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Warming-determined spatial and temporal patterns of forest die-off in Inner Asia

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Outline

- Introduction
- Monsoon-driven forest recession during the Holocene
- Recent forest-growth decline: patterns and drivers
- Semi-arid Inner Asian forests in the future
- Conclusions

I. Introduction

Dynamics of semi-arid forests moderate warming

Desertification over the past several decades contributed negative forcing at Earth's surface equivalent to ~20% of the global anthropogenic CO_2 effect over the same period, moderating warming

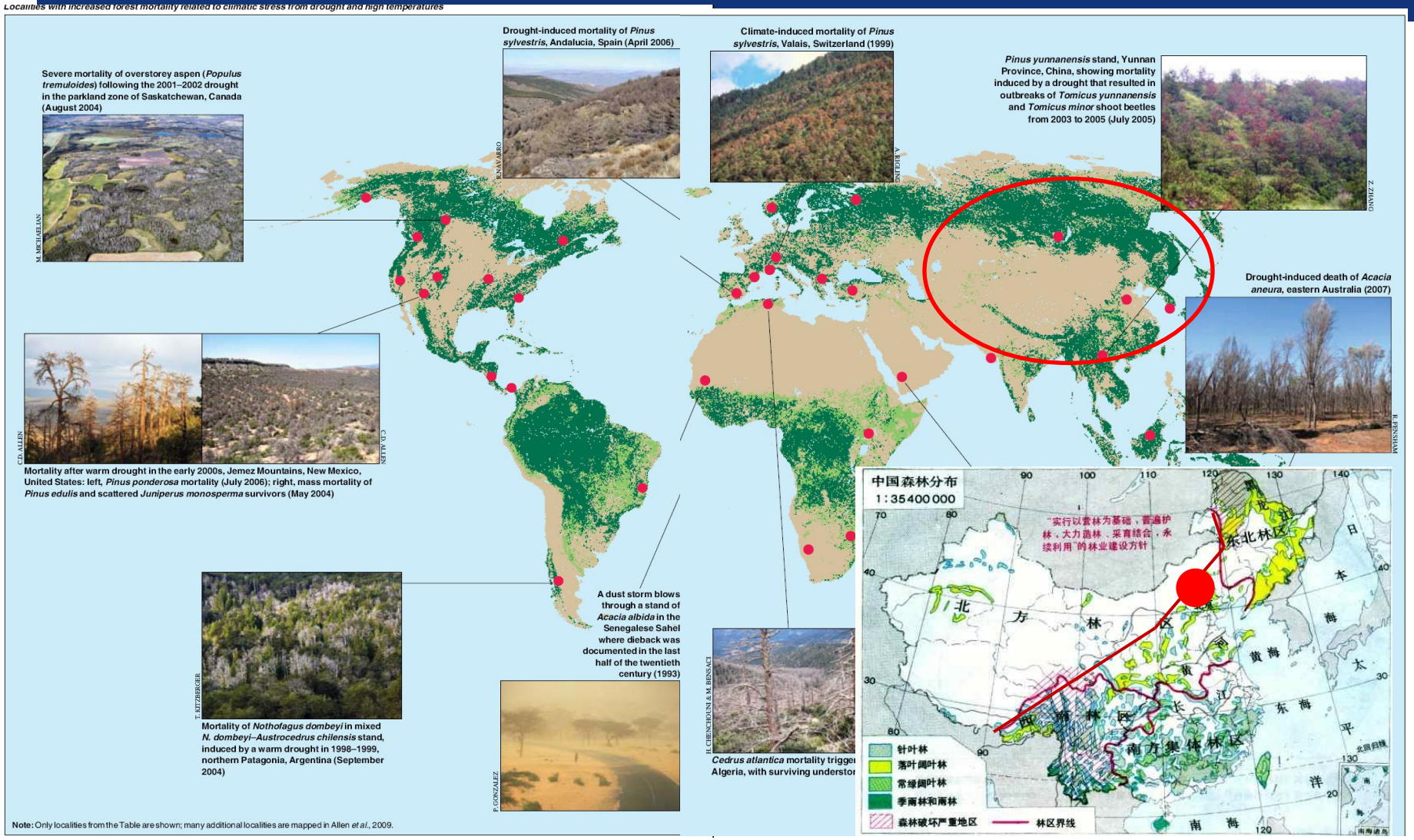
Contribution of Semi-Arid Forests to the Climate System

Eyal Rotenberg and Dan Yakir*

SCIENCE VOL 327 22 JANUARY 2010

I. Introduction

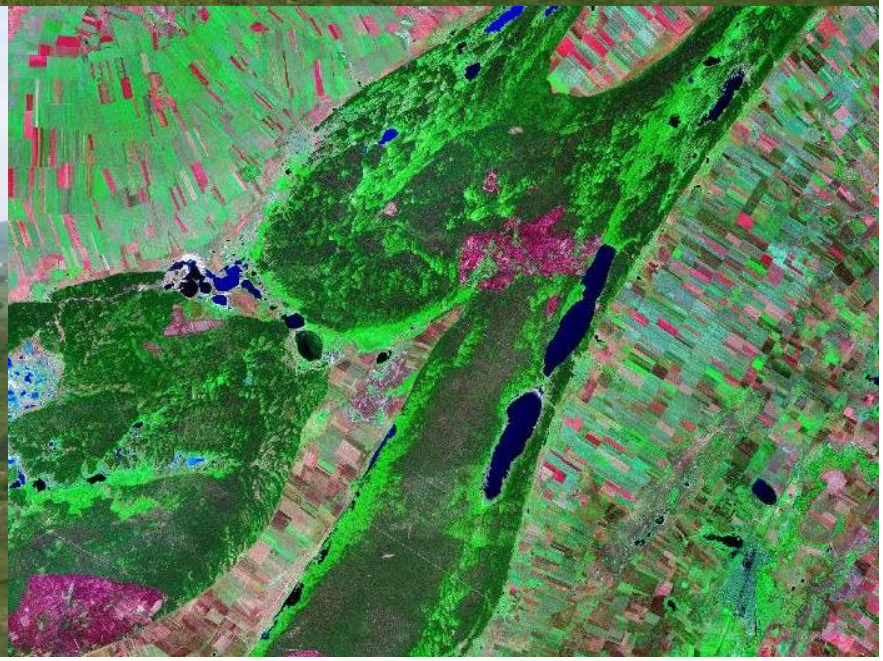
Forest dieback: mostly in semi-arid regions



From Craig C.D. et al., 2009

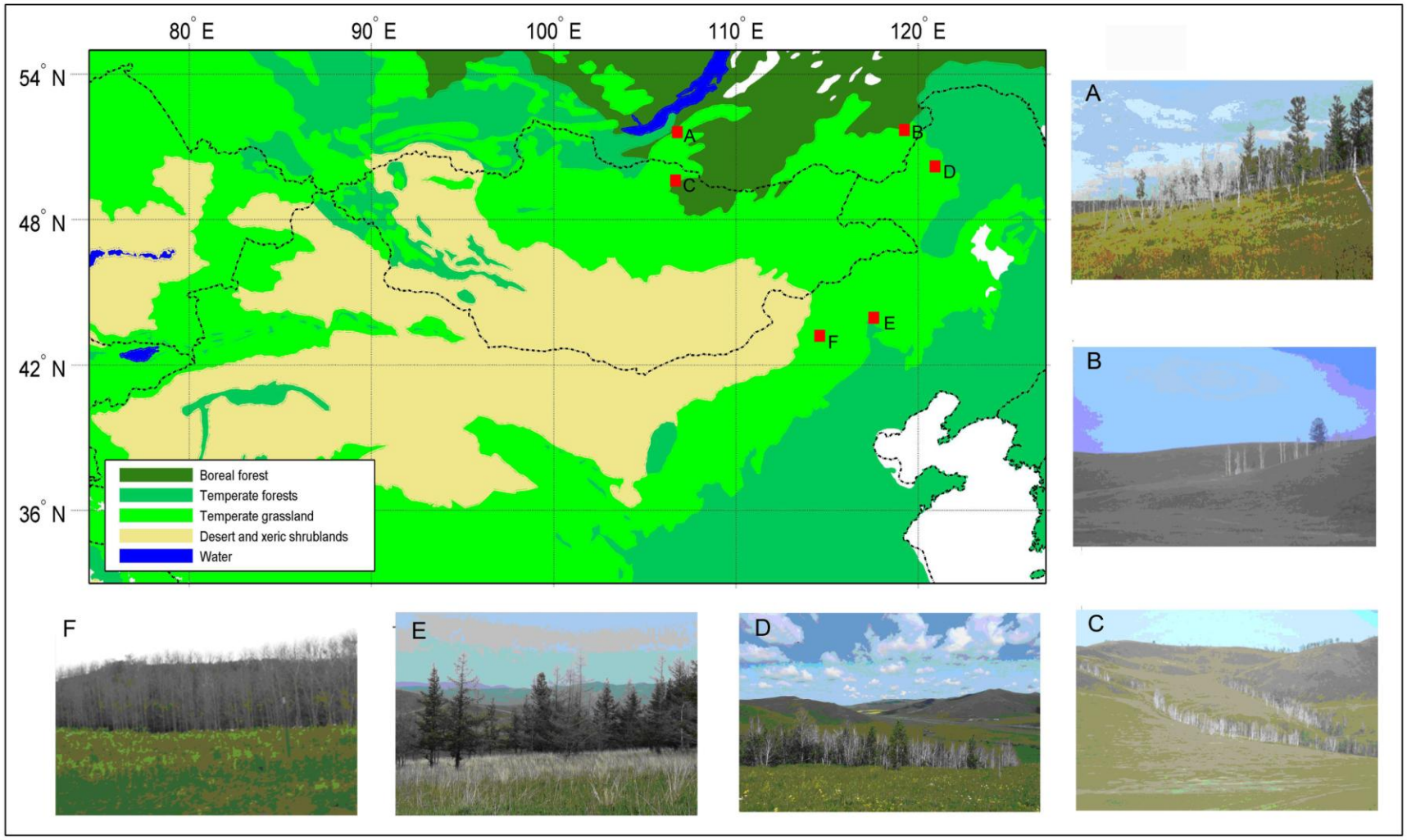
I. Introduction

Semi-arid forests in Inner Asia: an overview



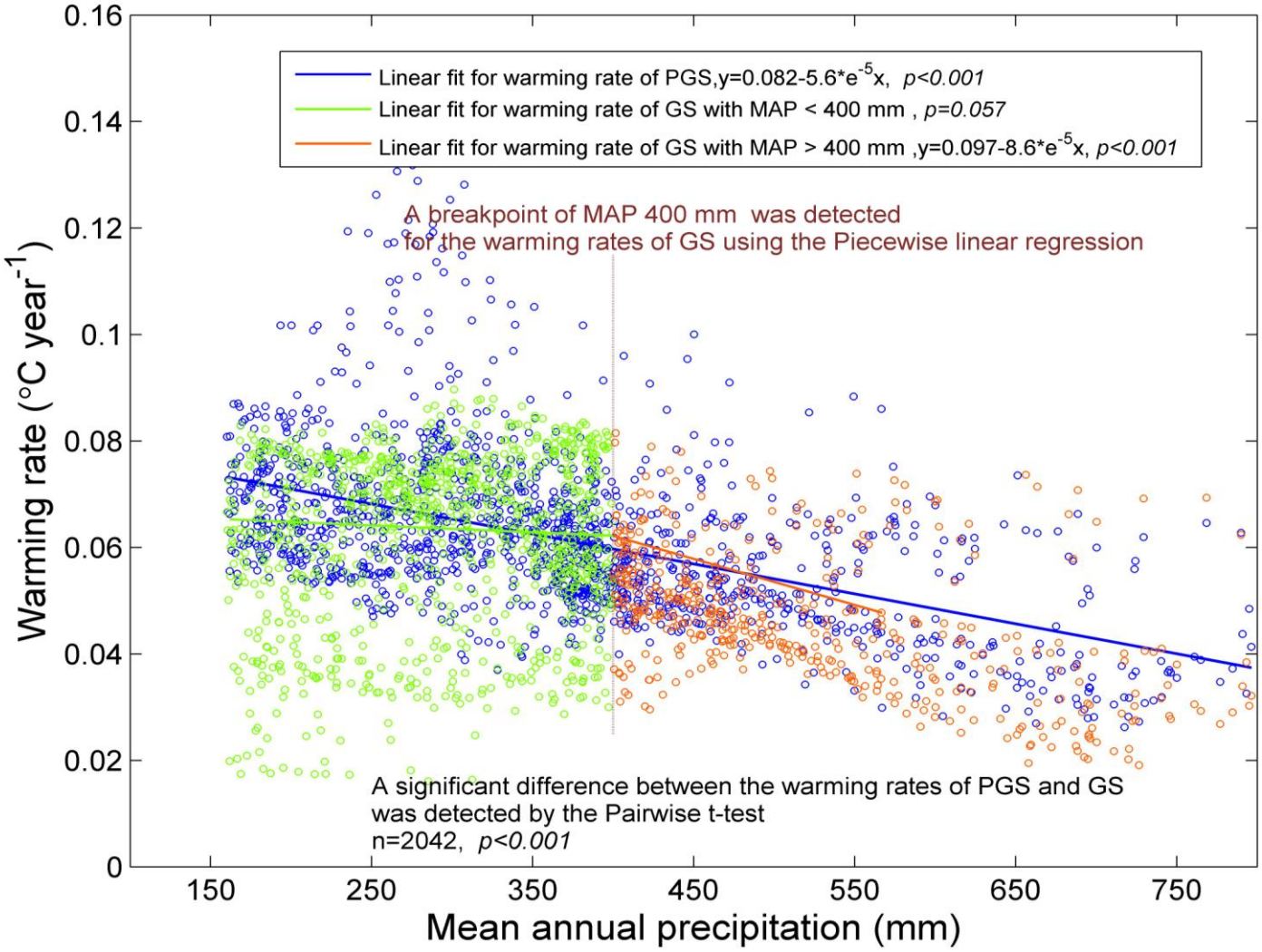
I. Introduction

Forest die-off in Inner Asia



III. Introduction

Faster warming up in dryer region



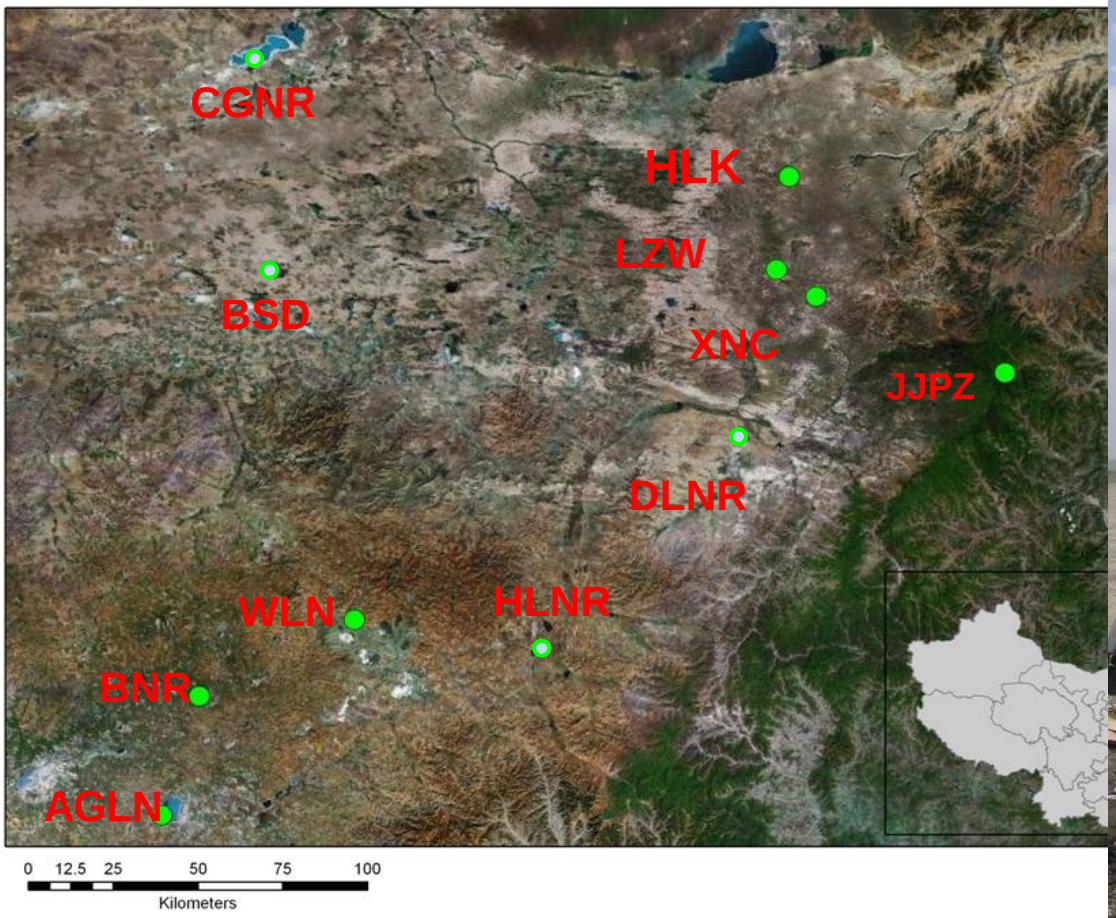
Scientific questions

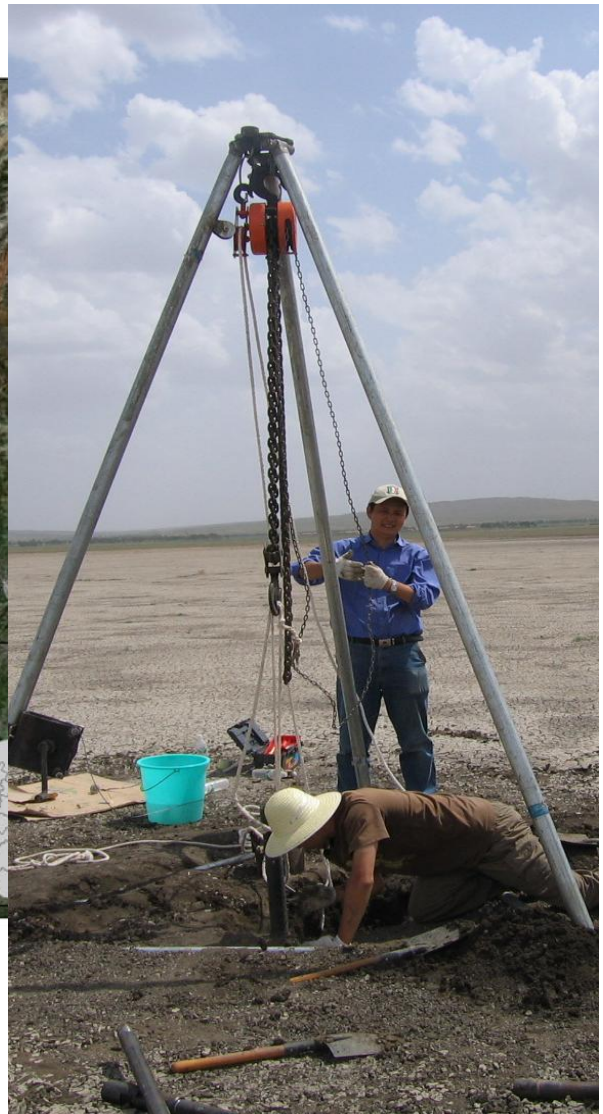
(1) What is the sensitivity of semi-arid forests in Inner Asia?

(2) How has climate-warming caused semi-arid forest die-off in Inner Asia?

(3) How will semi-arid forests in Inner Asia respond the estimated future climate warming?

Samples from semi-arid lakes





Sediment C/N ratio as indicator of biomes

C/N>17.5

Coniferous forest

14.8<C/N<17.5

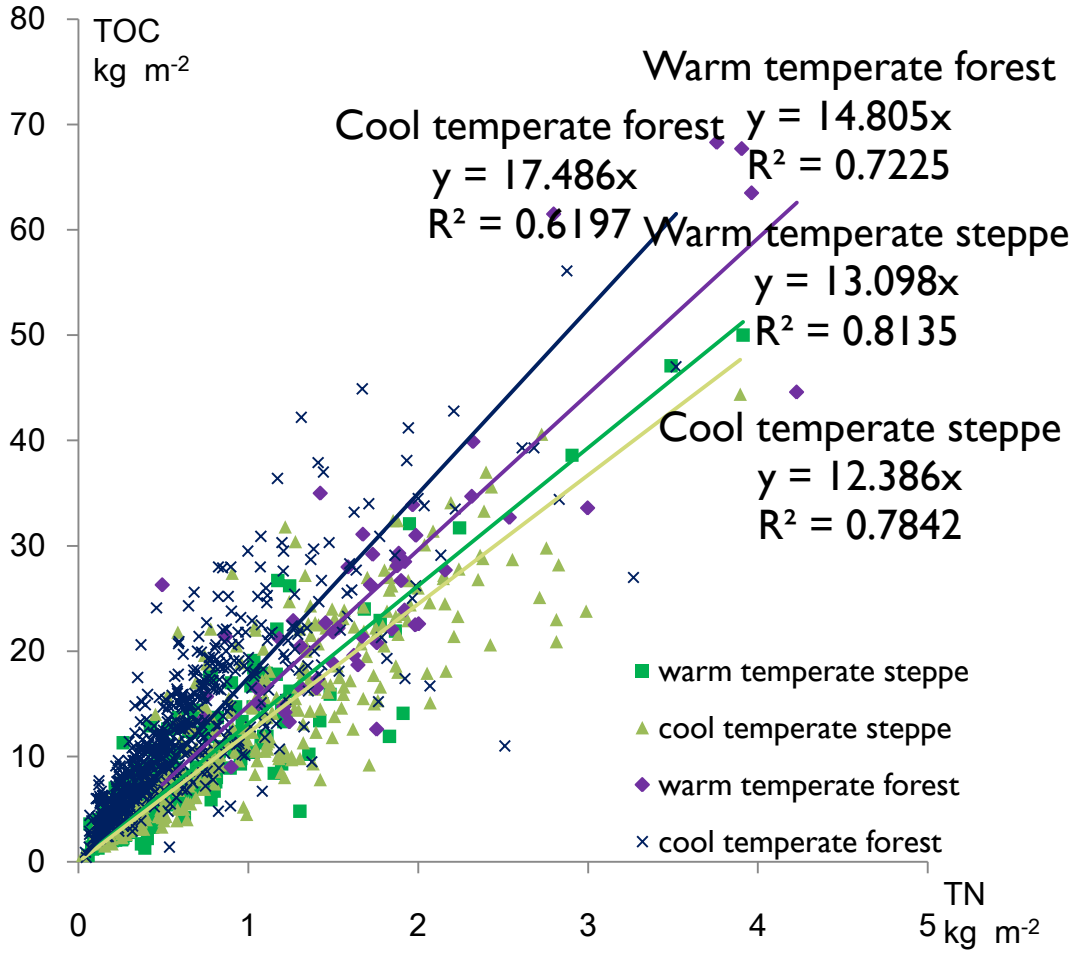
Forest

13.1<C/N<14.8

Forest-steppe ecotone

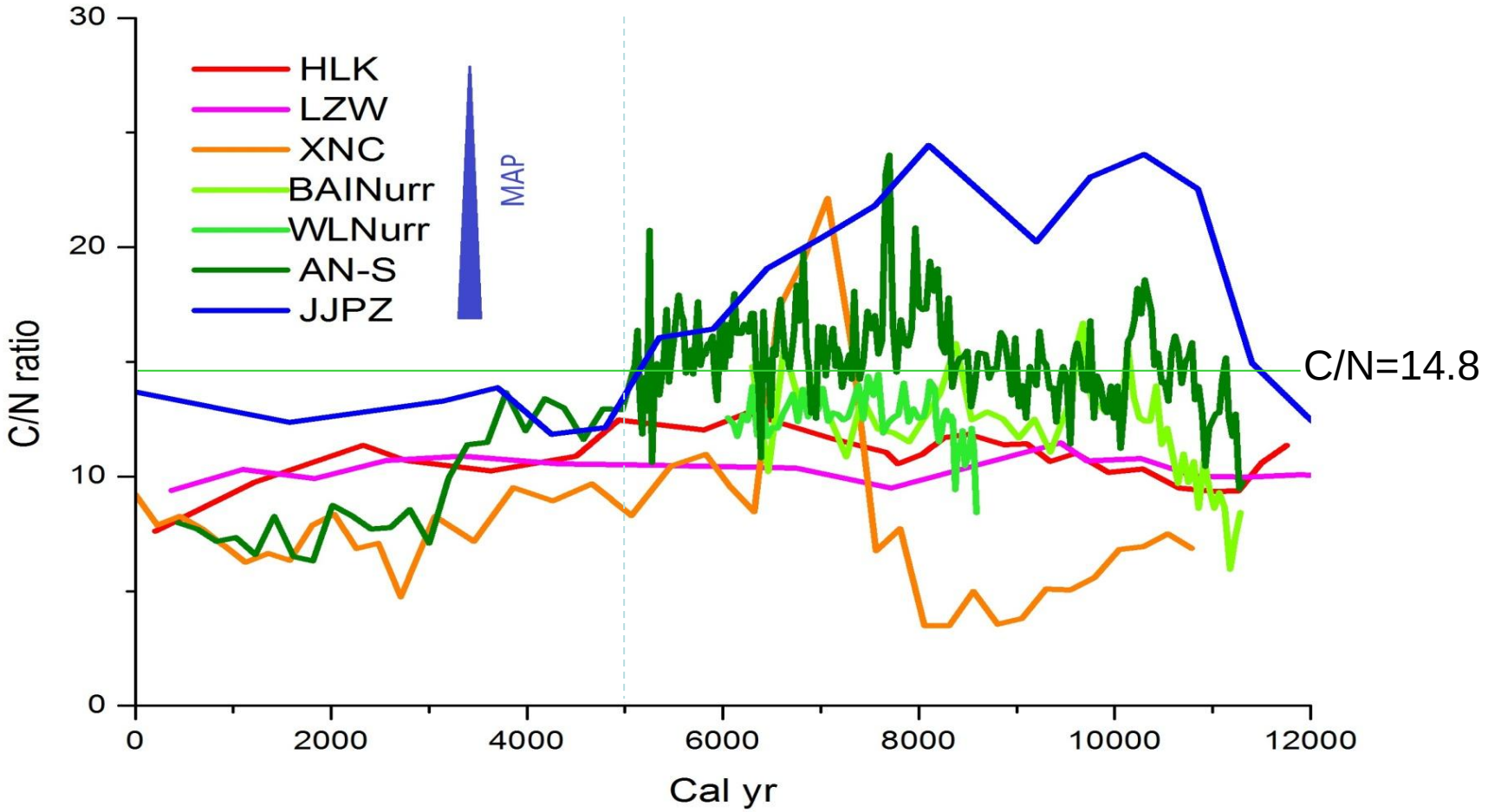
C/N<13.1

Steppe

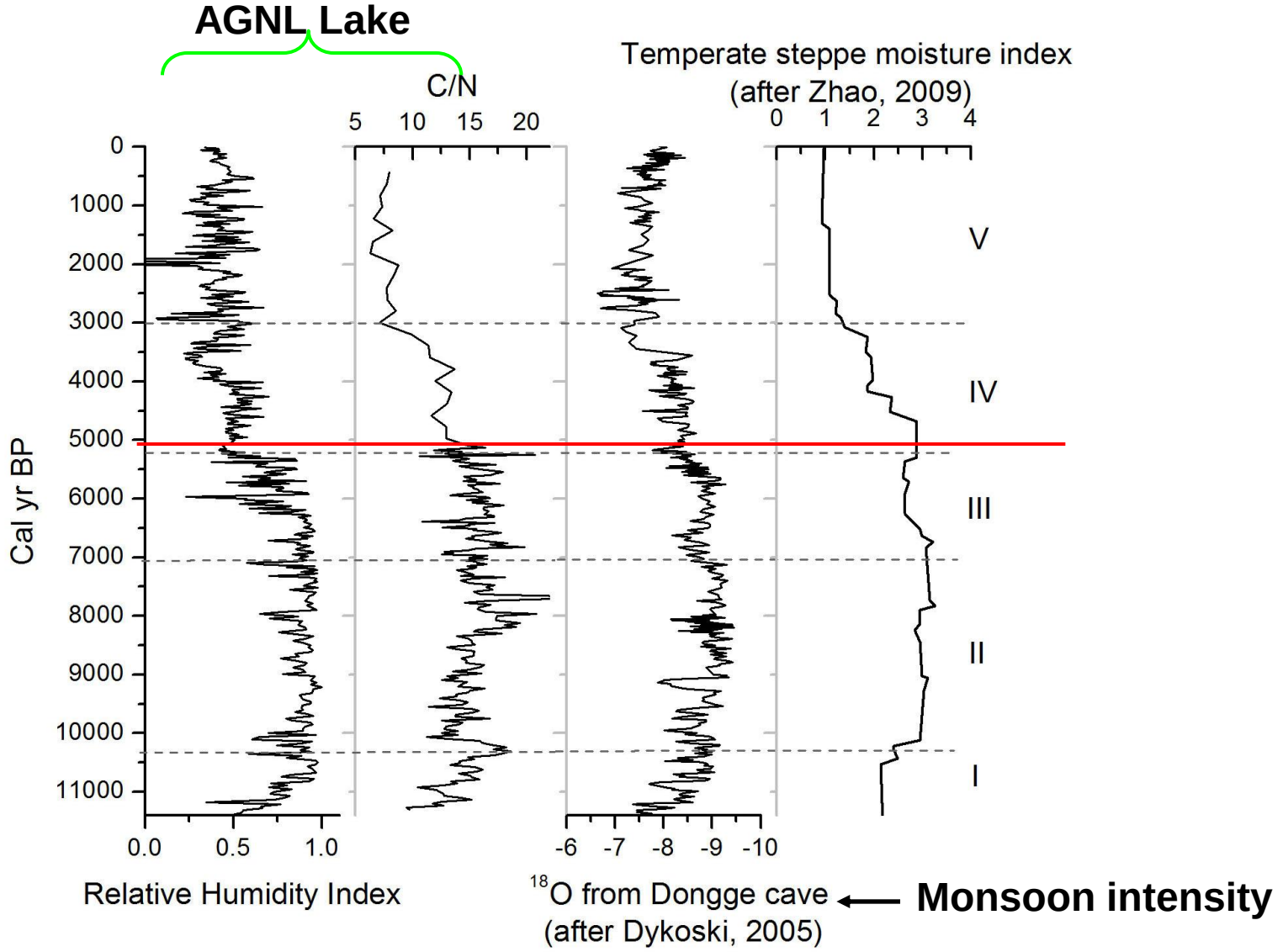


II. Monsoon-driven forest recession during the Holocene

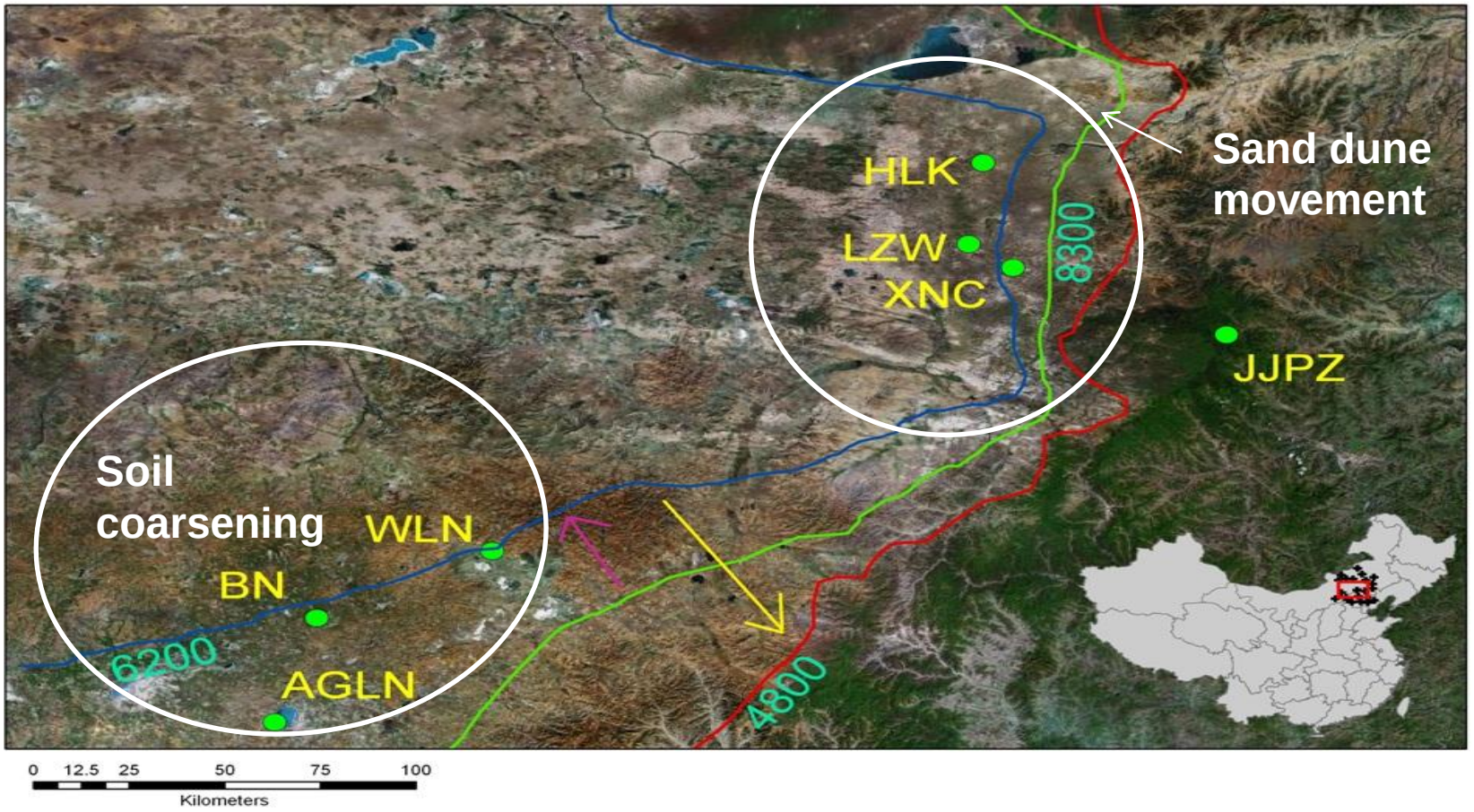
Forest were replaced by steppe or ecotone at 5000 aBP



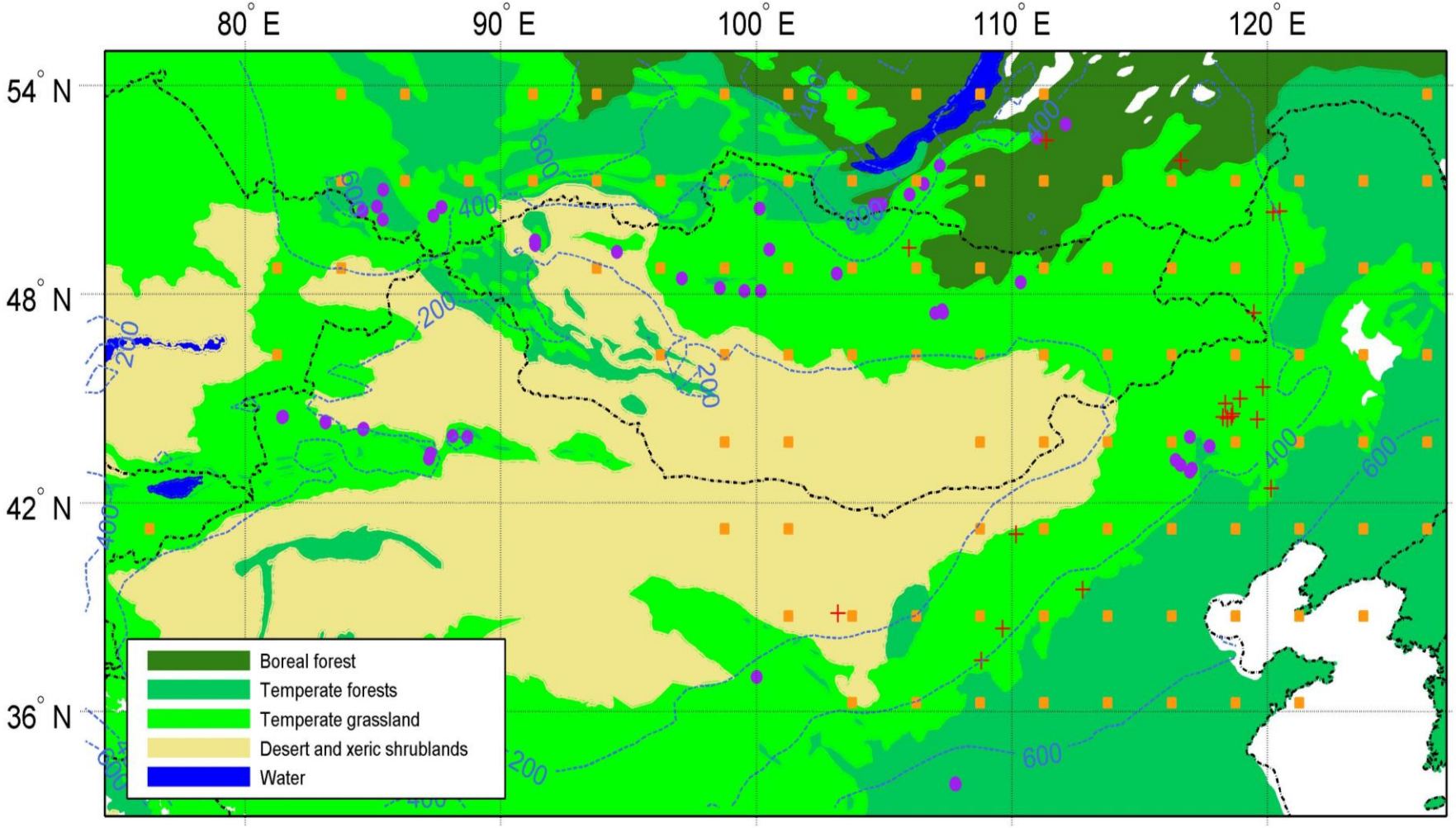
Monsoon-induced forest recession



Shifting of the forest-steppe ecotone

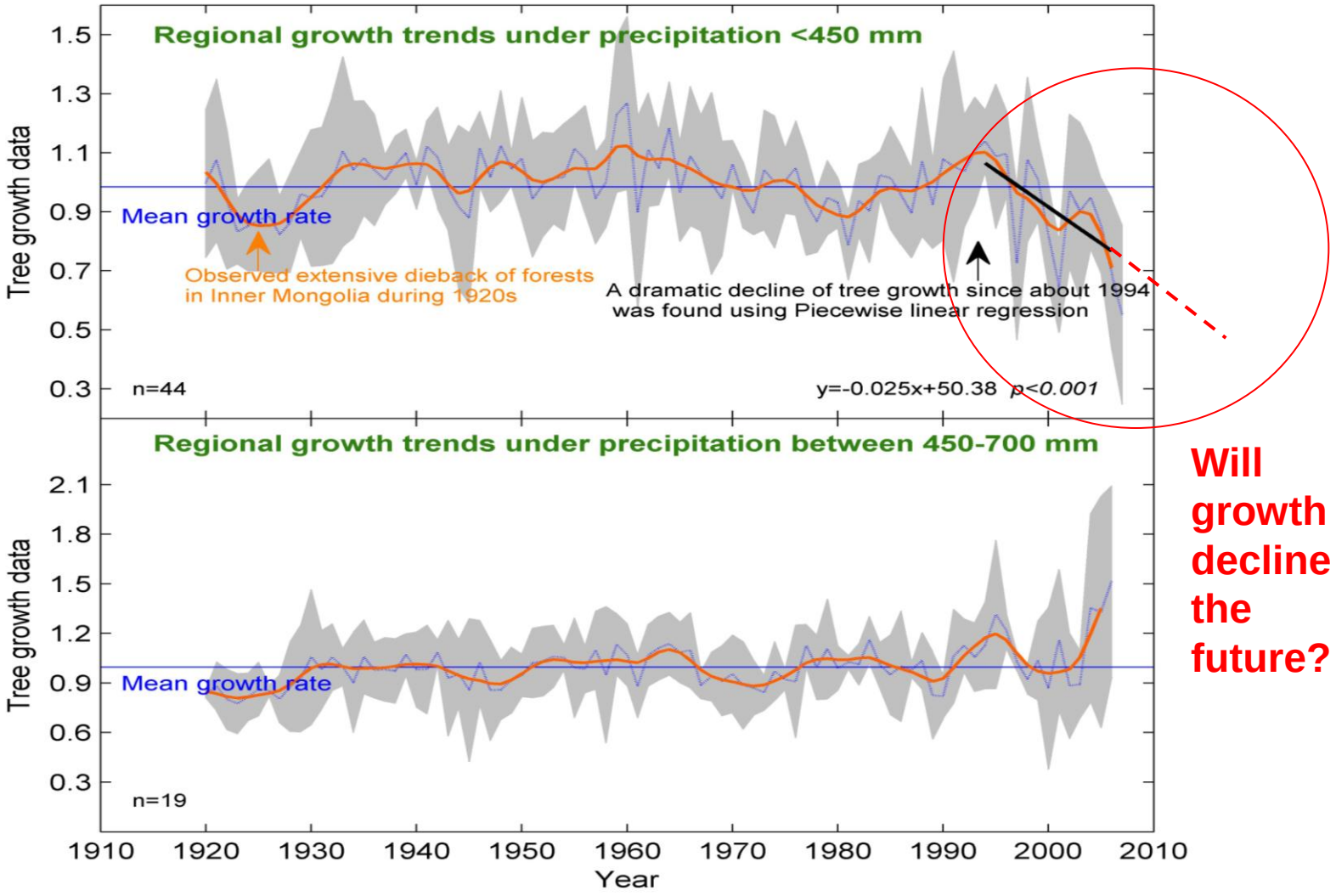


Tree-ring sample sites



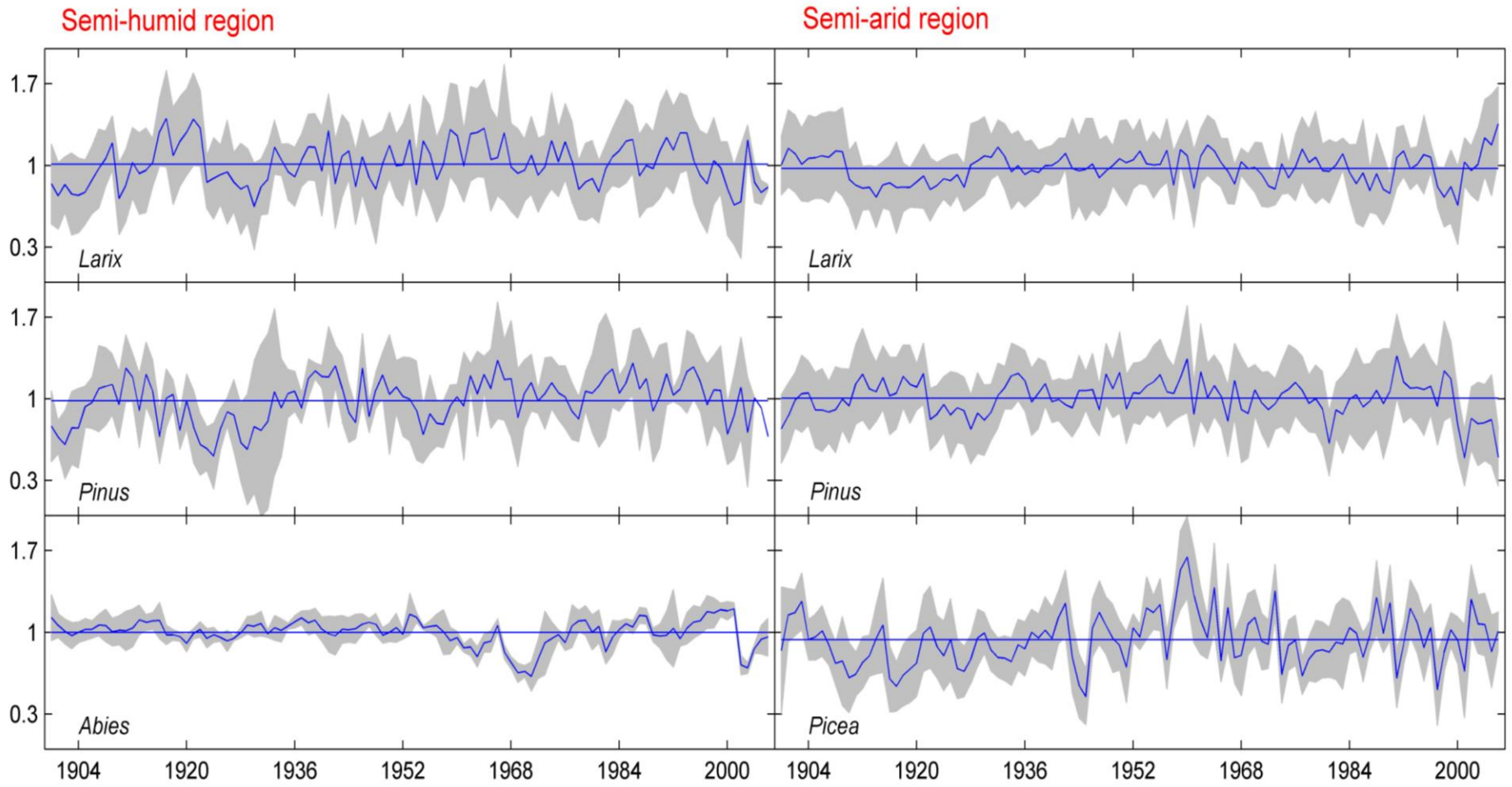
31 plots, 25 m X 25 m size, all trees with d.b.h.> 5 cm were cored

Growth decline in semi-arid region



Will growth decline in the future?

Reponses of tree species

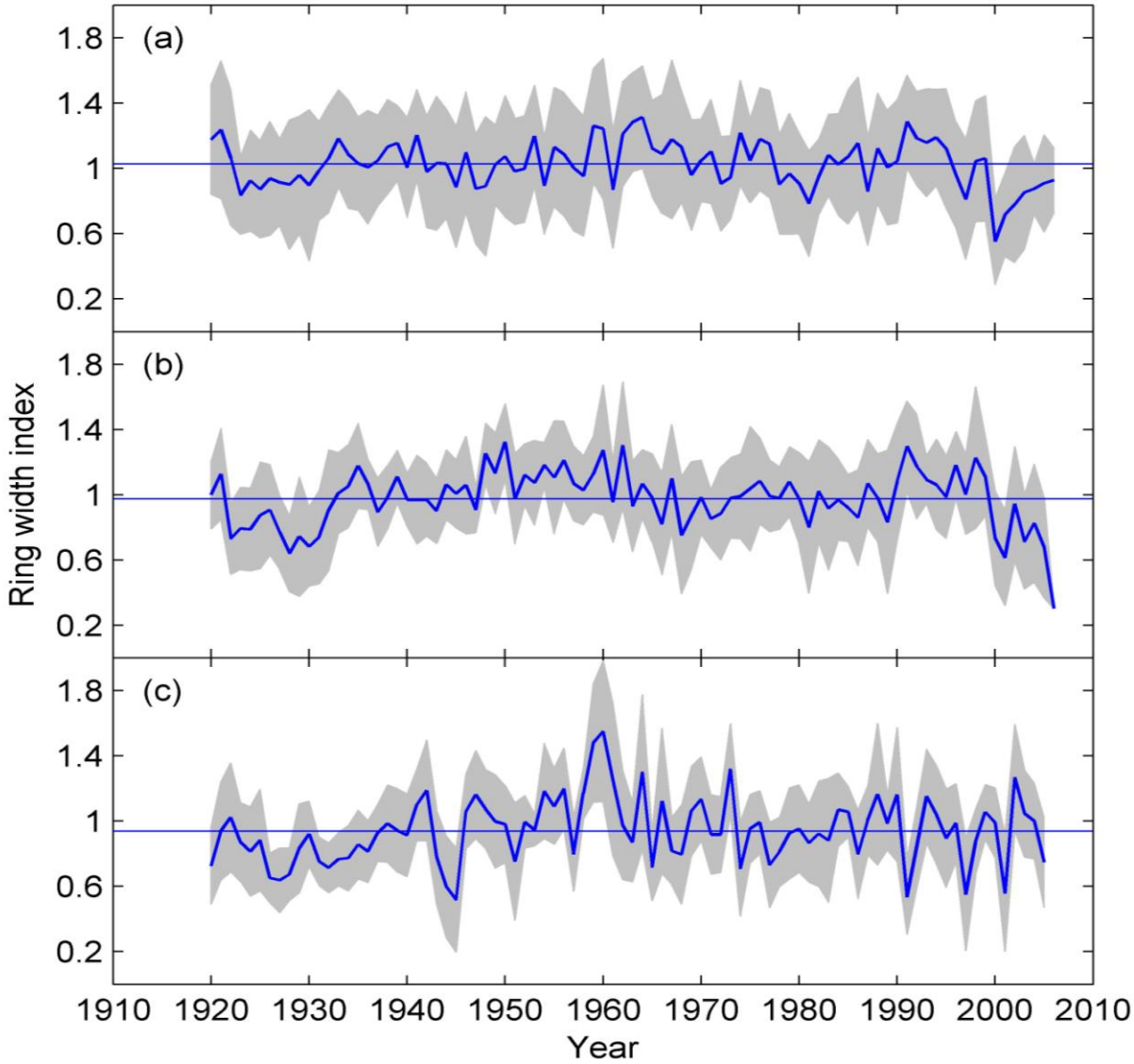


Reponses in sub-regions

Southern Siberia-Mongolia

North China

Northwest China



Regional and tree-species specific growth decline

- **Significant growth reduction in semi-arid pine forest, why?**

  Rapider warming in dryer region ->more evaporation

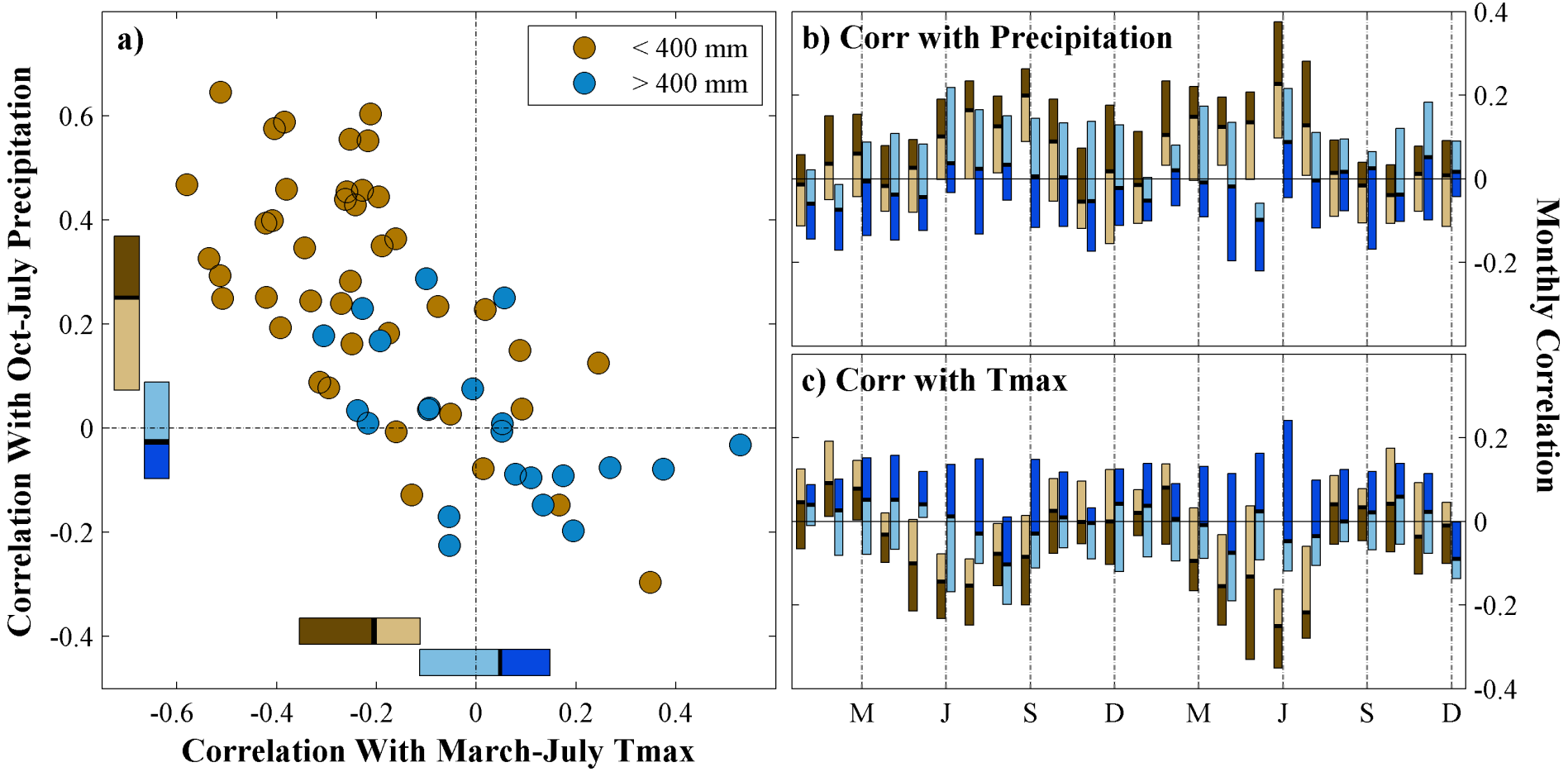
  -> less available soil water -> growth reduction

- **More frequent drought or long drought?**

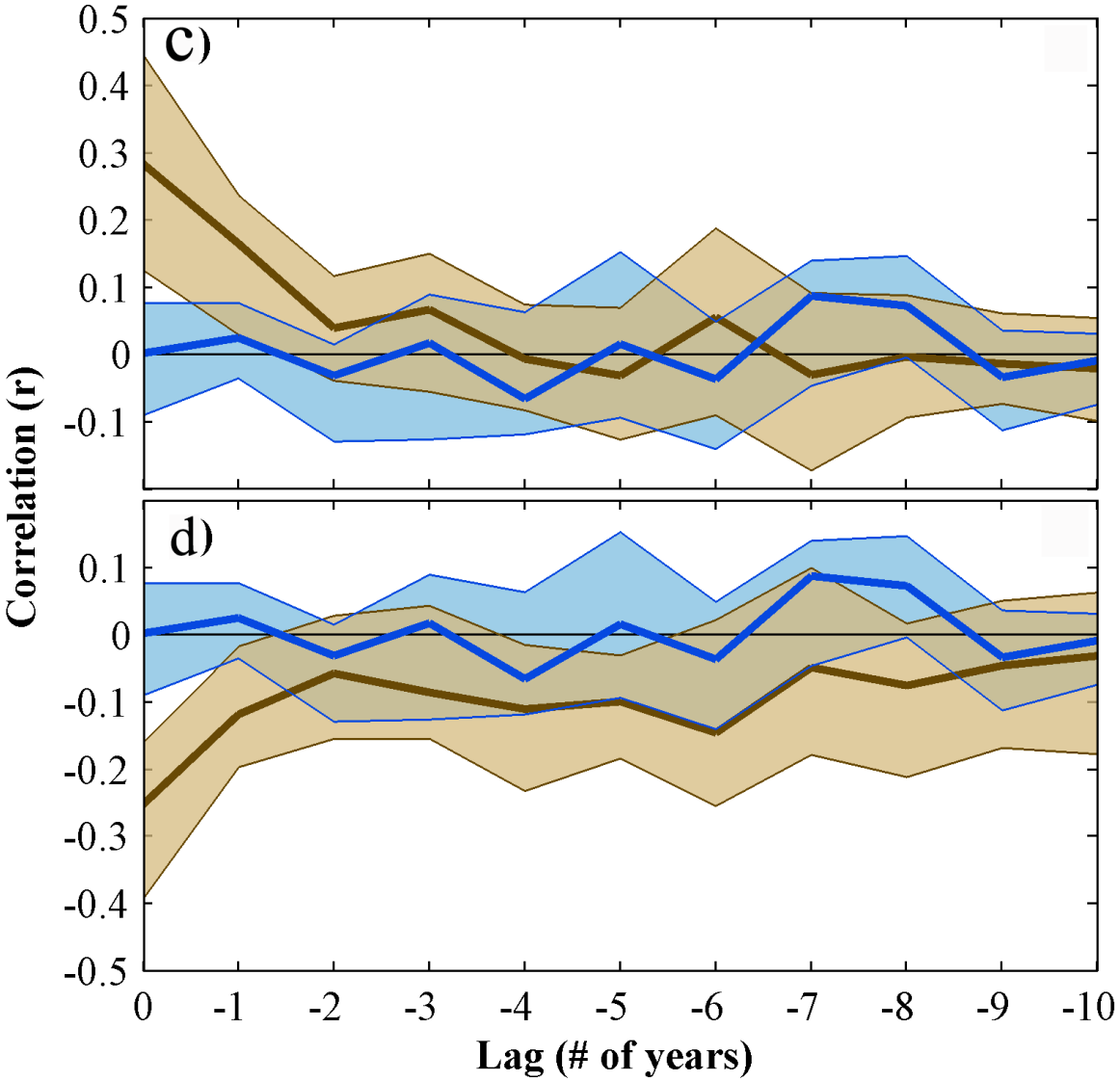
  But in our region we have chronic forest dieback, likely because in winter the temperature is < 0^{o}C and water storage in winter benefits tree growth. Early spring warming could exhaust this water storage.

- **It is therefore hypothesized that early spring temperature is most crucial for tree growth.**

Spatial patterns of forest-climate relationships



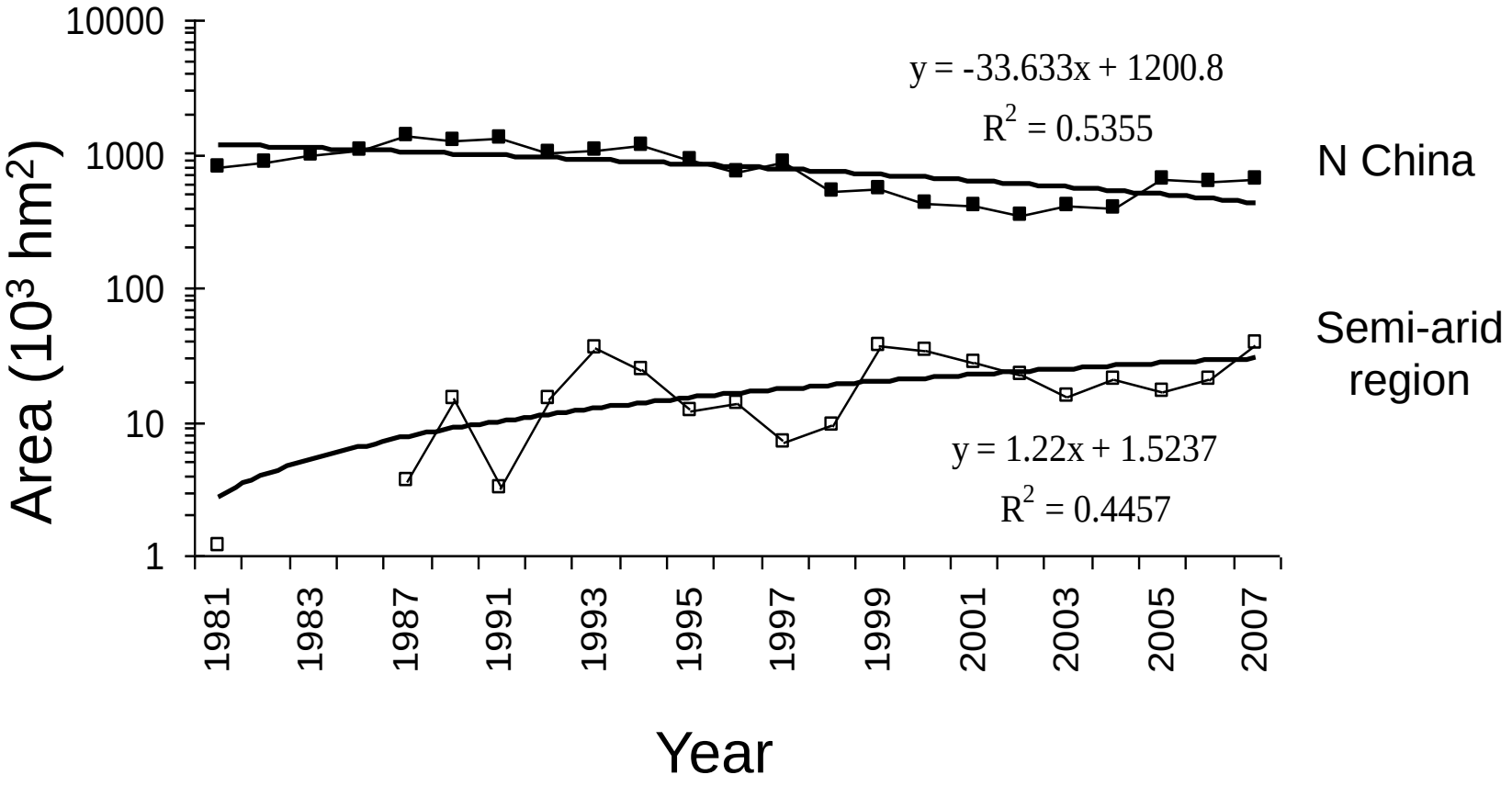
Accumulative drought and tree-growth



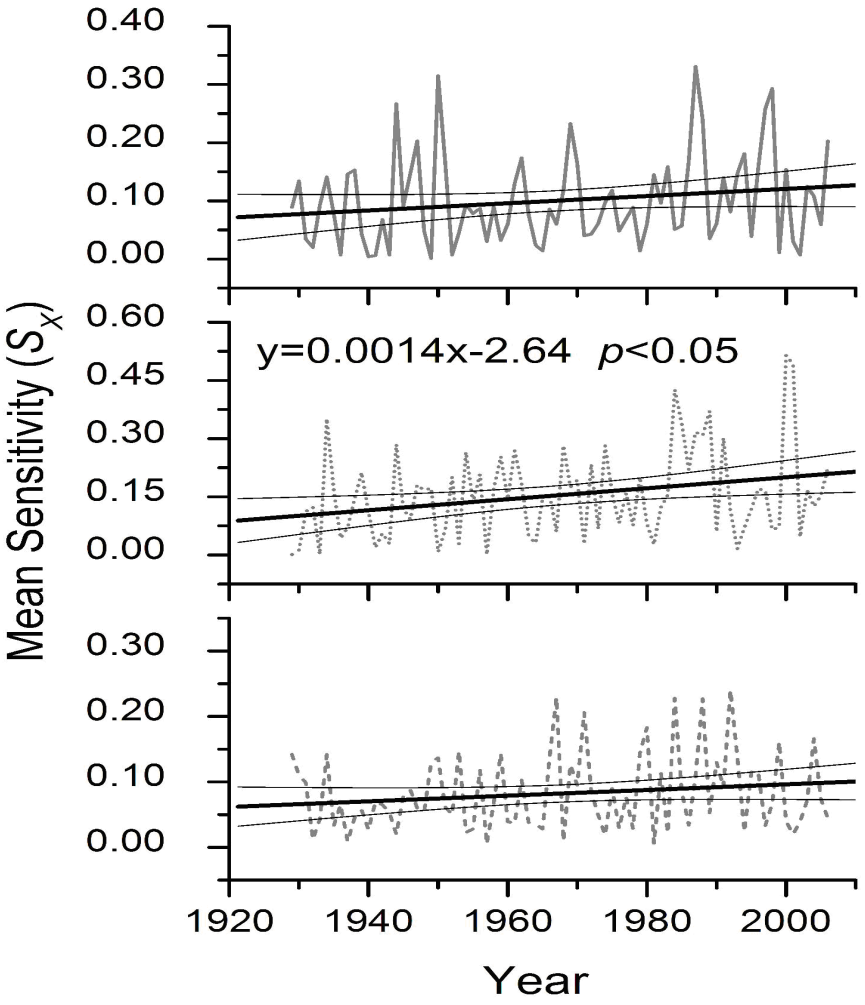
Spring warming as driving factor

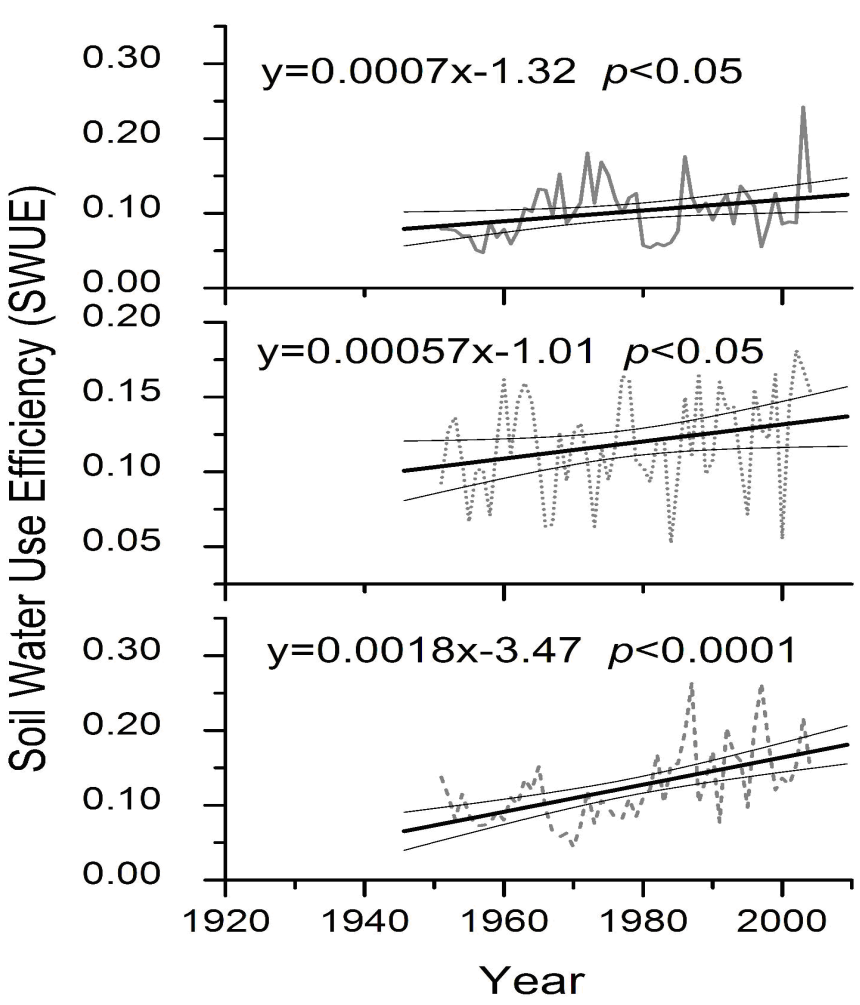
- Rising temperature in spring overly evaporates winter water storage and leads to more frequent drought events in early spring.
- Frequency of spring drought in 1990s is 2.6 times of the average for the last century as a whole, explaining the most recent forest dieback.
- Remaining of this trend in the future will lead to more serious forest dieback and even vanishing of the semi-arid forests.

Forest pathogen attack in N China



Tree-growth sensitivity in S Buryatia



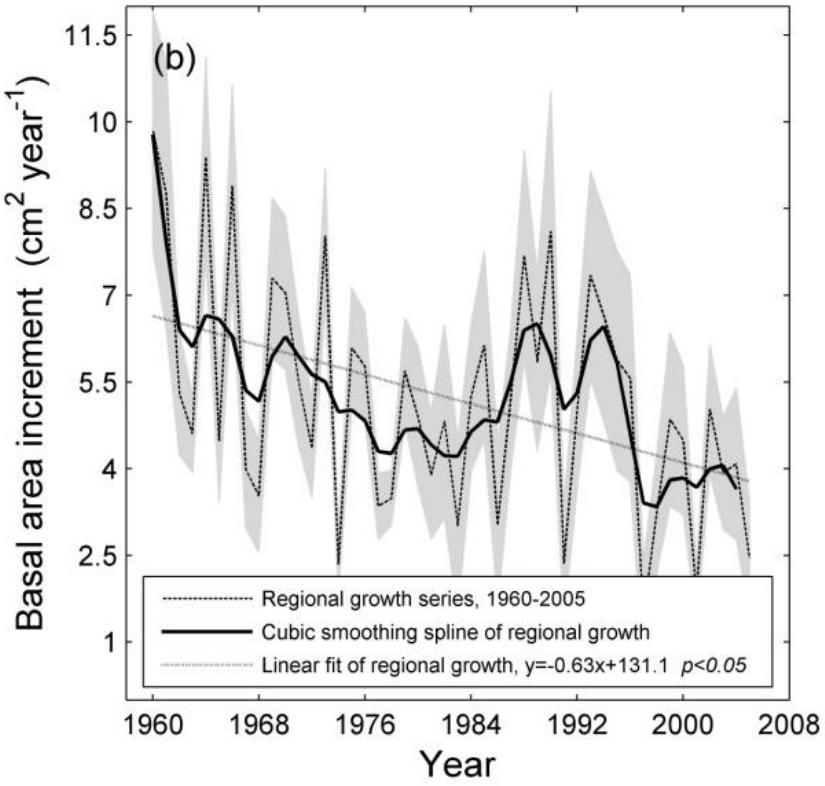


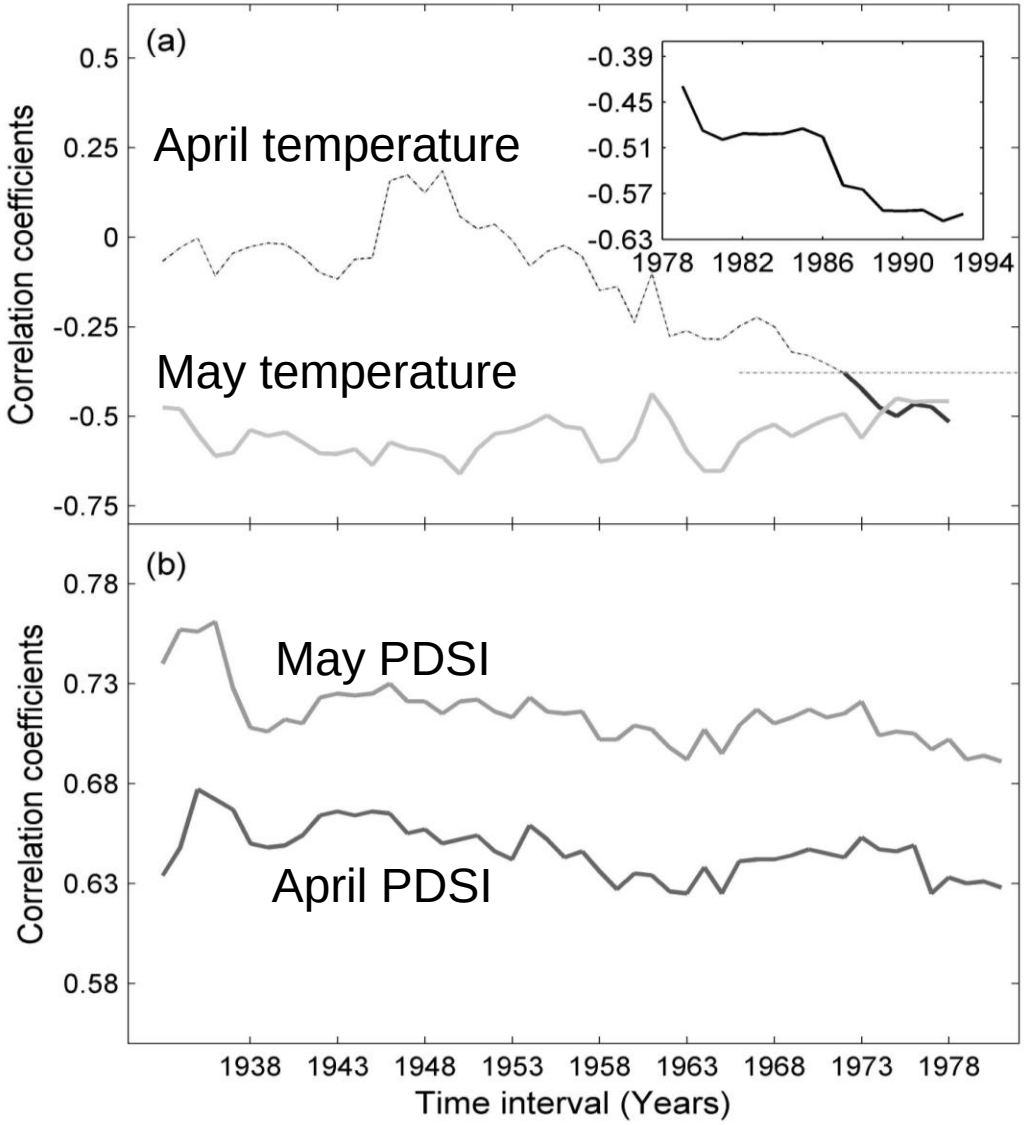
$S_X = 2|I_{t+1} - I_t| / (I_{t+1} + I_t)$

$SWUE = I_t / (PDSI_t + 10)$

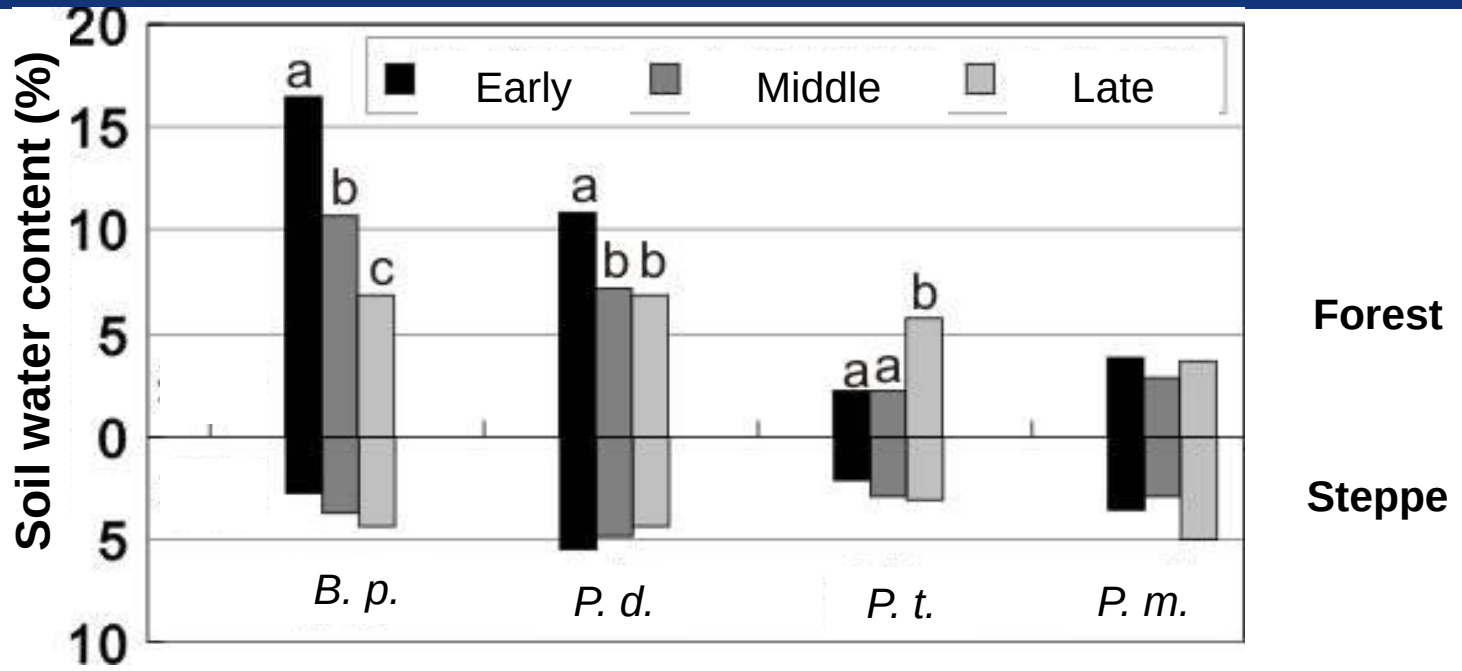
Prolonged limitation by spring warming in NW China

Correlation coefficients between tree ring width index and climate in April and May





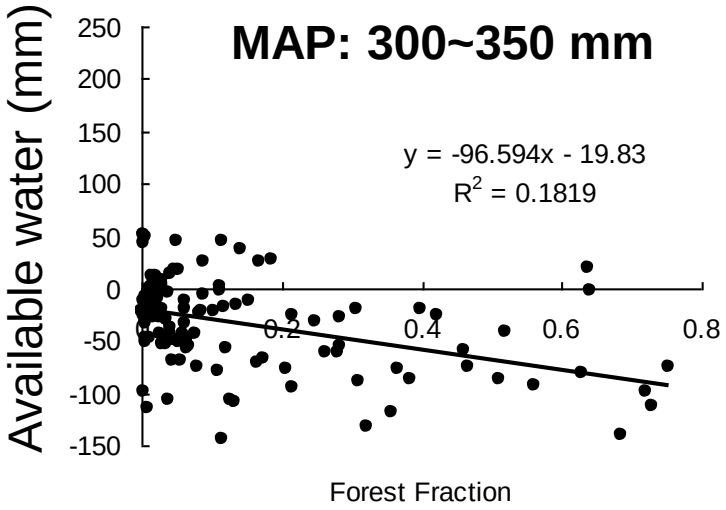
Available water in coarsened soil

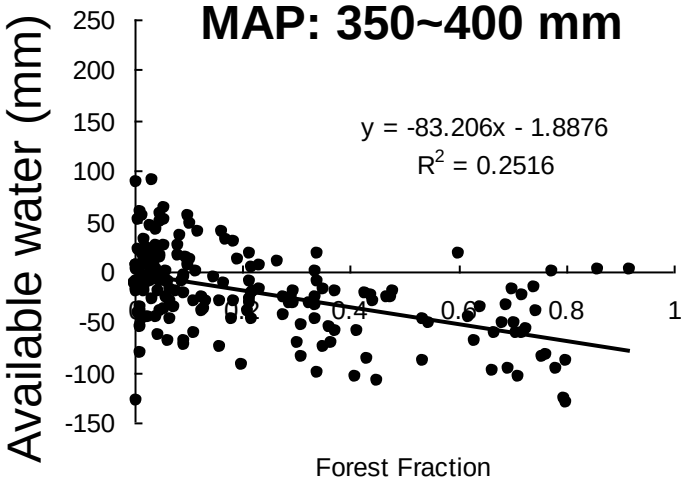


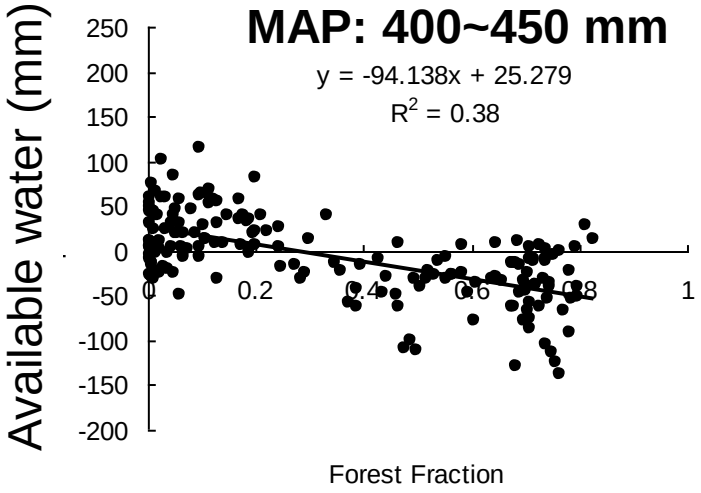
B.p. ***Betula platyphylla;*** **P.d.*****Populus davidiana;*** **P.t.*****Pinus tabulaeformis;*** **P.m.*****: Picea meyeri***

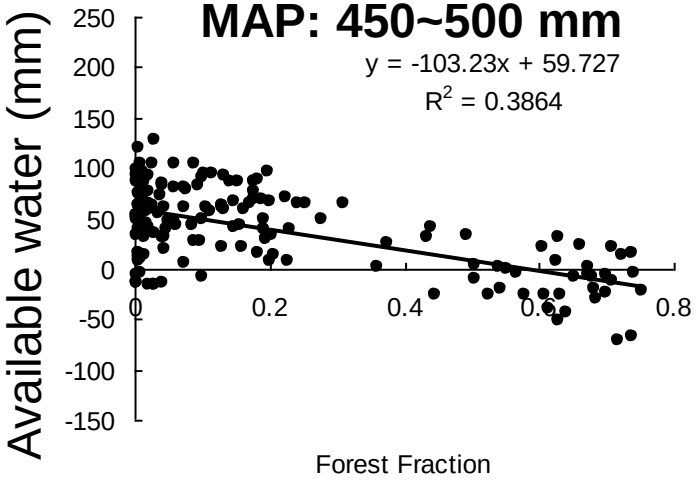
- Soil moisture is higher in deciduous broadleaved forest than in coniferous forest；
- Water consuming is more in deciduous broadleaved forest than in coniferous forest during the growing season

Available water required for forest survival

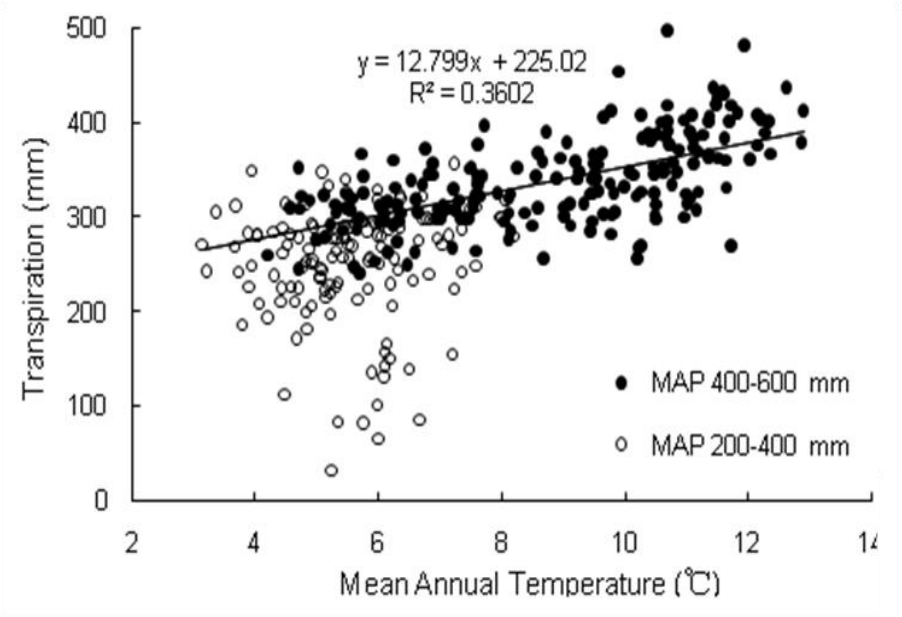






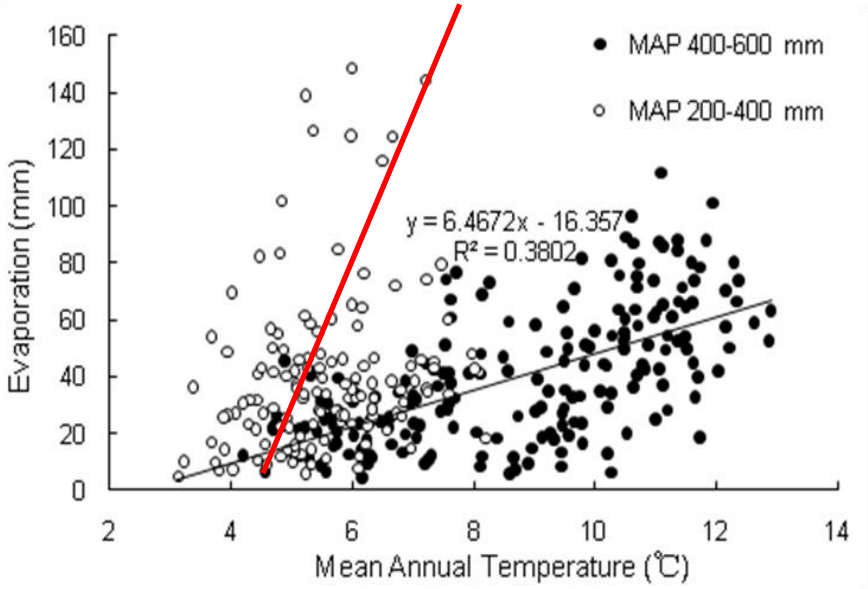


Warming enhanced Water consuming



Climate warming enhance transpiration in both semi-arid and semi-humid regions

Climate warming significantly enhance more evaporation in the semi-arid region than in the semi-humid region



Area for potential afforestation is decreasing!

Conclusions

- Climate drying has led to replacement of forest biomes by steppe as well as soil coarsening; however, forest communities remained, most likely due to available water in coarsened soil;
- Current trend of forest growth decline and die-off is becoming more significant, due to rapider warming in dryer regions. Soil water availability determines tree growth;
- Climate warming, particularly spring warming is increasing evaporation in forest patches, which may further cause forest die-off in semi-arid forests in Inner Asia

Thank you for your attention!

FASTER
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A Sino-Russian Joint Working Team
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Peking University Saihanba Station

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