Week 4: HOW CAN LDCS INCREASE FOOD PRODUCTION?  
F-2007

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I. How Has Agriculture Evolved?

A. Characteristics of “Traditional” Farming Systems  
   1) Types  
      o Cropping systems  
         ✓ “Extensive” (slash & burn agriculture)  
            Def. Move farm every few years  Why?
         ✓ “Mixed cropping”  
            Def. Plant several crops together in a field  Why?
      o Livestock systems  
         o Extensive pastoral/nomadic systems  
            Def. Move cattle in search of grass  Why?  

2) Farming practices are based on “local knowledge” passed from one generation to the next

3) Farm family provides all inputs (original “organic” farming system)
4) Farms are small (< 5 acres), farming is labor intensive (Photo)

5) Family mainly produces & processes food for own use (subsistence), but sell crops in good years when there’s a surplus (Photo)

6) Throughout history, farmers have increased food production by:
   - Planting more land How? (Photo)
   - Using traditional technology to increase yields Examples? (Photo)

7) Farmers using traditional farming systems are "Poor but Efficient" Def.

8) Limitations of traditional systems--can’t meet future food needs of growing population:
   - New & productive land not available for area expansion
   - Can’t rapidly increase yield using traditional technologies

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B. Characteristics of “Modern” Farming Systems in DCs

1) Types (Photo)
   - Crop/livestock systems
     - “Sedentary” and capital intensive Def.
     - Highly specialized, typically ”monoculture” Def.

2) Farming practices are based on "modern science”:
   - Genetics (Mendel, hybrids)
   - Chemical fertilizer (post-WW II)
   - Plant protection (pesticides since WW II, IPM now)
   - Power/equipment (mfg. tools, equipment, pumps)
   - Transport/processing/storage technologies

3) Farmers purchase most inputs from the market

4) Farms are large & mechanized (Photo)
5) Farmers produce for the market (profit oriented) (Photo)

6) Farmers increase production by increasing yields (use more inputs)

7) Farmers produce low cost food, but often receive subsidies from the government

8) Limitations of modern farming systems—growing concerns about environmental impacts of input intensive agriculture
   - Pesticides contamination
   - Fertilizer (nitrate) in groundwater, oceans (dead zones)
   - Wildlife habitat loss

C. How Can LDCs Modernize their Farming Systems?

1) How traditional/modern are farming systems in LDCs?
   - Varies greatly by country, due to crops grown, growing environment (rainfed vs. irrigated), governmental policies & programs, etc. (Photo)

   o Many farmers in LDCs plant new/improved crop varieties, apply some fertilizer & insecticide, but few use machinery Why?

2) In recent years, most of the increase in food production in LDCs (especially in Asia) has been due to higher yields (1980-90)
   - Higher yields (+27%)
   - More cropped area (4.5%)

3) Should LDCs follow the "intensification strategy" (i.e., increase yields) that DC used to "modernizing" their agriculture?

   Yes/No—Limitations?
   - More fertilizer?
   - More machinery?
   - More irrigation?
   - More improved crop varieties (including GM varieties)?
   - More pesticides?
Implications:
- LDCs must intensify their agriculture to develop **BUT a “double green revolution” is needed!**

- **Future technologies must:**
  - Increases crop yield (limited potential to increase planted area)
  - **But** be more “environmentally friendly” than past technologies, (e.g., IPM)

- LDC farmers need “appropriate technologies”
  **Def:** technologies that:
  - Solve farmer’s problems (in all growing environments)
  - Are simple to use (due to farmers’ limited education)
  - Are compatible with farmers’ limited resources (i.e., inexpensive)

4) Successful agricultural development in necessary to:
- Increase in per capita food production
- Reduce food prices (which especially benefits the urban poor)
- Increase the demand for industrial goods

II. How is International Agricultural Research Organized?

A. The [CGIAR System](#)

1) Early foundations
- Created in response to the fear of famine—esp. in Asia
- Rockefeller/Ford Foundation, wheat in Mexico (1940s)
- IRRI, targeted rice, located in the Philippines (1960)
- Today, 15 CGIAR-funded "IARCS", located throughout the developing world
- Each Center has a **mandate** to focus on specific crops/livestock species and/or environments
2) CGIAR Centers carry out research to:

- Increase productivity through genetic improvement & by developing new crop management practices (Photo) (e.g., higher yields, reduce inputs use, reduce crop risk)

- Protect the environment by conserving natural resources (forests, soil & water) (Photo)

- Save biodiversity by collecting plant genetic resources (Photo)

- Improve policies (economic studies) that accelerate the spread of new technology, and

- Help to strengthen national research program by training LDC scientists—key to strengthening national research programs (e.g., IRRI & Cambodia)

**Note:** CGIAR research is shared via international research networks at no cost to LDCs (public good!)

3) CGIAR Centers focus on the major food crops & livestock species, and environmental problems facing LDCs

- **Staple food crops:** rice, maize, wheat, barley, cassava, yams, millet, sorghum, potatoes, sweet potato, cowpea, banana
  
  **Note:** Not export crops (e.g., coffee, cocoa, oil palm, sugarcane)

- **Livestock:** focus on improving local breeds of cattle & goats
  
  **Why** local breeds?
  
  - Can tolerate heat/high temperatures
  - Resistant to diseases
  - Can survive on low quality grasses

- **Fish (aquaculture/inland fish ponds):** focus on increasing growth rate, disease resistance (Photo)

- **Agroforestry (trees & soil conservation):** focus on developing
  
  - Quicker-growing trees for firewood
  - Technologies (terracing) to reduce soil erosion
4) CGIAR System’s budget & staff are very small! (2005)
   o Funded by over 50 donors--DCs=69%, Int. org/found.=19%
   o Budget--$460 million/year
   o Employs about 1,100 scientists worldwide
   o Spends--SS-Africa (46%), Asia (30%), LAC (14%), other (10%)

   **Note:** MSU’s ag research budget is over $83 million;
   US has >23,000 ag & ag-related scientists

B. The **Worldwide Agricultural Research System** is a **Partnership**
   Between Developed & Developing Countries

   **Collaborators include:**
   o LDC’s national research institutes & universities
   o DC’s national research institutes & universities
   o Private research firms (Cargill, Pioneer, ADM)
   o CGIAR centers

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III. What is the "Green Revolution"?

A. Key Features of GR Technologies
   1) **Def:** use of science & technology to increase food production in
country developing countries (e.g., IRRI-Cambodia video)

   2) Emphasized biological, **not** mechanical technology **Why?**
      o Land:
      o Labor:

   3) Not really a "revolution", but rather an "evolution" **Why?**

   4) What crops and regions has the GR benefited?
      o **First** (1960s)—rice & wheat—mainly in Asia **(IR8—1965)**
      o **Later, but less impact**—corn, cassava, sorghum, millet, etc. in
        other regions
5) How do international scientists develop new crop varieties?
   o Set breeding goals (based on traits desired in new variety)

   **Rice: Example** *(Pyramid Figure)*
   * High yield
   * Drought tolerance
   * Pest/disease resistance
   * Other?
   * Shorter growing time
   * Better nutritional characteristics
   * Characteristics consumers prefer (seed color, taste, cooking time)

   o Select from the seed bank germplasm (seed) with the desired traits/*genes* *(Photo)*

   o Cross, evaluate, screen offspring (takes 7 generations)

   o Test "best" lines around the world (networks) *(Photo)*

   o Make available new varieties (*free*) to scientists in LDCs

   o LDC scientists/governments multiply/distribute seed to farmers

   **Note:** It takes 7-10 yrs. to produce a new variety

6) "Modern rice varieties": an example of a GR *success* story
   **Traits & Benefits to LDC farmers?**
   o Short in height, fertilizer responsive   **Benefit?** *(Photo)*
   o Mature in less time (100 vs. 160 days) **Benefit?**
   o Genetically resistant to diseases/pests  **Benefit?** *(Photo)*
   o Photoperiod insensitive--can plant in any month **Benefit?**
IV. What Was the Impact of the Green Revolution?

A. Impact/Success of the Green Revolution Varied by:
   Impact, Def. who benefited & how much?
   1) Crops—greatest impact on rice & wheat; less impact on maize, etc. Why?
   2) Region—mainly benefited Asia Why?
   3) Environment—mainly benefited irrigated farms Why?
   4) Country—depended on govt. policies, land tenure situation
      (e.g., Indonesia, small farmers vs India, large farmers)
   5) Region within a country—varied Why?

B. Overall Impact GR in Wheat & Rice (1960-1990)
   o Farmers adopted new varieties (70%)
   o Yields doubled
   o Production doubled (while population increased by 60%)
   o Prices declined (especially benefited the urban poor)
   o Strengthened the rural economy
      (e.g., > farmer income, more purchases, more non-farm jobs)
   o Improved nutrition (i.e., more income, cheaper grain)
   o Other?

   Example: Asia, Rice, 1965-91 (Production = area x yields)

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (m.ha)</th>
<th>Yld (t/ha)</th>
<th>Prod (mil. m. tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965:</td>
<td>114</td>
<td>2.0</td>
<td>232</td>
</tr>
<tr>
<td>1991:</td>
<td>133</td>
<td>3.6</td>
<td>477</td>
</tr>
</tbody>
</table>
   (+16%) | (+80%)     | (+106%)    |
C. Asian Success was Due to Several “Complementary” Factors
- Fertilizer
- New variety
- Irrigation
- Government policies:
  (e.g., Asian farmers had good access to credit for buying inputs—seed, fertilizer, pesticides—extension, markets)

D. Criticisms of the GR in Asia
- Benefited better growing environments (irrigated farms)
- Benefited richer farmers who could afford fertilizer
- Caused environmental damage
  (i.e., overuse of fertilizer, insecticide)

Future research needs to address these problems,
But, What if there hadn’t been a Green Revolution?

A key lesson: technology alone isn’t sufficient!!!

E. Recent GR Successes in Africa
- Hybrid maize/wheat—Kenya, Zimbabwe, Ghana
- Sorghum in Ethiopia—Global 2000 (Carter/Borlaug)
  ✓ Production doubled (1995-97)
  ✓ Government made agriculture a priority: improved farmer access to seed, fertilizer, credit
- But impact of the GR technology has been limited in Africa, due to:
  ✓ Diversity of crops grown—not just rice & wheat
  ✓ Many different farming systems—need specific technologies for each farming system
  ✓ Rainfed growing conditions (farming is risky)
  ✓ Poor government policies (weak research & extension systems, farmers have limited access to credit & markets)
  ✓ Widespread poverty—farmers can’t afford to buy inputs
V. New, Greener” Revolutions: Emerging Technologies

A. Genetic Engineering (very different from Traditional Plant Breeding)

1) What is biotechnology?
   - Tissue culture—used to produce disease free planting material (e.g., banana in the Philippines, potatoes in Peru)
   - DNA-based techniques (most controversial)—transferring genes across species (e.g., Bt, flounder gene to strawberries)
   - Diagnostic kits—used to identify disease (if seed is disease free)
   - Agro-industrial applications—change characteristics of products (e.g., less fat in coconut oil)

2) What are the potential benefits from biotechnology?
   - Reduces years needed to develop new varieties
   - Can introduce exotic genes into plants (bt for pest resistance)
   - Improved food quality (Golden rice, > vitamin A)
   - Safer/better environment (e.g., less pesticide use, less deforestation if farmers can grow more food on existing fields)
   - Higher farmer profits (e.g., higher yields, less pesticides)

3) What are some concerns of LDCs?
   - Cost: requires expensive infrastructure, trained scientists
   - Intellectual property rights (private sector owns most patents)
     - Must pass legislation protecting IPR (WTO)
     - Expensive to gain access to processes, novel genes
   - Biosafety—Will genes escape (superweeds)?
   - Food safety—Is GMO food safe? (food allergens, Brazil nut)
   - Biodiversity—Will success displace all local varieties?
   - Export substitution—Will DCs create synthetic food substitutes?
   - Market concerns—Will EU countries buy GMO crops?
But most LDCs (China, South Africa, Brazil) are more concerned about increasing food production than about food/biosafety.

4) Promising GMO-based technologies for food crops in LDCs
   - "Super" Rice—less straw, fertilizer, water; "Golden" Rice (vitamin A)
   - Hardier Corn—higher yield, drought & acid soil tolerant
   - "True seed" potatoes—virus free, higher yields, grow quicker
   - New animal vaccines—East Coast Fever in cattle
   - Bt corn/rice—protects crop from insects
   - Herbicide tolerant crops—can apply herbicide w/o killing crop
   - Salt tolerance gene—tomatoes, later other crops
   - Flood/submergence tolerance—rice
   - Other?

5) Will the Promises for GM Varieties be Realized?
   - Concerns in Europe, US, LDC regarding:
     - Food safety (Bt corn, Roundup Ready soybeans)
     - Environmental impact of GMOs (gene escape—super weeds)
     - Export market impact (EU won’t buy GM crops)
     - Corporate control of biotechnology (a few multinationals own the key genes, processes)
   - Increasingly complex/expensive regulatory environment
     - High cost for testing GMOs (> $30 million)
     - EU regulation on labeling GMOs uncertain
   - GMO research has focused on major crops grown in DCs (corn, cotton, soybeans), neglecting many “orphan crops” grown in LDCs
   - Private biotech firms in DCs not likely to develop GM varieties for farmers in poorer LDCs, who can’t afford to buy the seed
B. **New opportunities** for LDC farmers: Non-Traditional Crops for Niche Markets

1) Mexico—“exotic” crops—avocados, spices (Kalsec)  
   Why?

2) Kenya/India/C. America—horticultural/organic crops for export to Europe/US  
   Why?

3) Colombia—flowers/roses to the US  
   Why?

4) Fair trade—coffee, cocoa, rice, bananas`  
   Why?

5) Peru—endangered *paiches* (fish species)  
   Why?

VI. Future Challenges

A. Will Need To Develop & Promote Many "Greener" Mini-Revolutions  
   - Must "focus" on poor environments (e.g., dry, poor soils)
   - Must improve neglected crops (not just rice, wheat, corn)

B. Future Technology Must be More Environmentally Friendly  
   Examples--IPM, technologies to control erosion, more disease/pest/drought resistant crops, technologies that use water more efficiently (Kenya—water harvesting)

C. **BUT**........  
   Science Alone Can't Solve the Food Problem!
   - Developing country governments must give priority to:
     - Improving rural infrastructure—roads, dams
     - Investing more $ in agricultural research
     - Targeting neglected groups (women & the poor) to insure that they benefit from new agricultural technologies
     - Implement policies to promote agriculture—farmer access to credit, extension, markets (e.g. Ethiopia, commodity exchange; Kenya, internet/phone based marketing)
   - Developed countries can help by:
     - Providing more foreign aid, especially for agricultural research
     - Opening up their markets to LDC’s crops
     - Reducing farm subsidies
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Figure 2.3. Food Problems and Farm Problems Caused by the Relative Rate of Movement of the Supply and Demand Curves

Panel A
- Successful traditional agriculture
- Stable food prices
- Stable per capita food production and consumption
(no income growth)

Panel B
- Unsuccessful agricultural development
- Rising real food prices
- Decreasing per capita production and consumption
(food problem)

Panel C
- Successful agricultural development
- Falling real food prices
- Increasing per capita production and consumption
(farm problem?)

The CGIAR System: Institutes Agricultural Research Institutes

ISNAR
The Hague, Netherlands

ICARDA
Aleppo, Syria

CIMMYT
Mexico City, Mexico

IFPRI
Washington, D.C., United States

IPGRI
Rome, Italy

ITA
Rome, Italy

ICRAF
Nairobi, Kenya

ICRISAT
Borehamwood, India

WARDA
Bouaké, Côte d’Ivoire

IWMI
Colombo, Sri Lanka

ILRI
Nairobi, Kenya

ICLARM
Bogor, Indonesia

CIAT
Cali, Colombia

CIP
Lima, Peru
The response to nitrogen fertilizer of two semi-dwarf rice varieties—IR8 and Taichung Native 1—and of Peta, a tall, traditional variety, in the 1966 dry season on IRRI's experimental farm.