A scoping study to assess whether short term climate forecasting can improve water use efficiency

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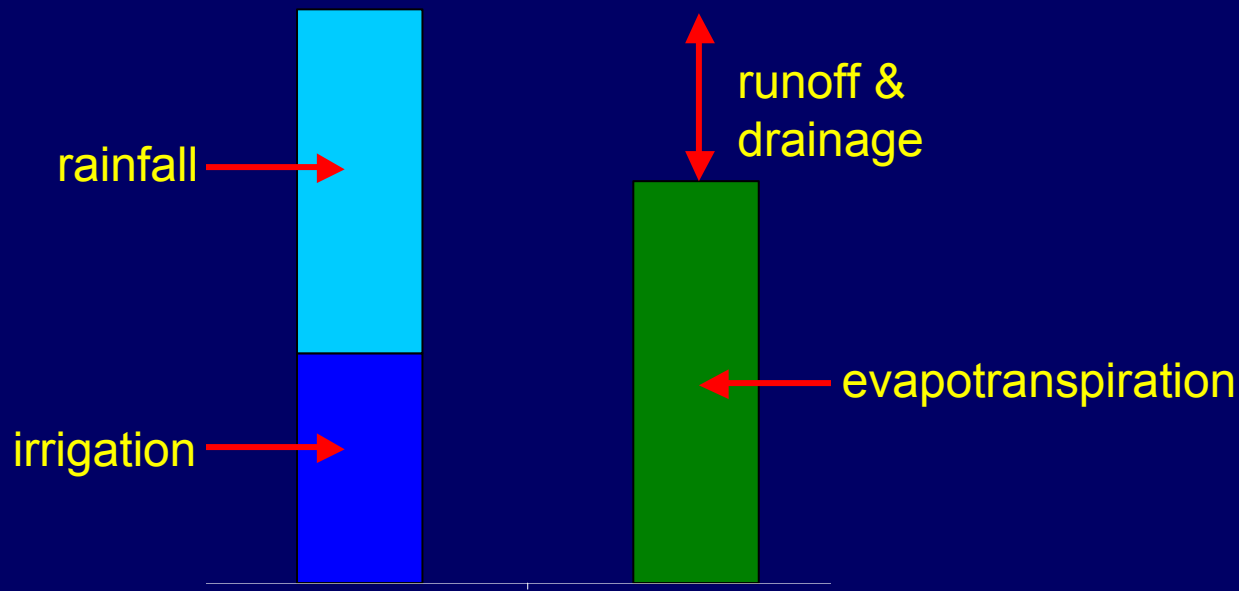
Queensland Government
Natural Resources and Mines

RURAL WATER USE EFFICIENCY INITIATIVE

Statement of the problem



Rainfall immediately after irrigation could result in:

- loss of water through drainage and runoff
- decreased production through waterlogging
- offsite flow of contaminants, e.g. pesticide, sediment

A suggested solution

Forecast

Using 3-7 day weather forecasts from the Bureau of Meteorology we have a reasonable idea of how much rainfall is going to fall in the near future.

Model

Using historic rainfall data and cropping system models such as PERFECT & APSIM we can evaluate the likely response to this irrigation management option.

If... (we had perfect knowledge)

Rudyard Kipling 1910

Perfect Knowledge

If we had perfect knowledge of the rainfall that is to fall in the next few days, can we delay irrigation to increase effective rainfall?

Given that we have perfect knowledge of rainfall from historic data, we can assess the effect of rescheduling irrigation (using water balance models).

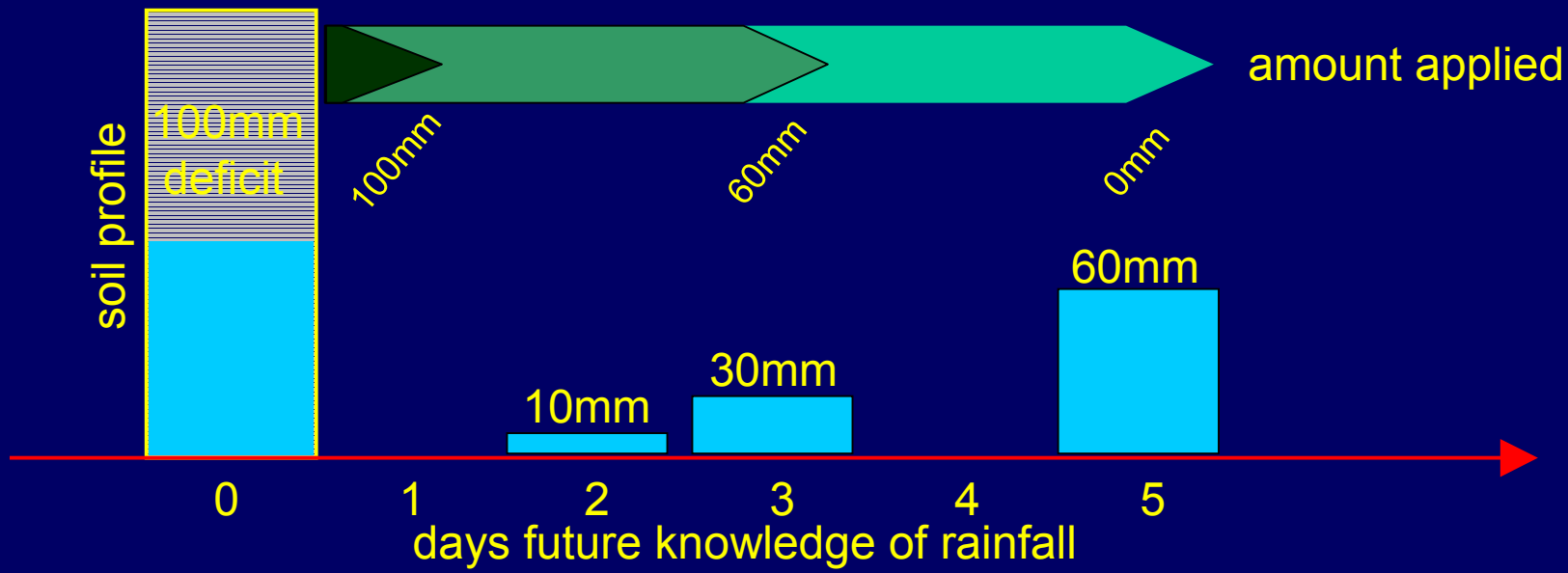
Crop & Geographic Variation

We can assess the influence of crop type and geographic location on the size and frequency of these water saving opportunities.

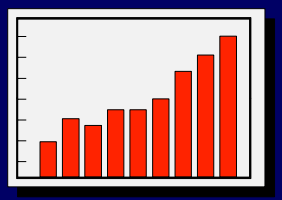
Hindcasting Technique

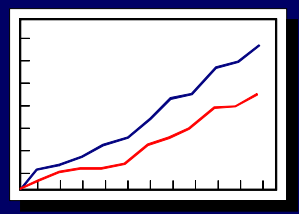
- Using historical rainfall records we know the amount of rainfall that is going to occur over the next five days.
- Given we have perfect knowledge we can identify the size of the irrigation saving.

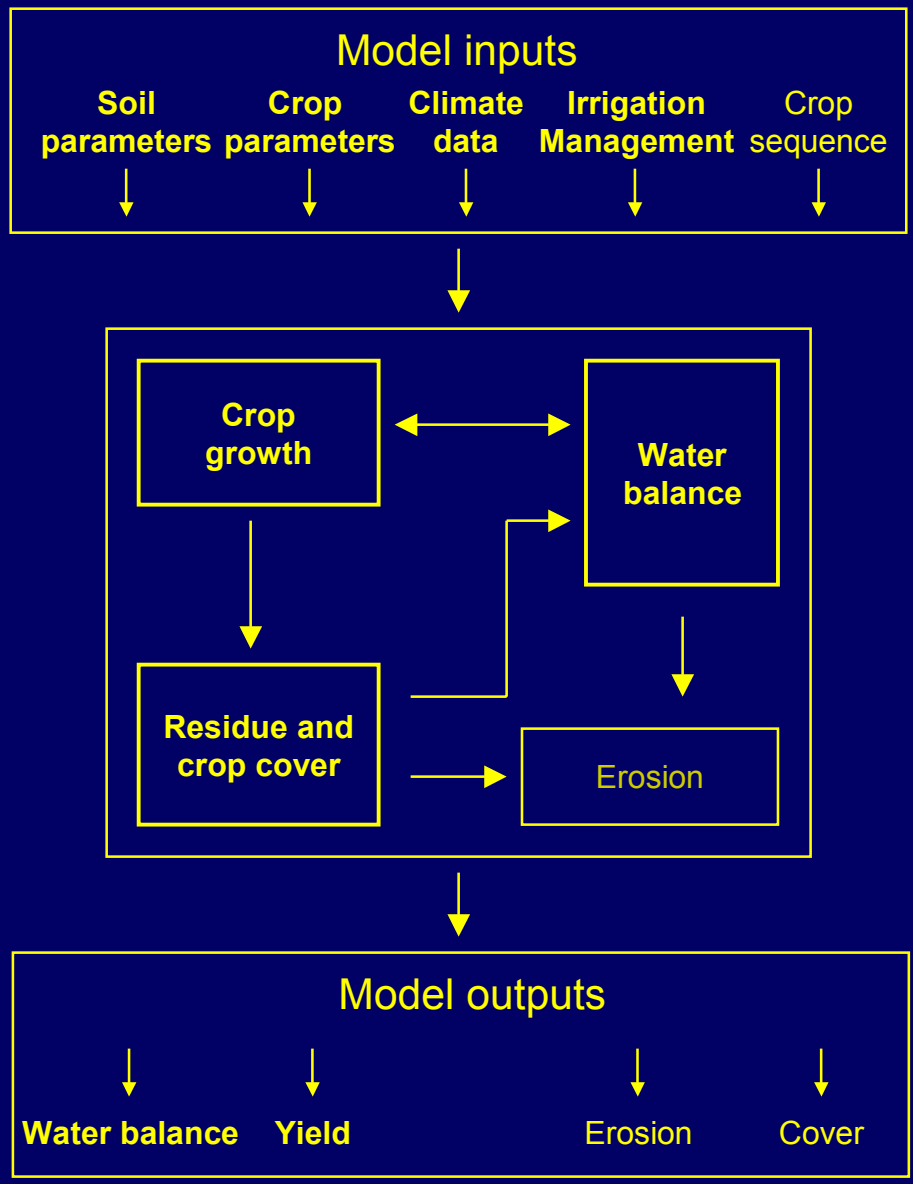
If we have a 100 mm soil water deficit today do we irrigate?



PERFECT crop system model

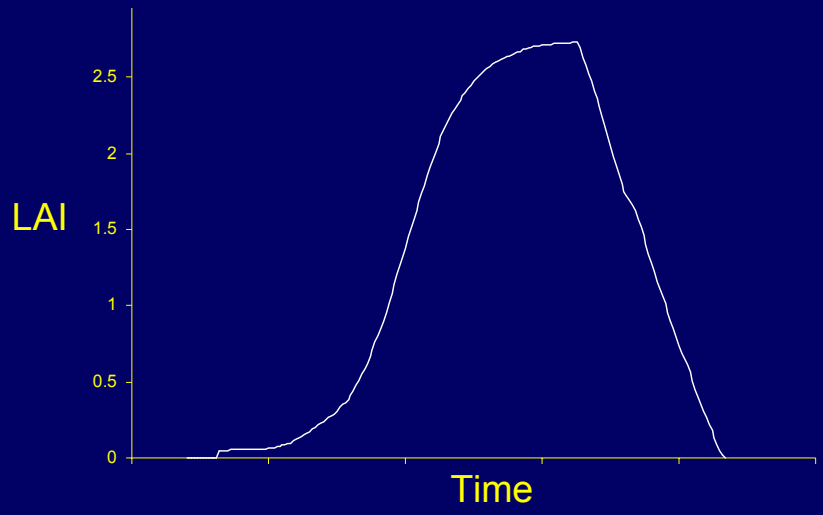






Courtesy of Mark Littleboy

Leaf Area Index (LAI) generic crop model



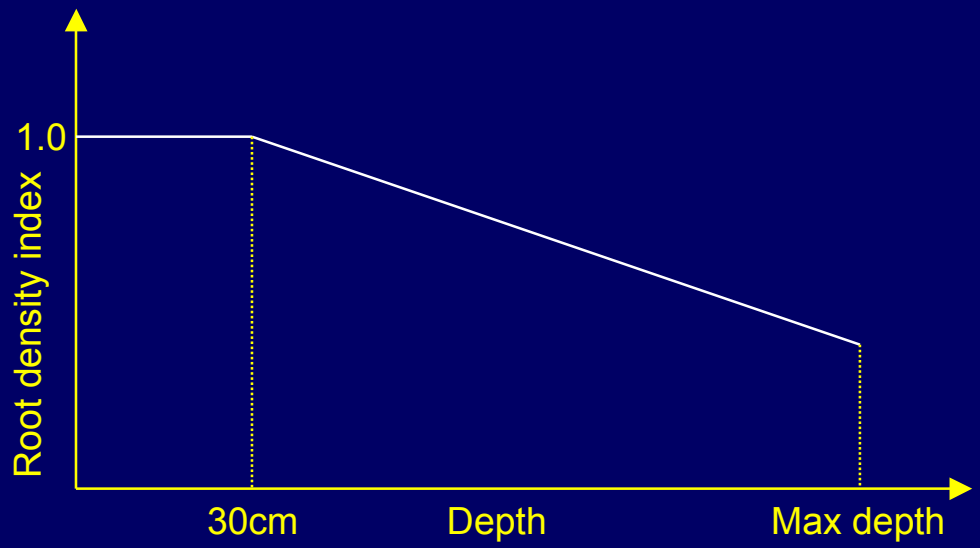
LAI Development

- Based on the EPIC crop model.
- LAI development based on functions determined from user input.
- LAI is predicted by day degrees and stress factors.

Transpiration & Biomass

Transpiration

- Transpiration is removed from individual layers using a generic root penetration and root density index.



Biomass accumulation

- Biomass is determined from intercepted radiation, radiation use efficiency, stress factors, and day length.
- Yield is determined by a user defined harvest index.

Runoff & Evaporation

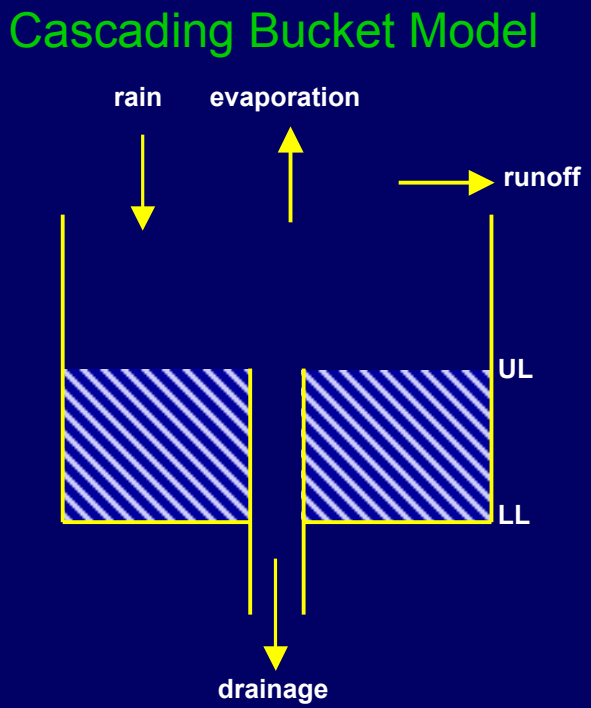
Runoff

- Uses a modified CREAMS Curve Number technique which captures the effect of antecedent soil moisture and soil type on infiltration.

Evaporation

- Evaporation is based on Ritchie's two stage evaporation algorithm.
  - Stage 1 limited by available energy.
  - Stage 2 limited by soil conductivity.

Water redistribution



- The water is distributed in the soil profile by a cascading bucket model.
- The height of the pipe is the available water capacity.
- The capacity of the bucket is the saturated water content.
- The rate of flow from the bucket is the saturated hydraulic conductivity.
- Water that drains from the bucket is deep drainage.
- Water that runs off from the bucket is runoff.

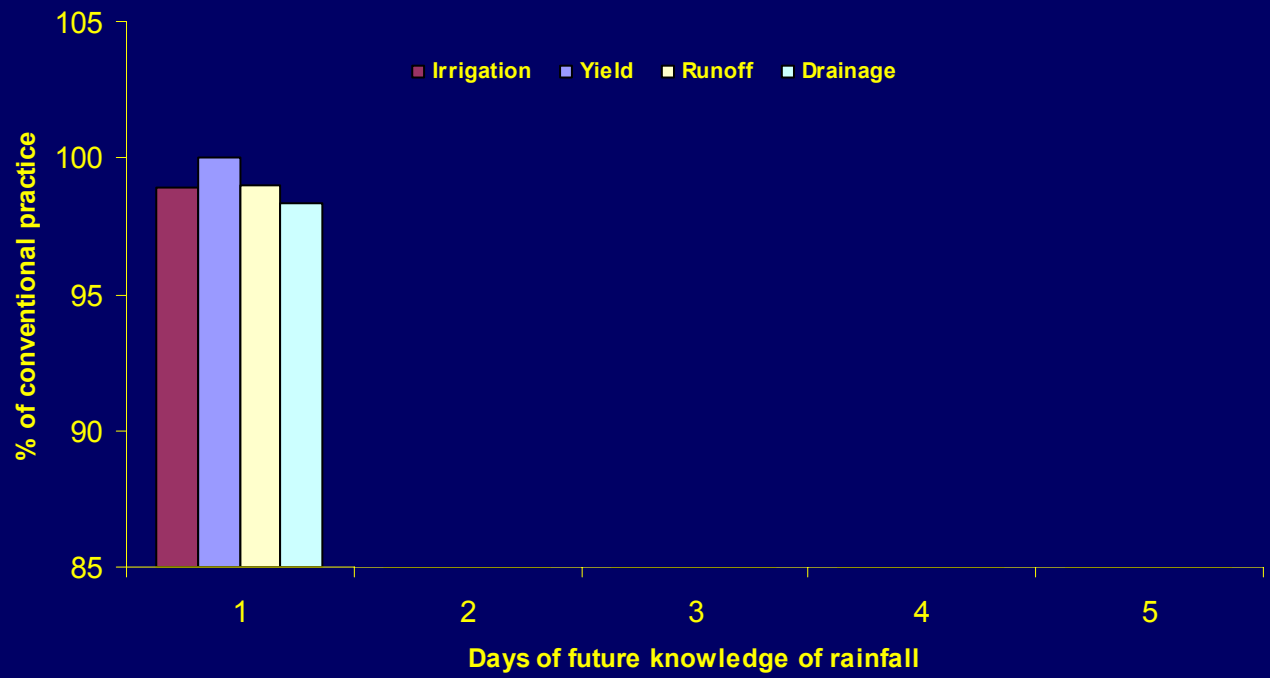
An example of a short term forecast scenario:
Cotton

- SILO data drill climate files
- A deep cracking clay
- A PERFECT crop model for a cotton
- Planted on the 1st of October each year
- Irrigation trigger is a 100mm soil water deficit
- Run for 42 years of climate data
- Multiple locations

Narrabri Cotton

PAWC 190mm rain 631mm/yr incrop rain 362 mm/season pan evap 1997mm/yr

19 >5mm rain days/season 42 years of simulated irrigation 50mm deficit irrigation



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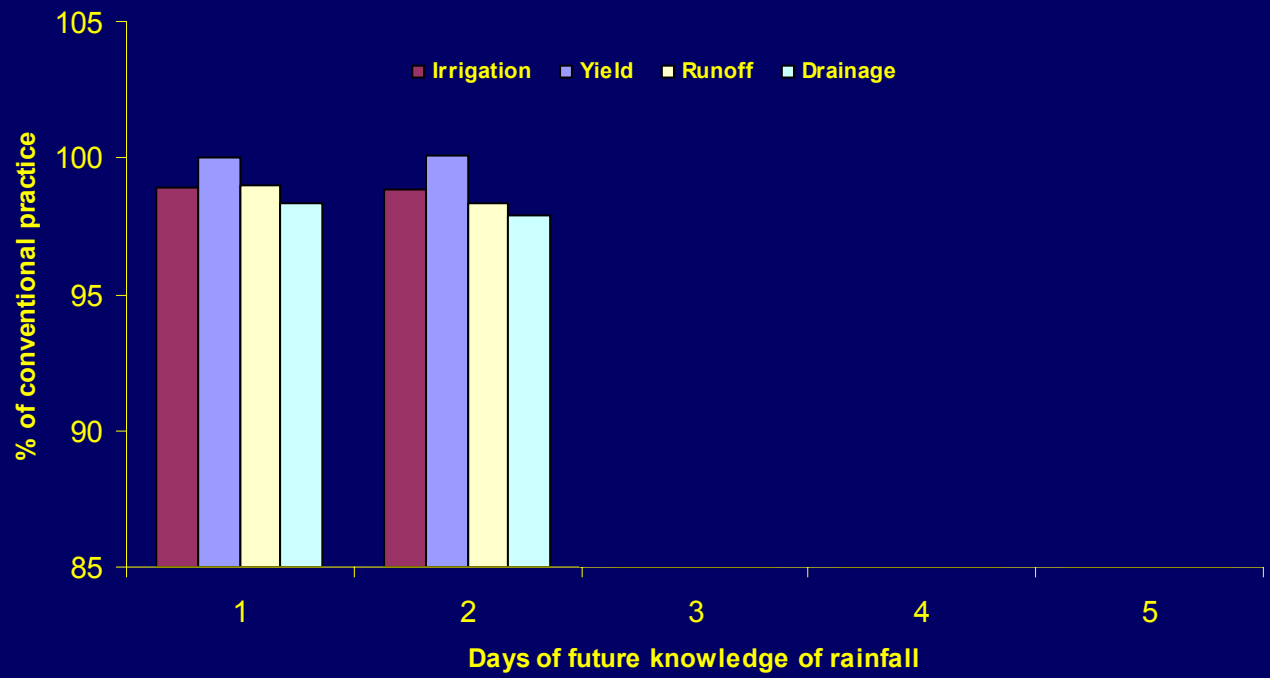

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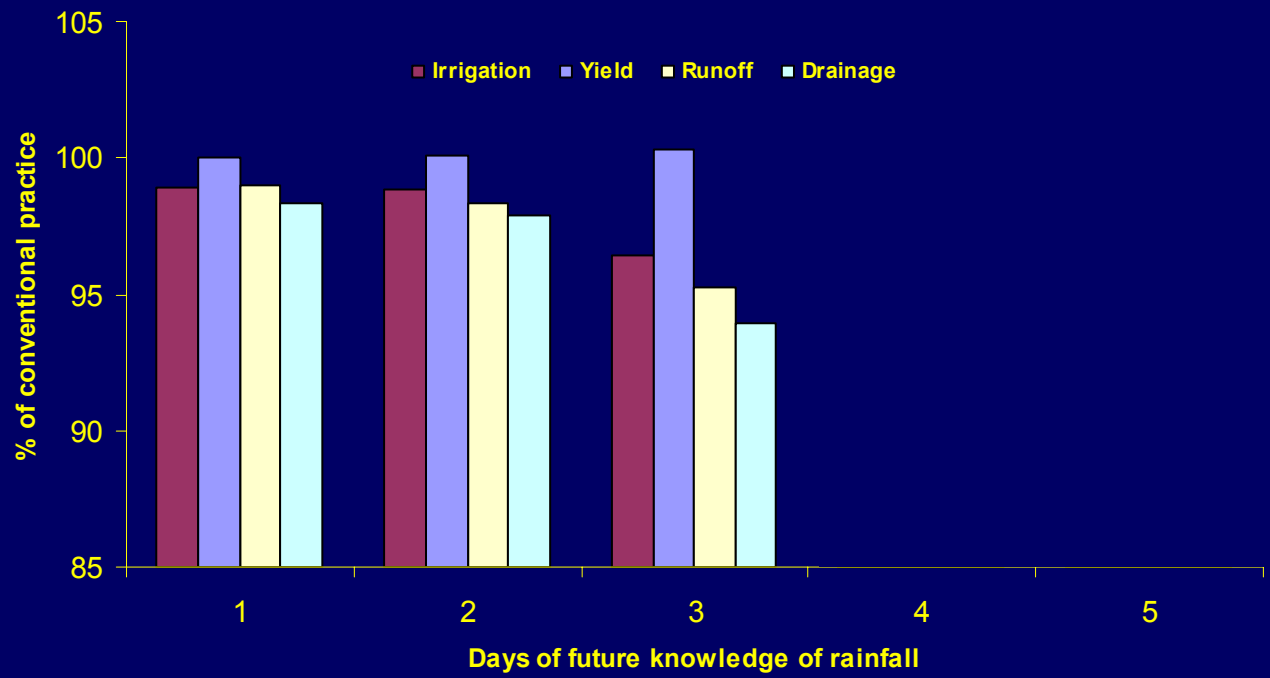

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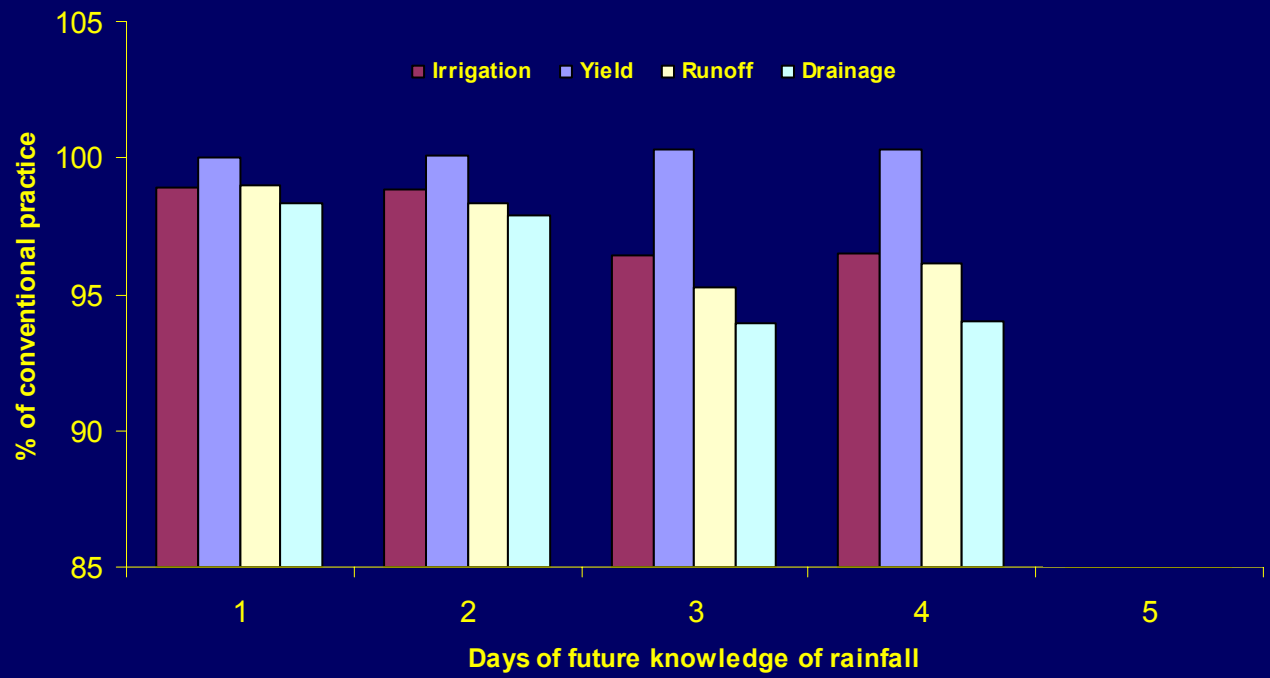

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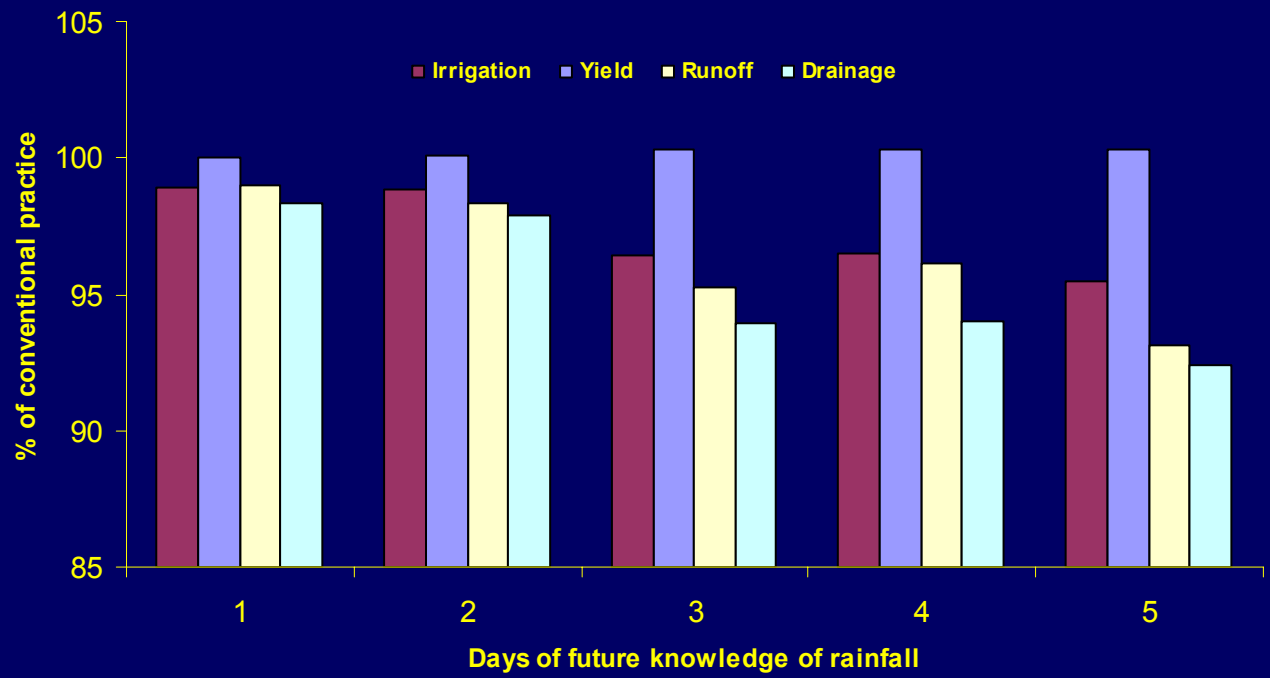

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PAWC 190mm rain 631mm/yr incrop rain 362 mm/season pan evap 1997mm/yr

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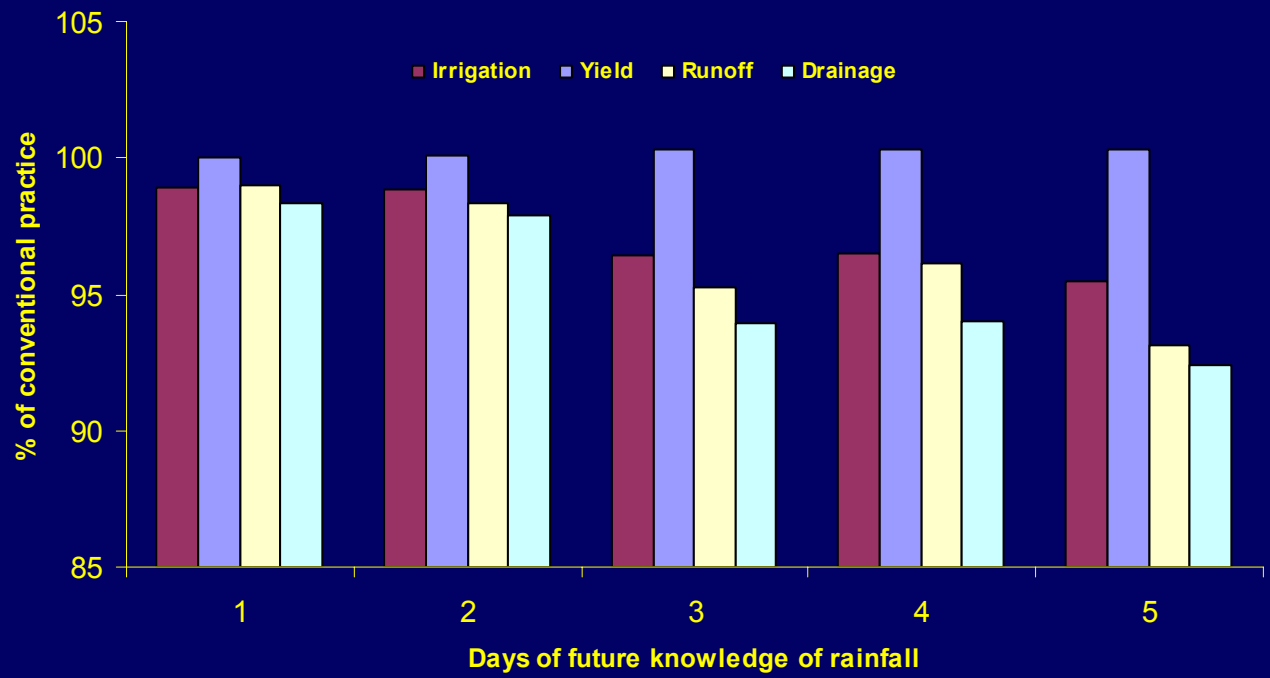
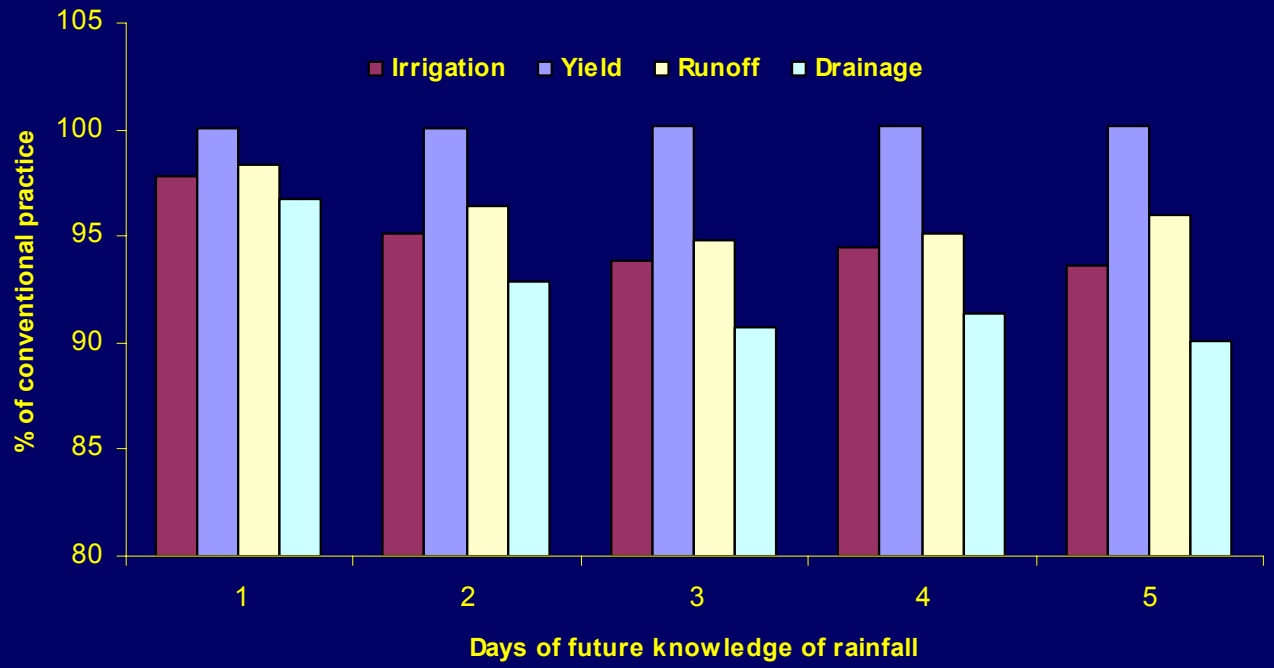


	conventional practice	5 days future knowledge	saving
Irrigation	4.2ML/ha	4.0ML/ha	4.5%
Runoff	0.2ML/ha	0.2ML/ha	7.0%
Drainage	2.6ML/ha	2.4ML/ha	7.5%
Yield	4688kg/ha	4700kg/ha	0.0%

Emerald Cotton

PAWC 190mm rain 596 mm/yr incrop rain 308 mm/season pan evap 2123mm/yr

20 >5mm rain days/season 42 years of simulated irrigation 100mm deficit irrigation

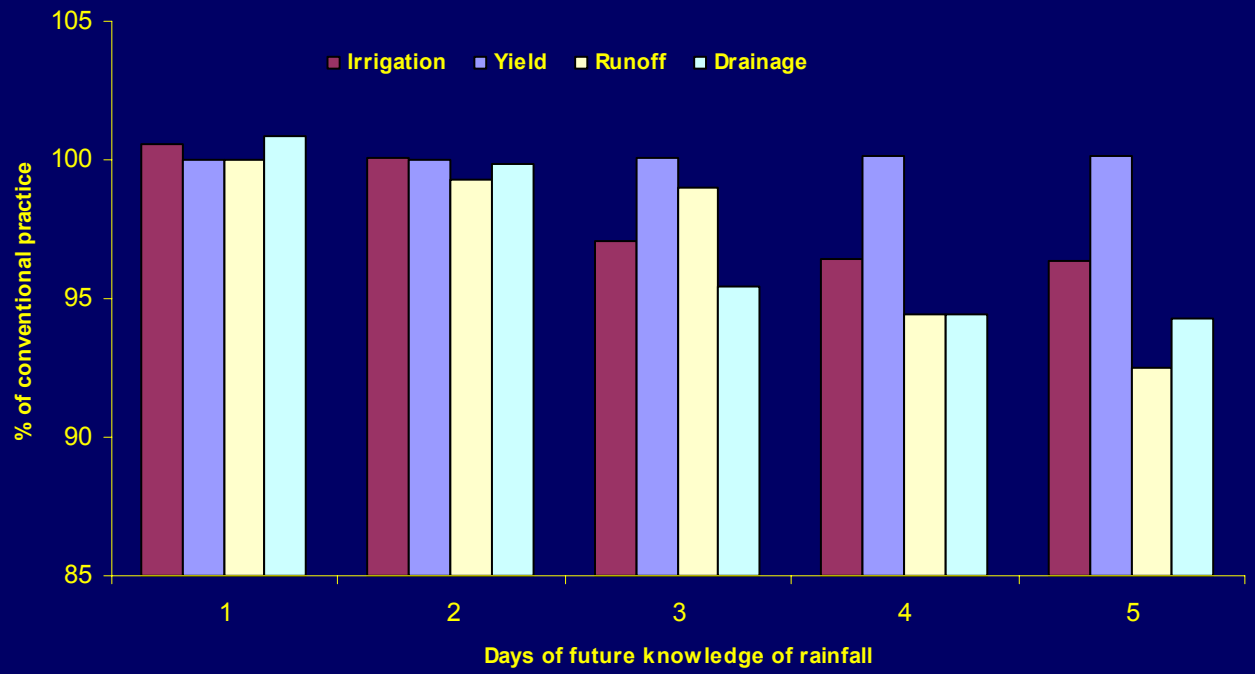


	conventional practice	5 days future knowledge	saving
Irrigation	3.1ML/ha	2.9ML/ha	6.5%
Runoff	0.2ML/ha	0.2ML/ha	4.0%
Drainage	2.5ML/ha	1.8ML/ha	10.0%
Yield	3871kg/ha	3879kg/ha	0.0%

Dalby Cotton

PAWC 190mm rain 596 mm/yr incrop rain 399 mm/season pan evap 1920mm/yr

22 >5mm rain days/season 42 years of simulated irrigation 100mm deficit irrigation



	conventional practice	5 days future knowledge	saving
Irrigation	3.4ML/ha	3.3ML/ha	4.5%
Runoff	0.1ML/ha	0.1ML/ha	7.5%
Drainage	2.2ML/ha	2.1ML/ha	6.0%
Yield	4796kg/ha	4800kg/ha	0.0%

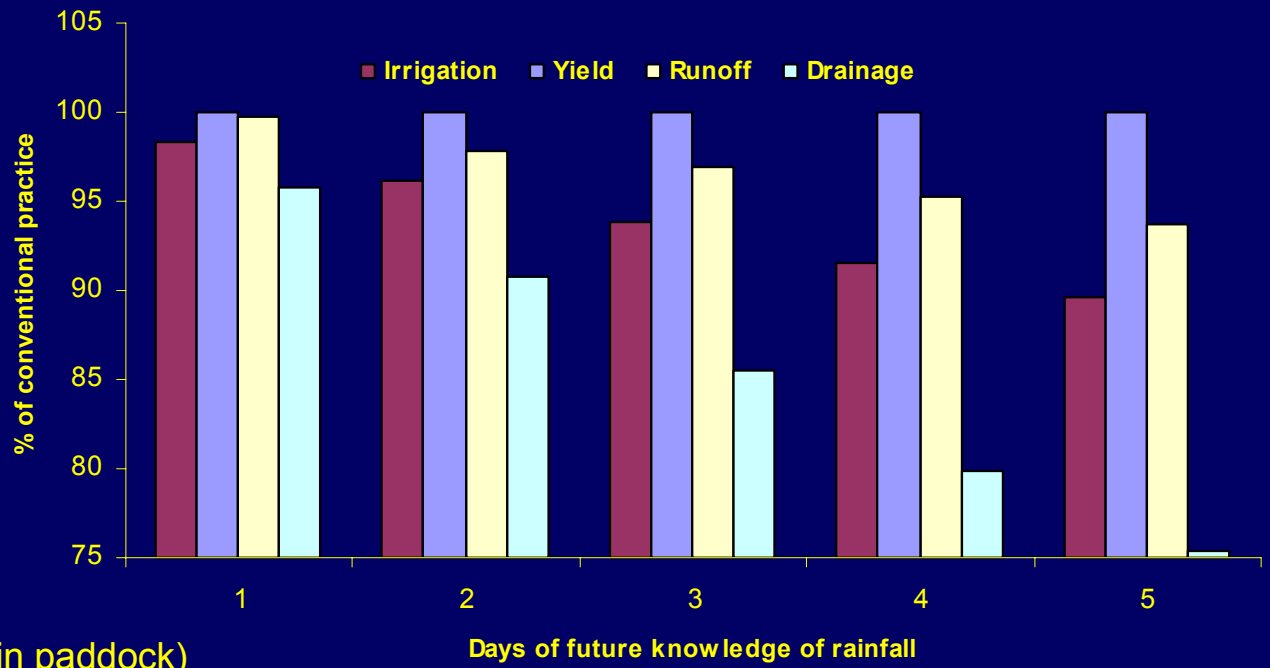
An example of a short term forecast scenario:
Sugar

- SILO data drill climate files
- A deep cracking clay
- A PERFECT crop model for a sugar
- Automatically planted on the 15th of October each year
- Irrigation is a 50mm soil water deficit
- Run for 42 years of climate data

Bundaberg Sugar

PAWC 190mm rain 1055 mm/season pan evap 1716 mm/yr

45 >5mm rain days/season 42 years of simulated irrigation 50mm deficit irrigation



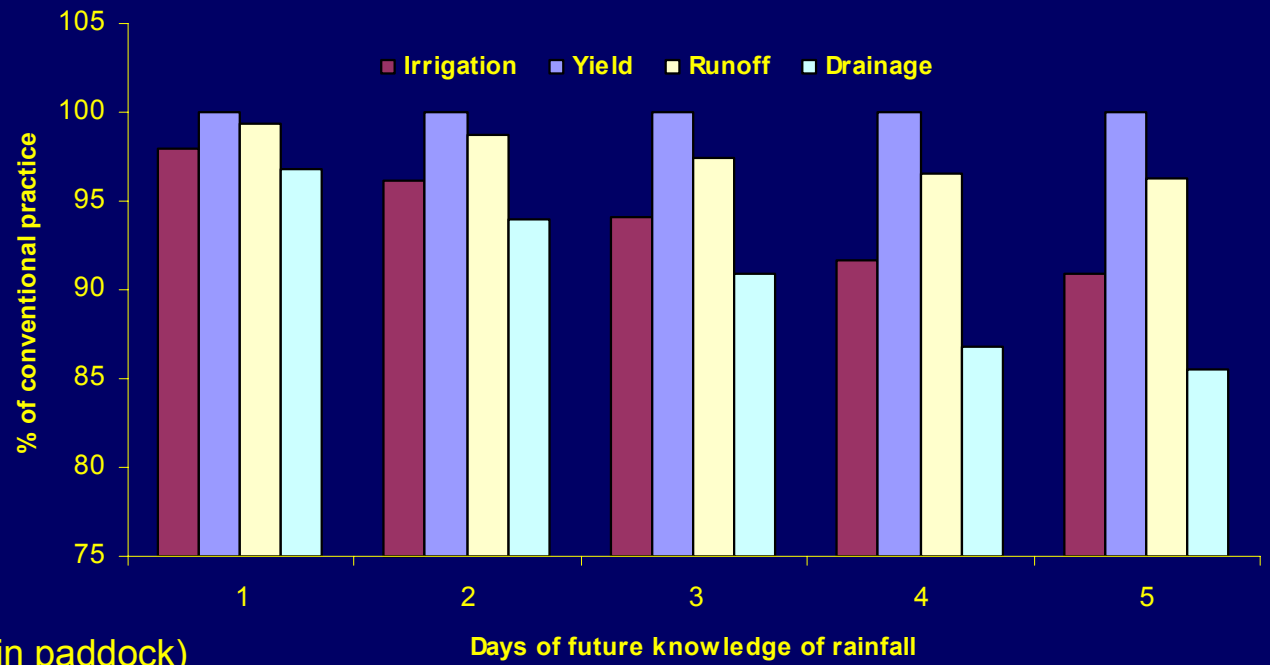
(harvested cane in paddock)

	conventional practice	5 days future knowledge	saving
Irrigation	8.6ML/ha	7.8ML/ha	10.4%
Runoff	1.0ML/ha	0.9ML/ha	6.3%
Drainage	3.4ML/ha	2.6ML/ha	24.7%
Yield	105t/ha	105t/ha	0%

Proserpine Sugar

PAWC 190mm rain 1550 mm/season pan evap 1972 mm/yr

58 >5mm rain days/season 42 years of simulated irrigation 50mm deficit irrigation



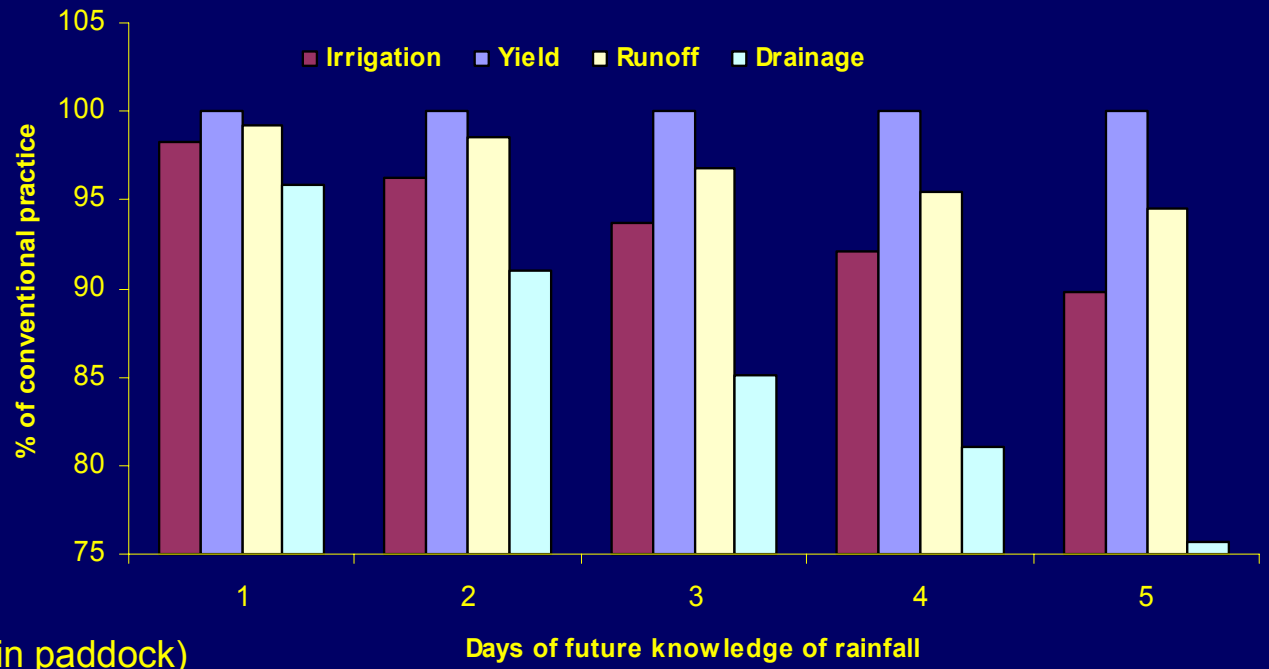
(harvested cane in paddock)

	conventional practice	5 days future knowledge	saving
Irrigation	10.0ML/ha	9.1ML/ha	9.2%
Runoff	2.4ML/ha	2.3ML/ha	3.7%
Drainage	5.7ML/ha	4.9ML/ha	14.4%
Yield	97t/ha	97t/ha	0%

Grafton Sugar

PAWC 190mm rain 1045 mm/season pan evap 1635 mm/yr

51 >5mm rain days/season 42 years of simulated irrigation 50mm deficit irrigation



(harvested cane in paddock)

	conventional practice	5 days future knowledge	saving
Irrigation	8.1ML/ha	7.3ML/ha	9.4%
Runoff	7.1ML/ha	6.7ML/ha	5.5%
Drainage	3.3ML/ha	2.6ML/ha	24.3%
Yield	101t/ha	101t/ha	0%

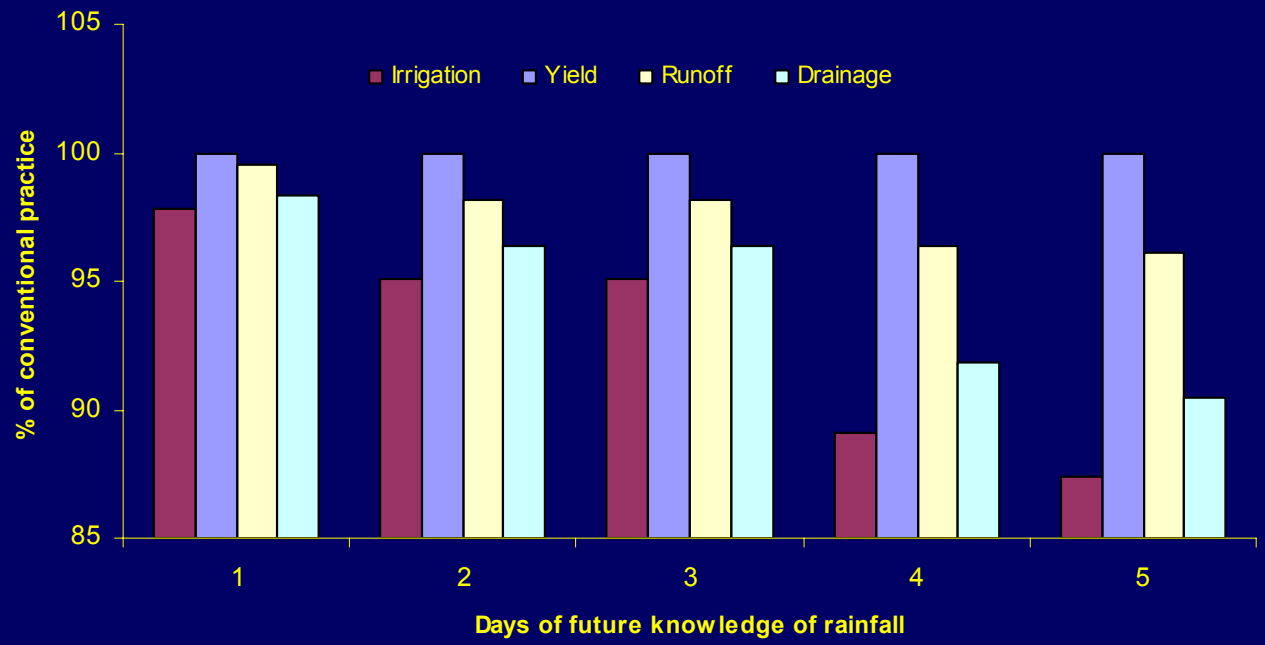
An example of a short term forecast scenario:
Pasture

- SILO data drill climate files
- A deep cracking clay
- PERFECT crop models for a summer and winter pasture
- Irrigation is a 50mm soil water deficit
- Run for 42 years of climate data

Gympie Pasture

PAWC 190mm rain 1116 mm/season pan evap 1535 mm/yr

51 >5mm rain days/season 42 years of simulated irrigation 50mm deficit irrigation

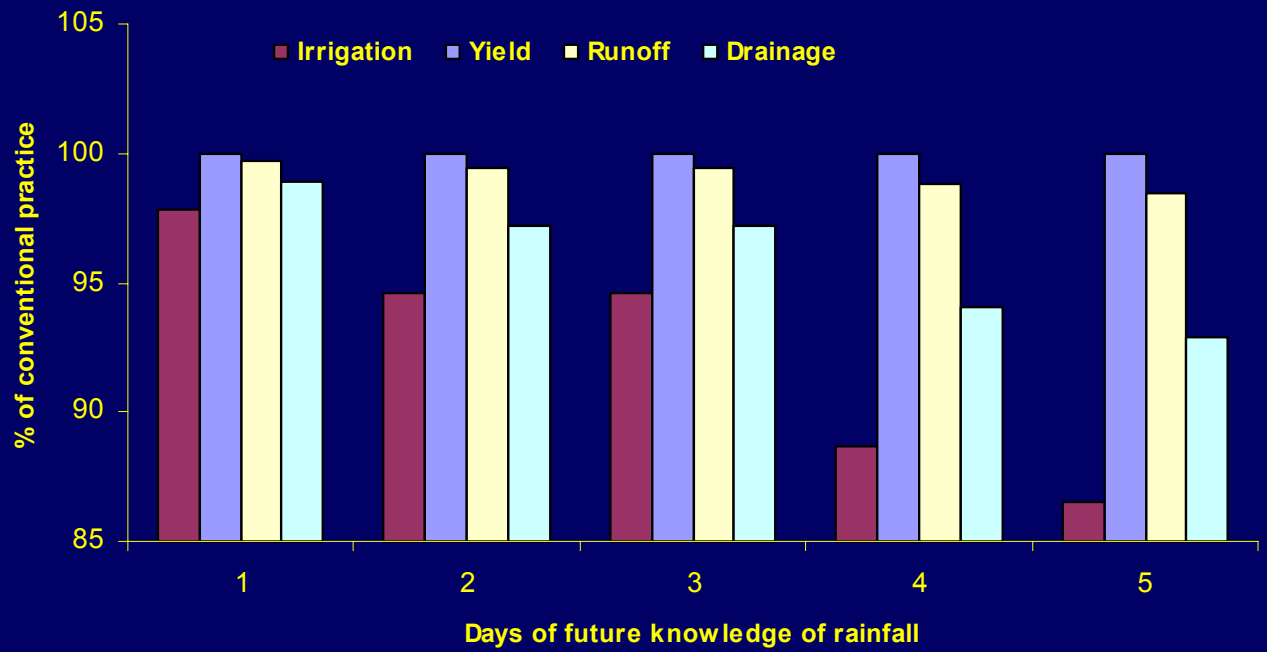


	conventional practice	5 days future knowledge	saving
Irrigation	3.8ML/ha	3.3ML/ha	12.6%
Runoff	0.8ML/ha	0.8ML/ha	3.9%
Drainage	4.8ML/ha	4.4ML/ha	9.6%
Yield	29,838kg/ha	29,838kg/ha	0%

Lismore Pasture

PAWC 190mm rain 1397 mm/season pan evap 1525 mm/yr

63 >5mm rain days/season 42 years of simulated irrigation 50mm deficit irrigation

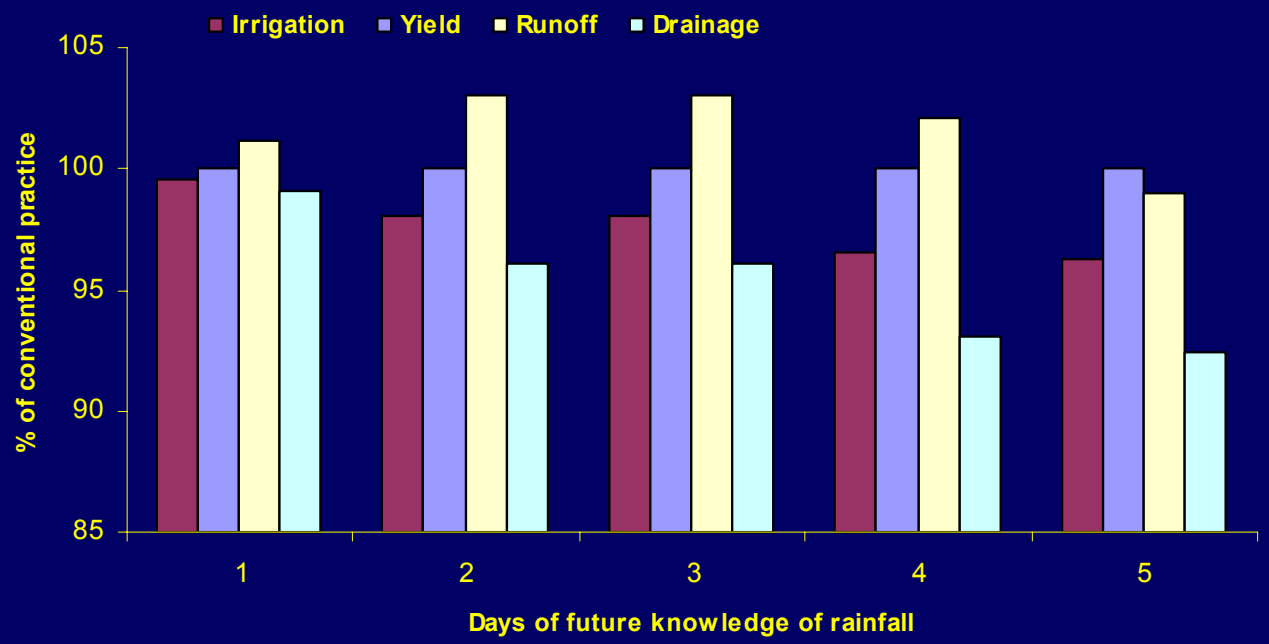


	conventional practice	5 days future knowledge	saving
Irrigation	3.5ML/ha	3.1ML/ha	13.4%
Runoff	1.3ML/ha	1.3ML/ha	1.5%
Drainage	6.5ML/ha	6.1ML/ha	7.1%
Yield	29,446kg/ha	29,446kg/ha	0%

Albury Pasture

PAWC 190mm rain 660 mm/season pan evap 1474 mm/yr

44 >5mm rain days/season 42 years of simulated irrigation 50mm deficit irrigation

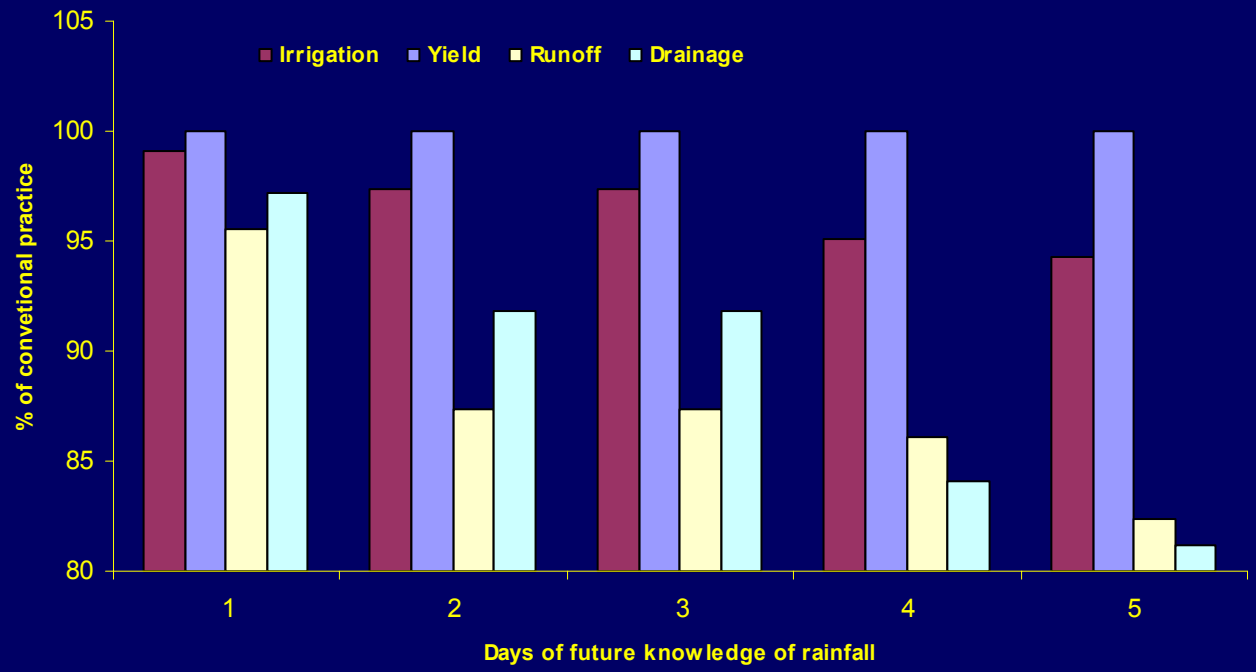


	conventional practice	5 days future knowledge	saving
Irrigation	4.8ML/ha	4.6ML/ha	3.7%
Runoff	0.1ML/ha	0.1ML/ha	1.0%
Drainage	2.4ML/ha	2.2ML/ha	7.6%
Yield	31,267kg/ha	31,267kg/ha	0%

Dalby Pasture

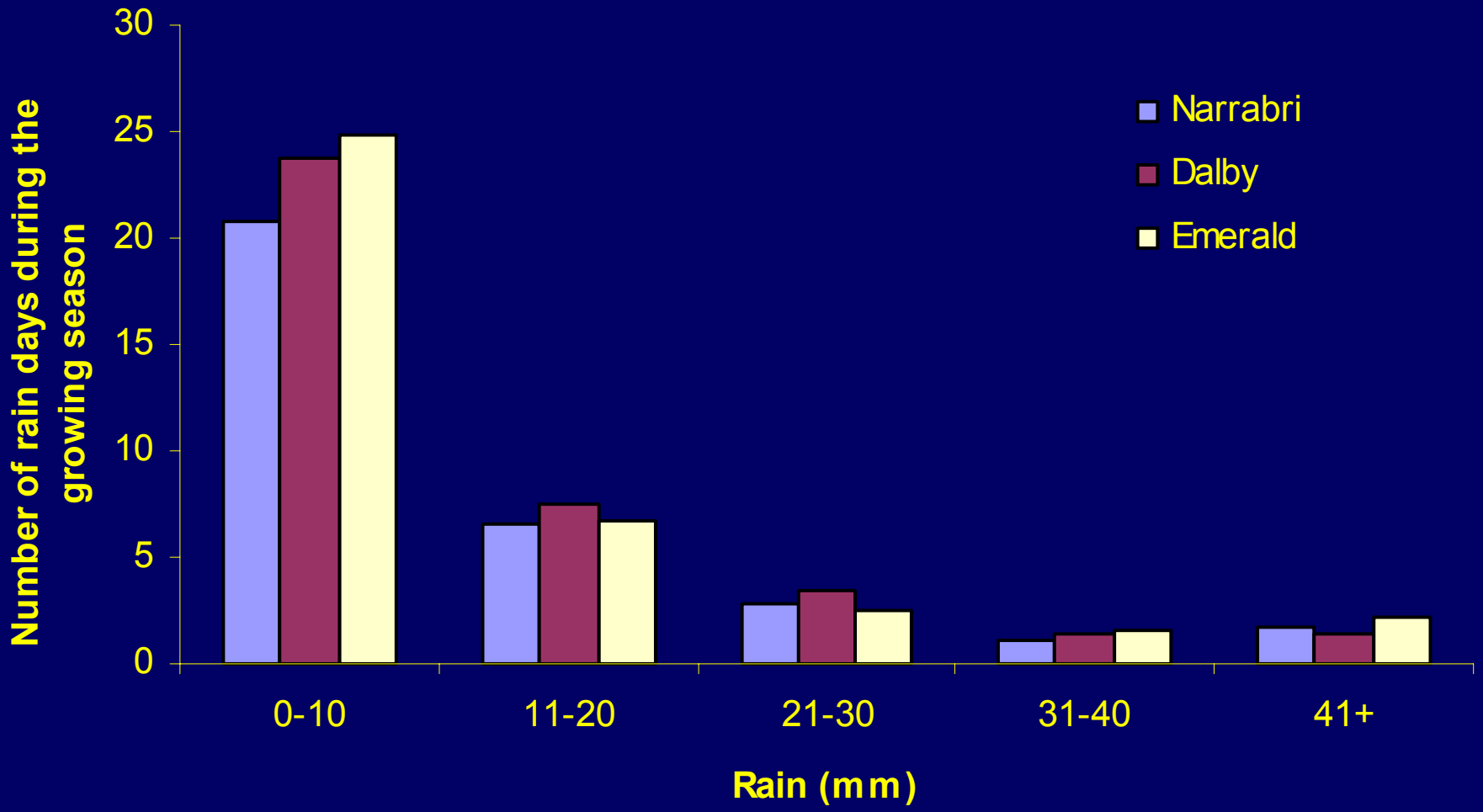
PAWC 190mm rain 596 mm/season pan evap 1920mm/yr

34 >5mm rain days/season 42 years of simulated irrigation 50mm deficit irrigation



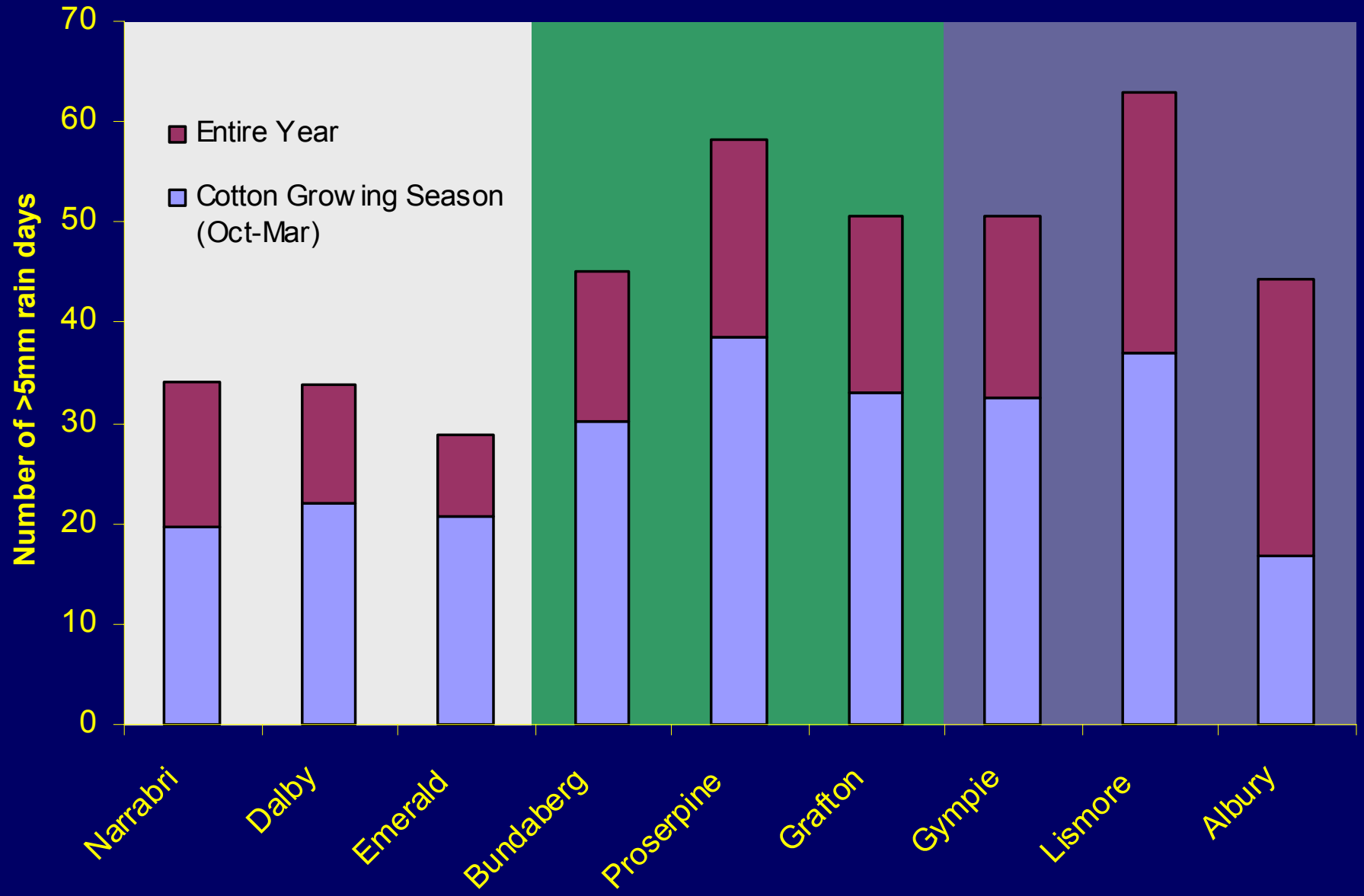
	conventional practice	5 days future knowledge	saving
Irrigation	6.8ML/ha	6.4ML/ha	5.8%
Runoff	0.1ML/ha	0.1ML/ha	18.0%
Drainage	1.9ML/ha	1.6ML/ha	19.0%
Yield	30,783kg/ha	30,782kg/ha	0%

Cotton rain days



The cotton growing season is from the 1st of October till the approximately the 31st March

Comparison of rain days



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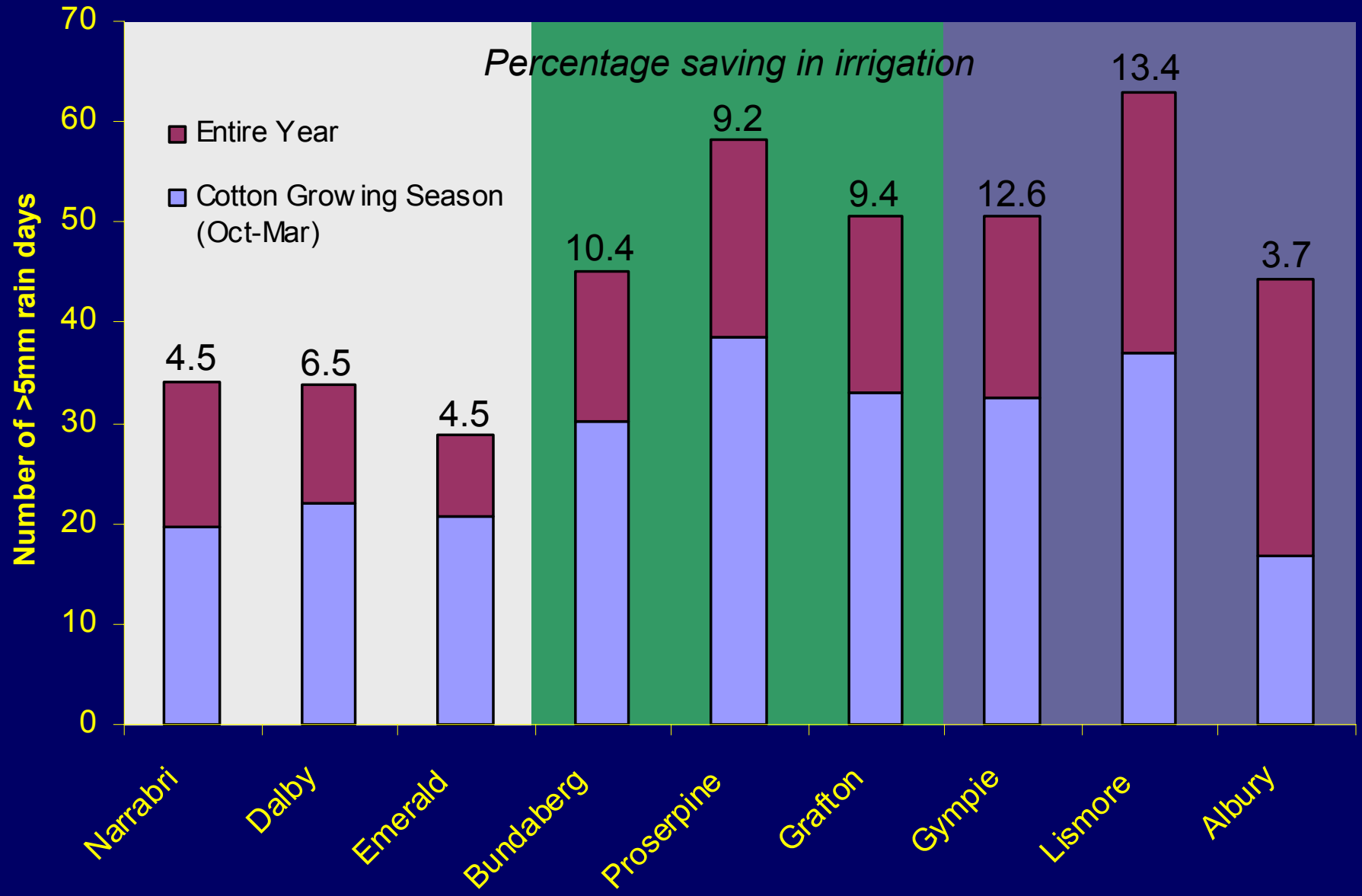

Narrabri soil comparison (Cotton) **50% PAWC irrigation trigger**

PAWC	Conventional Irrigation	Irrigation Saving	Runoff S.	Drainage S.
250mm	3.70ML/ha	3.07% (0.11ML/ha)	0.00ML/ha	0.13ML/ha
200mm	4.16ML/ha	4.55% (0.19ML/ha)	0.01ML/ha	0.20ML/ha

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200mm	4.16ML/ha	4.55% (0.19ML/ha)	0.01ML/ha	0.20ML/ha

Bundaberg soil comparison (Sugar)

PAWC	Conventional Irrigation	Irrigation Saving	Runoff S.	Drainage S.
250mm	6.78ML/ha	5.24% (0.36ML/ha)	0.03ML/ha	0.35ML/ha
200mm	7.34ML/ha	7.09% (0.52ML/ha)	0.05ML/ha	0.53ML/ha

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Gympie soil comparison (Pasture)

PAWC	Conventional Irrigation	Irrigation Saving	Runoff S.	Drainage S.
250mm	2.52ML/ha	2.10% (0.05ML/ha)	0.00ML/ha	0.07ML/ha
200mm	3.05ML/ha	12.6% (0.38ML/ha)	0.03ML/ha	0.36ML/ha

Conclusions

- Irrigation saving varies between location and crop type.
- Irrigation savings are dependent on the opportunities available to apply short term climate forecasts.
- There are more opportunities with:
    - reduced irrigation deficit triggers
    - higher number of significant rain days
    - higher annual rainfall
    - longer growing seasons
    - crops that use more water

Where to from here?

- Do we need to use sophisticated plant growth models in our water balance simulations?

- Can we ever prove experimentally that climate forecasting will work for you on average given that an experiment usually only runs for three years?

- What else can water balance be used for in an irrigation context?

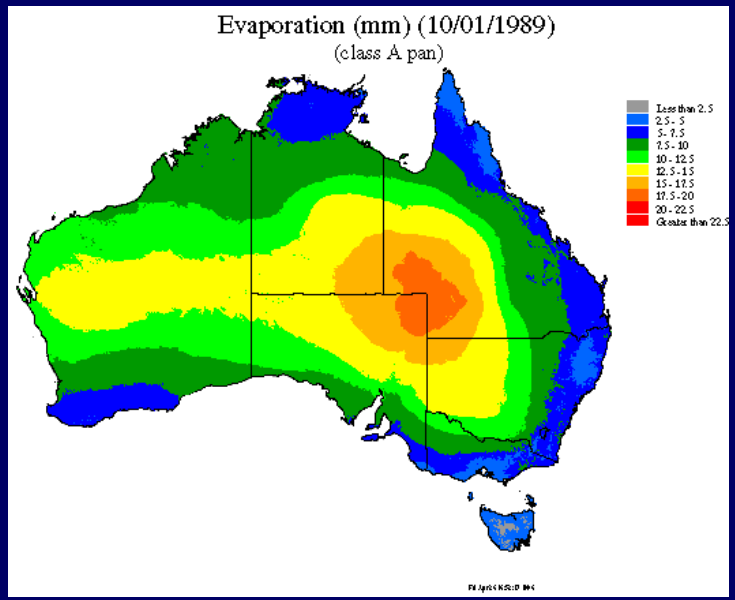
- How do we integrate water balance and climate predictions into onfarm management behaviour?

- Are there other opportunities for climate forecasting (spraying, insects)?

SILO

A rich source of meteorological information for rural industries

- The SILO data drill accesses grids of climate data derived from Bureau of Meteorology climate station records.
- The interpolations are calculated by splining and kriging techniques.



- The data produced is synthetic, however the advantage is that data is available for any location within the Australia.
- The data drill is only available for post 1957 climate data as most of the pre-1957 climate data is still on paper in the Australian Archives.
- Data quality can vary depending on the density of rain stations and topographic complexities.