Water Footprint in High Plains Agriculture

Science by the Glass, Climate Science Center - May 9, 2017

Chuck West
CASNR Water Center
Plant & Soil Science Department
Texas Alliance for Water Conservation

Water use data from 30 farms, 12 years

Annual decline of 3%-points, or ~50 cm.
Irrigation methods

- Sprinkler
- Sub-surface Drip
- Furrow
- Dryland
Comments about Water Use Efficiency vs. Water Footprint

\[
\text{WUE} = \text{yield/water input} \\
\text{ROI} \text{ or ‘Bang for the Buck’}
\]

\[
\text{WF} = 1/\text{WUE} \quad \text{water use/yield}
\]

Impact of using a nonrenewable resource for producing a low-value product because the economy depends on stretching the water supply.

Point: WUE of rain < that from irrigation.
Eddie Teeter Farm
Corn with subsurface drip

- **Yield = 15 t/ha** (240 bu/acre)
- **Water supply = 760 mm** (30 in.)
  - Rain: 330 mm (13 in.)
  - Irrigation: 430 mm (17 in.)
- **WUE = 2 kg/m^3**
- **WF = 0.5 m^3/kg**
Technology comparison and demonstration

Spray  PMDI  LEPA
### Comparison of LEPA vs. LESA - 3 years

<table>
<thead>
<tr>
<th></th>
<th>SPRAY</th>
<th>LEPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton lint yield, kg/ha</td>
<td>1046</td>
<td>1200</td>
</tr>
<tr>
<td>Total costs, $/ha</td>
<td>2314</td>
<td>2366</td>
</tr>
<tr>
<td>Net returns, $/ha</td>
<td>141</td>
<td>447</td>
</tr>
<tr>
<td>Water applied, mm</td>
<td>495</td>
<td>495</td>
</tr>
<tr>
<td>WUE, kg/m$^3$</td>
<td>0.21</td>
<td>0.24</td>
</tr>
<tr>
<td>Water footprint, m$^3$/kg</td>
<td>4.7</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Yates & Pate. 2014. Cotton Beltwide
Why forages and cattle?

- Native ecosystem is grassland.
- Perennials provide year-round ground cover, wildlife habitat, C sequestration, diversity.
- Beef cattle and hay are high-value commodities.
- Require modest water inputs.

**Hypothesis**: Forages/livestock production provides profitable means of transitioning to low water-input and dryland agriculture in the Texas High Plains.
Is it possible to strategically integrate high-quality legumes *without* increasing the water footprint?
Species comparison for water footprint

$\text{m}^3$ water used / kg biomass

kg transpiration / kg biomass yield

<table>
<thead>
<tr>
<th>Forage species</th>
<th>Water footprint</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg transpired/kg biomass</td>
</tr>
<tr>
<td>Corn</td>
<td>370</td>
</tr>
<tr>
<td>Wheat</td>
<td>500</td>
</tr>
<tr>
<td>Bermudagrass</td>
<td>265</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>770</td>
</tr>
</tbody>
</table>
## Beef Stocker Treatments

<table>
<thead>
<tr>
<th>Forage system</th>
<th>N fertilizer kg/ha</th>
<th>Avg irrigation mm/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass only</td>
<td>67</td>
<td>207</td>
</tr>
<tr>
<td>Grass-alfalfa</td>
<td>0</td>
<td>223</td>
</tr>
</tbody>
</table>

Lisa Baxter, PhD student
Grass-only grazing rotation
(12 head on 8.3 ha)

Dryland Native – 4.5 ha

Dryland Teff – 1.7 ha

OWB – 2.1 ha
GL grazing rotation (8 head on 4.1 ha)

Native – 0.9 ha

OWB-Legume – 2.1 ha

Teff – 0.2 ha

Alfalfa-tall wheatgrass – 0.9 ha
Literature values of WF for beef (m³/kg)

1. Life cycle in CA: 3.7
2. Life cycle in Southern Plains: 3.1
3. Global average: 15
4. Pasture-fed beef (U.S.): 22
5. Western feedlot: 4
Water Footprint Calculations

• Water footprint = \( m^3 \) water delivery / \( \text{kg} \) LWG

- \((\text{Effective rainfall} + \text{corrected irrigation}) \) / \text{observed LWG}
- \((\text{Effective rainfall} + \text{total irrigation}) \) / \text{total LWG}

This included gain predicted from feeding back the harvested hay.

- \( \text{Total irrigation} + \text{drinking water} \) / \text{total LWG}
Trials #1 and 2: Comparison of Observed LWG per ha

Bars represent SE mean.

LWG ha\(^{-1}\) (kg ha\(^{-1}\))

- Year 1
  - Grass-only
  - Grass-legume

- Year 2
  - Grass-only
  - Grass-legume

- Year 3
  - Grass-only
  - Grass-legume

Grass-only: n = 3; \( P < 0.001 \)
Water footprint in $m^3/kg$ beef gain

<table>
<thead>
<tr>
<th>Water inputs</th>
<th>Grass-only</th>
<th>Grass + legume</th>
<th>Δ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective rain + irrig + drinking</td>
<td>33</td>
<td>22</td>
<td>-34 %</td>
</tr>
<tr>
<td>Irrigation + drinking</td>
<td>3.3</td>
<td>2.4</td>
<td>-27 %</td>
</tr>
</tbody>
</table>

Why? Legume presence required slightly more irrigation, but it increased animal gain 60% over grass alone. Twice the protein content, more digestible energy.
Alfalfa uses more water per kg of forage, but leverages two major attributes:

1. Much higher nutritive quality
2. Fixes N via symbiosis, so C and GHG footprints are also lower.
Trials #1 and 2: Conclusions

- Inclusion of legumes increased beef stocker gain per ha
- Grass-Legume system did not require more water

→ Legumes reduced water footprint of system with respect to observed & total LWG
www.fieldtomarket.org

Field to Market®
The Alliance for Sustainable Agriculture

From Bill Robertson. 2014. Nat. Cotton Council
Program Goals

• Field to Market seeks to engage 50 million acres in its supply chain program by 2020 in order to:
  – Improve land use efficiency
  – Improve water quality
  – Improve irrigation water use efficiency
  – Improve energy use efficiency
  – Reduce GHG emissions per unit of output
  – Reduce soil erosion
Fieldprint Calculator SI for TAWC sites

Fieldprint Calculator SI for TAWC sites

Practices that Reduce WF in the Field

- Manage soil for high infiltration rate
- Irrigation type (drip)
- Irrigate <PET by monitoring and scheduling
- Variable rate irrigation by soil condition
- New varieties with higher WUE
- High quality forages
- Diversify farming system with dryland, low, and moderately irrigated crops
Yield response to total water

$$y = -505 + 724(1-e^{-0.385x}) \quad R^2=0.92 \quad SE_{est}=18$$
QUESTIONS?

Data contributed by P. Brown, R. Kellison, P. Johnson, J. Pate, L. Baxter, K. Stokes. Funding from USDA-Southern SARE award LS14-261 and Texas Water Development Board.