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Food Security and Climate Change in the Asia-Pacific Region: Evaluating Mismatch between Crop Development and Water Availability

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Institutions

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- South Australian R&D Institute (SARDI), Waite Campus, Australia

- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, AP, India.

- Institute of Environment and Sustainable Development in Agriculture (IEDA), Chinese Academy of Agricultural Sciences (CAAS), Beijing, China

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- Climate variability and climate change, and in particular the inability to predict or respond to growing season weather, are major threats to the profitability and even the viability of farming operations.
- This is the case in both developed and developing countries, although in developing countries the farmer’s livelihood is more affected by individual crop failures.

- One particular concern is that crop phenological development, which is largely determined by temperature and photoperiod, may be out of phase with rainfall and hence water availability during critical periods of grain yield determination

- The possible mis-match between crop phenology and water availability poses the following questions:
- a) What are the expected temporal shifts in crop phenology under future climates, and what are the driving forces behind these changes?
- b) What are the likely shifts in the pattern of rain and water availability?
- c) To what extent climate change will contribute to any mismatch between crop phenology and water availability?
- d) What are the expected consequences of this mismatch for food security?

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Objectives:

- To identify appropriate models, modelling framework and data needs to incorporate relevant climate risk factors for matching crop development with water availability
- To develop modalities for networking amongst three countries for identified activities
- To discuss the structure for target output report from three countries on the identified activities
- To identify the specific training needs, interests and strengths of this interdisciplinary multilateral project team, and to explore opportunities for increased collaboration.

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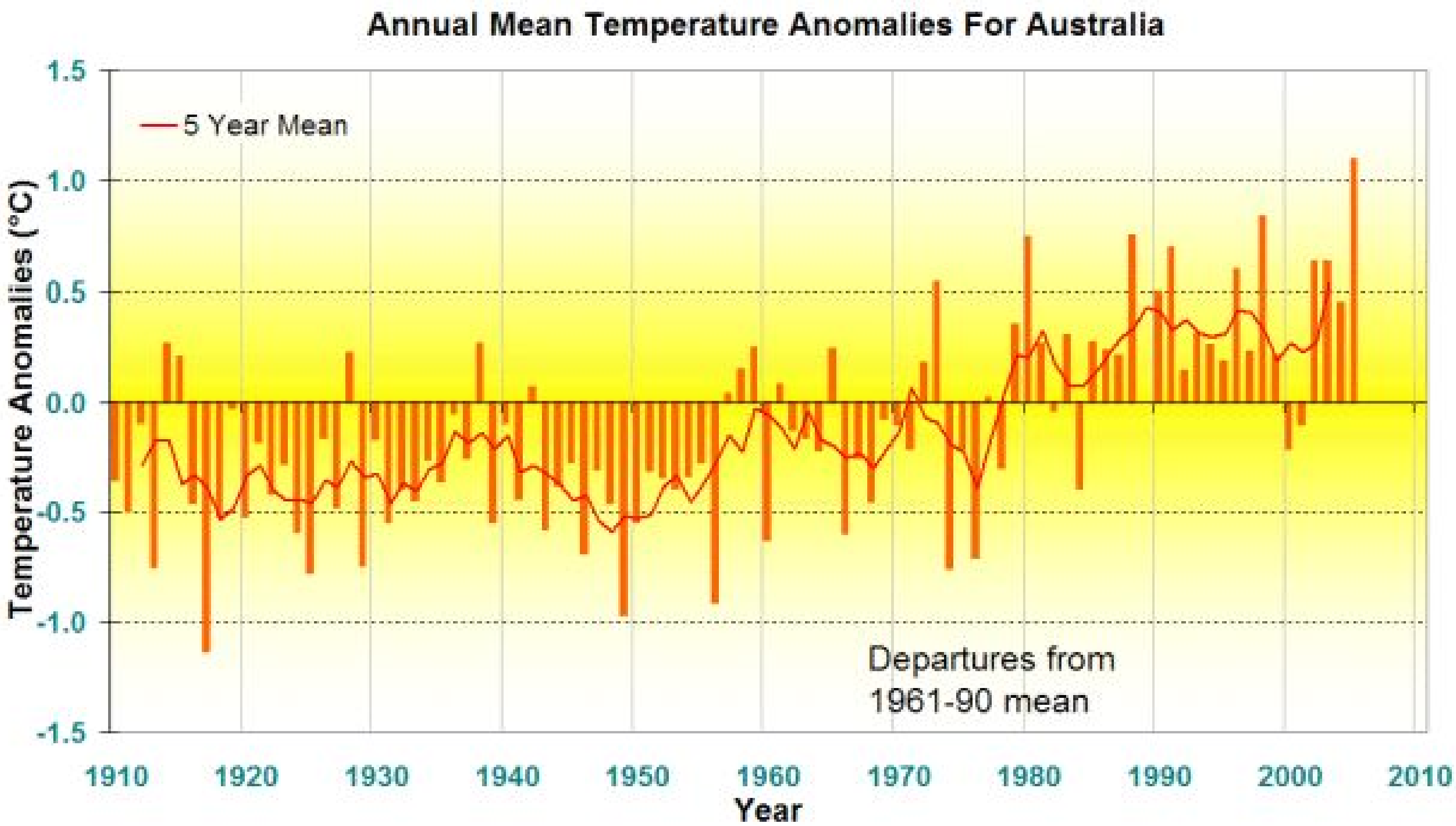


Sadras VO & JP Monzon

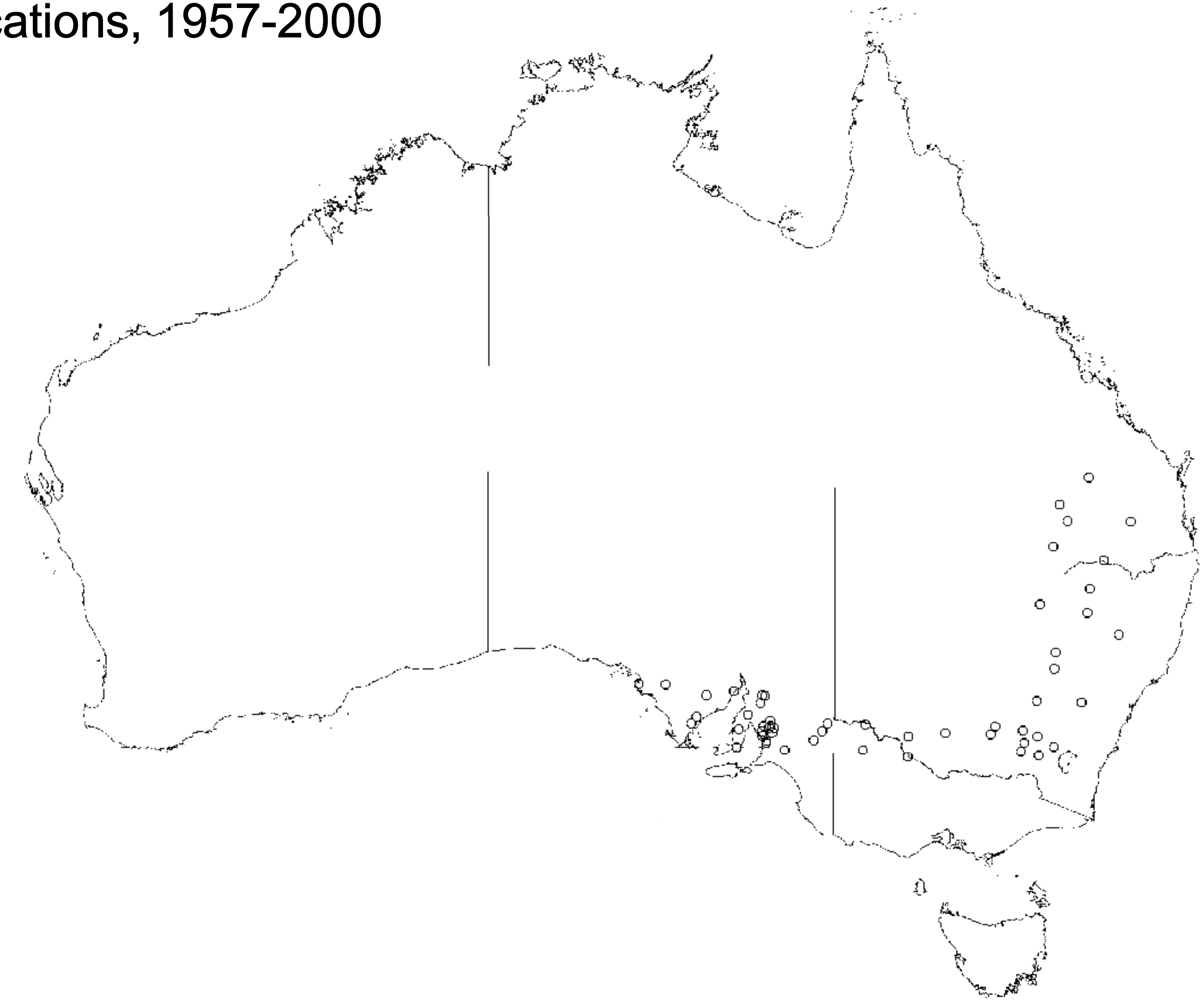
Modelled wheat phenology captures rising temperature trends: shortened time to flowering and maturity in Australia and Argentina

Field Crops Research (2006)

Wheat phenology in Australia

flowering and maturity time estimated with APSIM model

53 locations, 1957-2000



- **Temporal shifts in crop phenology with climate change**
- As the wheat module in APSIM and CERES-Wheat both assume that crop phenology is driven by photoperiod and temperature (Jones et al., 2003; Keating et al., 2003), changes in duration of crop phenophases simulated with these models can be primarily attributed to changes in temperature.

Phenology is variable and non-stationary

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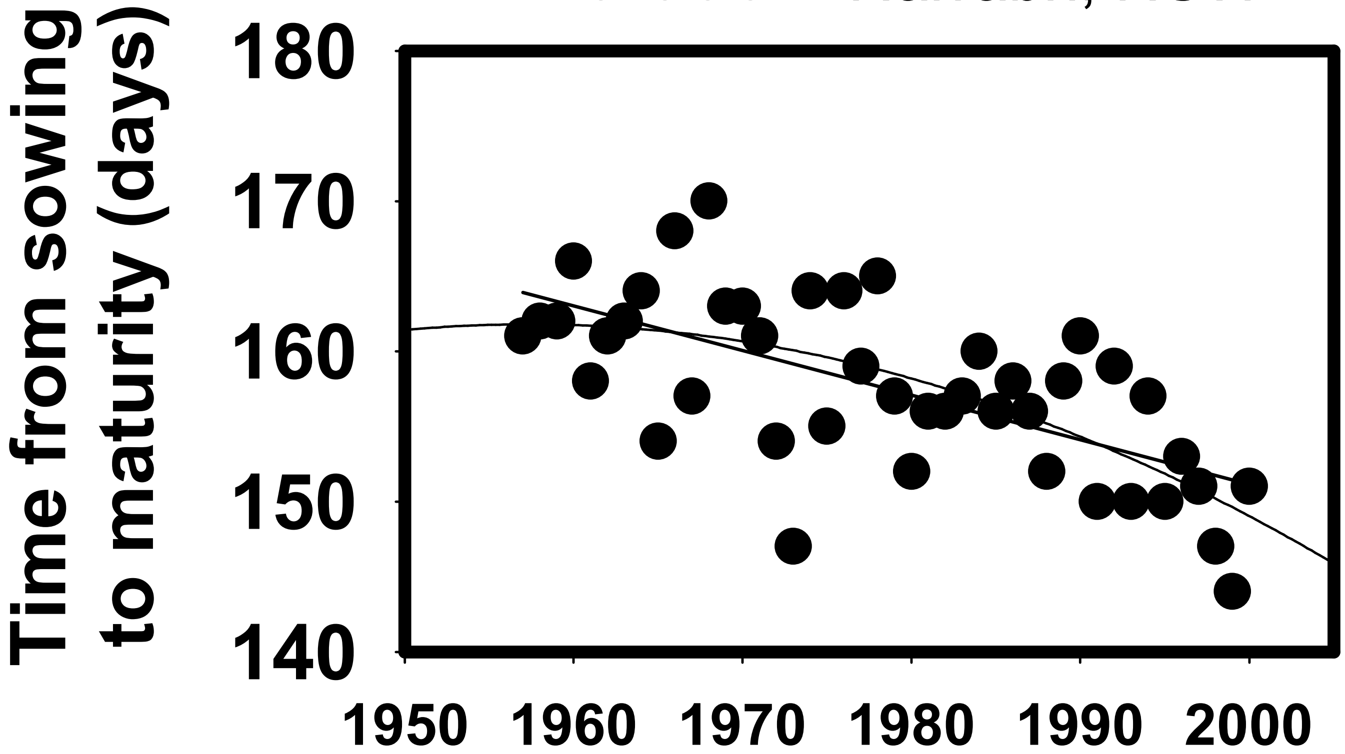
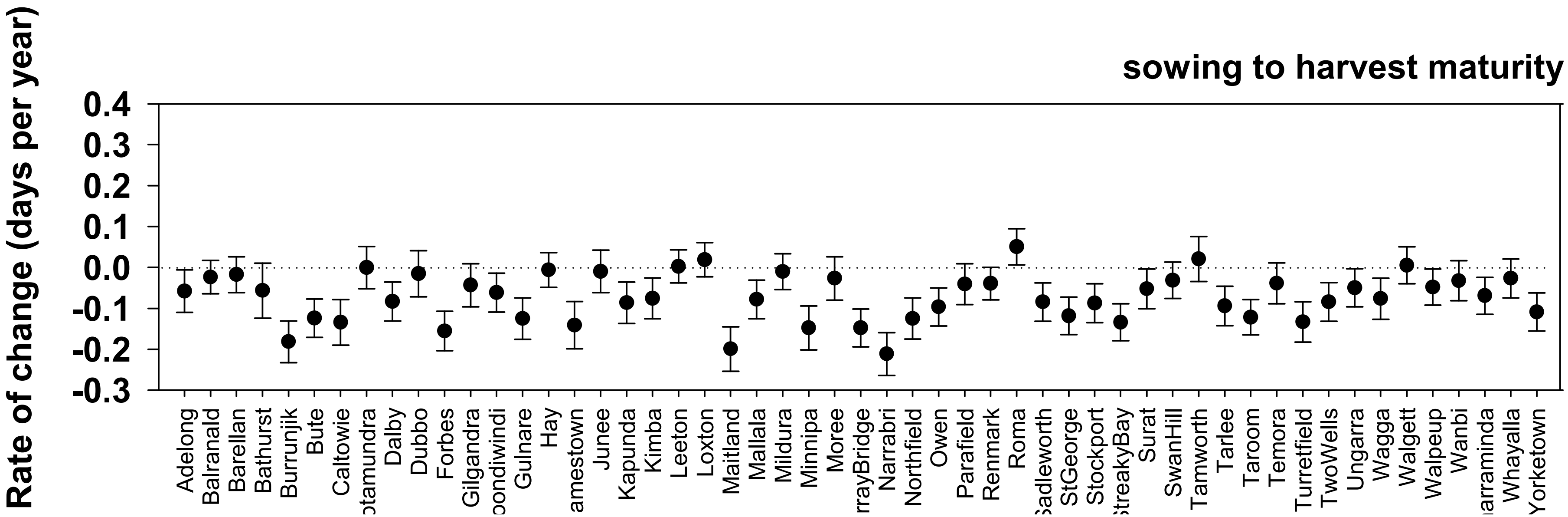
rate = 0.30 ± 0.054 d y^{-1}
P < 0.0001 Narrabri, NSW



- The expectation is shortened season length associated with warmer climate in the last decades. The aim of simulation modelling was to quantify the actual magnitude of phenological changes, the relative changes in the duration of pre- and post flowering phases, and the interaction between changing temperature and sowing date for wheat in eastern Australia.

1957-2000

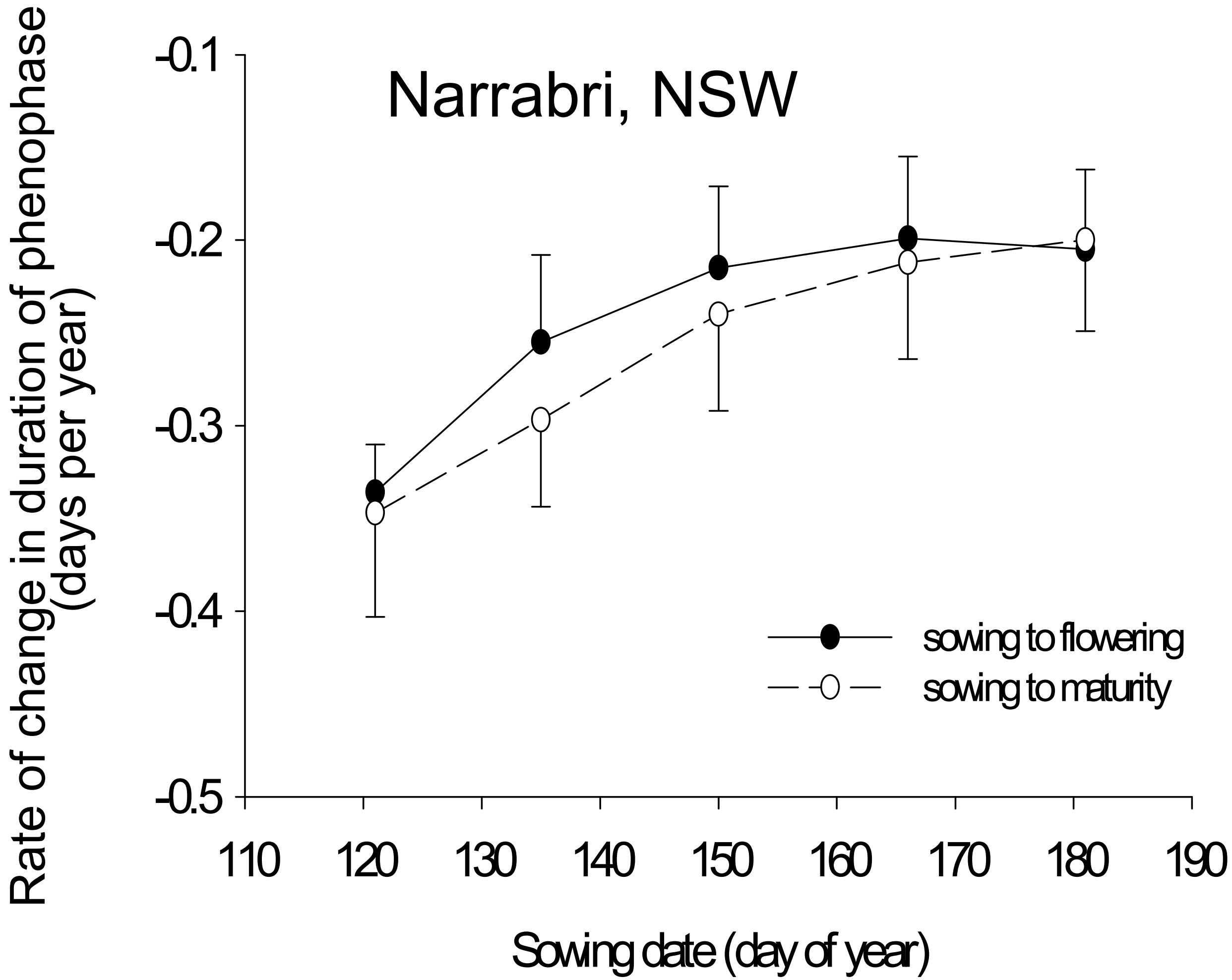


vs. rate due to breeding = -0.14 days per year

- Sadras and Monzon (2006) studied the changes to phenophases for wheat at Narrabri in northern NSW. Realized mean annual temperature changes over the period of simulation (1957-2000) were in the order of plus 0.2 degrees centigrade/10 year period (Hennessy *et al*, 2008). Simulated changes in phenophases are summarised below:

- Simulated time to maturity of crops sown in mid May was reduced at a rate of 0.30 - 0.054 days per year ($P < 0.0001$) using a linear regression model. A non-linear model fitted to the data shows a sharper decline in time to maturity in the last two decades due to a more rapid increase in temperature over this period.
- Simulated time from sowing to flowering was reduced at 0.26 -0.047 days per year ($P < 0.0001$), accounted for most of the variation in time to maturity ($r2 = 0.77$, $P < 0.001$)

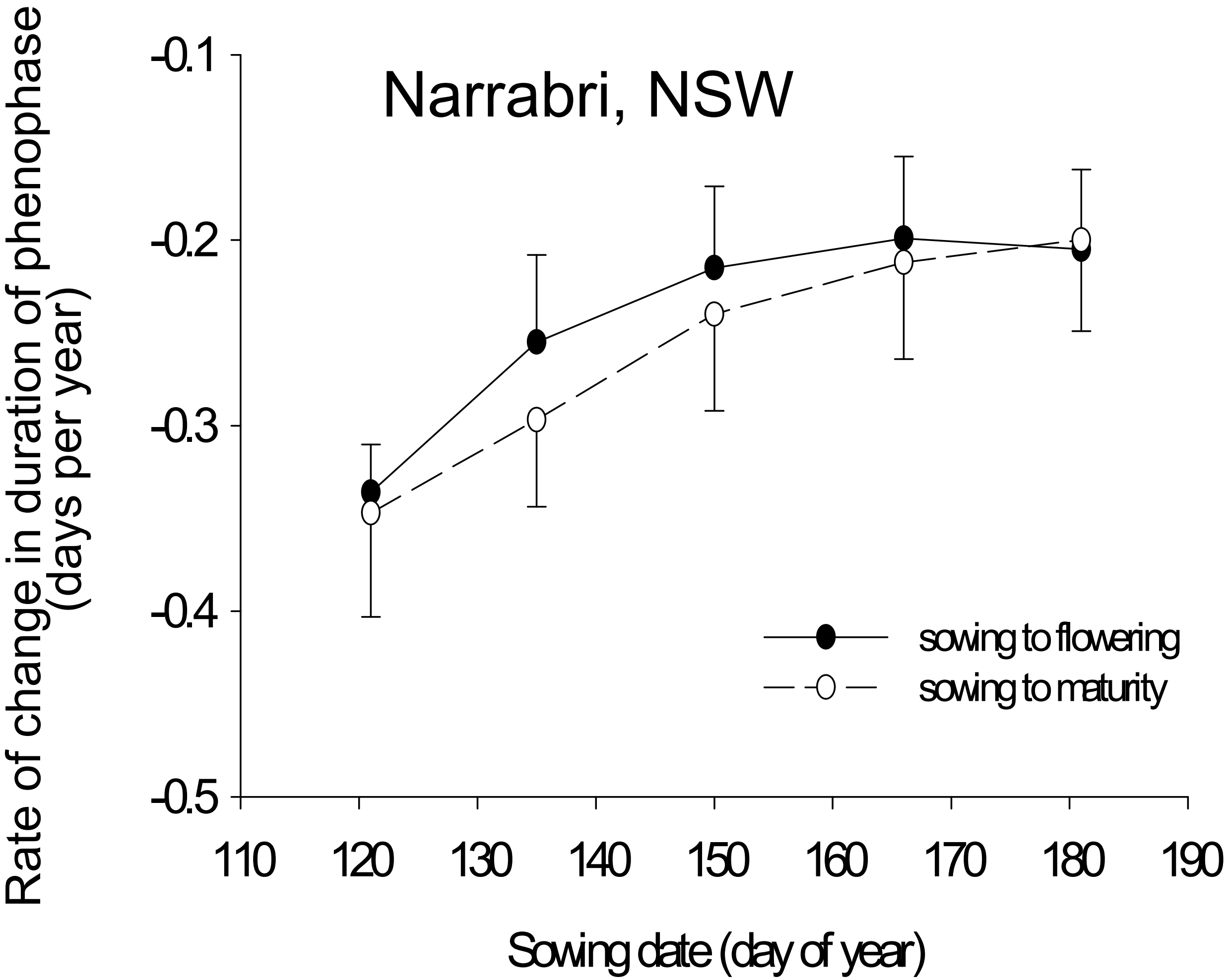
interaction with sowing date



- Duration of the modelled post-flowering phase was unchanged (P > 0.21). Shortened time to anthesis was associated with increased temperature in the pre-flowering phase, while the lack of change in the duration of the flowering-maturity phase corresponded with unchanged temperature in this phase. The lack of change in temperature during post-flowering resulted from earlier flowering , which shifted post-flowering development to relatively cooler conditions, thus neutralising the trend of increasing temperature detected for the average post-flowering phase.

- The rate of change in the duration of modelled wheat phenophases (sowing to flowering and sowing to maturity) declined with late sowing
- Full graphical representation of these data is shown in Sadras and Monzon (2006)

interaction with sowing date



- In China, due to a shift of rainfall (Liu *et al*, 2009; Shao Xiaomei et al., 2006), and especially increases in temperature, the northern boundary of winter wheat has extended. There have also been changes in sowing date and length of phenophases compared with 20 years ago.

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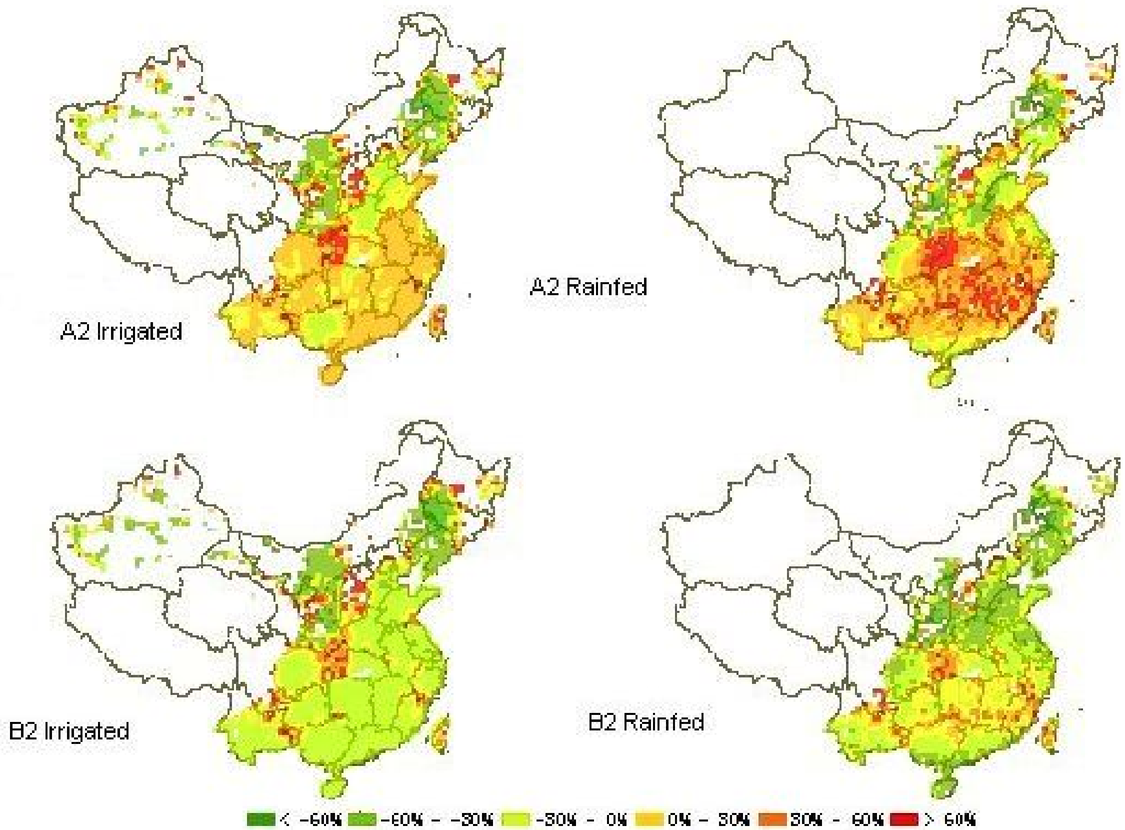
- ***Climate change***



By 2030, gross cereal productivity in China can decrease 5~10% if no action is taken. By the second half of the 21st century, climate change can cause yield reduction in rice, maize and wheat up to 37%.

Top: Rice Yield 2080

Down: Arable land -13%

- An analysis of trends in on-farm rice and wheat yields in the Indo-Gangetic Plains, starting from the 1980s using CERES models, revealed that reduced radiation and increased minimum temperatures have been associated with a decline in the simulated potential yields in several places. However, alternative interpretations of the link between increasing temperature and yield reductions are possible and correlative evidence needs to be interpreted with caution (Peng *et al.* 2004; Sheehy *et al.* 2006).

- Studies on the likely shifts in the rainfall pattern involve analysis of both realized change over the climate record, and projections of future trajectories using GCM. Many authors have produced projections of climate change in Asia using GCM. Our approach therefore combines (a) new analysis of realized changes, and (b) use existing and well accepted estimates from published work on future climates.

- One major outcome of this project is to link together existing projects in the Asia Pacific region.
- In India, we link with the Adarsha Watershed project. The watershed project is an innovative program of water, soil, and land management enabling farmers to access water and grow crops not just in the rainy season but all year round.
- In China our project links with the national key project of mapping agro-climatic resources and adaptation of agriculture to climate change, particularly in water availability.

Community Watersheds can Bridge the Yield Gaps

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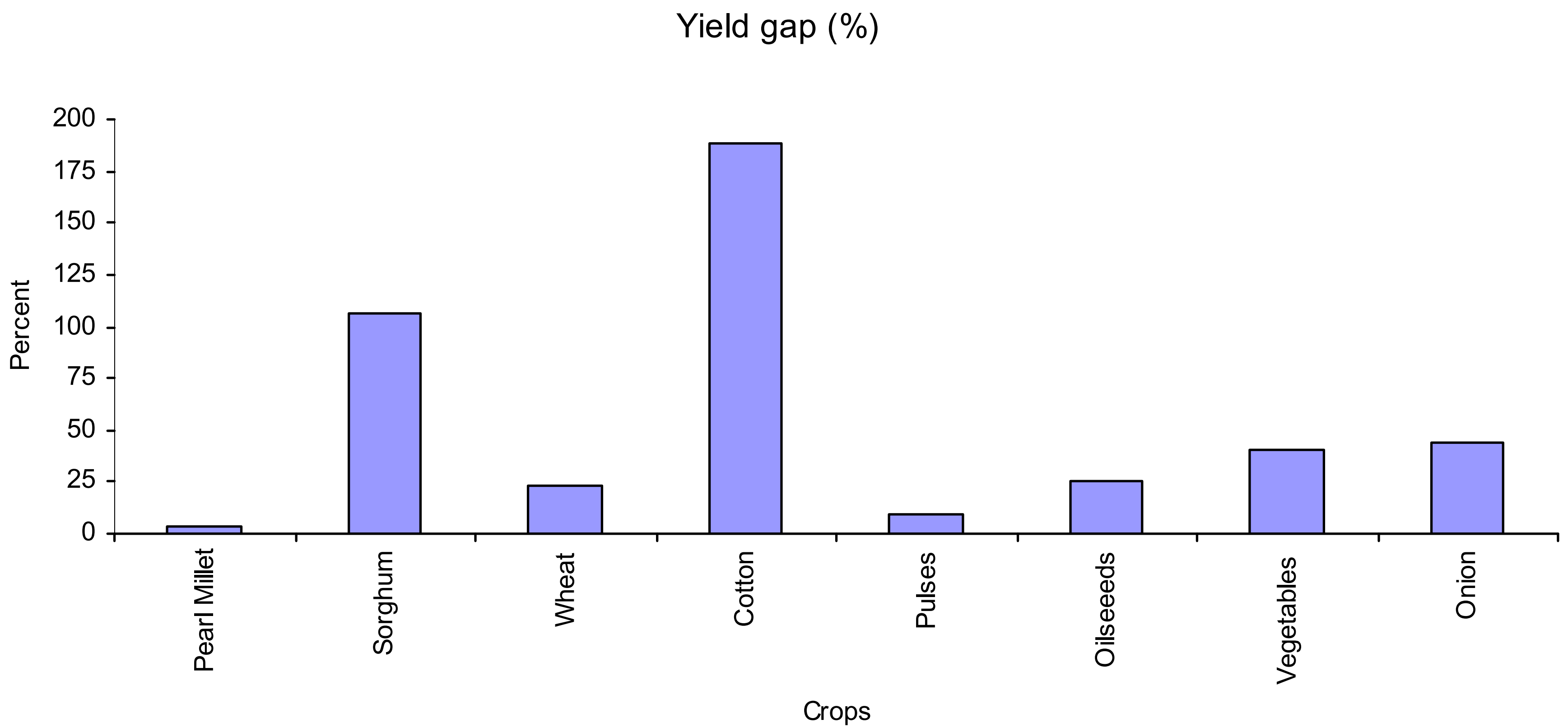

Effect Integrated Water Management interventions on runoff and soil erosion from Adarsha Watershed, Andhra Pradesh, India

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Year	Rainfall (mm)	Runoff (mm)		Peak runoff rate ($m^3/s/ha$)		Soil loss (t ha)	
		Untreated	Treated	Untreated	Treated	Untreated	Treated
1999	584	16	NI[a]	0.013	NI[a]	NI[a]	NI[a]
2000	1161	118	65	0.235	0.230	4.17	1.46
2001	612	31	22	0.022	0.027	1.48	0.51
2002	464	13	Nil	0.011	Nil	0.18	Nil
2003	689	76	44	0.057	0.018	3.20	1.10
2004	667	126	39	0.072	0.014	3.53	0.53
2005	899	107	66	0.016	0.014	2.82	1.20
2006	715	110	75	0.003	0.001	2.47	1.56
Mean	724	75 (10.4%)	44 (6.1%)	0.054	0.051	2.55	1.06

Crop Yields in Adarsha Watershed Kothapally during 1999-2007

Crop	1998 base-line yield	Yield (Kg ha $^{-1}$)									
		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	Av. yields	SE±
Sole maize	1500	3250	3750	3300	3480	3921	3420	3918	3635	3644	283.3
Intercropped maize	-	2700	2790	2800	3083	3129	2950	3362	3180	3029	263.0
Traditional	-	700	1600	1600	1800	1950	2025	2275	2150	1785	115.6
Intercrop pigeonpea	190	640	940	800	720	949	680	925	970	861	120.3
Traditional		200	180	-	-	-	-	-	-	190	-
Sole sorghum	-	3050	3170	2600	2425	2288	2325	2250	2085	2530	164.0
Traditional	1070	1070	1011	938	910	952	1025	1083	995	996	120.7
Intercrop sorghum	-	1770	1940	2200	-	2109	1980	1958	1850	1971	206.0

Farmers' Centric Watershed as an Entry Point

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- IGNRM, holistic livelihood approach
- Science-based approach
- Sustainability, empowerment and KS
- Social inclusion (equity & gender)

Consortium Approach for Community Watershed Management

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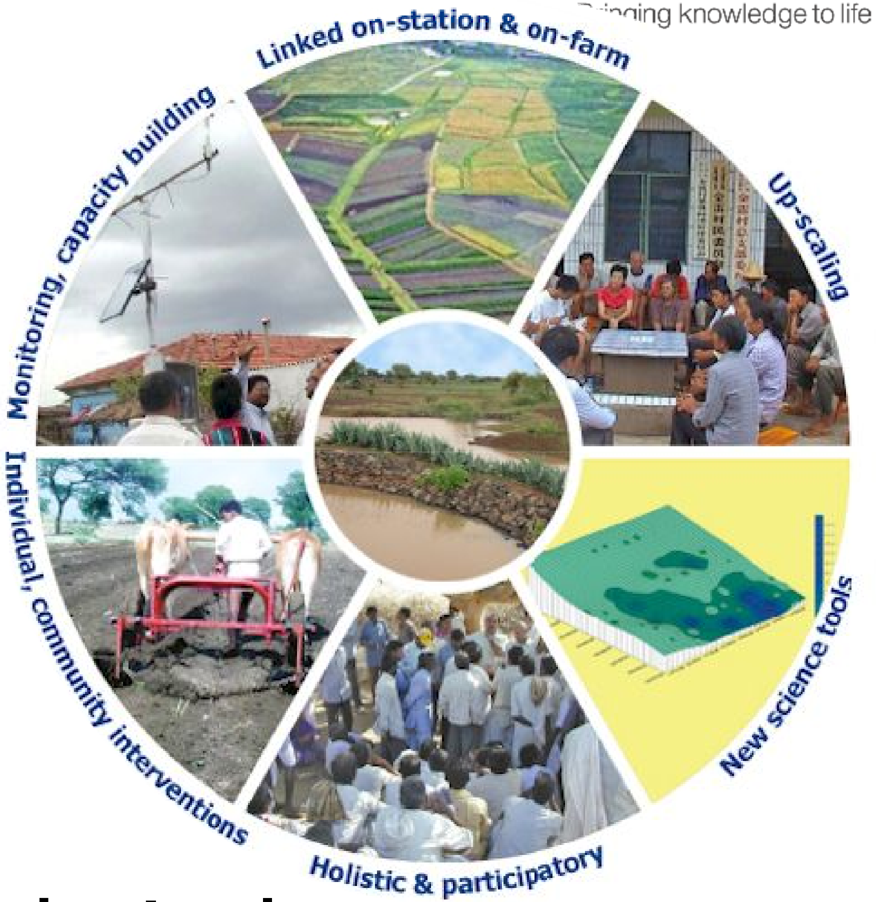


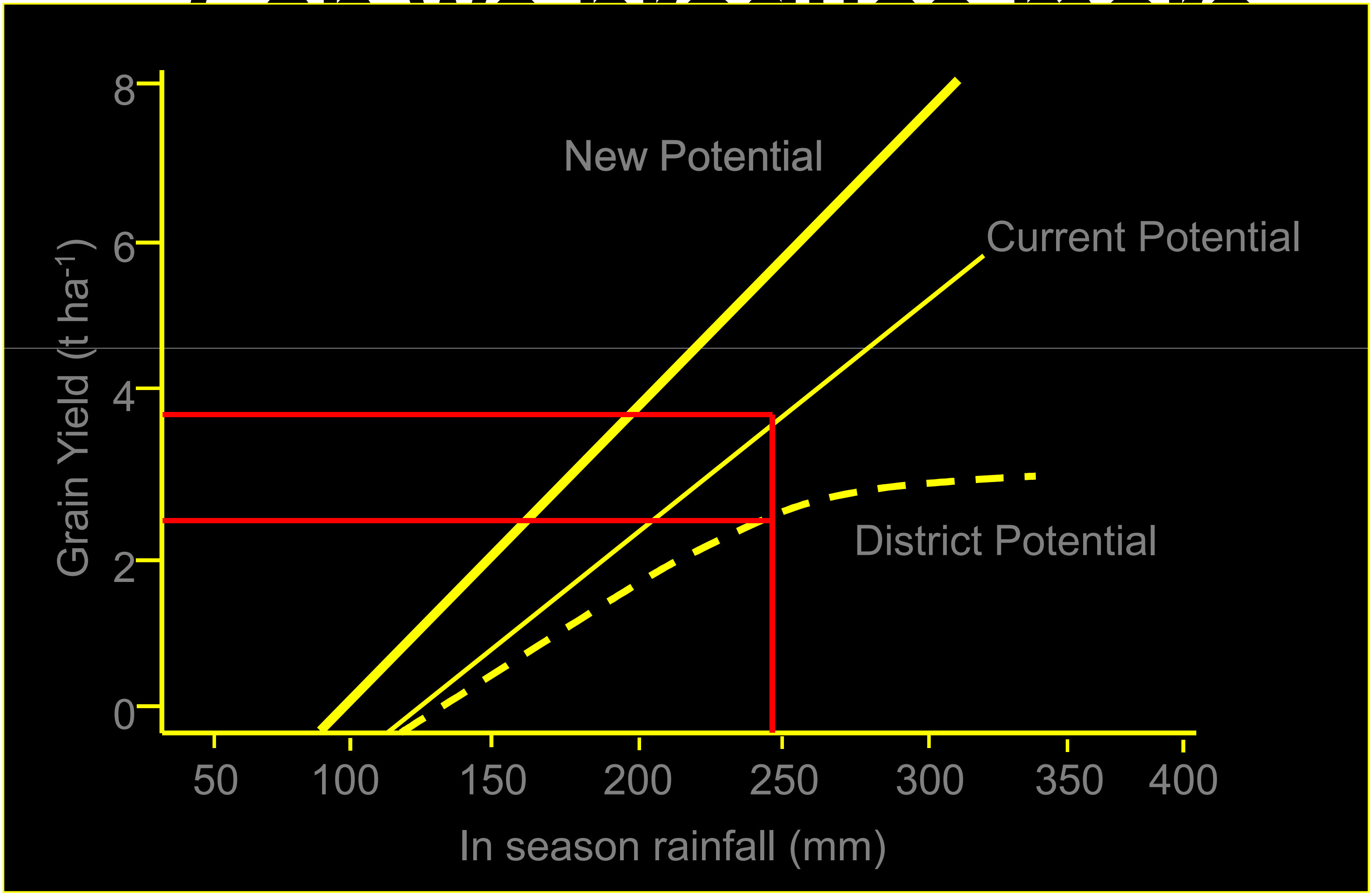
- Convergence
- Collective action
- Capacity building
- Consortium for technical backstopping

Community Watersheds

Converging community livelihoods

Some diverse agriculture in Australia

Can we produce more



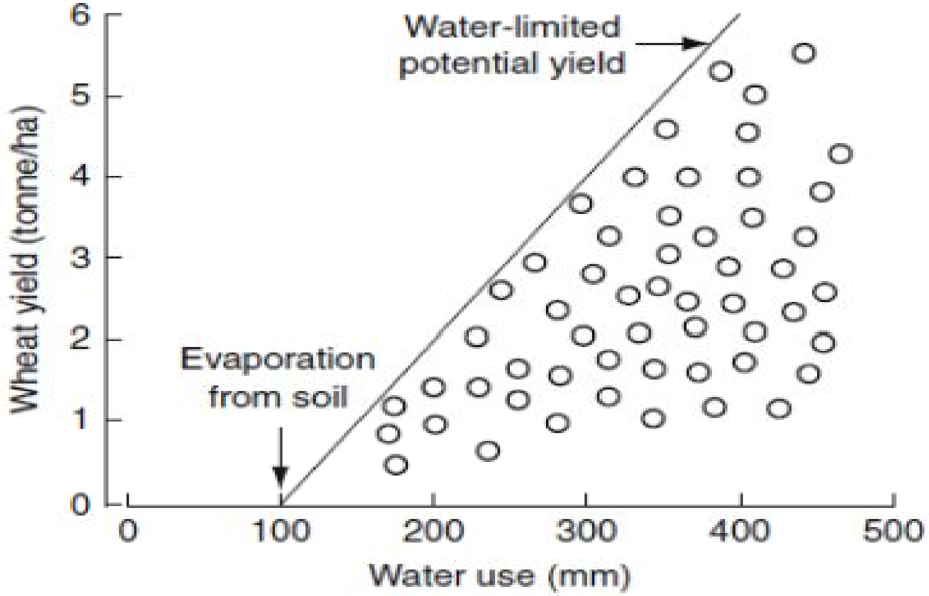


Figure 1 Schematic portrayal of wheat yield in relation to seasonal water supply (rainfall during the growing season plus available water in the soil at the time of sowing). The solid line depicts yield if water is the only limitation. It has a slope of about 20 kg ha^{-1} mm^{-1}. The intercept of that line on the *x*-axis reflects the loss of water by direct evaporation from the soil. The points cover the range of farmers' experience and are typically well below the solid line because of yield limitations due to weeds, disease, poor nutrition, frost, and other problems. Adapted from Passioura (2002) with permission of CSIRO Publishing.

Some adaptation strategies for sustainable development on agriculture in Vietnam (Van Viet)

Short term adaptation

a) Insurance: in agriculture to cope with weather variation,

b) Crop and livestock diversification: Changing crop types requires sufficient knowledge on the part of the farmer.

c) Changes in intensity of production

d) Improved nutrient and pest control management.

e) Changes in tillage practices and farm systems

f) Temporary migration

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Strengthen capability of climate forecast and warning system of agrometeorological Services for food security