Vegetation impact on mean annual catchment evapotranspiration: a global non-paired catchment perspective

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Peel MC, McMahon TA & Finlayson BL (2010)
Vegetation impact on mean annual evapotranspiration at a global catchment scale, *Water Resources Research,* 46, W09508.

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Motivation

- What is the long-term influence of vegetation type on mean annual catchment evapotranspiration (ET)?
  - catchment runoff (Q)?
- Primarily assessed through paired catchment studies
  - Two neighbouring or close catchments
    - 1 control & 1 treatment catchment
    - Treatment = land cover change
    - Vegetation influence assessed via response in Q to the treatment relative to control
  - Physical proximity of catchments minimises influence of
    - climate variability
    - inter-basin variability

Background

- >200 paired catchment studies reported in the literature
  - Review papers: Bosch and Hewlett (1982), Sahin and Hall (1996), Andréassian (2004), Farley et al. (2005), & Brown et al. (2005).
- Generally small catchments (<10 km^2)
- Restricted climate range
  - USA: ~47% of reported studies
    - Köppen climate types C & D
  - Australia: ~27% of reported studies
    - Köppen climate types C

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Background

- Paired catchment results
  - Forested ET > Non-forested ET
    - Forested Q < Non-Forested Q
- Are these results observed at
  - larger scales?
  - across a range of climate types?
  - when looking at results from single catchments (not paired catchments)?

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Research Questions

- Is climate type important when assessing vegetation impact on mean annual ET?
- Are differences in ET observed between catchments with:
  - forest and non-forest?
  - evergreen and deciduous forest?
  - evergreen broadleaf and evergreen needleleaf forest?
- If ET differences exist – are they related to catchment area?

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Analysis Method

- Large dataset of single catchments
  - Catchment area (km^2): 3.6 – 4,640,300, med. = 1,620
  - Record Length (years): 10 – 172, med. = 32
    - Mostly between 1950 – 1985
  - Group by dominant (≥75%) vegetation type
  - Compare long-term actual ET between groups
    - Here ET = P – Q (water balance approach)
      - Not directly estimated via meteorological variables
    - Look for differences in catchment ET between vegetation type groups

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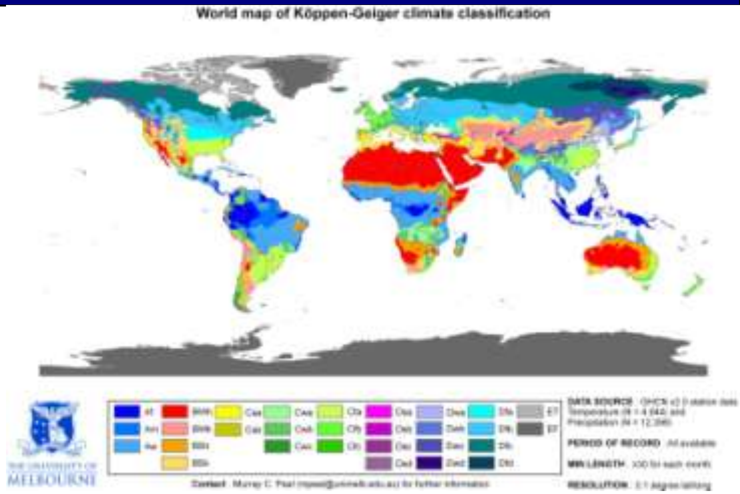
Catchment data

- Large global hydroclimatic dataset
  - 699 catchments from around the world
  - Spatially & climatically diverse
  - “Natural” catchments
    - not impacted by reservoirs / diversions



- Spatial
  - DEM: HYDRO1k & Aust. 250m
  - Climate type: Köppen (Peel et al., 2007)
  - Vegetation: Global Land Cover 2000 (GLC2000)
    - 1 km satellite based dataset (Fritz et al., 2003)
    - May not be the vegetation cover during the period of runoff observations

- Monthly data for each catchment
  - Precipitation (P), Temperature (T) & Runoff (Q)
    - Concurrent, no elevation correction for P or T
  - Monthly average Potential ET (PET)

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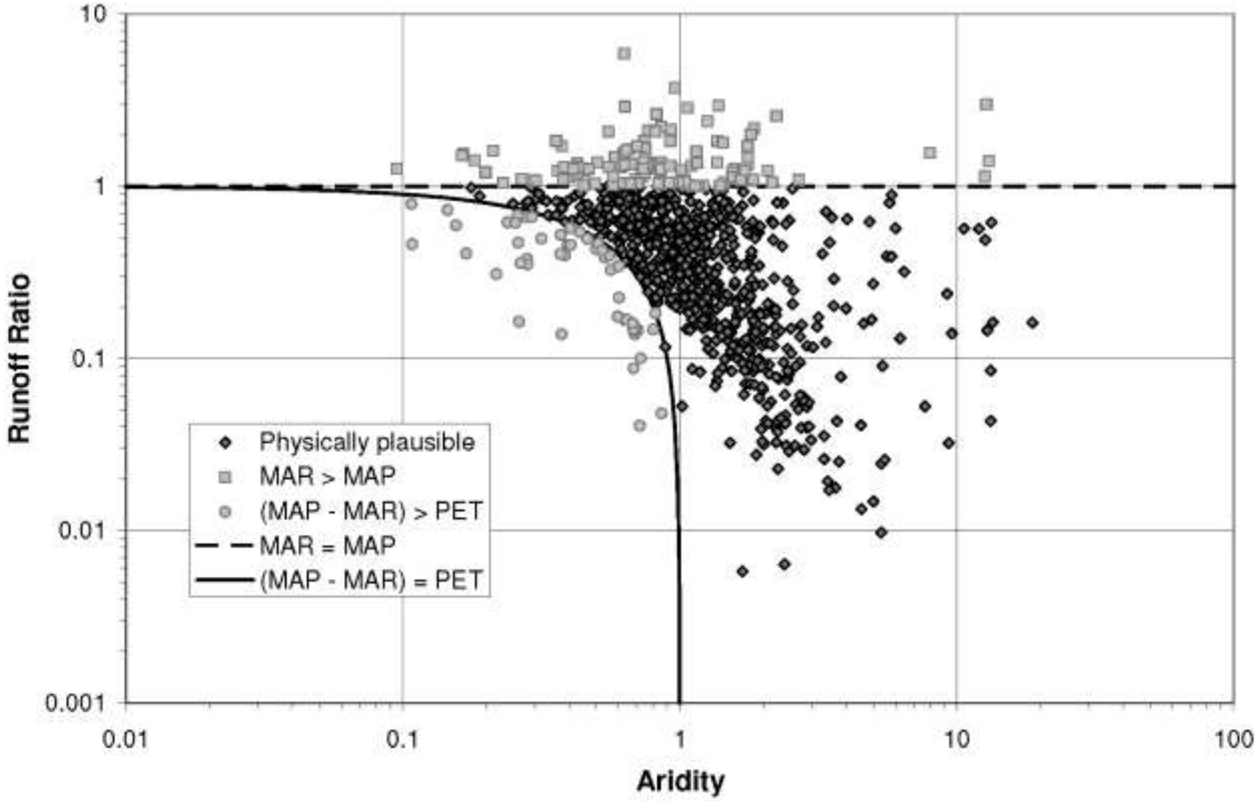
Water Balance check

- Runoff Ratio = Q/P, Aridity = PET/P



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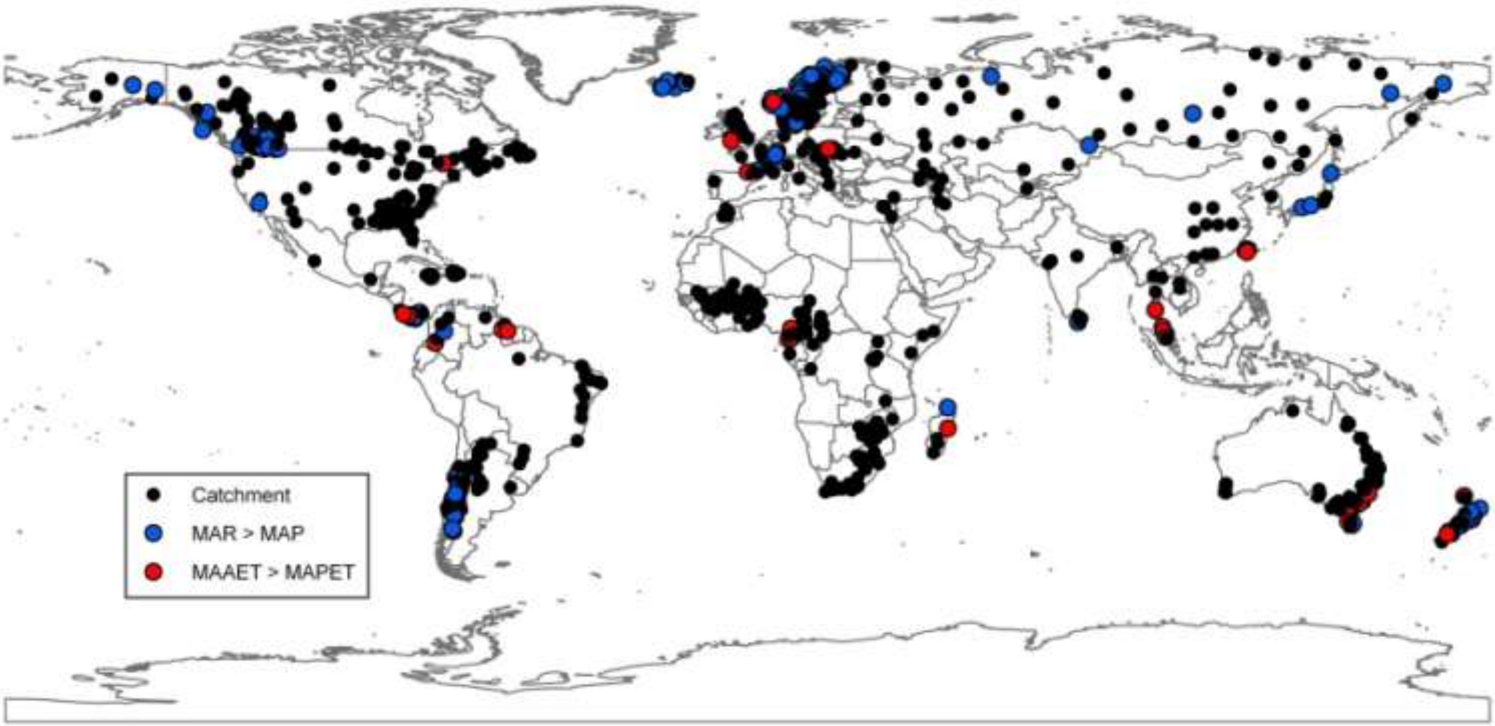
Water Balance Check



Peel, McMahon & Finlayson
(2010)

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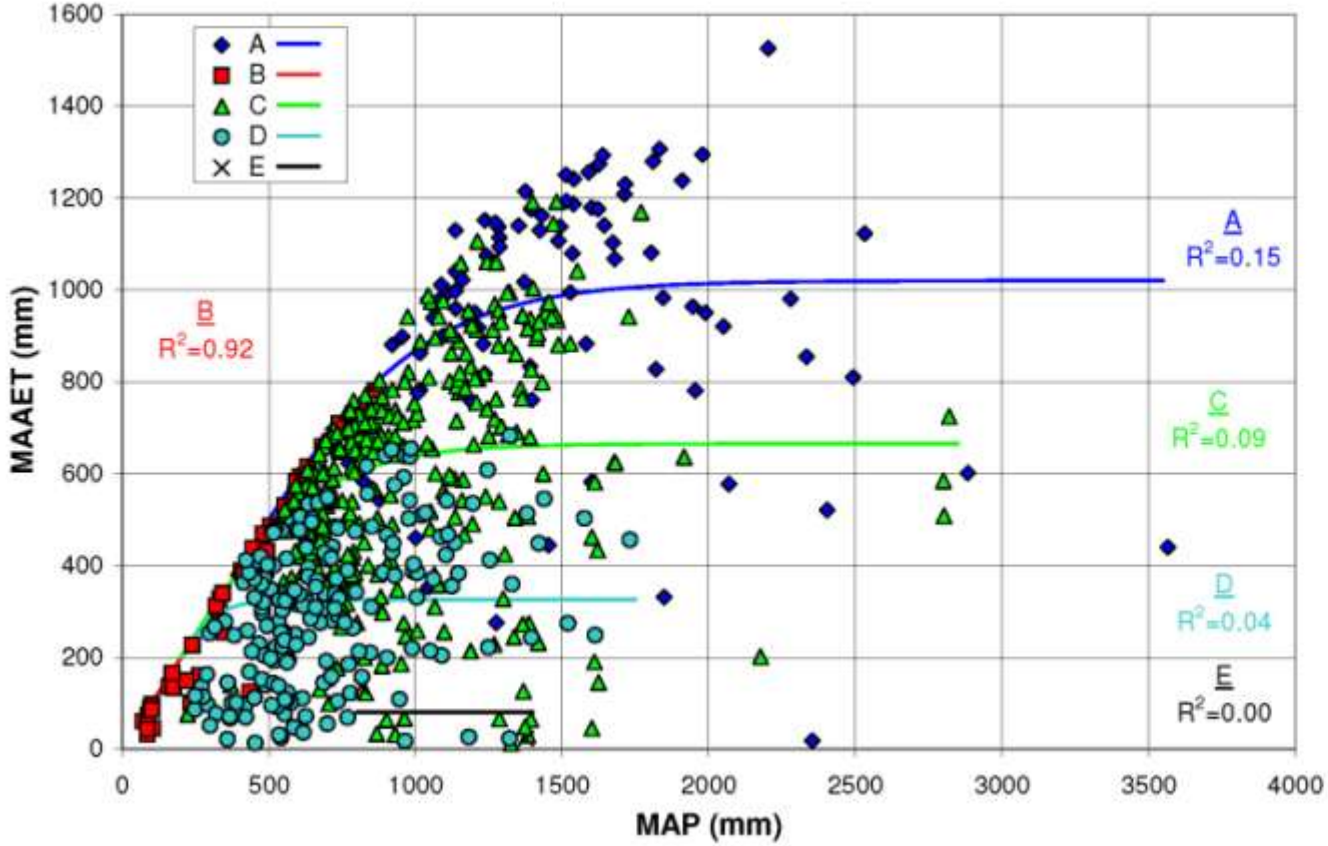
Is climate type important when assessing vegetation impact on mean annual ET?



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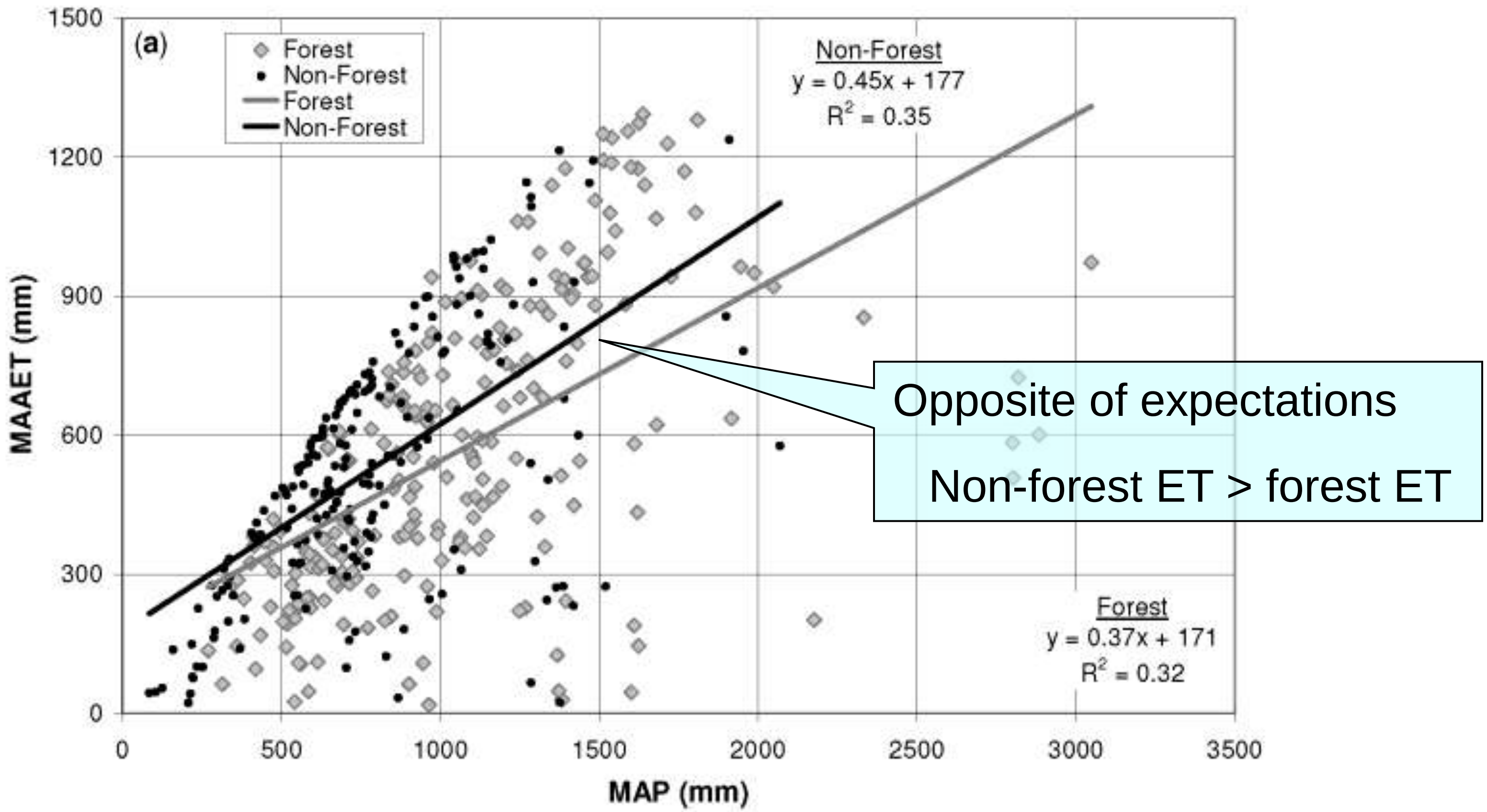
Forest vs non-forest ET

- Traditional: not stratified by climate type



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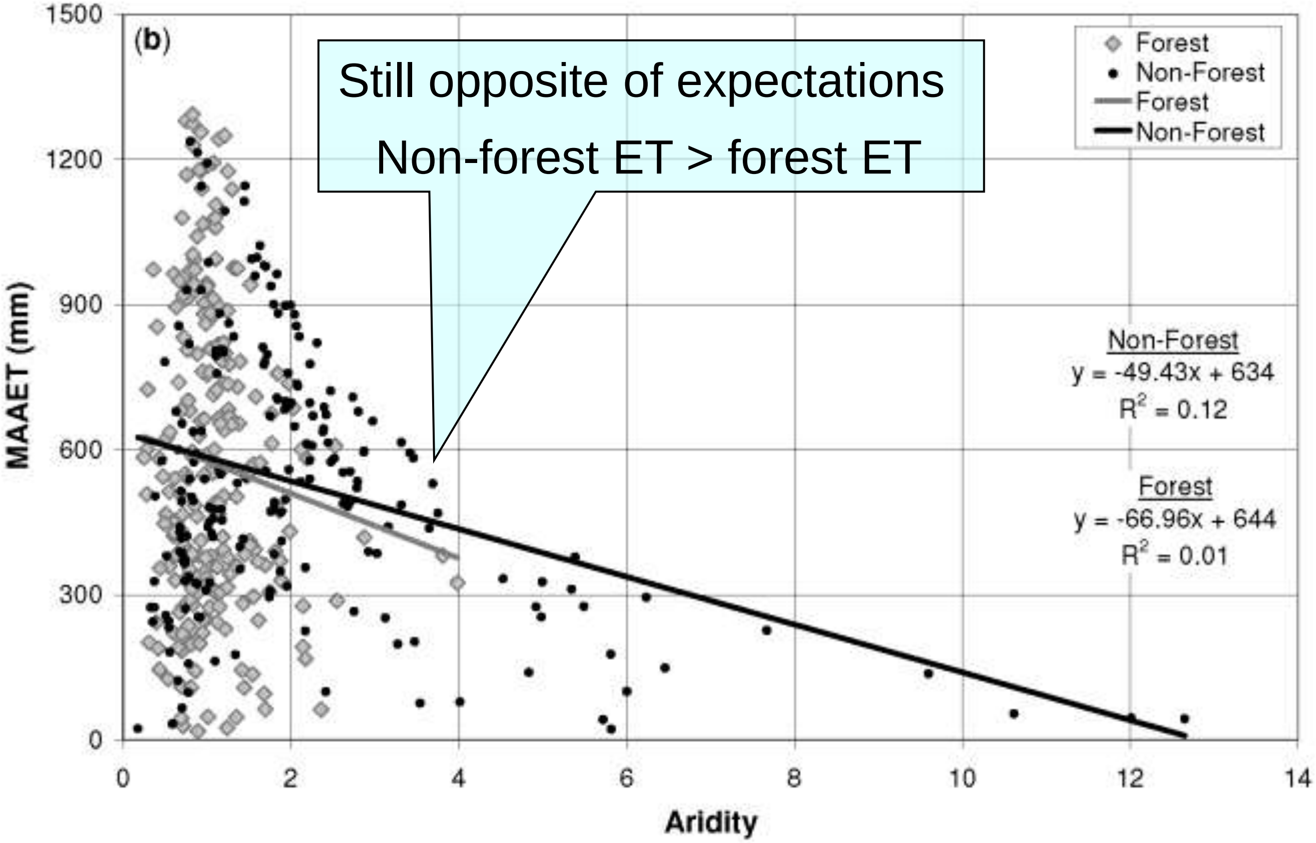
Forest vs non-forest ET Aridity

- Replace MAP with Aridity (PET/MAP)



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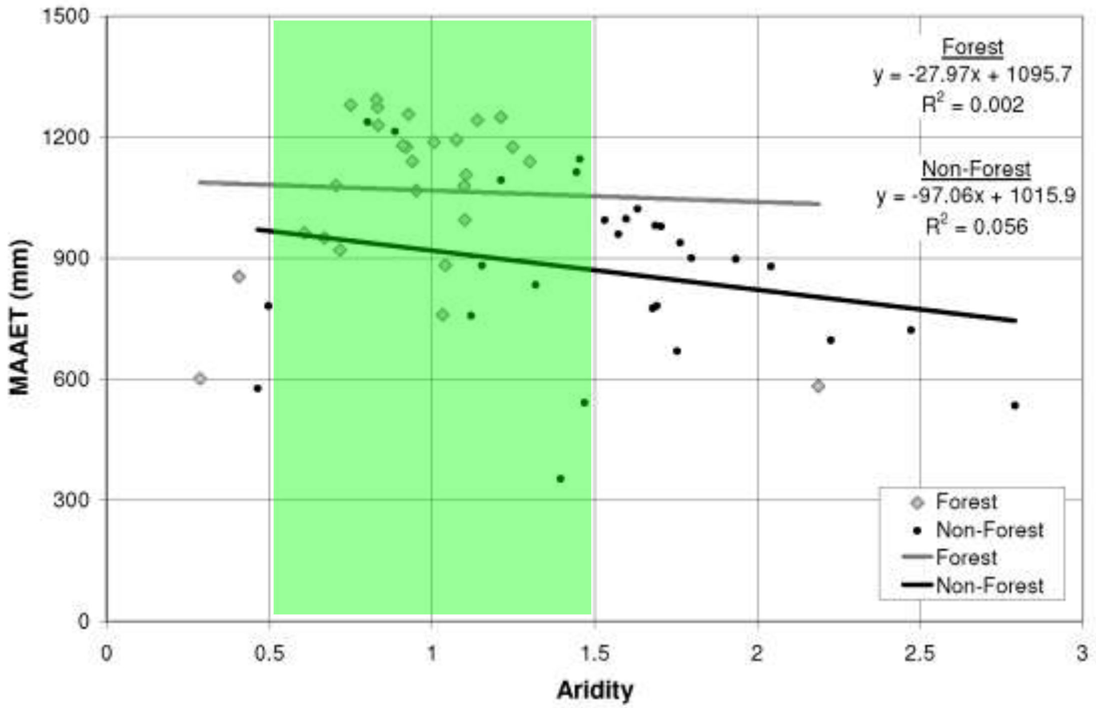
Forest vs non-forest ET Aridity & Climate type

- Tropical catchments
  - Forested ET ~170mm > non-forested ET (medians significantly different)



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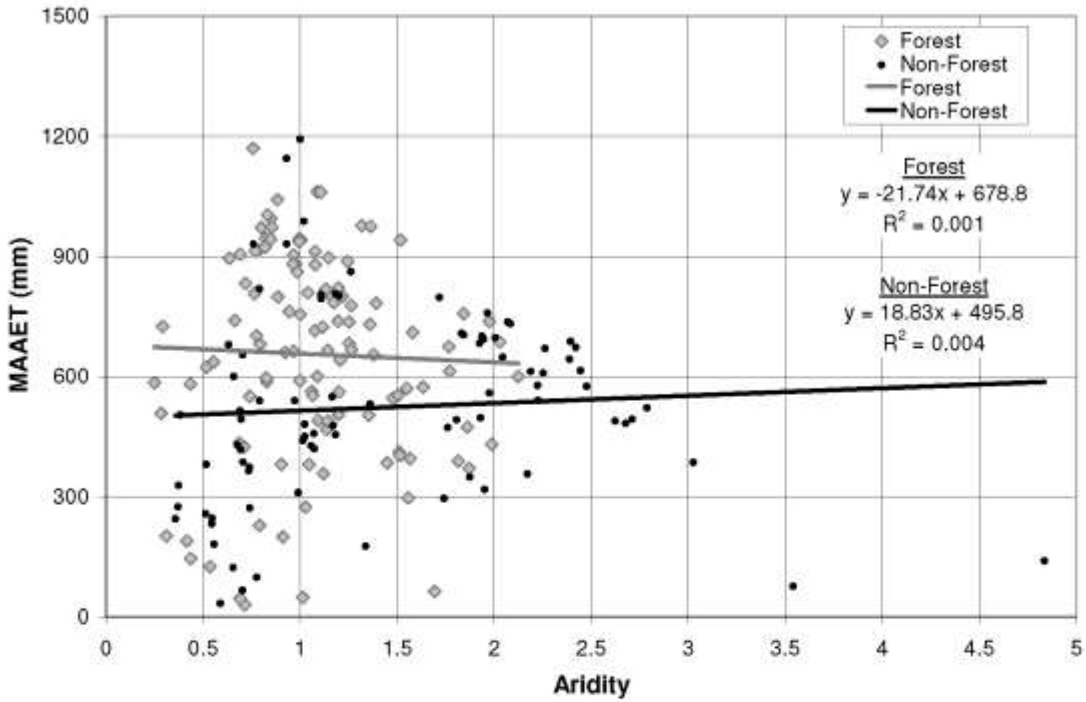
Forest vs non-forest ET
Aridity & Climate type

- Temperate catchments
  - Forested ET ~130mm > non-forested ET (medians significantly different)



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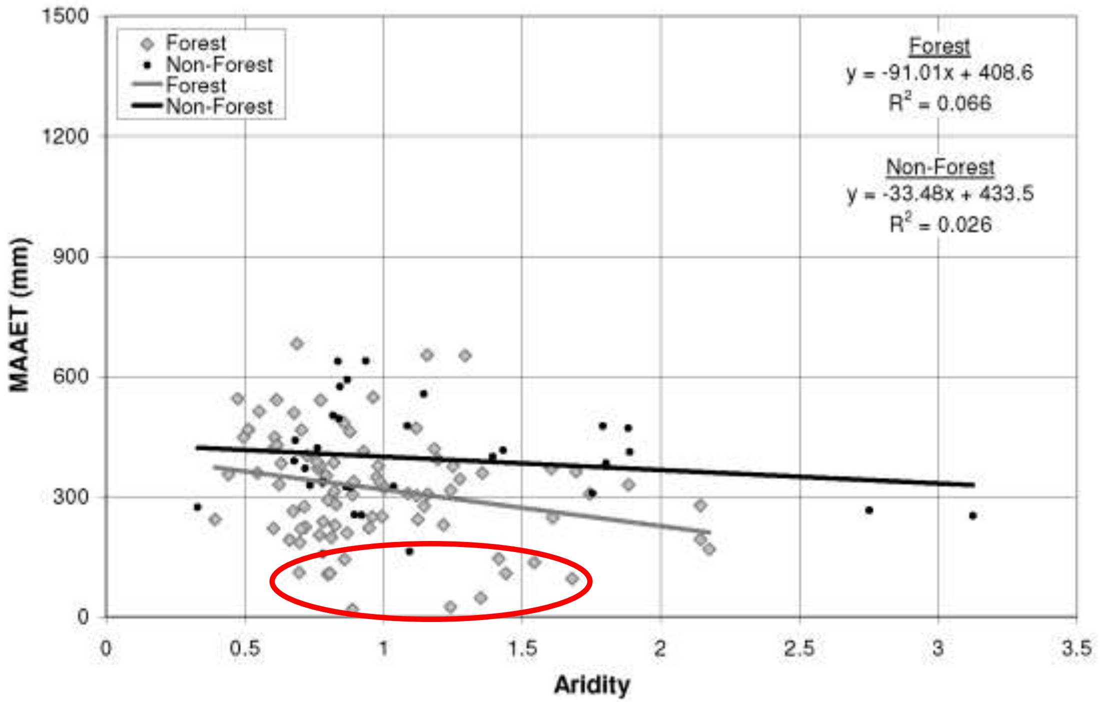
Forest vs non-forest ET Aridity & Climate type

- Cold catchments
  - Non-Forested ET ~90mm > Forested ET (medians significantly different)



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Are vegetation type differences in ET related to catchment area?

- Tropical catchments
  - Inconclusive
    - Distribution of catchments along aridity gradient made comparison impossible
- Temperate catchments
  - Forest ET significantly (~130mm) > non-forest ET
    - Maintained for catchments < 1,000 km^2
    - Not maintained for catchments ≥ 1,000 km^2
- Cold catchments
  - Forest ET significantly (~90mm) < non-forest ET
    - Not maintained for catchments < 1,000 km^2
    - Not maintained for catchments ≥ 1,000 km^2

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General Conclusions

- Climate type is important when comparing catchments
  - Influence of vegetation type on ET not observed when climate type ignored
- Aridity is important
  - Captures the interaction between water and energy limitation
  - Should be used in preference to MAP in this type of analysis
- Utility of a large spatially and climatically diverse dataset demonstrated

Specific Conclusions

- Vegetation type related differences in ET only apparent when stratified by climate type
- Forest vs Non-Forest hypothesis
  - Tropical (~170mm) & Temperate (~130mm) forested ET > non-forested ET
  - Cold (~90mm) forested ET < non-forested ET
    - Unexpected result, possible forested catchment data issues
- Evergreen vs Deciduous hypothesis
  - More deciduous catchments required to test
- Broadleaf vs Needleleaf hypothesis
  - More needleleaf catchments required to test
- Area hypothesis
  - Temperate forest vs non-forest results maintained for catchments < 1,000 km^2, but not ≥ 1,000 km^2

Peel, McMahon & Finlayson (2010)

Funding & References

- Australian Research Council Discovery Grants (DP0449685 & DP0773016)

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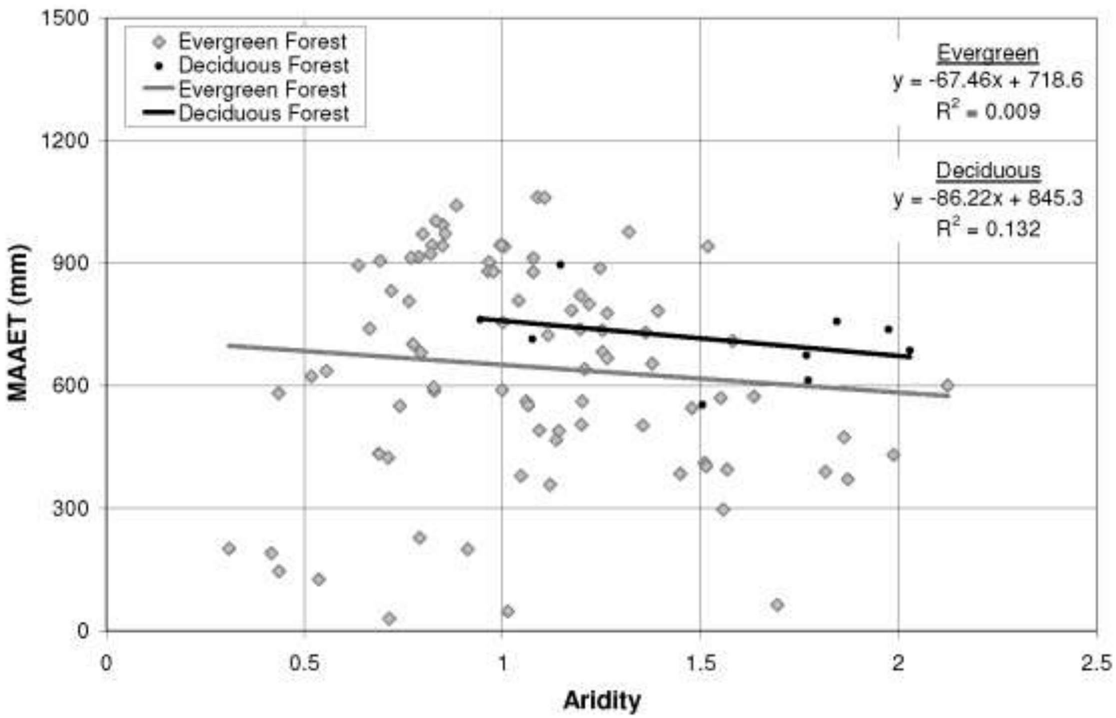
Evergreen vs deciduous forested ET

- Temperate catchments
  - Non-significant difference in median ET (unexpected result)



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Evergreen vs deciduous forested ET

- Most deciduous catchments (7 of 9) in summer dominant P regimes
  - Drought deciduous forest, not obligately deciduous
    - Expect little difference in ET between drought deciduous and evergreen forested catchments

- To test the initial research question requires more obligately deciduous forested catchments

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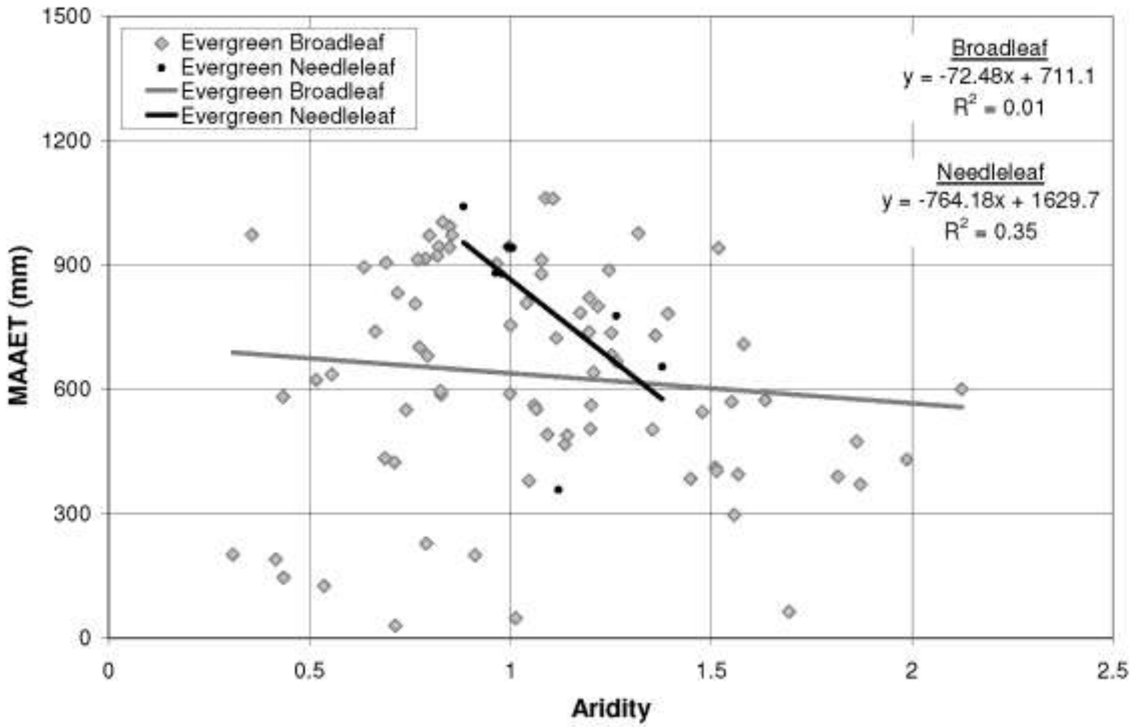
Broadleaf vs needleleaf evergreen forested ET

- Temperate catchments
  - Significantly different medians, but small needleleaf sample size



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