Seasonal and inter-annual climate forecasting:
the 'new' tool for increasing preparedness to climate variability and change in agricultural planning and operations

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APSRU

QCCA

Queensland Government
Department of Natural Resources
Department of Primary Industries

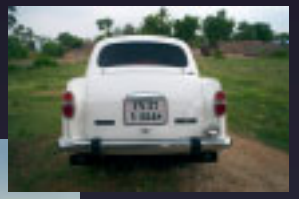
Objectives

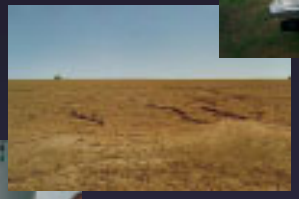
- Stress the need for cross-disciplinary R&D
- discuss the importance of systems approaches using agricultural simulation models for decision-making
- highlight the need for participatory approaches
- present case studies showing the consequences of climate variability and management responses and
- touch on issues of value, skill and artificial skill in forecast systems.

The ‘triple bottom line’

Using the best science has to offer we need to improve the performance of agricultural systems in terms of

- economic performance
- environmental impact
- and social consequences





effective integration (of data, information or knowledge) **requires an issue focus rather than a methodology or discipline focus**

Technologies must match the socio-economic system ==> need for rural sociology

Threshing finger millet, India

Threshing wheat, Australia

Current practices:
low profitability, high environmental impact

Future practices:
high profitability, low environmental impact

The role of climate forecasting

- climate forecasting is not the panacea to all our problems in agriculture
- It is one of many risk management tools that sometimes plays an important role in decision-making.
- to understand when to use this tool where and how is a complex and multi-dimensional problem (disciplines, scales, decision types etc).

A perfect forecast is also perfectly useless unless it changes a decision

"… the drought cycles … follow a rhythm in the opening and closing of their periods that is so obvious as to lead one to think that there must be some natural law behind it all, of which we are as yet in ignorance."

Euclides da Cunha, 'Os Sertões', 1902

Antonio Conselheiro

KICKING DUST: Sheep farmer Peter McShane waits for rain on his property Woodsprings near Bothwell. Picture: KIM EISZELE

Farmers fearful as drought grips

By ANNE BARBELJUK

WATER storage levels are critical in drought-affected parts of Tasmania, with some farmers so desperate for water they are taking the

"Carting water is costly and almost unheard of in some of these places, but these are

spell followed years of below-average rainfall.

He said average rainfall in September and October had produced more feed for animals, but the November and December rainfall had been well below average.

farmers wanting to irrigate were severely restricted.

"If there is no autumn rain the effect will be terrible because farmers will run out of feed," Mr Bignell said.

According to the Weather

Global warming to have huge impact

THE impact of global warming is more severe than first thought and the aftershocks of climate change will have a profound impact for centuries, said a major UN report released yesterday.

The report by the United Nations' Intergovernmental Panel on Climate Change paints a picture of weather changes that will raise global sea levels and temperatures, putting pressure on agricultural production and straining already scarce water resources.

"The scientific consensus presented in this comprehensive report about human-induced climate change should sound alarm bells in every national capital and in every local community," UN Environment Program executive director Klaus Topfer told reporters after a conference in Shanghai.

Topfer called on governments and the private sector to "move boldly ahead with clean energy technologies" and to begin preparing for "rising sea levels, changing rain patterns, and other impacts of global warming".

The IPCC report is a three-year compilation of the best scientific knowledge about the effects of rising global temperatures and concludes that much of the damage to the environment is already irreversible.

The atmospheric concentration of carbon dioxide, the most prevalent of the so-called "greenhouse gases", has surged by 31% since 1750

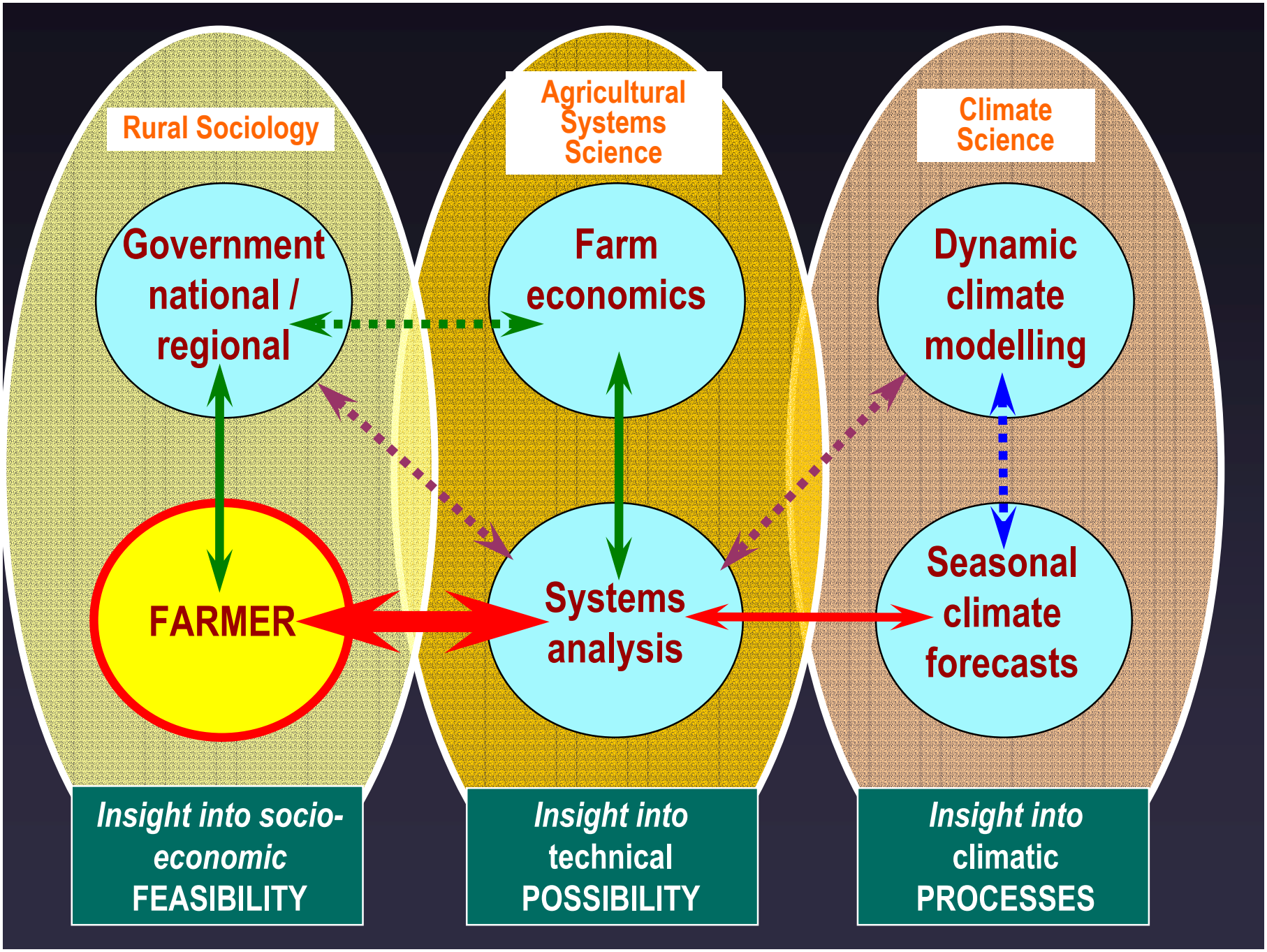
The facts are

- rainfall varies spatially and on different time scales
- this variability affects agricultural productivity
- some of this variability is predictable

How can be use such knowledge profitably?

To effectively manage agricultural systems in a variable and changing climate requires

- a sound scientific understanding of the causes of climatic variability and our ability to project ahead (predict) and
- knowledge and appreciation of how this ability to forecast production risks can influence and change management decisions.


Rural Sociology
Agricultural Systems Science
Climate Science
Government national / regional
Farm economics
Dynamic climate modelling
FARMER
Systems analysis
Seasonal climate forecasts
Insight into socio-economic FEASIBILITY
Insight into technical POSSIBILITY
Insight into climatic PROCESSES

Climate and Agriculture: From Vulnerable to Resilient Farming Systems

- ‘Resilient systems’ are systems that are to a large extent 'climate proof' by allowing farmers to draw on systems resources (eg. water, nutrients, reserves) at times of need, with these 'debts' being repaid once climatic conditions improve.
- Resilience requires the ability to address potentially conflicting goals simultaneously (‘triple bottom line’, sustainable development).

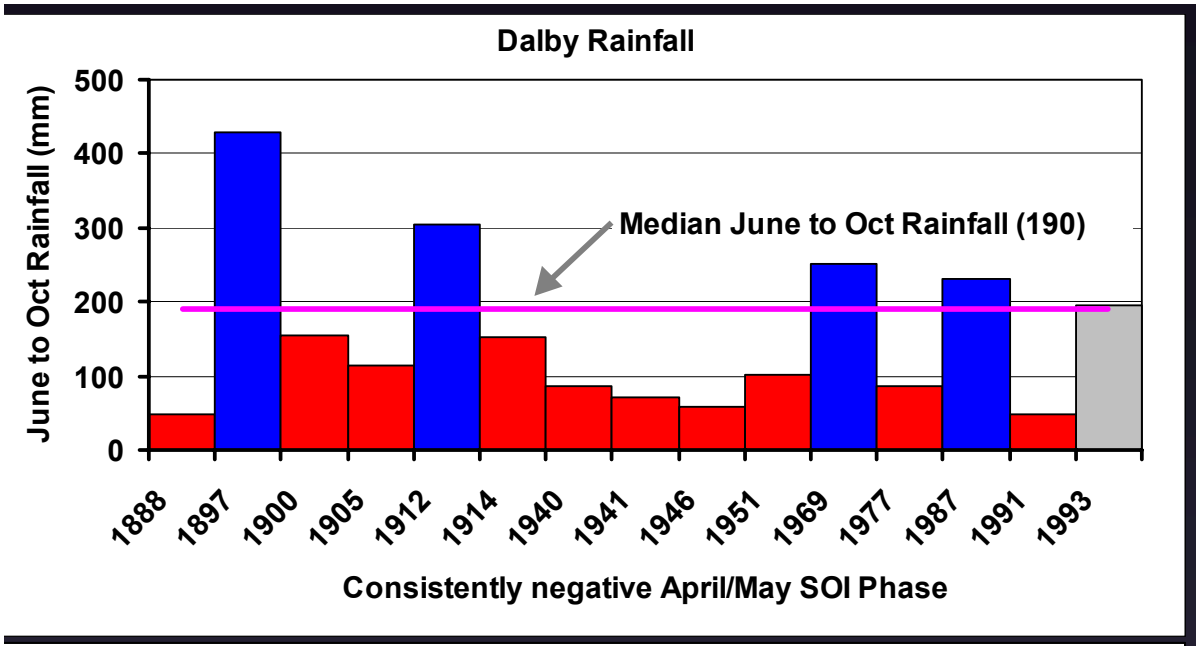
Name and/or Type of Climate Phenomena	*Frequency (years)*
Madden-Julian Oscillation, intraseasonal (MJO)	0.1 – 0.2
SOI phases based on El Niño – Southern Oscillation (ENSO), seasonal to interannual	0.5 – 7
Quasi- biennial Oscillation (eg. NAO)	1 – 2
Antarctic Circumpolar Wave (AWC), interannual	3 – 5
Latitude of Sub-tropical ridge, interannual to decadal	?? – 11
Interdecadal Pacific Oscillation (IPO)	13+
Decadal Pacific Oscillation (DPO)	13 – 18
Multidecadal Rainfall Variability	18 – 39
Interhemispheric Thermal Contrast (secular climate signal)	50 – 80
Climate change	???

Agricultural Systems and Climate Variability

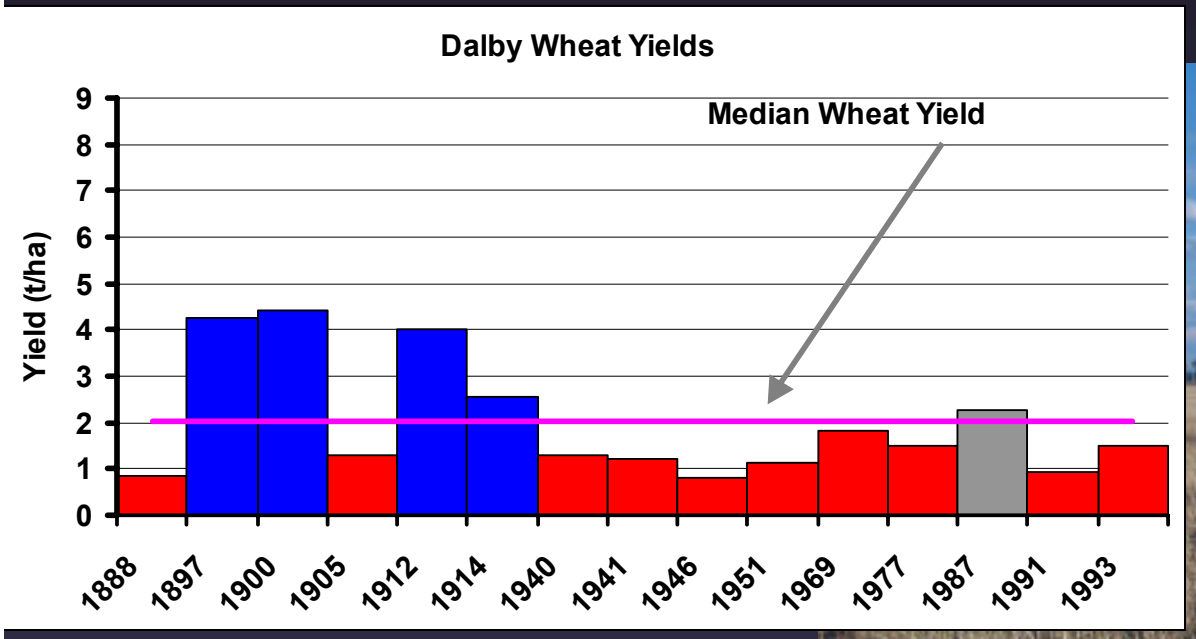
Decision Type (eg. only)	*Frequency (years)*
Logistics (eg. scheduling of planting / harvest operations)	**Intraseasonal (> 0.2)**
Tactical crop management (eg. fertiliser / pesticide use)	**Intraseasonal (0.2 – 0.5)**
Crop type (eg. wheat or chickpeas)	**Seasonal (0.5 – 1.0)**
Crop sequence (eg. long or short fallows)	**Interannual (0.5 – 2.0)**
Crop rotations (eg. winter or summer crops)	**Annual / biennial (1 – 2)**
Crop industry (eg. grain or cotton, phase farming)	**Decadal (~ 10)**
Agricultural industry (eg. crops or pastures)	**Interdecadal (10 – 20)**
Landuse (eg. agriculture or natural systems)	**Multidecadal (20 +)**
Landuse and adaptation of current systems	**Climate change**

What we learned from experience

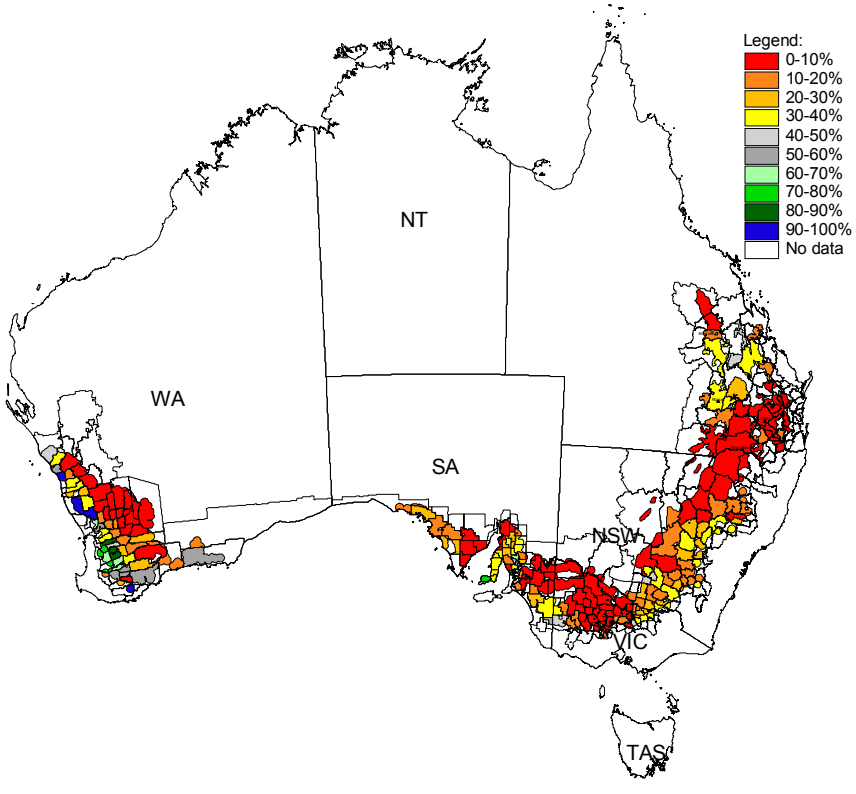
- Farmers are often targeted as the users of climate forecasts. However, they might not be the most responsive target group.
- Climate forecasting is one of many instruments that aims to reduce production uncertainty.
- Participatory systems analysis needs to establishes the role of climate forecasting in relation to other tools.



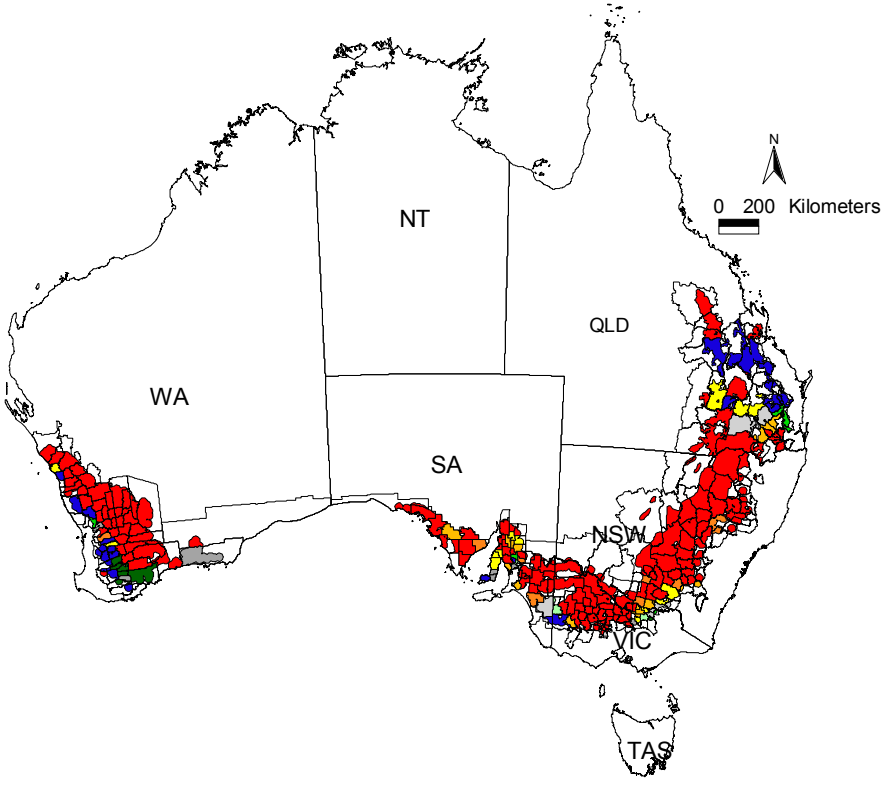
Why do we need agricultural models?



Shire wheat yield forecast based on SOI phase



Start-of-season forecast
(June 2002)

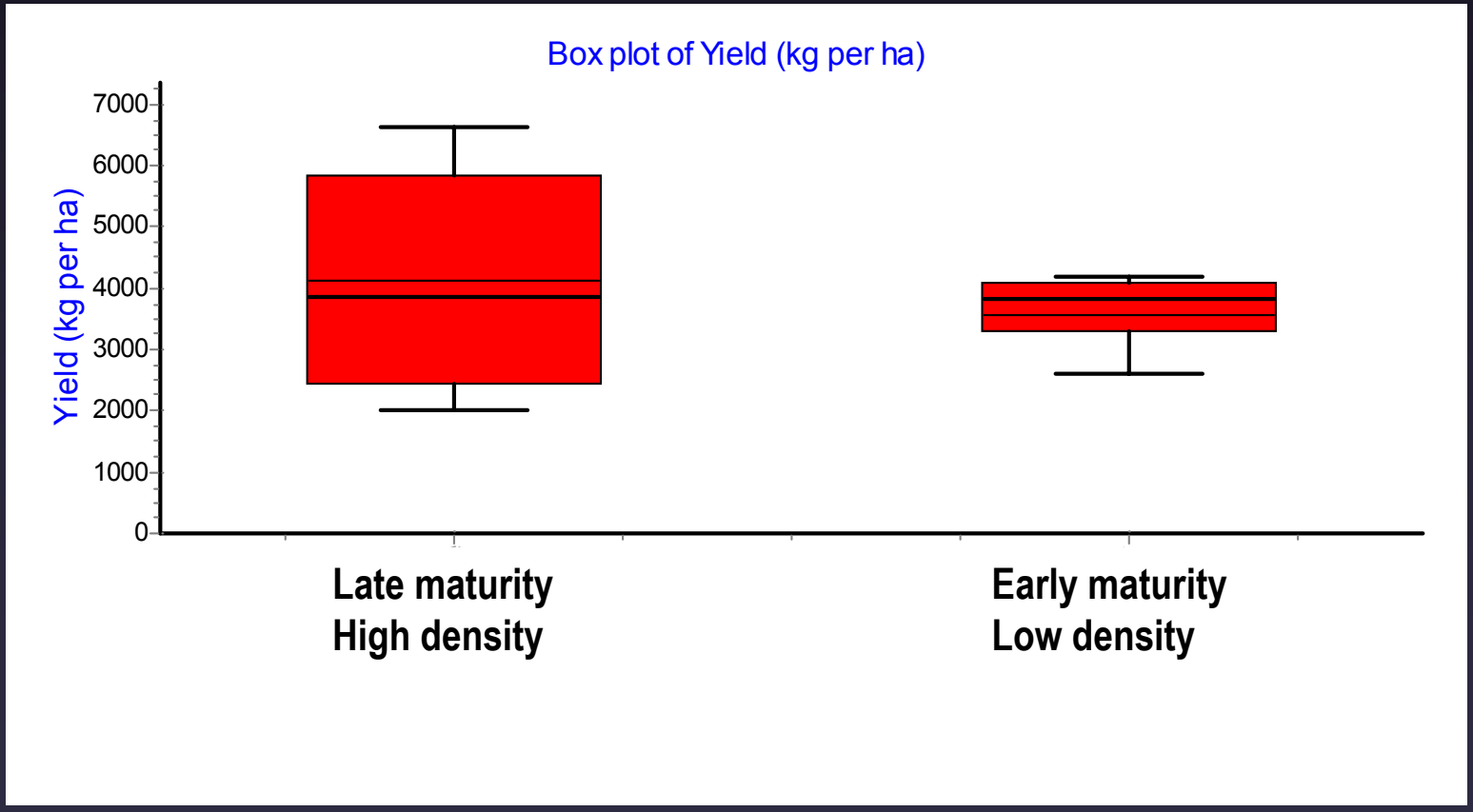


End-of-season forecast
(September 2002)

Managing Water & N in a Variable Climate

Maturity * density * SOI (Emerald)

Moderate depth vertisol, full profile, Nov planting

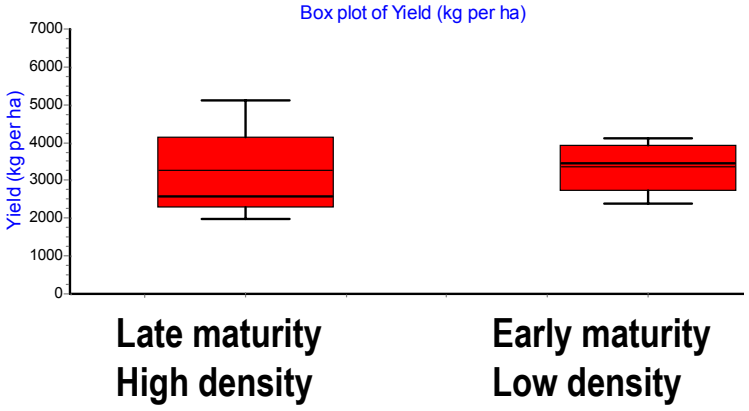


Managing Water & N in a Variable Climate

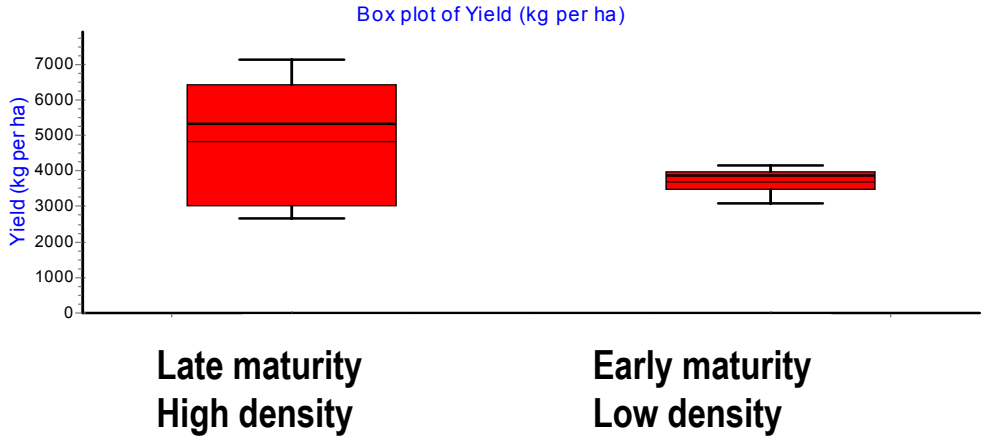
Maturity * density * SOI (Emerald)

Moderate depth vertisol, full profile, Nov planting

SOI phase consistently negative



SOI phase consistently positive



- Basis of simulation-aided discussion - process not tool
- Private and public advisors being trained

Pakistan:
wheat - fallow - wheat system

Issue:

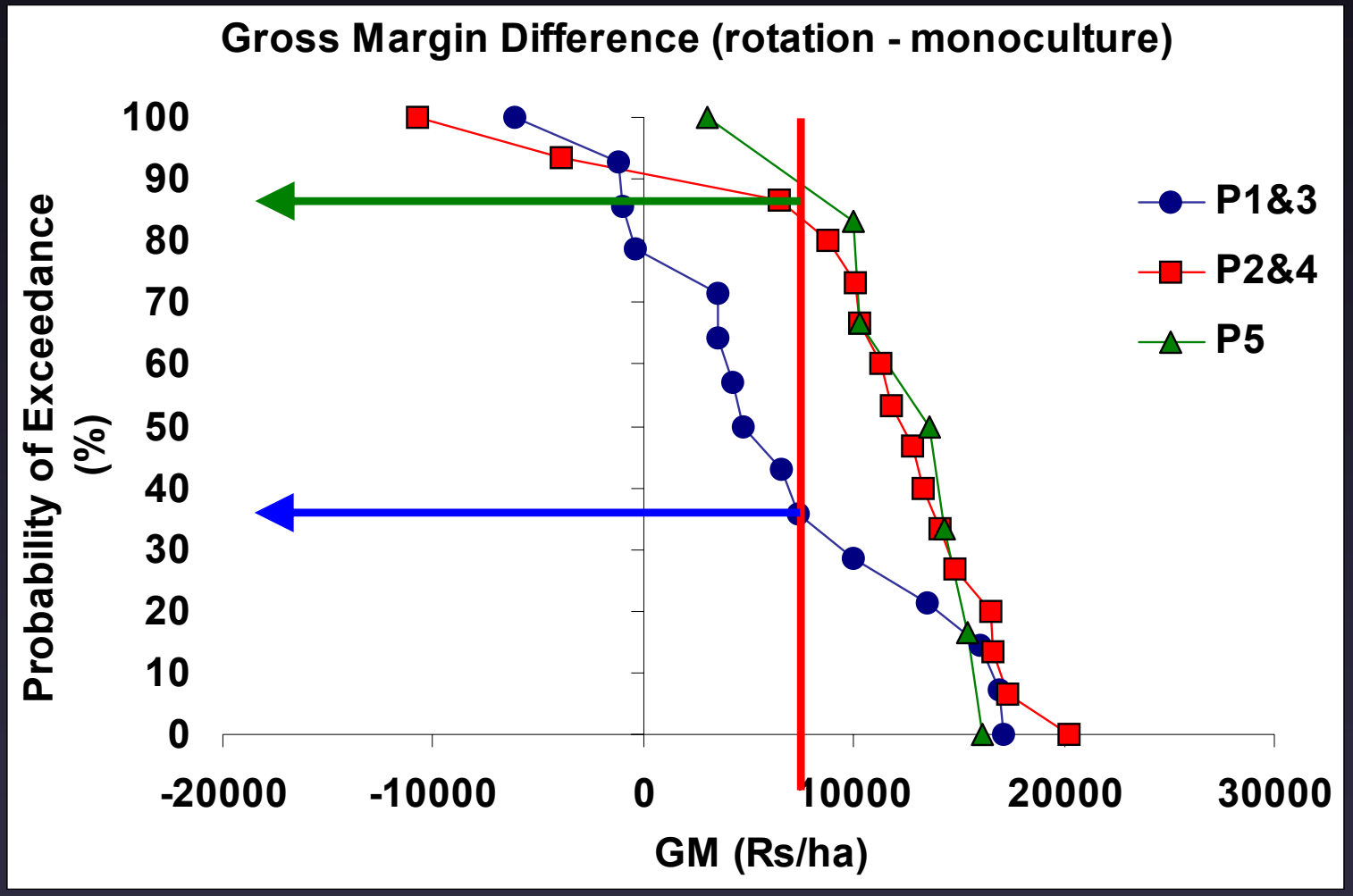
- traditional summer fallow followed by wheat

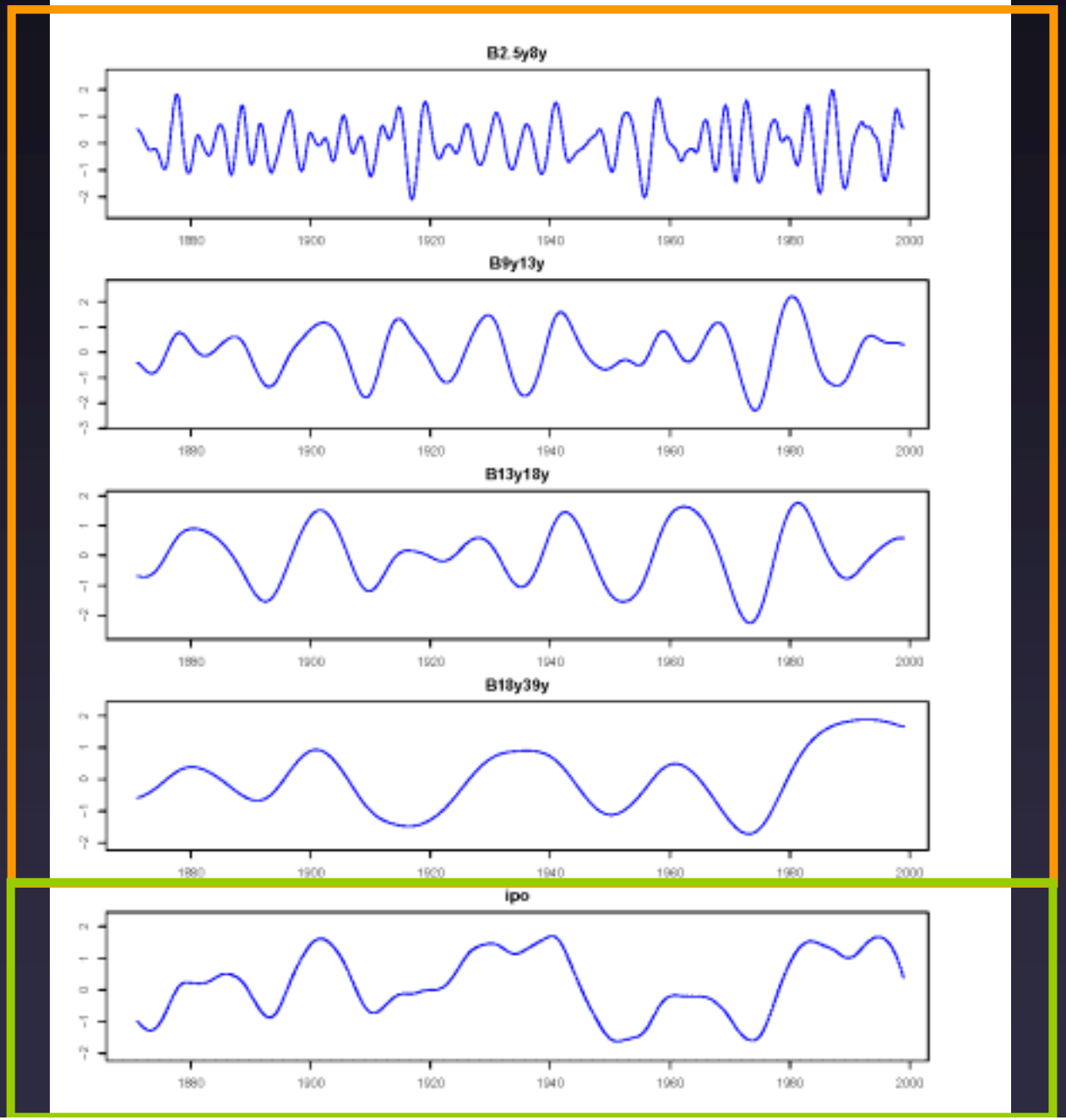
Question:

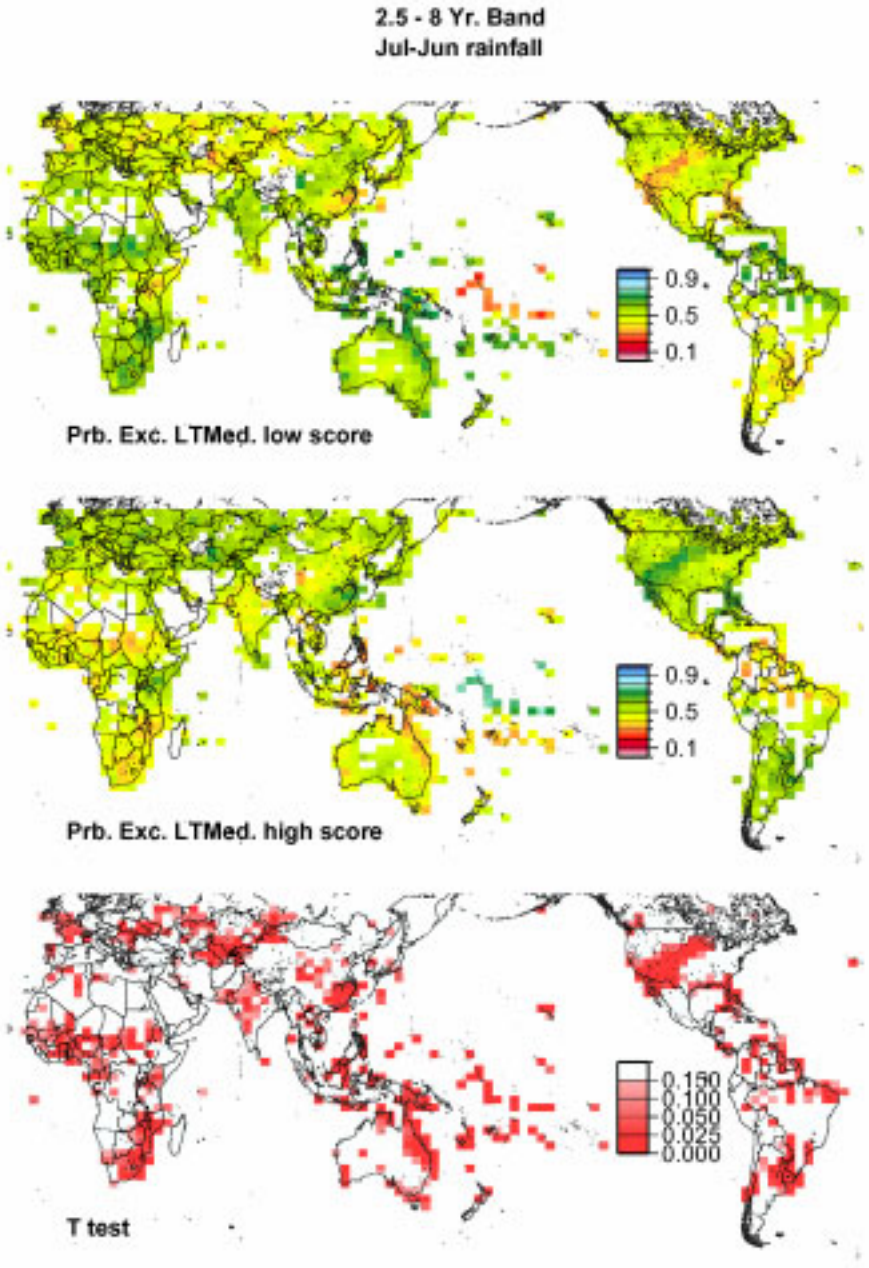
- can a legume opportunity crop instead of fallow be economically viable?

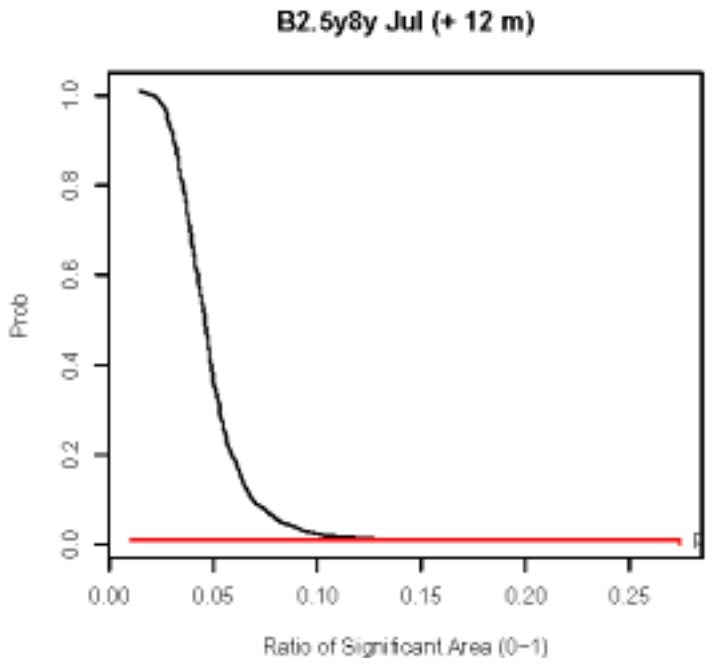
Approach:

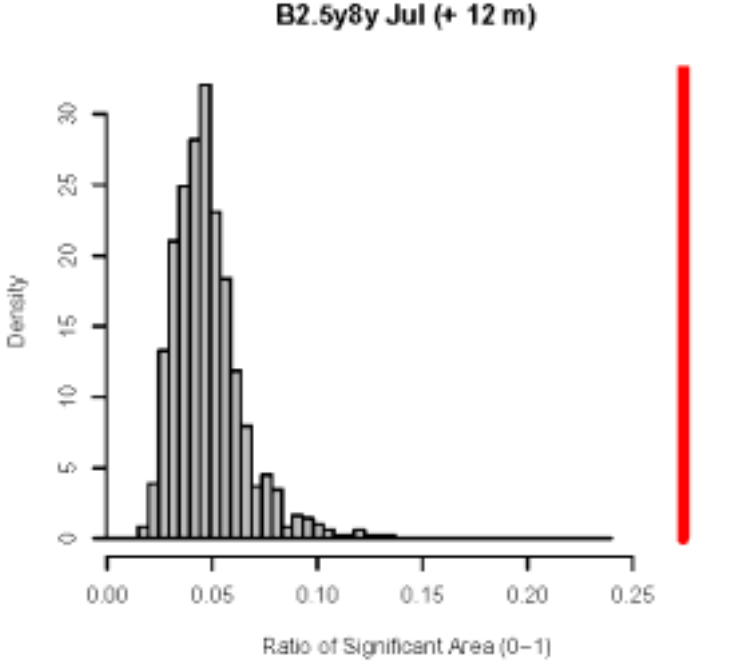
- simulate it!

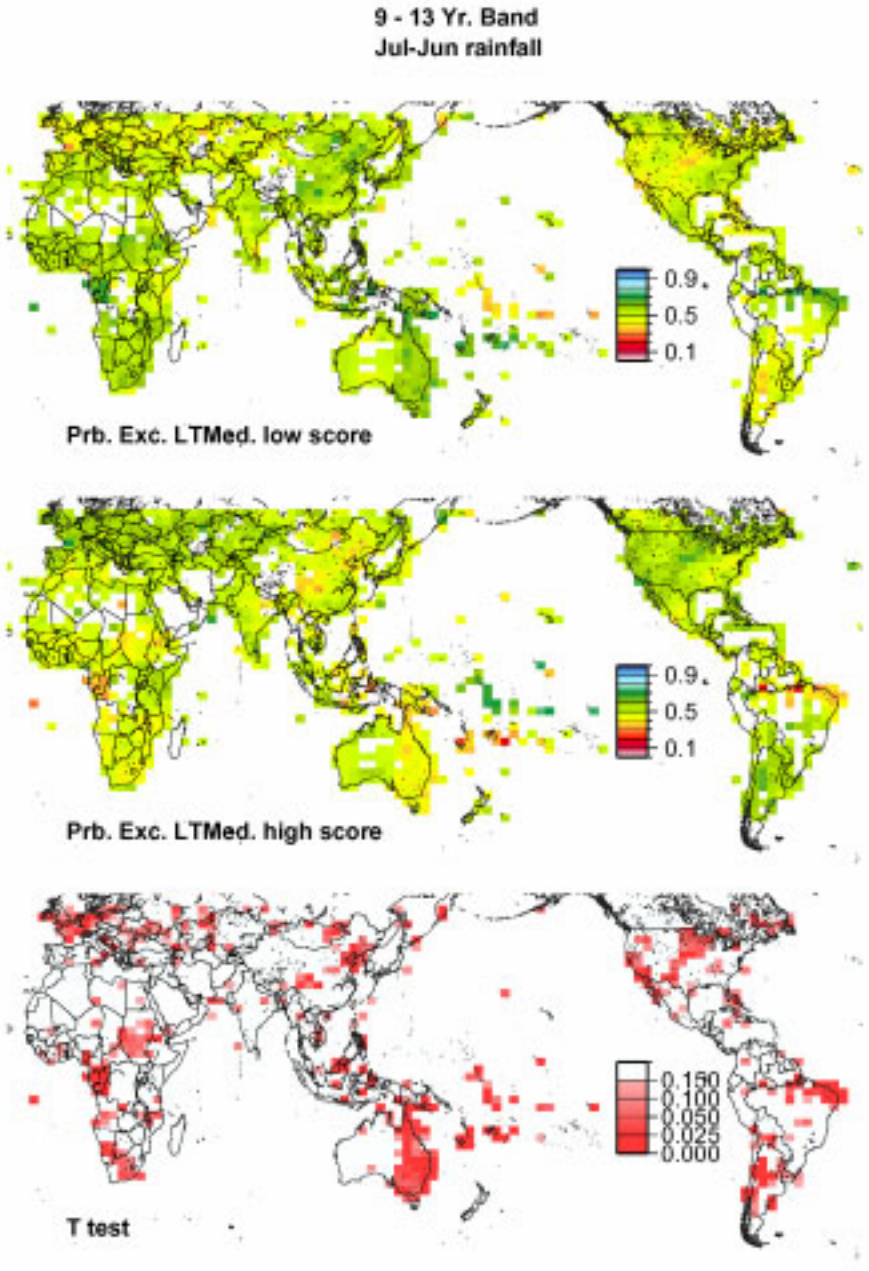

Gross Margin Difference (rotation - monoculture)
Probability of Exceedance (%)
100
90
80
70
60
50
40
30
20
10
0
-20000
-10000
0
10000
20000
30000
GM (Rs/ha)
P1&3
P2&4
P5

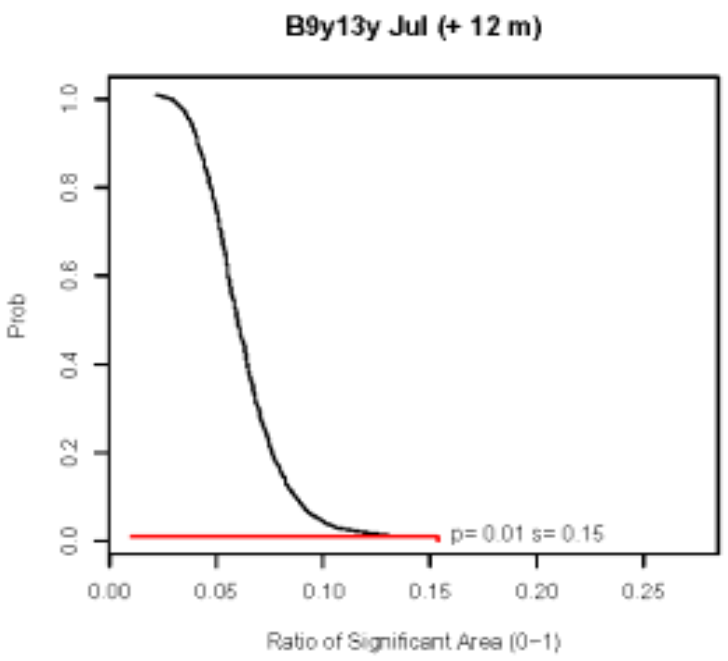

B2.5y8y
B9y13y
B13y18y
B18y39y
ipo
1880
1900
1920
1940
1960
1980
2000

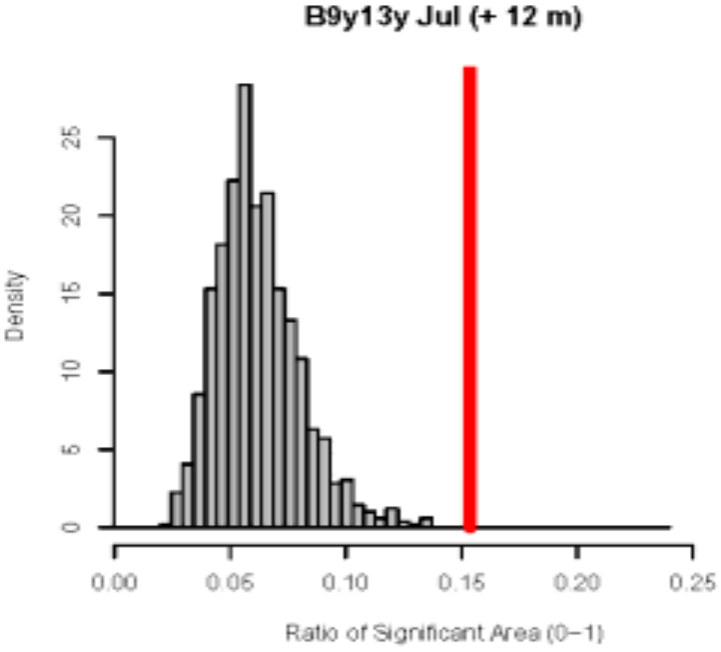

2.5 - 8 Yr. Band
Jul-Jun rainfall
0.9
0.5
0.1
Prb. Exc. LTMed. low score
0.9
0.5
0.1
Prb. Exc. LTMed. high score
0.150
0.100
0.050
0.025
0.000
T test


B2.5y8y Jul (+ 12 m)
Prob
0.0
0.2
0.4
0.6
0.8
1.0
0.00
0.05
0.10
0.15
0.20
0.25
Ratio of Significant Area (0-1)

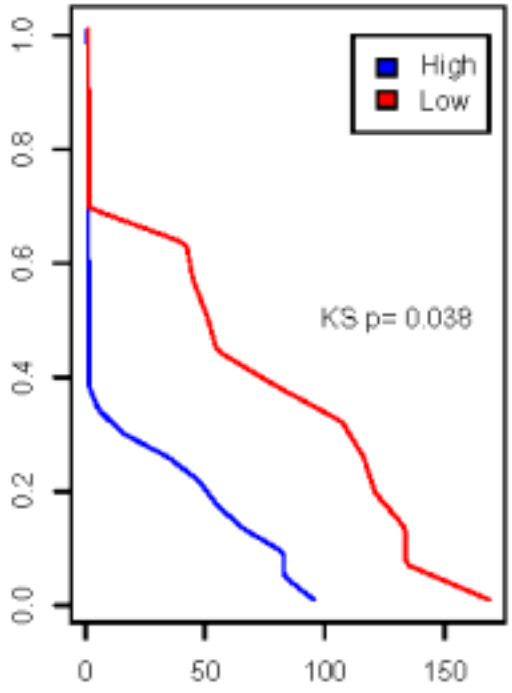

B2.5y8y Jul (+ 12 m)
Density
0
5
10
15
20
25
30
0.00
0.05
0.10
0.15
0.20
0.25
Ratio of Significant Area (0-1)

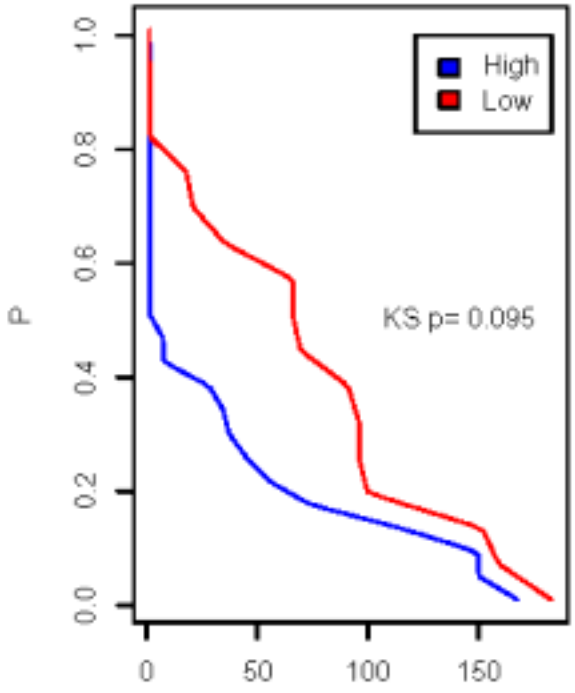

9 - 13 Yr. Band
Jul-Jun rainfall
0.9
0.5
0.1
Prb. Exc. LTMed. low score
0.9
0.5
0.1
Prb. Exc. LTMed. high score
0.150
0.100
0.050
0.025
0.000
T test

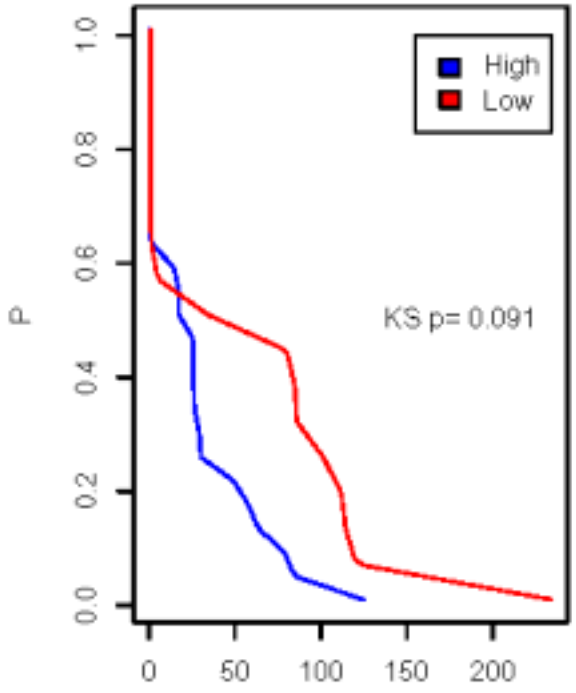

B9y13y Jul (+ 12 m)
Prob
0.0
0.2
0.4
0.6
0.8
1.0
p= 0.01 s= 0.15
0.00
0.05
0.10
0.15
0.20
0.25
Ratio of Significant Area (0−1)


B9y13y Jul (+ 12 m)
Density
0
5
10
15
20
25
0.00
0.05
0.10
0.15
0.20
0.25
Ratio of Significant Area (0−1)

Simulated drainage under a wheat - fallow - wheat rotation in Qld







Wallumbilla

Roma

Talwood

Specifications for a new climate forecasting system

Question: have we reached the limits of predictability with statistical forecast techniques?

Caution: Any dynamic approach must be clearly better than our current statistical methods.

Forecast verification issues

- Scoring techniques
- LEPS, ROCS, hit rates
- hindcast verification issues
- cross-validation
- artificial skill

Specifications for a new climate forecasting system

- mechanistically sound
- statistically sound (eg. x-validated)
- reproducible and transparent
- able to be explained - not a black box
- demonstrate how it would have operated over time
- peer and collegiate review incl. publication in a refereed journal

Specifications for a new climate forecasting system

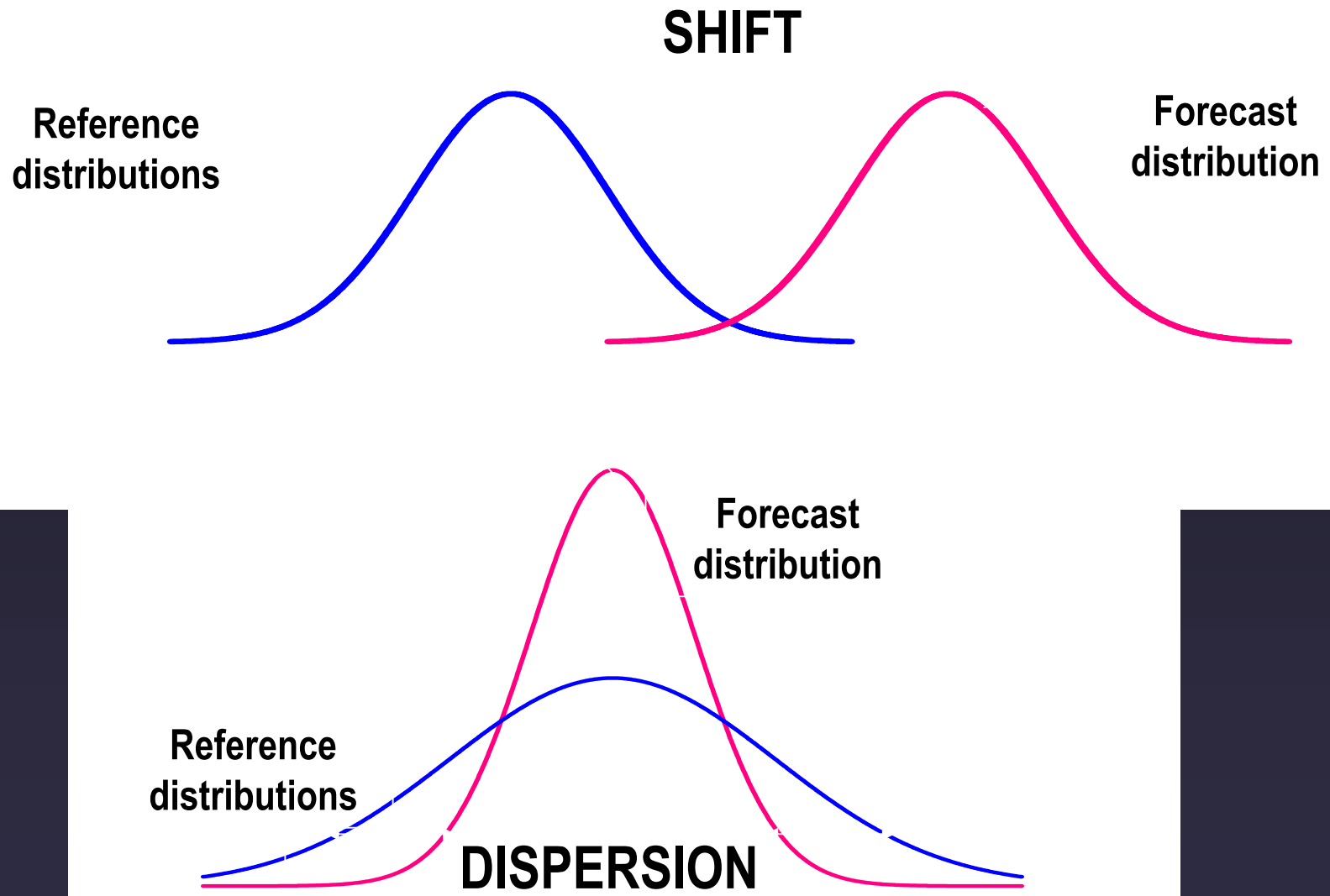
- can be used in agricultural models and supported by delivery system
- supported by collegiate activity
- liaison with National Met Services
- risk management system in place (legal/political)

Forecast Quality (FQ)

- FQ does not linearly translate from one forecast quantity to the next (eg. rainfall not equal production)
- FQ is an essential but not a sufficient attribute of a effective forecasting system
- FQ must be seen in context with the decisions based on the forecast
- ‘Skill’ is a statistical component of FQ

‘Skill’ vs ‘Value’

- Clearly define what we mean by ‘skill’
- Need to move towards a consensus view why we need to measure forecast skill and how to do it
- Put forecast skill into perspective together with other essential attributes of effective forecasting systems


SHIFT
Reference distributions
Forecast distribution
Forecast distribution
Reference distributions
DISPERSION

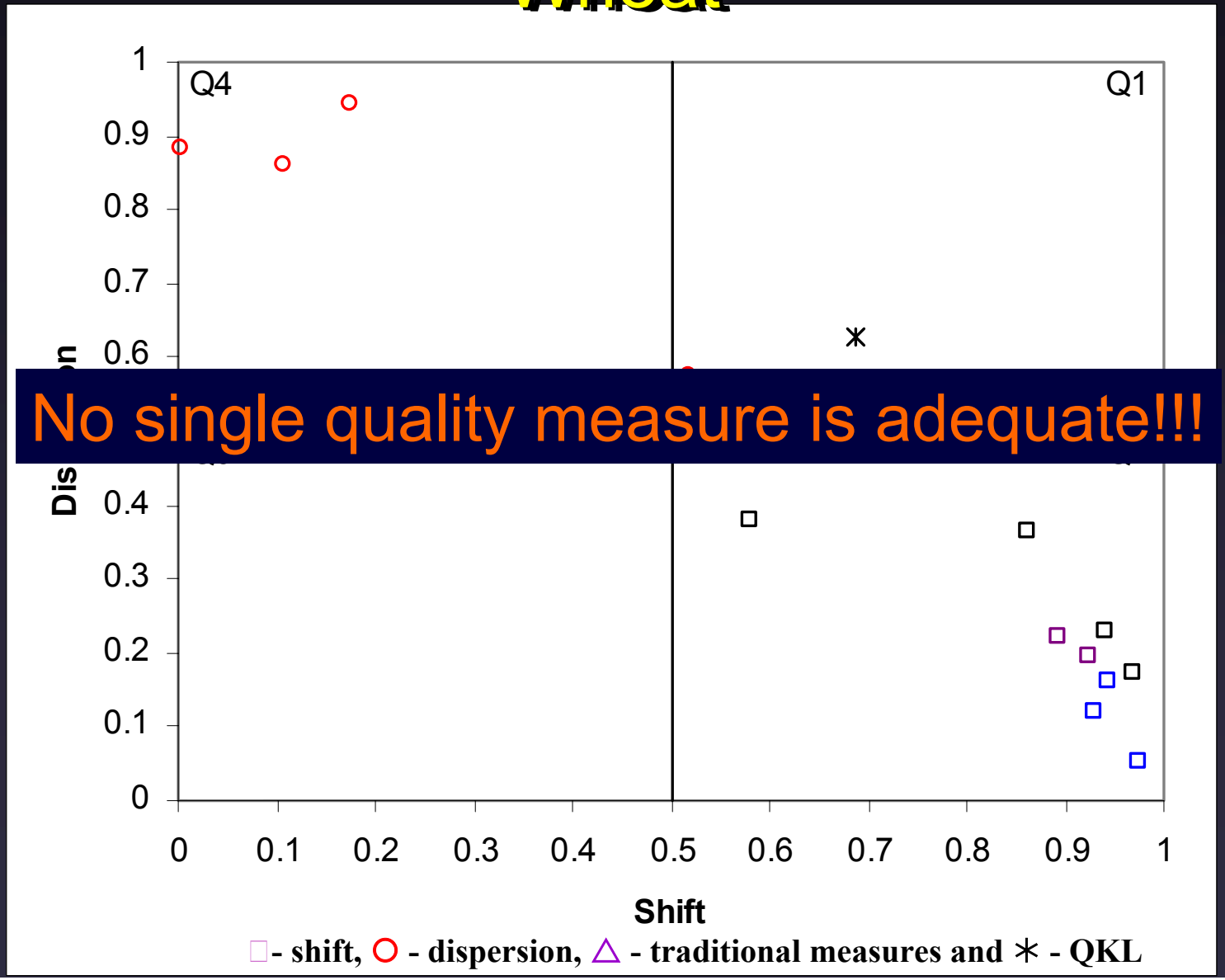
Quality Measures

LEPS	Revised LEPS score
BS	Brier score
BSP	Brier score (adapted)
LEPSP	Revised LEPS score (adapted)
KWP	Kruskall-Wallis test p- value
ICCP	Intra Class Correlation
PEX	Probability of exceedence
QKL	Kullback-Leibler Divergence measure (KL1 + KL2)
LRP	Log rank test p-value
KL1	Measure of shift in QKL
SAVGD	Squared Average Deviation
AMD	Absolute Median Difference
VR	Variance Ratio
KL2	Measure of variance in QKL
RR	80% Range Ratio
IQR	Inter Quartile Range Ratio

- Traditional measures (4)
- Other (7)
- Shift (3)
- Dispersion (4)

***All quality measures were derived using cross validation

Comparison of Forecast Quality Measures – Wheat



No single quality measure is adequate!!!

Value of a forecast

Effective applications of climate forecasts (value, V) is a function of the quality of the forecast (FQ), timing and mode of forecast delivery (**communication, C**) and its suitability for influencing specific decisions (**utility, U**).

$$V = f(\alpha\ FQ, \beta\ C, \chi\ U)$$

If the forecast does not lead to a chance in a decision that has a better outcome, it has no or negative utility and hence no value

Coefficients α, β, and χ will vary and depend on individual circumstances (range: 0 to 1). Hence, the impact of a forecast is maximised when all coefficients approach unity.

'Skill' or FQ is an essential but not a sufficient attribute of a forecasting system

Why probabilities?

- We know that chaos plays a large role in climate systems
- We have a responsibility to communicate our knowledge as well as our ignorance
- We are not the decision makers – all we can provide is discussion support, the ultimate decision rests with the practitioner (choices, chances, consequences)
- ‘Dumbing down’ the message can lead to poorer risk management (moving from stable to fickle systems)
- Don’t insult farmers’ intelligence – they are already good risk managers
- Beware of gurus!

Artificial skill

- ‘apparent’ hindcast skill in statistical forecasting schemes arising from “chance”
- skill that does not survive when the forecasting scheme is applied in real time to new or independent data (need for cross validation)

Artificial skill

- The smaller the sample size, the greater the chance of spuriously exceeding a given skill level
- The greater the number of potential predictors, the greater the chance of artificial skill
- The more combinations you try, the more spurious relationships you'll find
- The atmosphere acts in part as a random number generator

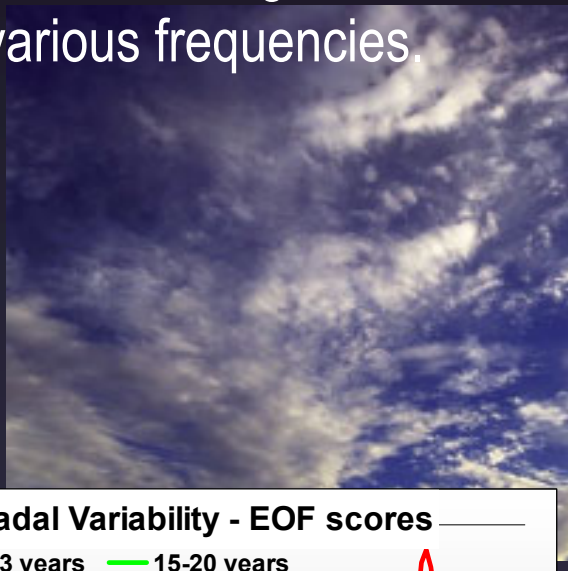
Moral: don't go trawling through vast numbers of potential prediction models in search of apparent skill

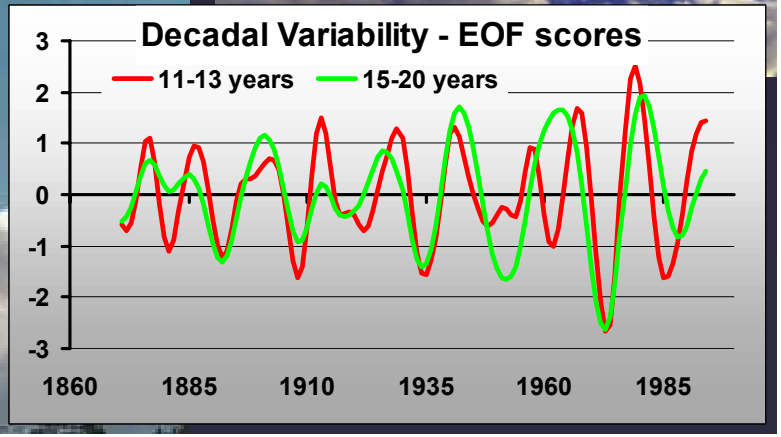
Commandment: Thou shalt not search for the highest score and simply use the model that generates that score!

Modelling as a communication tool

- The language of climatologists

Decadal climate variability is evident in the first EOF of near-global SSTs and Pressure Field data, band filtered for various frequencies.

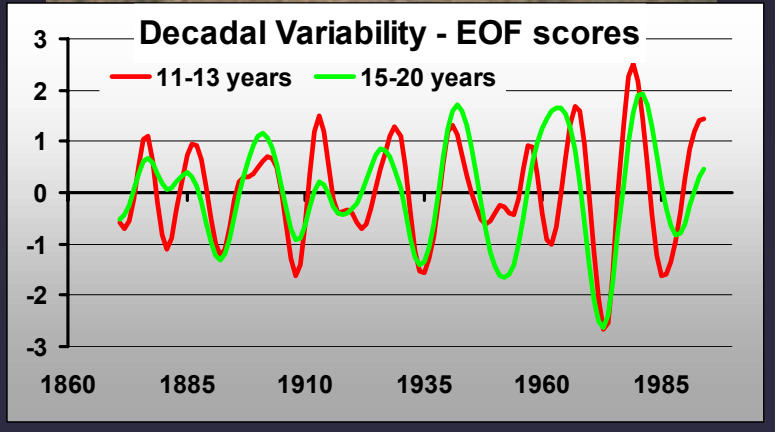




Modelling as a communication tool

- The language of farmers

The last few years were bad - first the drought and then too much rain. What can I do to better cope with such a variable climate?



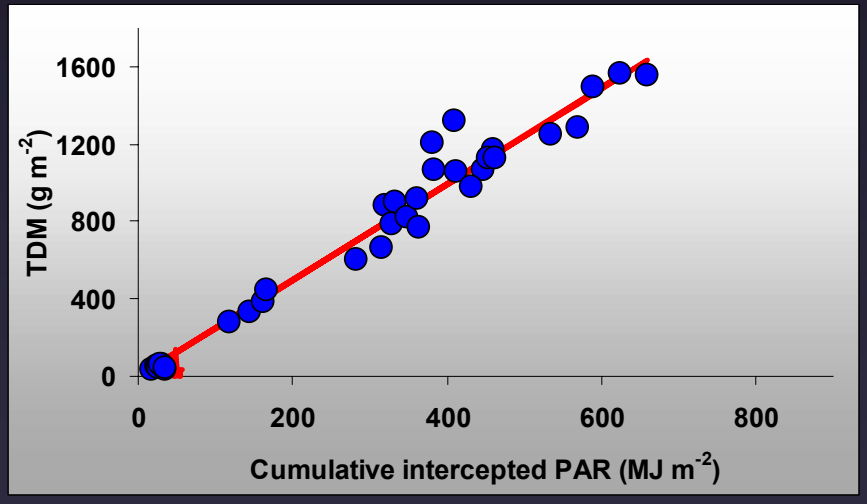
Modelling as a communication tool

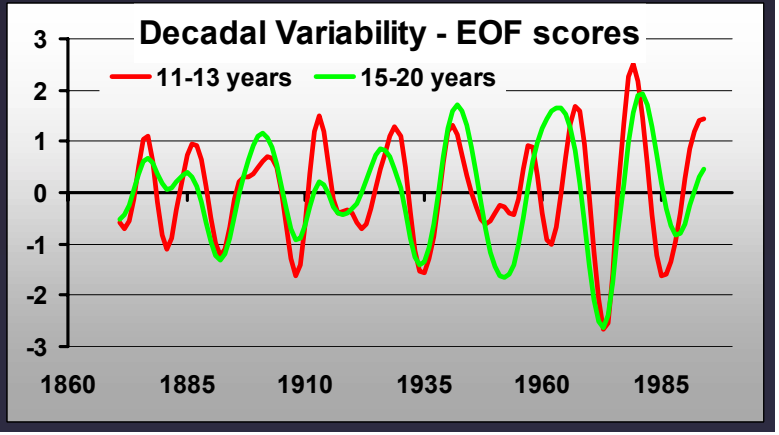
- The language of crop physiologists

Crop transpiration demand (T_d) is determined by the amount of intercepted radiation and VPD

$$T_d = TE_c / VPD * (RUE * I)$$

(TE_{c_Wheat} = 4.7 g m^{-2} mm^{-1} kPa)

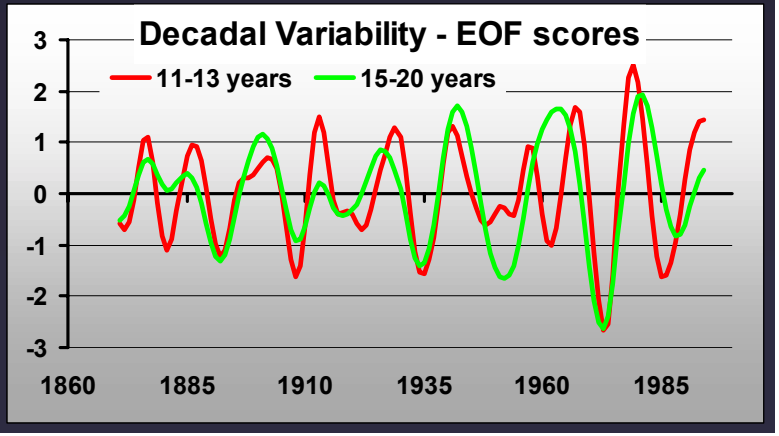




Modelling as a communication tool

- The language of computer programmers

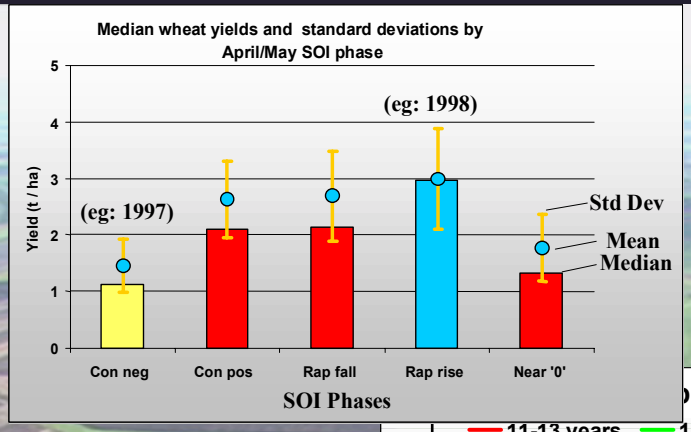
```
! potential biomass production based on intercepted radiation
            call dm_plt_tot_pot ()
! demand for soil water. new subroutine sw_demand uses
! dm_plt_tot_act_dlt to determine demand for soil water based on
! a tec of 4.7
            call sw_demand (c_demand_switch)
```

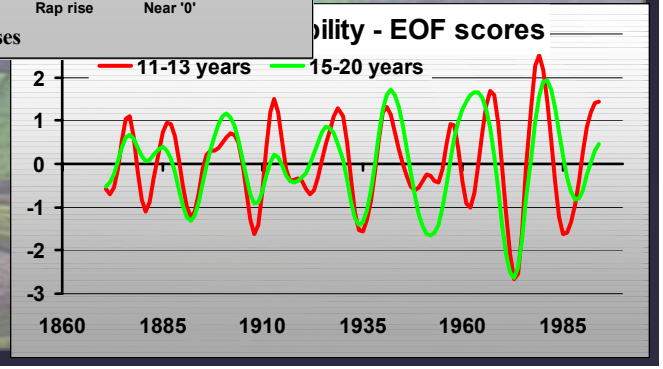


Modelling as a communication tool

The language of cross-disciplinary systems scientists

Changing between dryland cotton and intensive cereal rotations based on the long-term climate outlook could lift your average profits by 50%. This would also reduce your runoff and erosion potential.





Modelling as a communication tool

The aim is to provide knowledge and wisdom systems rather than information systems