

Water and carbon cycles are tightly coupled in loblolly pine (*Pinus taeda* L.) plantations along the coastal plain of southeastern U.S.

Maricar Aguilos¹, Ge Sun², Asko Noormets³, Jean-Christophe Domec⁴, Steve McNulty², Michael Gavazzi², Prajaya Prajapati⁵, Kevan Minick¹, Bhaskar Mitra⁶, John King¹

¹Department of Forestry and Environmental Resources, NC State University, Raleigh, NC 27695, USA; mmaguillo@ncsu.edu; ²USDA Forest Service EFETAC Raleigh, NC 27606, USA; ³Department of Ecosystem Science and Management, Texas A&M University, College Station, TX 77843-2138, USA; ⁴Bordeaux Sciences Agro, UMR 1391 INRA ISPA, CEDEX, 33175 Gradignan, France; ⁵Institute of Environment and Department of Biological Sciences, Florida International University, 11200 SW 8th Street, Miami, FL 33199, USA; ⁶School of Informatics, Computing and Cyber Systems, Northern Arizona University, Flagstaff, AZ 86011, USA

Introduction

- Ecosystem water use efficiency (WUE) is expressed as the fraction of carbon gained through gross primary productivity (GPP) to water lost through evapotranspiration (ET) at the ecosystem level.
- Studying WUE is important to determine the carbon–water coupling amidst climate change and extreme weather events.
- However, multiple-year information about the response of forested wetland ecosystems to global warming and drought is scarce.
- Here, we investigated the WUE of converted forested wetlands in North Carolina, USA using the eddy covariance flux towers at two adjacent young (YP) and mature (MP) loblolly pine plantations.

Objectives

- Determine the inter-annual and seasonal trends in GPP, ET, and WUE;
- Evaluate the impact of age and climate, to include the 2007/2008 drought, on WUE and its components.

Methods

The Study Sites

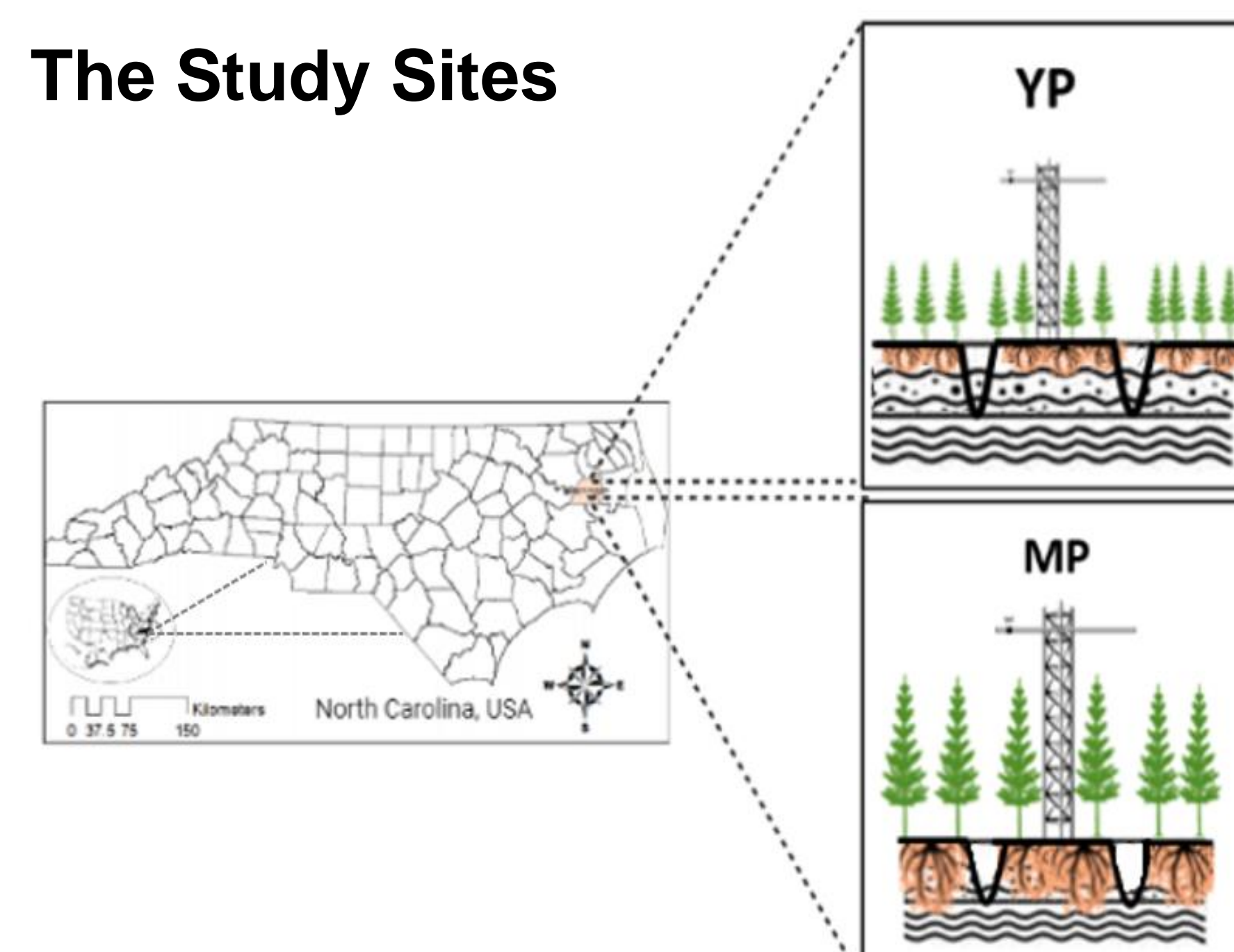


Fig 1. Map showing the location of YP and MP flux towers established in North Carolina, USA.



Fig. 2 Registered under FLUXNET as (left) US-NC1 (herein YP, 2–8 years old) and (right) US-NC2 (MP, 15–28 years old). Measurements covered from 2005–2011 at YP and 2005–2018 at MP.

Climate and Eddy Covariance Flux Monitoring

- Atmospheric CO₂ and H₂O concentrations
- Air temperature and humidity
- Global and infrared incident and reflected radiations
- Incident and reflected photosynthetic photon flux density
- Rainfall
- Wind direction and speed
- Atmospheric pressure
- Soil temperature
- Volumetric soil water content

Results

Interannual variation in GPP, ET, and WUE

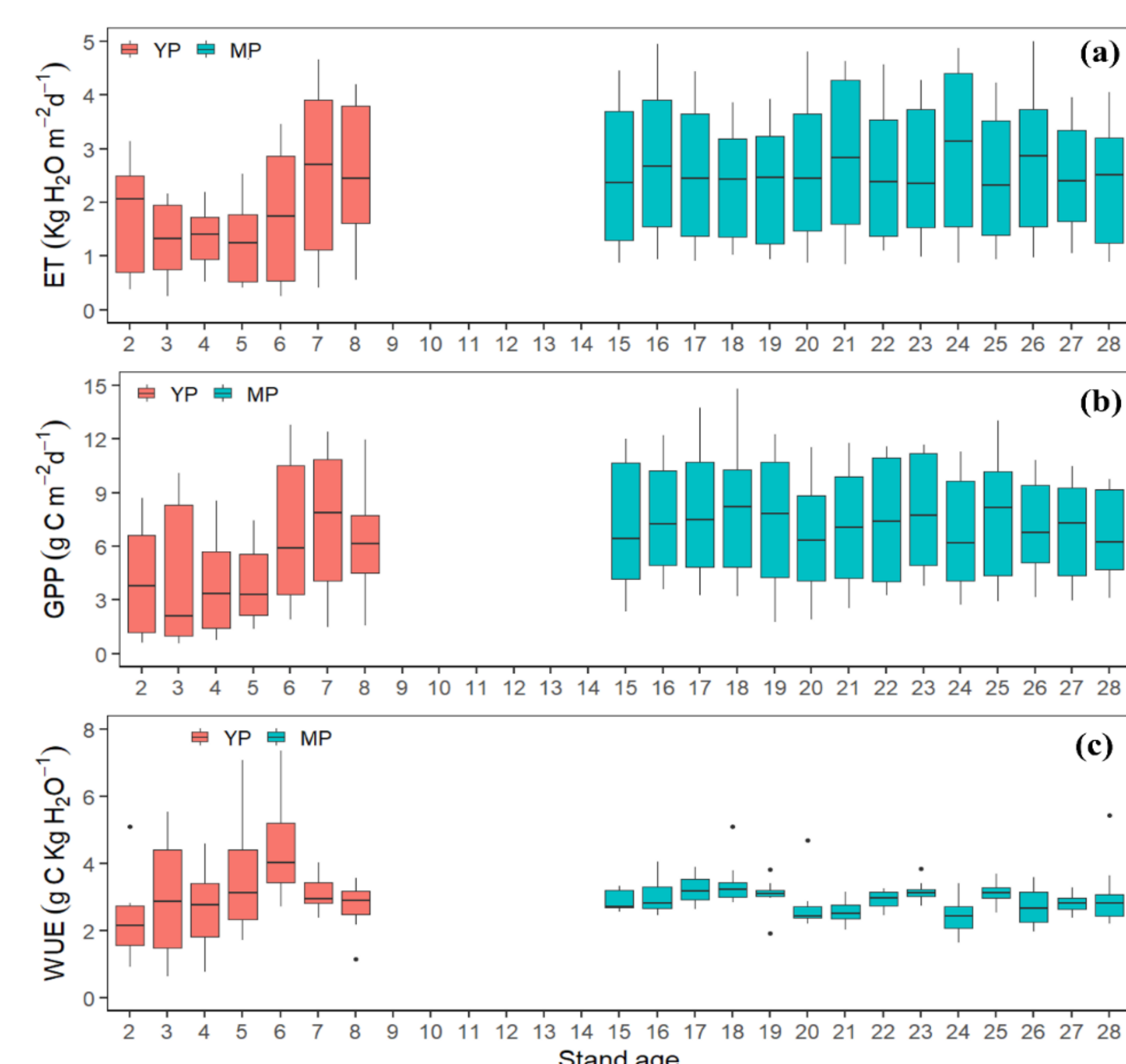


Fig. 3 Inter-annual variation in ET, GPP, and WUE at different ages of the chronosequence (YP and MP). Monthly data were used in the analysis.

Monthly Variation in GPP, ET, and WUE

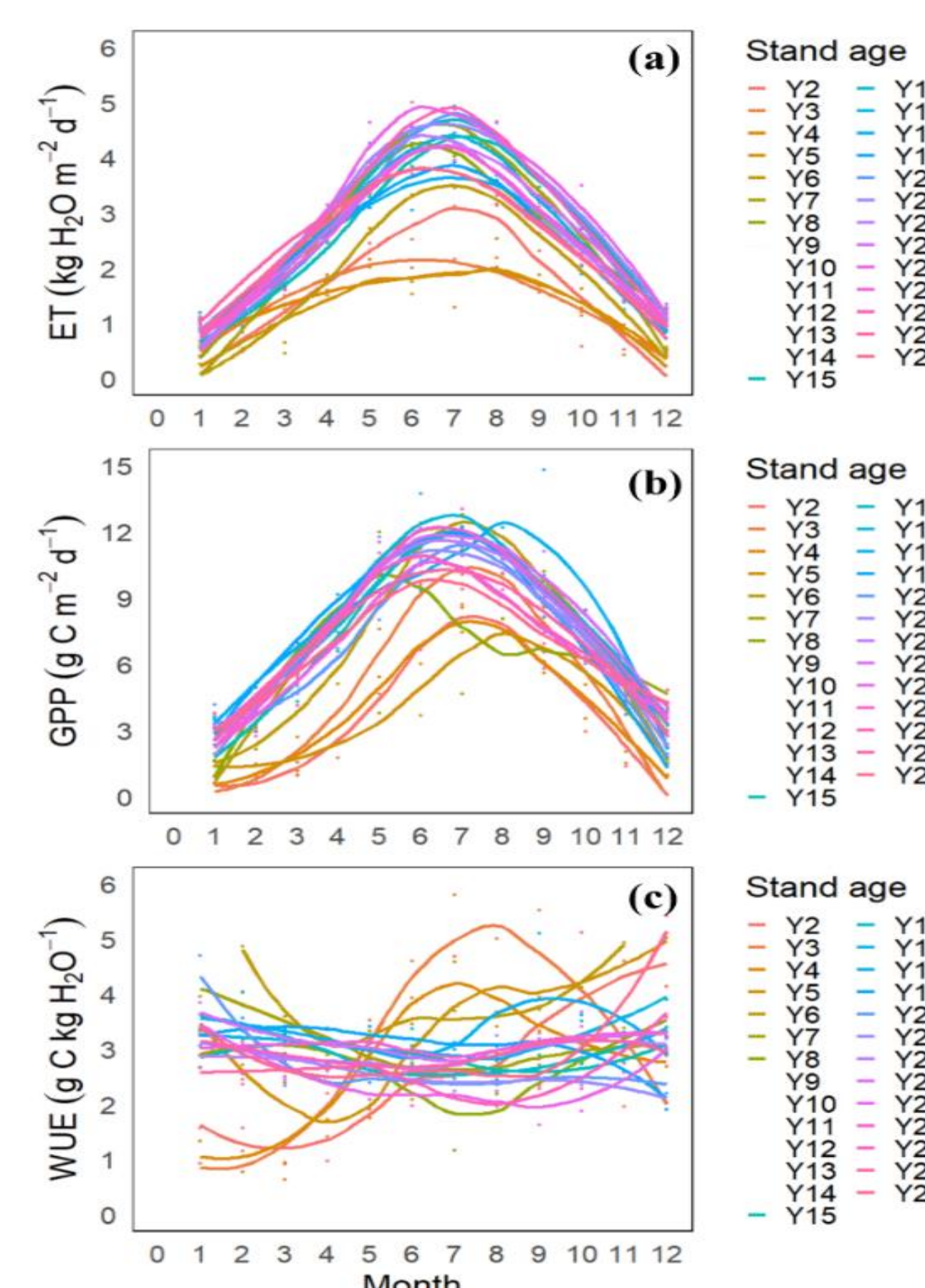


Fig. 4 Seasonal trend in ET, GPP, and WUE across different age levels of the chronosequence sites (YP and MP) based on monthly smoothed values for each year.

Age-Dependency of GPP, ET, and WUE

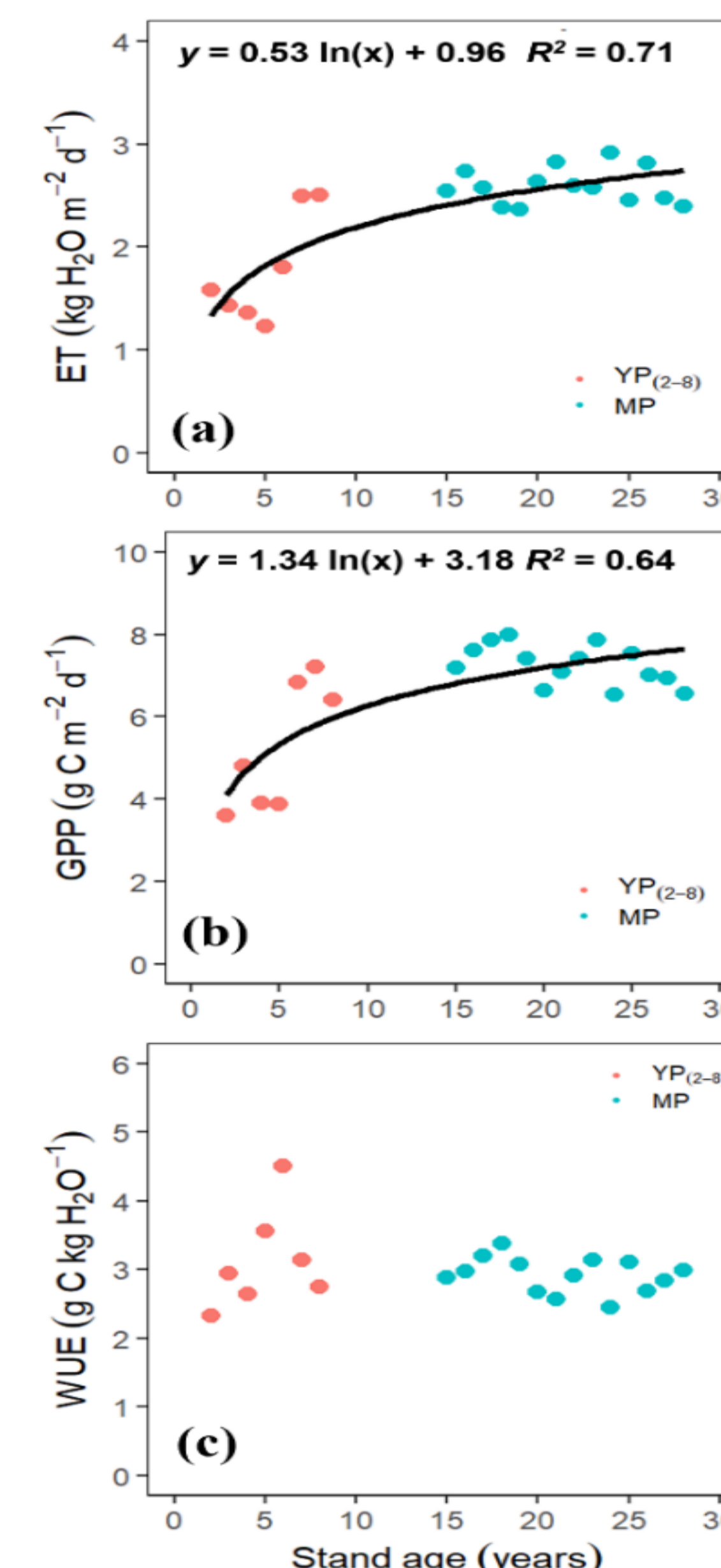


Fig. 5 Regression curves between stand age and ET, GPP, and WUE

The Coupling of GPP and ET

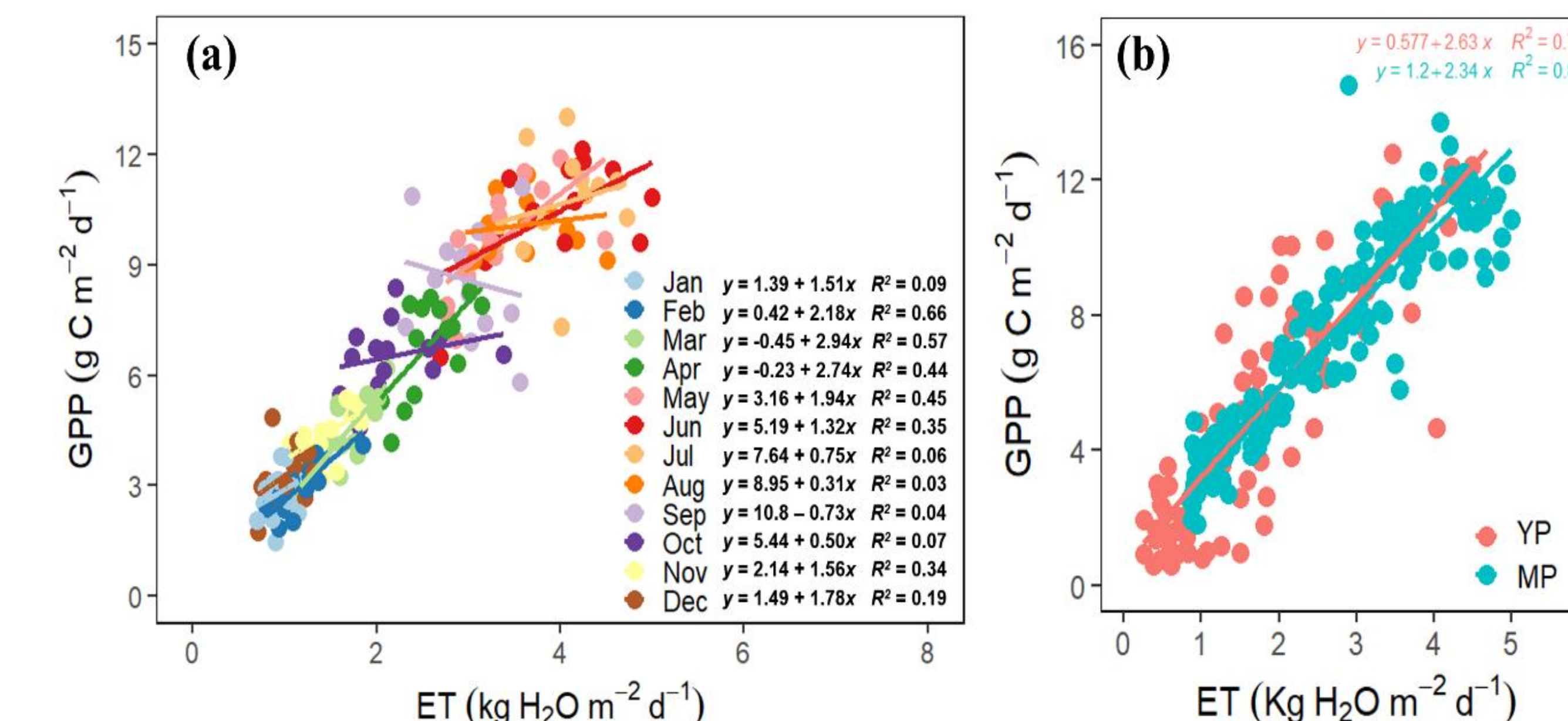


Fig. 6 Panel (a) is the relationship between ET and GPP across all years in YP and MP with season as a factor. Panel (b) is the ET–GPP relationships across the entire period with site as a factor.

Environmental Effects on ET, GPP, and WUE

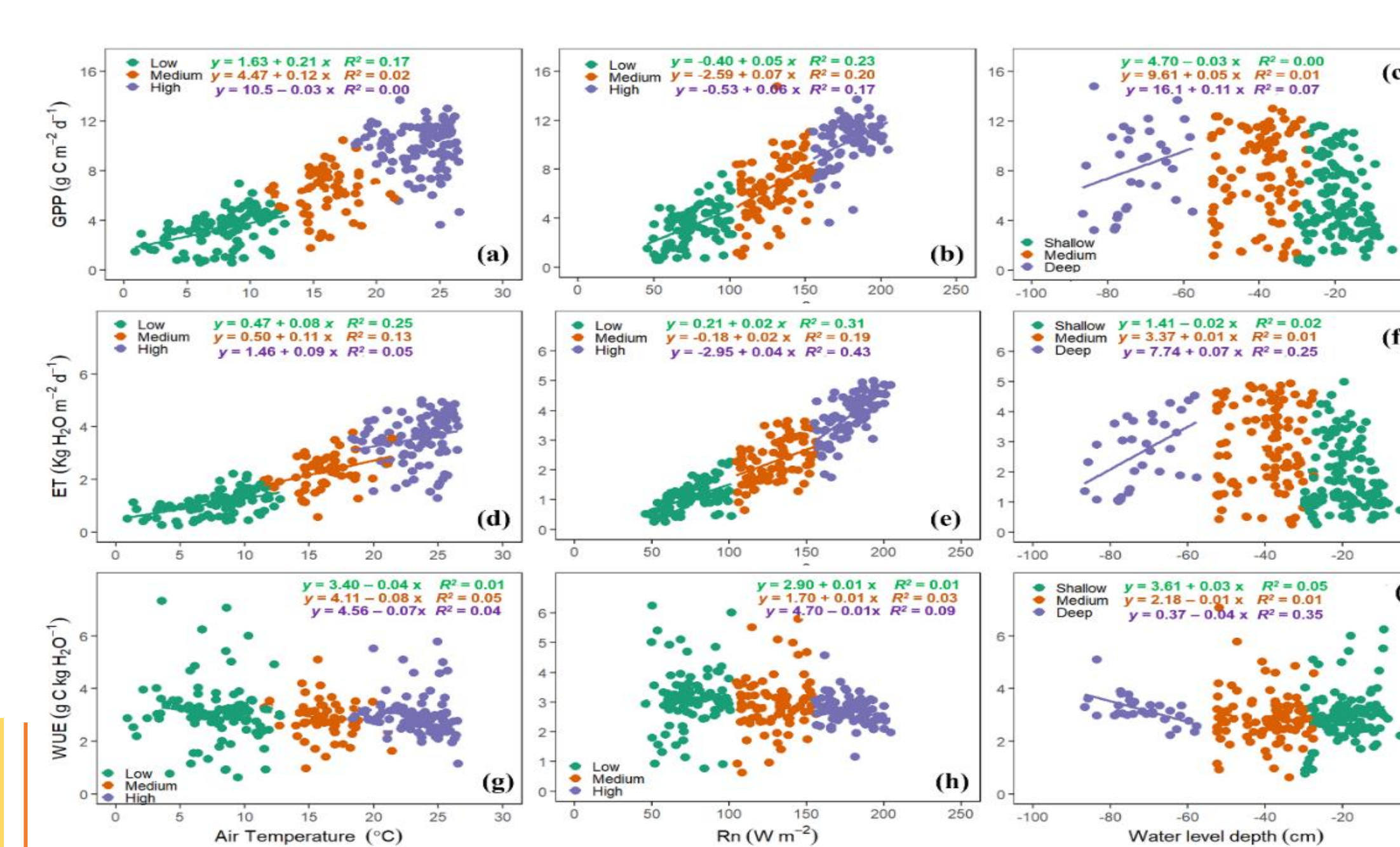


Fig. 7 Relationship of clustered air temperature and net radiation (low, medium, high) and water table depth (shallow, medium, deep) on (a–c) ET, (d–f) GPP, and (g–i) WUE across all years at YP and MP combined.

Drought Effects on GPP, ET, and WUE

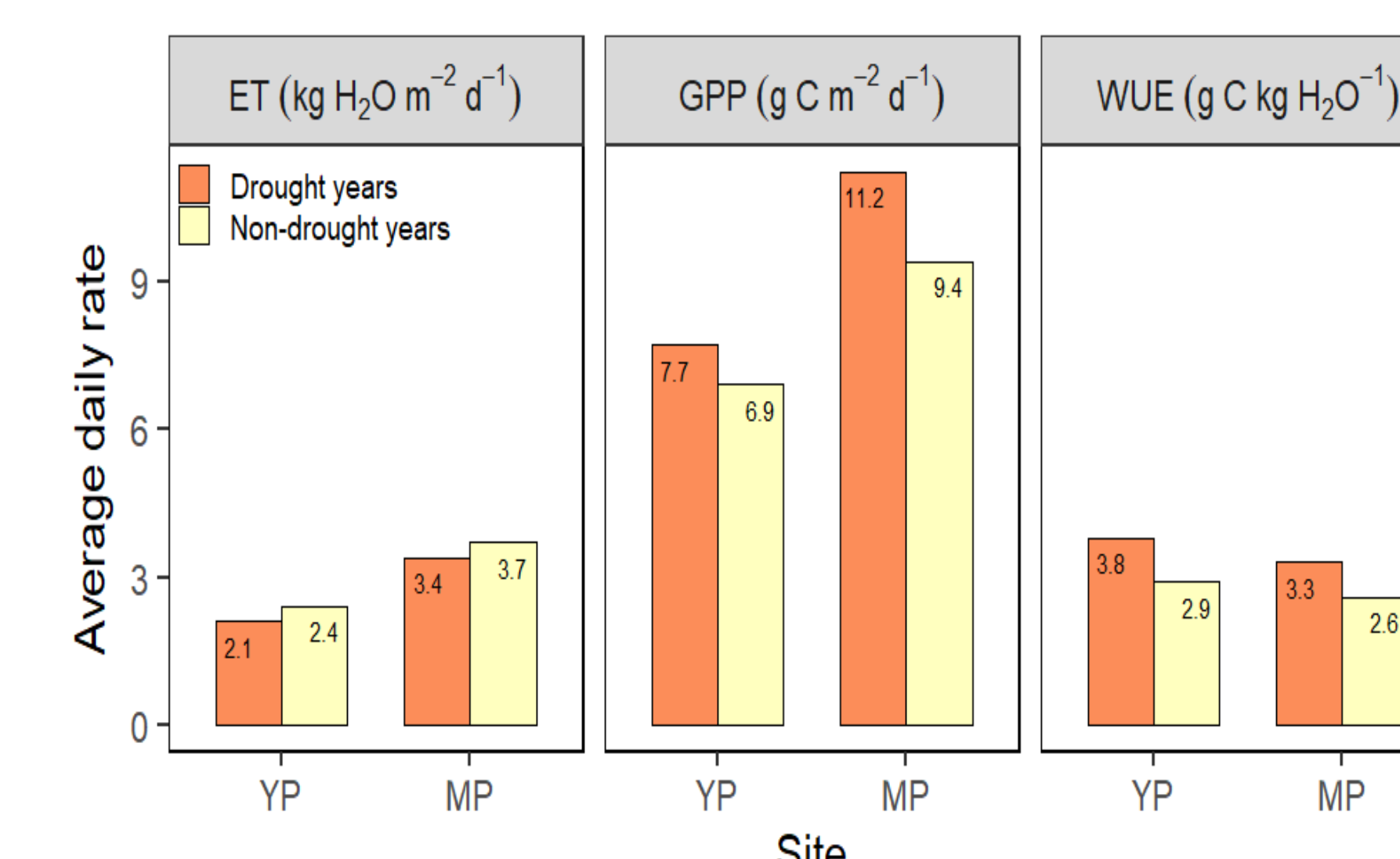


Fig. 8 Daily average ET, GPP, and WUE at YP and MP. Daily values during the growing season (April – September) were averaged during 2007 and 2008 (drought years) and the rest of the years (non-drought years).

Conclusions

- The absence of distinct seasonal and inter-annual patterns in WUE for a mature stand (age > 10) confirms that carbon and water cycles are tightly coupled.
- Although the processes involved in CO₂ and H₂O fluxes varied individually, they converged towards a relatively stable water use efficiency as the pine plantation matured.
- A stable WUE suggests that the pine ecosystem productivity can be readily predicted from ET and vice versa.
- Drought events in 2007/2008 affected little of pine plantation WUE suggesting an effective coping mechanism of pine plantations during drought.
- Our study presents aspects of improving ecosystem models to understand better the trade-off between the carbon absorbed and water released in vegetation–climate–hydrology feedback loops.

Acknowledgement

Primary funding was provided by the USDA NIFA (Multi-agency A.5 Carbon Cycle Science Program) award 2014-67003-22068. Additional funding was provided by the DOE NICCR award 08-SC-NICCR-1072, the USDA Forest Service award 13-JV-11330110-081, and the DOE LBNL award DE-AC02-05CH11231. We are grateful to Weyerhaeuser NR Company for the long-term access to the managed loblolly pine plantations.