A Climate-water balance model for whitebark pine distribution modeling within the GYE

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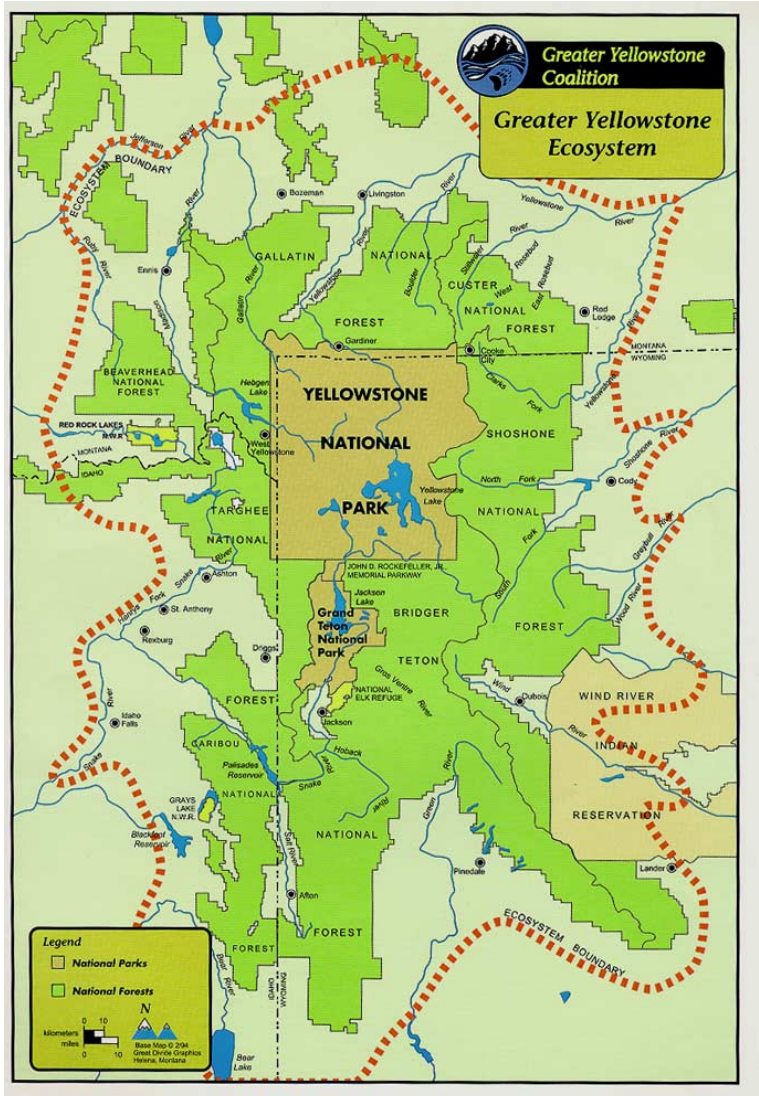
Introduction

Study area



The Greater Yellowstone Ecosystem encompasses Yellowstone National Park, Grand Teton National Park, and 10 wilderness area.

Introduction

Climate change in the Greater Yellowstone Ecosystem

Play movie here

1. The mean temperature of the GYE has seen a 0.6°C increase in the last 30 years
2. Warming is effecting alpine regions ($>$ 2250m $\approx$ 7500ft) elevations, the habitat of Whitebark Pine (aka WBP)
3. Projected warming in the next century to exceed 3°C across the region

Methods

1. Summarize PRISM climate dataset for the GYE spatial domain at 30 arc-second resolution (Daly et al 2002)
2. Construct water balance model for predictor variable dataset
3. Calibrate Random Forest model given Forest Inventory Analysis (FIA) and Whitebark Limber Pine Information System (WLIS) presence and absence dataset
4. Generate prediction probability across all cells within GYE spatial domain (Breiman 2001)

Water balance model

Thornthwaite method for calculating AET and deficit (Thornthwaite 1948, Dingman 2002)
We calculate the melt factor F_m

$$\begin{aligned} T_a \leq 0^oC &: F_m = 0 \\ 0^oC < T_a < 6^oC &: F_m = 0.167 T_a \\ T_a \leq 6^oC &: F_m = 1 \end{aligned} \tag{1}$$

where T_a is the mean monthly temperature, we then estimate the amount of rain and snow from the known P_m precipitation values:

$$\begin{aligned} RAIN_m &= F_m P_m \\ SNOW_m &= (1 - F_m) P_m \end{aligned} \tag{2}$$

Water balance model

We then determine the monthly total accumulated snow pack $PACK_m$ and snow melt $MELT_m$

$$\begin{aligned} PACK_m &= (1 - F_m)^2 P_m + = (1 - F_m) PACK_{m-1} \\ MELT_m &= F_m (SNOW_m + PACK_{m-1}) \end{aligned} \tag{3}$$

The monthly water input W_m to the system (or individual cell) is:

$$W_m = RAIN_m + MELT_m \tag{4}$$

Water balance model

The point is that we want to find out the soil moisture. & ET

$$SOIL_m = \text{minimum}[SOILmax, [(W_m - PET_m) + SOIL_{m-1}]] \quad (5)$$

But soil moisture evaporates so we need that rate PET_m:

$$PET_m = 29.8 * nDays * Daylength * \frac{e_a(T_a)}{T_a + 273.2} \quad (6)$$

e_a is the saturation vapour pressure at T_a:

$e_a = 0.611 \exp(\frac{17.3 T_a}{T_a + 237.3})$

Results

Random Forest model of WBP distribution

Results

Projection scenario 1: RCP 4.5 650 ppm CO_2

Results

Projection scenario 2: RCP 8.5 1464 ppm CO_2

Conclusion

1. 80% mortality of WBP already in GYE (MacFarlane et al 2013)
2. Whitebark pine climate envelope projected to reduce significantly over the next century
3. Active management should be considered for conservation of species