Rice Production and Paddy Irrigation in the Asian Monsoon Region

By

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• Paddy Irrigation
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INTRODUCTION
Food Shortage

- FAO $\rightarrow$ 815 million people undernourished
- 777 million in developing countries of which 504 million from Asia
- 25,000 people die every day from hunger
- World Food Summit (1996) and MDG (2000) goal $\rightarrow$ reduce by 50% by 2015
- Need to reduce by 22 million/yr c.f. current rate only 6 million/yr
FAO estimates of the number of undernourished people in the world are necessarily based on imperfect information. As better data become available, the estimates are revised retrospectively. Range estimates therefore provide a more reliable illustration of the number of undernourished over time. The estimated range for past, projected and target paths is based on a range of 5 percent above and below the past, projected and target numbers considered by the World Food Summit in 1996. Within these ranges, the most recently calculated point estimates are shown. The graph refers to developing countries only, because FAO does not have estimates of the undernourished in developed countries for the reference period [1990–1992] and earlier years.
RICE FARMING
Rice

Family: Poaceae
Genus: Oryza
1. Staple food for half world’s population

- 2 billion people in Asia obtain 60-70% of their calories from rice and its products
- Many by-products
2. Deeply embedded in cultural heritage of Asian societies
   • Ingrained into culture and tradition, festivals, paintings, poems, songs …

3. Important economic sector in many Asian countries
   • Rice-based production systems and associated post-harvest operations employ > 1 billion people in rural Asia
4. Grown in paddy fields
5. Multi-functional roles of paddy fields
Multi-functional Roles

- Source of protein
- Navigation
- Groundwater recharge
- Water purification
- Flood and erosion control
- Air cooling effect
- Aesthetics and landscapes
- Environment eg. migratory birds
Rice Production & Paddy Irrigation

Groundwater recharge

Earthen irrigation canal

Paddy field

Underground aquifer
Redistribution of Solar Energy above Paddy Fields

Fig.1: Two-dimensional air temperature profiles above paddy fields

Air cooling effect
THE CHALLENGES AHEAD
1. Population Growth

- 50% increase in population by 2050
- Rural - urban migration
Rice Production & Paddy Irrigation

World Population

Year

WORLD POPULATION

Ref: UN
ASIA - Population vs Land Area

World - Population

World - Area

40%

60%
DECLINING CONTRIBUTION OF AGRICULTURE - MALAYSIA

% Labour force / agric sector

% GDP / Agric sector


1970

1980

1990

2000
2. Land Utilisation

- 1.5 billion ha used for crop production
- Arable land declined from 0.43 (1962) to 0.26 (1998) ha/person
- Crop production areas growing @ 1.3 % per yr vs 2.2 % during past 30 years
- Harvested area decreasing from 0.113 ha/person to 0.083 ha/person (2030)
- Expansion of land base to marginal lands
Challenges Ahead

3. Water

- Irrigation water use efficiency generally low: 20% (paddy) to 90% drip
- Average for developing countries ~43%
- Need improvement in water productivity → water efficiency & higher crop yields
- Use of lower quality water
- To meet 2025 food production levels need ~ 2,000 cubic km additional water
- 2030 water withdrawals for irrigation in developing countries → 14% increase
- Chronic competition for water expected
Water Withdrawal

- Agriculture: 70%
- Domestic: 20%
- Industry: 10%

Water Consumption

- Agriculture: 93.5%
- Domestic: 3.8%
- Industry: 2.7%
4. Changes in Lifestyle

- More disposal income $\rightarrow$ Change in diet, more consumption of meat
- Developed countries $\rightarrow$ 70-100 kg/p/yr c.f. < 20 kg/p/yr in developing countries
- Developing world catching up
- Need to increase cereal production 1.84 b tons $\rightarrow$ 2.8 b tons by 2030 [50 % food, 44 % feed]
## Water Requirement Equivalent

<table>
<thead>
<tr>
<th>Food Product</th>
<th>Unit</th>
<th>Equivalent water, m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>head</td>
<td>4,000</td>
</tr>
<tr>
<td>Sheep and goats</td>
<td>head</td>
<td>500</td>
</tr>
<tr>
<td>Fresh beef</td>
<td>kg</td>
<td>15</td>
</tr>
<tr>
<td>Fresh lamb</td>
<td>kg</td>
<td>10</td>
</tr>
<tr>
<td>Fresh poultry</td>
<td>kg</td>
<td>6</td>
</tr>
<tr>
<td>Wheat</td>
<td>kg</td>
<td>1</td>
</tr>
<tr>
<td>Rice</td>
<td>kg</td>
<td>2</td>
</tr>
<tr>
<td>Citrus fruits</td>
<td>kg</td>
<td>1</td>
</tr>
<tr>
<td>Palm oil</td>
<td>kg</td>
<td>2</td>
</tr>
<tr>
<td>Pulses, roots, tubers</td>
<td>kg</td>
<td>1</td>
</tr>
</tbody>
</table>

Ref: FAO
5. Investments in Irrigation and Drainage

- Reduction in irrigation investment
- World Bank funding: US$ 1.5 b → US$ 300 - 400
- Number of projects 20-25 → 5-6
- New projects → Rehabilitation
- Avoiding controversial projects
Irrigation Expansion

Ref: Hopper
Environment

- Irrigation and Drainage schemes perceived as not friendly to environment
- Over-extraction of groundwater
- Salinization of soils
- Use of chemicals, fertilisers, pesticides
Global Fertilizer Usage

Ref: FAO

Present: 43%
Future: 84%

Graph showing the percentage of global fertilizer usage.
### Top 10 Rice Producers, 2003

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Paddy Production, metric tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>China</td>
<td>166,000,000</td>
</tr>
<tr>
<td>2.</td>
<td>India</td>
<td>133,513,000</td>
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<tr>
<td>3.</td>
<td>Indonesia</td>
<td>51,849,200</td>
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<tr>
<td>4.</td>
<td>Bangladesh</td>
<td>38,060,000</td>
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<tr>
<td>5.</td>
<td>Viet Nam</td>
<td>34,605,400</td>
</tr>
<tr>
<td>6.</td>
<td>Thailand</td>
<td>27,000,000</td>
</tr>
<tr>
<td>7.</td>
<td>Myanmar</td>
<td>21,900,000</td>
</tr>
<tr>
<td>8.</td>
<td>Philippines</td>
<td>13,171,087</td>
</tr>
<tr>
<td>9.</td>
<td>Brazil</td>
<td>10,219,300</td>
</tr>
<tr>
<td>10.</td>
<td>Japan</td>
<td>9,863,000</td>
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</table>

Ref: FAO
<table>
<thead>
<tr>
<th></th>
<th>1997/98</th>
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<th>2000/01</th>
<th>2001/02</th>
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<td>OP</td>
<td>T</td>
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<tr>
<td>Asia</td>
<td>-81.9</td>
<td>-8.3</td>
<td>-79.3</td>
<td>-7.8</td>
<td>-81.1</td>
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<td>-30.8</td>
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<td>77.7</td>
<td>14.6</td>
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<td>15.1</td>
<td>3.4</td>
<td>22.8</td>
<td>5.8</td>
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<td>17.9</td>
<td>56.1</td>
<td>20.9</td>
<td>61.3</td>
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<td>World</td>
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<td>0.2</td>
<td>0</td>
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<td>Developed Countries</td>
<td>99.6</td>
<td>11.4</td>
<td>111.8</td>
<td>13.3</td>
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<td>Emerging developing countries</td>
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<td>-5.7</td>
<td>-65.5</td>
<td>-5.9</td>
<td>-74.5</td>
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<td>Least developed Countries</td>
<td>-37.1</td>
<td>-26.6</td>
<td>-43</td>
<td>-29.4</td>
<td>-42.8</td>
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</tbody>
</table>

Source: Schultz et al. (2003)
INCREASE RICE PRODUCTION

POPULATION GROWTH

CHANGES IN DIET

ANIMAL FEED
INCREASE RICE PRODUCTION

HORIZONTAL DEVELOPMENT

VERTICAL DEVELOPMENT
Horizontal Development

Development of New Rice Production Areas
Global Rice Outlook

- Increase of 40%
- Require additional 9.8 million ha of land
- Assuming yields of 3.2 tons of rice per ha.

Rice Production & Paddy Irrigation

1990
455.2 million tons

2020
781.3 million tons

International Rice Research Institute

Global Rice Outlook
Cropland in use and total suitable land (million ha)

Limited Arable Land and Competition for other Usage

Ref: FAO data and Fischer et al. (2000)
INCREASE RICE PRODUCTION

HORIZONTAL DEVELOPMENT

VERTICAL DEVELOPMENT
Vertical Development

Cropping Intensity

Higher Yields
Cropping Intensity

- Growing more intense / frequently on same piece of land, thus increasing crop production
- Soil management important
- Water may be limiting resource
- Irrigation and Drainage facilities needed in many situations
PRODUCTION INCREASE IN DEV. COUNTRIES

70 % - Higher Yields

30 % - Other Factors

Source: FAO
### Average Yields

**Average yield (tons/ha) of rice, wheat, maize, 1960 and 1994**

<table>
<thead>
<tr>
<th>Region</th>
<th>Rice</th>
<th></th>
<th>Wheat</th>
<th></th>
<th>Maize</th>
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<tr>
<td>Sub-Saharan Africa</td>
<td>0.90</td>
<td>0.93</td>
<td>0.77</td>
<td>1.61</td>
<td>1.10</td>
<td>1.25</td>
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<td>Latin America</td>
<td>1.22</td>
<td>1.95</td>
<td>1.06</td>
<td>2.2</td>
<td>1.23</td>
<td>2.31</td>
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<td>South Asia</td>
<td>1.03</td>
<td>1.82</td>
<td>0.81</td>
<td>2.17</td>
<td>1.05</td>
<td>1.66</td>
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<td>Middle East</td>
<td>1.52</td>
<td>2.37</td>
<td>0.77</td>
<td>1.59</td>
<td>1.09</td>
<td>3.00</td>
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<td>North Africa</td>
<td>3.34</td>
<td>4.99</td>
<td>0.77</td>
<td>1.9</td>
<td>1.59</td>
<td>5.05</td>
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<tr>
<td>East Asia</td>
<td>3.08</td>
<td>4.49</td>
<td>2.08</td>
<td>2.73</td>
<td>2.14</td>
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<td>European Union</td>
<td>3.11</td>
<td>3.73</td>
<td>1.92</td>
<td>5.37</td>
<td>2.69</td>
<td>7.65</td>
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<tr>
<td>United States</td>
<td>2.72</td>
<td>4.67</td>
<td>1.76</td>
<td>2.53</td>
<td>3.43</td>
<td>8.68</td>
</tr>
</tbody>
</table>
INCREASE YIELDS

MORE FERTILIZER/PESTICIDE
Effect of Fertilizers on Yields
INCREASE YIELDS

MORE FERTILIZER/PESTICIDE

NEW TECHNOLOGY
Objective:

Development and integration of remote sensing, GIS, GPS and related technologies for efficient and precision plantation management to increase national rice and oil palm production and quality of environment.

Use of Technology - Precision Farming
Sprinklers for rice, Brazil

Water use reduced to one quarter (¼) cf. flood irrigation
INCREASE YIELDS

MORE FERTILIZER/PESTICIDE

NEW TECHNOLOGY

CAPACITY BUILDING
Accept new ways, farmers advised

KUALA LUMPUR, Mon. — “We don’t feel so confused and lost now,” said farmer Awang Taha from Terengganu.

“Now that things have been explained to us and the direction laid out, there is hope that things will improve,” he added.

Awang, one of 2,500 farmers who attended a Farmers’ Organisation Authority gathering at the Putra World Trade Centre, was referring to the Agriculture and Agro-Based Industries Minister’s message to change attitudes and embrace technology.

Tan Sri Muhdyidin Yassin had reminded farmers to change their laid-back ways to improve their livelihoods.

“Our neighbour, Thailand, is now the ‘kitchen of the world’ as they have succeeded in large-scale food production. What is it they have that we do not?”

“There is a dire need for farmers to be aware of new things and be ready to accept changes.

“Attitudes and practices must change. I ask that farmers adopt a mental revolution in the way they work,” he said.

For modern farming to succeed, farmers had to improve their skills by taking part in training courses to learn the best practices.

“Farmers’ associations should organise more hands-on courses continuously, so they can learn the latest technology and issues like quality products or pesticide use.”

Muhdyidin spoke of the Government’s efforts to improve the sector, such as new incentives to attract private players and make agriculture a growth engine of the economy.

To make the sector more dynamic, he said the ministry was also prepared to review any restrictive rules and ensure there was sufficient staff in its district and state offices.

“However, to make the country self-reliant in food by 2010, a transformation is needed. It is not just about changing agricultural activities.

“It needs a change in the way farmers, fishermen and livestock breeders think and put effort into learning new things,” he said.

Abdul Majid Adam, another farmer from Terengganu, said Muhdyidin’s speech would give farmers the drive to work harder.

“The change in attitude that he spoke of is necessary because we are really behind,” he said.

Muhdyidin later said he wanted the Farmers’ Organisation Authority to play a more prominent role in educating farmers.

The new incentives for agriculture were being finalised by the ministry, and would be discussed with the Finance Ministry this month.
INCREASE YIELDS

MORE FERTILIZER/PESTICIDE

NEW TECHNOLOGY

CAPACITY BUILDING

IRR & DR FACILITIES
World Food Production

- 40% Irrigated
- 17% Non-Irrigated

World - Food
World - Area

Ref: Postel
Figure 3  Typical response to water for cereal crops

- High-yielding varieties, high inputs
- High-yielding varieties, low inputs
- Traditional varieties, high inputs
- Traditional varieties, low inputs

Water availability (m³/ha)

Cereal production (kg/ha)
Rice Production & Paddy Irrigation

Source: Kawasugi
INCREASE RICE PRODUCTION

HORIZONTAL DEVELOPMENT

VERTICAL DEVELOPMENT
Sources of growth in production, 1961 to 1999

Ref: FAO
PADDY IRRIGATION
1. Providing Irrigation and Drainage Infrastructure

- Irrigation infrastructure for more reliable water supply / off-season supply
- Drainage infrastructure to remove excess water
- Drainage infrastructure to improve soil bearing capacity to facilitate harvesting, mechanisation
- Road network for access, transportation
### Irrigated and Drained Areas

<table>
<thead>
<tr>
<th>Continent</th>
<th>Irrigated Area Mha</th>
<th>Drained Area Mha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total -101 countries</td>
<td>262.10</td>
<td>171.39</td>
</tr>
<tr>
<td>Americas</td>
<td>40.75</td>
<td>64.56</td>
</tr>
<tr>
<td>Europe</td>
<td>23.46</td>
<td>46.06</td>
</tr>
<tr>
<td>Oceania</td>
<td>2.66</td>
<td>2.17</td>
</tr>
<tr>
<td>Africa</td>
<td>11.72</td>
<td>3.88</td>
</tr>
<tr>
<td>Asia</td>
<td>183.51</td>
<td>54.72</td>
</tr>
</tbody>
</table>

Ref: ICID 2000
Rate of Increase of Irrigated Area

Developed Countries

Developing Countries

World

China

India

Area (M Ha)


Future Prospects
New Irrigation & Drainage Projects

1. Rising capital cost
2. Low return on capital
3. Problem of operation and maintenance
4. Low efficiency of water use.

5. Low level of water charges and revenues
6. Environmental impacts of projects (dams)
7. Degradation of natural resources
2. Improving Water Use Efficiency
More Crop Per Drop

More Crop Less Drop
Less Drop

Improving Water Efficiency
World Summit on Sustainable Development (WSSD) J’burg 2002

WSSD Plan of Action

• “To develop integrated water resource management and water efficiency plans by 2005”
Improving Water Efficiency

- Systems
- Improving O&M
- Cost Recovery
- Modernisation

WATER USE
Benchmarking

- Comparing and assessing scheme’s performance
- Improve weaknesses
- Learn, borrow, adapt best management practices
Cost Recovery

- Wastage because of little or no water recovery cost from farmers
- Where available, quantum low and inadequate
- Need adequate and appropriate charges, with measurement system
“Irrigation Modernisation is a process of technical and managerial upgrading of irrigation scheme combined with institutional reforms with the objective to improve resource utilisation (labour, water, economic, environmental) and water productivity”
Institutional Reforms

- Wider stakeholders’ participation
- Water user groups, Farmers Associations
- Turnover programs
- Participatory Irrigation Management (PIM)
- Governance
3. Improving Rain-fed Areas

- Represents 87% of cropped land
- Small improvement → large impact
- Subjected to risk of droughts and floods
- Providing basic infrastructure
- Small scale projects
World - Area

RAIN-FED

World - Food

WORLD FOOD PRODUCTION

Ref: Postel
4. Knowledge Development

- Research & Development
- Improvements to systems and processes
- Field application / best practices
- Better risk management models
- Capacity building, humanware, TOT
5. Integrated Approach

- Holistic view
- Hardware & software
- Integration within scheme
- Integration within river basin
- Irrigation and Drainage as a component of IWRM
### 6. ICID Strategies

<table>
<thead>
<tr>
<th>Category of countries*</th>
<th>Food Self Sufficiency</th>
<th>Economic Status (GNP)</th>
<th>Population</th>
<th>Status of WRD</th>
<th>Governance</th>
<th>Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Deficient</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Deficient</td>
<td>Aid, Investment, Develop Water Resources, Improve Efficiency, Population Control</td>
</tr>
<tr>
<td>II</td>
<td>Deficient</td>
<td>High</td>
<td>Low</td>
<td>Adequate</td>
<td>Adequate</td>
<td>Virtual Water - Import</td>
</tr>
<tr>
<td>III</td>
<td>Sufficient</td>
<td>Low and Low Medium</td>
<td>High</td>
<td>Medium</td>
<td>Evolving</td>
<td>Investment, Develop Water Resource, Improve Efficiency, Population Control</td>
</tr>
<tr>
<td>IV</td>
<td>Surplus</td>
<td>High</td>
<td>Low</td>
<td>Adequate</td>
<td>Adequate</td>
<td>Trade - Export</td>
</tr>
</tbody>
</table>

* Categories of countries arranged from Deficiency to Surplus food self-sufficiency.

Category I : Many countries in Sub-Saharan Africa
Category II : Saudi Arabia, Japan etc.
Category III : India, China etc.
Category IV : USA, Canada etc.
CONCLUSION
1. Food Production in Asia → Pressing problems to be solved

- Population growth
- Increasing food production
- Water issues
- Environmental issues
Conclusion

2. Irrigation and Drainage
   Significant enablers in meeting challenges
   • Enabling role to achieve required production increase
   • Small scale infrastructure → Significant improvement to rain-fed areas
   • Need to be more environment friendly
3. Need to improve on water use efficiency
   • More Crop Less Drop

4. Holistic approach → IWRM