Footprint Standard

The Global Water Footprint Standard has been developed through a joint effort of the Water Footprint Network, its 130 partners, and scientists from the University of Twente in the Netherlands. The standard has gained international support from major companies and organizations that recognize the importance of understanding water use and its impact on water resources.

The Global Water Footprint Standard is available in several languages and offers guidance on the use of water footprint data to support decision-making processes.

Download the manual

The Global Water Footprint Standard is contained in the Water Footprint Assessment Manual.
References

Chapagain et al. (2006). Water saving through international trade of agricultural products
Chapagain, A.K., & Hoekstra, A.Y. (2010b). The green, blue and grey water footprint of rice from both a production and consumption perspective: Value of water research report series no.40. UNESCO-IHE
Jeon WT, et al. (2011) Effects of green manure crops and mulching technology on reduction in herbicide and fertilizer use during rice cultivation in Korea
Thank you for your attention!
For Q&A
Terminology

- Water footprint – The water footprint is an indicator of freshwater use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. Water use is measured in terms of water volumes consumed (evaporated) and/or polluted per unit of time. A water footprint can be calculated for a particular product, for any well-defined group of consumers (e.g. an individual, family, village, city, province, state or nation) or producers (e.g. a public organization, private enterprise or economic sector). The water footprint is a geographically explicit indicator, not only showing volumes of water use and pollution, but also the locations.
Direct WF of a consumer or producer: The freshwater consumption and pollution that is associated to the water use by the consumer or producer. It is distinct from the indirect water footprint, which refers to the water consumption and pollution that can be associated with the production of the goods and services consumed by the consumer or the inputs used by the producer.

Indirect WF of a consumer or producer: The freshwater consumption and pollution ‘behind’ products being consumed or produced. It is equal to the sum of the water footprints of all products consumed by the consumer or of all (non-water) inputs used by the Producer.
Virtual-water content – The virtual-water content of a product is the freshwater ‘embodied’ in the product, not in real sense, but in virtual sense. It refers to the volume of water consumed or polluted for producing the product, measured over its full production chain. If a nation exports/imports such a product, it exports/imports water in virtual form. The ‘virtual-water content of a product’ is the same as ‘the water footprint of a product’, but the former refers to the water volume embodied in the product alone, while the latter term refers to that volume, but also to which sort of water is being used and to when and where that water is being used. The water footprint of a product is thus a multidimensional indicator, whereas virtual-water content refers to a volume alone.
WF of national consumption

Fig. 1 The relation between the water footprint of national consumption and the water footprint within a nation in a simplified example for two trading nations
Source: Hoekstra et al. (2009)
Virtual water trade of Rice
Total water consumption of Elovena Oat Flakes

"From field to an end product"

OATS CULTIVATION
- Rainfall
- Evaporation

PROCESSING
- Use of water in processing
- Steaming
- Energy

PACKAGING MATERIALS
- Use of water in manufacturing of the packaging materials

99.3%
Map 2.1  
**Expected areas of population growth and decline, 2000-2080**

Ratio of population 2080/2000

- **Increase**
  - 1.00-1.24
  - 1.25-1.49
  - 1.50-1.74
  - 1.75-1.99
  - 2.0-2.99
  - 3.0-5.8
- **Decrease**
  - 0.5-0.7
  - 0.8-1.0
  - No data

*Source: Lutz, Sanderson, and Scherbov 2008.*
Virtual Water – A World View of Sustainability

James J. Pescatore, P.E., BCEE

NEWWA Annual Conference
September 19, 2009

Water vs. Virtual Water

• Direct Water Use
  – Drinking, Washing, Flushing
    Toilets, Watering Lawns

• Indirect "Virtual" Water Use
  – Irrigating crops,
  – Watering livestock
  – Water used in the Production
    of Leather, Paper, Cotton,
    Manufactured Goods etc.
• **Ecological Footprint** (Wackernagel & Rees, 1996)
  Def.: human pressure on the planet in terms of the aggregate demand that resource-consumption and CO₂ emissions places on ecological assets.

• **Water Footprint** (Hoekstra, 2002)
  Def.: human appropriation of natural capital in terms of the total freshwater volume required (blue, green, grey) for human consumption.

• **Carbon Footprint** (multiple authors, ~2000 / 2008)
  Def.: human pressure on the planet in terms of the total GHG emissions (associated with an activity or accumulated over the life stages of a product) and human contribution to climate change.
<table>
<thead>
<tr>
<th>ECOLOGICAL FOOTPRINT</th>
<th>CARBON FOOTPRINT</th>
<th>WATER FOOTPRINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Temporally explicit and multi-dimensional indicator that can be applied to single products, cities, regions, nations and the whole biosphere.</td>
<td>• Multi-dimensional indicator that can be applied to products, processes, companies, industry sectors, individuals, governments, populations, etc.</td>
<td>• Geographically explicit and multi-dimensional indicator: calculated for products, organizations, sectors, individuals, cities and nations.</td>
</tr>
<tr>
<td>• More than 200 countries for the period 1961-2007 are tracked (Ewing et al., 2010).</td>
<td>• 73 nations and 14 regions for the year 2001 only are tracked (Hertwich and Peters, 2009).</td>
<td>• 140 nations for the period 1997-2001 (Chapagain and Hoekstra, 2004).</td>
</tr>
<tr>
<td>• It has a consumption-based point of view and thus considers trade.</td>
<td>• It has a consumption-based point of view and thus considers trade.</td>
<td>• It has a consumption-based approach and considers trade.</td>
</tr>
</tbody>
</table>
Table 10 Options for crop farmers to reduce their water footprint

<table>
<thead>
<tr>
<th>Reduce green water footprint in crop growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Increase land productivity (yield, ton/ha) in rain-fed agriculture by improving agricultural practice; since the rain on the field remains the same, water productivity (ton/m^3) will increase and the green water footprint (m^3/ton) will reduce.</td>
</tr>
<tr>
<td>• Mulching of the soil, thus reducing evaporation from the soil surface</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reduce blue water footprint in crop growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Shift to an irrigation technique with lower evaporation loss.</td>
</tr>
<tr>
<td>• Choose another crop or crop variety that better fits the regional climate, so needs less irrigation water.</td>
</tr>
<tr>
<td>• Increase blue water productivity (ton/m^3) instead of maximizing land productivity (yield, ton/ha)</td>
</tr>
<tr>
<td>• Improve the irrigation schedule by optimizing timing and volumes of application.</td>
</tr>
<tr>
<td>• Irrigate less (deficit irrigation or supplementary irrigation) or not at all.</td>
</tr>
<tr>
<td>• Reduce evaporation losses from water storage in reservoirs and from the water distribution systems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reduce grey water footprint in crop growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Apply less or no chemicals (artificial fertilizers, pesticides), for example, organic farming.</td>
</tr>
<tr>
<td>• Apply fertilizers or compost in a form that allows easy uptake, so that leaching and run-off are reduced.</td>
</tr>
<tr>
<td>• Optimize the timing and technique of adding chemicals, so that less is needed and/or less leaches or runs off.</td>
</tr>
</tbody>
</table>

Source: Hoekstra et al. (2011)
Table 11 Options for governments to reduce water footprints relevant to national agricultural policy

- Include the goal of sustainable use of available domestic water resources in formulating national food security policy.
- Do not subsidize water-intensive agriculture in water-scarce areas.
- Promote crops that are suitable and adapted to the local climate in order to reduce irrigation demand.
- Support investments in irrigation systems and techniques that conserve water.
- Promote farmers to avoid or reduce the use of fertilizers, pesticides and insecticides or better apply so that less chemicals reach the water system.
- Promote water footprint reduction in agriculture – see Table 10. This can be done in various alternative or complementary ways: regulation or legislation (for example, on license, quota, full-cost water pricing, tradable water use permits, subsidies for specific irrigation techniques, compulsory water metering, awareness-raising).

Source: Hoekstra et al. (2011)