Applying the New Economy to the Sustainable Irrigated Paddy Rice Agriculture and Ecosystems

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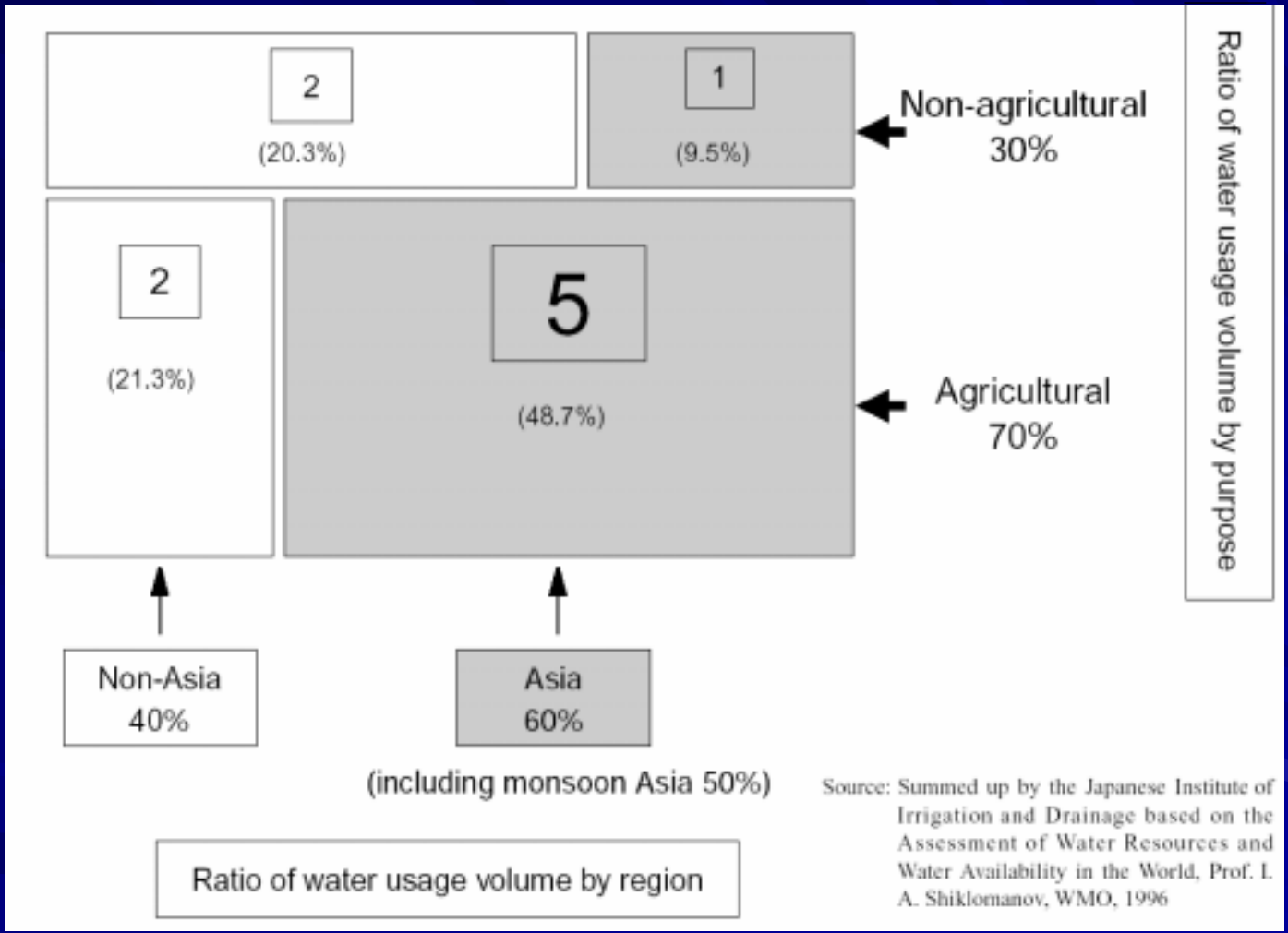
Contents

- Magnitude of impact in the world and attribution of water use for paddy agriculture in the Asian monsoon region
- True relation between irrigated paddy rice agriculture and ecosystems in humid regions
- Socio-economic mechanisms behind the remarkable sustainability of a paddy irrigation system in the Asian monsoon region
- Conclusion

Proportion of water usage worldwide by purpose and region[1]

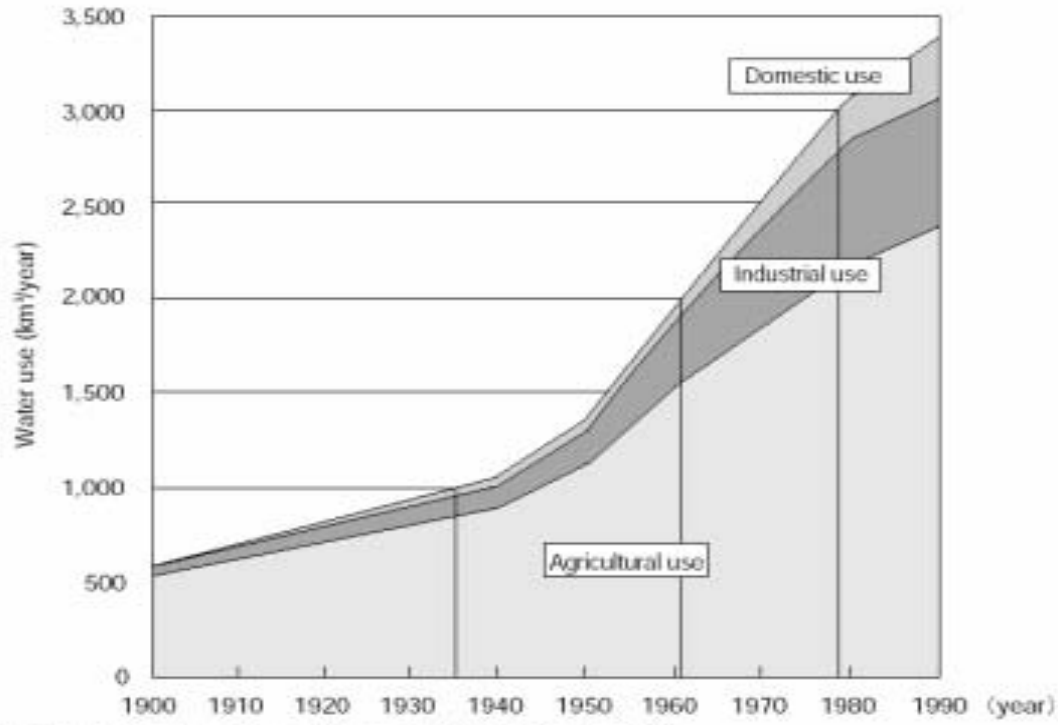


1 Yamaoka K, Ochii Y (2003) Why a Message from Japan and Asia Now, A Message from Japan and Asia to the World Water Discussions, The Japanese Institute of Irrigation and Drainage (JIID), Tokyo, Japan, p. ii

- Sharp increase in demand of global water use especially for domestic and industrial use puts pressure on water allocation

But agriculture still account for 70 % of world water use

Transitions in world water use*



Source: I. A. Shiklomanov, Assessment of Water Resources and Water Availability in the World, 1996 (WMO)

World water use and per-capita water usage in 1950 and 1995*

	1950		1995		Rate of increase	
	Total volume (1)	Per-capita (2)	Total volume (3)	Per-capita (4)	(3)/(1)	(4)/(2)
	(km3/yr)	(L/day/person)	(km3/yr)	(L/day/person)	(%)	(%)
Agricultural use	1,124	1,235	2,504	1,231	223	100
Industrial use	182	200	714	351	392	176
Household use	53	58	354	174	668	300
Total	1,359	1,493	3,572	1,756	263	118
Population	2.49 billion	—	5.57 billion	—	224	—

Source: I. A. Shiklomanov, Assessment of Water Resources and Water Availability in the World, 1996 (WMO)

* Yamaoka K, Ochii Y (2003) Why a Message from Japan and Asia Now, A Message from Japan and Asia to the World Water Discussions, The Japanese Institute of Irrigation and Drainage (JIID), Tokyo, Japan, pp. 9-10

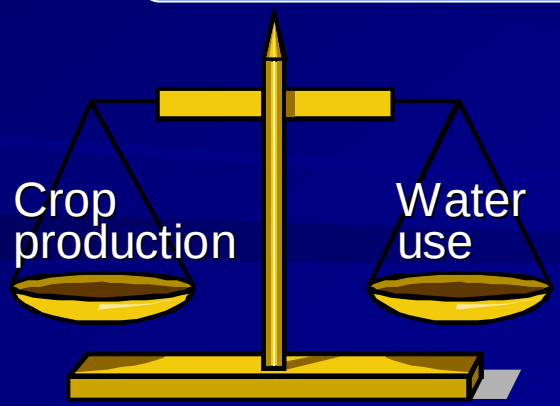
Arguments of international water discussions

- Water is indispensable for human activities
- Agriculture is the biggest water user
- Global water supply meets with a limitation

Increase water use efficiency in agriculture!!

= Reduce water use for agriculture to protect ecosystems!!

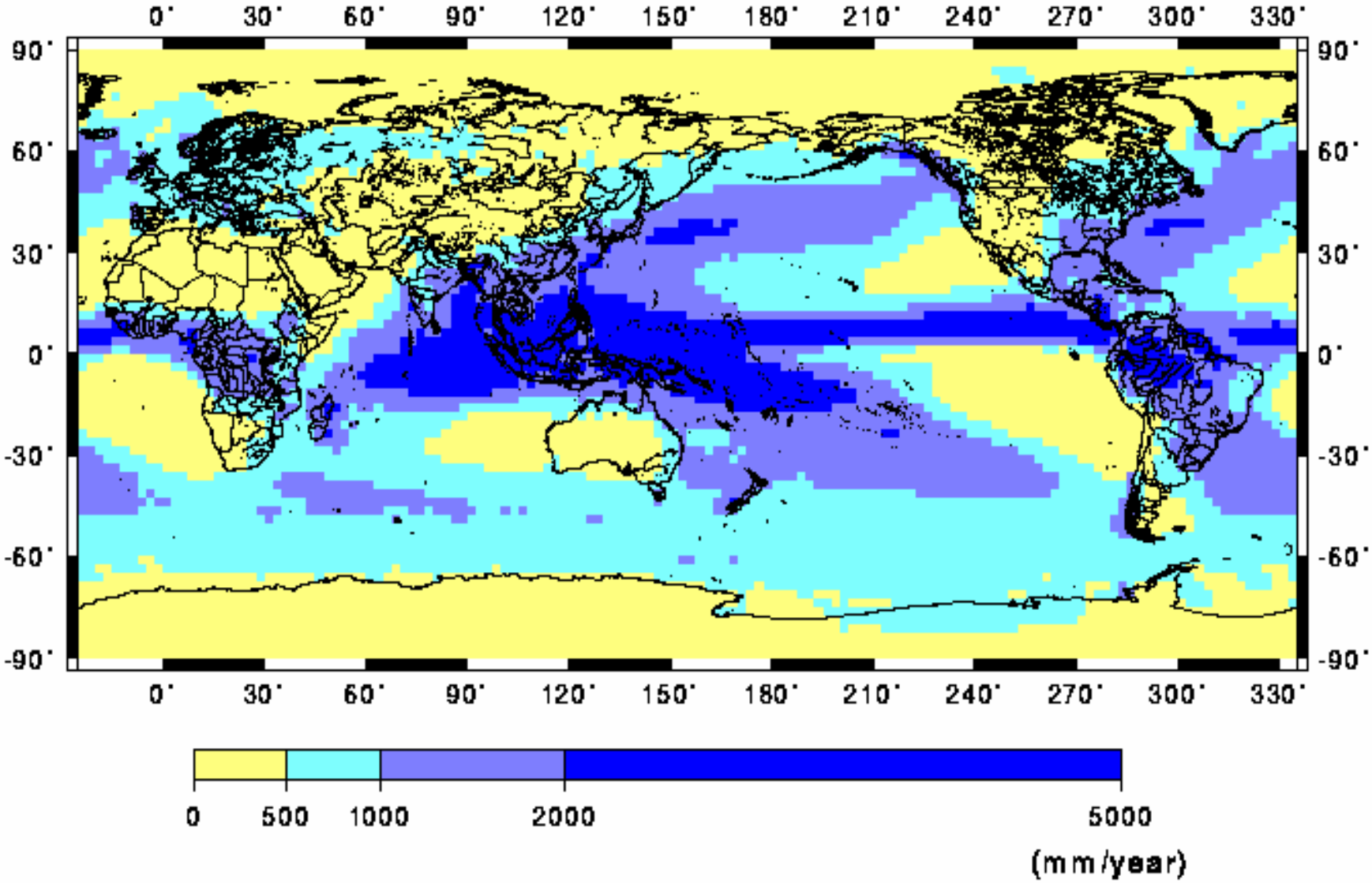
This concept adapts well to arid regions



Definition of water use efficiency

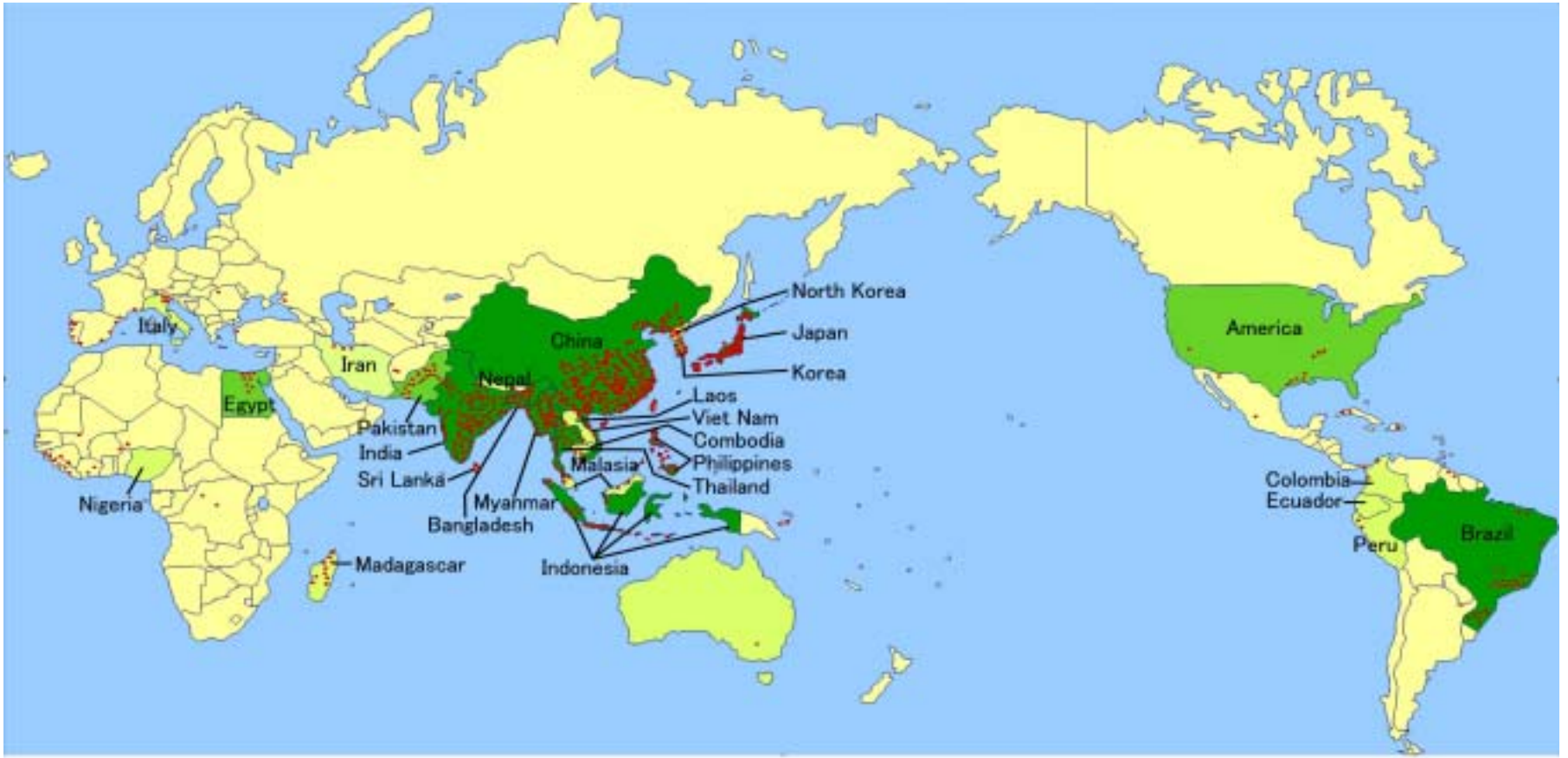
ex.

$$\text{Water Productivity} = \frac{\text{Crop production}}{\text{Amount of water use}}$$



Mean Annual Precipitation (Average of 1979-1999)

Major rice production area in the world



Regional ratio of production of rice (2002)

Asia	516,398,800 ton (90.7%)
South Africa	19,608,477 ton (3.4%)
Africa	16,866,611 ton (3.0%)
North/Central America	12,133,719 ton (2.1%)
Europe	3,209,583 ton (0.6%)
Oceania	1,309,652 ton (0.2%)

Legend: Annual production in main producing countries (2002)

- over 10 million tons/year
- 5–10 million tons/year
- 1– 5 million tons/year

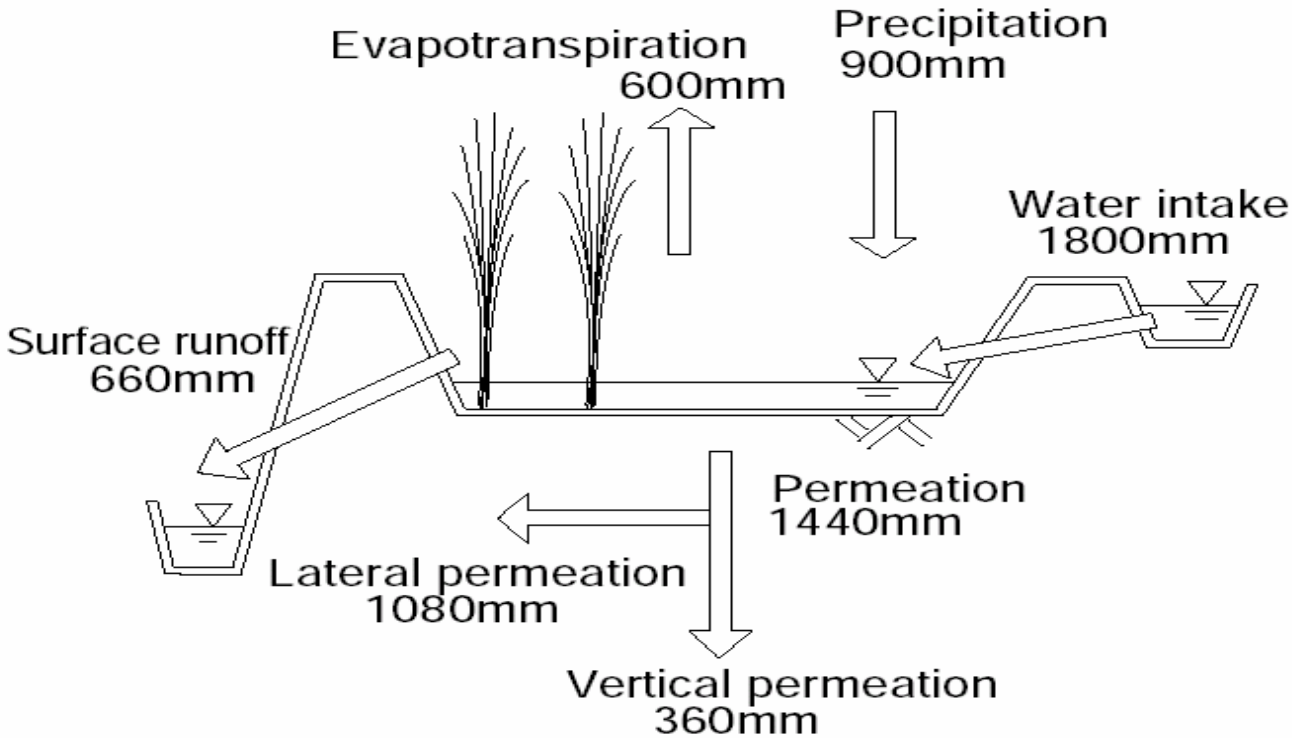
Source: FAOSTAT, Oxford Economic Atlas

Water balance in rice paddies [1)]

The water balance in rice paddies is expressed by the following equation.

Water intake = evaporation & dissipation + permeation + surface runoff - rainfall + change in stored volume

Water balance in rice paddy field during the Irrigation period (120 days) [2)]



Note: Since the amount of evapotranspiration , permeation, etc., differ depending on the climate of the area, soil conditions and other factors, the total water volume in the diagram is a rough estimation.

1) Yamaoka K, Ochii Y (2003) Why a Message from Japan and Asia Now, A Message from Japan and Asia to the World Water Discussions, The Japanese Institute of Irrigation and Drainage (JIID), Tokyo, Japan, p. 41

Diverse advantages to reduce labor force and investments in farming[1]

Items	Advantages provided through paddy rice agriculture with plentiful water
a) Reducing weed control	Flooding can prevent growth of weeds, except vascular plants like reeds that normally grow quickly and thickly when the soil is not submerged in the wet and warm climate.
b) Preventing soil erosion	Use of levees around rice fields and a standing pool of water reduce soil erosion-losses even during periods of heavy rain. In fact rice paddies act as a settling basin for suspended sediments in water.
c) Reducing fertilization	Organic matter in the soil decomposing slowly through anaerobic decomposition when the soil is flooded maintains soil fertility. Organic nitrogen is transformed into ammonia nitrogen while the soil is under reduced conditions and nitrogen is easily taken up by plants and attaches to soil particles. Less phosphate fertilizer is required for flooded soils because soluble, plant-available phosphates are formed while the soil is in a reduced state.
d) Reducing plowing	Paddy rice cultivation in clay-rich soil involves a year long process whereby flooding expands and softens the soil (swelling) and drying shrinks the soil forming cracks. This process increases the pore space between grains of soil, which facilitates movement of water, improves soil leaching that occurs with rainfall and prevents the buildup of salts in the soil.
e) Preventing a fall in yield from repeated cropping	The soil is under reduced conditions when it is flooded and becomes oxidized when water is drained. This process promotes alternation between anaerobic and aerobic microbes, which maintains bacterial balance and soil fertility and prevents a fall in yield from repeated cultivation of the same crop on the same ground.

1 Yamaoka K, Horikawa N, Tomosho T (2004) Water Productivity and Economic Externalities of Rice Paddy Agriculture in the Asian Monsoon Region, The Collection of Theses of International Academic Forum for 2260th Anniversary of the Founding of Du Jiang Yan Irrigation System, Sichuan Dujiangyan Irrigation System Administration, pp.303-311

Socio-economic externalities generated by irrigation and rice paddy agriculture in the Asian monsoon region

Automatically provided by agricultural activities

a-1. Multiple use of water by farmers and residents

Aquaculture, duck raising, washing, cleaning, bathing, cooling, gardening, fire fighting, etc.

a-2. Nonuse-value in cultural-religious activities

a-3. Multifaceted socioeconomic benefits to the public

Protect aqua-ecosystem, enhance water-related environment, form landscape, recharge groundwater aquifer, stabilize downstream river flow by returned flow, etc.

b. Intentionally provided by special consideration and actions

- Provide water from agriculture for domestic use during severe dry spells
- Increase performance of paddy fields as outflow-retarding reservoirs during extreme floods
- Create winter sanctuaries for migratory birds
- Restore groundwater level for downstream city, etc.

Nakamura R (2004) Development of Sustainable Agriculture Based on Rice, Water and the Living Environment, World Rice Research Conference 2004 Abstract, pp.4-9

Monetary Estimation for Multifunctional Roles of Agriculture in Japan

Unit: Billion Yen

	National Agricultural Research Institute (1998)	Mitsubishi Research Institute (2001)
Flood Damage Relief	*2,879*	*3,499*
Stabilizing Downstream River Flow	*1,289*	*1,463*
Groundwater Recharge		*54*
Preventing Soil Erosion	*285*	*332*
Preventing Landslide and Collapse	*143*	*478*
Organic Waste Treatment	*6*	*12*
Atmospheric Purification	*10*	*-*
Climate Regulation	*11*	*9*
Recreational and Relaxing Function	*2,257*	*2,376*
Total	*6,879*	*(8,223)*

Note: Amount in brackets is calculated by author

Paddy rice agriculture in humid region attributes to…

Normally in the wet season…

- Plenty of rainfall in the wet season
- Ample water use can reduce labor cost for farming
- Ample agricultural water generates vast externalities

During occasional dry spells in the wet season…

- Temporally additional labor can reduce water use
- Fairy saved water allocation is desirable

Such external economies rarely bring farmers economic gain, however, remarkable sustainability of irrigated paddr rice agriculture has been observed in various areas of the Asian monsoon region

Hardly any studies exist that clearly explain it from a socio-economic perspective

Battambang, Cambodia

a-1. Multiple use of water by farmers and residents

- Aquaculture, duck raising, washing, cleaning, bathing, cooling, gardening, fire fighting, etc

Fish farming in rice paddy

Nong Khai, Thailand

Socio-economic externalities generated by irrigation and rice paddy agriculture in the Asian monsoon region

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Nakamura R (2004) Development of Sustainable Agriculture Based on Rice, Water and the Living Environment, World Rice Research Conference 2004 Abstract, pp.4-9

a-2. Nonuse-value in cultural-religious activities

- Worshiped and ritual image, symbolic implication for unifying community, etc.

The irrigation system itself is worshipped in Bali, Indonesia.

a-3. Multifaceted socioeconomic benefits to the public

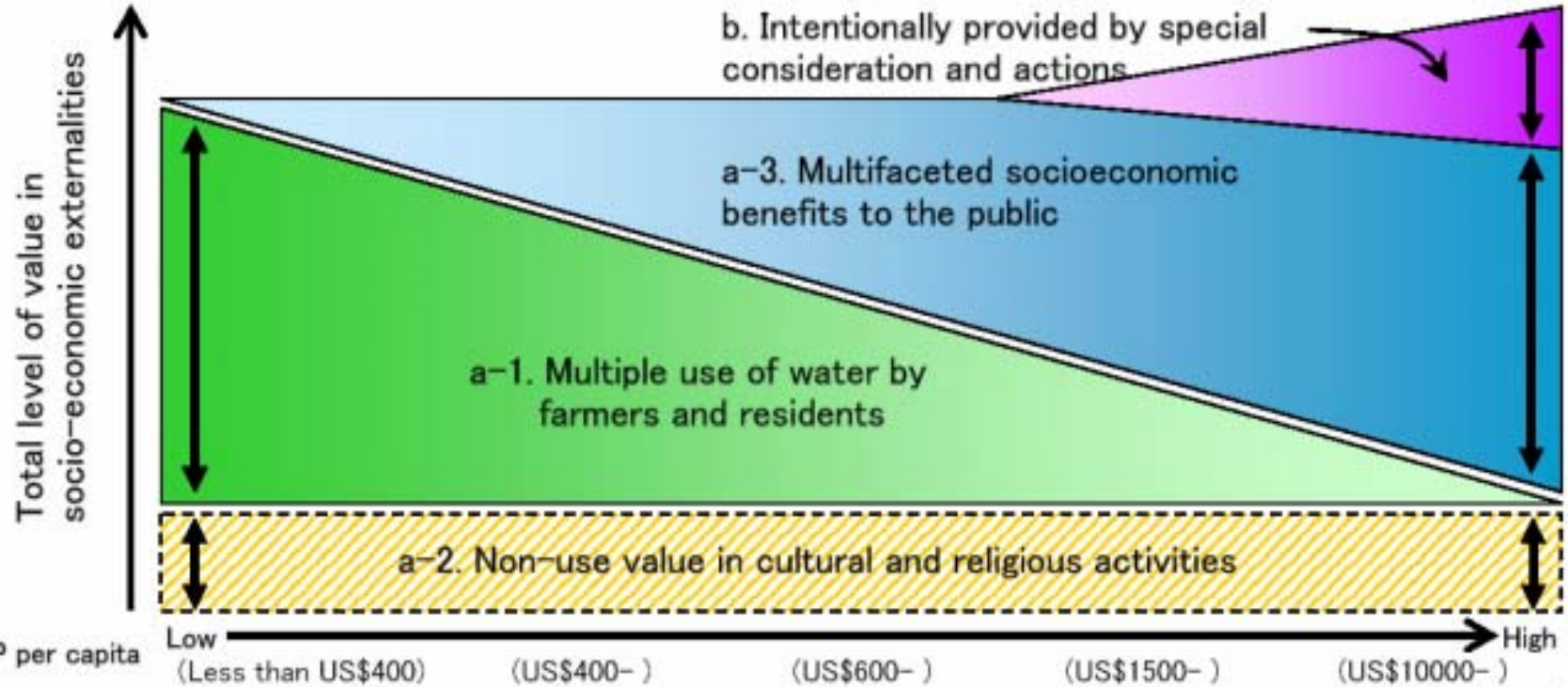
- Protect aqua-ecosystem, enhance water-related environment, prevent landscape, recharge groundwater, stabilize downstream river flow by returned flow, etc.

Paddy field as a feedin and dwelling place for migratory birds in winter.

Kaga-city, Ishikawa Pref. Japan

(http:www.jawgp.org/anet/)

Socio-economic development and externalities generated by irrigation and rice paddy agriculture in the Asian monsoon region

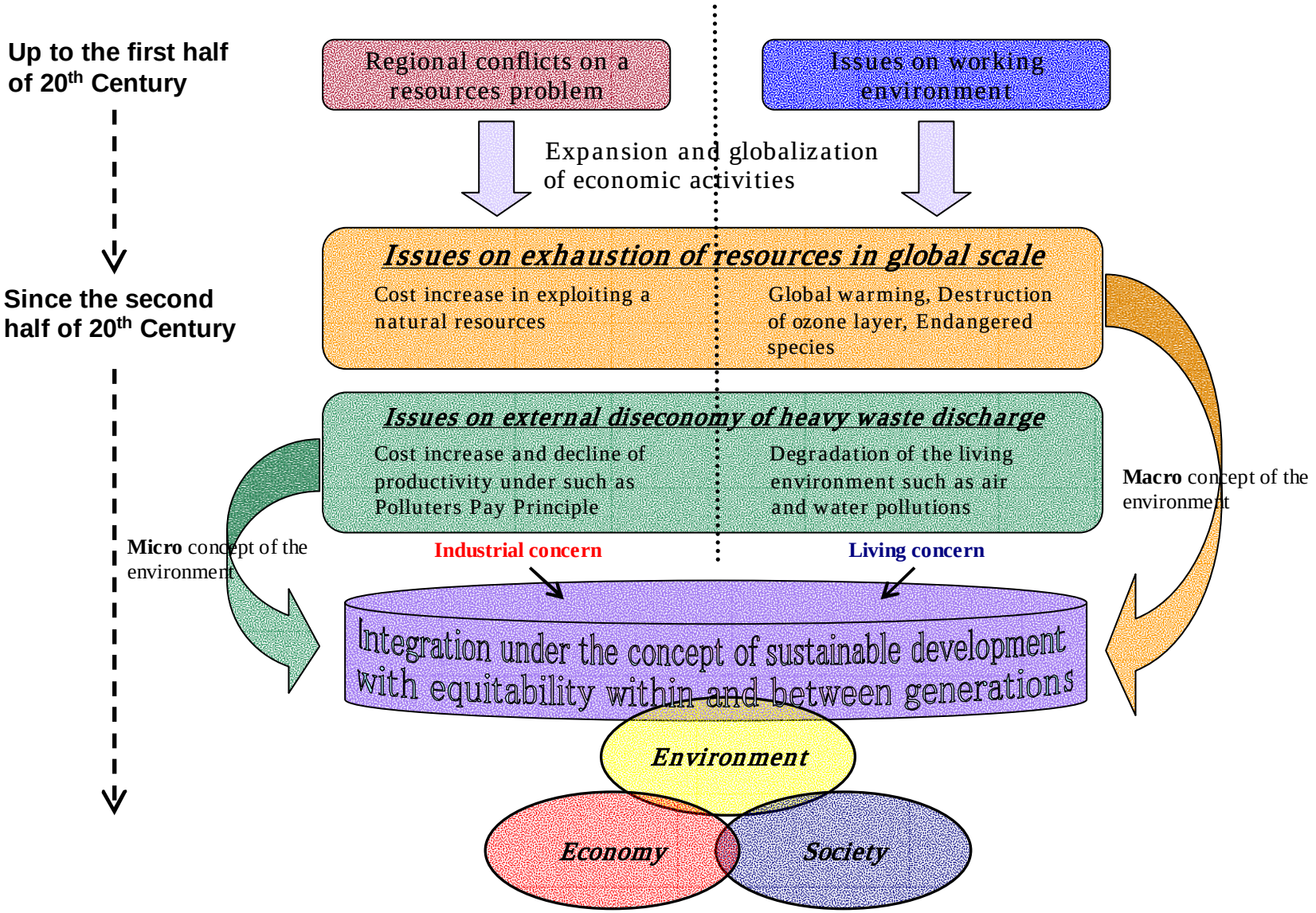


Irrigation	Small scale traditional irrigation (natural river flow)	Large scale development in the plain area (water resources and main facility)	Improving water management and on-farm irrigation technology	Strong requirement for supplying water in cities and improving agricultural water use efficiency	Restoring facility and enhancing to provide benefits to the public
Socio-economic situation	Agriculture as a national key industry Expansion of population Poverty as a whole Fragile national finance	Agriculture as a national key industry Expansion of population Poverty in rural area Tight national finance	Socio-economic disparity between city and rural Overcrowded city problems Promoting industrialization	Diminishing propotion of agriculture in GDP Rural development for good living environment	Diminishing propotion of agriculture in GDP Rural development for good living environment Preserving environment Providing paddy
Typical countries	Laos, Cambodia	Viet-num, Myanmer	China, Indonesia,	Thailand, Malaysia	Korea, Japan

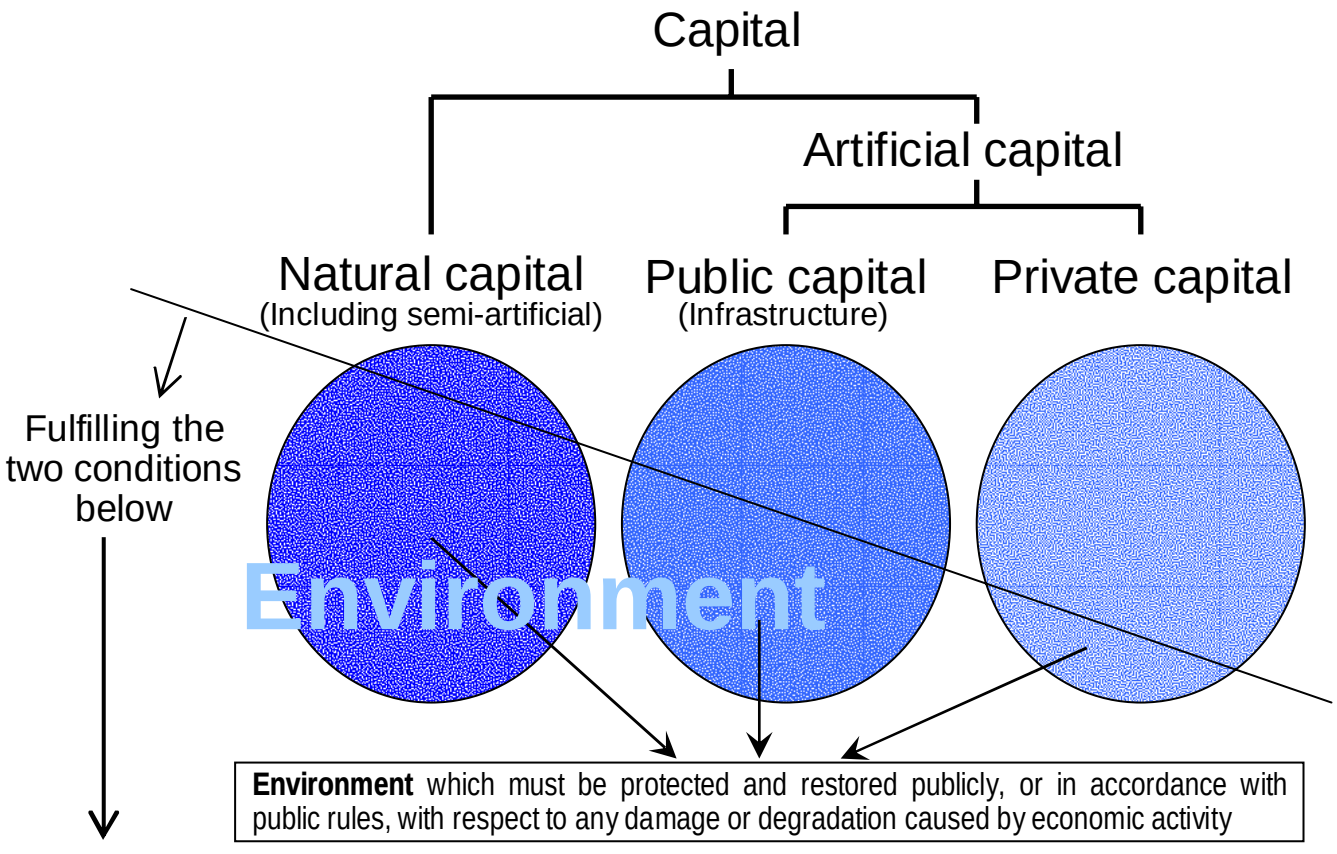
In traditional irrigation systems collectively managed by farmers in various parts of the Asian monsoon region,…

- Does the economy and the ecosystems stand face to face each other?
- Does the active economy impact on the passive ecosystems with external diseconomy or economy?
- Or can we recognize/define the irrigation systems as a part of the ecosystems?

Development of concept on the environment in the 20th Century

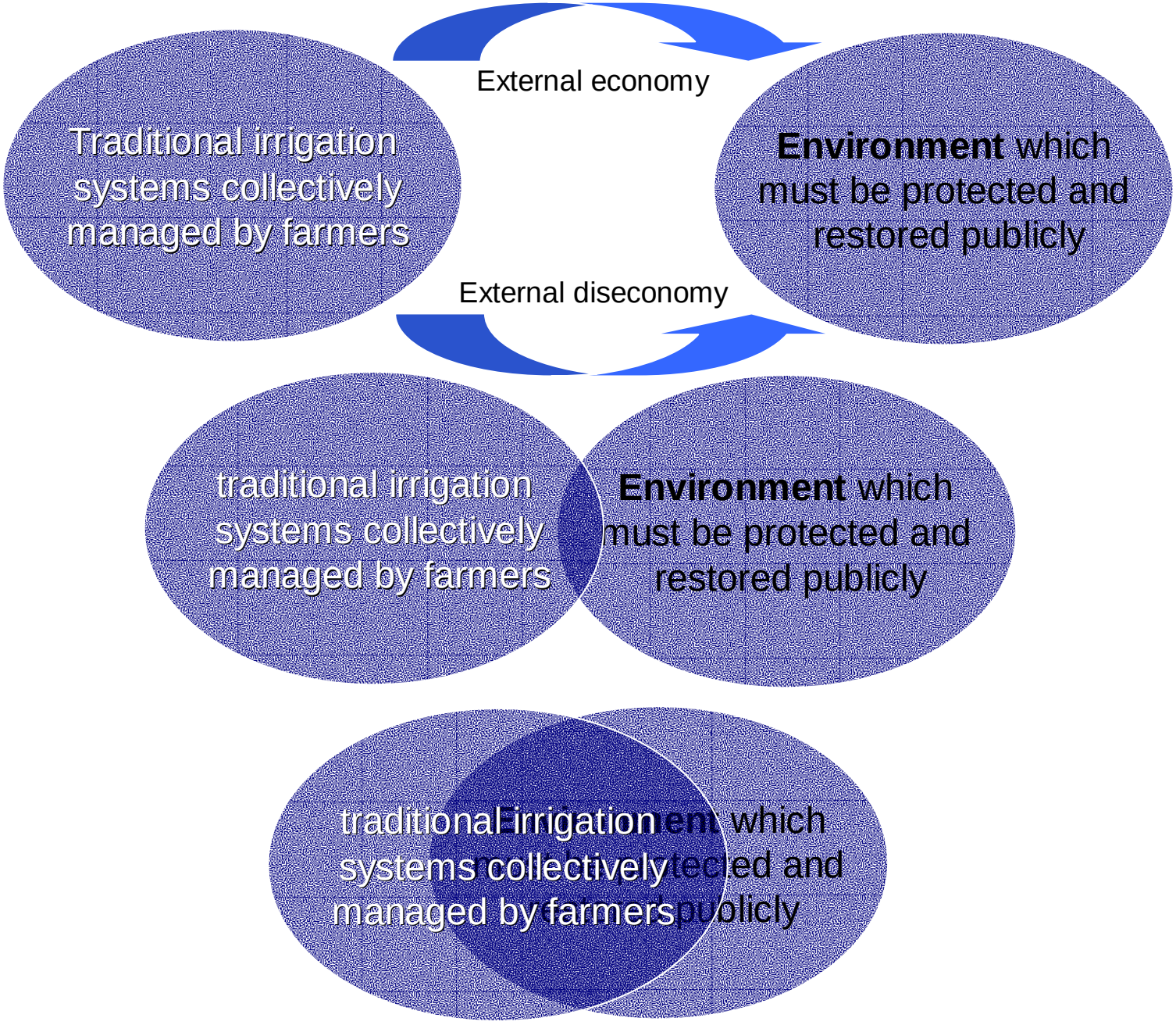


New definition of **environment** which must be protected and restored publicly, or in accordance with public rules



(a) Concerning its provision of goods and services, the capital provides essential goods and services on people's life by means of open access for beneficiaries or with considerable number of free riders unavoidable.

(b) Concerning investment for maintaining and restoring it, the capital is subject to severe degradation and depletion in the course of providing goods and services, unless it can receive investment under public and collective control.


External economy
Traditional irrigation systems collectively managed by farmers
Environment which must be protected and restored publicly
External diseconomy
traditional irrigation systems collectively managed by farmers
Environment which must be protected and restored publicly
traditional irrigation systems collectively managed by farmers

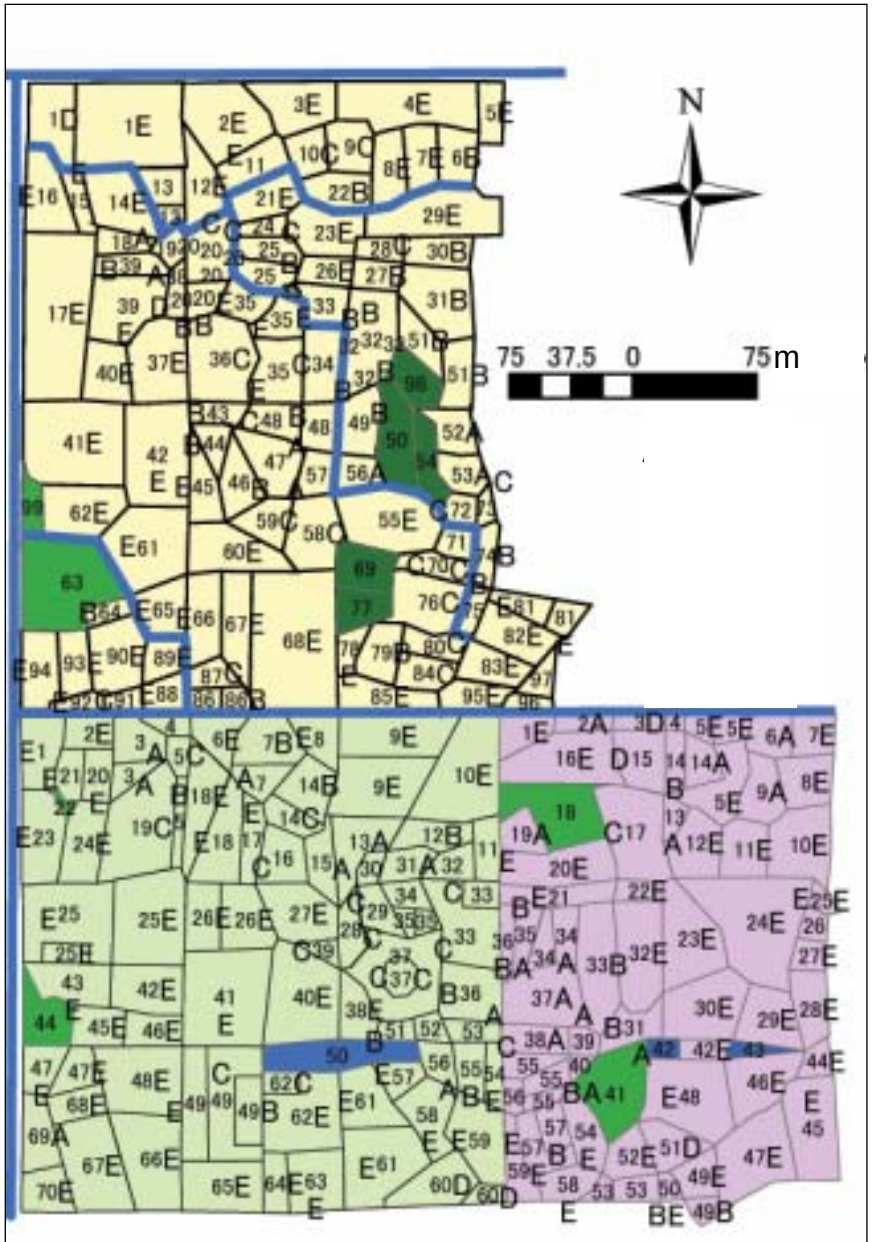
What constitutes good governance for the capital duplicated by irrigation systems and ecosystems?

- Plenty of rainfall in the wet season
- Ample water use can reduce labor cost for farming
- Ample agricultural water generates vast externalities
- Temporally additional labor can reduce water use
- Fairy saved water allocation is desirable

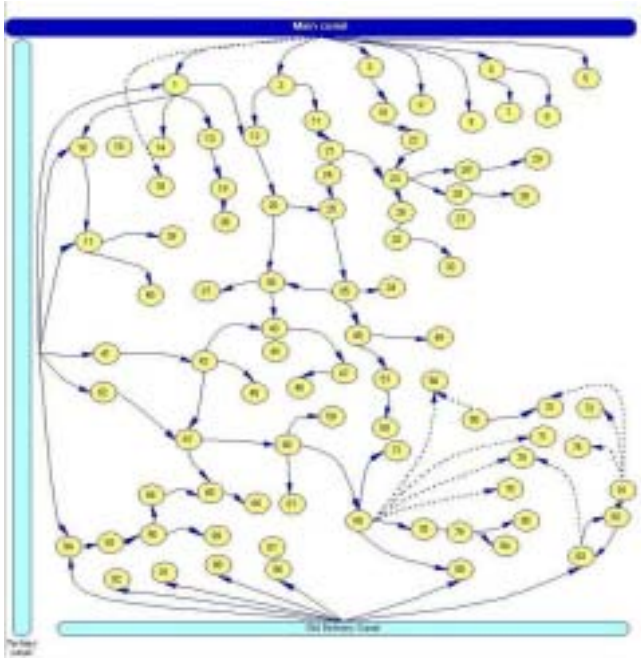
- Advantageous institutional framework set up and run by the initiative of individual farmers
- Establishment of a network among farmers underpinned by trust and spirit of reciprocity
- That is a “social capital”

Complicated relations among farmers on water

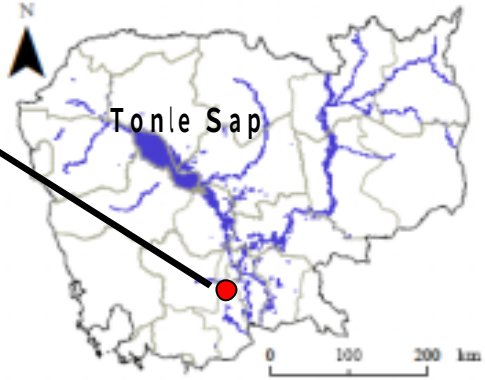
Kandal Stueng, Cambodia



Tomosho T (2004)

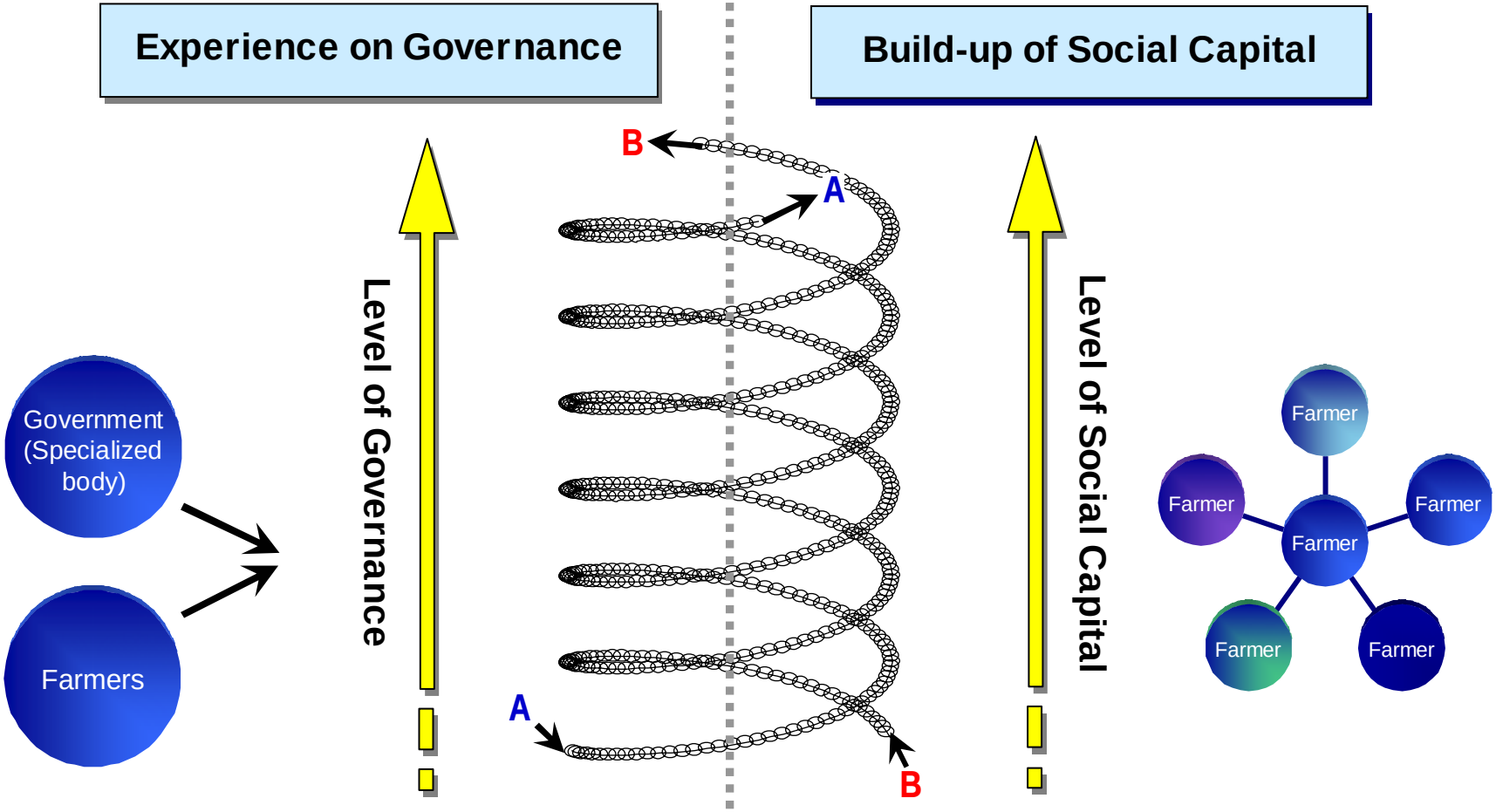


- Average paddy plot area: 0.126ha
- Average number of plots per farmer: 7



Cambodia

Twin Spirals of Interaction between Governance and Social Capital



A: Spiral between governance on services for water distribution and social capital
B: Spiral between governance on maintenances for infrastructure and social capital

Evolved concept on water productivity

More crop per drop (arid/semi-arid)

More values per drop (humid/sub-humid)

- Crop
  - Rice (source of nutrient/culture)
  - Others (source of money)
- External economy
  - Multiple use by farmers
  - Multi-functionality to the public
- Social capital

Values for Individual farmer

Values for public society

Positive spiral

Good governance

- Equitable distribution of water during severe dry spells
- Using water and generating external economy as much as possible

For sustainable water management on agriculture and ecosystems

Public support on investment accounting holistic values

Conclusion

- Magnitude of impact of water use for paddy agriculture in the Asian monsoon region is huge in the world.
- Irrigated paddy agriculture in this region produces not only rice but also diverse external economies and social capital through good governance for water use.
- According to the new definition of the environment as capital we can define most of traditional-type irrigation systems, which are collectively managed by farmers in various parts of this region, as part of the environment.
- A two way synergistic effect exists between cumulative experience of governance and build-up of social capital, and it leads to twin positive spirals in providing services (water) and developing stocks (facilities); that is a key factor for the remarkably sustainable food production and ecosystems.
- We have to develop an evolved concept “more values per drop” for the irrigated paddy agriculture in this region.