102 年天氣分析與預報研討會
臺灣地球科學聯合學術研討會
中華民國102年5月13-15日於桃園縣龍潭

氣候變遷下氣象資訊
對於農業的重要性與應用

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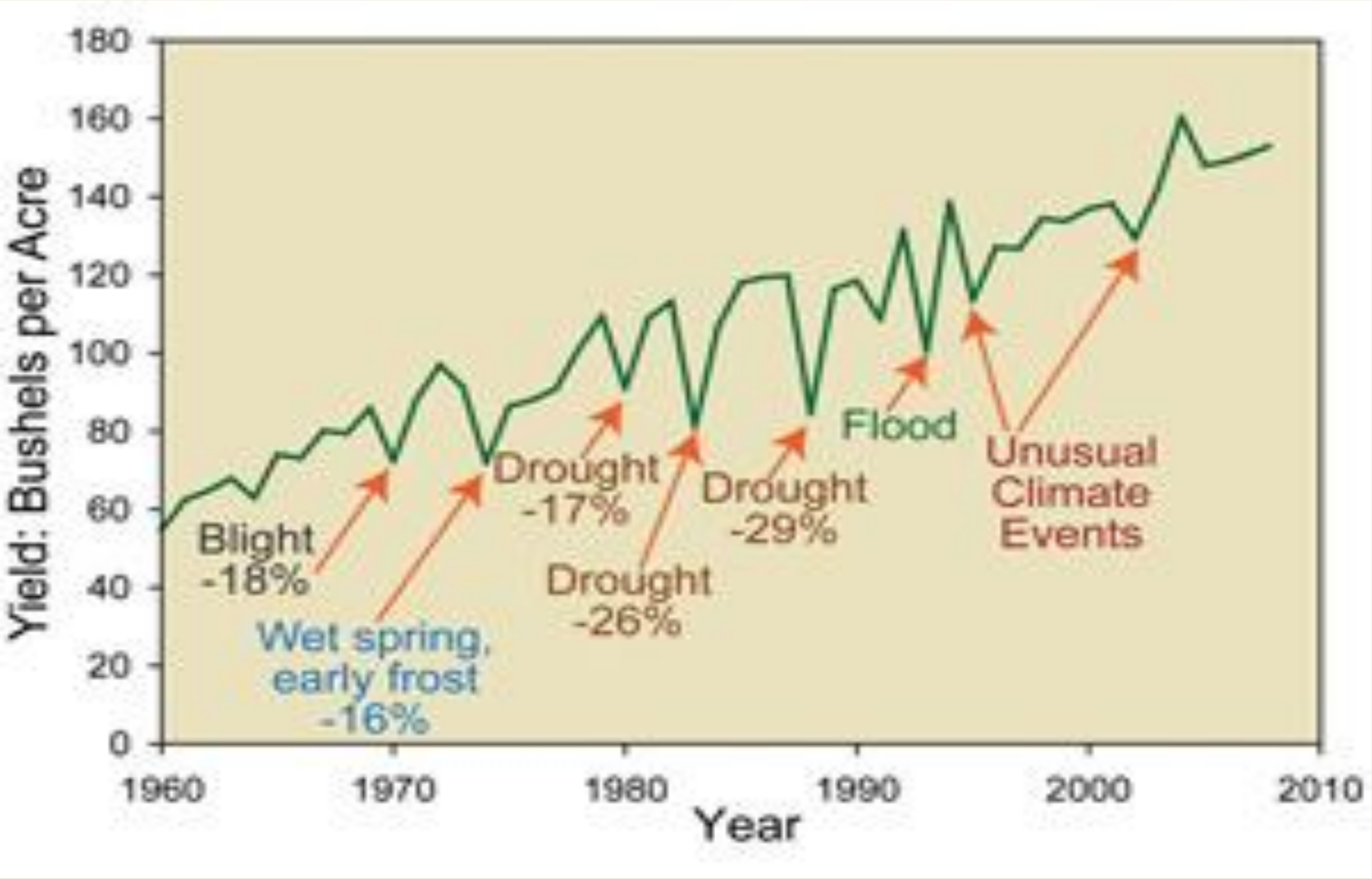
Outline

- **Climate and Agriculture**
  - Climate Impact
  - Information needed
- **Climate Change Adaptation**
  - Options
  - Case Study
    - Farm/Management Level

Climate and Agriculture

- **Agriculture** is prone to 2 types of **Climate Risks**:
  - **Climate change**
    - Long-term shifts in **mean** values
  - **Climate variability**
    - Changes in temperature, wind fields, hydrological cycles, ... etc. at **annual to decadal** time scales
    - May well increase both **in frequency and intensity** under projected climate change
    - Induce **secondary** hazards which claim lives and incur large economic losses long after event passes

Climate Change Impacts on Crops



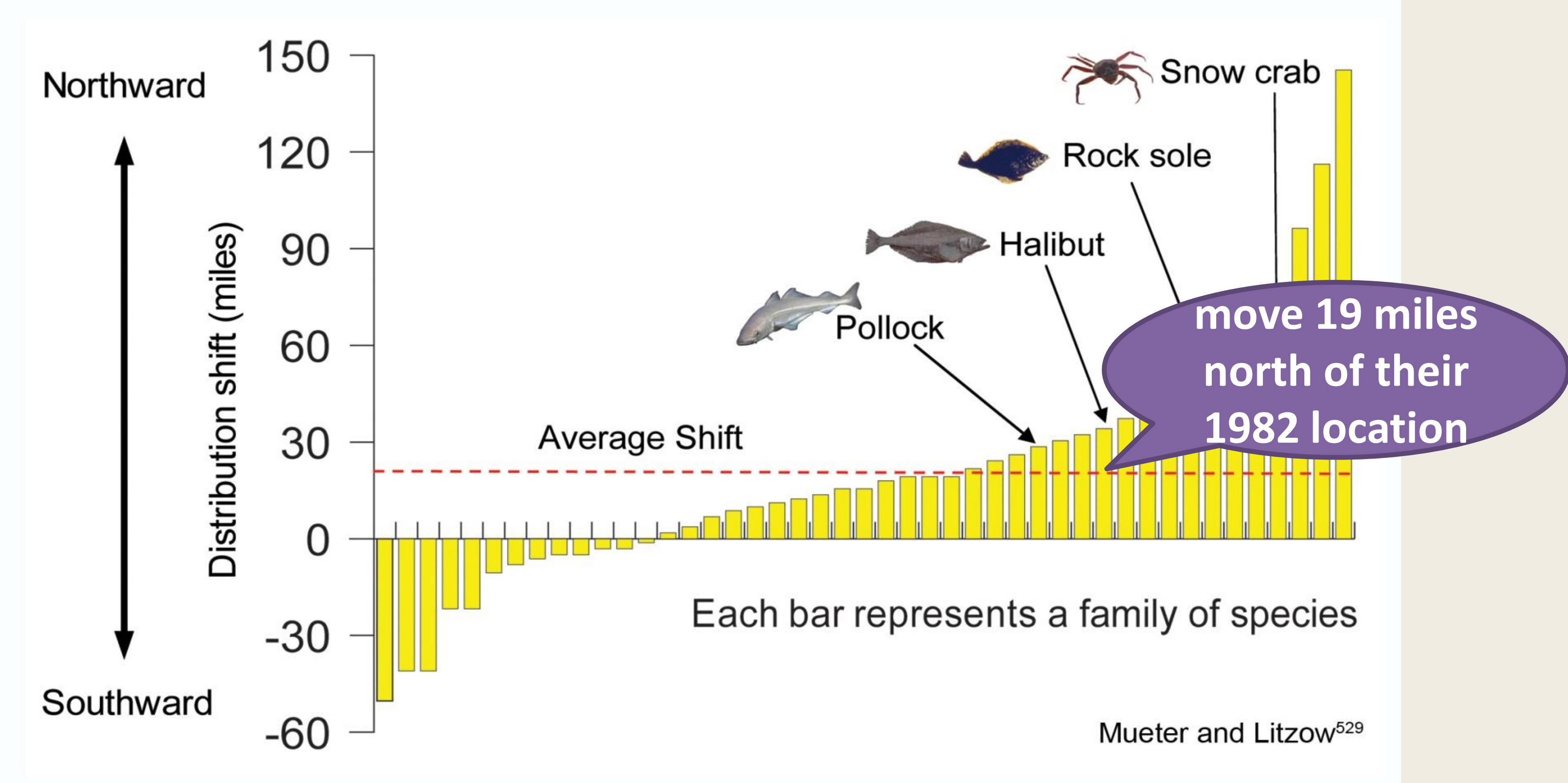
Source: USGCRP (2009), available at:

http://www.epa.gov/climatechange/impacts-adaptation/agriculture.html

Impacts on Livestock

- **Heat waves**
  - increase vulnerability to disease, reduce fertility and milk production.
- **Drought**
  - threaten pasture and feed supplies.
  - reduces the amount of quality forage
  - increase prevalence of parasites and diseases that affect livestock.
- **Increases in CO_2**
  - increase the productivity of pastures
  - but may decrease their quality.
  - need to eat more to get the same nutritional benefits.

Impacts on Fisheries



As air and water temperatures rise, marine species are moving northward, affecting fisheries, ecosystems, and coastal communities that depend on the food source. On average, by 2006, the center of the range for the examined species moved 19 miles north of their 1982 locations.

Source: USGCRP (2009) . Available at: http://www.globalchange.gov/components/com_joomgallery/img_originals/global_climate_change_impacts_in_the_united_states_1/alaska_17/alaska_9_20090707_1126954867.jpg

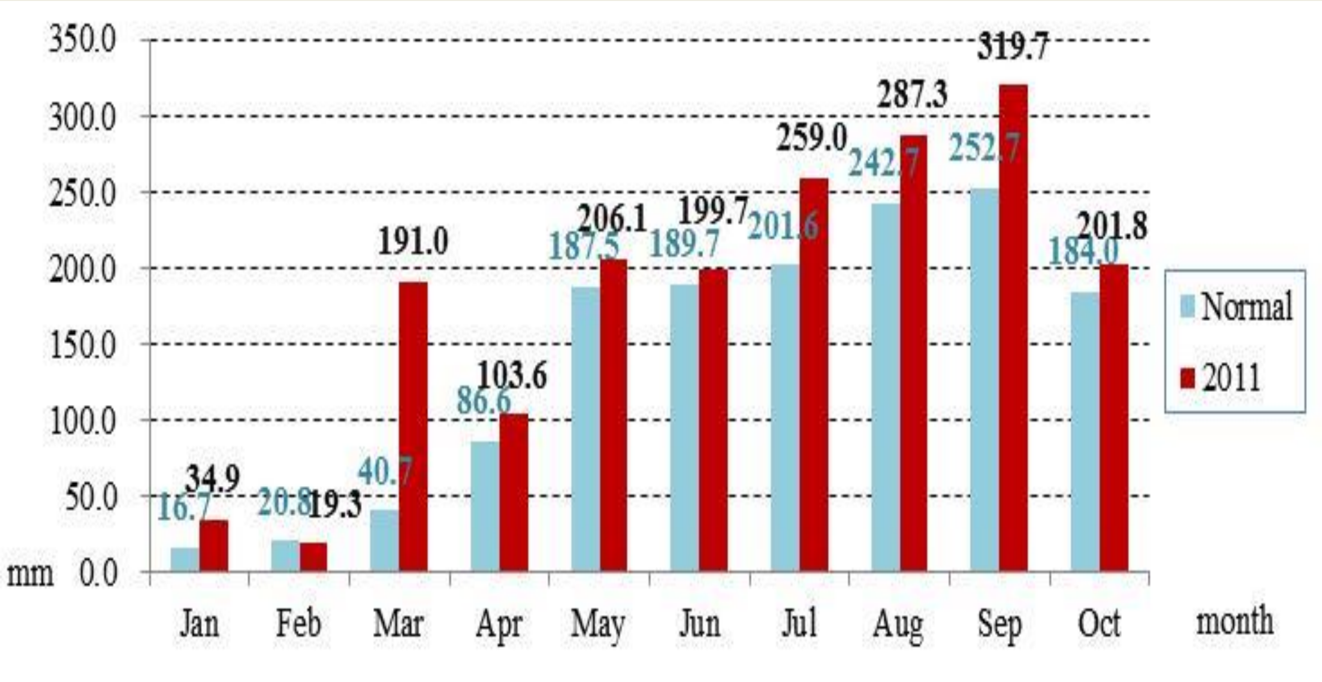
Regional Impact in Asia-Pacific
1. East-Asian Monsoon

- **Observations since 1950s:**
  - Weakening of summer and winter monsoon
  - Moving southward where both land and sea surface temperature rise
- **Examples**
  - **Thailand** Flood, 2011 (684 death)
  - Typhoon Sendong in **southern Philippines**, 2011 (>900 death, 70,000 families affected)

2011 Thailand Flood

Monthly rainfall from Jan-Oct

- 18-67 mm of rainfall above normal since March, 2011



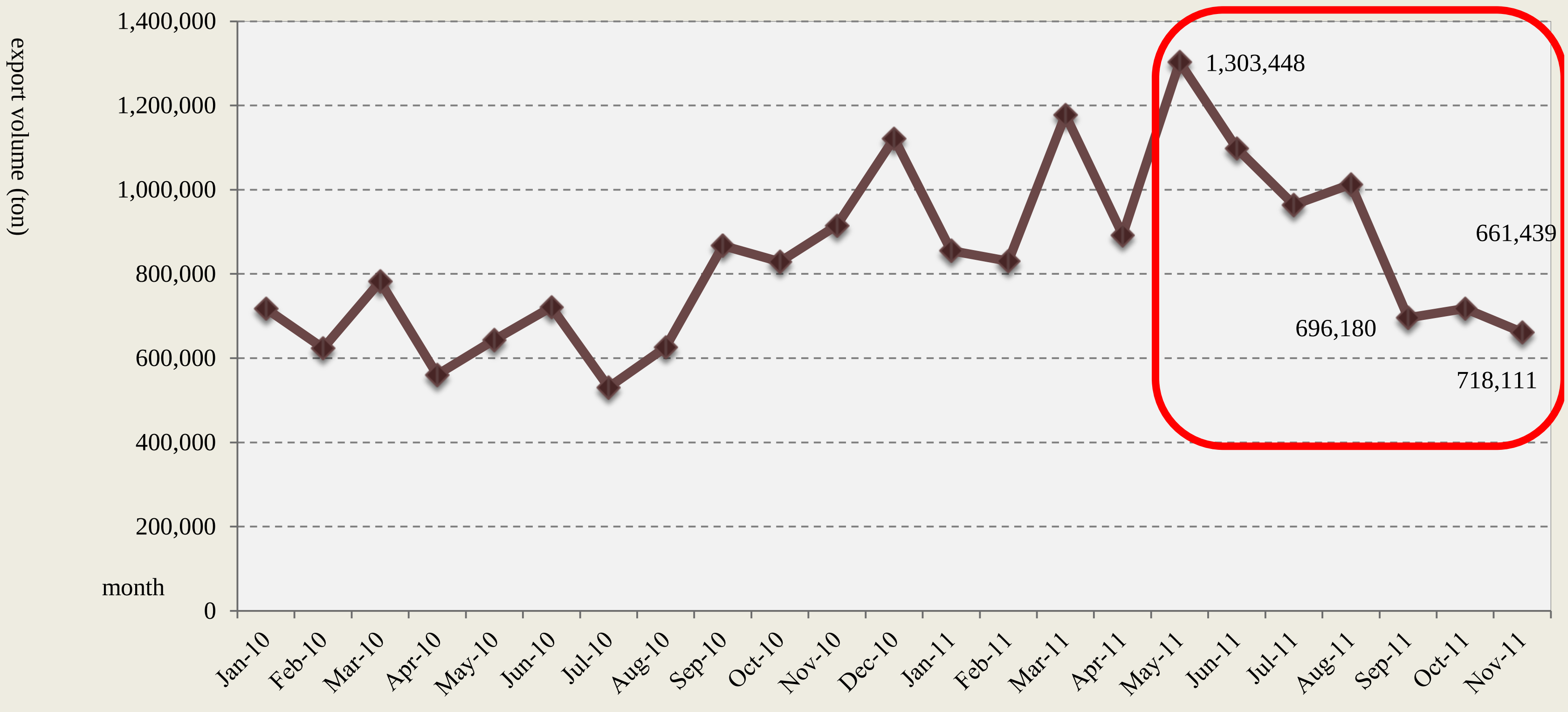
Source: Thai Meteorological Department

Flooding area

- Mostly in N.E. and Central provinces

Photo Source: Esri, http://www.esri.com/services/disaster-response/floods/index.html, Oct 2011.

Export volume of Thai rice, Jan. 2010- Nov. 2011



Source: Office of Agricultural Economics, Thailand, Agricultural Statistics,.
http://www.oae.go.th/oae_report/export_import/import.php

2. El Niño Southern Oscillation (ENSO)

- **Risk**
  - Enhance **variability of precipitation and stream flow**
  - Lead to greater risk of **droughts and floods**
- **Examples:**
  - 1997-98 in **Indonesia**: caused substantial threat to rural livelihood
  - 2010-11 in **Queensland:** Flood

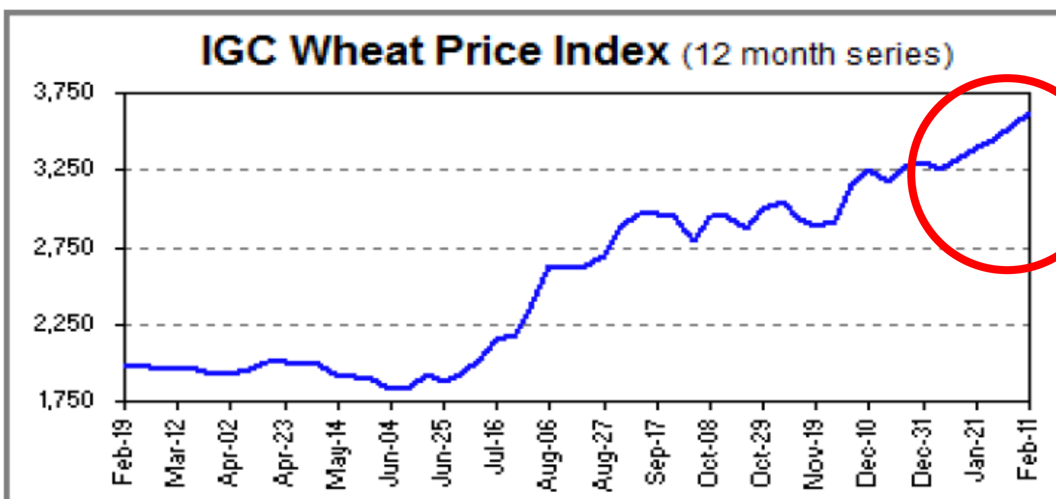
Multi-scale Interaction for Heavy Rainfall Queensland, Dec. 2010

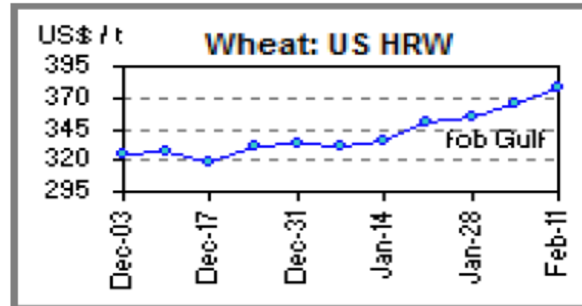
Reference

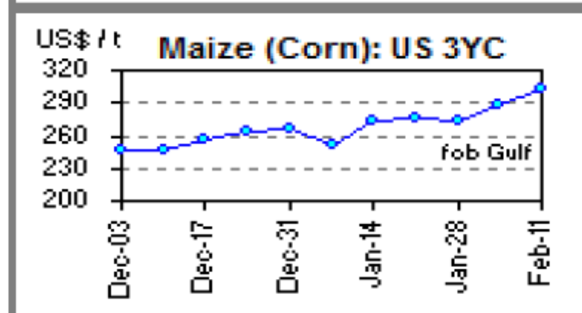
1. National Climate Centre, 2011. An extremely wet December leads to widespread flooding across eastern Australia. *Special Climate Statement,* **24**.
2. Australian Government Bureau of Meteorology, *http://www.bom.gov.au*
3. Climate Prediction Center, National Oceanic and atmospheric administration, *http://www.cpc.ncep.noaa.gov*

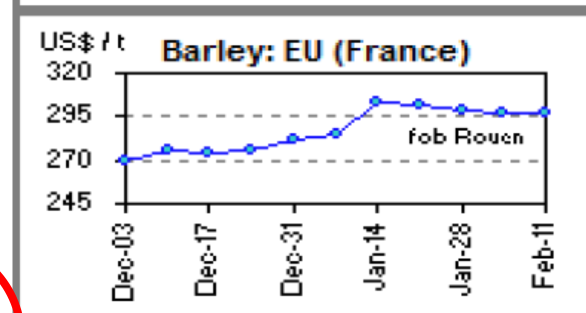
International Grains Council Export Prices

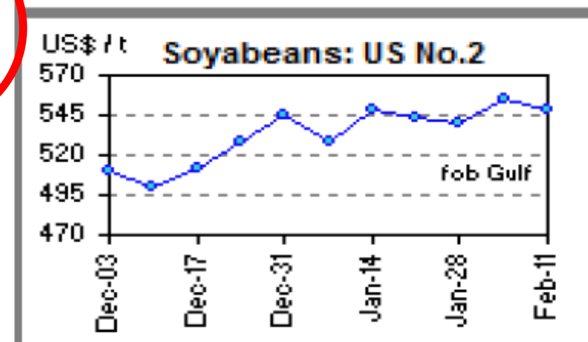
	11 - Feb	04 - Feb	Year ago
Wheat			
US - HRW (Gulf)	**378**	365	206
EU - France Grade 1 (Rouen)	**376**	375	169
Maize (Corn)			
US - 3YC (Gulf)	**302**	288	167
Barley			
EU - France (Rouen)	**297**	297	141
Soyabeans			
US - No.2 (Gulf)	**548**	555	377
Argentina - (Up River)	**543**		349
Rice			
Thai -100% Grade B (Bangkok)	**545**	534	573











Impact on Agriculture - How to Measure?

Crop Yield Response (Agronomy/Statistical) Model

-- Integrate Climate and Non-Climate Factors

↓

General Circulation Model (GCM)
Statistical Model (Historical Data)
IPCC Scenarios (SRES)

↓

Economic Model with Adaptation Options

Food price, Production, GDP, Social welfare

Research Focus

- **Take into account uncertainties in**
  - **Scientific Info (Hazard, Exposure)**
    - Climatologically/meteorological dynamics
    - Climate simulation modeling
    - Downscaling method/local impact
    - Future development scenarios
  - **Human Behavior (Vulnerability)**
    - ✓ Decision-making process
    - ✓ “Life is a chance”
  - **Government Actions**
    - How costly they are
    - Decision-making process
    - Institutional failure

Climate Change Adaptations
—What Are the Options?

- A survey of options by **R Barichello & B Gilmour** "***Moving Beyond Market Volatility towards Agri-food System Resilience***", presented at 2011 PECC Agri and Food Policy Forum, Dec 1-2, 2011, Taipei

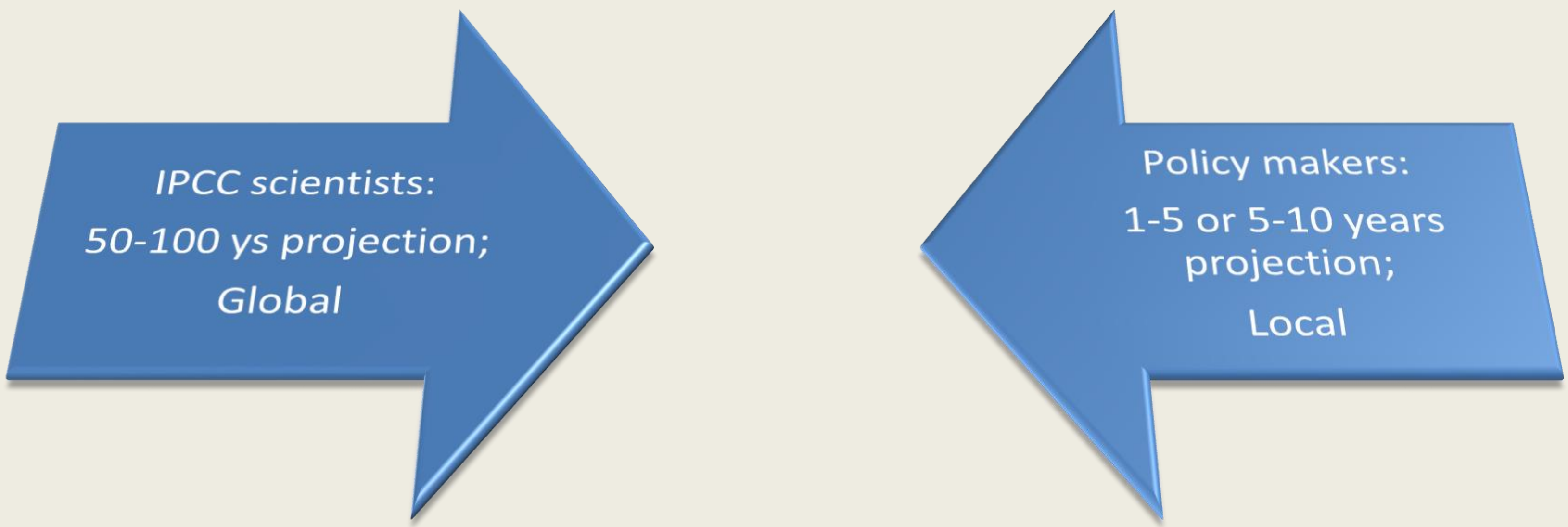
1. **Adapt to increased volatility**
2. **Add resilience by increasing income**
   - Farm level → **Production Volatility**
   - Supply Chain → **Production & Price Volatility**
   - Market/Policy level → **Price Volatility**

A Tool Box

- **Farm Level:**
  - Diversification, insurance
  - Add value to move away from raw product
  - Adopt agricultural research
- **Supply Chain level:**
  - Add value by moving up value chain
  - Improve food research
  - Invest in better infrastructure
  - New distribution methods (network v.s. hub and spoke)
- **Policy/Market level:**
  - Hedging options, price pooling,
  - **Food reserves**
  - Insurance tools
  - Information (monitoring, early warning)

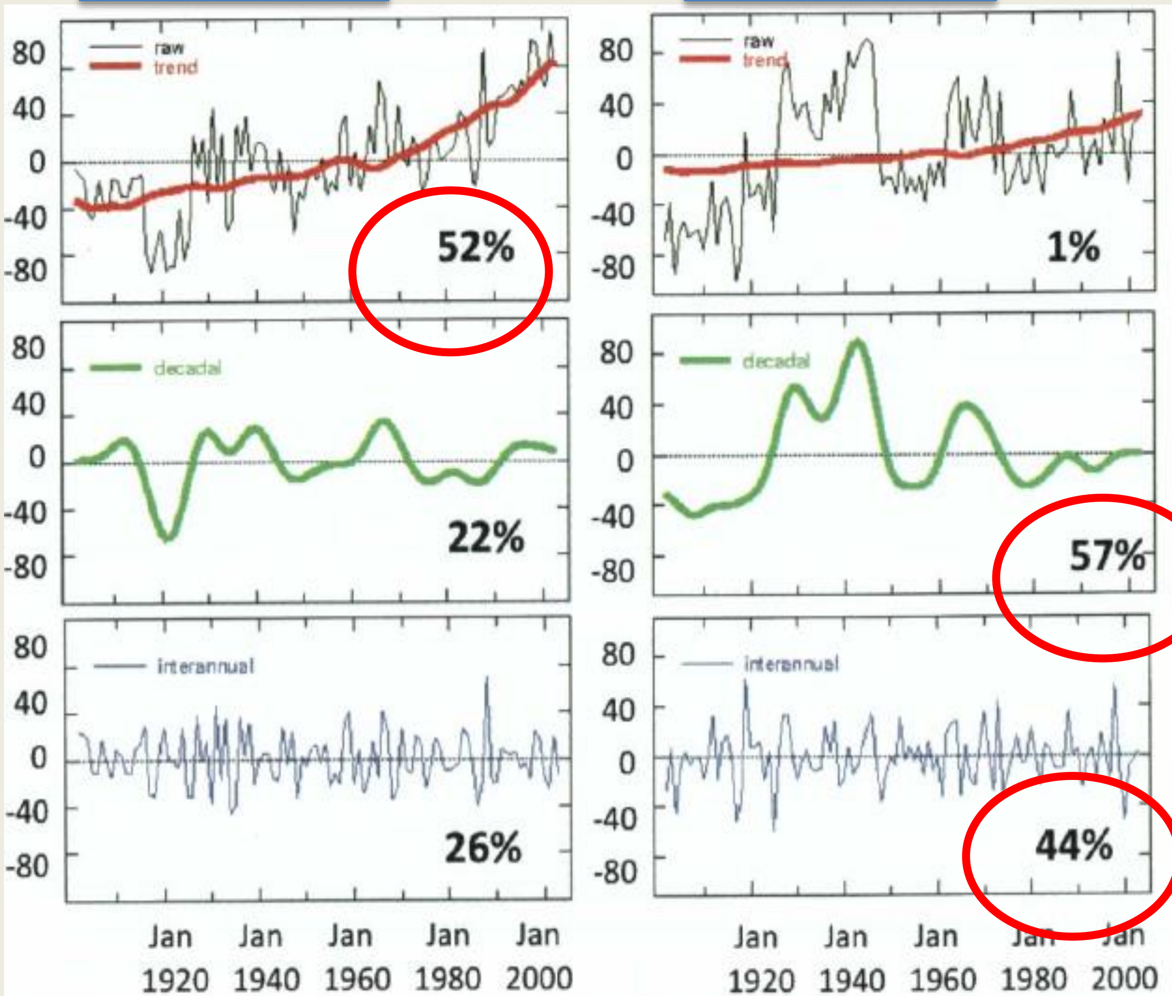
Information needed for Adaptation on Climate Change and Variability

- **Shortcoming of existing global climate model**
  - Accuracy and uncertainty
  - Spatial resolution
  - Temporal downscaling



Magnitude of Temperature Variability at 3 temporal scales, 2 small regional scales

Eastern Brazil | Western Peru



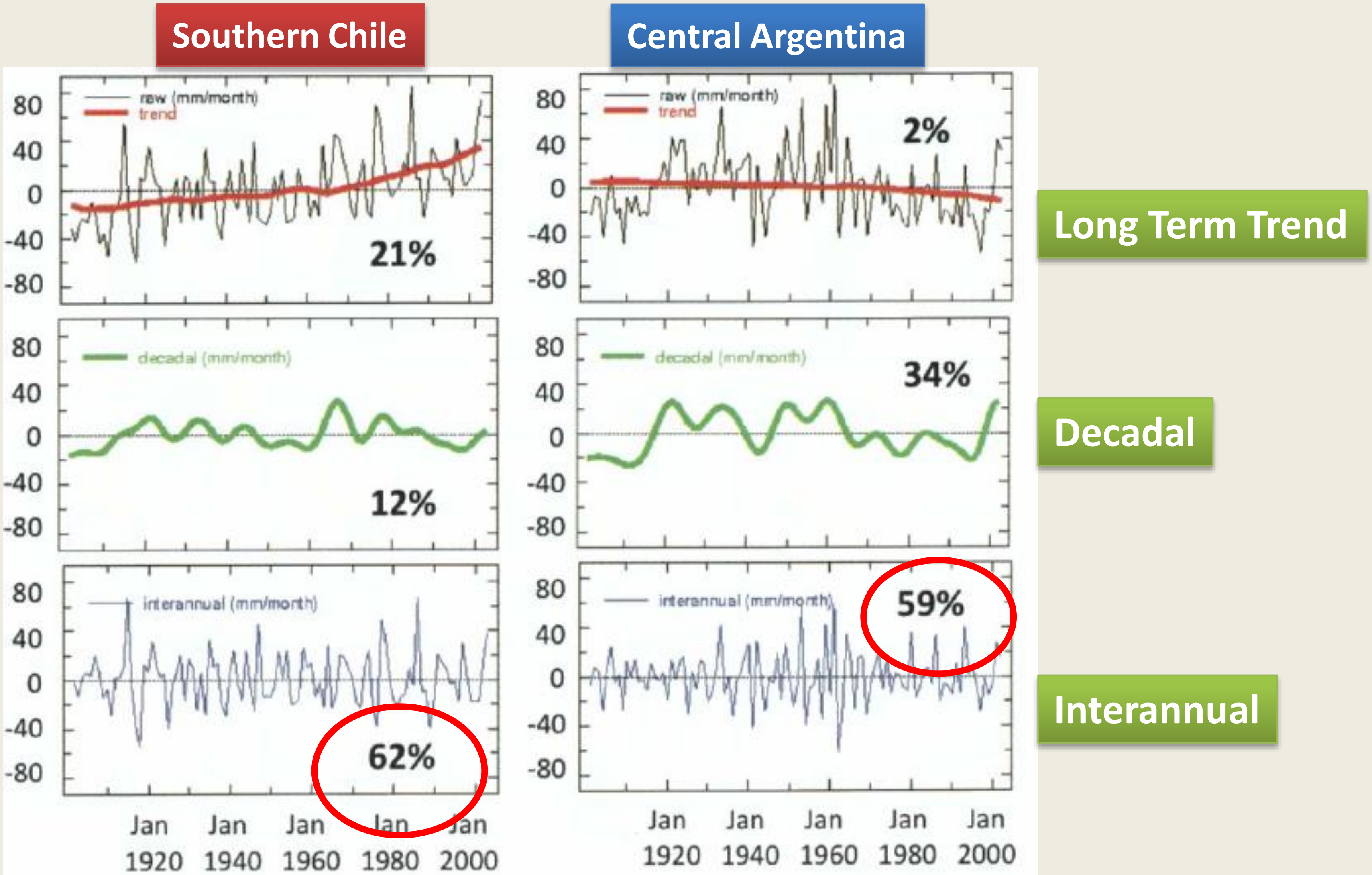
Long Term Trend

Decadal

Interannual

Source: Baethgen W and L Goddard (2012), Chapter 4 in <u>Handbook of Climate Change and Agroecosystems</u>, Ed by Hieele D and C Rosenzweig. Imperial College Press.

Magnitude of Precipitation Variability at 3 temporal scales, 2 small regional scales

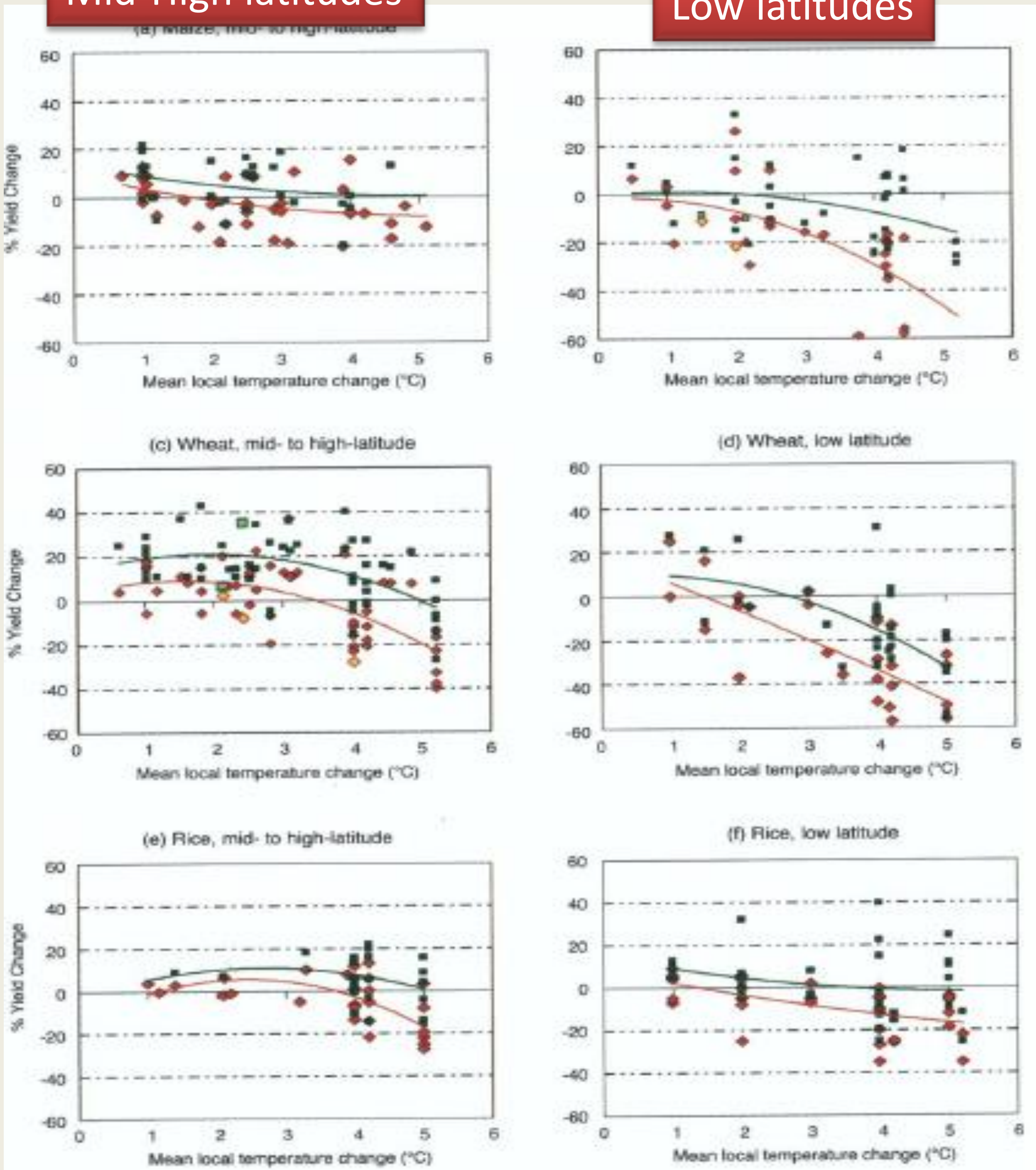


Source: Baethgen W and L Goddard (2012), Chapter 4 in Handbook of Climate Change and Agroecosystems, Ed by Hieele D and C Rosenzweig. Imperial College Press.

Simulated yield change of maize, wheat, and rice

Mid-High latitudes

Low latitudes



Maize

Wheat

Rice

- With vs. without Adaptation

Source: Easterling et al., 2007

Key Question in Adaptation

➔How to customize weather information to meet local need for agricultural production?

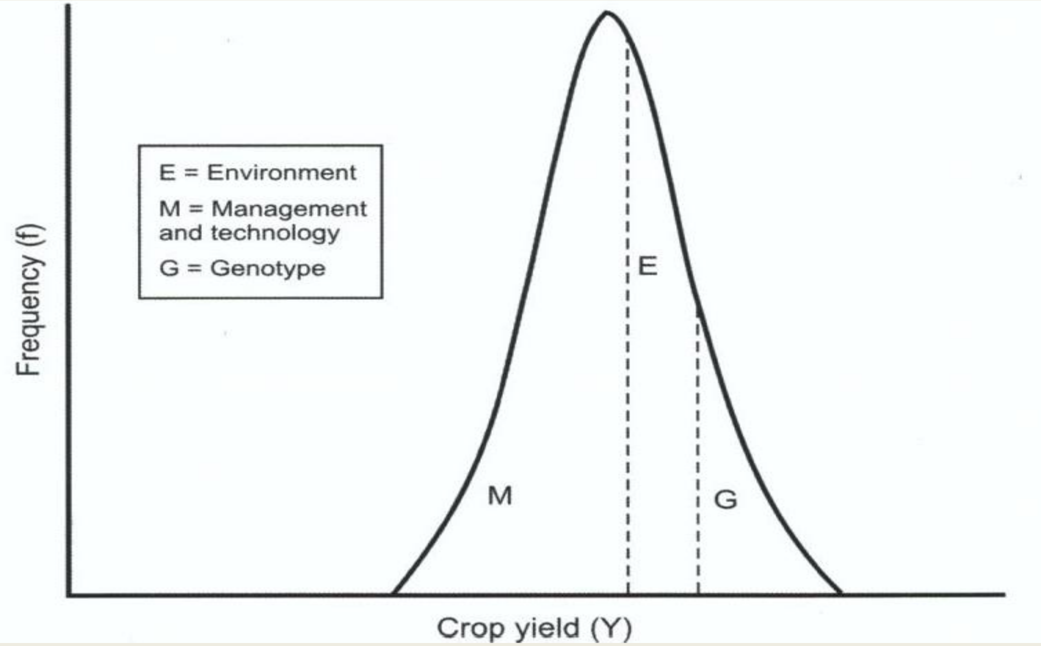
- Link **field data** and local weather data **directly**
  - Limited funding for experimental data
  - Growing demand in emergent markets from:
    - contract farming
    - index-based crop insurance contract
- Identify **Temperature and precipitation thresholds** affecting crop yield performance
  - Not all forecasts are accurate
  - Preventive measures can be developed to reduce losses

The Role of Agronomy

- **Help buffer yields against mean climate change and adapt to increased climate variation**
- **Ensure sustainable food production in the future**
  - Intrinsically multi-disciplinary
  - Encompasses plant genetics, crop physiology, climate and meteorology, and soil science.
- **Express the interactions**
  - **Genotype*Environment*Management*Technology (GEMT)**
- **Predict responses** of food producing systems to using models and statistical tools

How to use GEM to decompose crop yield?

- **Yield Variation:**
  - Management 55%, Environment 15%, Genotype 30%
  - M operates at lower end and contribute to the lowest yield
- **Climate variation**
  - Expect lower mean and widened yield distribution
  - Adaptation requires better seasonal forecasts



➔ Need to identify how sensitivity varies with stage of development
➔ max temperature thresholds and their variability

Source: Porter J, et al (2013), P.81, Fig 3 in Chapter 5 in Handbook of Climate Change and Agroecosystems, Ed by Hieele D & C Rosenzweig. Imperial College Press.

Implications for Agriculture

- **Year-to-year climate variability** will lead to greatest socio-economic impact.

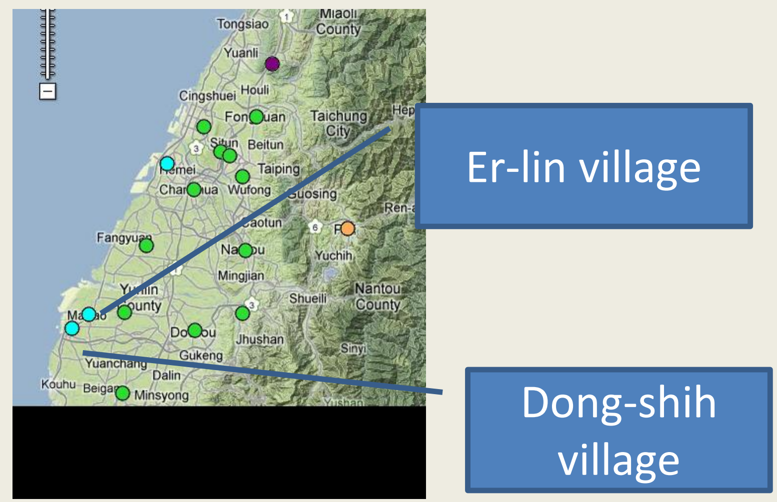
➔Agricultural production systems should build resilience to the impact associated with **current climate variability**

➔Planning for possible evolution over the next 10-30 years must consider **decadal variability**

➔**Appropriate use of climate information** must take into account the limitations and advantages of **both climate model and observational data.**

Case Study I – Carrot Cooperative

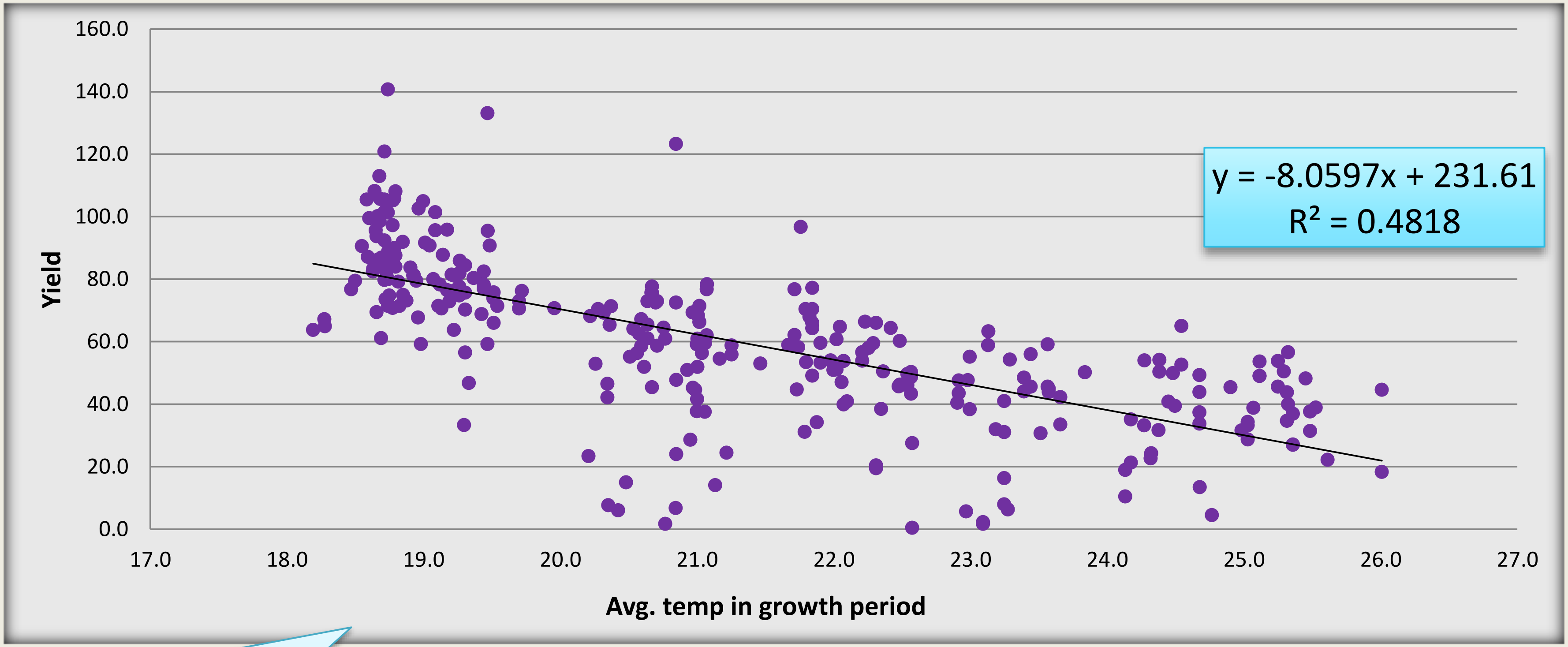
- Located at central Taiwan and marked in blue
- Belongs to 2 counties divided by a river



Empirical Analysis- Data

- Field data of carrot
  - Collected from 275 farms of a carrot co-op
  - locations
  - Planting/Harvest date
  - Irrigation type
  - Carrot yield
  - Class (by size)
- Climatic data
  - 2 EPA monitoring stations
  - Temperature: hourly averaged
  - Precipitation: hourly accumulated
-

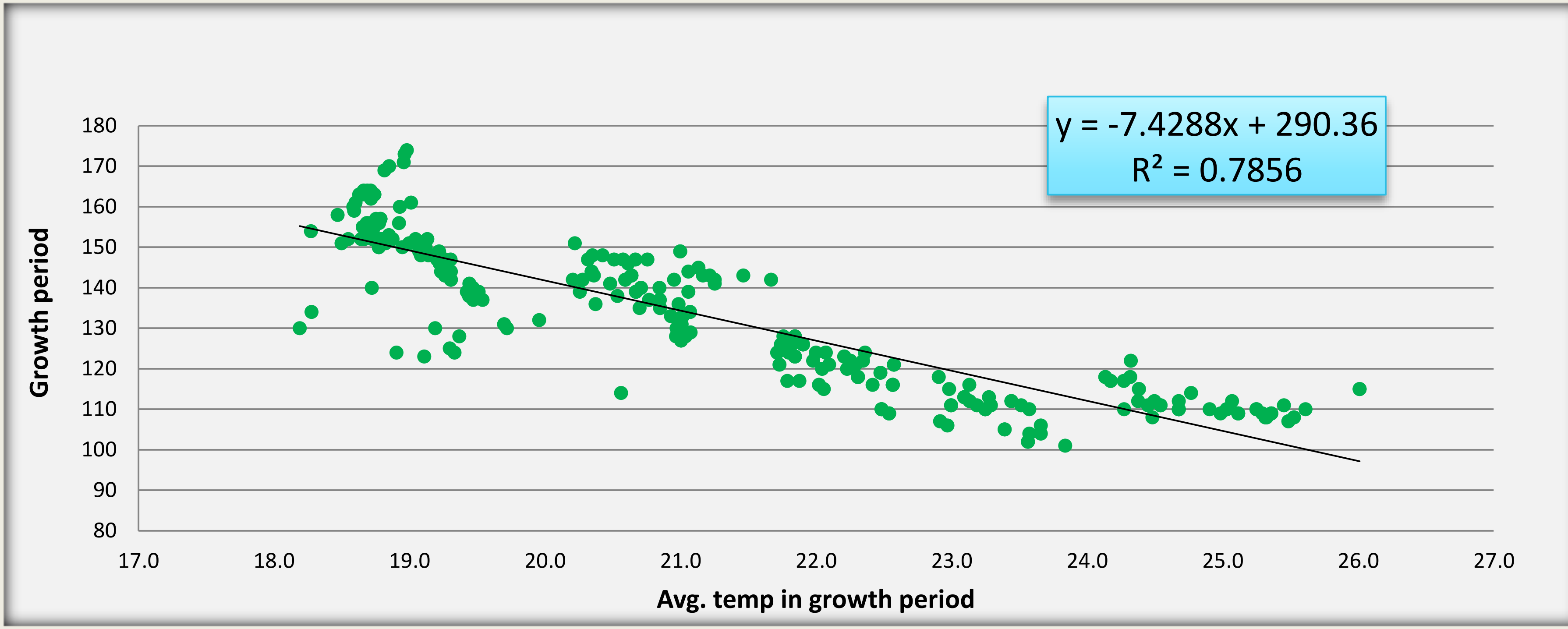
Does temperature have impacts on yield?



➔Cooler weather have positive impact on yield

ANOVA					
	df	SS	MS	F	P-value
迴歸	1	90319.19	90319.19	271.4633	1.4E-43
殘差	292	97152.02	332.7124		
總和	293	187471.2			

Does temp have impact on the length of growing period?



Warmer weather shorten the length of growing period

ANOVA					
	df	SS	MS	F	P-value
迴歸	1	76732.38	76732.38	1070.16	1.2E-99
殘差	292	20936.95	71.70188		
總和	293	97669.33			

Methodology

- Thresholds of growing temperature can be estimated by **the maximum Pearson Correlation coefficients** of
  - Observed yield and Hours of Growing Degree (HGD)
  - Observed yield and Hours of Growing Rainfall (HGR)

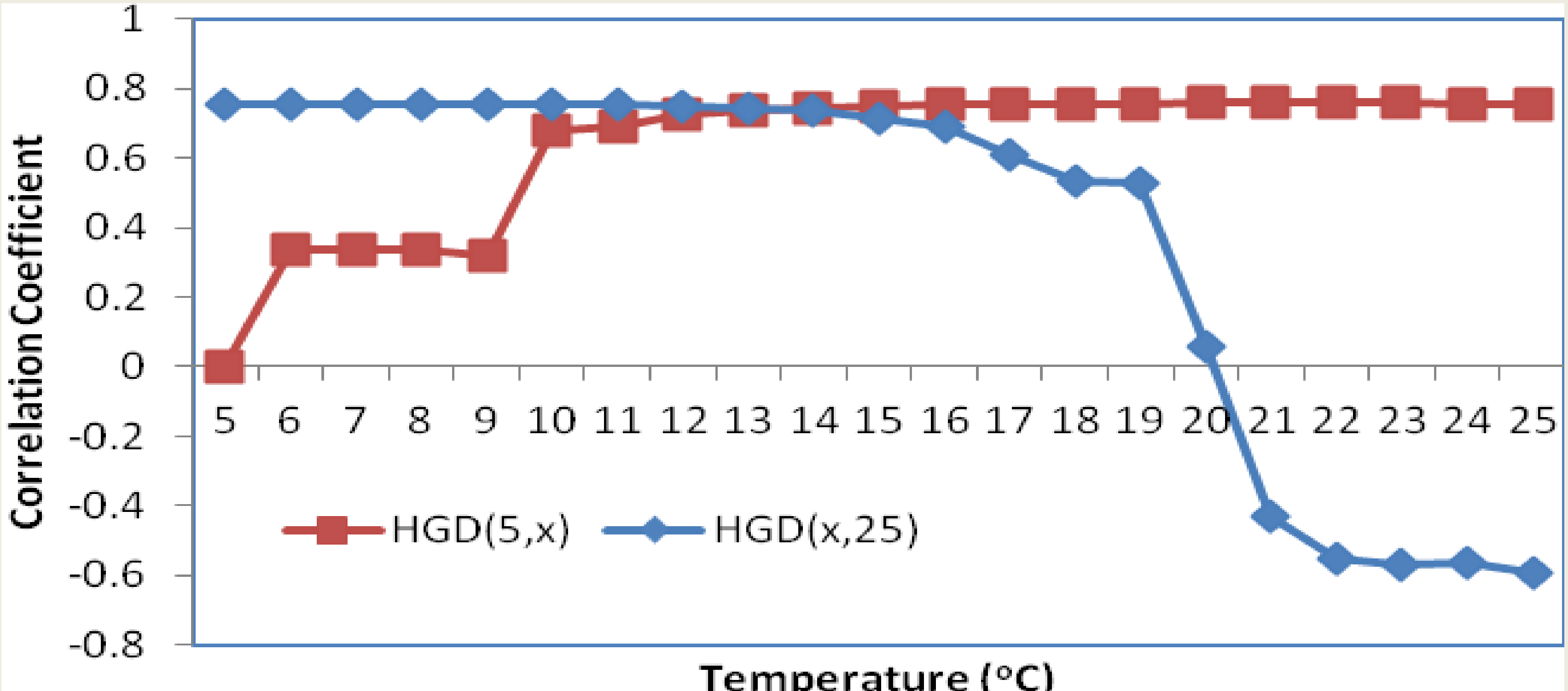
$$HGD_{min,max} = \sum_{t=1}^{N} H_t \,, \quad H = \begin{cases} 0 & \text{if } T_t < T_{min} \text{ or } T_t > T_{max} \\ 1 & \text{if } T_{min} \le T_t \le T_{max} \end{cases}$$

- t: an individual hour within the growing season
- T_t: observed average temperature during the hour
- N: number of hours between sowing and maturity, i.e. length to maturity

Example:

- **$HGD_{5,30}$** corresponds to equation with T_{min}=5°C and T_{max}=30°C
- **$HGR_{0,2.5}$** is the total hours of accumulated rainfall between 0mm and 2.5mm.

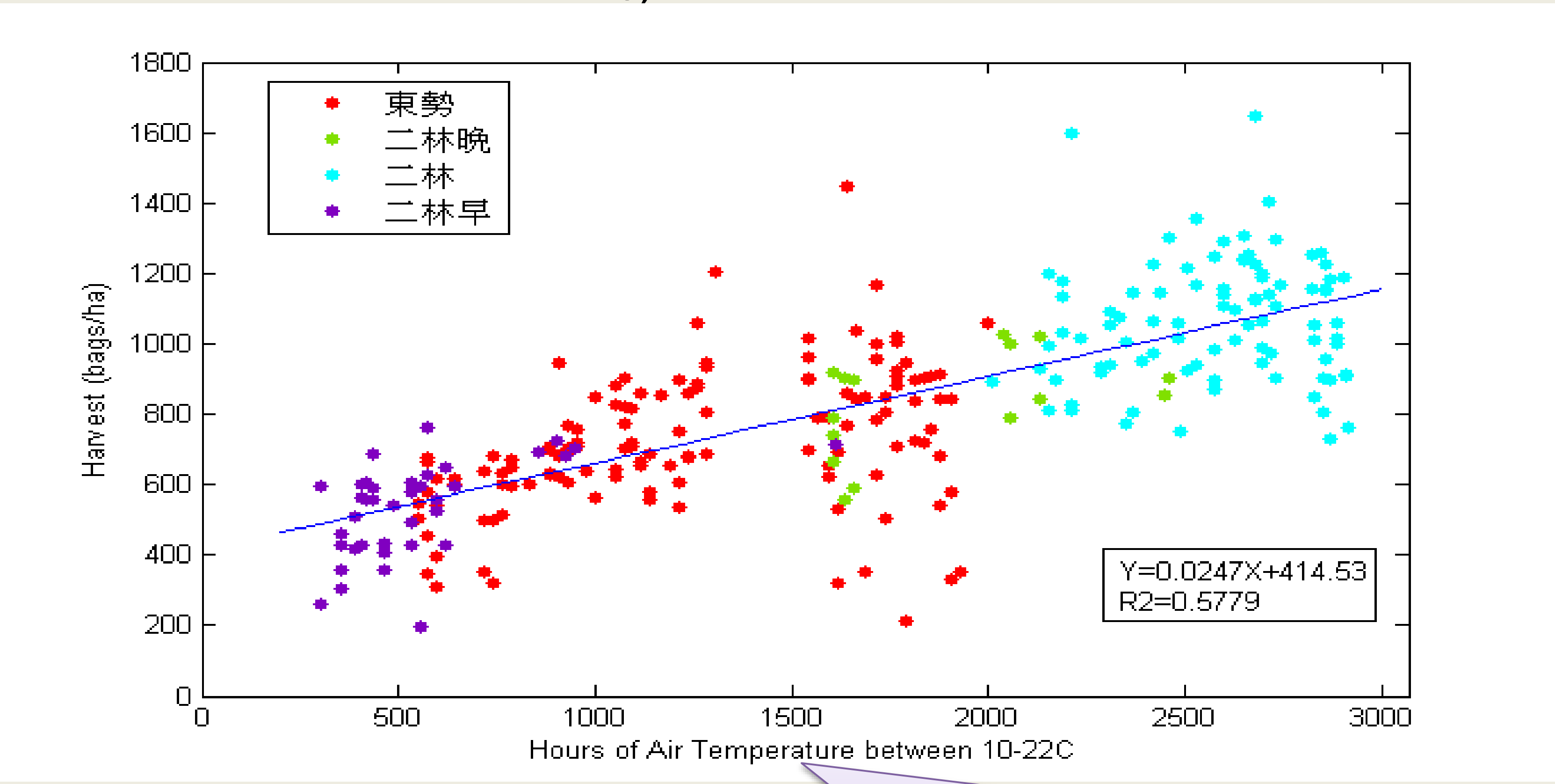
Major Findings-1
Optimum Temperature Range



- **Optimum growing temperature is <u>between 10-17C</u>.**
- **Temperature <u>below 10C and above 21C</u> may reduce yields**

Major Findings-2

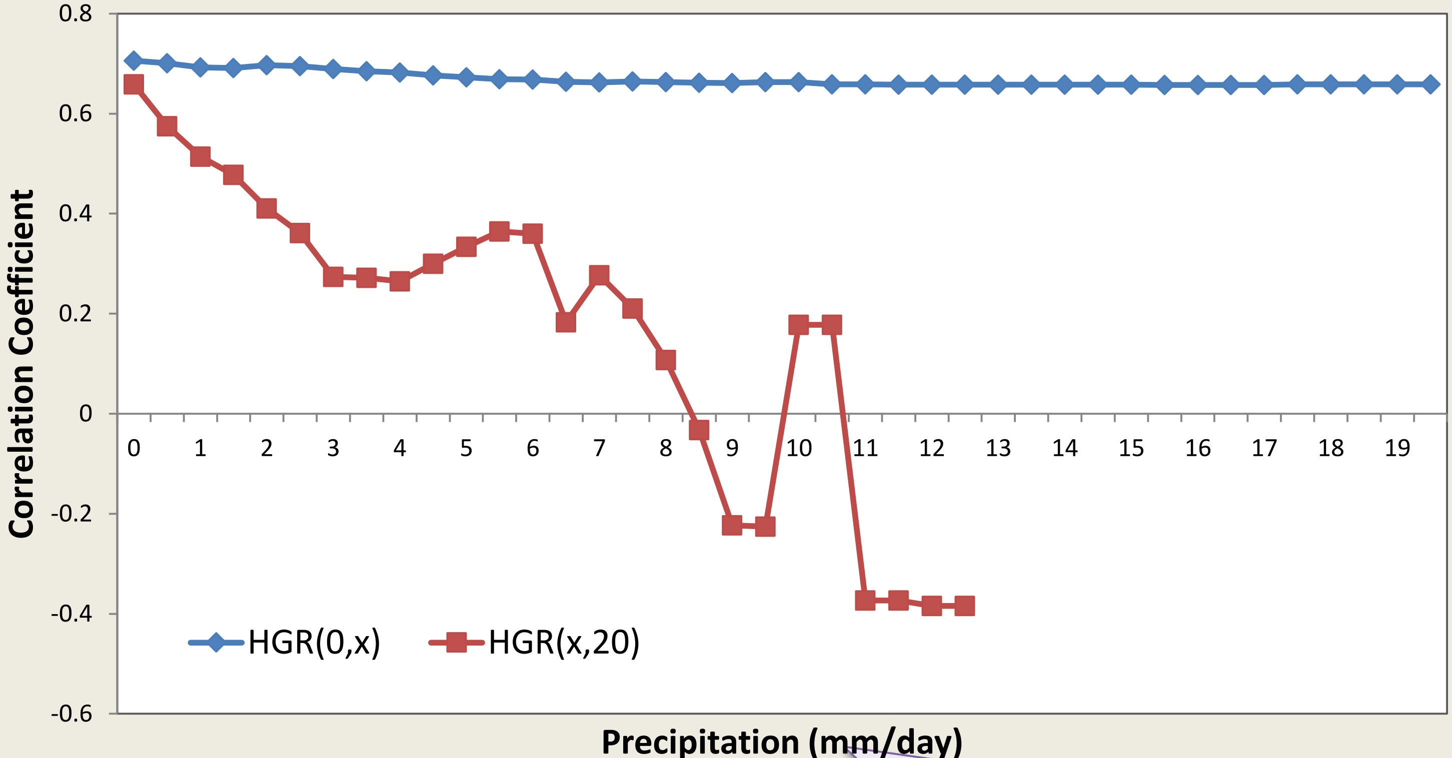
Yield and $GDH_{10,21}$ are positively correlated



Scatter distribution of yield and $GDH_{10,21}$

➔Carrot yield is positively related to the no of hours in the optimal temperature range (10-21°C).

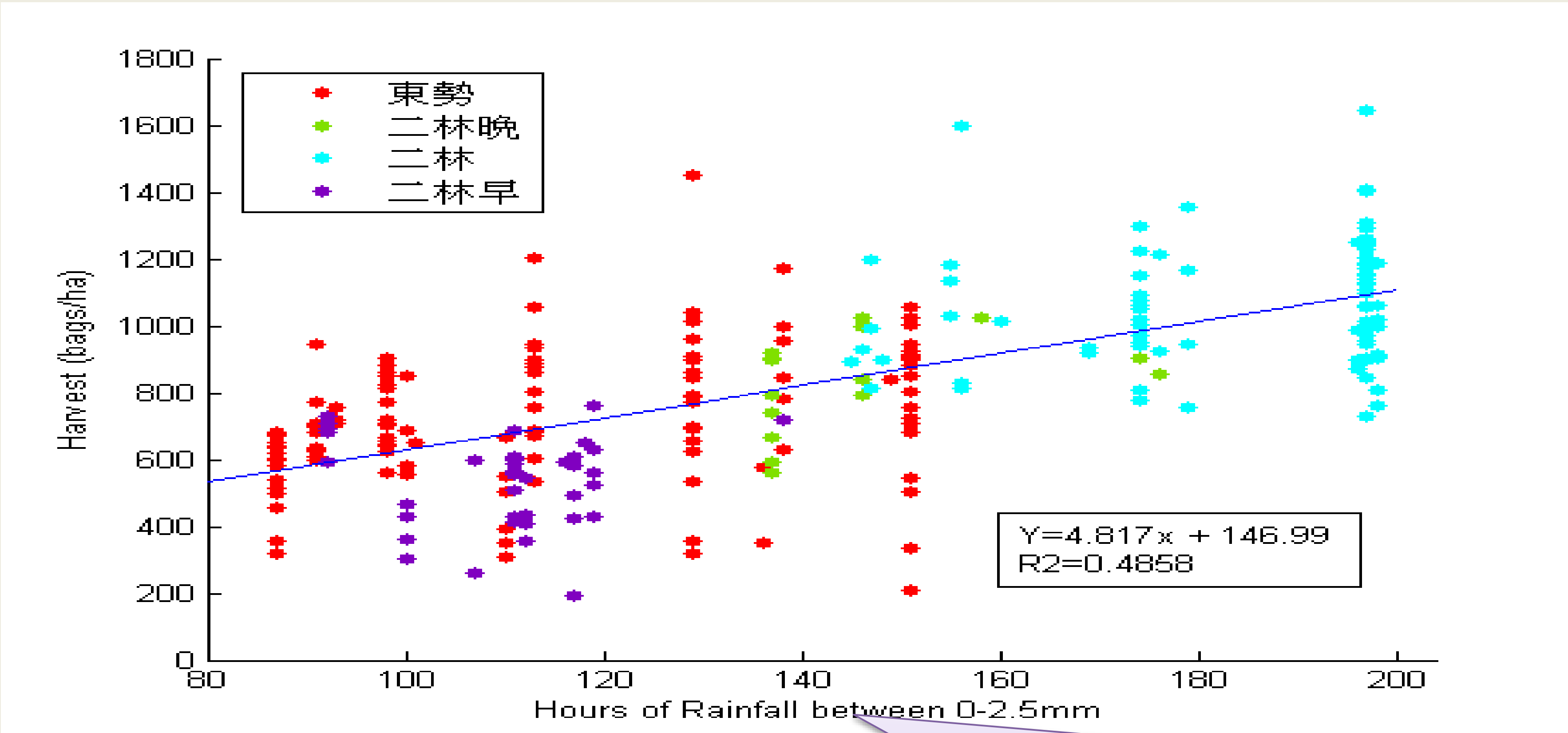
Major Findings-3
Optimum Rainfall Range



- Cannot identify the optimal range for precipitation
    - No direct correlation between HGR and yield.
- Rainfall strength larger than **8~10mm/hr** may cause damage on yield

Major Findings-4

Yield and $HGR_{0,2.5}$ are positively correlated



- Despite irrigation control, hours of rainfall less than 2.5mm **($HGR_{0,2.5}$)** are **positively** related to final yield

Major Findings-5
Multiple regression analysis

	Coefficient estimates	Standard Deviation	t -statistics	P-value
Intercept	92.11766	19.33655	4.76391	0.00000
$HGD_{10,21}$	0.02885	0.00509	5.67146	0.00000
$HGR_{0,2.5}$	-0.01231	0.00769	-1.59994	0.11078
Irrigation (Canal)	-11.30040	3.61583	-3.12526	0.00197

- **$HGD_{10,21}$** is a **positive** contributor to yield ➔ **confirmed**
- **$HGR_{0,2.5}$** is negative but insignificant ➔ **need better indicators**
- **Canal irrigation** is **negatively** associated with yields significantly.

Value Come from Downstream Users

- **Farming is sensitive to weather**
  - ✓ Optimal temperature can be identified ➔ No risk
  - ✓ **Uncertainty in rainfall** becomes a major risk factor
- **Weather forecasts can be instrumental in:**
  - ✓ Reduce potential losses from natural hazards
  - ✓ Stabilize **farm income**
- **Value of weather information depends upon:**
  - ✓ **How** to transform local weather info into agron info?
  - ✓ **When/How** to disseminate this information?
  - ✓ **Who** should be the targeted recipient?

➔**Who determines the price farmers received?**

➔**Is customized weather info still "public " goods?**

Implication for Decision Making

1. Decision-Making "Before Planting"

- **Traditional wisdom**

  ➔ Need vegetable **germplasm** to reduce environmental stress

  ➔ Need **seasonal forecast** to select crop variety

- **New challenges**

  ➢ Market offers better prices for off-seasonal harvests

  ➢ Market demands safe/organic products

  ➔How to provide farmers "advanced knowledge" to meet conflicting demand?

Implication for Decision Making

Decision Making "After Planting"?

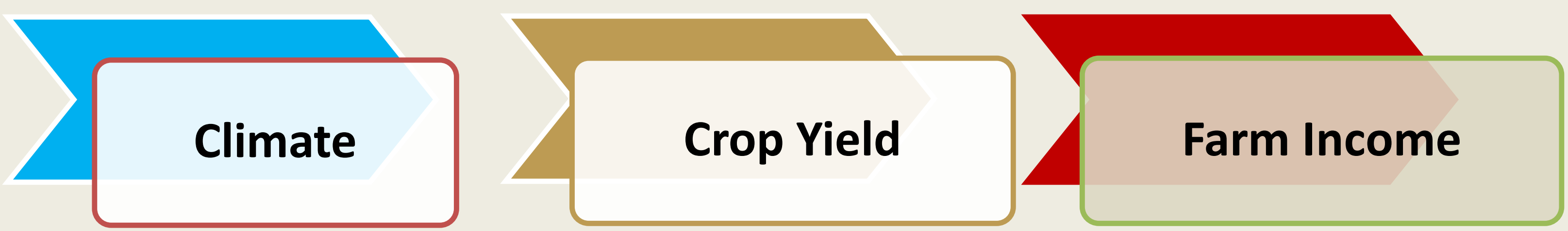
- Raised beds
- Mulching
- Nets, shelters

➔Need to decide whether to invest

➔Need innovations to reduce labor and costs

Public or Private Goods?

- **Weather is critical in all stages of crop growth and market value.**
  - **Scientific Side**
    - Will climate change enhance environmental stress on crop?
    - Can weather info offer an opportunity to raise farm income?
  - **Policy Side**
    - Who should pay-Is customized info public or private goods?
    - What kind of public-private partnership is needed?
    - How should the supply chain be involved?



Conclusions (1)

1. **Linkages between climate and agricultural production are complex.**
   - Sustained programs of observations, projections, and research are needed to meet the challenges

2. **Agricultural regions of the world are already responding to current climate change and planning for the future.**

Conclusions (2)

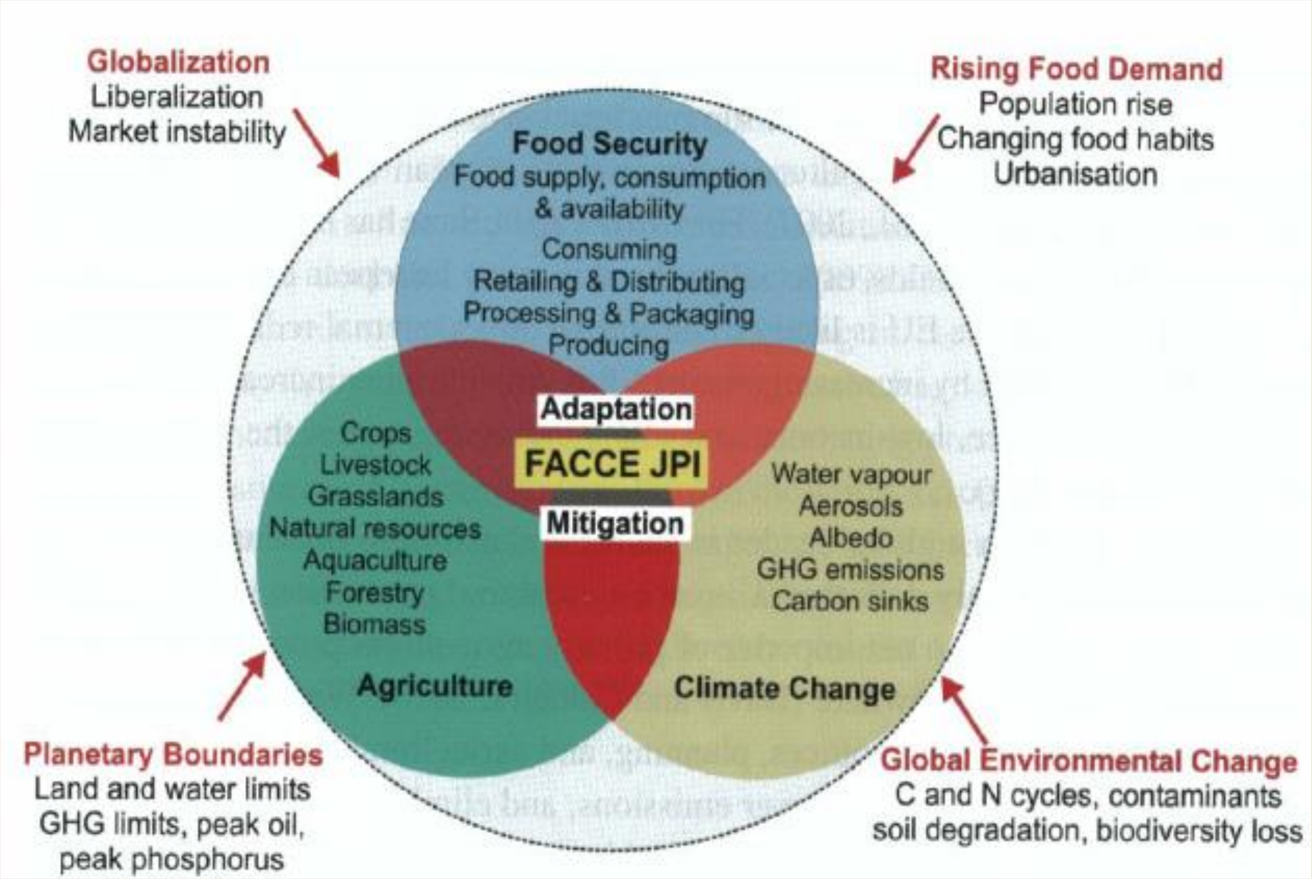
- **Great variety of options to make ag-food system more resilient to climate risks**
  - **Private** actors as well as **Public** policy
  - **National** effort with **International** cooperation
  - **Risk reducing/sharing** and **income/efficiency enhancing**

- **Most policies require careful, critical appraisal before being accepted**
  - Need analytical **tools**
  - Need to collect **information**
  - ➢ How to **deploy and use them** adequately and effectively?

Climate-Smart Agriculture

– A multifaceted problem

- Difficult to have a perfect model



Source: FACCE-JPI Strategic Research Agenda,
http://www.faccejpi.com/FACCE-JPI-Home/SRA-press-release