David Adamson & Adam Loch – FEEM 13th June 2016

Adaptation responses to increasing drought frequency

THE CENTRE FOR GLOBAL FOOD AND RESOURCES

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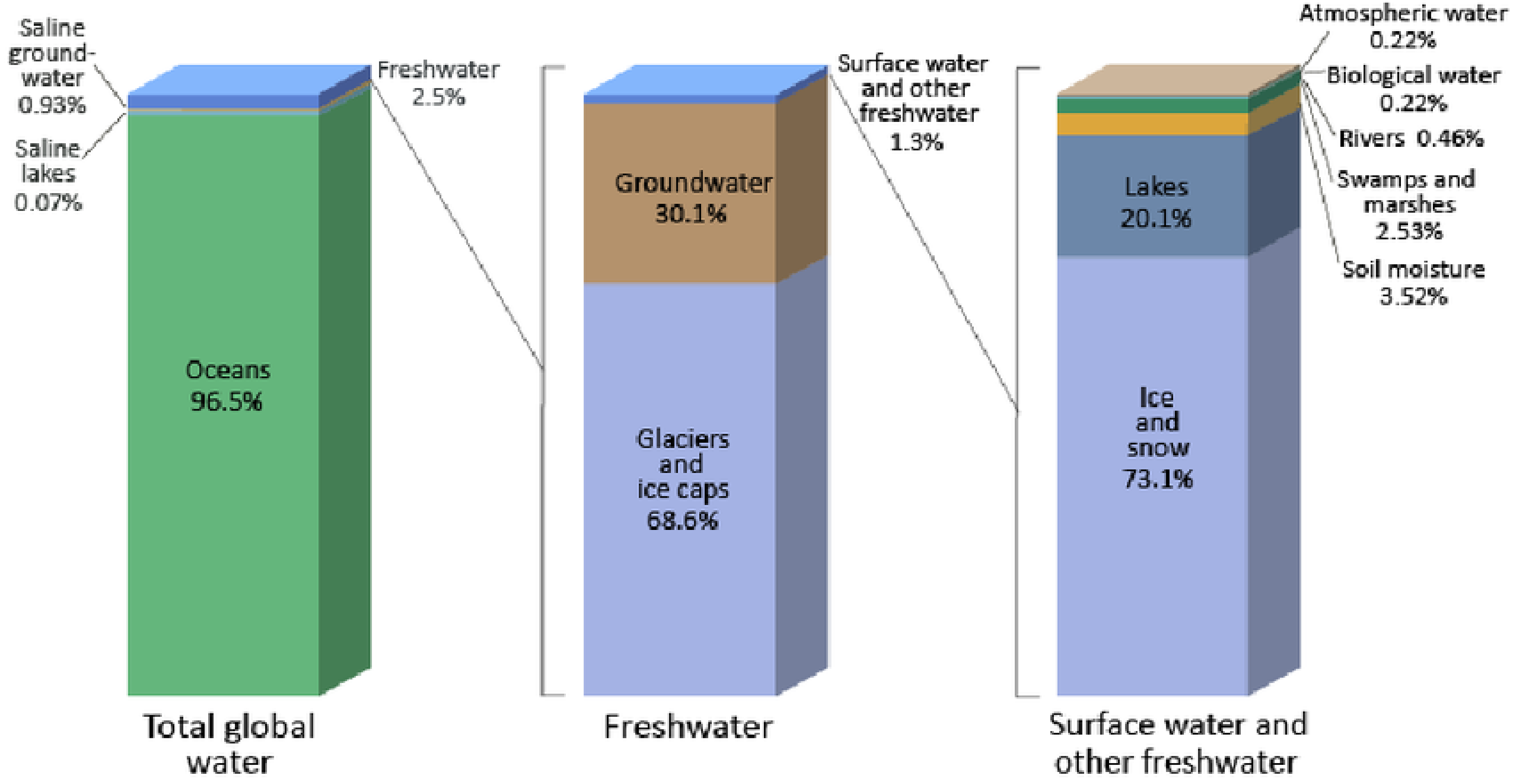
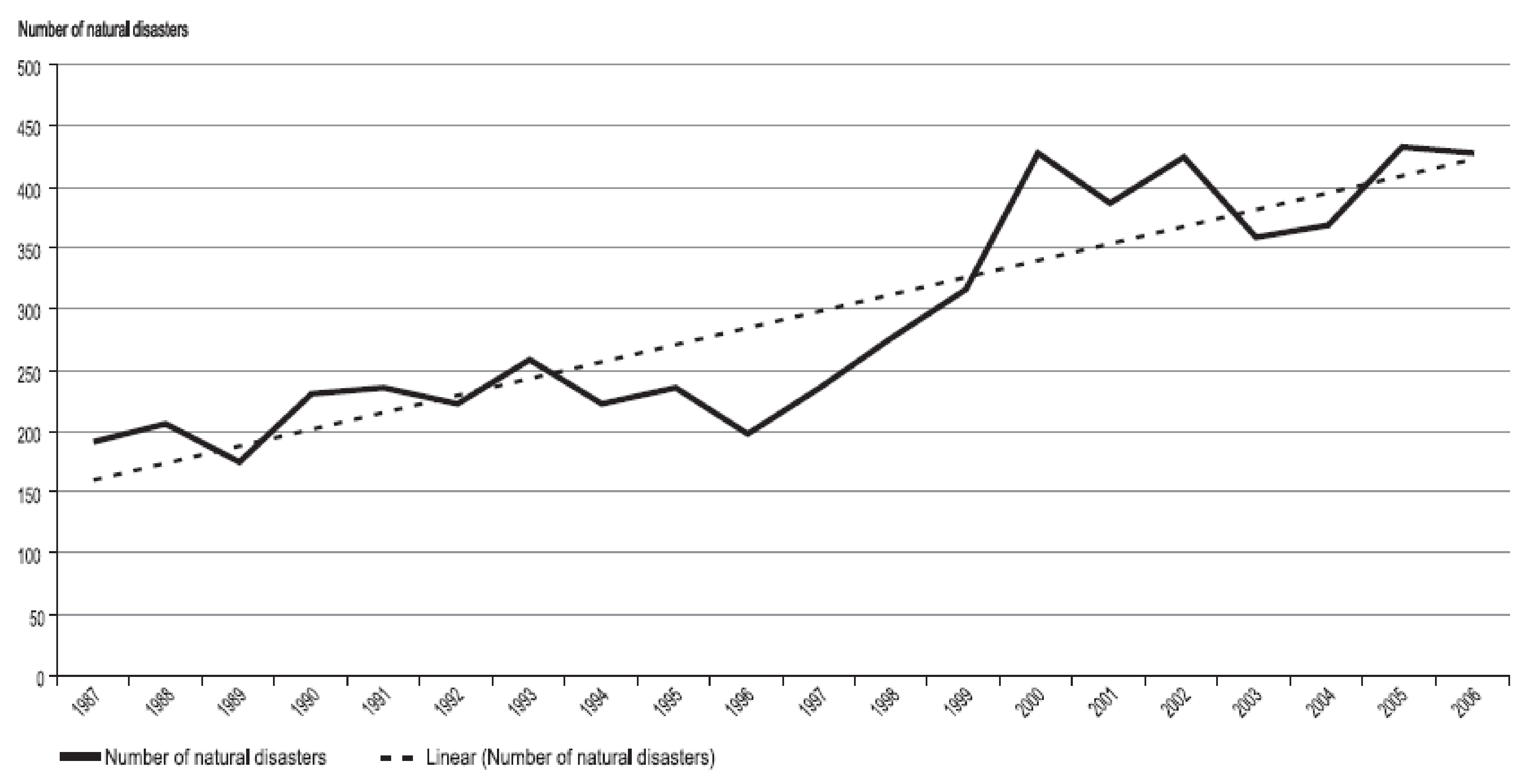
Distribution of Earth's Water

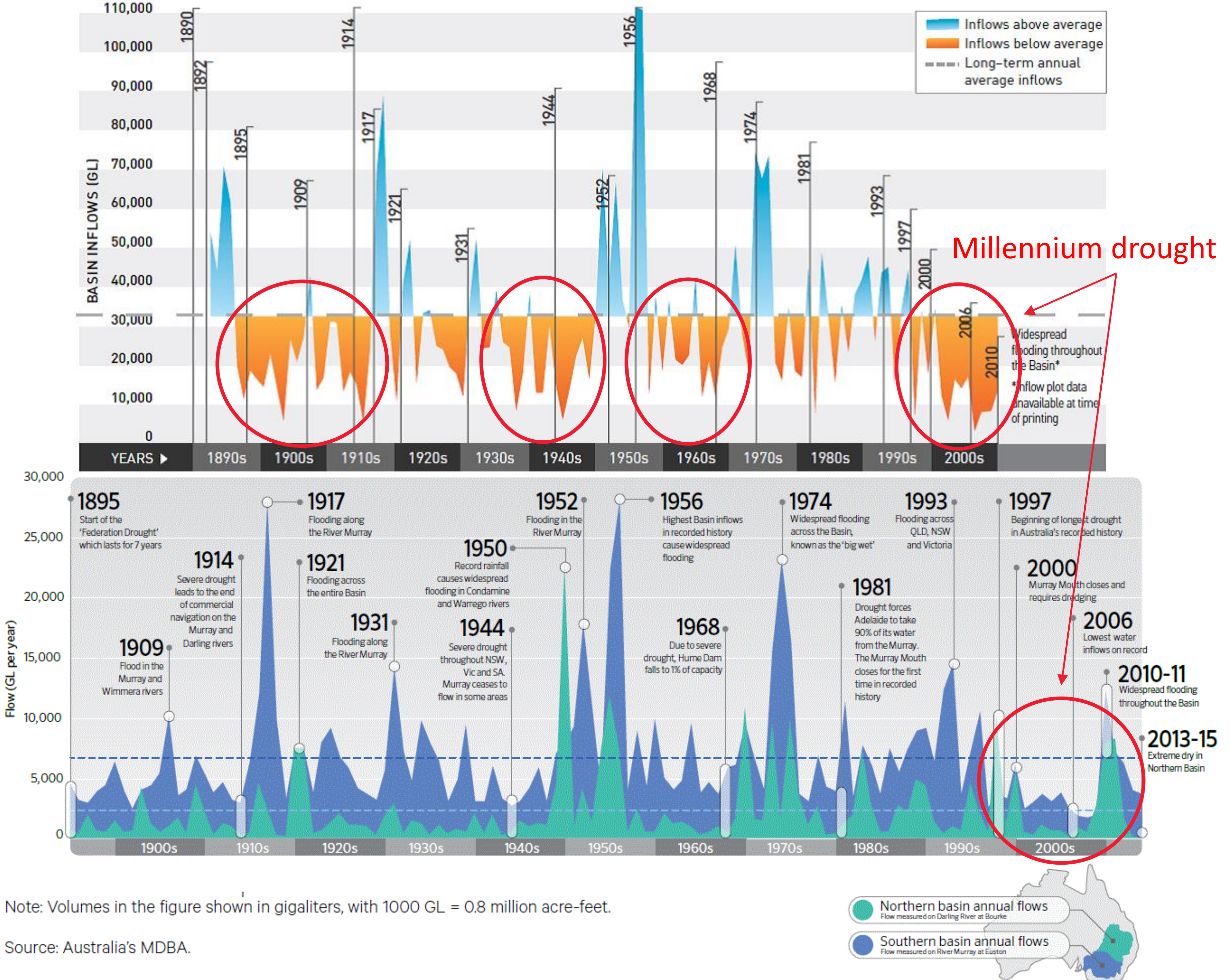


Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.



Source: Hoyois, Below, Scheuren and Guha-Sapir (2007).

The trend in natural disasters appears to be upwards



Note: Volumes in the figure shown in gigaliters, with 1000 GL = 0.8 million acre-feet.

Source: Australia's MDBA.

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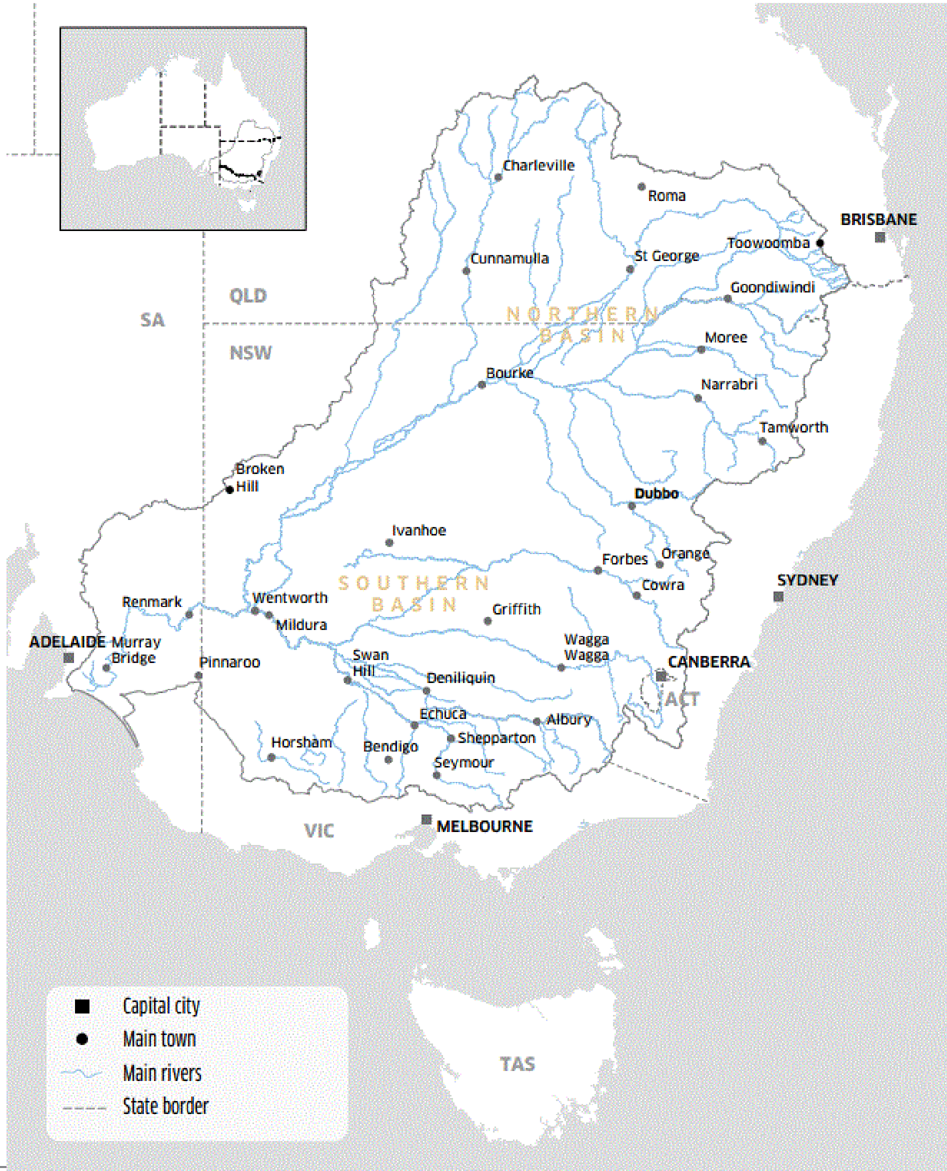
Question:

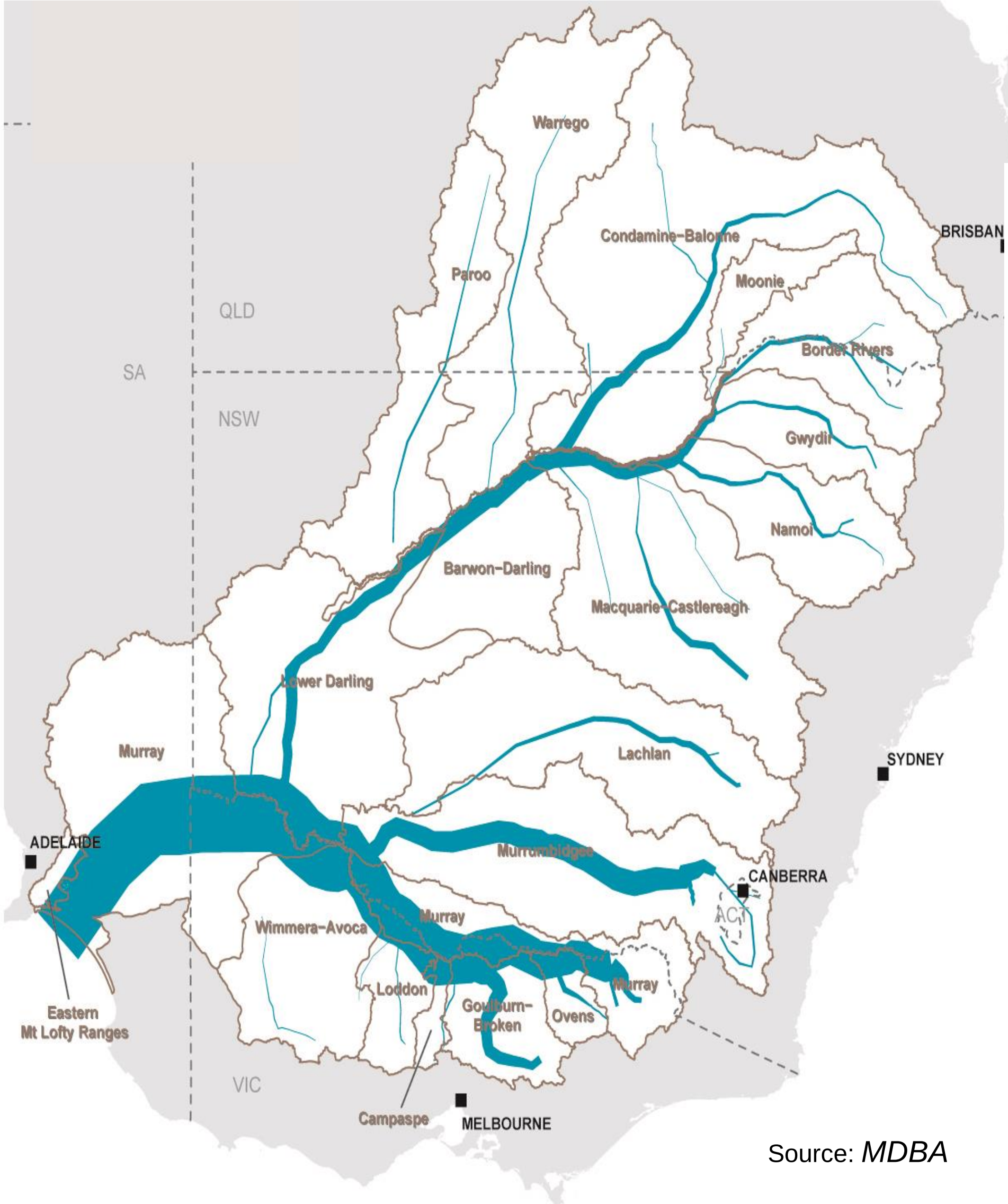
So, how do MDB farmers adapt to drought?

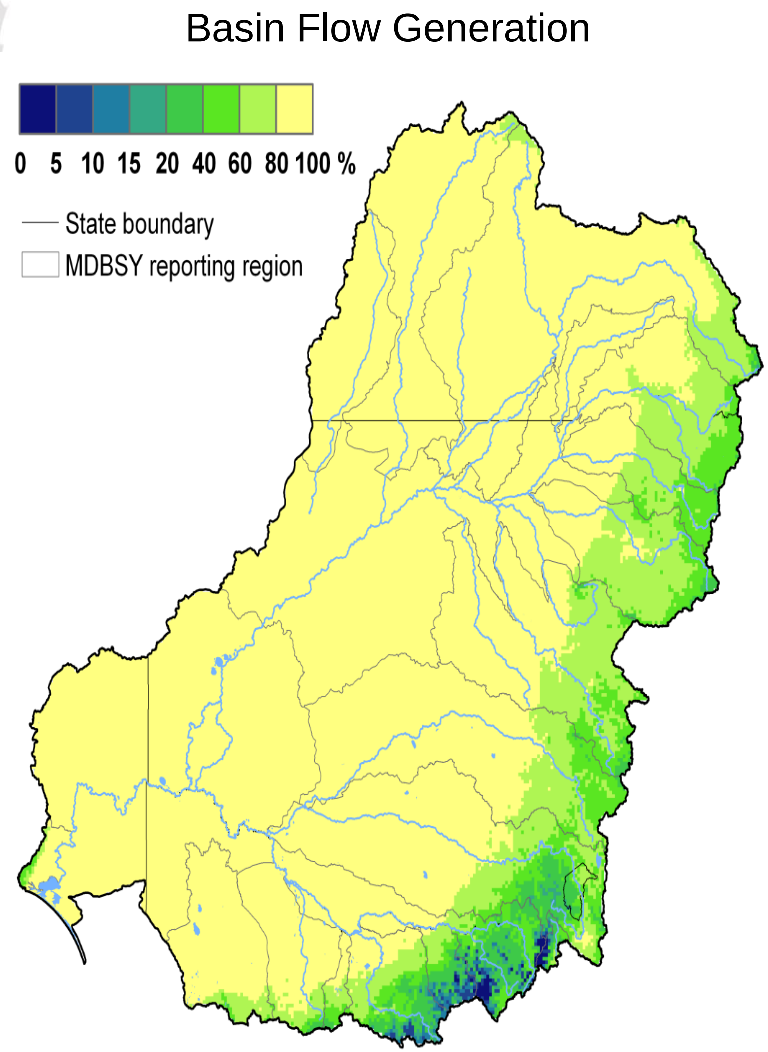
The Murray Darling Basin (MDB)



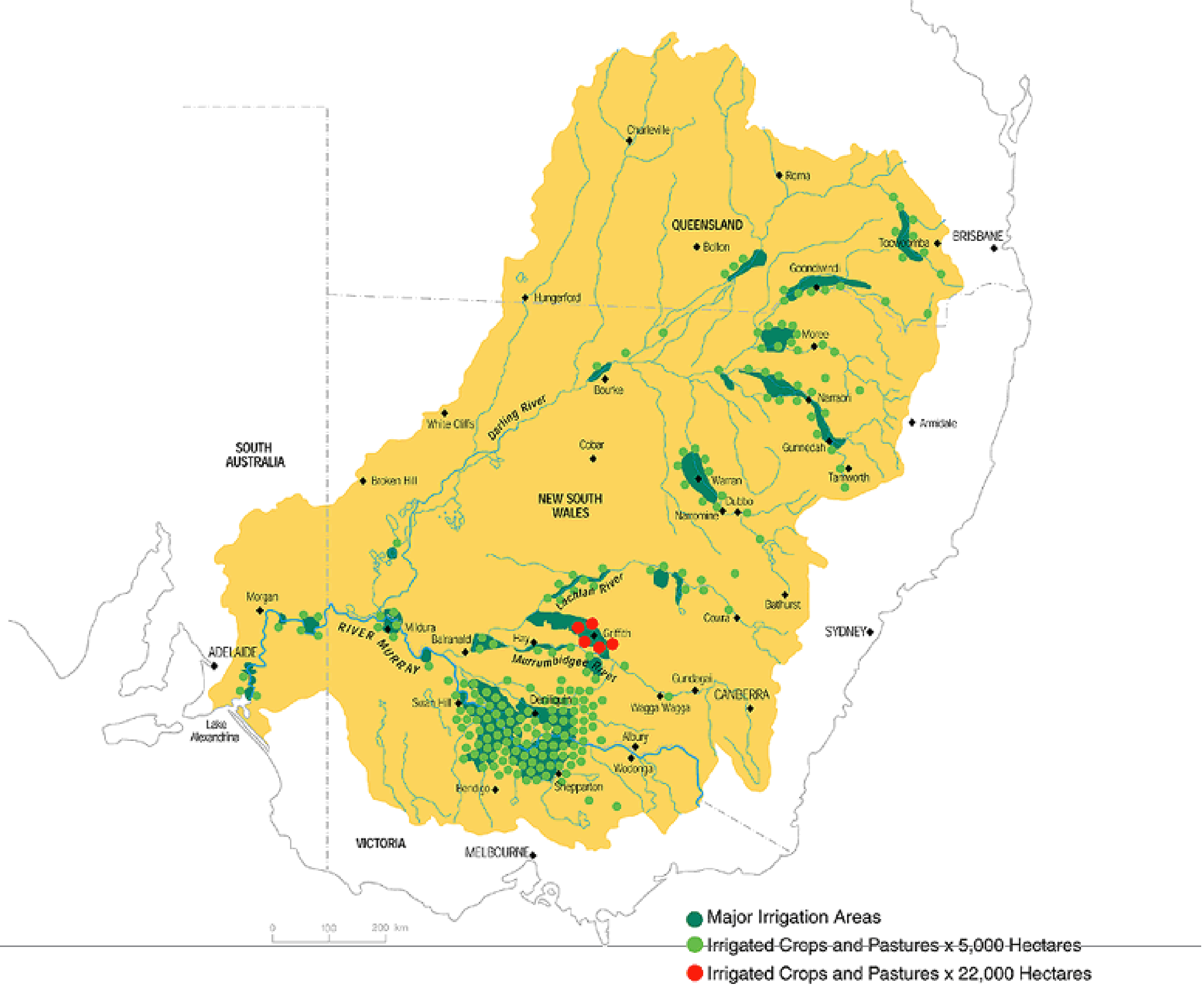
- 1,000,000 km²
- 14% of Australia (size of Spain & France)
- 80% of basin is agriculture
- 60% of Australia's irrigation with 40% of Australia's farmers
- "Food Bowl" of Australia
- Population 2,000,000; supports 20 million
- 5 jurisdictions
- Significant environmental values
- Australia's three longest rivers
- Home to 34 major Indigenous groups

Hydrological complexity of the Basin





Source: *MDBA*



QUEENSLAND
NEW SOUTH WALES
SOUTH AUSTRALIA
VICTORIA
BRISBANE
SYDNEY
CANBERRA
MELBOURNE
ADELAIDE
Charleville
Roma
Bollon
Toowoomba
Goondiwindi
Hungerford
Moree
Bourke
Narrabri
Armidale
White Cliffs
Darling River
Cobar
Gunnedah
Tamworth
Warren
Dubbo
Narromine
Broken Hill
Lachlan River
Bathurst
Cowra
Morgan
Mildura
Balranald
Hay
Griffith
RIVER MURRAY
Murrumbidgee River
Gundagai
Wagga Wagga
Swan Hill
Deniliquin
Albury
Wodonga
Lake Alexandrina
Bendigo
Shepparton
0
100
200 km
Major Irrigation Areas
Irrigated Crops and Pastures x 5,000 Hectares
Irrigated Crops and Pastures x 22,000 Hectares

Irrigated Farm Differences across the MDB

VICTORIA

- Small irrigated farms, medium water entitlements (low and high security)
-Mainly permanent pasture (dairy) or annual fodder cropping

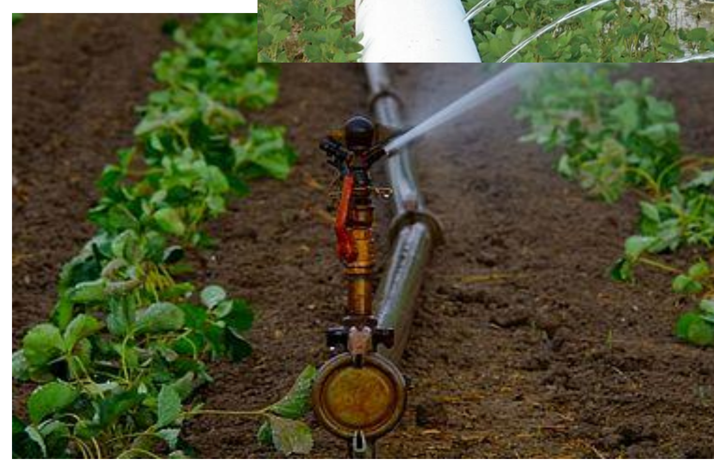
NSW

•annual croppers (cotton, rice)
• have larger farm sizes
• have much larger water entitlements (mainly general security)
• Some horticulture

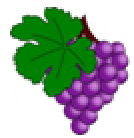
SA

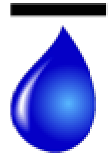
•Permanent plantings (horticulture)
•Small farms, small water entitlements (but high security)

Focus on efficiency (engineering) solutions



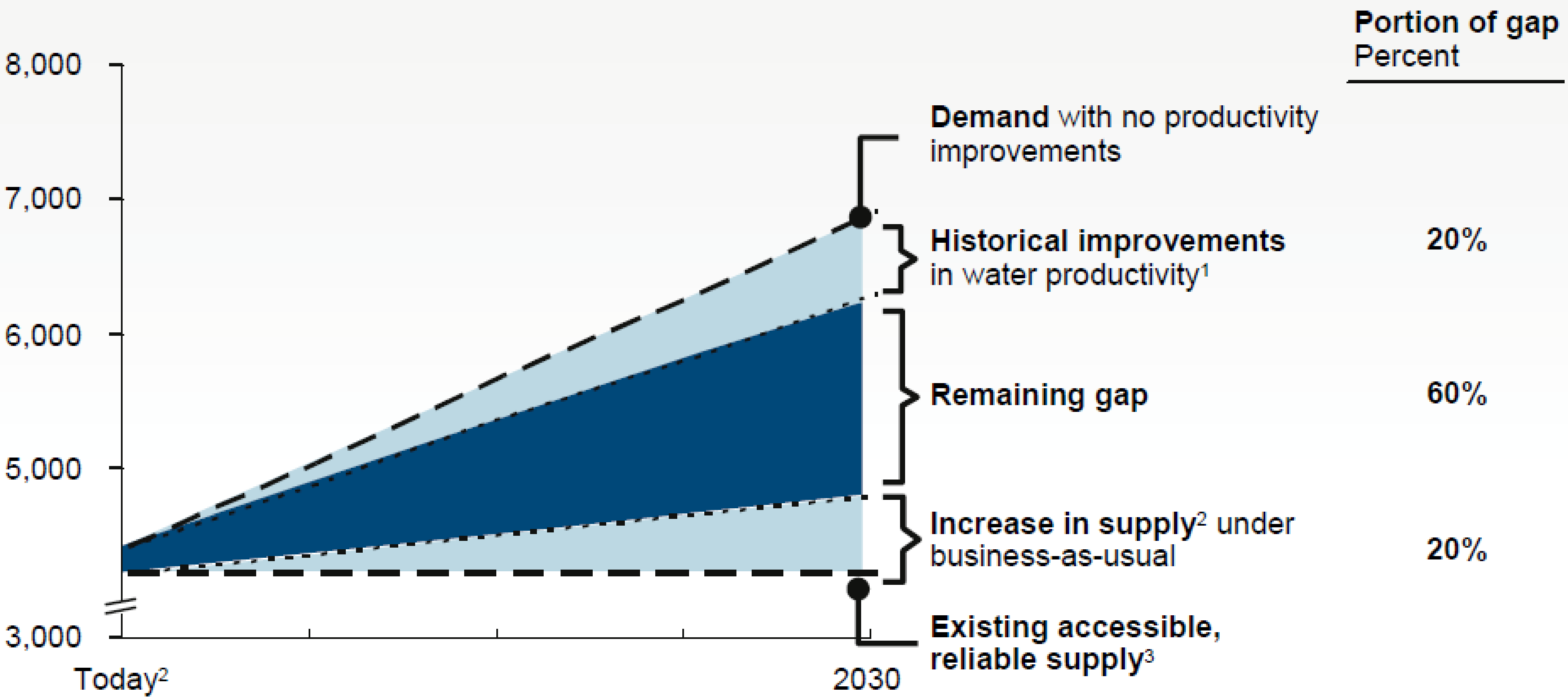
On-farm →



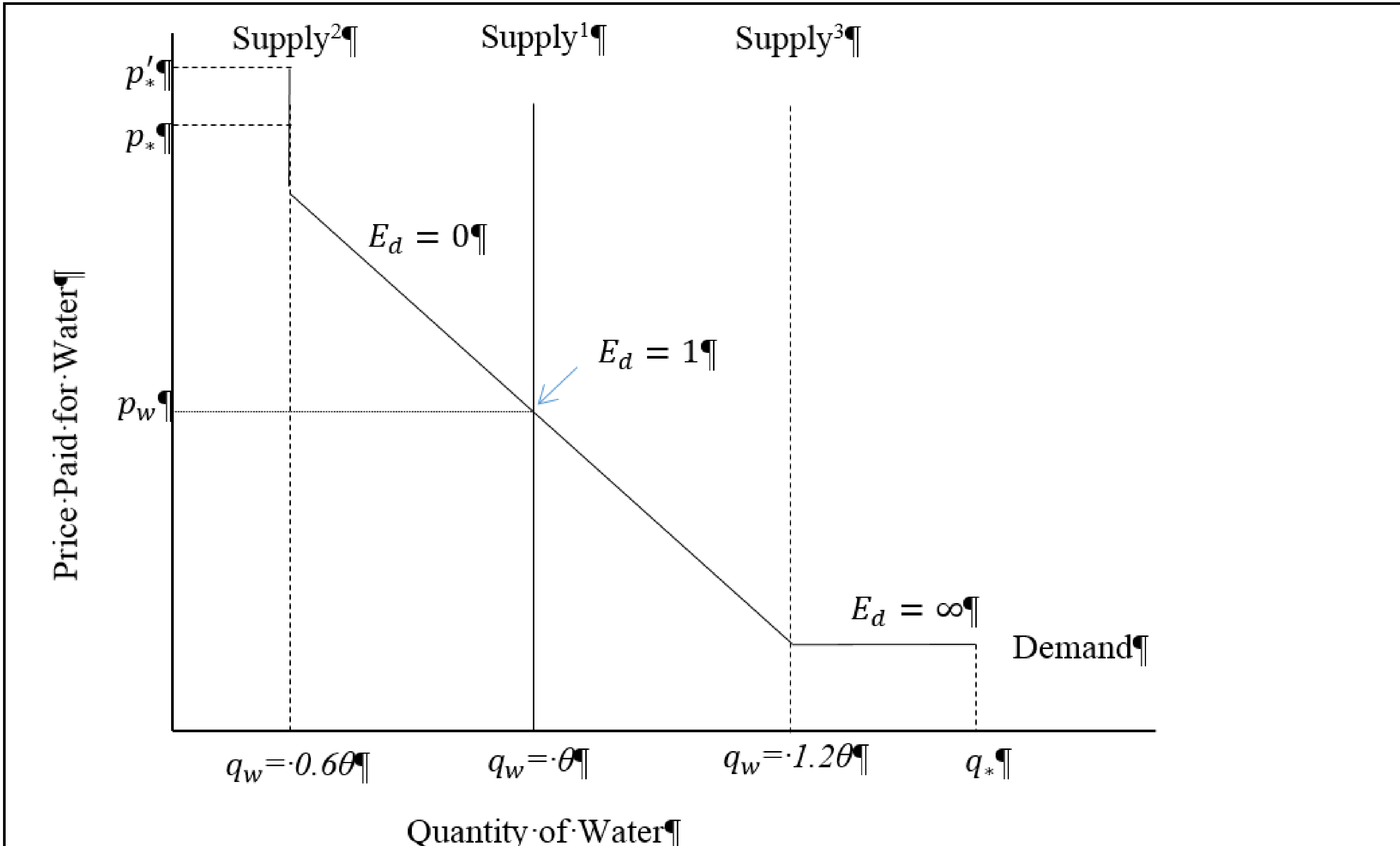


$$WUE = \frac{\textit{Crop yield (kg)}}{\textit{Water consumption } (m^3)}$$

← Off-farm



Portion of gap
Percent
8,000
7,000
6,000
5,000
3,000
Today2
2030
Demand with no productivity improvements
Historical improvements in water productivity1
20%
Remaining gap
60%
Increase in supply2 under business-as-usual
20%
Existing accessible, reliable supply3


Supply[2]
Supply[1]
Supply[3]
p'_*
p_*
$E_d = 0$
$E_d = 1$
p_w
Price Paid for Water
$E_d = \infty$
Demand
$q_w = 0.6\theta$
$q_w = \theta$
$q_w = 1.2\theta$
q_*
Quantity of Water

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We will explain how and why farmers respond differently to these signals

Section 2:

State contingent analysis (SCA)

Decision making under uncertainty

- Decision making models are the cornerstone of risk and uncertainty
- Traditionally involves stochastic representation of uncertain variables and parameters
- Helps illustrate the inherent variability in natural systems
- BUT … Just and Pope (2003) find this provides little practical policy benefit
  - In response, suggest state-contingent analysis (SCA)

State Contingent Analysis (SCA)

- Foundations are derived from Arrow (1953) and Debru (1959) work on state-space:
  - Nature = provides a complete description of the state-space of uncertainty ($S \epsilon \mathbf{\Omega}$)
  - possible states (s) are exhaustive, mutually exclusive, and real

- Chambers & Quiggin(2000) expanded on this
  - dual optimisation
  - Decision maker has no ability to control what state occurs
  - Each *s* has unique management response, yields, prices, inputs and outputs
  - Provides a mechanism for dealing with discontinuous functions (non-convexity)
  - Once a state is revelled all uncertainty disappears allowing for traditional approaches to deal with risk to be used

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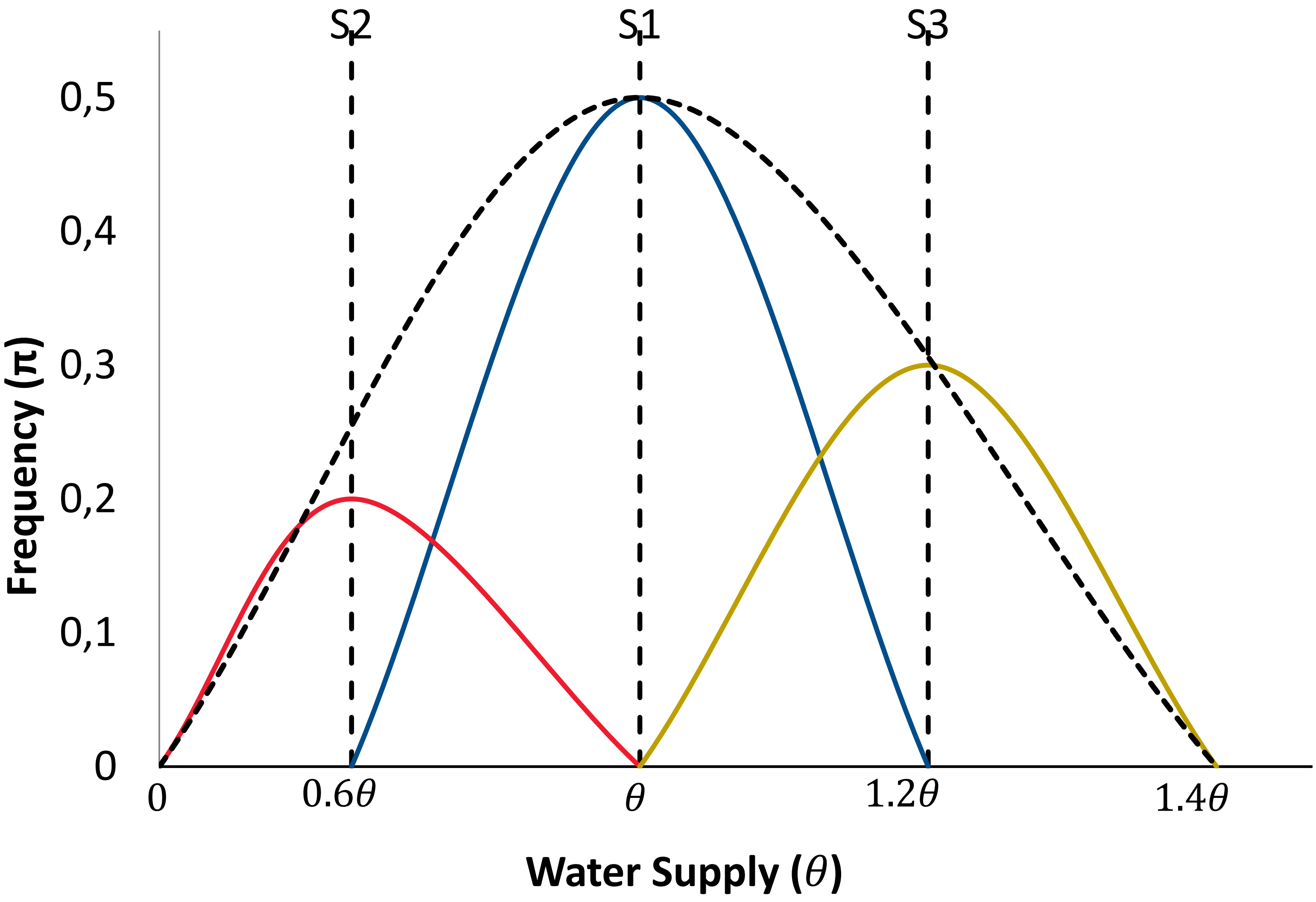
- Separates the environmental signal from the management action

Stochastic Water Supply



Water supply and allocation problem

- Variability in rainfall necessitated the need for a portfolio of water rights with declining reliability of supply.
  - High Security
  - General Security
  - Supplementary Security

- The allocation of water to rights is made throughout the season.

Farmer Water Supply

- Total water supply in a given state (TW_s) is the sum of announced supply $\left(AS_{s,n}\right)$ toward all water entitlements over a given number (n) of allocation announcements:

- $TW_S = \sum_{i=1}^{n} AS_{s,n}$

Where AS is

- is the product of the water entitlement portfolio E (matrix with dimensions $[E \times 1]$) and the reliability of those entitlements ER with dimensions $[E \times S \times n]$:

- $AS_{s,n} = E \times ER_{s,n}$

Crop Requirements

- Crop water requirements by state (WR_s) are the sum of maintenance water (MW_s) required to keep a crop alive, and productive water (PW_s) required to generate a commercial yield:

- $WR_s = (MW_s + PW_s)$

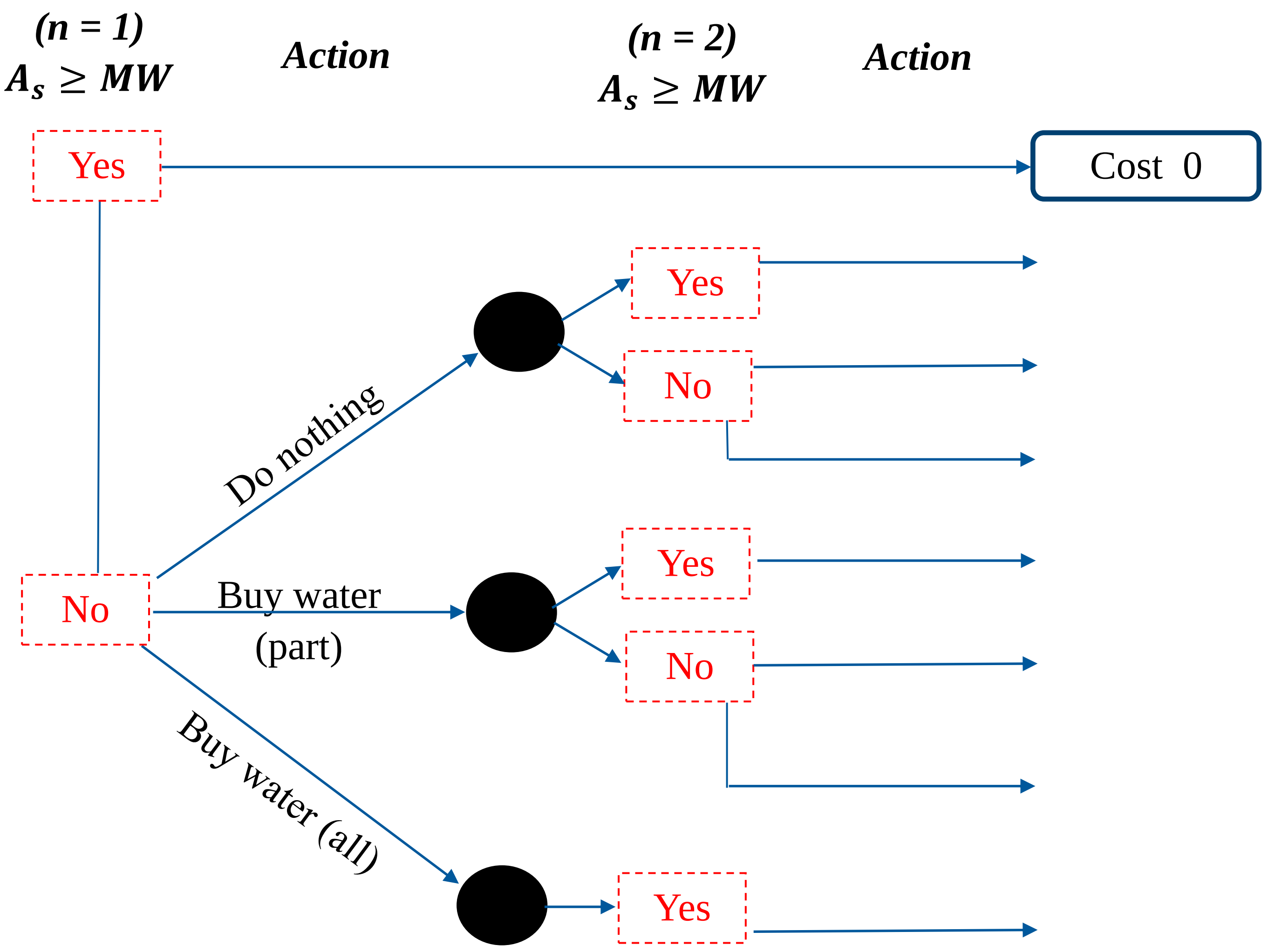
Decision makers response to a drought

- if $TW_s < MW_s$ the crop dies.

- In our game there are two announcement periods ($n = 2$) and a commodity can survive without water or yield loss until ($n = 2$) is revealed.

- Illustrate differences between perennial and annual crop producers in a two-period game between the producer and nature within the state space.

Overview of the game



Perennial Producer

- At $(n = 1)$, if $AS_{s,1} < MW_s$ a producer has two options:
  - Wait until $AS_{s,2}$ is revealed betting that it will satisfice MW_s
  - Or enter the market and purchase water

Perennial Producer: Decision Wait

- Wait until $AS_{s,2}$ is revealed

- As the maintenance supply gap $MG = MW_s - AS_{s,1} \rightarrow AS_{s,1} - MW_s$ the producer becomes the ultimate risk-taker, betting that $AS_{s,2} = MW_s - AS_{s,1}$.

- If $AS_{s,2} < MW_s - AS_{s,1}$ and the producer wishes to keep the crop alive:
  - Water price $\rightarrow$ choke price P_* or P_*' per megalitre
  - The cost of this strategy will be $MG \times P_*$ or P_*' .

Perennial Producer: Decision Wait

- But, if water is not available:
  - reduce their irrigated area until $TW_{s,n} = WR_s$
  - In this case the per Ha loses are
    - capital invested and,
    - opportunity costs associated with bringing forward investments.

Perennial Producer: Decision Buy All

- at $(n = 1)$, purchase water $\left(WT_{s,1}\right)$ to offset MG.

- As $WT_{s,1} \rightarrow MG$, the producer is betting that $AS_{s,2} \rightarrow 0$; they can be described as the ultimate risk-averse producer with perfect capital preservation objectives.

Perennial Producer: Decision Buy All

- at ($n = 1$) if the majority of producers believe that the future state will be $s1$ then the price of water $\cong p_w$.

- At ($n = 2$), should $WT_1 + TW_s > WR_s$, the producer can:
  - bring idle resources into production;
  - Sell surplus water on the market;
  - Carry the water over to use next year if they believe $TW_s < WR_s$;
  - or deliver third-party benefits (e.g. environmental or return flow positive externalities).

Perennial Producer: Decision Buy Part

- Instead, if $WT_1 + TW_s < WR_s$ the producer can repeat the strategy adopted at $(n = 1)$ and purchase more water $(WT_{s.2})$, or revert to the risk-neutral/taking strategy of maintaining capital stocks with reduced yields.

- But purchases of water in $(n = 1)$ reduce the total costs of purchases in $(n = 2)$ by WT_1 * Price

Perennial Producer: Decision Buy Part

- If no water to trade then
  - the area lost to production is WT_1 less than the decision not to buy water.

- So a risk-averse producer should ensure their water entitlement portfolio
  - maintenance requirements in all states $AS_{s=2,n=2} = MW_{s,n}$; and
  - maximum irrigation land is constrained by $TW_{s=2,n=2}$.

- This conforms with Rasmussen (2003), who argued
  - that risk-averse producers will use more inputs that risk-neutral producers, especially if that input increases output in adverse states of nature.

Annual Producer

- For annual producers, water is a state allocable input for which $MW_S = 0$

- As don't have to keep the capital stock alive

Annual Producer: Risk Adverse

- The risk-averse annual producer will only apply water x if: there is sufficient TW_s at either $(n = 1\ or\ 2)$ to rationalise the use of their other inputs (land, labour, capital), and where the expected profit from consumptive production is greater than the expected returns from selling $AS_{s,1}\ or\ AS_{s,2}$ water on the market.

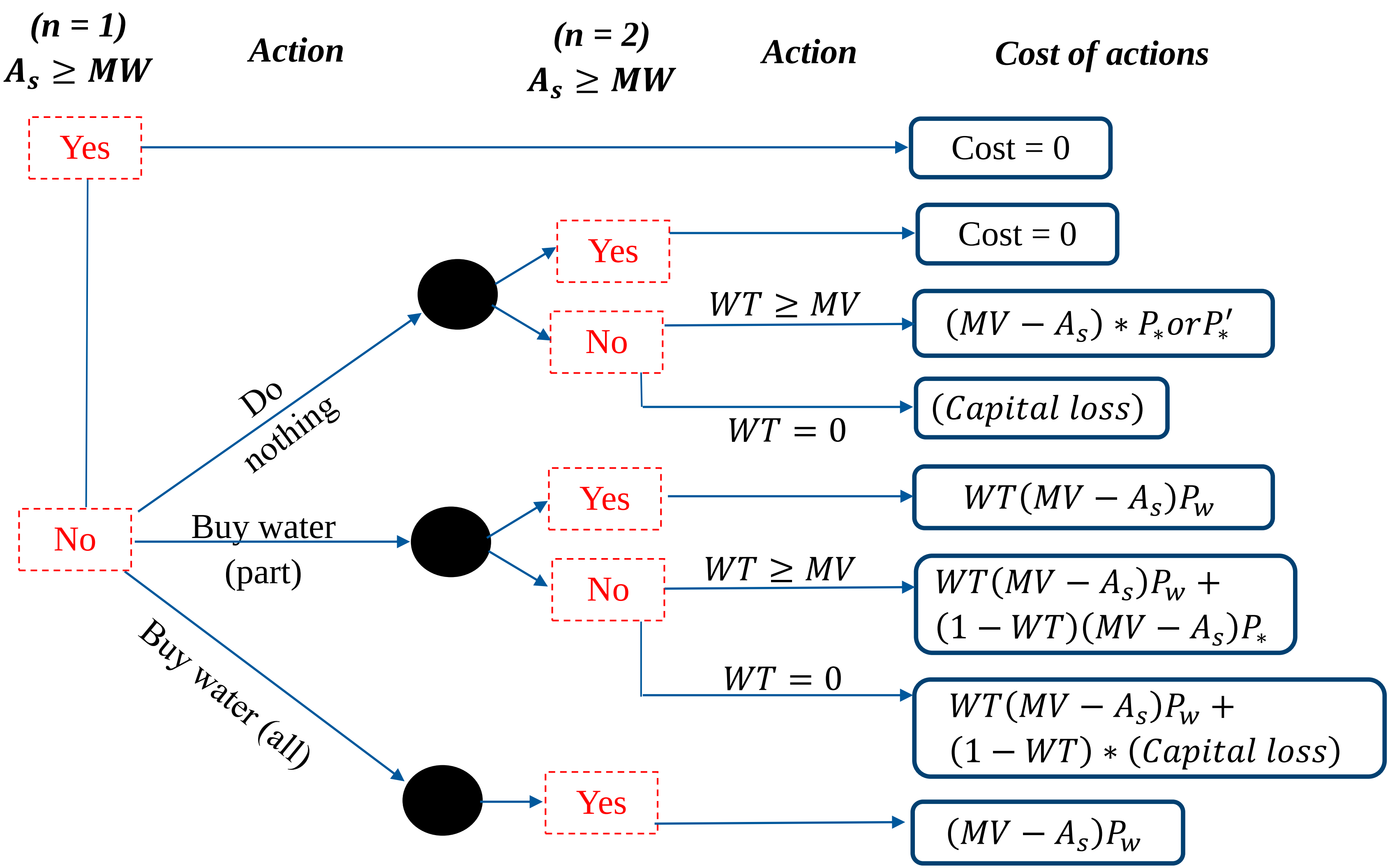
- The production choice sets at $(n = 1\ and\ n = 2)$ are different, varieties, choices (due to delay in planting time).

Annual Producer: Risk Taker

- If the annual producer plants at $(n = 1)$, and ultimately at $(n = 2)$, if $TW_s < MW_s = 0 + PW_s$, they can engage in the same management choice sets as the perennial producer—

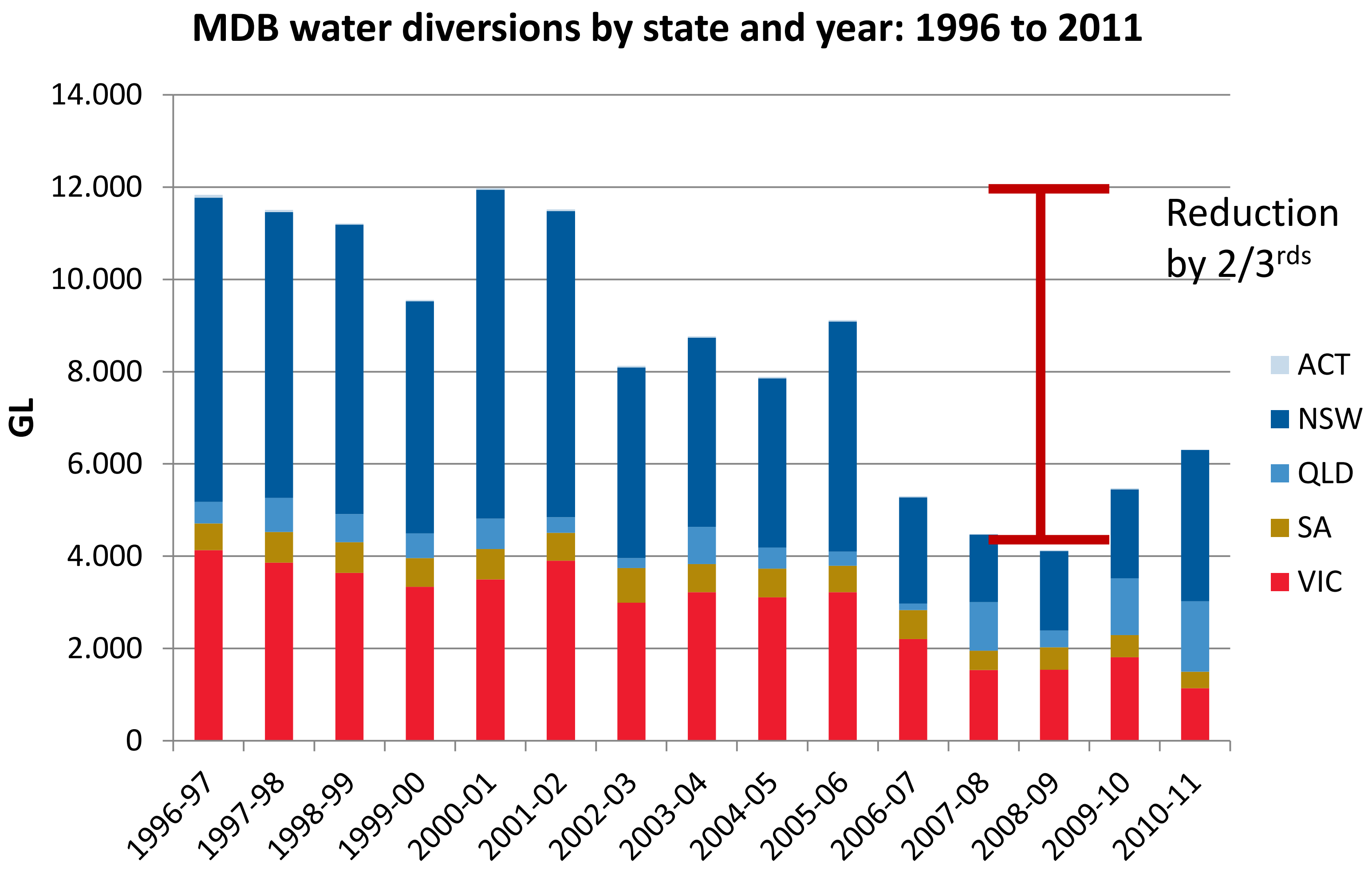
- but zero risk of losing capital, or the opportunity costs of replacing capital.

Outcomes

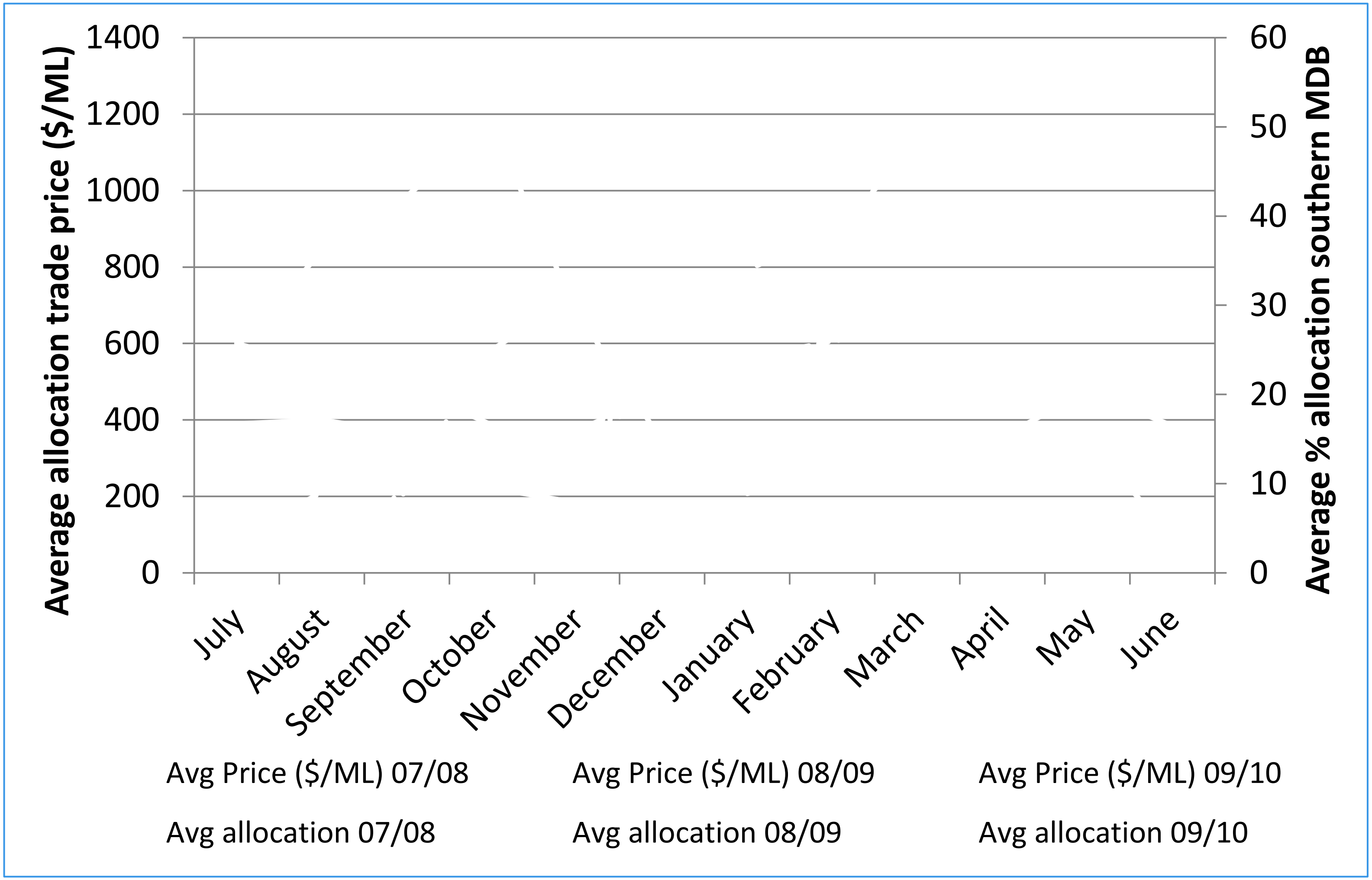


(n = 1)
$A_s \geq MW$
Action
(n = 2)
$A_s \geq MW$
Action
Cost of actions
Yes
Cost = 0
No
Do nothing
Buy water (part)
Buy water (all)
Yes
Cost = 0
No
$WT \geq MV$
$(MV - A_s) * P_* or P'_*$
$WT = 0$
$(Capital\ loss)$
Yes
$WT(MV - A_s)P_w$
No
$WT \geq MV$
$WT(MV - A_s)P_w +$
$(1 - WT)(MV - A_s)P_*$
$WT = 0$
$WT(MV - A_s)P_w +$
$(1 - WT) * (Capital\ loss)$
Yes
$(MV - A_s)P_w$

The Millennium Drought: Black Swan Event



How good was the last prior? (Inductive reasoning?)



Source: Loch (2011)

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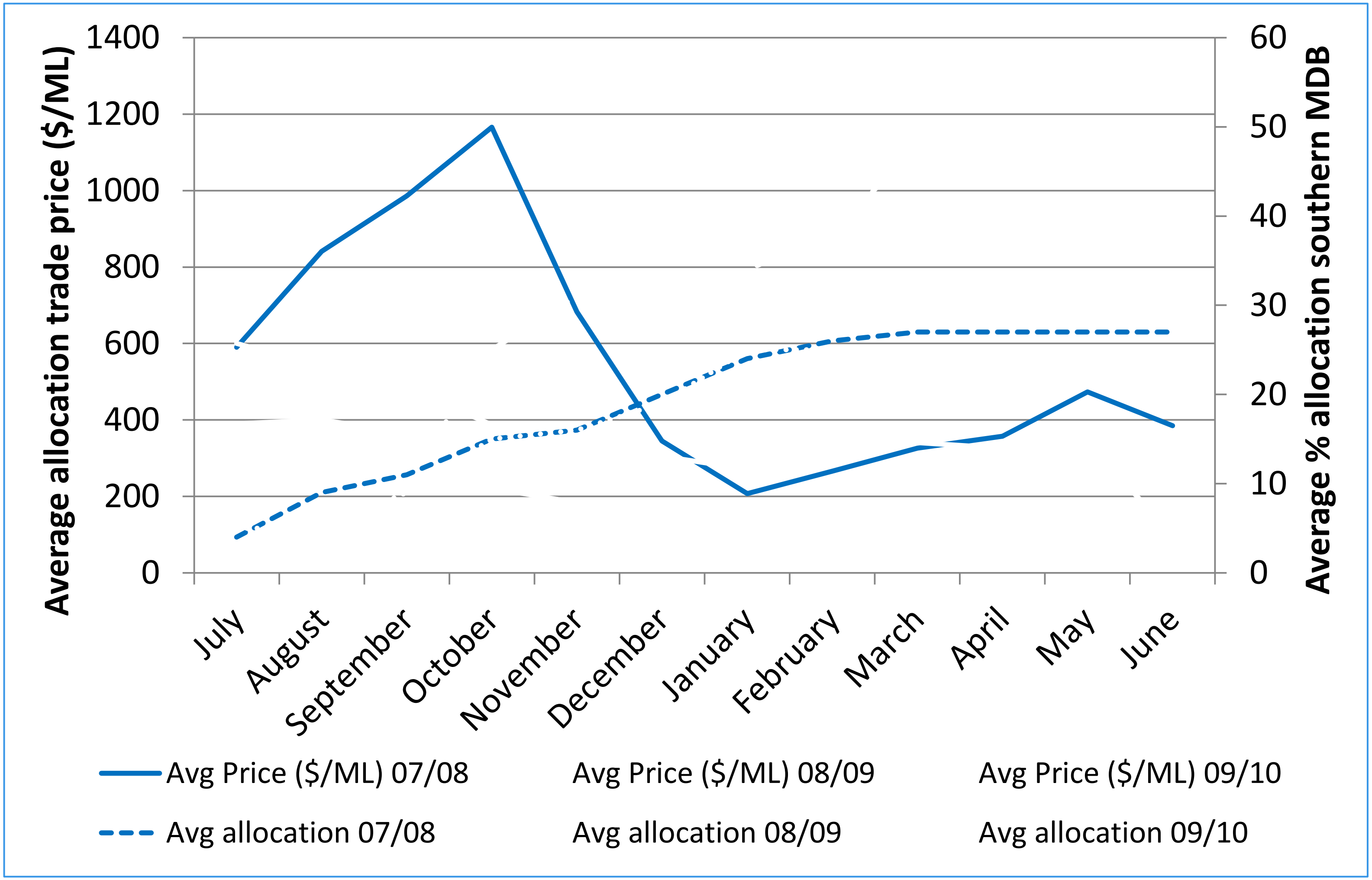

Source: Loch (2011)

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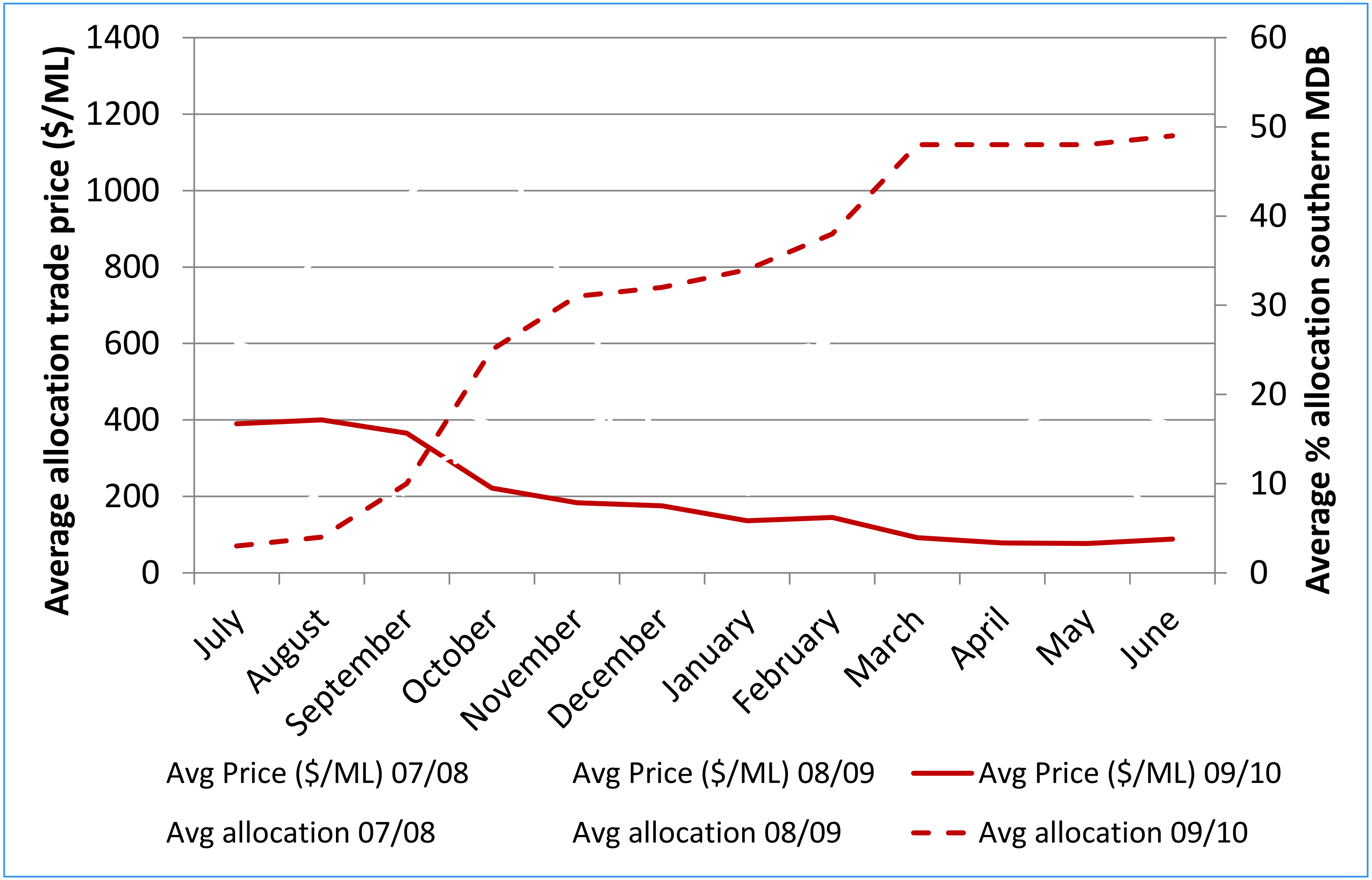


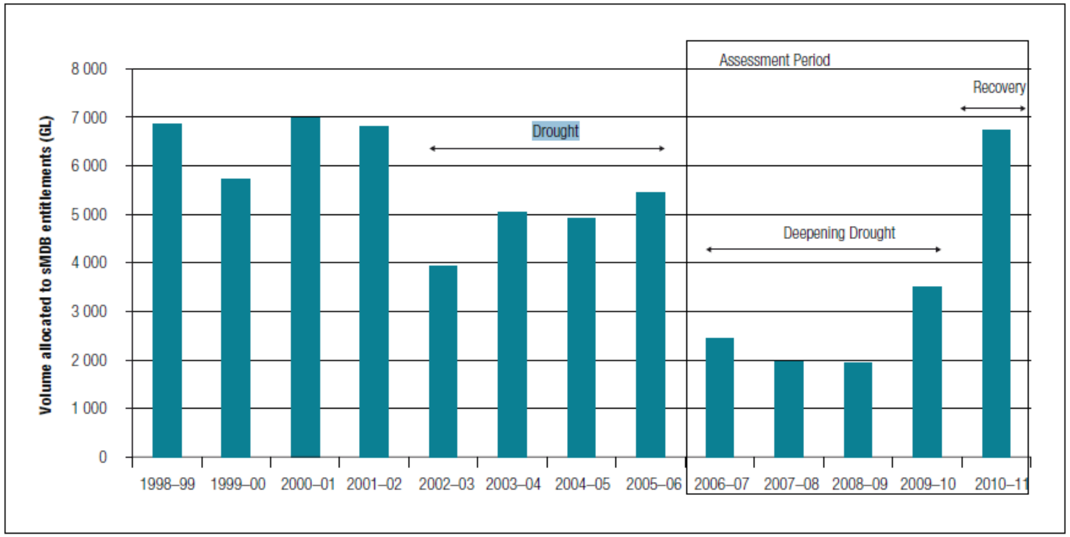
Source: Loch (2011)

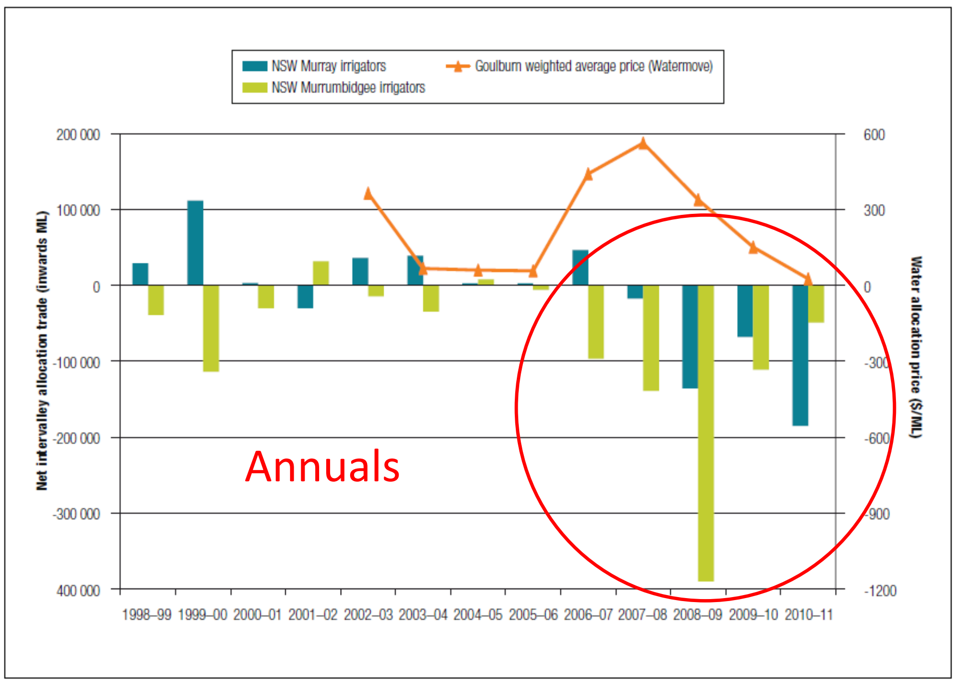
Change in Irrigated Area ('000 Ha)

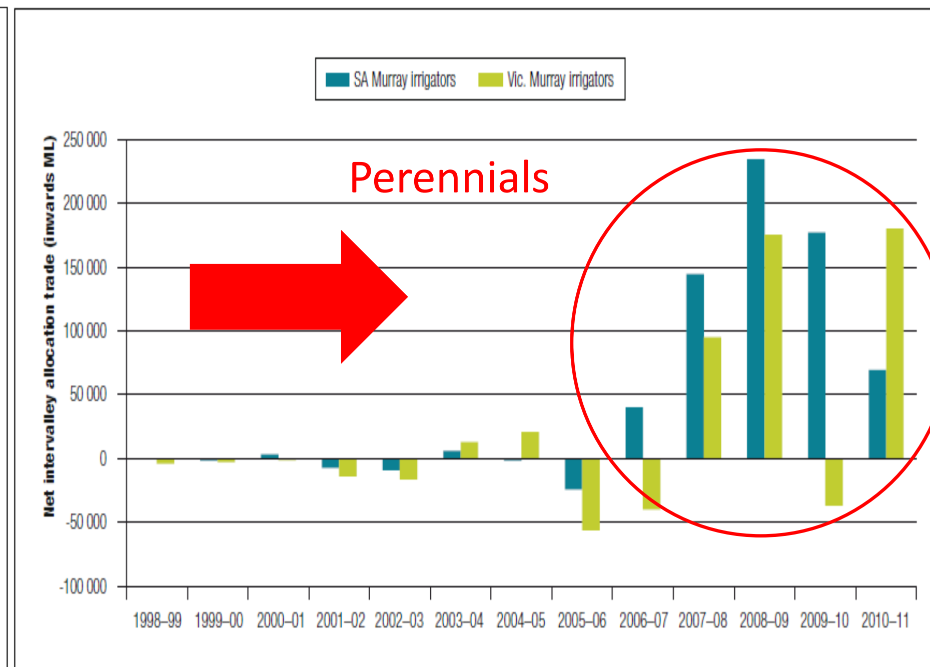
Commodity group	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11
Pasture for dairy and other livestock	760	707	551	669	703	717	446	365	272	393	375
Rice	178	145	44	65	51	102	20	2	7	19	74
Cereals (excl. rice)	260	354	416	340	324	329	266	291	245	216	165
Cotton	405	394	218	174	258	247	126	53	104	138	332
Grapes	84	86	89	87	92	106	112	106	101	96	94
Fruit (excl. grapes)	59	62	74	59	63	75	78	71	67	79	80
Vegetables	37	35	31	40	35	32	26	28	22	25	32
Other agriculture	41	34	43	67	62	46	52	42	111	8	3
Total Agriculture#	**1,824**	**1,817**	**1, 466**	**1,501**	**1,588**	**1,654**	**1,101**	**958**	**929**	**976**	**1,201**

Source: ABS (multiple years) Water Use on Australian Farms.

Totals may not equal the sum due to multiple cropping practices and errors in estimates







Source: NWC, 2012 Impact of water trading in the southern Murray-Darling Basin between 2006-07 and 2010-11, National Water Commission, Canberra.

Section 3:

Discussion

- Incorrect specification of risk essentially shifts producer perceptions of the reliability of their portfolio of water property rights away from q_w

- Results in a gradual transition toward more homogenous production systems

- Risk mitigation policies should encourage reallocation of water entitlements towards enhanced flexibility to deal with future unknowns
  - Paper provides more detail on frequency/description of states' change reallocation responses. Time constraints prevent us doing same here.

- Annual commodities should be recognised as a very important risk-mitigating strategy to increase the resilience of Australian agricultural production in dry states of nature

- Increased drought frequencies will create:

  - increased future capital vulnerability;
  - future farm debt where positive returns diminish over time; and
  - increased reliance on both water entitlement and allocation transfers in a relatively more constrained market supply context.

Australia already going that way?

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Lower Darling River irrigators propose new plan to pull out permanent crops and return water allocations for cash

Vic Country Hour By Emma Brown

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Posted yesterday at 2:00pm

PHOTO: The Darling River. Block banks have stopped the river from flowing to conserve water for landholders. (Emma Brown)

As the Lower Darling River begins to dry up for the third time in 12 years, irrigators are proposing a new plan to manage an unreliable water supply.

Irrigators Alan Whyte and Rachel Strachan said the Darling River was no longer a reliable water source for high security allocations.

MAP: Pooncarie 2648

00:00 00:00

AUDIO: Darling River irrigators Alan Whyte and Rachel Strachan on their proposal to move from high security allocations (ABC Rural)

Vic Country Hour

- Dry dams, shrivelled grain, but still no drought concessional loan scheme in Victoria
- $1.2m to establish national Fruit Fly Council
- Lower Darling irrigators put forward plan to adjust to unreliable river flows
- As California enters its fifth year of drought, state lawmakers undertake study mission to Australia
- Canadian farmers target new PM to keep protections for dairy industry

Horticulture Top Stories

- $1.2m to establish national Fruit Fly Council
- Lower Darling irrigators put forward plan to adjust to unreliable river flows
- New mango variety ready for sale next year
- New Mackay Sugar CEO to focus on production
- Bumper cherry crop expected this year if weather holds

Banana Freckle timeline

Top Rural stories

- First live shipment of beef cattle flies in to Chongqing for Chinese meat trade
- Queensland taskforce will investigate rural debt levels
- Church meets with Baiada over worker worries
- Growers report increased pests in

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Thank you