Sustainable Agricultural Production
Definitions, Constraints and Critical Linkages and an attempt to answer the question, “If economists are so smart, why is Africa so poor?”

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Outline

• Our goal
• Why is CSA urgent? Welcome to the Anthropocene
• What is Sustainable Ag or Climate Smart Agriculture (CSA)? What are the criteria?
• What is the impact of current models?
• Does CSA work? If so, where and if not, why?
• What model has worked? Is it replicable?
The Nexus

To Improve **Socio-Ecological (SES) Systems**

**SOCIO**

Food Security

- Increase Food Production
- Reduce Poverty and Undernourishment
- Improve Quality of Life

**ECOLOGICAL**

Environmental Security

- Mitigate Impacts of Environmental Externalities
- Adapt to New Environmental Conditions
- Develop Sustainable and Integrated Systems
The New Epoch

The Anthropocene
With Thanks

• With thanks and homage and debt to:

Johan Rockstrom

Stockholm Environment Institute, Stockholm Resilience Centre, Department of Water and Environmental Studies at Linkoping University, and the Stockholm International Water Institute
<table>
<thead>
<tr>
<th>Earth system process</th>
<th>Parameter</th>
<th>Proposed boundary</th>
<th>Current status</th>
<th>Pre-Industrial status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>• Atmospheric carbon dioxide concentration (PPM)</td>
<td>350</td>
<td>387</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>• Change in radiative forcing (watts per meter sq)</td>
<td>1</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Rate of biodiversity loss</td>
<td>Extinction rate (number of species per million number of species)</td>
<td>10</td>
<td>&gt;100</td>
<td>0.1-1.0</td>
</tr>
<tr>
<td>Nitrogen Cycle</td>
<td>Amount of N removed from the atmosphere for human use (millions of tons per year)</td>
<td>35</td>
<td>121</td>
<td>0</td>
</tr>
<tr>
<td>Phosphorus Cycle</td>
<td>Amount of P flowing into the ocean (millions of tons per year)</td>
<td>11</td>
<td>8.5-9.5</td>
<td>-1</td>
</tr>
<tr>
<td>Stratospheric Ozone depletion</td>
<td>Concentration of Ozone (Dobson units)</td>
<td>276</td>
<td>283</td>
<td>290</td>
</tr>
<tr>
<td>Ocean acidification</td>
<td>Global mean saturation state of aragonite in surface sea water</td>
<td>2.75</td>
<td>2.90</td>
<td>3.44</td>
</tr>
<tr>
<td>Global freshwater use</td>
<td>Consumption of freshwater by humans (km³.year)</td>
<td>4000</td>
<td>2600</td>
<td>415</td>
</tr>
<tr>
<td>Land use</td>
<td>Percentage of global land converted to cropland</td>
<td>15</td>
<td>11.7</td>
<td>Low</td>
</tr>
<tr>
<td>Atmospheric aerosol loading</td>
<td></td>
<td></td>
<td></td>
<td>To be determined</td>
</tr>
</tbody>
</table>
Agricultural Land/% of total
(World Bank, 2012)

Global pct is 36%. If extensive rate of agricultural expansion continues, global pct will climb to 60% by 2030:

The Quadruple Squeeze

99% of change occurs from 1% of events

*Ashok Khosla, president of the IUCN in Johan Rockström and Louise Karlberg The Quadruple Squeeze: Defining the safe operating space for freshwater use to achieve a triply green revolution in the Anthropocene
Cities, roads, railways and cables in Europe
Air routes between Europe and North America

Moderate Resolution Imaging Spectroradiometer (MODIS)

https://earthdata.nasa.gov/data/near-real-time-data/rapid-response/modis-subsets
Population Growth and Movement
(Mexico City)

In 1800 3% of the world’s population lived in cities. Today it’s 50%
It’s All About the Curve

It is time to bend the curves!
Trend in the number of recorded flood and drought events in Africa
World Energy Consumption
(ourfiniteworld.com)
Global Population Growth from 6.5 billion to 9.5 billion in 30
Rate of Population Growth

After taking all of human history for population to reach one billion, it took only a little over a century to reach two billion in 1930. The third billion was added in just 30 years, the fourth in only 15 years.
Emergence of the Anthropocene

(Steffen, Grinevald, Crutzen, McNeill)
Development of the Anthropocene
(Steffen, Grinevald, Crutzen, McNeill)

The emerging critical driver
LDC Annual growth from Ag 1995-2010 in pct
Change in agricultural production in LDCs 2000-2010 (FAO)

Compare Areas: Agriculture (PIN) Gross Production Value (constant 2004-2006 1000 I$) (1000 Int. $) (2000 - 2010)

M = Million, K = Thousand
Childhood Stunting 1995-2005

[Graph showing trends in childhood stunting across Africa, Eastern Africa, Northern Africa, and Western Africa from 1995 to 2005.]

- **Africa**: 1995 data is lower than 2005 data. The trend shows a gradual increase from 1995 to 2005.
- **Eastern Africa**: Similar to Africa, with a decrease from 1995 to 2005.
- **Northern Africa**: Shows a significant decrease from 1995 to 2005, with a sharp dip in 2005.
- **Western Africa**: Bars for 1995 and 2005 are approximately equal, indicating little change over the decade.

The data suggests a mixed picture of change in childhood stunting across different regions of Africa from 1995 to 2005.
And Lose: Prevalence of Stunting

(FAO)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>40.5</td>
<td>39.2</td>
<td>37.8</td>
<td>36.5</td>
<td>35.2</td>
<td>33.8</td>
</tr>
<tr>
<td>Eastern Africa</td>
<td>46.5</td>
<td>46.9</td>
<td>47.3</td>
<td>47.7</td>
<td>48.1</td>
<td>48.5</td>
</tr>
<tr>
<td>Northern Africa</td>
<td>32.7</td>
<td>29.6</td>
<td>26.5</td>
<td>23.3</td>
<td>20.2</td>
<td>17.0</td>
</tr>
<tr>
<td>Western Africa</td>
<td>36.2</td>
<td>35.8</td>
<td>35.5</td>
<td>35.2</td>
<td>34.9</td>
<td>34.6</td>
</tr>
</tbody>
</table>
Least Developed Countries
Smallholders are our LEVEL OF ANALYSIS

2 billion
500 million farms
70% of all food grown

But sustainable agriculture is scalable

Andrew Noble,
Director WLE at
World Water Week
2013
Our Collective Objective

• To **IMPLEMENT Sustainable Agricultural Production**, 

*Or by other names:*
  – Farming System Innovations
  – Climate-Smart Agriculture
  – Innovative Irrigation Systems

• But first, what are the tools of Sustainable Agricultural Production and what are the criteria?
What is Sustainable Agriculture Production?
A tool Kit

Water Harvesting
Conservation
Tillage
Low Volume/High Uniformity
Irrigation
ET Based Irrigation
Run-Off Control

Intensive Production
Integrated Pest and Nutrient Mgt
The Criteria for CSA

- Sustainable Agricultural Production produces a win/win/win:
  1. Greater yields, fewer outputs, increased profitability for growers in least developed countries
  2. Adaptation to environmental change
  3. Mitigation of global environmental consequences of agriculture

Does it work?
The Fundamental Agricultural Axioms

#1 Improvements in Agricultural Production and Irrigation lead to reductions in poverty and undernourishment

- **1 percent increase in productivity will reduce incidence of poverty by 0.31 %**. 


The Fundamental Agricultural Axioms

#2 Sustainable Agricultural Production Leads to Increased Production


The Fundamental Agricultural Axioms

#3 Sustainable Agricultural Production Leads to Increased Production and Environmental Mitigation

The Fundamental Agricultural Axioms

#3 Sustainable Agricultural Production Leads to Increased Production and Environmental Mitigation

• **SAP increased yields by 79% and reduced pesticide use by 77%** Pretty, J., Sutherland, W. J., Ashby, J., & Auburn, J. e. (2010). The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8 (4), 219-236.


### Summary of Adoption and Impact of Sustainable Ag Practices (Pretty et al)

<table>
<thead>
<tr>
<th>Farm System</th>
<th>Number of farmers</th>
<th>Number of hectares</th>
<th>Average % yield increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smallholder irrigated</td>
<td>177,287</td>
<td>367,940</td>
<td>129.8</td>
</tr>
<tr>
<td>Wetland rice</td>
<td>8,711.236</td>
<td>7,007,564</td>
<td>22.3</td>
</tr>
<tr>
<td>Smallholder rainfed humid</td>
<td>1,704,958</td>
<td>1,081,071</td>
<td>102.2</td>
</tr>
<tr>
<td>Smallholder rainfed highland</td>
<td>401,699</td>
<td>725,535</td>
<td>107.3</td>
</tr>
<tr>
<td>Smallholder rainfed dry/cold</td>
<td>604,804</td>
<td>737,896</td>
<td>99.2</td>
</tr>
<tr>
<td>Dualistic mixed</td>
<td>537,311</td>
<td>26,846,750</td>
<td>76.5</td>
</tr>
<tr>
<td>Coastal artisanal</td>
<td>220,000</td>
<td>160,000</td>
<td>62</td>
</tr>
<tr>
<td>Urban base kitchen</td>
<td>207,479</td>
<td>36,147</td>
<td>146</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>12,564,774</strong></td>
<td><strong>36,952,903</strong></td>
<td><strong>79.2</strong></td>
</tr>
</tbody>
</table>
## Summary of Changes in Water Productivity (WP)

<table>
<thead>
<tr>
<th>Crop</th>
<th>WP before intervention</th>
<th>WP after intervention</th>
<th>WP gain</th>
<th>% increase WP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated rice</td>
<td>1.03</td>
<td>1.19</td>
<td>0.16</td>
<td>15.5</td>
</tr>
<tr>
<td>Irrigated cotton</td>
<td>0.17</td>
<td>0.22</td>
<td>0.05</td>
<td>29.4</td>
</tr>
<tr>
<td>Rainfed cereal</td>
<td>0.47</td>
<td>0.80</td>
<td>0.33</td>
<td>70.2</td>
</tr>
<tr>
<td>Rainfed legume</td>
<td>0.43</td>
<td>0.87</td>
<td>0.44</td>
<td>102.3</td>
</tr>
<tr>
<td>Rainfed tuber</td>
<td>2.79</td>
<td>5.79</td>
<td>3.00</td>
<td>107.5</td>
</tr>
<tr>
<td>Urban veg/fruit</td>
<td>0.83</td>
<td>2.96</td>
<td>2.13</td>
<td>256.6</td>
</tr>
</tbody>
</table>
## Summary of Carbon sequestered

<table>
<thead>
<tr>
<th>Category</th>
<th>Carbon sequestered/hectare (tC ha⁻¹ y⁻¹)</th>
<th>Total carbon sequestered (MtCy⁻¹)</th>
<th>Carbon sequestered /household (t C y⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smallholder irrigated</td>
<td>0.15</td>
<td>0.011</td>
<td>0.06</td>
</tr>
<tr>
<td>Wetland rice</td>
<td>0.34</td>
<td>2.53</td>
<td>0.29</td>
</tr>
<tr>
<td>Smallholder rainfed humid</td>
<td>0.46</td>
<td>0.34</td>
<td>0.20</td>
</tr>
<tr>
<td>Smallholder rainfed highland</td>
<td>0.36</td>
<td>0.23</td>
<td>0.56</td>
</tr>
<tr>
<td>Smallholder rainfed dry/cold</td>
<td>0.26</td>
<td>0.20</td>
<td>0.32</td>
</tr>
<tr>
<td>Dualistic mixed</td>
<td>0.32</td>
<td>8.03</td>
<td>14.95</td>
</tr>
<tr>
<td>Coastal artisanal</td>
<td>0.20</td>
<td>0.032</td>
<td>0.15</td>
</tr>
<tr>
<td>Urban base kitchen</td>
<td>0.24</td>
<td>0.015</td>
<td>0.07</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0.35</td>
<td>11.38</td>
<td>0.91</td>
</tr>
</tbody>
</table>
## Water productivity gains

(World Bank report; 2006)

Table 4.4. More from Less: Water Productivity Gains from Shifting to Drip from Conventional Surface Irrigation in India

<table>
<thead>
<tr>
<th>Crop</th>
<th>Change in yield/ha (percent)</th>
<th>Change in water use/ha (percent)</th>
<th>Change in water productivity (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bananas</td>
<td>+52</td>
<td>−45</td>
<td>+173</td>
</tr>
<tr>
<td>Cotton</td>
<td>+27</td>
<td>−53</td>
<td>+169</td>
</tr>
<tr>
<td>Grapes</td>
<td>+23</td>
<td>−48</td>
<td>+134</td>
</tr>
<tr>
<td>Sweet potatoes</td>
<td>+39</td>
<td>−60</td>
<td>+243</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>+50</td>
<td>−39</td>
<td>+145</td>
</tr>
</tbody>
</table>
# The Constraints and Input Challenges to Agricultural Production

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Input Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social: gender, land tenure</td>
<td>Labor</td>
</tr>
<tr>
<td>Governance: statutory v traditional law, highly centralized, corruption</td>
<td>Water</td>
</tr>
<tr>
<td>Economics: restrictive, outdated policies, state-centric</td>
<td>Land</td>
</tr>
<tr>
<td>Finance: credit, loans</td>
<td>Seeds</td>
</tr>
<tr>
<td>Weather: vulnerability</td>
<td>Cultivars</td>
</tr>
<tr>
<td>Knowledge: lack of training, unskilled labor force</td>
<td>Fertilizers</td>
</tr>
<tr>
<td>Land Tenure</td>
<td>Irrigation</td>
</tr>
<tr>
<td></td>
<td>Credit</td>
</tr>
<tr>
<td></td>
<td>Mechanization</td>
</tr>
<tr>
<td></td>
<td>Knowledge</td>
</tr>
</tbody>
</table>

Solving for the constraints is important but insufficient if we persist with the same model.
Development Model

500 million papers on Agricultural Water Management

$40 billion in research and $? Billion in Technological Change

$250 Billion in Aid
Development Model

Financial Input, Agricultural Growth, and Population in LDCs

<table>
<thead>
<tr>
<th>Years</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDC Population (Africa and Haiti) in 10,000</td>
<td>40</td>
<td>41</td>
<td>42</td>
<td>44</td>
<td>45</td>
<td>46</td>
<td>47</td>
<td>49</td>
<td>50</td>
<td>51</td>
<td>53</td>
</tr>
<tr>
<td>LDC Crop Production Index (2004-2006=100)</td>
<td>99</td>
<td>104</td>
<td>106</td>
<td>111</td>
<td>113</td>
<td>122</td>
<td>126</td>
<td>128</td>
<td>135</td>
<td>137</td>
<td>138</td>
</tr>
<tr>
<td>LDC Annual Growth from Agriculture by pct</td>
<td>-1</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Total Financial Flows and ODA from all sources to LDCs in $ hundred million</td>
<td>135</td>
<td>140</td>
<td>150</td>
<td>178</td>
<td>225</td>
<td>240</td>
<td>260</td>
<td>320</td>
<td>380</td>
<td>390</td>
<td>400</td>
</tr>
</tbody>
</table>
The Model has Failed
Let’s Look at Numbers

- Smallholders make up 2 billion people (500 million farms)
- Number of extremely poor people (<$1 day/capita) increased from 2002-2007 to 1.3 billion; percentage of adults earning less than $1.25/day doubled from 18%-36%, and 2.6 billion live on less than $2/day
- Undernourishment increased from 2002-2007. 95% of 850 million undernourished are in LDCs
- 70% of all smallholder produce is locally consumed
- Crop production in smallholder farms has increased 2% over the past decade
- Smallholder production must increase 100% over the next 20 years
- 4% of all arable land in LDCs is under irrigation. 85% of land rain-fed
- 80% of population growth over the next 30 years will be in LDCs. Population in LDCs will triple from 1.2 billion to 4.2 billion between 2011 and 2100.
- Agriculture occupies 36% percent of all arable surfaces. If production is only increased extensively, ag land will occupy 60% of all arable surfaces
- Agriculture produces 36% of all greenhouse gas emissions
- Net ODA flows from DAC reached $128.7 billion in 2010
**Current Status: Lose/Lose**

- “4% of cultivated area is under irrigation in Sub-Saharan Africa”  

- “With no regard for impacts of climate change, agricultural production needs to increase by 70% overall and by 100% in developing countries by 2050. This equates to an additional billion tons of cereal and 200 million tons of meat annually”  

- 85% of land in LDCs in Africa is rainfed but...

- “New data suggests that rainfed crop yields in some African countries are projected to decline by 50 per cent by 2010 due to climate change”  
  (IFAD, 2012).
The Disconnect

The Development Community

Local Institutions

The Professional Agricultural Community

Scientific Community
The New Model

- The Grower
- The Manufacturer
- The Distributor
The Distributor Model

- Livelihood Interdependency
- Financial stakeholders
- Imperative Knowledge transfer
- Institutional knowledge is developed
- Culture and Passion and Respect for Agriculture
- Personal bonding
The Triple Nexus
Manufacturer, Distributor, Smallholder

The Key Actors in the new Model

In the same interdependent and interlinked Financial boat

Who is the most important person on a daily basis for the smallholder farmer?

This is the model used in the developed world. Is this model transferable?
Without Local Institutional Professional Support...

Of the 6 million ha equipped for irrigation 1 million need rehabilitation (You, 2008)

Of all the drip kits distributed in Africa over the last three years, 84% have been abandoned (Burney and Naylor, 2011)

Estimates vary from 20-40% of all irrigation systems are ‘down’ in LDCs at any one time (interview with Minister of Ghana, Stockholm 2012)
SAM MODEL

“Make it simple, but not simpler” - Einstein
Distribution Models
The Critical Agro-Economic Institution

Models

• Private Entrepreneur
  1. Owned by individual, family or corporation
• Partnership Agreement
  1. Co-owned by manufacturer
  2. Preferential promotion of manufacturers’ products
• Collective
  1. Owned and operated by group of growers
• Agro-Business Model
  1. Private ownership
  2. Farm Center model

Major Functions

1. Managed by certified and trained staff
2. Makes deliveries
3. Stocks products, keeps inventory
4. Provides warranty service
5. Provides design and design support
6. Conducts seminars, workshops
7. Extends terms of credit
Conclusions

1. Farming is a business
2. All models are good
3. Technology is advanced
4. Funding for agriculture and irrigation is plenty
5. The urgency of improving production in a sustainable way cannot be overemphasized
6. Local, in situ and trained, institutional support is the critical link for implementation
Questions?