# Methods

## Study System

Kruger National Park serves as an ideal study system for questions of savanna fire ecology. Kruger NP is located in eastern South Africa, sharing its eastern borders with Mozambique and northern border with Zimbabwe. The park is over 2 million ha, and spans 350 km from north to south. A north-south rainfall gradient spans the park, peaking at 950 mm yr-1 in the southwest and <400 mm yr-1 at Pafuri in the northeast{Mabunda:2003vc}}. The park’s soils vary in productivity based on their parent material: in the west, low fertility granite, and to the east, high fertility basalt{Mabunda:2003vc}}.

Fire is common in Kruger NP, and much of it is anthropogenic in origin \cite{VanWilgen:2000tc}. Fires vary in seasonality, intensity, and frequency, and are used by Kruger NP managers to meet specific and general objectives {Govender:2006im, Govender:2003uo}.

## Model Description

The model simulates a cohort of trees for a given mean annual rainfall (MAR). The trees grow annually as a function of MAR ({Higgins:2000up, Shackleton:ua}). This rainfall is sampled from a range within the 95% confidence interval of the modeled bivariate relationship between mean fire return interval and MAR at Kruger National Park . Each year, the occurrence of a fire is calculated by sampling from a binomial distribution with a probability equal to the inverse of the sampled mean fire return interval (i.e., the fire frequency (fires yr-1)). If a fire occurs, the intensity of the fire is calculated as a function of MAR following Govender et al. (2006). Probability of topkill was calculated as a function of height and intensity {Higgins:2012fc}

## Growth rates

We compared three different potential growth scenarios with regard to rainfall: positive, negative, and flat. The initial scenario was first outlined in Higgins et al. (2009) and described a general increase in growth rates (height increments, cm yr-1) across a rainfall gradient. This growth relationship was generalized from a study across South Africa ({Shackleton:ua}). We fit a linear model to this relationship so that we could predict growth rates anywhere along the curve.

For the negative relationship, we mined the data for diameter and height increments for a known dry site specialist, *Colophospermum mopane* (cite vegetation of southern Africa, coates and palgraves). We hypothesized that because of their range limitation, decreased growth rates in areas of increased MAR would be observed. Where necessary, we standardized the diameter increments to height increments using height ~ basal diameter relationships taken at Kruger National Park (Cummings and Holdo 2014, Unpublished Data).

For the null relationship, we combined growth rates used in the calibration of the negative and positive models and fit a generalized linear model to them that assumes no relationship with rainfall.

## Mean Fire Return Interval and MAR

Gridded mean annual rainfall from worldclim was overlaid across the rasterized mean fire return interval (MFRI) for Kruger National Park, South Africa {WorldClimversion:2005tr} **CITE SMIT**. Smit et al. (**year)** mapped fire extents from a **n** year period at Kruger National Park to calculate mean fire return interval. We modeled MFRI as a function of MAR by fitting a generalized linear model (glm) with a gamma distribution and a log link function. We compared this to a null model (MFRI ~ 1) and selected based on Akaike Information Critereon as well as analyses of model suitably plots (cite AIC). We calculated the 95% confidence interval of the relationship between MFRI and MAR and sampled within this space for values relating this bivariate relationship.

## Fire intensity and MAR

After analyzing the results of the ongoing Kruger National Park experimental burn program, Govender et al. (2006) found a positive relationship between MAR and Byram’s fireline intensity. Fire intensity was calculated from a **50** year dataset from Kruger National Park’s Experimental Burn Plots. **Relate how Byram’s is calculated here**

We reanalyzed this relationship by fitting a generalized linear model in the base *stats* package **(cite base stats)**. We related the previously calculated Byram’s fireline intensity to MAR at the site using a gamma distribution for the response variable (fireline intensity). We also calculated a null model (fireline intensity ~ 1) that assumes no connection between fireline intensity and MAR. After assessing plots of model fit, we compared these two models with likelihood ratio tests. **(section about comparing to original model)?**

## Probability of Topkill

We calculated probability of topkill as a function of stem height and fireline intensity using Higgins et al. (2012) model. Their model was calibrated on a dataset of monitored species of different height in the Experimental Burn Plots at Kruger National Park. After an experimental fire treatment, individual-level topkill was recorded and associated with the Byram’s fireline intensity of the fire. Higgins et al. included season as a covariate in their model; We hold this constant as a dormant season fire.