Resource use efficiency, produce quality, plant biodiversity and externalities in UPA systems of Africa and Asia: From a status quo analysis to effective policy recommendations

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UPA – a widespread response to the food crisis
UPA – a widespread response to rural insecurity and war

Image source: own, afp. dpa
# Extent of urban food production in Africa

<table>
<thead>
<tr>
<th>City</th>
<th>Proportion of urban dwellers involved in UPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kano (Nigeria)</td>
<td>75</td>
</tr>
<tr>
<td>Ouagadougou (Burkina Faso)</td>
<td>36</td>
</tr>
<tr>
<td>Harare (Zimbabwe)</td>
<td>80</td>
</tr>
<tr>
<td>Nairobi (Kenya)</td>
<td>29</td>
</tr>
<tr>
<td>Mombasa (Kenya)</td>
<td>30</td>
</tr>
<tr>
<td>Dar-Es-Salaam (Tanzania)</td>
<td>44-70</td>
</tr>
</tbody>
</table>

Smith 2001, IDRC
Income effects of UPA along the marketing chain

**Introduction**

<table>
<thead>
<tr>
<th></th>
<th>Farmers</th>
<th>Wholesalers</th>
<th>Sellers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of observations</td>
<td>62</td>
<td>54</td>
<td>190</td>
</tr>
<tr>
<td>Average household size (adults and children)</td>
<td>4.7</td>
<td>5.2</td>
<td>4.6</td>
</tr>
<tr>
<td>Net profit from vegetable sales</td>
<td>17-23</td>
<td>80-108</td>
<td>9-25</td>
</tr>
<tr>
<td>Nonagricultural income</td>
<td>0-8</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Contribution by other household members</td>
<td>15-16</td>
<td>35</td>
<td>6-11</td>
</tr>
<tr>
<td>Total household income per week</td>
<td>32-39</td>
<td>124-152</td>
<td>23-44</td>
</tr>
</tbody>
</table>

Note: n.a. = not available.

Source: IWMI, unpublished.

Drechsel et al., 2006
The UrbanFood research locations

- Faisalabad, Pakistan
- Mumbai, India

Introduction

Resources  Biodiversity  Externalities  Sustainability
UrbanFood – Opportunities & Challenges

Introduction

Resources      Biodiversity      Externalities     Sustainability
Spatial development of UPA (Khartoum, Sudan)
Introduction
Resources
Biodiversity
Externalities
Sustainability

UPA – Spatial dynamics & water demand


Water demand (million m³ year⁻¹)

+2.7 million m³ year⁻¹

R² = 0.97

Year


Plant biodiversity
Mean plant species diversity in the cold, hot and rainy season 2007

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cold season (n=51)</th>
<th>Hot season (n=51)</th>
<th>Rainy season (n=45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species richness</td>
<td>14.1</td>
<td>9.8</td>
<td>6.7</td>
</tr>
<tr>
<td>Species density</td>
<td>15.0</td>
<td>10.2</td>
<td>6.8</td>
</tr>
<tr>
<td>Shannon index</td>
<td>1.0</td>
<td>0.8</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Plant biodiversity in UPA gardens
- Example: Niamey, Niger -

Other possible determinants:
- Ethnic affiliation of gardeners
- Garden size
- Degree of commercialisation

Highest species diversity found in gardens of nomads!

- Yoruba (1%)
- Gourmantché (2%)
- Mossi (3%)
- Djerma (53%)
- Peul (25%)
- Tuareg (8%)
- Hausa (8%)

Plant biodiversity in UPA gardens
- Example: Niamey, Niger

The irrigation water issue

Introduction Resources Biodiversity Externalities Sustainability
Heavy metal distribution and balance

- Profile samples
- Vegetable, fertilizer and irrigation water samples
- Heavy metal analysis by AAS

- Atmospheric deposition
- Leaching of heavy metals
Irrigation water characteristics in Kano (Nigeria)

<table>
<thead>
<tr>
<th>Metals</th>
<th>Conc (mg l⁻¹)ᵃ</th>
<th>Limitsᵇ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>8.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Fe</td>
<td>4.8</td>
<td>5.0</td>
</tr>
<tr>
<td>Mn</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Cr</td>
<td>28.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Ni</td>
<td>1.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Pb</td>
<td>28.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>

ᵃ Kano State Environmental Planning and Protection Agency
UPA – Quality of irrigation water

Weckenbrock, Drescher, Amerasinghe and Simmons, 2008.
Irrigation water used in the two research villages Chakera and Kehala Kalar, Pakistan

Irrigation Kehala 2006  Irrigation Chakera 2006
- CW and TW
- TW and some CW
- CW, TW and V
- no irrigation water
- Settlement area
- Focus village boundaries
- Main drains
- Freshwater Canals
- Main roads
- Untreated WW
- Partially treated WW
- Treated WW
- VWW
- CW
- Mix of different water types
- Other irrigation
- No irrigation
- Chakera WSP

Abbreviations:
- CW = Canal Water
- TW = Tubewell Water
- V = Village Water
- WSP = Waste Stabilisation Pond
- WW = Wastewater from Faisalabad

APT, ph.d philipp.weckenbrock@geographie.uni-freiburg.de, May 2008

Weckenbrock, Drescher, Amerasinghe and Simmons, 2008.
Main sources of irrigation water

![Bar chart showing the number of households (n) using different sources of irrigation water in Kano, Bobo, and Sikasso. The sources include Well, Waste, and Stream.]

- **Kano**: 40 households (Well: 30, Waste: 10, Stream: 0)
- **Bobo**: 50 households (Well: 40, Waste: 10, Stream: 0)
- **Sikasso**: 90 households (Well: 80, Waste: 10, Stream: 0)
Heavy metal pollution and balance

- Bobo-Dioulasso ≈ Sikasso
- Positive HM balances in Kano
  - Cd: 0.98-1.56 kg ha\(^{-1}\) yr\(^{-1}\)
  - Zn: 9.2-35.8 kg ha\(^{-1}\) yr\(^{-1}\)

HM pollution in Kano > Bobo-Dioulasso ≈ Sikasso

Koki 1559
Zungeru 699
Kwakwaci 4158
Gada 976
Katsina road 1168
Distribution of Zn in the different geochemical fractions in vegetable garden soils of Kano

- Wastewater irrigation = major input of Cd and Zn in Kano
- High percentage of mobile fractions of Cd and Zn in Kano soils → Risk of HM pollution
- Estimated dietary intake of Cd and Zn still within safety limits

Contamination of lettuce by faecal coliforms in Bobo Dioulasso and Sikasso

![Bar chart showing contamination levels of faecal coliforms in harvest and market lettuce from Bobo Dioulasso and Sikasso. The chart indicates higher contamination in Bobo Dioulasso compared to Sikasso.]

Introduction Resource Biodiversity Externalities Sustainability
Mean helminth egg concentrations on different types of vegetables in the fields and on a market in Faisalabad during the period April 2004–March 2005 (Vertical bars represent 95% CI).

Sustainability – Matter balances
Nutrient fluxes at the garden and field scale

**Inputs**
- Manure, mineral fertilizer

**Gaseous losses**
- CH$_4$, CO$_2$, NH$_3$, N$_2$O

**Leaching losses**
- NO$_3$, P$_{org}$

**Outputs**
- Exported harvest
Photo-acoustic multigas monitoring of gaseous C & N losses

Closed-chamber system
Gaseous N losses from three UPA gardens
- Example: Niamey, Niger -

### Total N balances of UPA gardens
- **Example: Niamey, Niger** -

<table>
<thead>
<tr>
<th>Garden</th>
<th>Input (kg ha(^{-1}) a(^{-1}))</th>
<th>Output (kg ha(^{-1}) a(^{-1}))</th>
<th>Horizontal N fluxes</th>
<th>Gaseous N losses</th>
<th>N leaching</th>
<th>Total N balance (kg ha(^{-1}) a(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>River 1</td>
<td>470</td>
<td>100</td>
<td></td>
<td>53</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>River 2</td>
<td>780</td>
<td>190</td>
<td></td>
<td>48</td>
<td>59</td>
<td>41</td>
</tr>
<tr>
<td>Sewage water</td>
<td>3,820</td>
<td>830</td>
<td></td>
<td>92</td>
<td>32</td>
<td>68</td>
</tr>
</tbody>
</table>

\(^*\) values of rainy season 2007

## Total C balances of UPA gardens

- Example: Niamey, Niger -

### Horizontal C fluxes

<table>
<thead>
<tr>
<th>Garden</th>
<th>Fertilizer (kg ha⁻¹ a⁻¹)</th>
<th>Roots* (kg ha⁻¹ a⁻¹)</th>
<th>Output (kg ha⁻¹ a⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>River 1</td>
<td>30,520</td>
<td>2,200</td>
<td>2,200</td>
</tr>
<tr>
<td>River 2</td>
<td>12,280</td>
<td>2,190</td>
<td>2,190</td>
</tr>
<tr>
<td>Sewage water</td>
<td>7,820</td>
<td>7,030</td>
<td>7,030</td>
</tr>
</tbody>
</table>

### Gaseous C losses

<table>
<thead>
<tr>
<th></th>
<th>Total (kg ha⁻¹ a⁻¹)</th>
<th>CO₂ (%)</th>
<th>CH₄ (%)</th>
<th>Total C balance (kg ha⁻¹ a⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>River 1</td>
<td>25,150</td>
<td>98</td>
<td>2</td>
<td>5,270</td>
</tr>
<tr>
<td>River 2</td>
<td>20,190</td>
<td>98</td>
<td>2</td>
<td>- 7,910</td>
</tr>
<tr>
<td>Sewage water</td>
<td>26,630</td>
<td>98</td>
<td>2</td>
<td>- 18,810</td>
</tr>
</tbody>
</table>

* Estimated to be equivalent to the harvested shoot C

Manure use for brick making in Khartoum, Sudan
Mean annual amounts of nitrogen, phosphorus, potassium and carbon deposited as inputs in 2008 from the River Nile flood sediments on Gerif soils in Khartoum, Sudan. ‘Lowlands’ refer to gardens adjacent to the banks of the River Nile (L1 and L2; n = 4) and ‘Highlands’ refer to gardens away from the banks of the River Nile (H1 and H2; n = 6).

Babiker et al., Nutrient Cycling in Agroecosystems (submitted).
Mean annual horizontal balances of nitrogen, phosphorus, potassium and carbon in vegetable gardens during the study period from October 2007 to March 2010 in Khartoum, Sudan. Data presented are means for L1 (n = 7), L2 (n = 5), H1 (n = 7) and H2 (n = 5) plus one standard error. L1 and L2 denominate gardens adjacent to the banks of the River Nile (Lowlands), and H1 and H2 gardens away from the banks of the River Nile (Highlands).

Babiker et al., Nutrient Cycling in Agroecosystems (submitted).
Average net return, total return and total cost for farms and kilns (in SDG\(^1\)), Gini-coefficient, benefit cost ratio (B/C), and land share of total cost for farms and kilns in urban Khartoum, Sudan, 2009.

<table>
<thead>
<tr>
<th>Items</th>
<th>Red brick kiln owners (n = 45)</th>
<th>Urban farmers (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average total return</td>
<td>147,761.00</td>
<td>8,267.00</td>
</tr>
<tr>
<td>Average total cost</td>
<td>116,559.00</td>
<td>3,718.20</td>
</tr>
<tr>
<td>Average net return</td>
<td>31,202.12</td>
<td>4,626.00</td>
</tr>
<tr>
<td>Gini coefficient</td>
<td>0.37</td>
<td>0.49</td>
</tr>
<tr>
<td>B/C</td>
<td>1.27</td>
<td>2.22</td>
</tr>
<tr>
<td>Land share of total cost (%)</td>
<td>6.00</td>
<td>29.00</td>
</tr>
</tbody>
</table>

\(^1\) SDG (New Sudanese Pound) ≈ 0.4 US$

Source: Formal survey 2009

Mean annual amounts of nitrogen, phosphorus, potassium and carbon deposited as inputs in 2008 from the River Nile flood sediments on Gerif soils in Khartoum, Sudan. 'Lowlands' refer to gardens adjacent to the banks of the River Nile (L1 and L2; n = 4) and 'Highlands' refer to gardens away from the banks of the River Nile (H1 and H2; n = 6).

Babiker et al., Nutrient Cycling in Agroecosystems (submitted).
Conclusions & Recommendations

Urban and peri-urban agriculture (UPA) can make an important contribution to supplying food and income opportunities to the rapidly growing urban populations of developing countries, but its role strongly varies between locations.

• Negative externalities of UPA need careful analysis and consistent action to derive effective recommendations (policies) fostering the sustainability of the systems and securing product safety and finally consumer health.

• Carbon and nutrient balances strongly vary between and within locations. While N balances are often excessively positive leading to N losses via volatilisation, C-balances heavily depend on the use of manure.

• A thorough understanding of the biophysical, economic and social sustainability of UPA systems may also allow us to derive important conclusions for the farm-level adoption of improved soil fertility management options in the vast rainfed systems across semi-arid Africa and parts of Asia.
Use of membrane filtration: Cross-flow filtration for cleaning up wastewater

=> From ISO norms to sustainable cloth production: a call for concerted legislative action!

Tangential water flow across membrane surface keeps particles in suspension, prevents settling and blocking of the membrane.
The membrane forms a barrier: Particle size bigger than the pore cannot pass through the membrane.

- **Bacteria** (0.2 - 100 μm)
- **Protist** (2 - 200 μm)
- **Algae** (> 1 μm)
- **Virus** (0.015 – 0.2 μm)
- **Suspended Solid** (> 2 μm)

**UF** (0.01 - 0.03 μm)
Disadvantages of conv. membrane designs - Spiral wound

Narrow Feed Channel and Permeate Channel Spacers:
- high flow restriction
- high risk of fouling
- difficult to clean
- high grade pre-treatment necessary
Disadvantages of conv. membrane designs – Hollow Fibre

Membrane fouling at top

- Fibers cannot move at the top flange (air scour), limited water flow velocity at top flange
- Manual cleaning necessary
- High risk of breaking fibres

Reference: Desalination and Water Purification Research and Development Report No.103
Disadvantages of conv. membrane designs – Flat Sheet

- Permeate Outlet
- Permeate Outlet of Single Plates
- Modules
- Membrane
- Membrane Fouling
- Areas in the Corners of the Membrane Plate are difficult to clean due to low Water Flow Velocity

Plate / Frame UF Assembly

Single Plate

Membrane Fouling

Kubota Type 510 Membrane (single sheet)

Kubota Type 510 Membrane (after 2 months operation)
A new alternative: The filter (membrane) stack

- Membrane disc
- Spacer with interlock
- Seal

Filtered water is collected and drained through the center pipe.

Raw water goes through membrane disks (two membranes with spacer layer).

Membrane stack

→ The spacer avoids dead space on the membrane surface and membrane stack!
→ The disc-shaped design allows for an even flow velocity across the membrane surface!
The filter (membrane) stack before and after cleaning

Fouling        Easy cleaning        Recover complete
Thank you / Shugria!