Incorporating the Water Footprint and Environmental Water Requirements into policy: Reflections from Doñana National Park (Spain)

IV Botín Foundation Water Workshop
Re-thinking water and food security paradigms
Santander, 22-24 September 2009

Maite M. Aldaya

Water Observatory – Marcelino Botín Foundation
University of Twente – the Netherlands – Water Footprint Network
Overview presentation

1. EWR: Theory and definitions
2. EWR: Doñana National Park
3. Concluding remarks
1

EWR

Theory and definitions
Environmental flow

water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits (Dyson et al., 2003).

Environmental flow (or water) requirement

the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems (The Brisbane Declaration, 2007).
# EWR: Theory and definitions

## EWR assessment methods

<table>
<thead>
<tr>
<th>Description</th>
<th>Duration of assessment (months)</th>
<th>Major advantages</th>
<th>Major disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrological Index</td>
<td>½</td>
<td>Low cost, rapid to use</td>
<td>Not site-specific, ecological links assumed</td>
</tr>
</tbody>
</table>

- Based on historical flow records
- EFR a percentage of average annual flow or percentile from the low duration curve on an annual, seasonal or monthly basis
- Minimum flow requirement

| Hydraulic rating | 2-4  | Low cost, site specific  | Ecological links assumed |

- Based on historical flow records
- Assume hydraulics (wetted perimeter, depth, velocity) - habitat availability links
- Optimal minimum flow
- Absorbed within Habitat simulation or Holistic methods

| Habitat simulation | 6-18  | Ecological links included  | Extensive data collection and use of experts, high cost |

- Based on hydrological, hydraulic and biological response data
- Model links between discharge, habitat conditions and their suitability to target biota

| Holistic | 12-36  | Covers most aspects  | Requires very large scientific expertise, very high cost, (not operational) |

- Based on hydrological, hydraulic and habitat simulation models.

Source: based on Korsgaard, 2006
EWR: Theory and definitions

Global assessment Smakhtin et al. (2004)

\[ \text{EWR} = \text{LFR} + \text{HFR} \]

**Low flow requirement (LFR)**

LFR = Q90 (monthly flow that is exceeded 90% of the time)
Q90 mostly falls between 0 and 50% of mean annual runoff (MAR)

**High flow requirement (HFR)**

<table>
<thead>
<tr>
<th>Highly variable flow regimes</th>
<th>Q90 &lt; 10% MAR</th>
<th>HFR = 20% MAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% MAR &lt; Q90 &lt; 20% MAR</td>
<td>HFR = 15% MAR</td>
<td></td>
</tr>
<tr>
<td>20% MAR &lt; Q90 &lt; 30% MAR</td>
<td>HFR = 7% MAR</td>
<td></td>
</tr>
</tbody>
</table>

| Very stable flow regimes    | 30% MAR < Q90 | HFR = 0       |

*Source: Smakhtin et al. (2004)*
EWR: Theory and definitions

Source: Smakhtin et al. (2004)
Water scarcity taking EWR into account

the proportion of water withdrawal with respect to water available to human use. Water available to human use is equal to the total amount of water available in the basin minus the estimated environmental water demand (the water needed by the ecosystem to sustain its integrity) (Smakhtin et al., 2004).
EWR: Theory and definitions

Water scarcity: The Traditional View

Human Water Stress by River Basins
Water Use as a Proportion of Total Water Availability

Source: Smakhtin et al. (2003)
EWR: Theory and definitions

Water scarcity: Taking Environmental Water Requirements into Account

Human infringement on Environmental Water Demand
Water Withdrawal as a Proportion of Water Available for Human Use

Source: Smakhtin et al. (2004)
### Proportions between blue and green water use worldwide

<table>
<thead>
<tr>
<th>Flow domain</th>
<th>System</th>
<th>Annual freshwater withdrawals/use (km³/yr)</th>
<th>% of rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct blue</td>
<td>Food</td>
<td>1800</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Domestic + industry</td>
<td>1300</td>
<td>1</td>
</tr>
<tr>
<td>Indirect blue</td>
<td>Instream ecology</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>remaining time-stable runoff</td>
<td>9400</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>flood runoff</td>
<td>30150</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td><strong>subtotal blue flow</strong></td>
<td><strong>42650</strong></td>
<td><strong>38</strong></td>
</tr>
<tr>
<td>Direct green</td>
<td>Food</td>
<td>5000</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Permanent grazing</td>
<td>20400</td>
<td>18</td>
</tr>
<tr>
<td>Indirect green</td>
<td>Grasslands</td>
<td>12100</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Forests and woodlands</td>
<td>19700</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Arid lands</td>
<td>5700</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Wetlands</td>
<td>1400</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Lake evaporation</td>
<td>600</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Evaporation from reservoirs</td>
<td>160</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Green ares in urban settlements</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Unaccounted green flow</td>
<td>5690</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td><strong>subtotal green flow</strong></td>
<td><strong>70850</strong></td>
<td><strong>62</strong></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td><strong>113500</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*Source: Falkenmark and Rockström (2004)*
2
EWR
Doñana National Park
EWR: Doñana National Park

Doñana and Guadalquivir basin (Spain)

- Mediterranean climate (oceanic influence)
- Average annual rainfall 560 mm
- Mean annual temperature 17ºC
- Potential evapotranspiration 900 mm/yr
- National Park: 54,250 ha (World Heritage Site, UNESCO Biosphere reserve, Ramsar)
- Natural Park: 53,800 ha (protected buffer)

Source: CHG (2009)
Blue water footprint of crop production by river basin (2006)

Blue water apparent productivity (GVA/m³)(2002)

Source: Garrido et al. (2009)

Source: based on data from the Spanish Ministry for the Environment
Virtual Water ‘exports’ by River Basin (2006)

Source: Garrido et al. (2009)
EWR: Doñana National Park

Traditional water scarcity

Water stress (withdrawal-to-availability)

- < 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1.0
- > 1.0

Source: Alcamo et al. (2003)

Water scarcity taking EWR into account

WSI

- < 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- > 1

Source: Smakhtin et al. (2003)
EWR: Doñana National Park

Doñana ecosystems

Source: Montes and Borja (in press)
Surface and groundwater components in Doñana

Source: Custodio et al. (2006)
EWR: Doñana National Park

Land uses in Doñana
## Water Footprint and Environmental Flows (Mm³/year)

<table>
<thead>
<tr>
<th>DOÑANA NATIONAL AND NATURAL PARK</th>
<th>Green</th>
<th>Blue</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>surface</td>
<td>ground</td>
</tr>
<tr>
<td>Agricultural WF¹</td>
<td>13</td>
<td>21</td>
<td>116</td>
<td>150</td>
</tr>
<tr>
<td>Urban and industrial WF²</td>
<td></td>
<td>14</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Environmental Flows³</td>
<td>68</td>
<td>116</td>
<td>38</td>
<td>222</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>137</td>
<td>168</td>
<td>386</td>
</tr>
</tbody>
</table>

Environmental water requirements⁴: 80-200

---

1 Source: CHG (2009), Rodríguez et al. (2009), Andalusian Regional Government (1999)
2 Source: CHG (2008)
3 Source: Andalusian Regional Government, 2002
4 Source: WWF (2009)
Agricultural land use – Doñana and surroundings
EWR: Doñana National Park

Agricultural land use – Doñana and surroundings

Source: Custodio et al. (2006)
EWR: Doñana National Park

Green and blue WF of agriculture in Doñana (average rainfall year)

Source: CHG (2009), Rodríguez et al. (2009)
Total water consumption and water apparent productivity in the lower Guadalquivir basin

Source: Rodriguez et al. (in press)
Green and blue WF of agriculture and forests in Doñana (average rainfall year)

Source: Own elaboration, CHG (2009), Rodríguez et al. (2009), Andalusian Regional Government (1999)
Green and blue WF of agriculture and forests in Doñana (average rainfall year)
Eucalyptus plantations 1950-2000

Source: Own elaboration, CHG (2009), Rodríguez et al. (2009), Andalusian Regional Government (1999), CSIC (2009)
Groundwater dependent wetlands

Source: García Novo and Marín Cabrera (2006)
EWR: Doñana National Park

Water inflow from upstream

Rainfall

Ground water

Urban, Industry WF 14 Mm$^3$

Agricultural WF 137 Mm$^3$

Environmental flow 154 Mm$^3$

Environmental flow requirements 200 Mm$^3$

Utilizable water 105 Mm$^3$

Utilizable water 225 Mm$^3$

Environmental flow requirements 80 Mm$^3$

Water available for human use = total EF – EWR

Actual

Theoretical

AVERAGE YEAR

DRY YEAR

Total water available
Concluding remarks
Doñana

- Achieve a more compatible agricultural production with the protection of ecosystems (groundwater wetland conservation)
- Need for integrated water resources management, including surface and groundwater and green water.
- Considering the interlinkages between EFR and land-use changes e.g. wetlands close to the aquifer discharge areas are vulnerable to the effect of water table level fluctuations produced by the intensive groundwater abstraction (agriculture and forest plantations).
- Long-term land and water planning
- EF and WF analyses provide transparent information to take water allocation decisions
EFR Challenges

- Need of an agreed definition of EFR and WS
- Incorporating the whole water cycle (surface, groundwater, and estuaries) into the assessments
- Applying EFR to large-scale land-use changes that intercept and exacerbate overland flows
- Integrating EFR and WF into river basin management plans to inform water allocation decisions
- Developing methods for systematically linking biophysical and socioeconomic impacts
- Incorporating water quality aspects – Grey WF
Thank you