# Discriminating accelerated from natural wind erosion at continental scale in Australia

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Griffith UNIVERSITY

Department of
Environment, Climate Change and Water NSW

# THIS PAPER

- Uses meteorological records to measure continent scale spatio-temporal patterns of wind erosion over 49 years (1960 - 2008).

- Explains these patterns in terms of two “natural” drivers; climate and sediment supply, and two land management drivers; grazing and mining.

Dust storm at Umuwa. Photo: Gary McWilliams, Mining Tenement Officer, APY

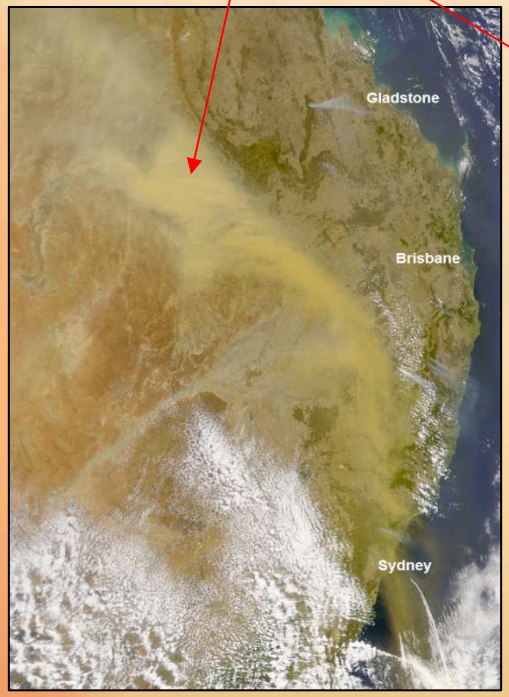
# Background

Mapping wind erosion across a continent is challenging because:

- Scales of wind erosion processes can range from *local events* covering a few hectares and lasting a few minutes.

Local Dust event: Diamantina river floodplain, Queensland, Australia

- To *large dust storms* traversing large sectors of the continent and lasting hours to days




Dust storm eastern Australia: 23 Oct 2002

Dust storm at Nappa Merrie station, SW Queensland. (Photo, Mark Coombe 2004. www.outbackpics.com)

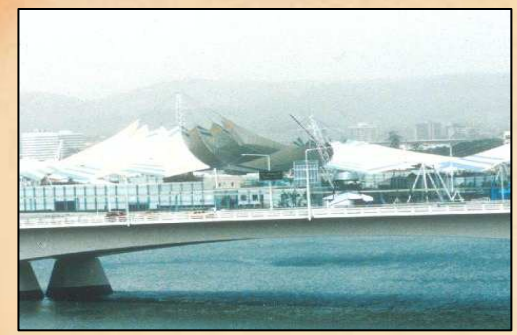
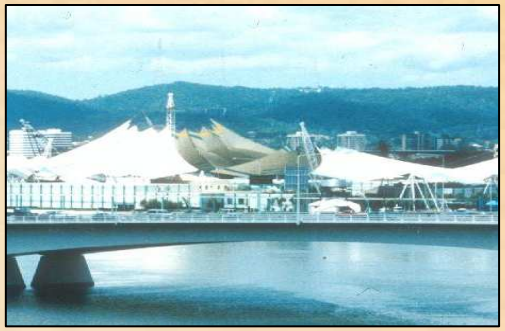
# On-site impacts of wind erosion :

- Soil removal – infertile B horizon exposed by wind erosion.

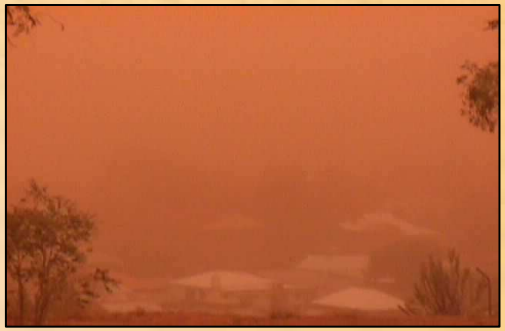
- Reduction in soil fertility and moisture storage capacity in eroded dusts.

# Off-site impacts of wind erosion:

- Reduced air quality in cities

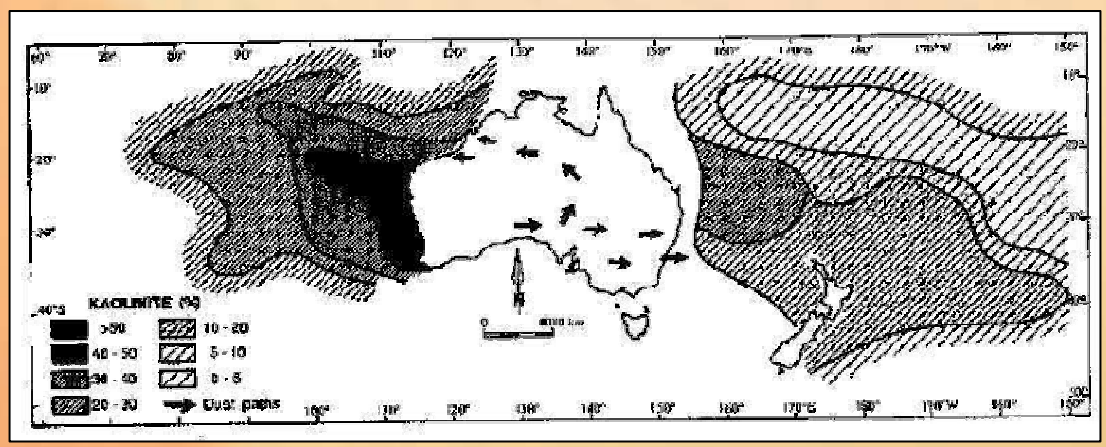



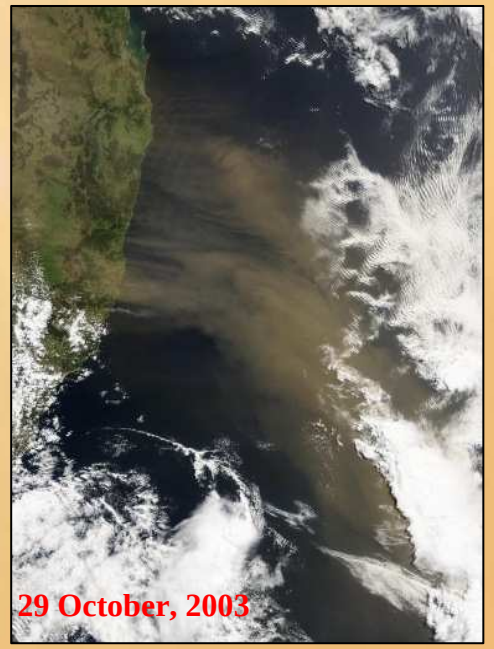
Brisbane Dust storm - December 1987



Broken Hill May 1994

- Offshore deposition contributes to marine sediments and deposits nutrients into the oceans

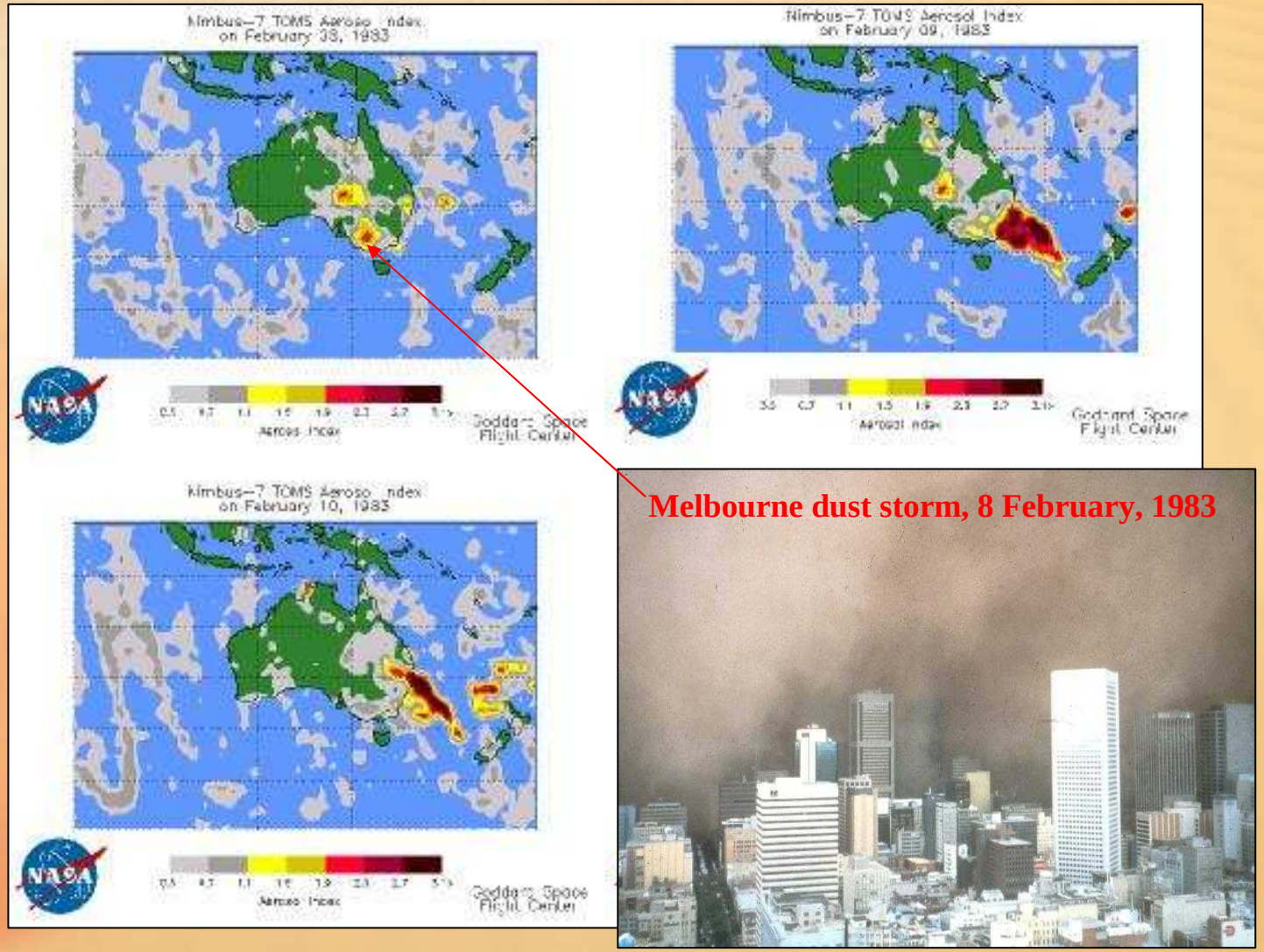



- Iron-rich dust may play an important role in fertilising the Southern Ocean. Boyd et al (2004) had a go but didn't establish a relationship – a work in progress.

To better understand these on-site and off-site impacts more information is needed on WHERE, WHEN and HOW MUCH wind erosion occurs

1. **Remote Sensing has gaps** (spatial and temporal), but provides valuable event-based data

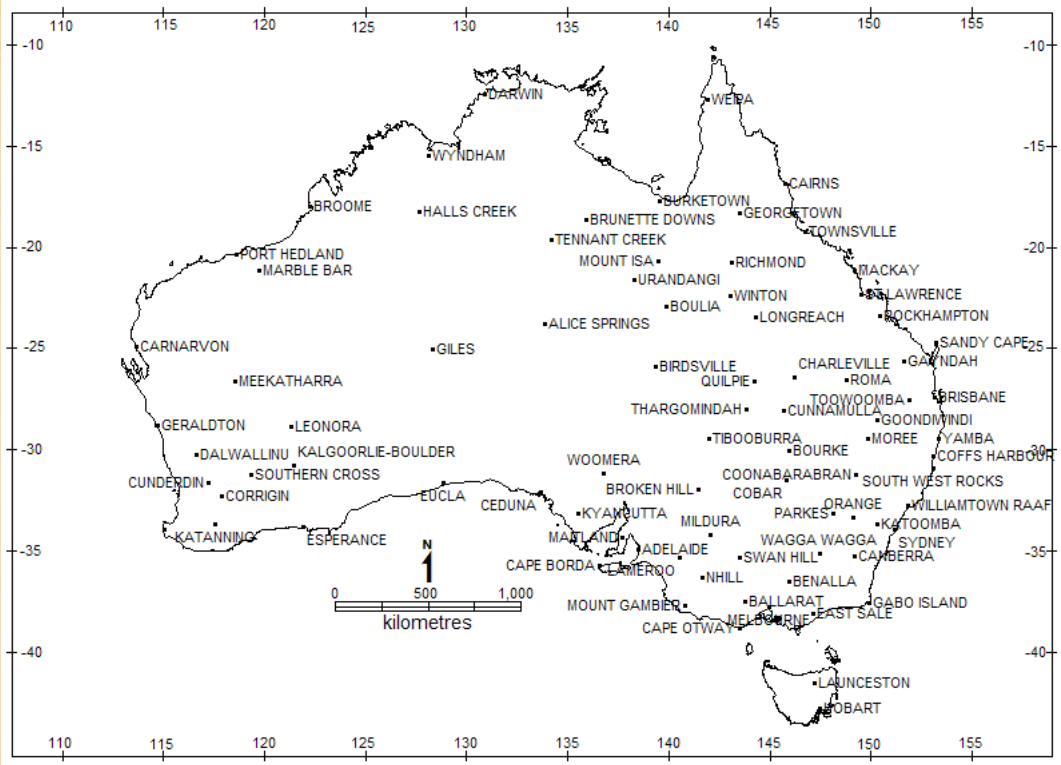


## 2. **Field-based Measurement techniques** are impractical for broad scale mapping

**Field dust sampling towers in the Channel Country, N.E. Lake Eyre Basin, Australia.**

**Bureau of Meteorology (BoM) records** of “weather phenomena” provide data on wind erosion events across Australia.

06 = dust haze event (dust in suspension)
07 = local dust event (raised dust or sand)
08 = local dust event (Willy willy or dust devil)
09 = dust storm distant or in past hour
30 = moderate dust storm - decreased in past hour
31 = moderate dust storm - no change in past hour
32 = moderate dust storm - increase in past hour
33 = severe dust storm - decreased in past hour
34 = severe dust storm - no change in past hour
35 = severe dust storm - increased in past hour
98 = thunderstorm with dust storm




These records cover relatively long time periods - since 1960 (for ~110 stations), since 1942 (for ~ 25 stations) and archival records extend into C19.

These data are held in the Dust Event Database (DEDB) at Griffith University.

# Dust Storm Index (DSI)

The DSI measures dust entrainment *frequency* and *intensity*.

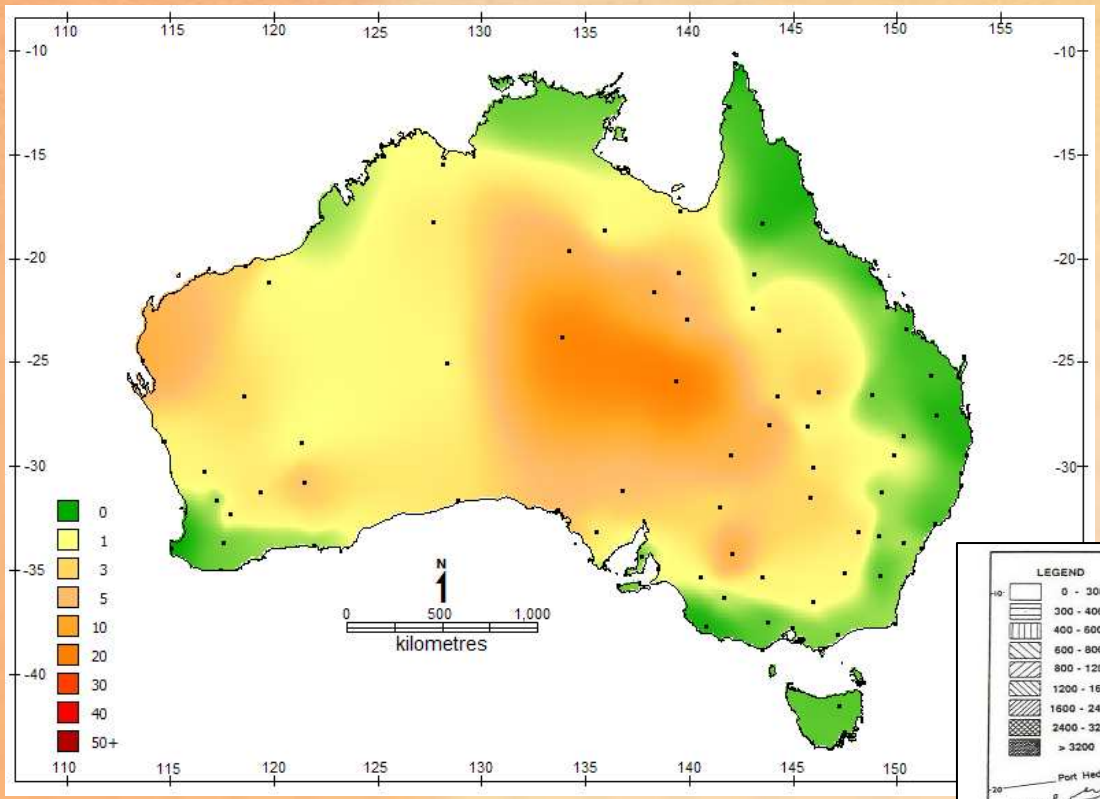
Event intensity is measured using a composite measure of the contributions of: local dust events, moderate dust storms and severe dust storms using weightings for each event type, based upon visibility reduction for each event type.

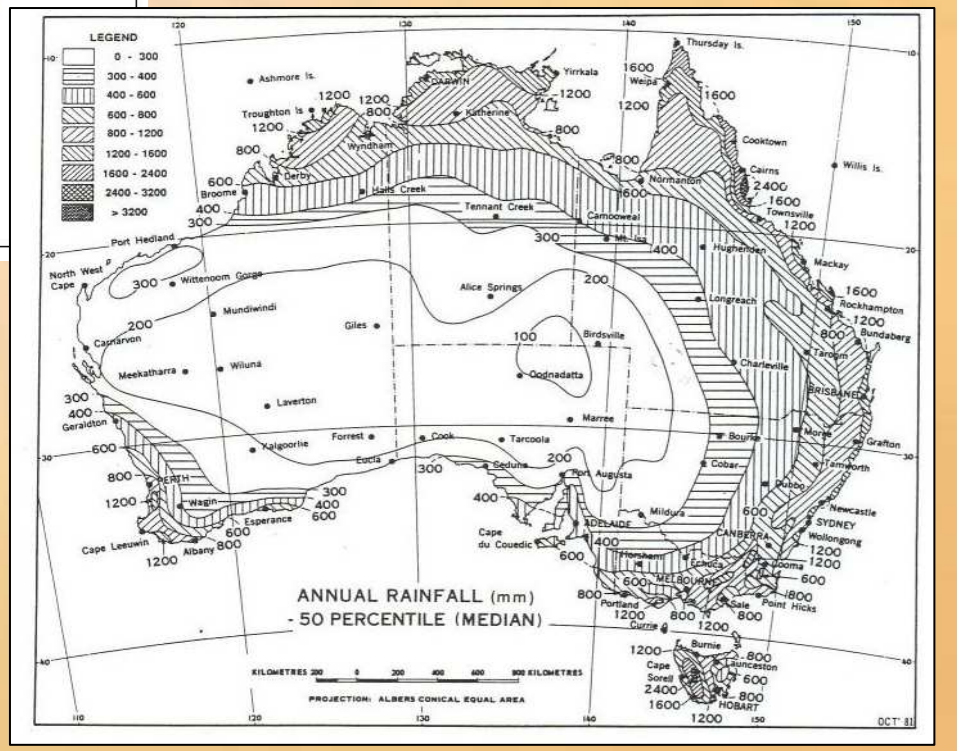
$$DSI = \sum_{i=1}^{n} \left[ (5 \times SDS) + DS + (0.05 \times LDE) \right]_i$$

Where:
DSI = Dust Storm Index at n stations where i is the ith value of n stations for i=1 to n.
n = The total number of stations recording a dust event in the time period.
SDS = Severe dust storm (daily maximum weather codes: 33, 34, 35)
DS = Dust storm (daily maximum weather codes: 09, 30, 31, 32 and 98)
LDE = Local dust event (daily maximum weather codes: 07 and 08)

McTainsh, G.H. (1998). “Dust Storm Index”. In: SUSTAINABLE AGRICULTURE: ASSESSING AUSTRALIA’S RECENT PERFORMANCE. A report of the National Collaborative Project on Indicators for Sustainable Agriculture. SCARM Technical Report 70, 65-72.

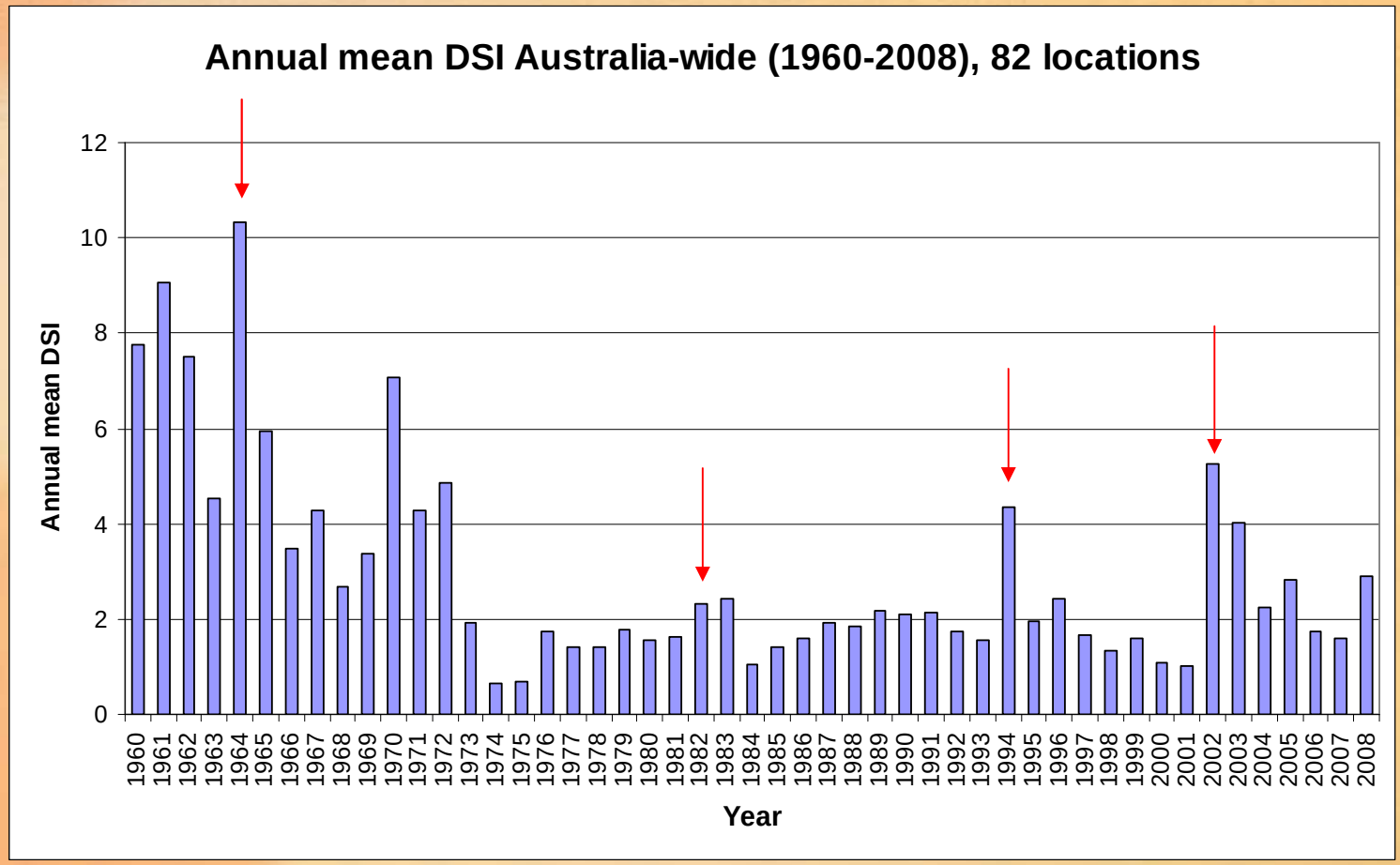
# **1. Spatial pattern** of wind erosion (DSI) - 49 year averaged (1960–2008)




Wind erosion (DSI) is highest in the driest part of the continent, but this relationship doesn't apply in the **WEST** - why? (later)

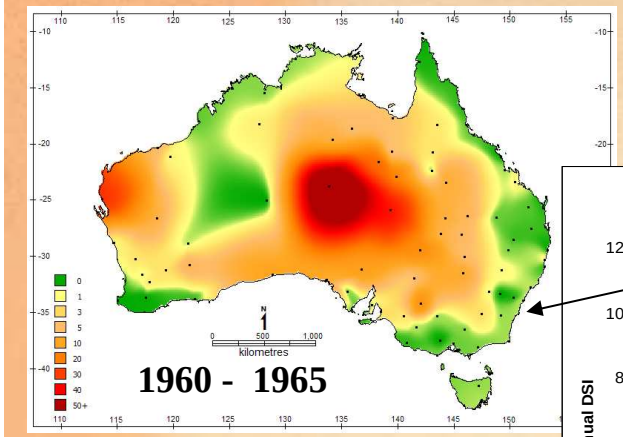
## 2. **Temporal pattern** of wind erosion (1960-2008) – for the continent

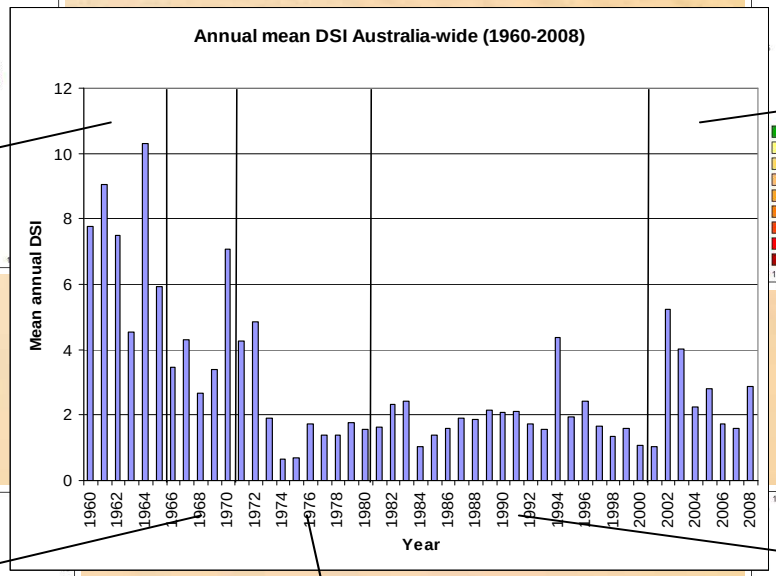


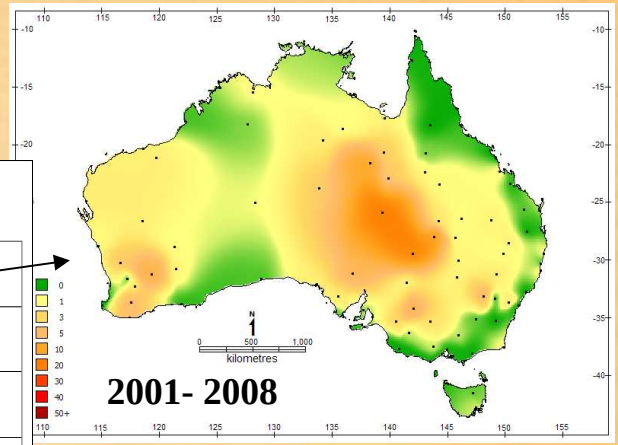

Inter-annual variability is very high and is drought driven

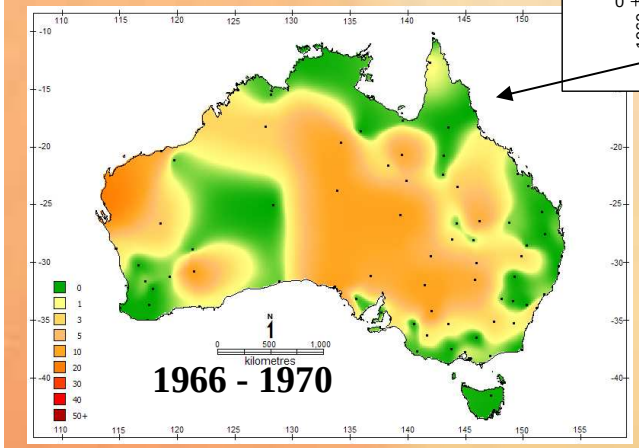
BUT averaging for the continent as a whole smooths out trends

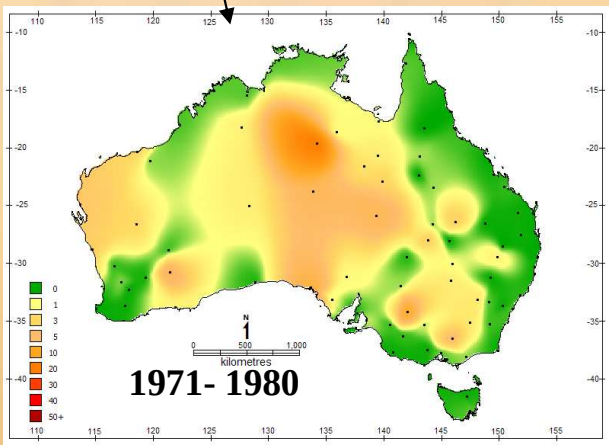
# Spatio-temporal patterns of wind erosion in 5 time slices (1960-2008)

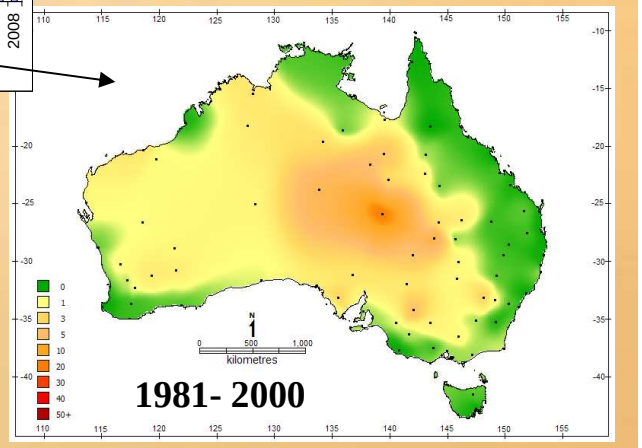


A quantitative spatio-temporal view can be gained by examining temporal trends in erosion in 4 major drainage regions which traverse the continent

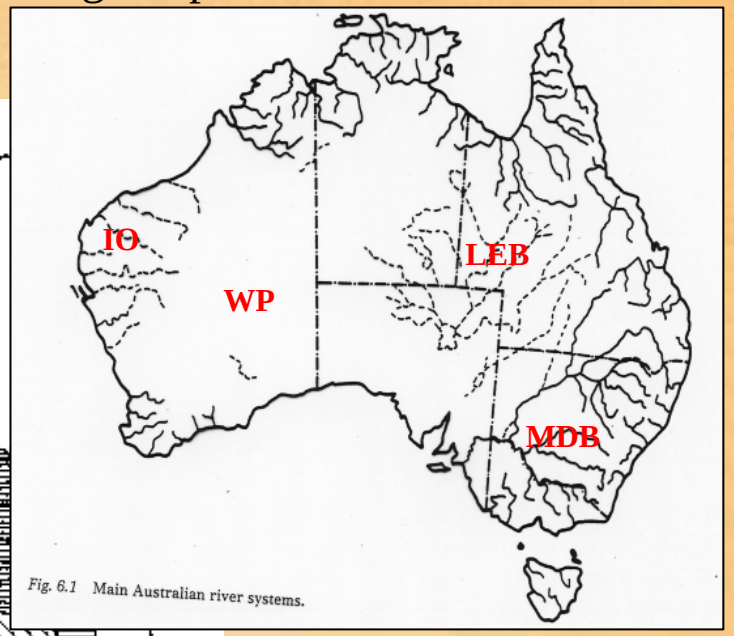
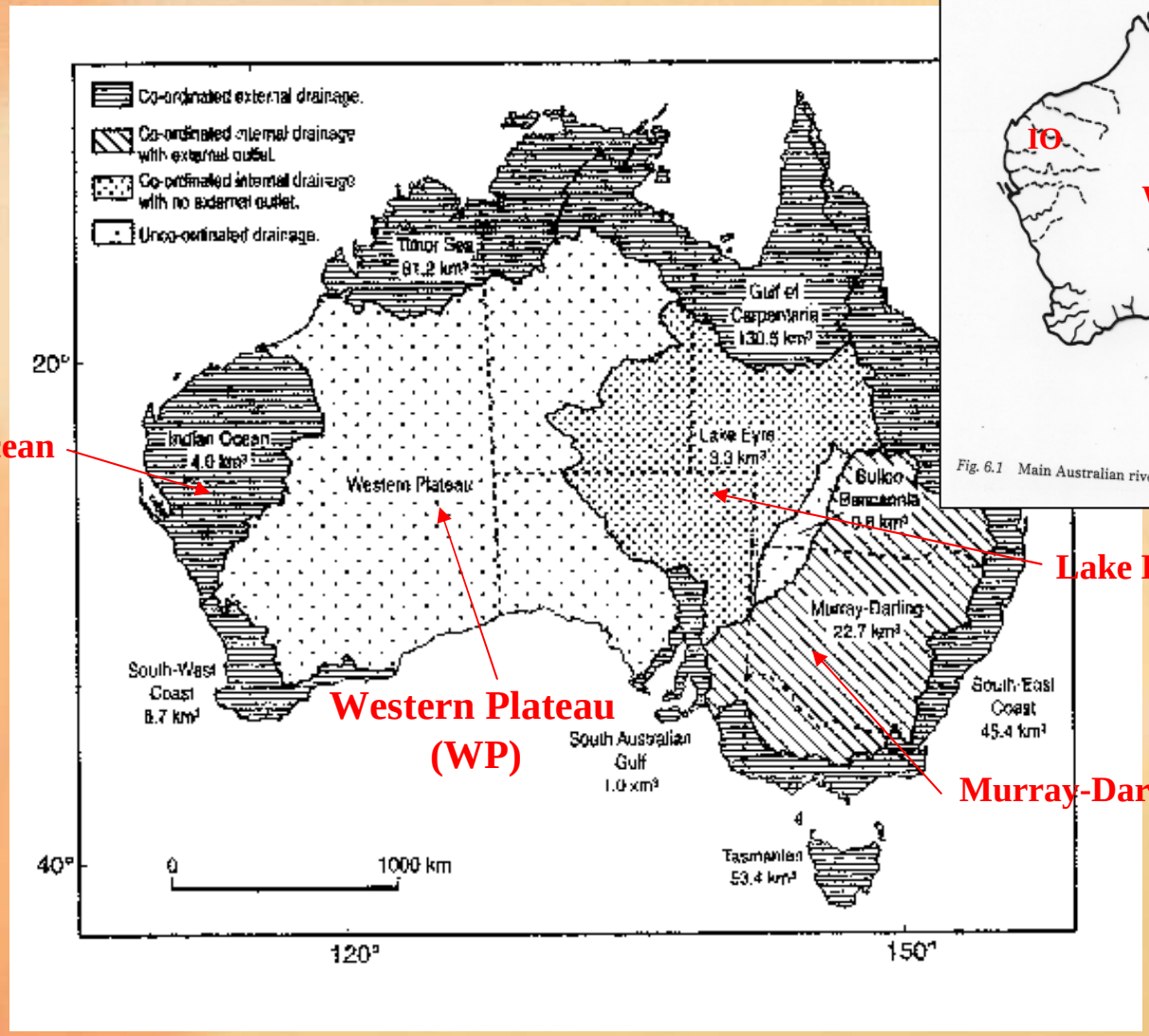



Fig. 6.1 Main Australian river systems.



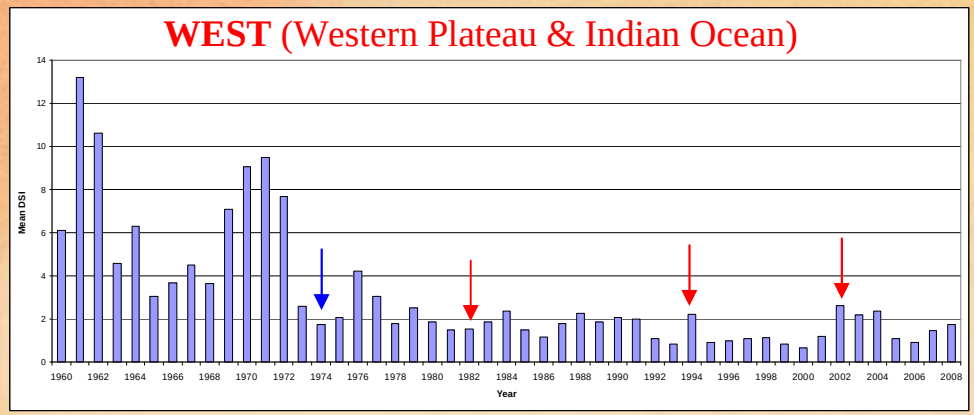

Indian Ocean (IO)

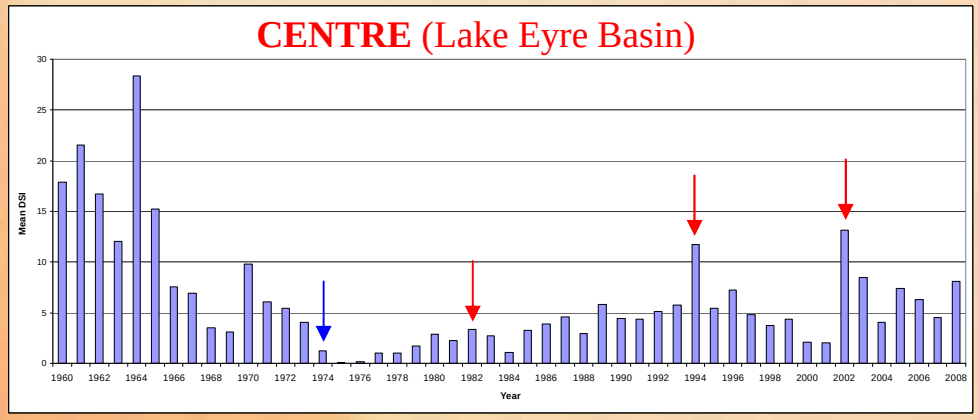
Western Plateau (WP)

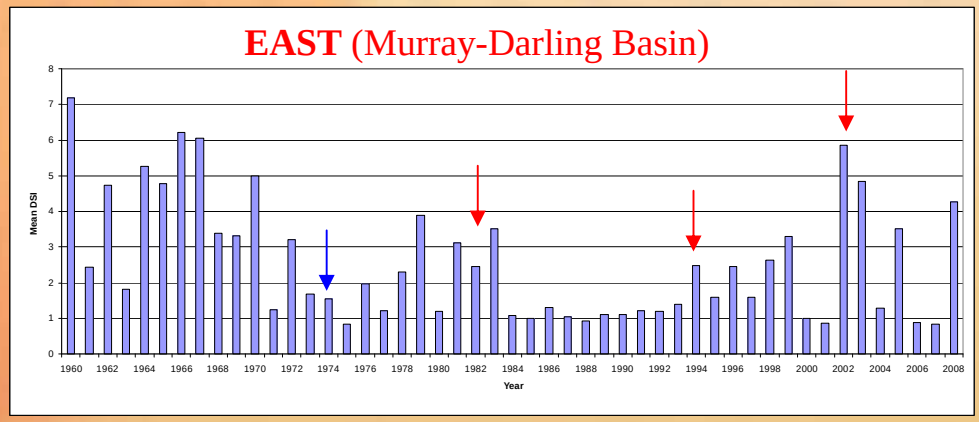
Lake Eyre Basin (LEB)

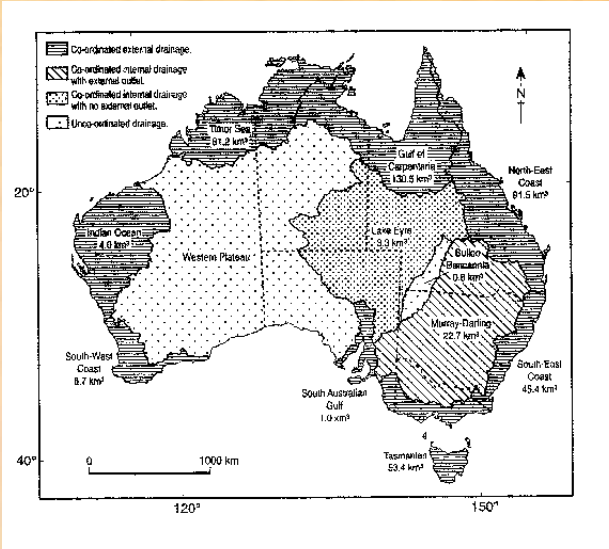
Murray-Darling Basin (MDB)

1. Temporal patterns of wind erosion (DSI) in the West, Centre and East are **driven by climate**



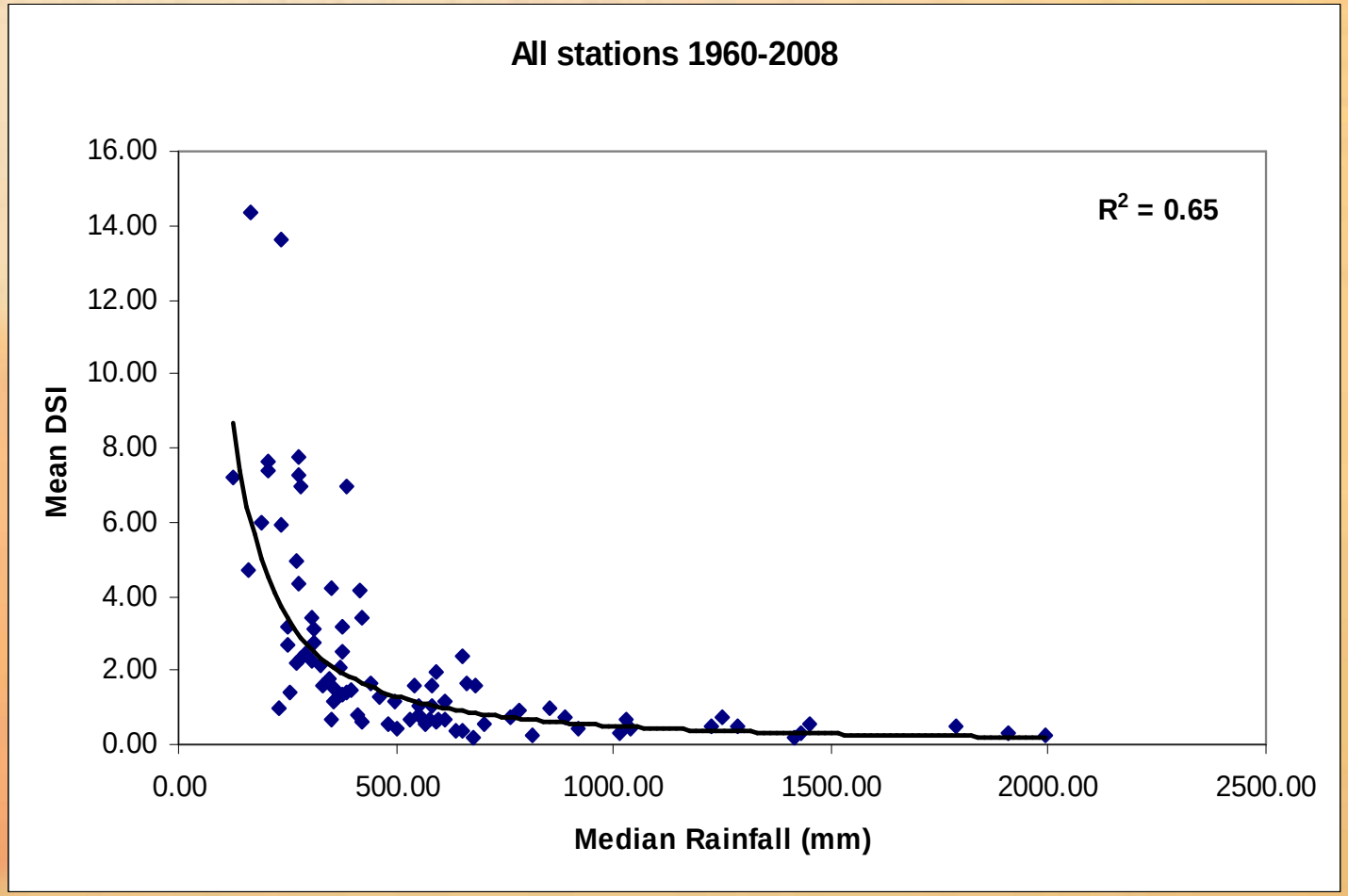




Rainfall in the West is driven by the *Indian Ocean Climate System* and in the East and Centre by the *Pacific Ocean Climate System*

The rainfall-DSI relationship for the continent as a whole has a large data scatter.

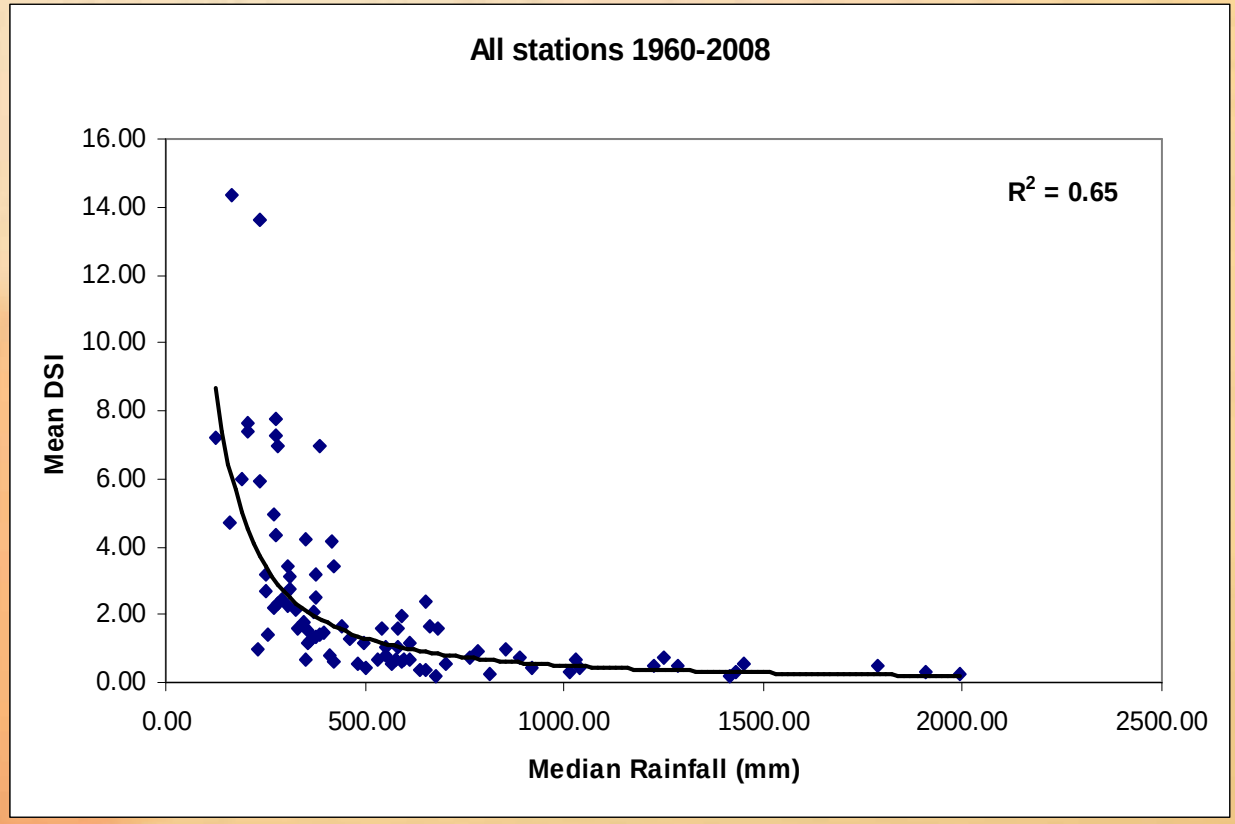
*To what extent does this reflect "natural" drivers; climate and sediment supply and/or land management drivers; grazing and mining?*



## Climate

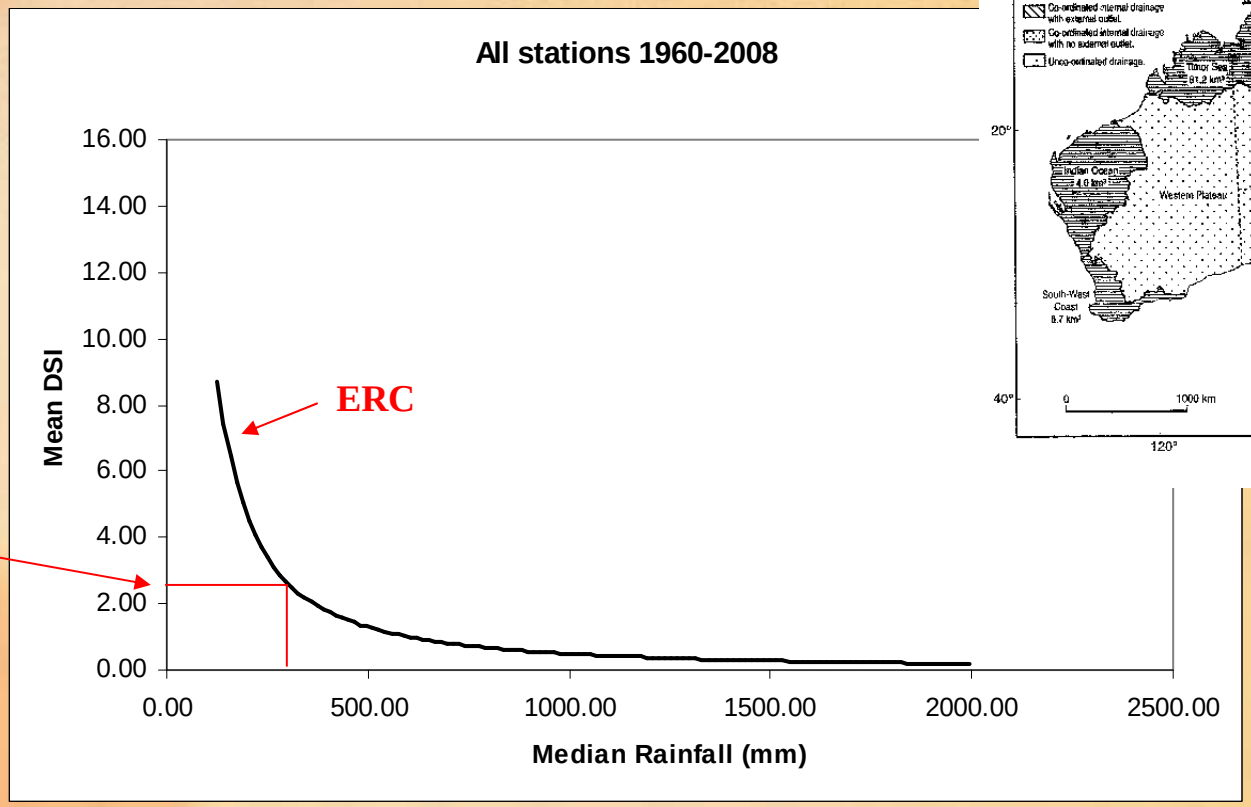
There is a clear inverse relationship with *rainfall*, but what other aspects of climate (eg wind conditions) are driving wind erosion?

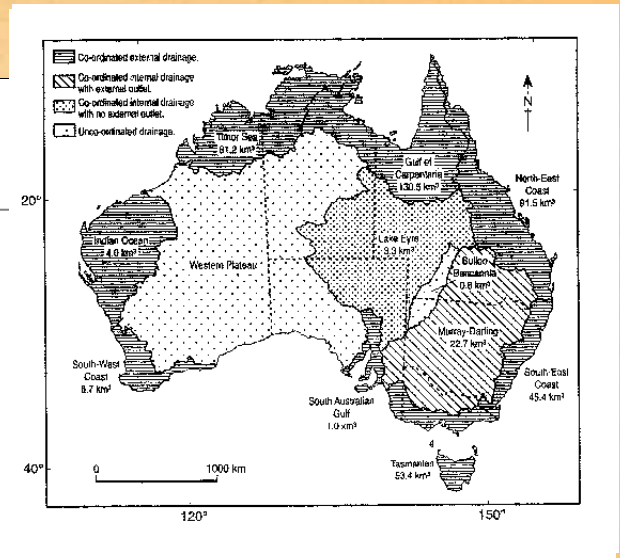
This issue can be resolved by correlating DSI with climate (rather than rainfall) – eg using the wind erosion climate index model of McTainsh et al., (1998).*




* McTainsh, G.H., Lynch A.W. and Tews, E.K. (1998). "Climatic controls upon dust storm occurrence in eastern Australia". JOURNAL OF ARID ENVIRONMENTS, 39, 457-466.

**Sediment supply** and **land management** effects can be examined by comparing the DSI-rainfall relationship in the 4 major drainage regions



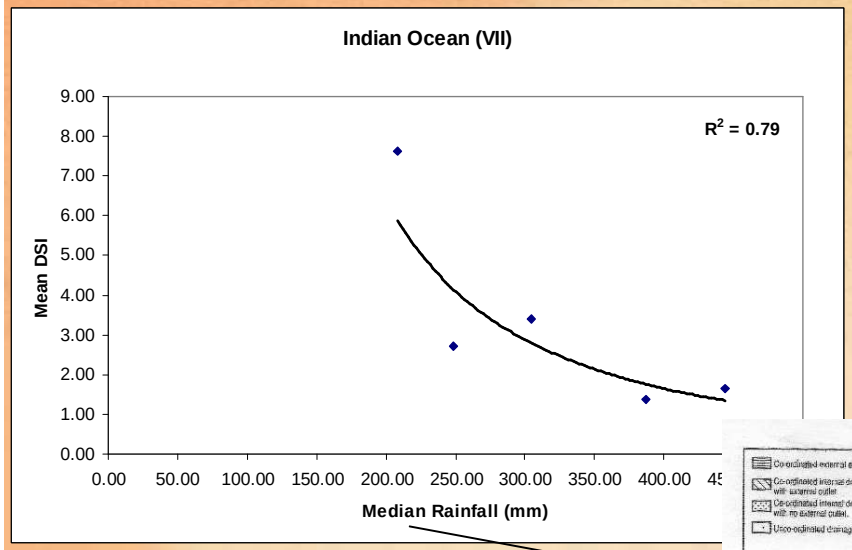



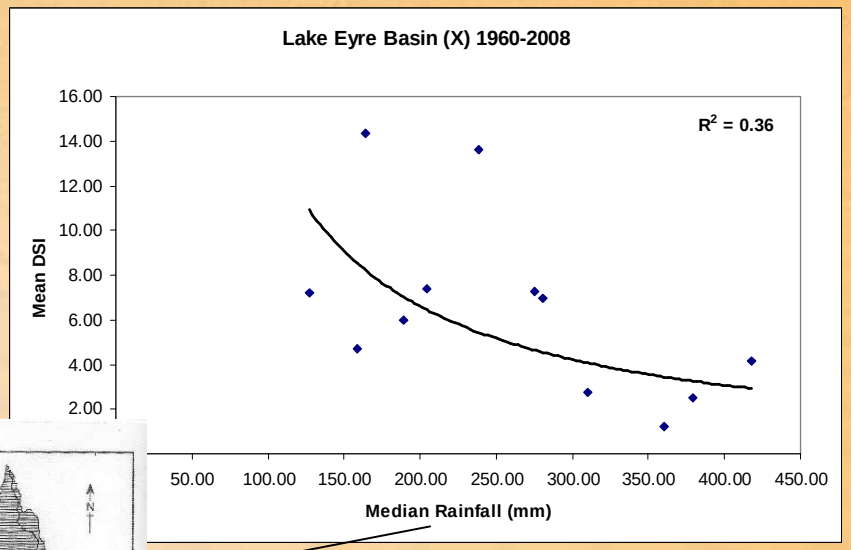

**Two measures** are used here:

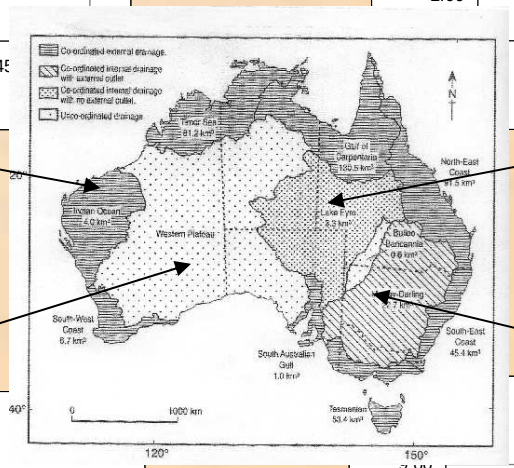
1. Relative Erosion Rate **(RER)** (for 300 mm rainfall)

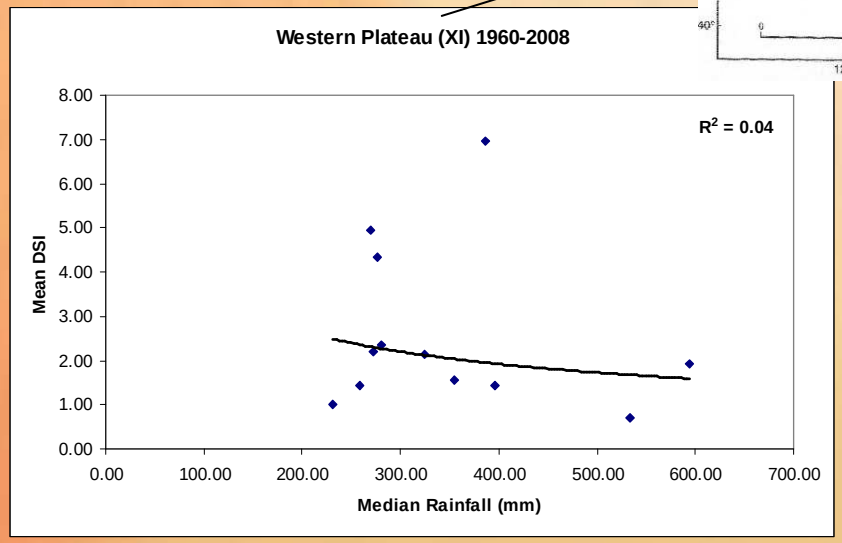
2. Erosion Response Curve **(ERC)** – the rate of erosion increases in response to decreasing rainfall

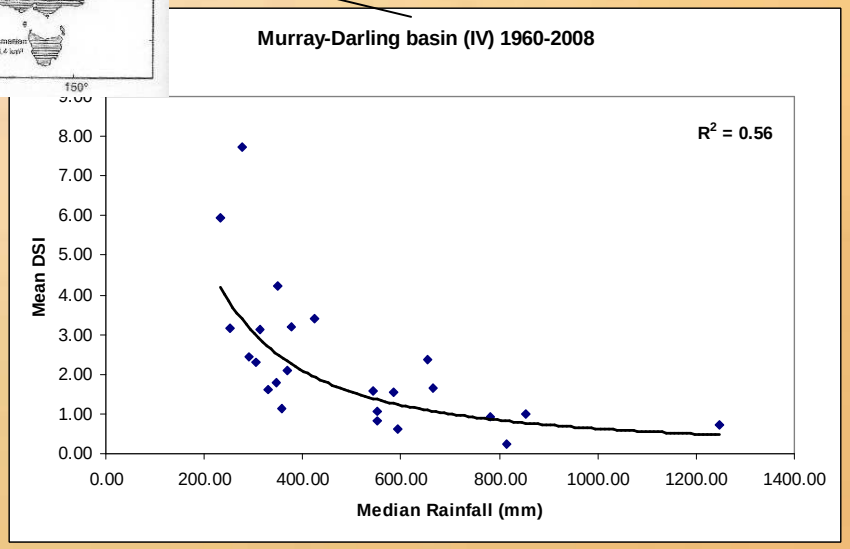
# The rainfall-DSI relationship changes in the different drainage regions

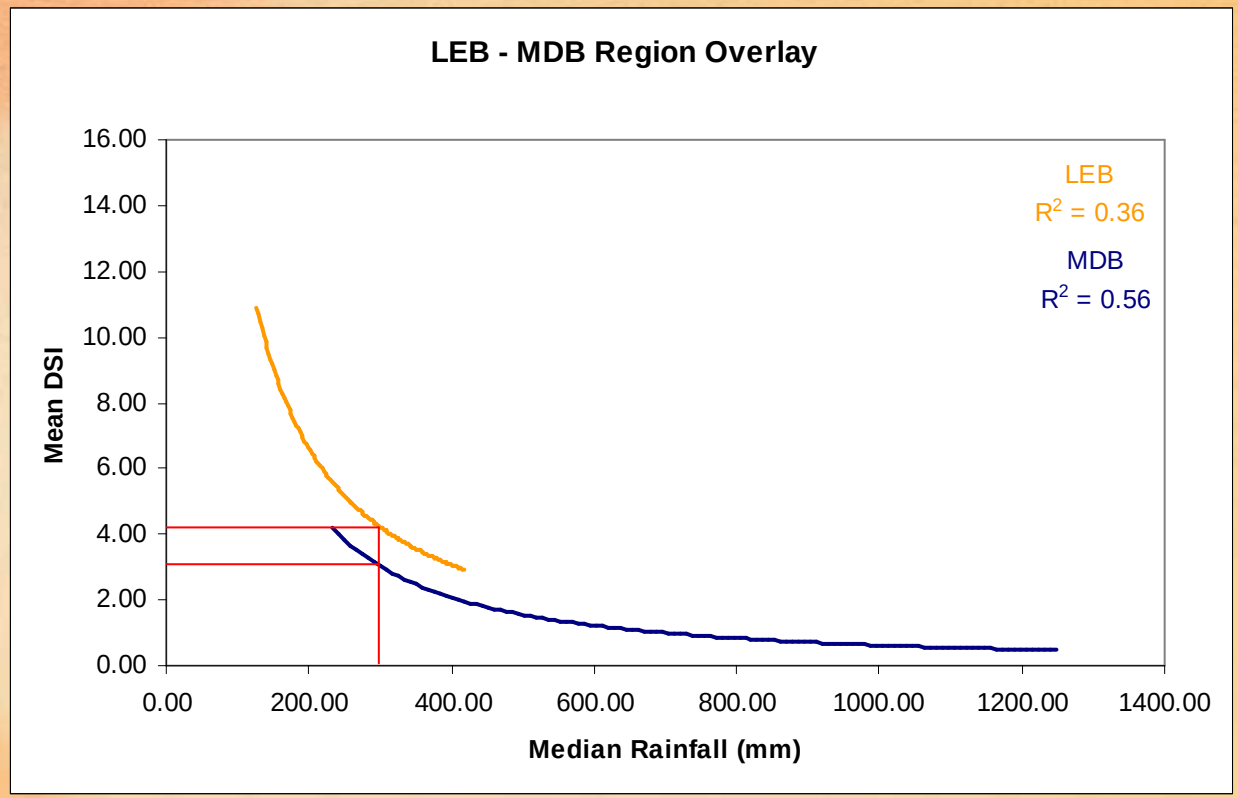





**Erosion comparison:**

- Relative Erosion Rate of LEB is ~1.6 times higher than MDB
- Erosion Response Curves are very similar

**Erosion drivers:**

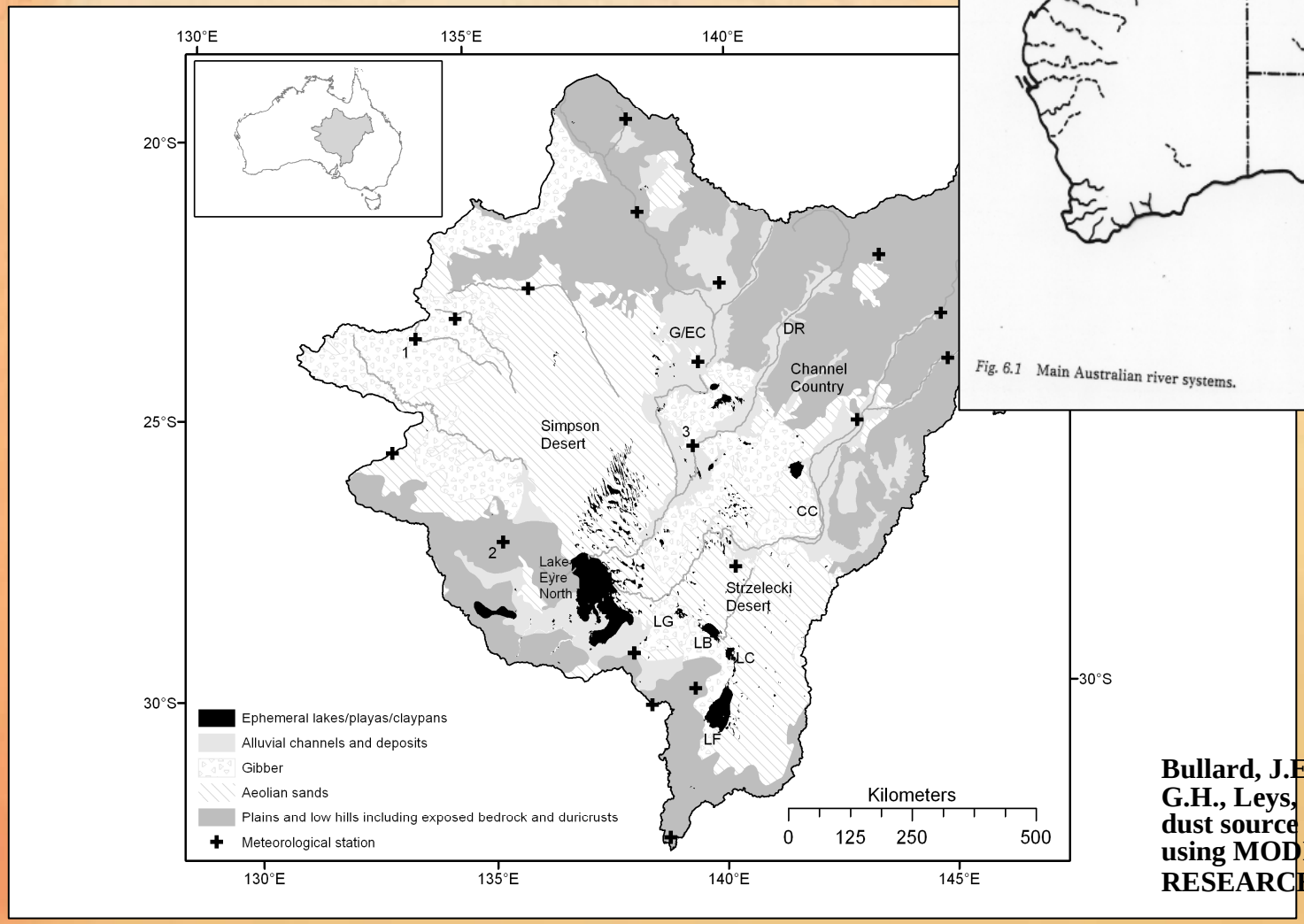
- Climate - *very similar* (Pacific Ocean climate system – drought driven)
- Sediment supply - *very similar* (internally-draining rivers) *but LEB is more active*
- Land management – *very similar* (cattle grazing is widespread)

Sediment supply

Internally-draining rivers supply sediment to dust source areas in two (*contrasting*) ways:

1. Rivers feed silts and clays to:

- Floodplains
- Clay pans (playas)
- Dry lake beds



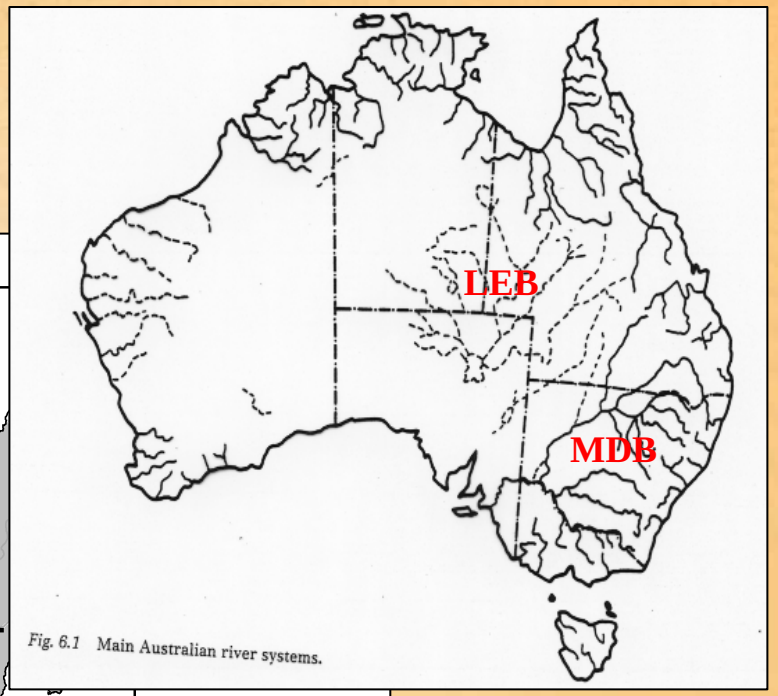
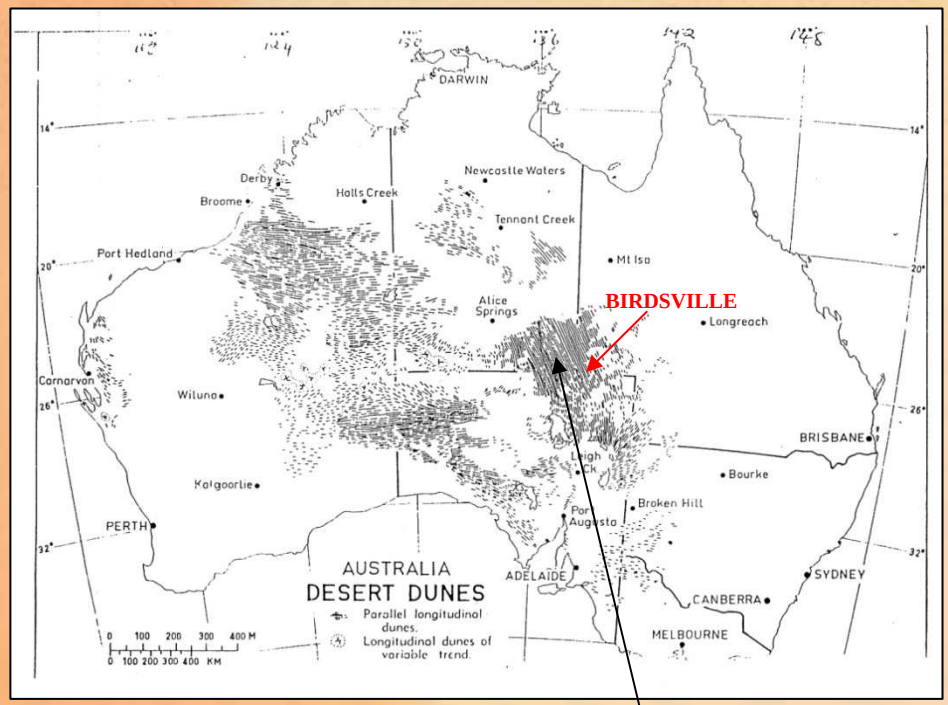
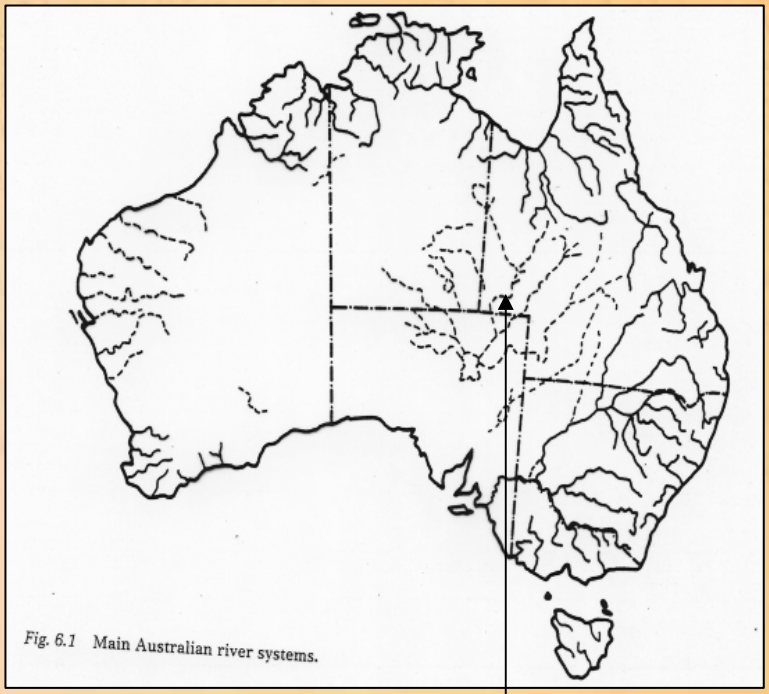




*Fig. 6.1* Main Australian river systems.

**Bullard, J.E, Baddock, M., McTainsh, G.H., Leys, J.F (2008) "Sub-basin scale dust source geomorphology detected using MODIS." GEOPHYSICAL RESEARCH LETTERS, 35. L15404.**

2. Internally-draining rivers feed sands into dunefields (on geological timescales)
- some of which are active dust sources (mainly the red dunefields).

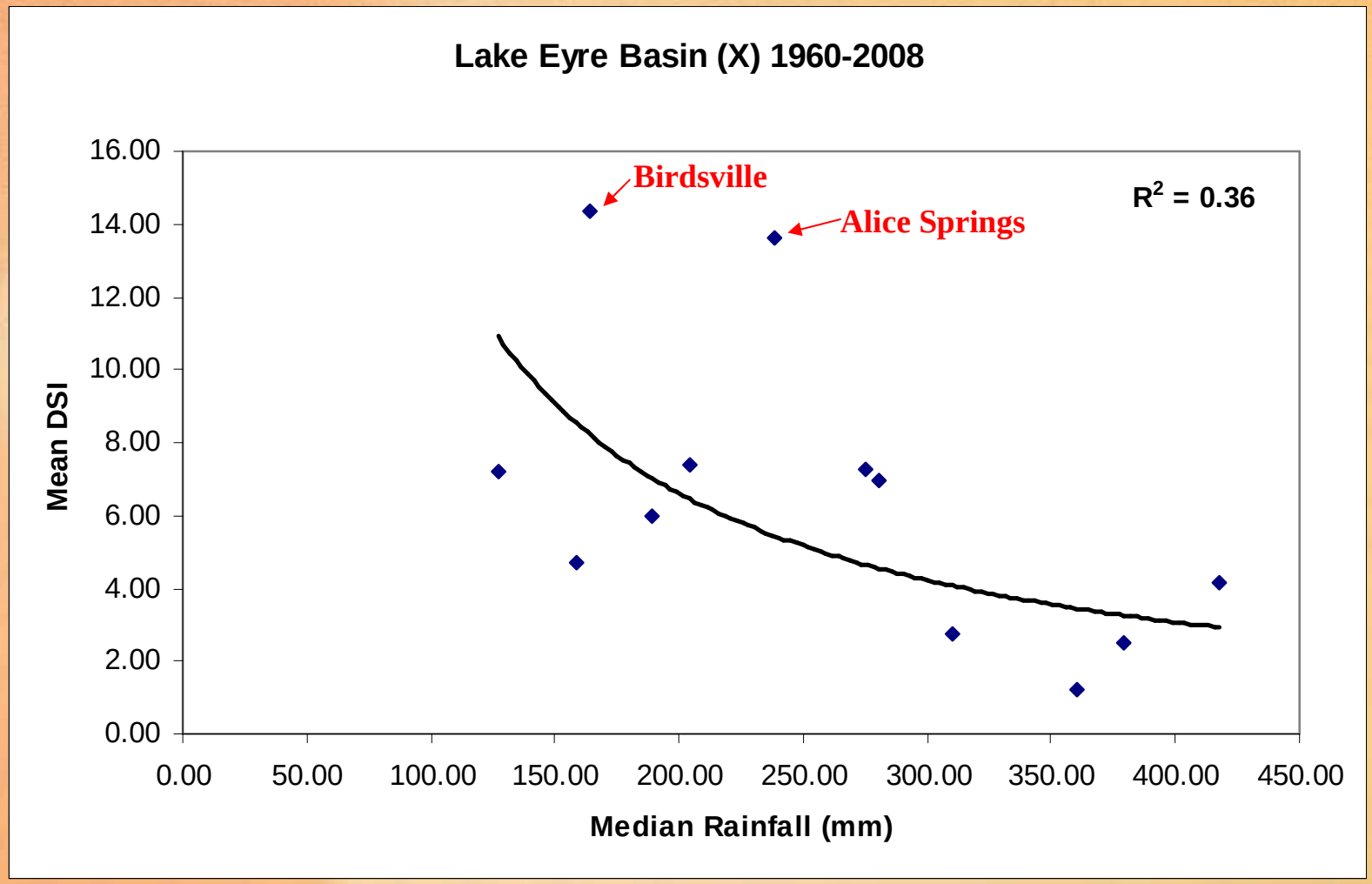



The best developed (and reddest) dunefields in the LEB are fed by the Channel Country rivers

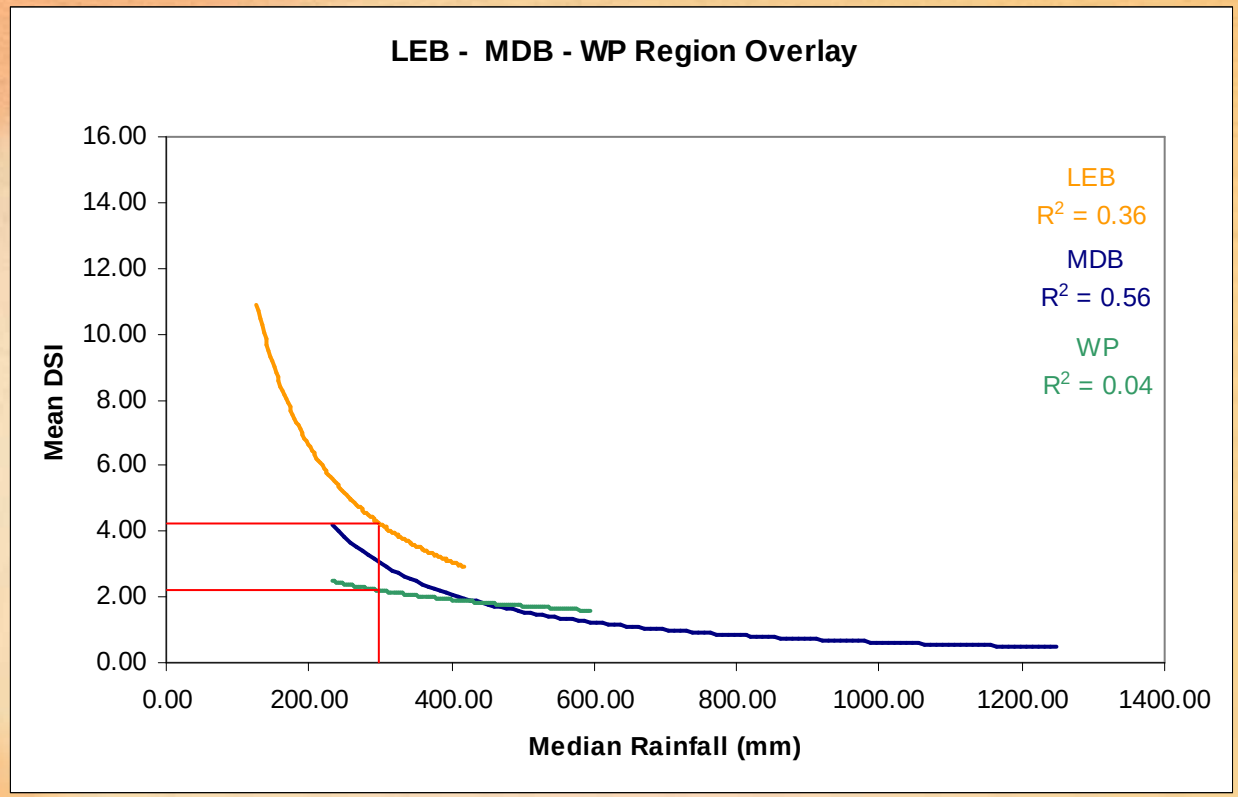
**Birdsville** (on the edge of the Simpson Desert) has the highest dust storm frequency in Australia

**Birdsville dust storm (Source: The Australian newspaper)**




Very high erosion at **Birdsville** is driven by *sediment supply* - on the edge of the Simpson Desert which has an additional dust entrainment process; clay skin abrasion

**Alice Springs** erosion was extremely high during the 1960s – due to *overgrazing*, but has decreased




**Erosion comparison:**

- Relative Erosion Rate of the WP is 50% of the LEB
- Erosion Response Curve of WP is much flatter than both LEB and MDB

**Erosion drivers:**

- Climate - *very different* (Indian Ocean climate system influences WP)
- Sediment supply - *very different*
- Land management - *very different*

## Sediment Supply

The Western Plateau (**WP**) has *no organised river systems* - in contrast to the Lake Eyre Basin (**LEB**) and Murray-Darling Basins (**MDB**).

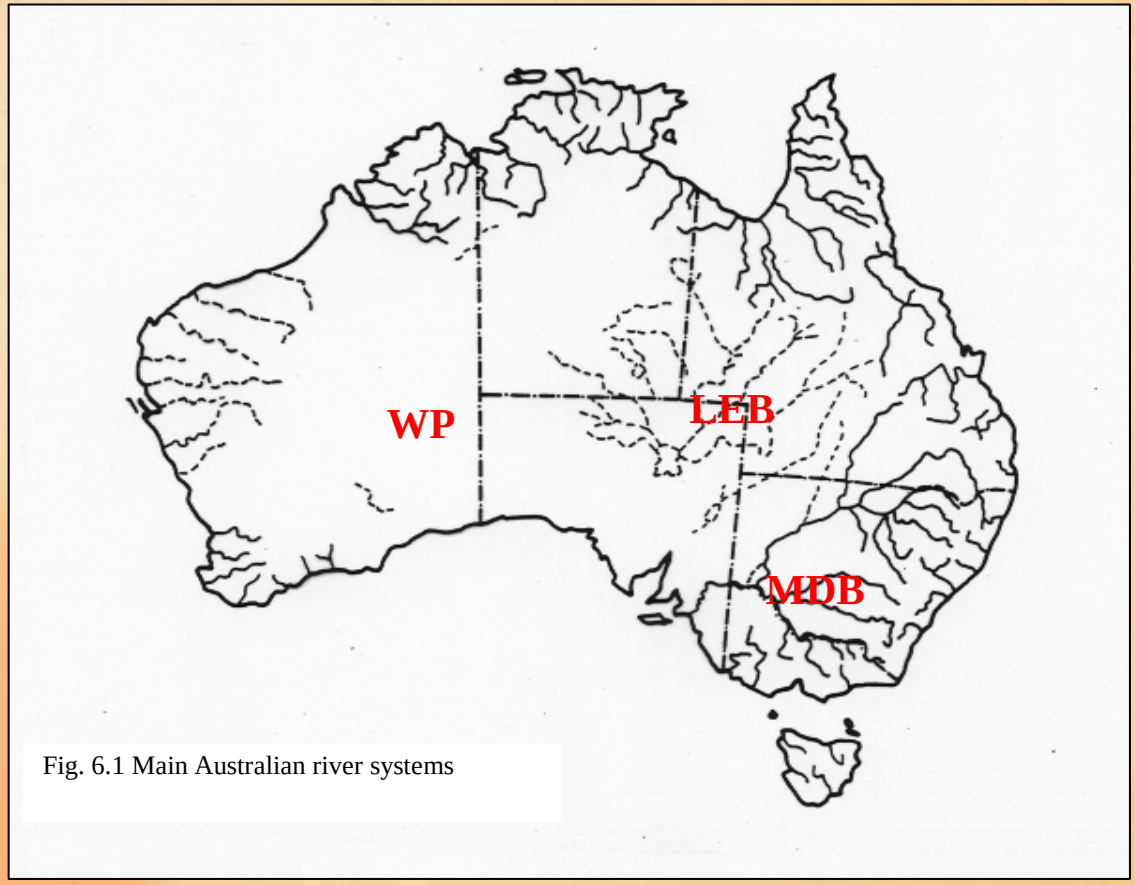



Fig. 6.1 Main Australian river systems

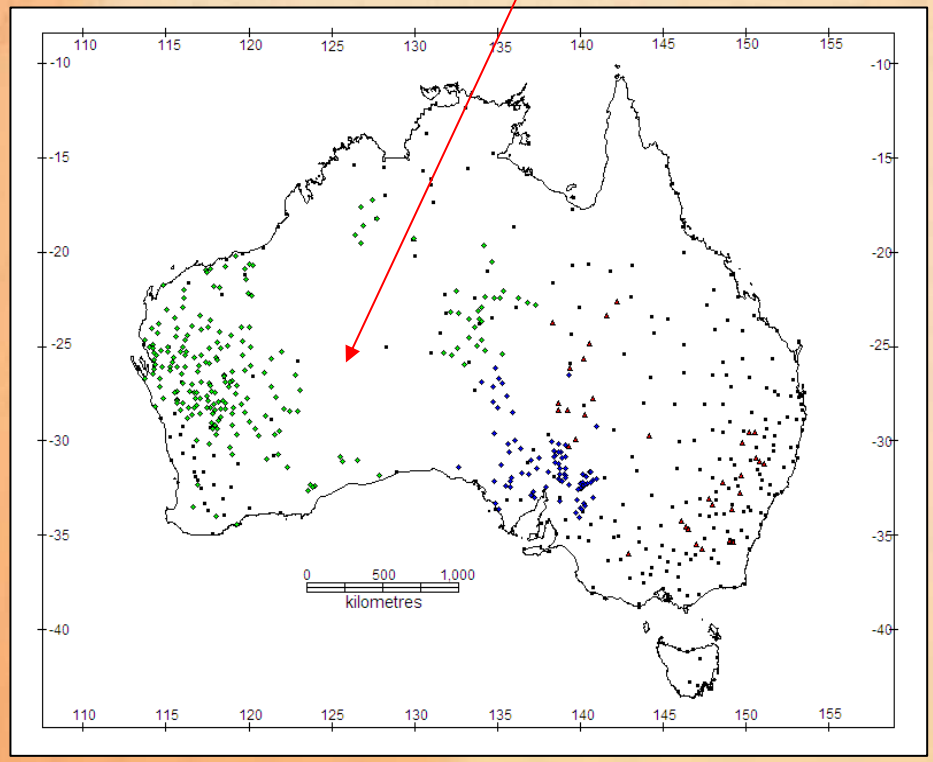
The absence of sediment supplying internally-draining rivers in WP reduces the number of active dust source areas and partly explains the low Relative Erosion Rate.

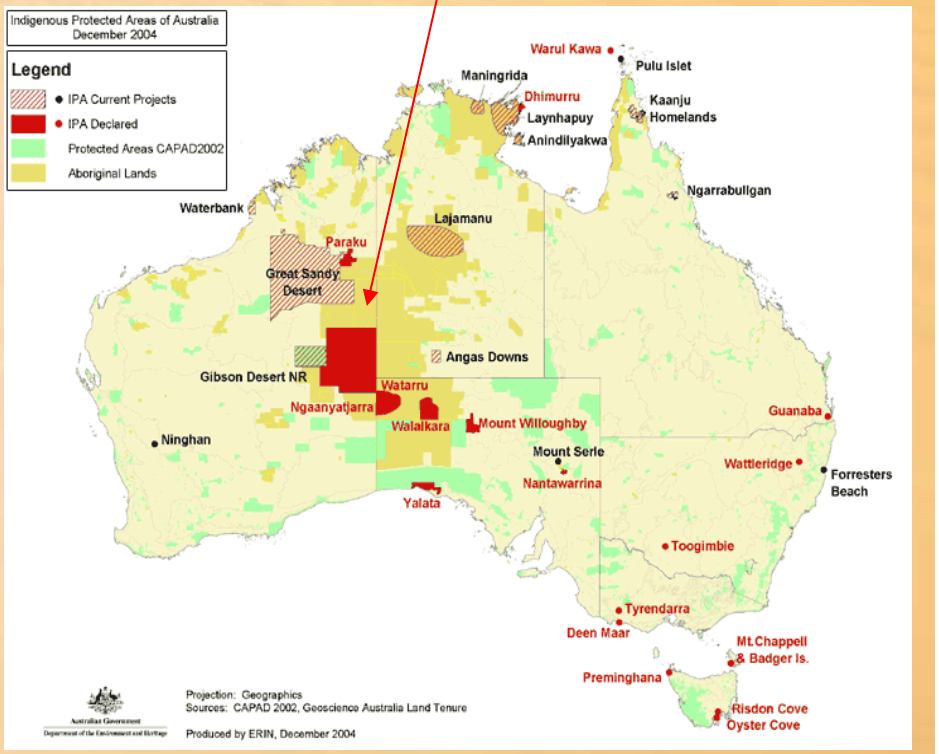
# Land management - grazing

Rivers also control land management as surface water is needed to sustain pastoral properties

There are ***no pastoral properties*** over large areas of the Western Plateau

This region has indigenous protected areas.

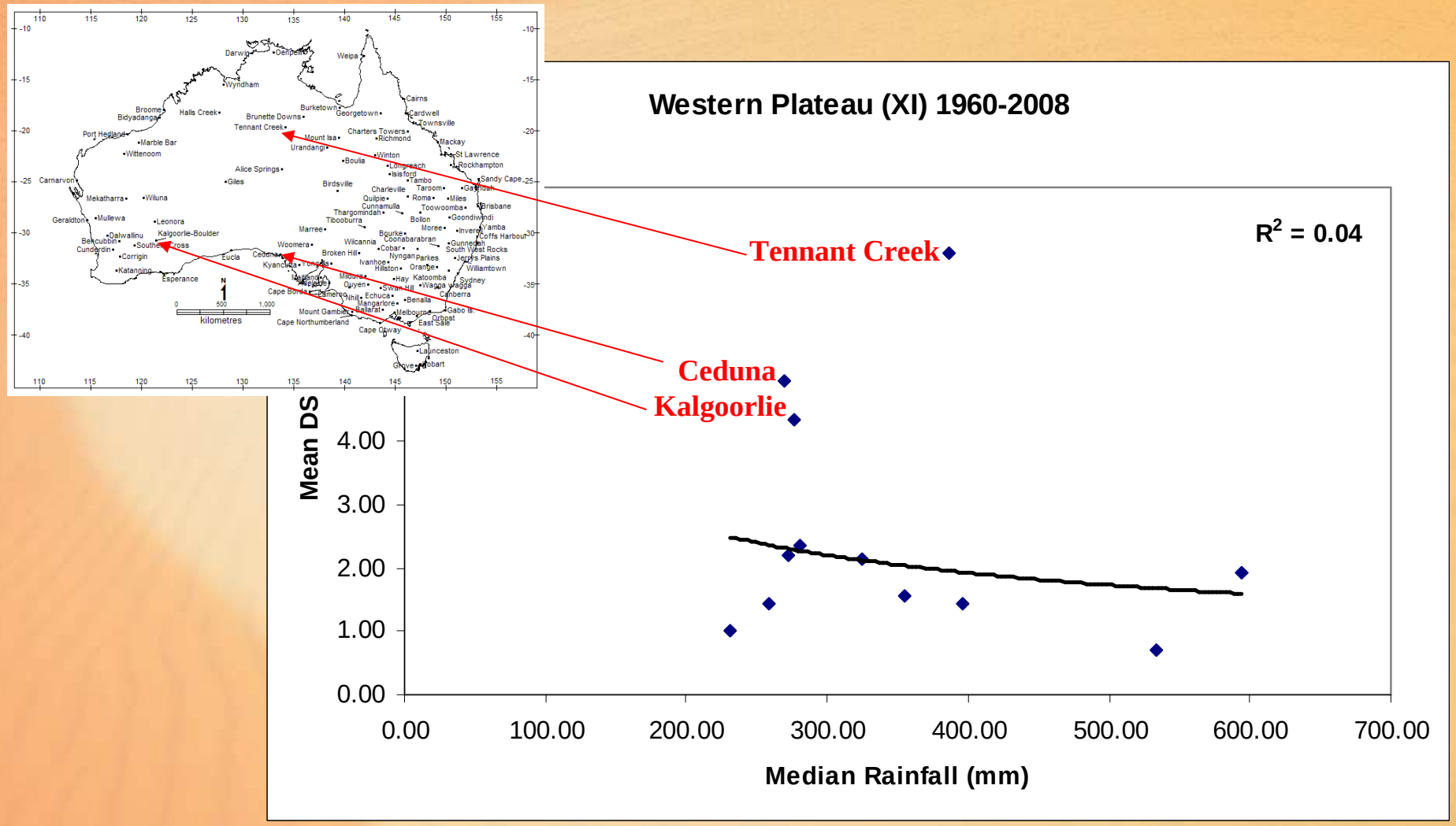



**Pattern of pastoral properties from a DustWatch survey.**

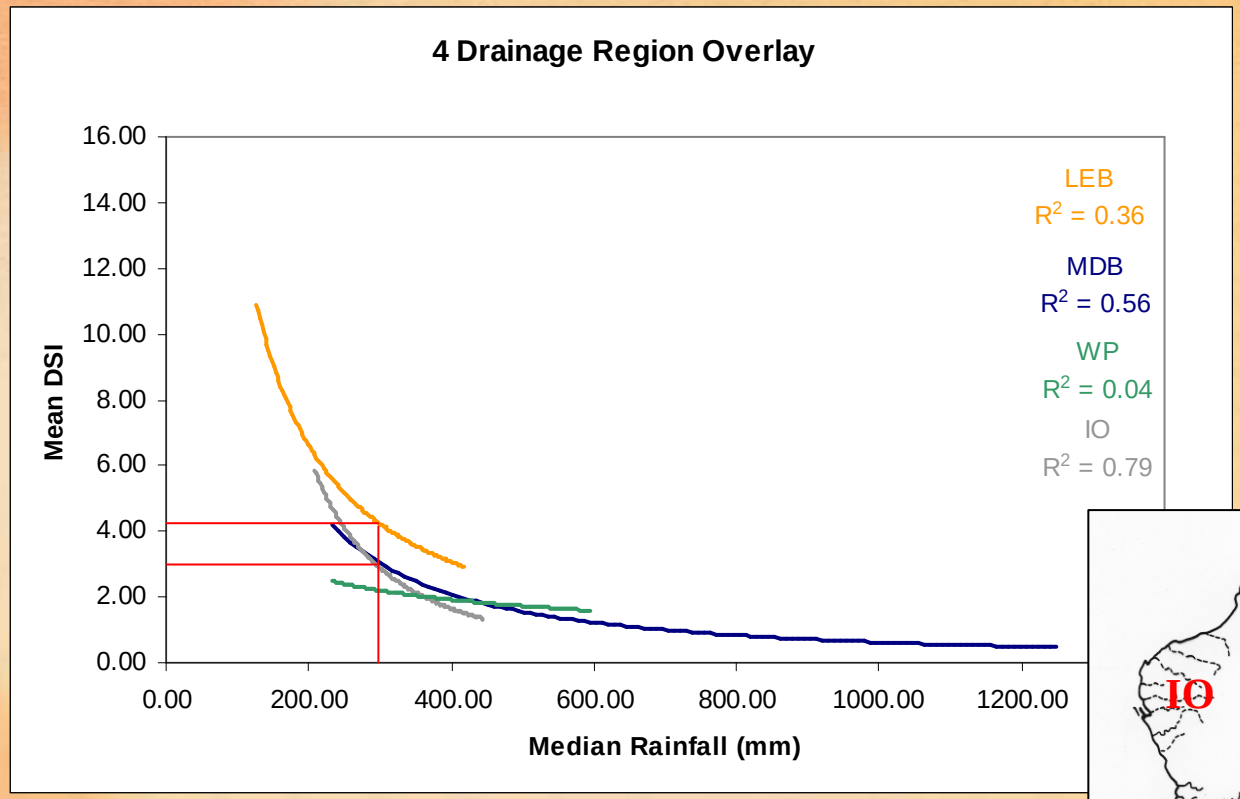
Therefore there is less vegetation reduction from grazing in the Western Plateau which may partly explain the low wind erosion rates.

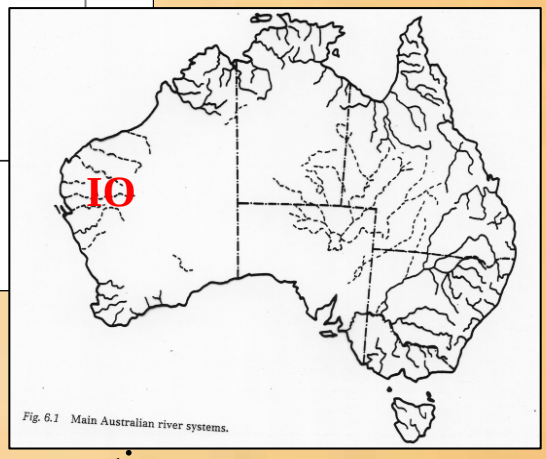
Is dust entrainment in the WP more “natural” ?




Erosion hotspots at **Tennant Creek** and **Kalgoorlie** are associated with gold mining areas.

**Ceduna** is on the edge of Eyre Peninsula – the only intensive agricultural area in the WP which has accelerated erosion.




**Erosion comparison:**

- Relative Erosion Rate of IO region is similar to the MDB
- Erosion Response Curve of IO is much steeper than all other regions

**Erosion drivers:**

- Climate – *similar to the WP* but different from LEB and MDB
- Sediment supply – *different from all.* Externally-draining river floodplains produce active erosion near the coast (e.g. Carnarvon)
- Land management – *very different* from all (grazing plus very intensive iron ore mining)

## SUMMARY

- Temporal patterns of wind erosion differ between the WEST and EAST of the continent due to different oceanic climate drivers.

- Natural and land management drivers of erosion are discriminated by comparing the **Relative Erosion Rate** (RER) and **Erosion Response Curves** (ECR) of the 4 major drainage regions:

- The **Lake Eyre Basin** is the most actively eroding region due mainly to active dust source areas supplied with sediments by internally-draining rivers

- The **Murray-Darling Basin** has a lower RER but a very similar ERC, reflecting common erosion drivers

- The **Western Plateau** has a very low RER and a flat ERC, reflecting the absence of internally-draining rivers, therefore: few dust source areas and no grazing, but erosion hotspots are associated with mining

- The **Indian Ocean region** on the West Australian coast has a very steep ERC reflecting active erosion near the coast on externally-draining river floodplains and possibly land management impacts from intensive iron ore mining.