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

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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
- Generally small catchments (<10 km²)
- Restricted climate range
  - USA: ~47% of reported studies
    • Köppen climate types C & D
  - Australia: ~27% of reported studies
    • Köppen climate types C
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)?
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?
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
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)
Water Balance check

- Runoff Ratio = Q/P, Aridity = PET/P
Water Balance Check

Peel, McMahon & Finlayson
(2010)
Is climate type important when assessing vegetation impact on mean annual ET?

Peel, McMahon & Finlayson (2010)
Forest vs non-forest ET

- Traditional: not stratified by climate type

Opposite of expectations
Non-forest ET > forest ET
Forest vs non-forest ET

Aridity

- Replace MAP with Aridity (PET/MAP)

Still opposite of expectations
Non-forest ET > forest ET

Peel, McMahon & Finlayson (2010)
Forest vs non-forest ET
Aridity & Climate type

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

Peel, McMahon & Finlayson
(2010)
Forest vs non-forest ET
Aridity & Climate type

- Temperate catchments
  - Forested ET $\sim 130$mm $>$ non-forested ET (medians significantly different)

Peel, McMahon & Finlayson (2010)
Forest vs non-forest ET
Aridity & Climate type

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

Peel, McMahon & Finlayson
(2010)
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$^2$

Peel, McMahon & Finlayson (2010)
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 km², but not ≥ 1,000 km²

Peel, McMahon & Finlayson (2010)
Funding & References

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Peel, McMahon & Finlayson (2010)
Evergreen vs deciduous forested ET

- Temperate catchments
  - Non-significant difference in median ET (unexpected result)
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
Broadleaf vs needleleaf evergreen forested ET

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