Enhancing resilience to climate and ecosystem changes by combining traditional and modern bio production systems in rural Asia

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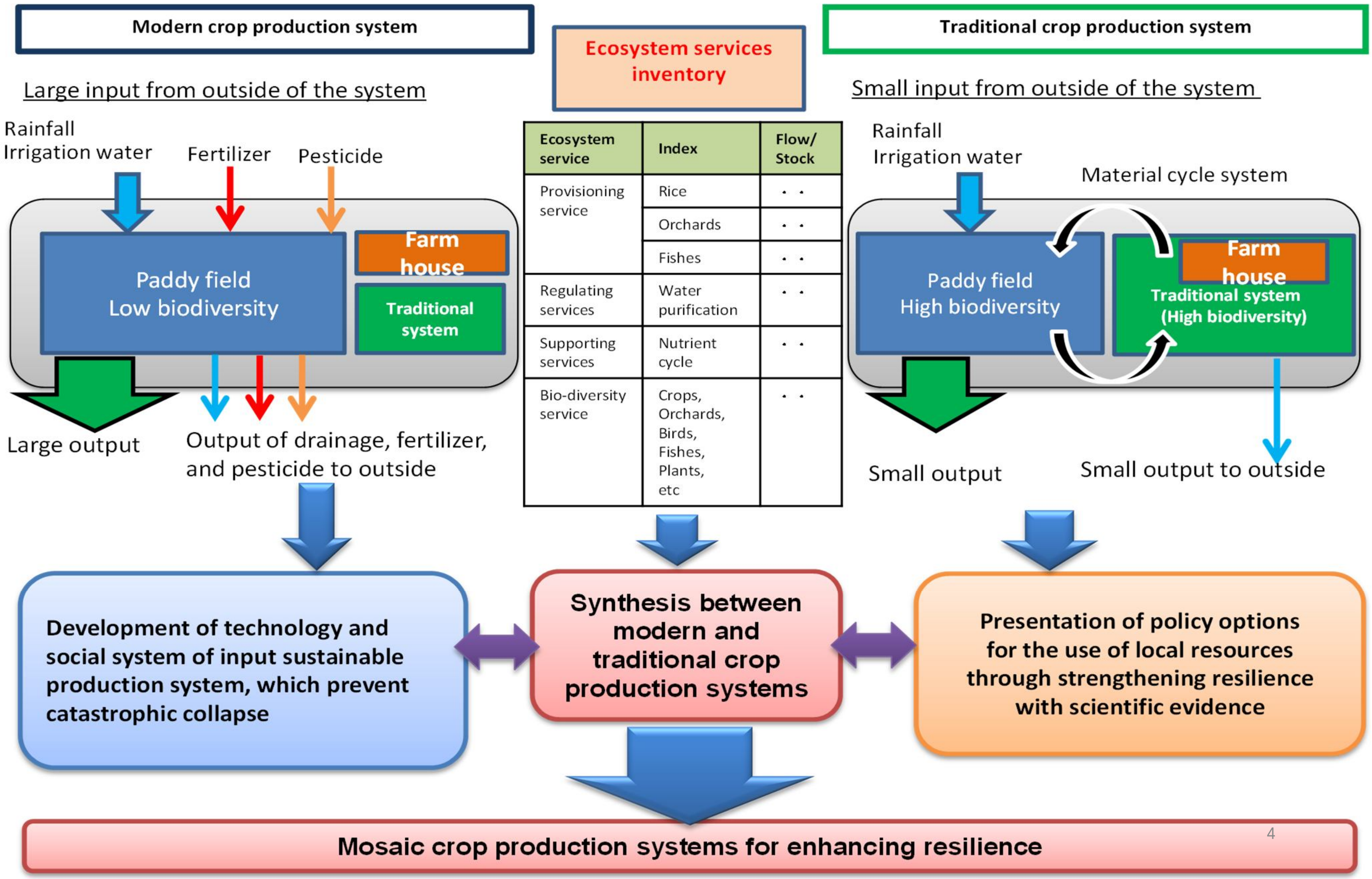
Outline

- Objectives
- Concept of Mosaic Systems for Crop Production
- Proposal of Mosaic Systems for Sustainability in Rural Asia
- Integrating Traditional and Modern Bio-production Systems
  - Case Studies: Vietnam, Indonesia and Sri Lanka
- Assessment of Resilience Based on Field Surveys

Major Objectives

- Quantitative and qualitative assessment of resilience to climate and ecosystem changes in rural Asia (focused on Vietnam, Indonesia, Sri Lanka)
- Proposal of bio-production systems to enhance local resilience, utilizing biodiversity and ecosystem services and traditional knowledge and technologies

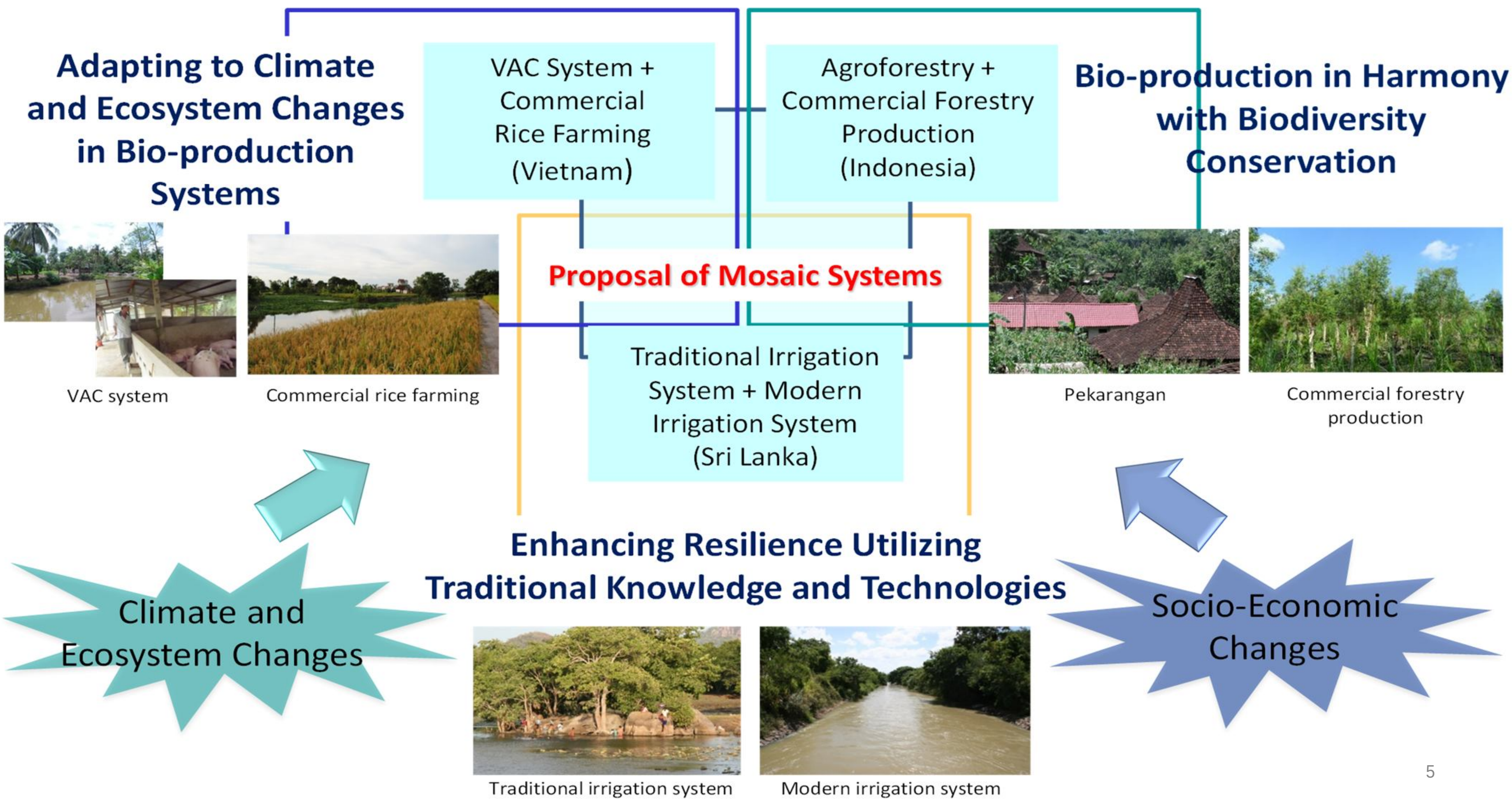
Concept of Mosaic Systems for Crop Production



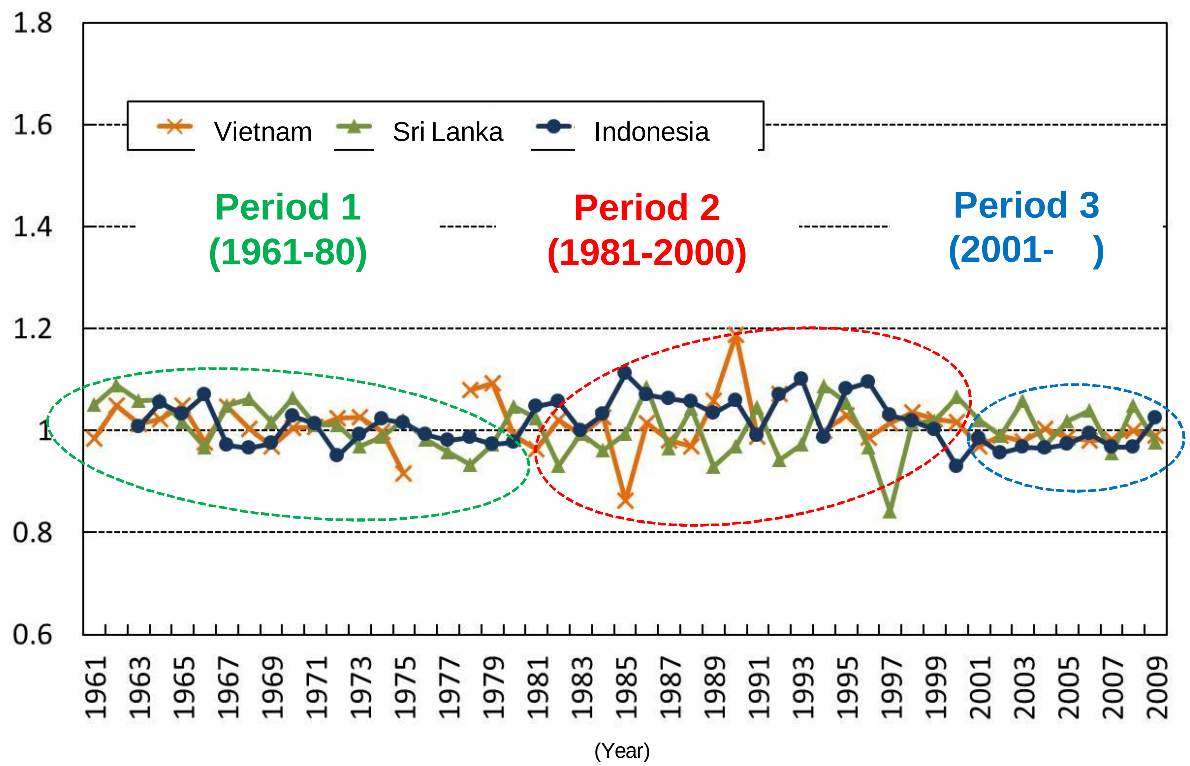
Ecosystem service	Index	Flow/ Stock
Provisioning service	Rice	・・
	Orchards	・・
	Fishes	・・
Regulating services	Water purification	・・
Supporting services	Nutrient cycle	・・
Bio-diversity service	Crops, Orchards, Birds, Fishes, Plants, etc	・・

Proposal of Mosaic Systems for Sustainability in Rural Asia

Shaping resilient societies by means of mosaic systems that combine traditional and modern knowledge and technologies to address climate and ecosystem change



Change in agricultural technical development in the target countries



Change in Productivity with All Elements in Agriculture

* Productivity with all elements:

- Ratio of all the production elements (labor and capital etc.) and output
- Index to show the volume of production at a specific production element

- After popularization of modern agricultural production technics brought by the Green Revolution in Period 1 (1961-80), technical progress regarding agricultural production was observed in Period 2 . In Period 3 (2001-), technical progress slowed down, and the progress of agricultural production technics stagnated (There is a possibility that the conventional agricultural production technics have faced difficulties in dealing with climate changes in recent years)
- Necessity of verifying the cause of the stagnation in Period 2 from climatic and socioeconomic viewpoints

The Malmquist Index

- The Malmquist Index measures the TFP changes between two data points (for e.g. those of a particular regions in two adjacent time periods)
- TFP growths and decomposition components (Efficiency and Technical Change).
- Following Färe et al. (1994) the Malmquist TFP index between period t and t+1 is given by

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}}$$

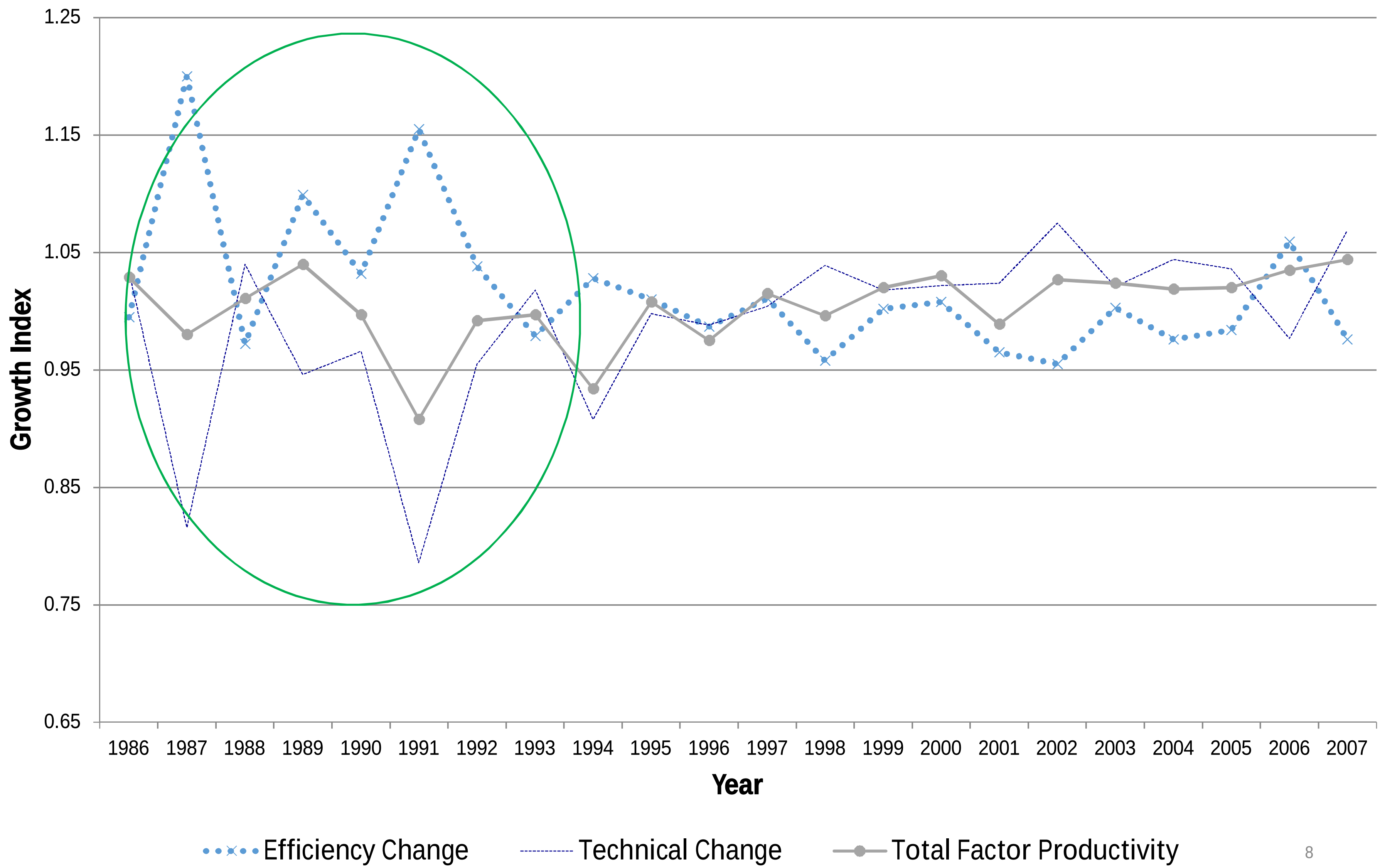
The Malmquist index could be decomposed into an efficiency change component and a technical change component

$$Efficiency\ change = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}$$

$$Technical\ change = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right) * \left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{1/2}$$

M_0 >1 indicates positive TFP growth from period t+1 to period t, while M_0 <1 indicates a TFP decline.

Total factor productivity, Efficiency change, Technical growth in Vietnam Agriculture



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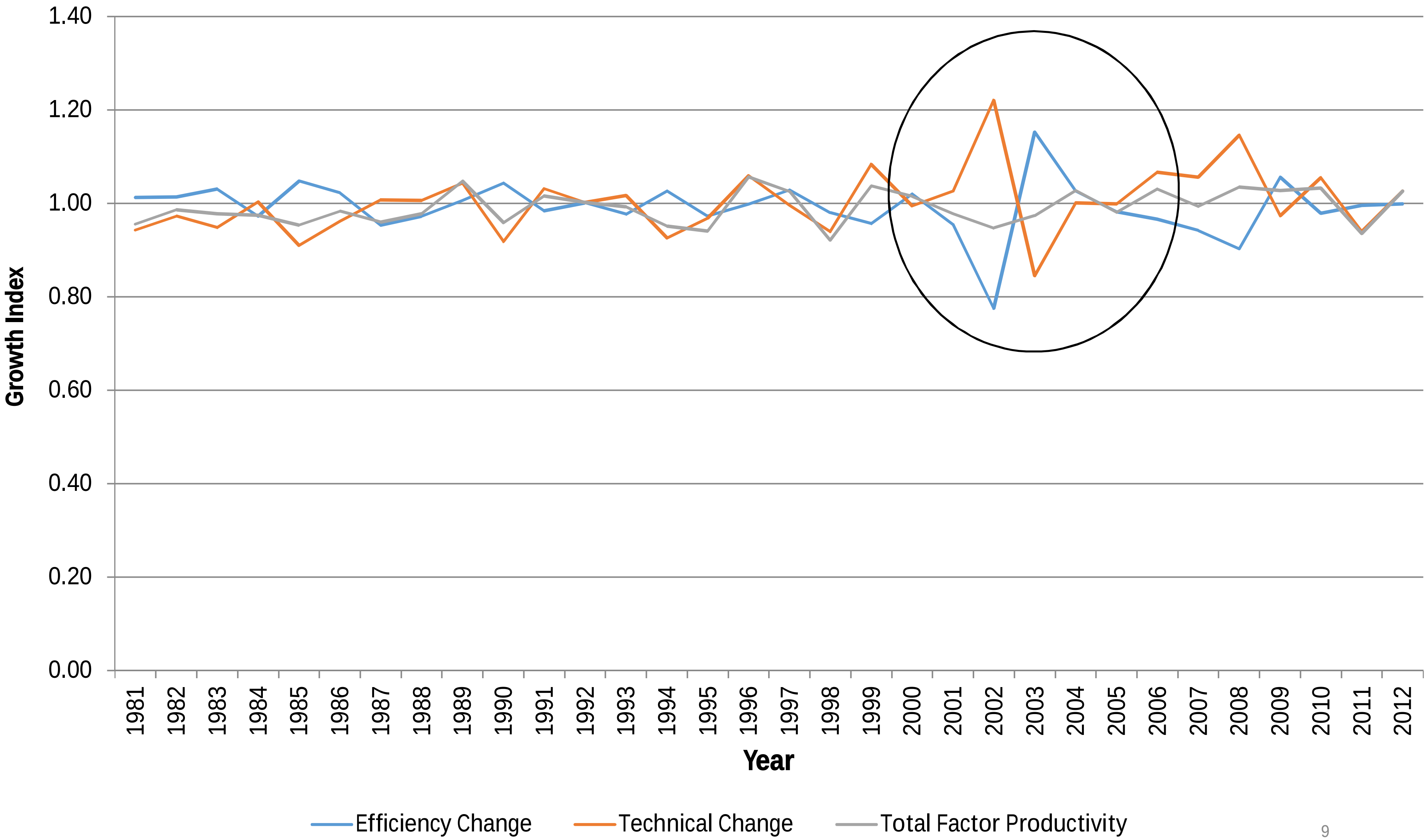
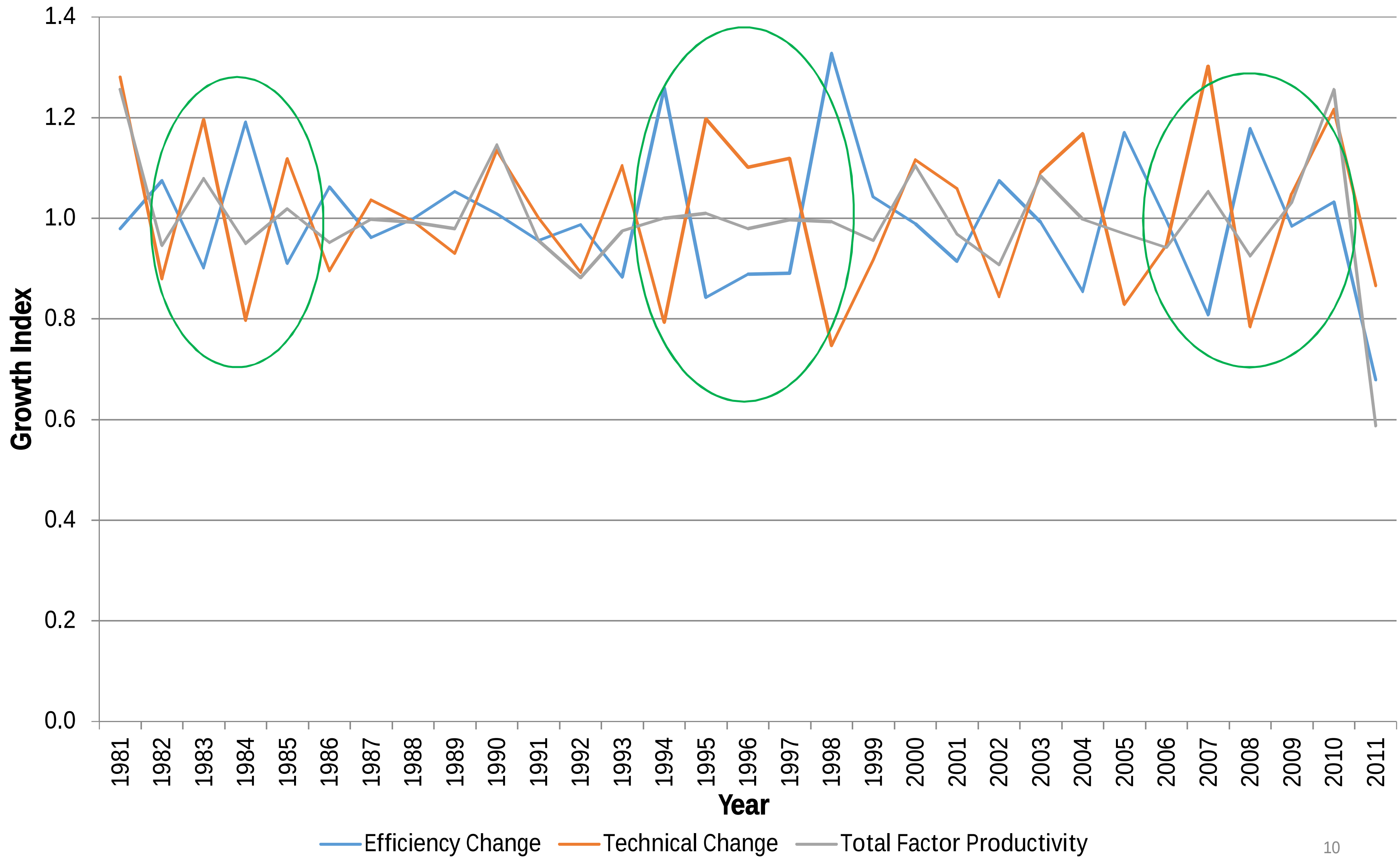
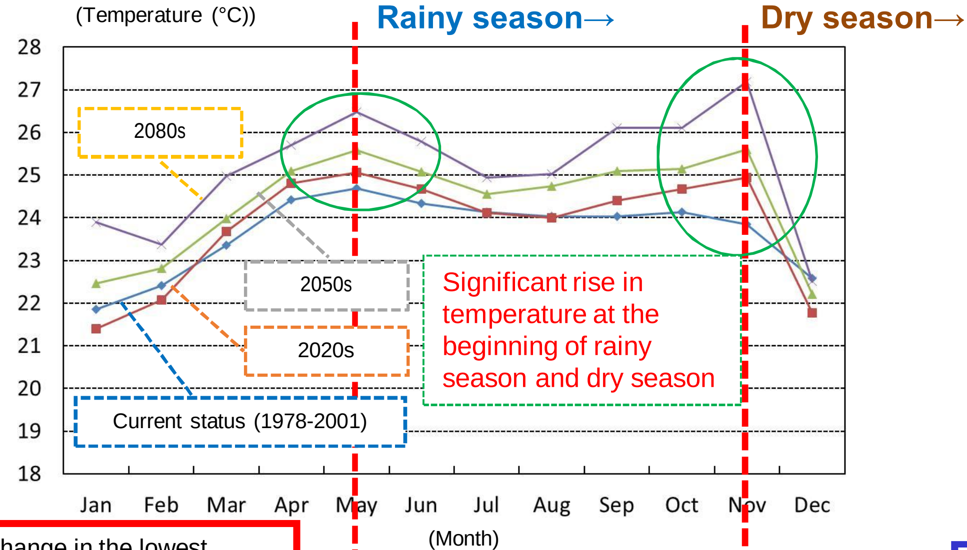
Total factor productivity, Efficiency change, Technical growth in Indonesia Agriculture



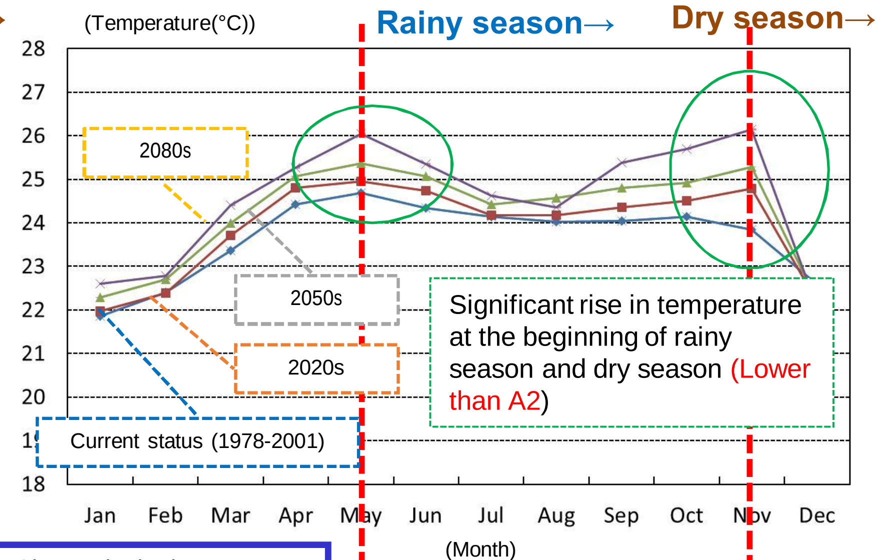
Total factor productivity, Efficiency change, Technical growth in Sri Lanka Agriculture



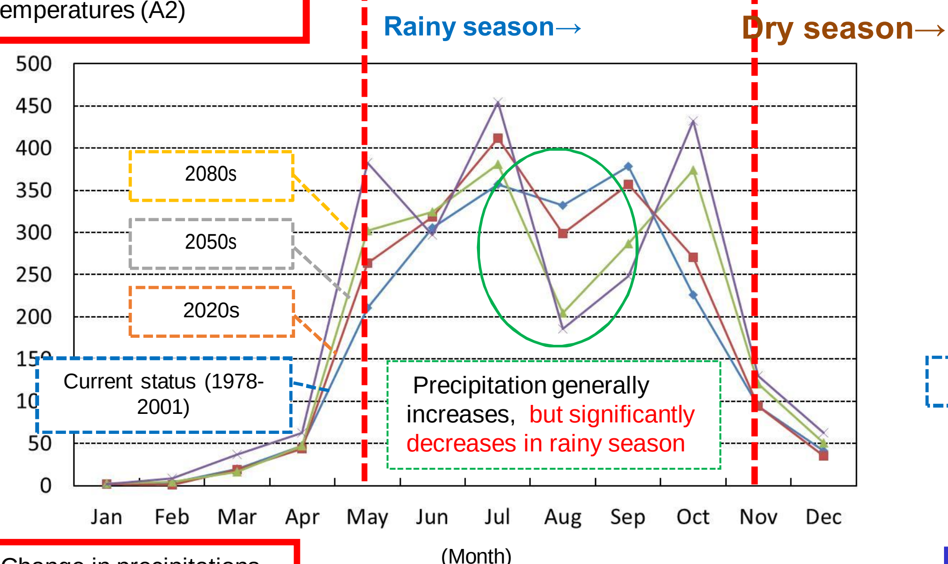
Prediction of the impact of climate change



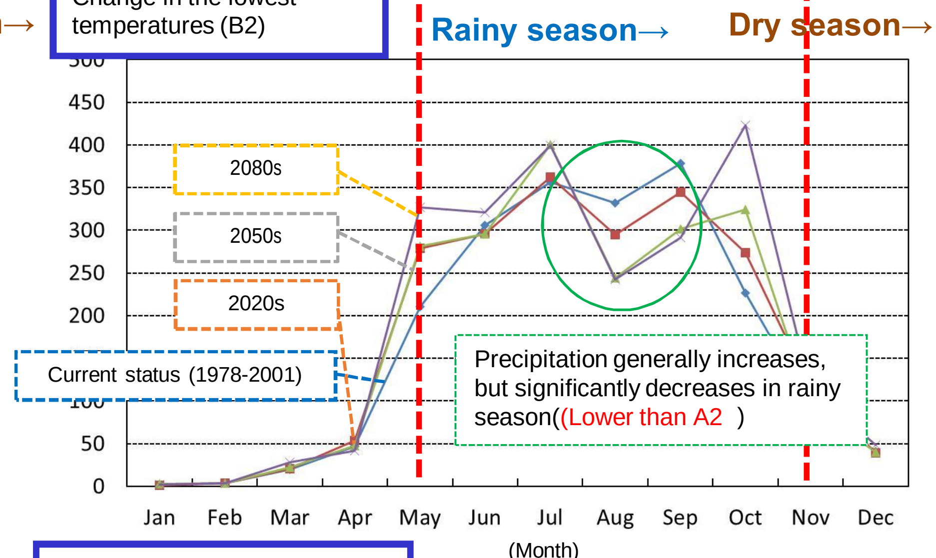
Change in the lowest temperatures (A2)



Change in the lowest temperatures (B2)

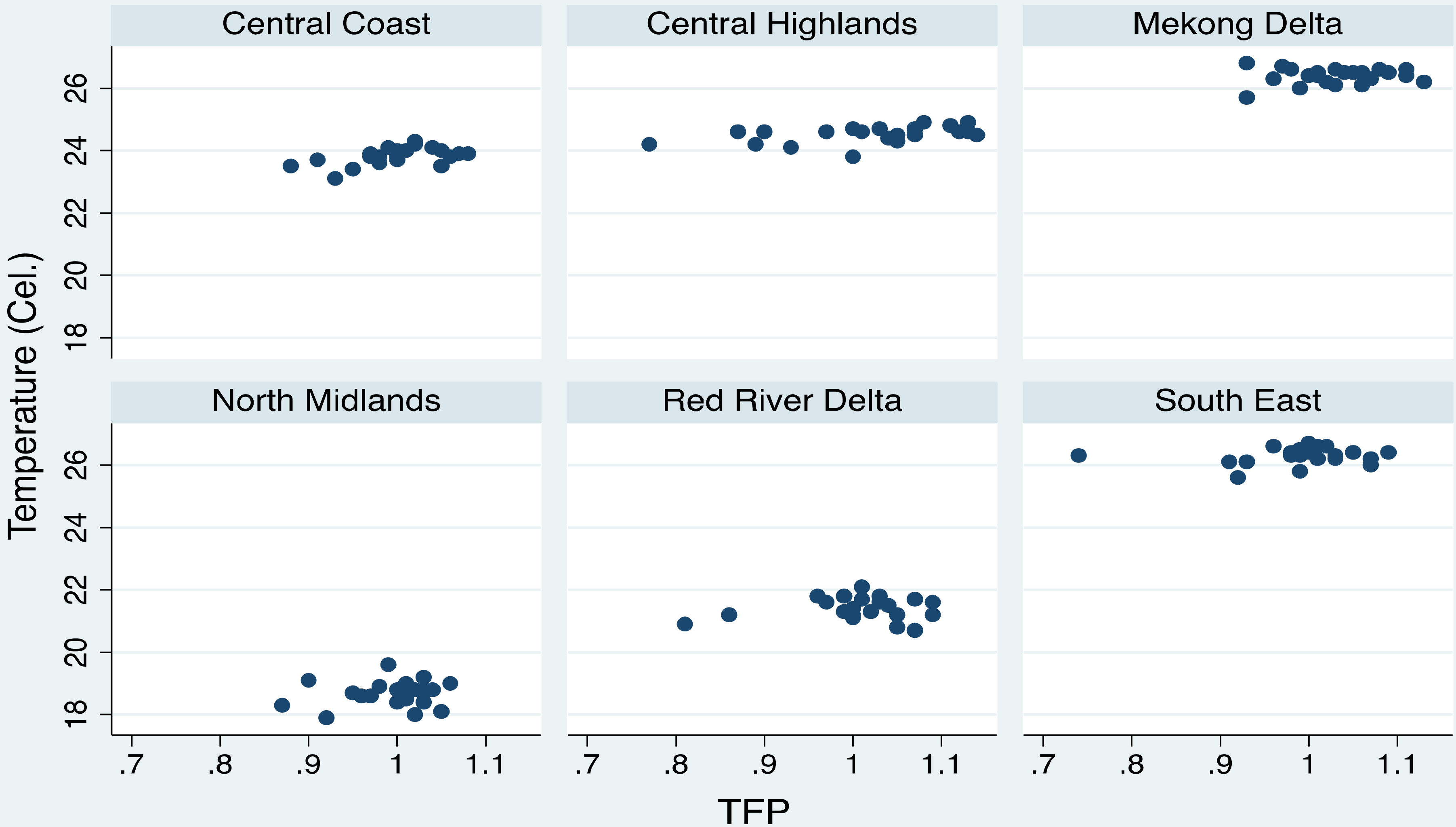


Change in precipitations (A2)



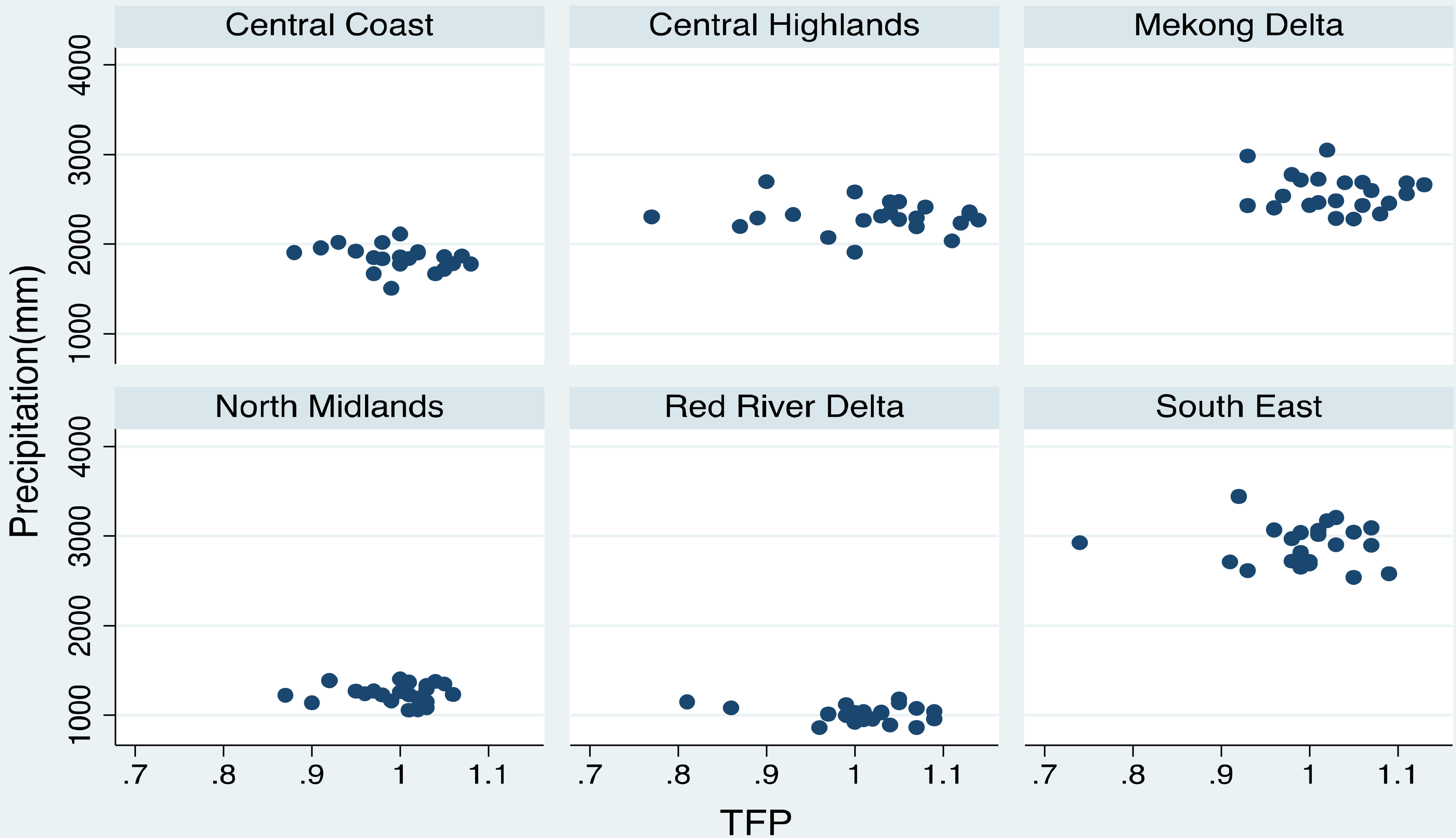
Change in precipitations (B2)

Relationship bewteen TFP Growth and Air Temperature(Celsius) by Region



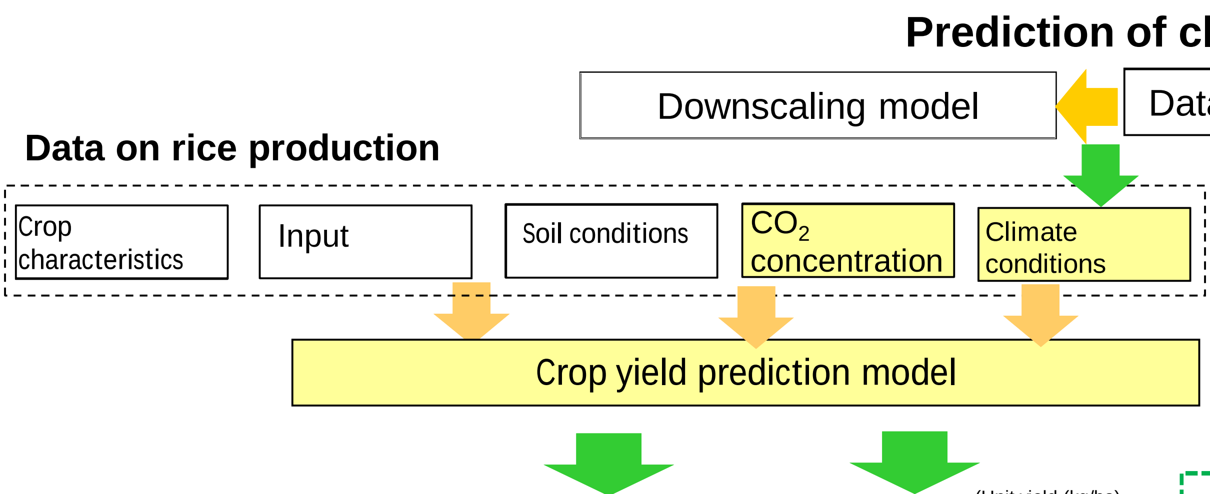
Source: Climate Change Scenarios Network, Canada; Author Calculations

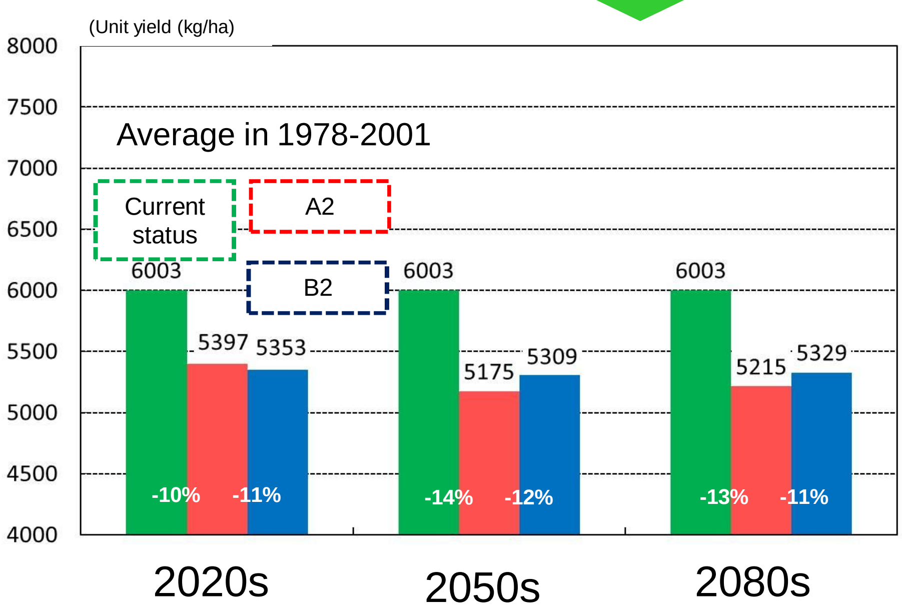
Relationship between TFP Growth and Precipitation(mm) by Region



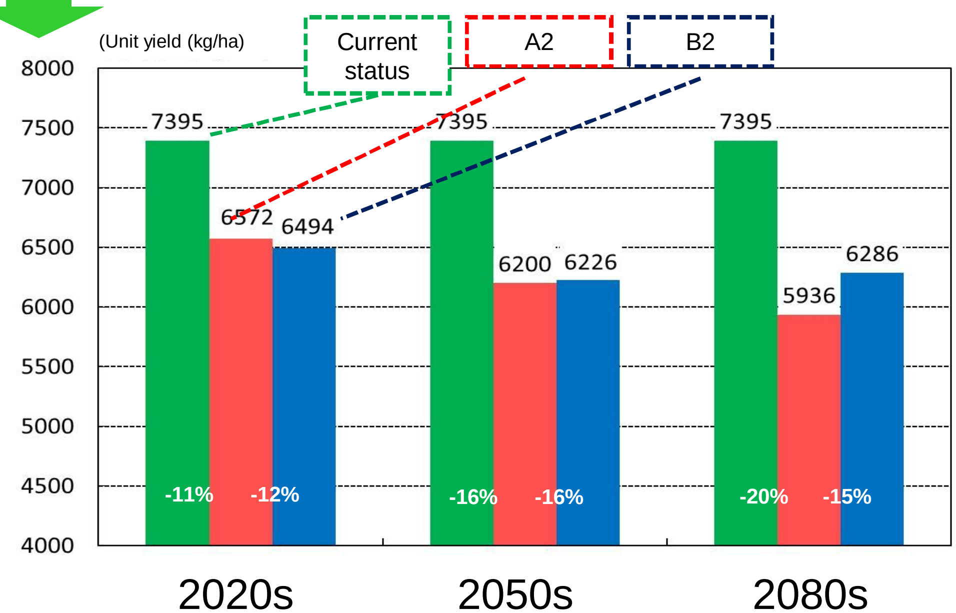
Source: Climate Change Scenarios Network, Climate, Author Calculatons

Prediction of the impact of climate change on rice production in Vietnam





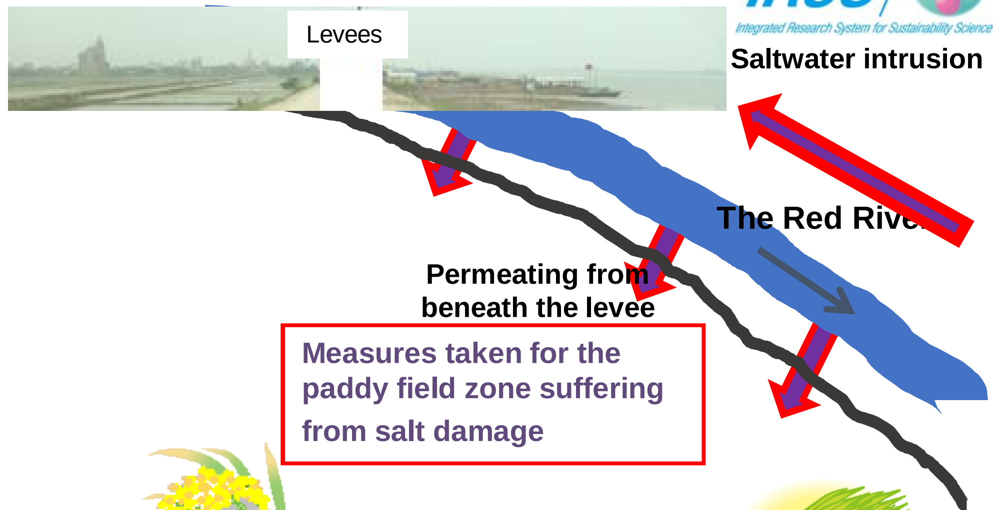
Prediction of rice production volume in rainy season



Prediction of rice production volume in dry season

Cropping system adapted to salt intrusion in Vietnam

- To adapt to salt intrusion, cropping was converted from high-yield varieties to native varieties/sticky rice or from rice to rush.



Distant from the levee
High-yield varieties (Tap Giao, BC15)

High-yield varieties BC15 (Agriculture field distant from the levee and not suffering from salt damage)

・Rice 6.7±0.6 t/ha
・Straw 6.5±0.5 t/ha

Near the levee
High-yield varieties→native sticky rice

Nep Sticky rice varieties (Agriculture field suffering from salt damage near the levee)

・Rice 4.3±0.1 t/ha
・Straw 10.0±0.1 t/ha
・Used for mushroom cultivation etc

Near the levee
Conversion from rice to rush

Rush (Agriculture field suffering from salt damage near the levee)

・Quantitative survey is scheduled in the future.
・Used for tatami and straw mats etc

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Prediction of the impact of climate changes on rice production in Sri Lanka

	Variety	Growing period
Early-maturing variety	Bg 250	2.5 months
	At 307	3 months
Late-maturing variety	Bg 357	3.5 months
	Bg 379-2	4 months

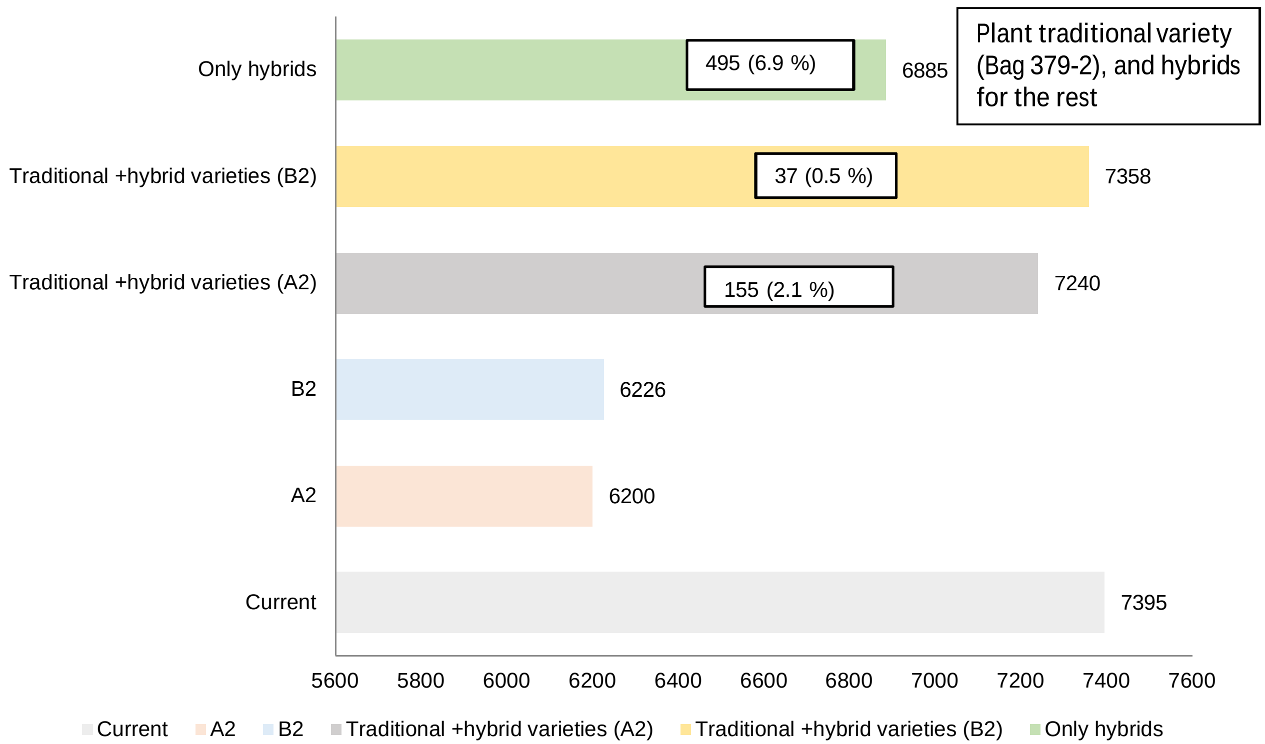
Prediction of yield variation by rice variety in Sri Lanka (Average rate of change in 2011-20 (%))				
Emission Scenario	Rice variety			
	Early-maturing variety		Late-maturing variety	
	Bg 250	At 307	Bg 357	Bg 379-2
A2	-13.6	-10.3	-6.0	-2.1
B2	-6.2	-5.1	-1.8	-0.5

CO_2 level is assumed to remain at the current status.

Late-maturing varieties have less reduction in yield.

- Usual variety improvement tends to aim at better yield and early-maturity
- It suggests that traditional late-maturing varieties have smaller degrees of yield reduction due to the impact of climate changes.
- It suggests the possibility that the combination of the traditional and modern varieties enhances resilience to climate changes.

Adaptation to Climate Change by Selecting Rice Varieties in Sri Lanka and Vietnam



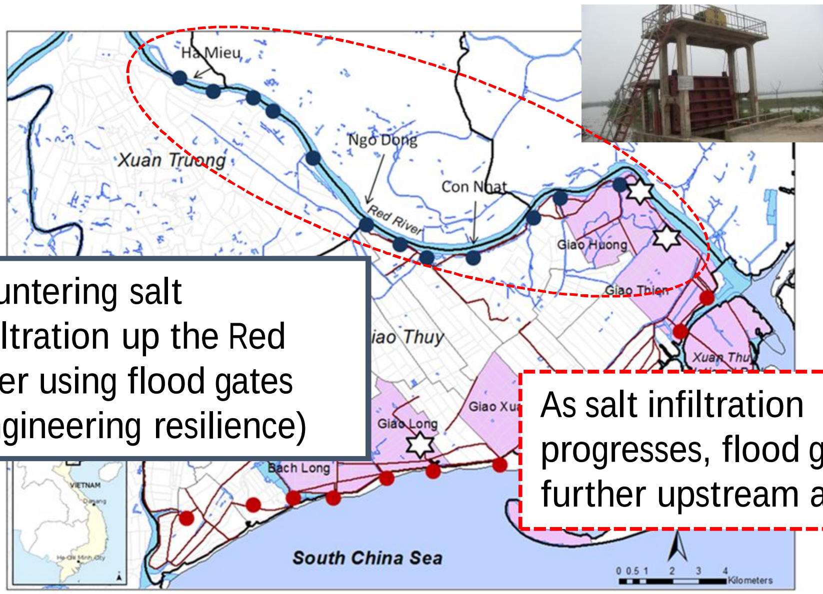
Difference in yields between rice varieties in Vietnam (2010)

	Rice variety	
	Normal varieties (inbred)	Hybrid rice
Yield (t/ha)	5.2	6.9
Crop area (%)	92	8

Hybrid rice varieties can achieve higher yields.

- Suggests that loss in yield is less for traditional late varieties (Sri Lanka)
- Production maintained by increasing hybrid rice cultivation (8%↗) (Vietnam)
- Adoption of new flood-resistant varieties (Indonesia)
- Conclusion: By primarily using traditional varieties, but also combining them with modern hybrid varieties, it is possible to enhance resilience to climate change

Integrating Traditional and Modern Bio-production Systems



Countering salt infiltration up the Red River using flood gates (engineering resilience)

As salt infiltration progresses, flood gates further upstream are used.

- **Crop planting to address salinization (ecological resilience)**
  - Switch from high-yield varieties (in fields not damaged by salt, far from rivers) to traditional varieties or to glutinous rice, or switch from rice to rushes (in fields affected by salt, close to the river)
    →Tackling climate and ecosystem change

- **Bio-production systems to address socio-economic change (socio-economic resilience)**
  - Modify traditional VAC systems to suit increasingly market-oriented economics
    →Address not just climate and ecosystem changes but also socio-economic risks
  - Cater to markets by adopting certification systems for international markets, such as the Vietnamese version of good agricultural practices (GAP) and focusing on quality to offer high value-added products
    →Achieve high profits while holding back from pursuing excessive efficiency

The above strategies increase resilience to climate and ecosystem changes and to socio-economic changes.

Bio-Production Systems in Harmony with Biodiversity

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Example of Gunung Kidul, Indonesia

Traditional bio-production

Pekarangan

Teak planting by residents, mainly in pekarangan (in woods around their homes)

High biodiversity features

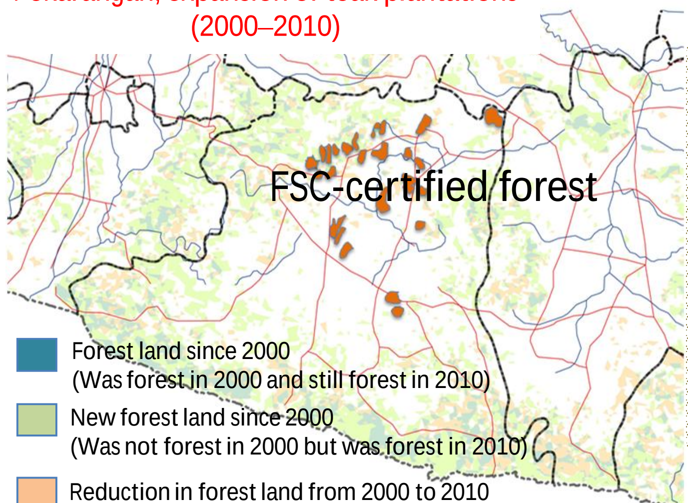
- Diversity of plants (49 types)
- Variety of biota (10 species of mammals, 30 species of birds, 15 species of amphibians)

Role of pekarangans

- Community use
- Trees can be cut to sell high-priced materials such as teak and mahogany when needed to cover expenses of healthcare, education, disaster recovery (saving function)

A huge tree said to be 300 years old

Pekarangan, expansion of teak plantations (2000–2010)



- Pekarangans are traditional home gardens that protect against various kinds of shock
- Pekarangans also protect against socio-economic changes
- Biodiversity conservation by means of agroforestry and forest certification, while enhancing protection against socio-economic changes by commercial reforestation (correction of excessive focus on efficiency and economics)
- Increasing resilience by combining the two

Modern bio-production

HTI (Hutan Tanaman Industry) Commercial reforestation

Sengon (*Albizia chinensis)*

Kayu Putih (*Melaleuca leucadendron*)

Soil erosion/agrochemicals/excess fertilizer

Managed as shrubs to press oil from branches and leaves.

External output is high. Disease-pest damage.

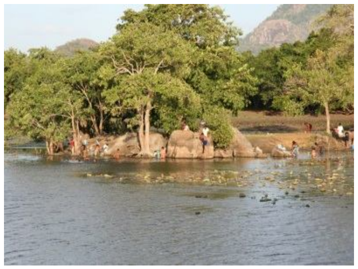
Encourage farming between forests (agroforestry)

Forest Certification System (FSC)

Putting a premium on certified materials, expanding sales channels, regulating the use of agrochemicals on seedlings, protect forests of high conservation value, contribute to biodiversity conservation

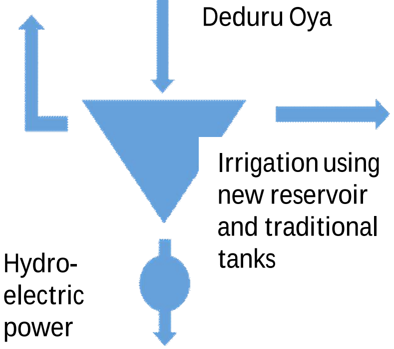
Acquired group certification for a small teak forest in 2012
Certified area: 330.5 ha
Total of 96 groups of farmers in the alliance
Price of certified material: 30% higher

Integration of Traditional and Modern Irrigation Systems

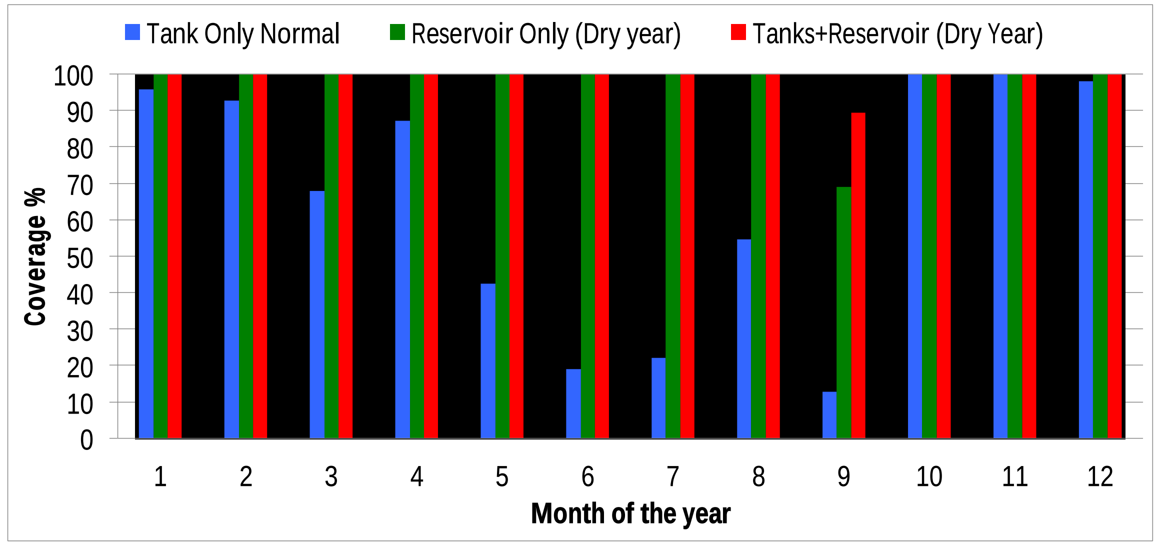


Traditional tank

New reservoir



Trial of mosaic system in water catchment (Deduru Oya, Sri Lanka)



- Test of mosaic system in water catchment of Deduru Oya, Sri Lanka
- Sixth largest river in Sri Lanka
  Catchment – 2,620 km^2
  90% - Intermediate
  10% - Wetlands
- Construction began in 2007; scheduled for completion in 2014

- Traditional systems alone cannot meet the irrigation needs of both existing and new rice crop production.
- A new reservoir (modern) can meet all the demand in a normal year, but it is not sufficient for drought years (approx. 1 every 5 years)
- The combination of traditional tanks and a new reservoir can improve on this, but if water distribution is conducted separately, the water demand cannot be met.
- Analyze the flow of the river in detail for each reservoir, and create a model of the operation of the overall system when the new reservoir and traditional tanks are combined.

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Assessment of Resilience Based on Field Surveys

Survey location	Climate-ecosystem/socio-economic change	Systems	Shock-resistance	Resilience rating (current)			Intervention options	Resilience rating (after intervention)	
Vietnam ·Xuan Thuy	·Rainstrom /flooding ·Disease-pest damage ·Saltwater infiltration ·International market adaptation ·Market economy penetration	VAC	·Commercial livestock production	Ecological	M	↘	·Use certification system ·More stable operation by combining VAC and rice farming ·Combine traditional and modern varieties ·Improve quality	Ecological	M
				Socio-economic	M	↗		Socio-economic	H
		Rice Cultivation	·Moving irrigation water source upstream ·Selection of varieties	Ecological	L	↘		Ecological	M
				Socio-economic	M	↘		Socio-economic	M
Indonesia ·Gunung Kidul	·Long dry season ·Lack of rain/change in rainfall pattern ·Flooding ·International market adaptation ·Market economy penetration	Social forestry/Pekarangan	·Diversity livelihood ·Biodiversity	Ecological	H	→	·Use forest certification system ·Create resource management system ·Move to agroforestry by commercial reforestation	Ecological	M
				Socio-economic	L	→		Socio-economic	M
		Commercial reforestation	·Sale of high value-added wood products	Ecological	L	→		Ecological	M
				Socio-economic	H	→		Socio-economic	H
Sri Lanka ·Kilinochchi ·Deduru Oya ·Mahaweli H	·Dryness/declining rainfall ·Damage to irrigation infrastructure due to civil war ·International market adaptation ·Market economy penetration	Traditional storage water tanks	·Restore/use traditional irrigation systems ·Multi-functionality	Ecological	M	→	·Integrate new and old irrigation systems ·Create communities ·Appropriate resource management system to avoid drought	Ecological	H
				Socio-economic	L	↘		Socio-economic	H
		New irrigation system	·Efficient use ·Collaborative management	Ecological	L	→		Ecological	H
				Socio-economic	L	→		Socio-economic	H

Conclusions

- On the basis of previous research, a framework was developed for assessing and analyzing resilience in specific detail, not just conceptually, and concrete strategies to enhance resilience were formulated in accordance with case studies for which field surveys and analyses were conducted.
- Field surveys and statistical analysis demonstrated that it is possible to develop strategies to adapt to climate and ecosystem change by primarily using traditional varieties of crops that can adapt better to climate change, in combination with modern varieties. This is different to the strategy of improved varieties on which the success of the Green Revolution was based.
- As seen in the VAC systems and rice cultivation of Vietnam, the pekarangans and commercial reforestation of Indonesia, and the traditional tanks and new reservoir of Sri Lanka, it is possible to develop resilience-enhancing measures that depend on ecosystem services and which are quite different to conventional technological solutions, by means of mosaic systems that integrate traditional and modern systems.

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Thank you for your kind attention