



## 1 The APSIM Oil Palm Model

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The base configuration of the oil palm model has been configured to match commercial dura x pisifera palms developed in Dami, West New Britain in Papua New Guinea. Other varieties are specified in terms of how they differ from this base variety.

### 1.1 SuperFamily

SuperFamily overrides the following properties:

[FronMaxArea].XYPairs.X = 0,2,4.5,8.5,14

[FronMaxArea].XYPairs.Y = 0.1,0.9,0.63,10.8,12.6

### 1.2 Nigeria\_IRHO

Nigeria\_IRHO overrides the following properties:

[BunchSizeMax].XYPairs.X = 0, 1,3,7,11,15

[BunchSizeMax].XYPairs.Y = 0, 53,265,7000,11600,12750

[FronAppearanceRate].XYPairs.X = 0, 2, 5, 10, 15

[FronAppearanceRate].XYPairs.Y = 10.1, 7.7, 10.1, 11, 11

### 1.3 Nigeria\_SOCFINDO

Nigeria\_SOCFINDO overrides the following properties:

[BunchSizeMax].XYPairs.X = 0, 1,3,7,11,15

[BunchSizeMax].XYPairs.Y = 0, 53,265,7000,11600,12750

[FronAppearanceRate].XYPairs.X = 0, 2, 5, 8, 15

[FronAppearanceRate].XYPairs.Y = 10.1, 7.7, 10.1, 11, 11

KNO3 = 0.02

The proportion of plant growth partitioned to roots has been set to 10% as this value lies between estimates used by Henson and Dolmat (2003) and van Kraalingen et al. (1989).

RootFraction = 0.1

Root nitrogen concentration is set at 0.39% (Goh, 2005)

RootNConcentration = 0.39

A constant root turnover rate of 0.001 d<sup>-1</sup> is used for all soil layers. This value is larger than the value of 0.00065 which can be calculated from the root turnover functions given by Henson and Dolmat (2003), reflecting the slightly higher fraction of growth partitioned to roots in this model.

RootSenescenceRate = 0.001

InitialFronNumber = 5

### 1.4 RelativeDevelopmentalRate

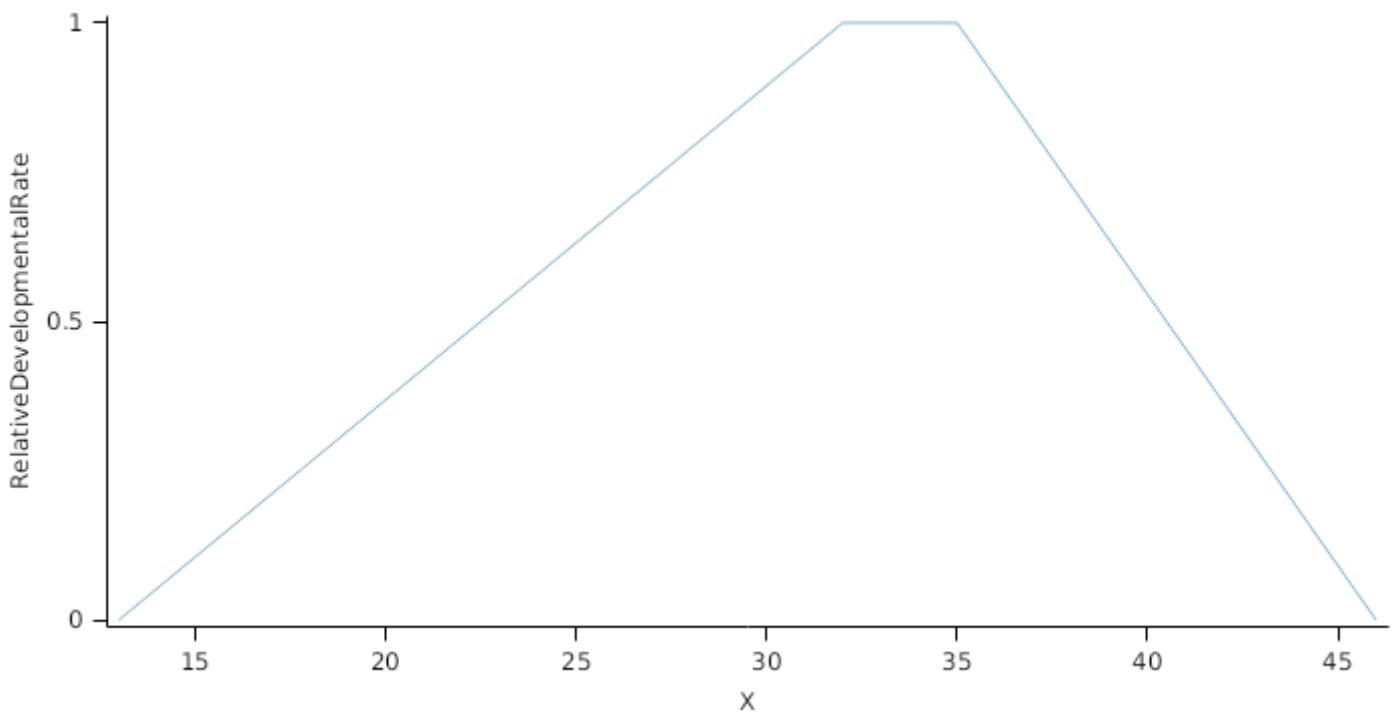
RelativeDevelopmentalRate is the average of sub-daily values from a XYPairs.

Firstly 3-hourly estimates of air temperature ( $T_a$ ) are interpolated using the method of [Jones et al., 1986](#) which assumes a sinusoidal temperature. pattern between  $T_{max}$  and  $T_{min}$ .

Each of the interpolated air temperatures are then passed into the following Response and the Average taken to give daily RelativeDevelopmentalRate

X	RelativeDevelopmentalRate
13.0	0.0
32.0	1.0
35.0	1.0
46.0	0.0

### RelativeDevelopmentalRate

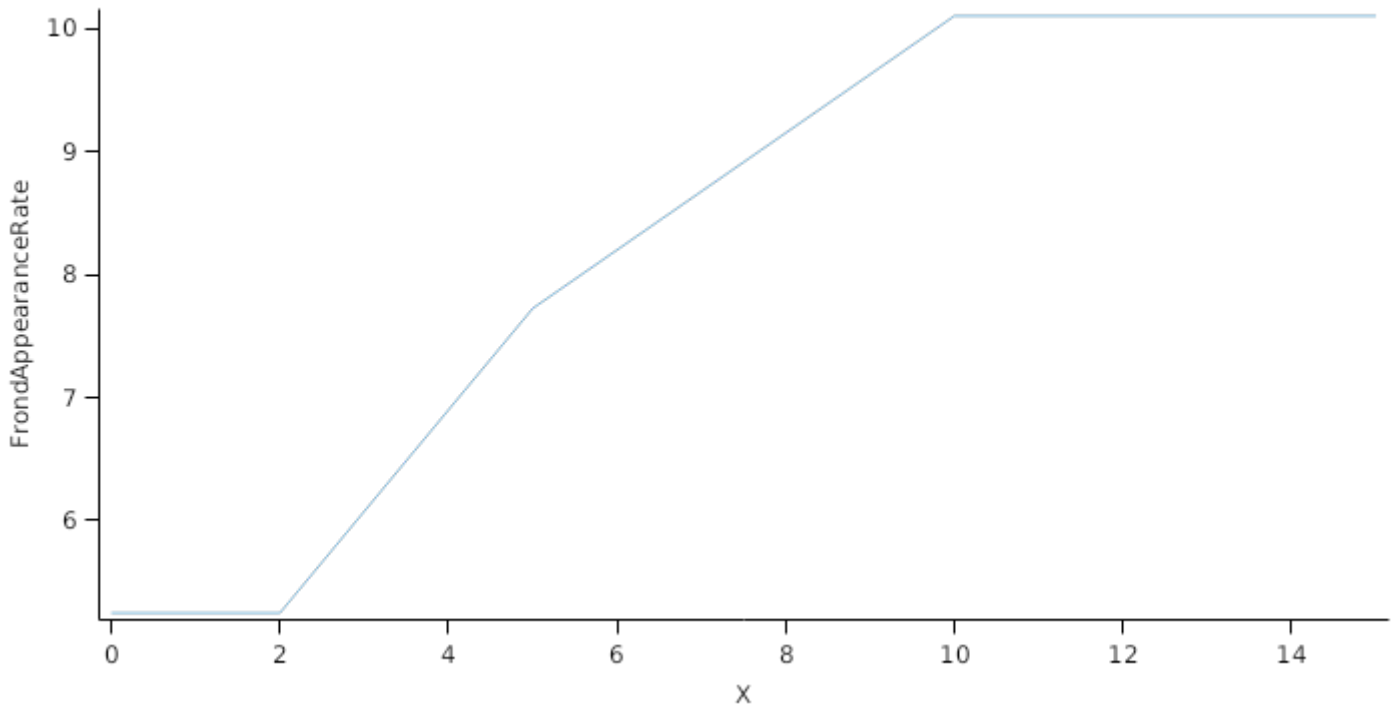


### 1.5 FrondAppearanceRate

*FrondAppearanceRate* is calculated using linear interpolation

X	FrondAppearanceRate
0.0	5.2
2.0	5.2
5.0	7.7
10.0	10.1
15.0	10.1

## FronDAppearanceRate



ExpandingFronds = 5

FronDMaximumNConcentration = 1.15

FronDCriticalNConcentration = 1.1

FronDMinimumNConcentration = 0.5

### 1.6 FronDMaxArea

#### 1.6.1 FronDMaxArea

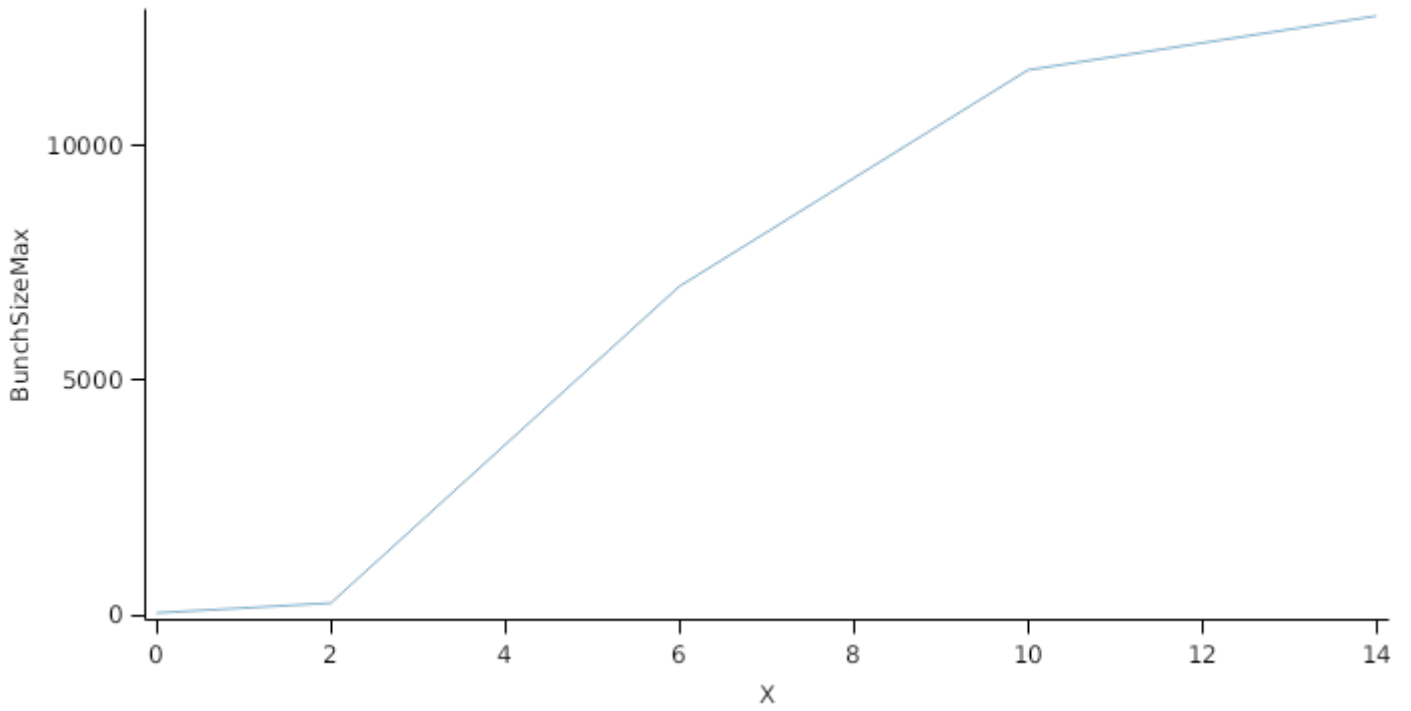
A value is returned via Akima spline interpolation of a given set of XY pairs

### 1.7 BunchSizeMax

*BunchSizeMax* is calculated using linear interpolation

X	BunchSizeMax
0.0	53.0
2.0	265.0
6.0	7000.0
10.0	11600.0
14.0	12750.0

## BunchSizeMax

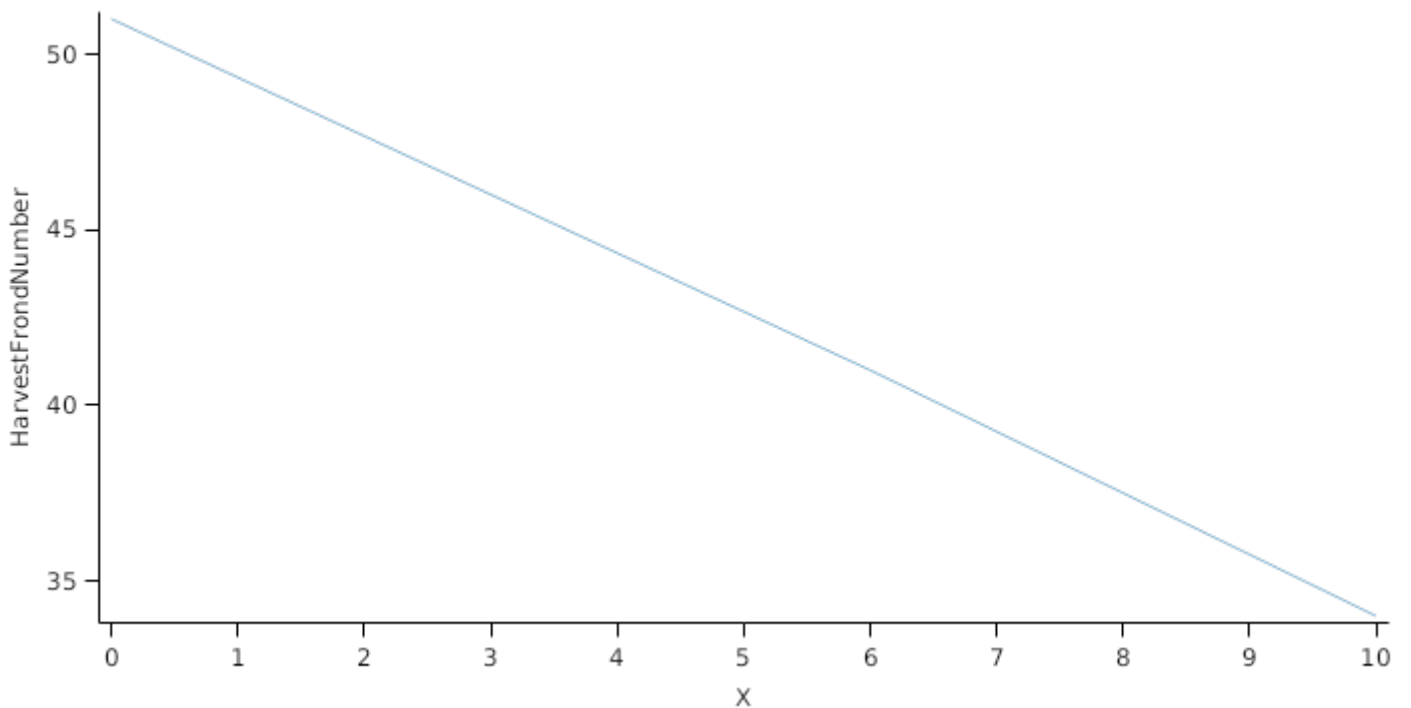


## 1.8 HarvestFronNumber

*HarvestFronNumber* is calculated using linear interpolation

X	HarvestFronNumber
0.0	51.0
6.0	41.0
10.0	34.0

## HarvestFronNumber



Sex determination is calculated during a phase occurring 49 to 57 fronds before bunch maturity. A constant value is assumed for Female Flower Fraction at the beginning of this phase. This represents the fraction of female flowers in the absence of any further stress effect.

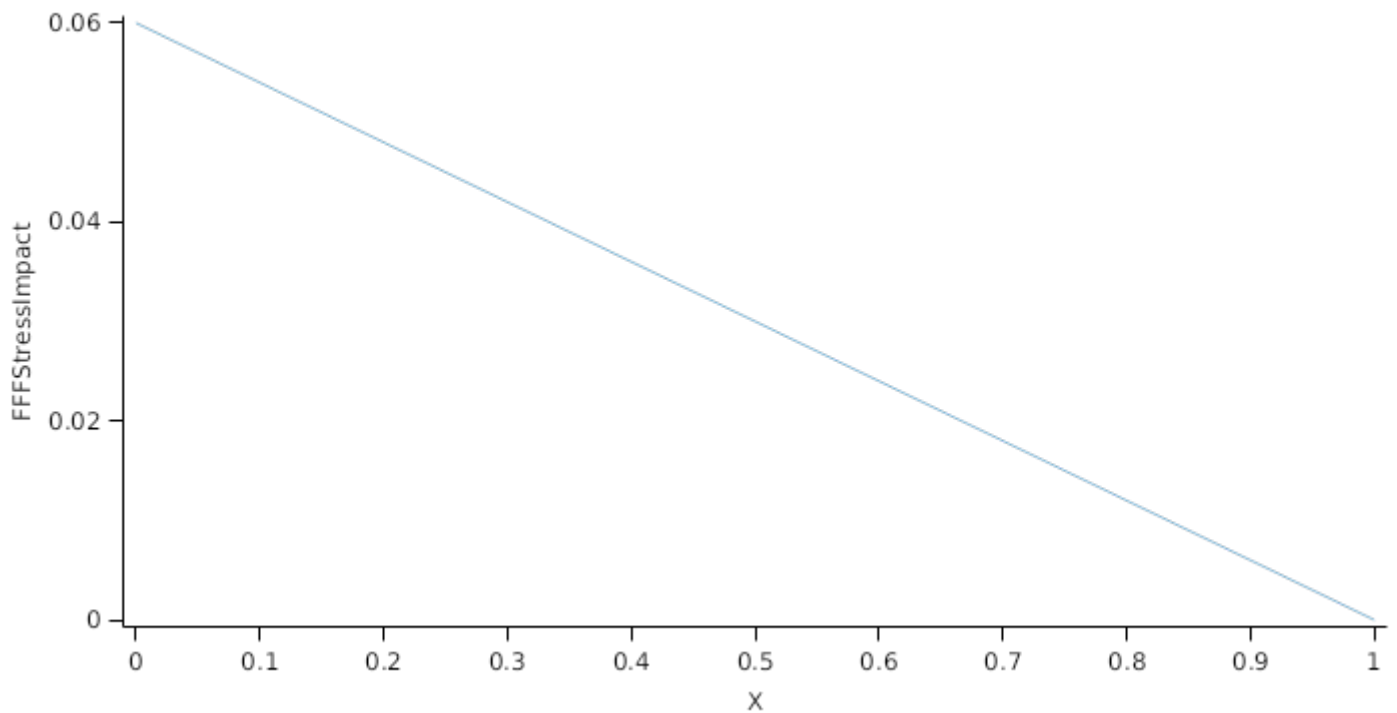
FemaleFlowerFraction = 0.8

### 1.9 FFFStressImpact

*FFFStressImpact* is calculated using linear interpolation

X	FFFStressImpact
0.0	0.1
1.0	0.0

### FFFStressImpact

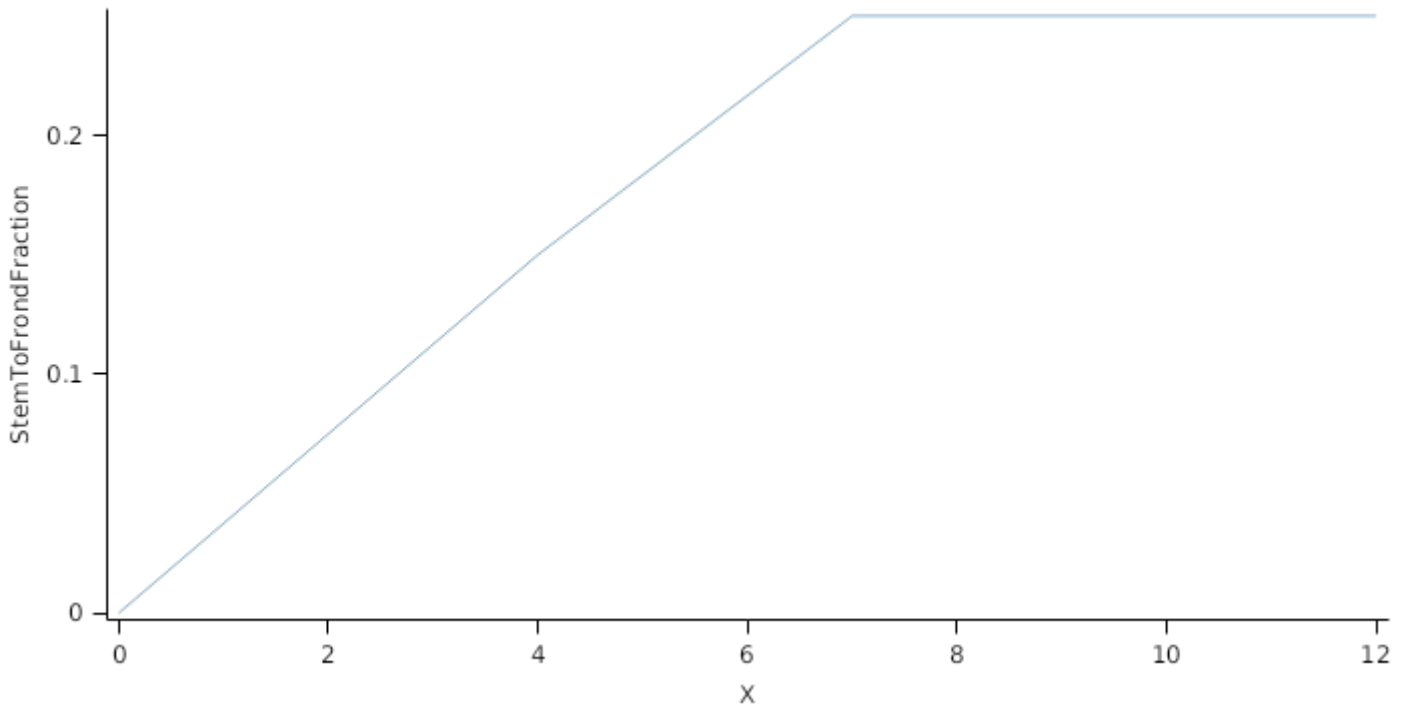


### 1.10 StemToFrondFraction

*StemToFrondFraction* is calculated using linear interpolation

X	StemToFrondFraction
0.0	0.0
4.0	0.1
7.0	0.2
12.0	0.2

## StemToFrondFraction

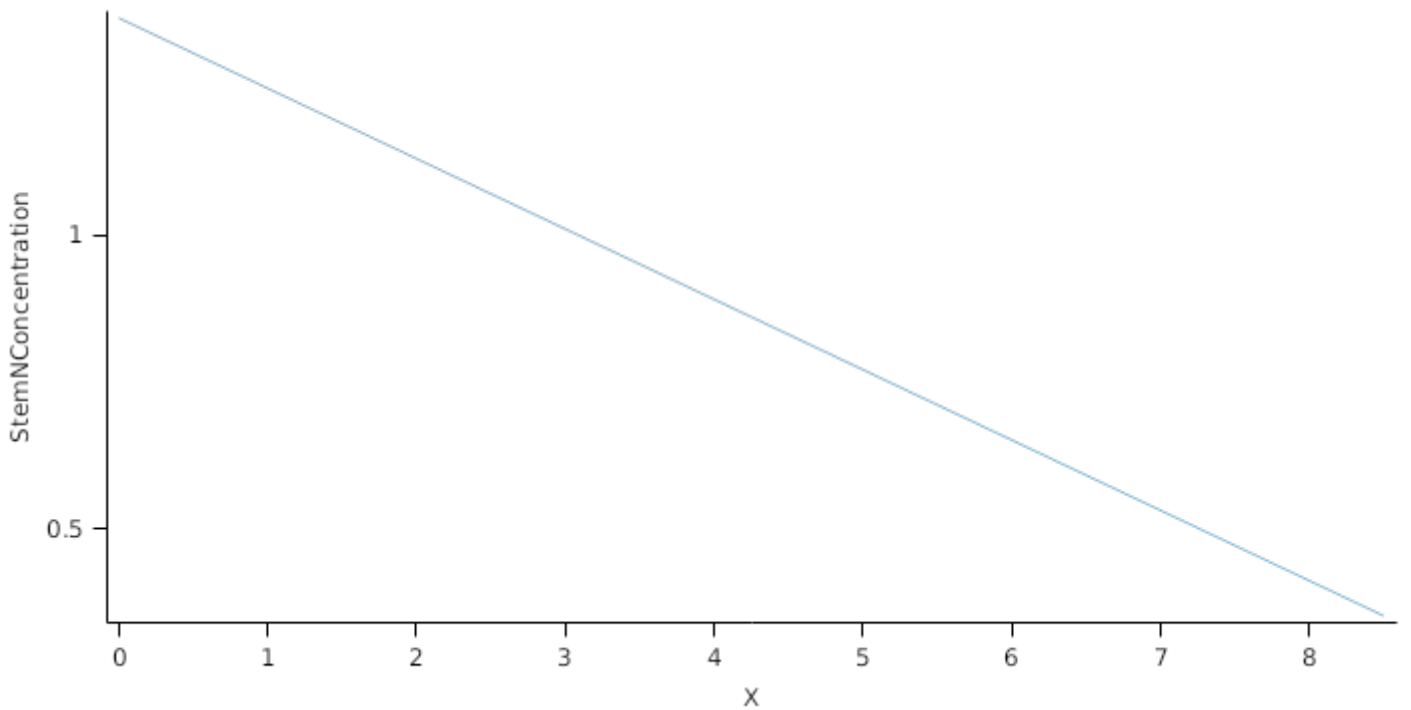


### 1.11 StemNConcentration

*StemNConcentration* is calculated using linear interpolation

X	StemNConcentration
0.0	1.4
8.5	0.4

## StemNConcentration



BunchOilConversionFactor = 1.55

RipeBunchWaterContent = 0.47

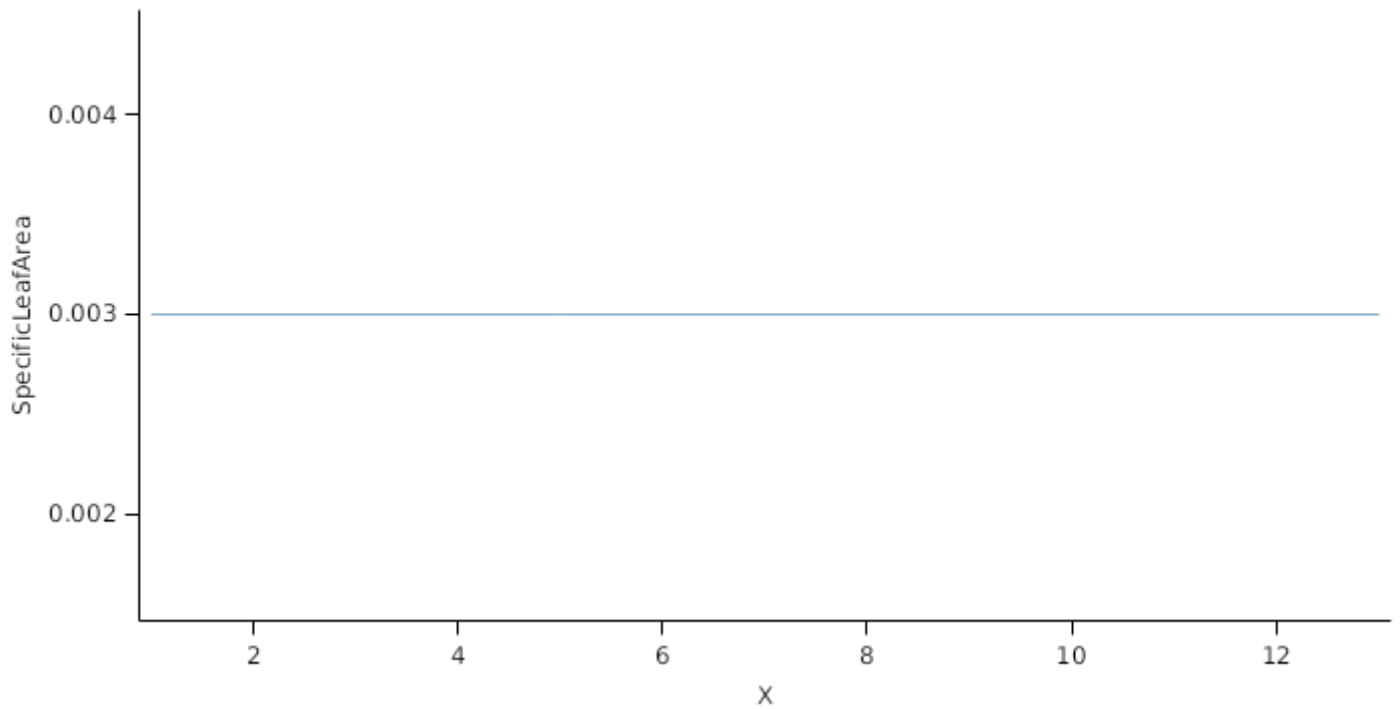
BunchNConcentration = 0.603

## 1.12 SpecificLeafArea

*SpecificLeafArea* is calculated using linear interpolation

X	SpecificLeafArea
1.0	0.0
5.0	0.0
13.0	0.0

### SpecificLeafArea

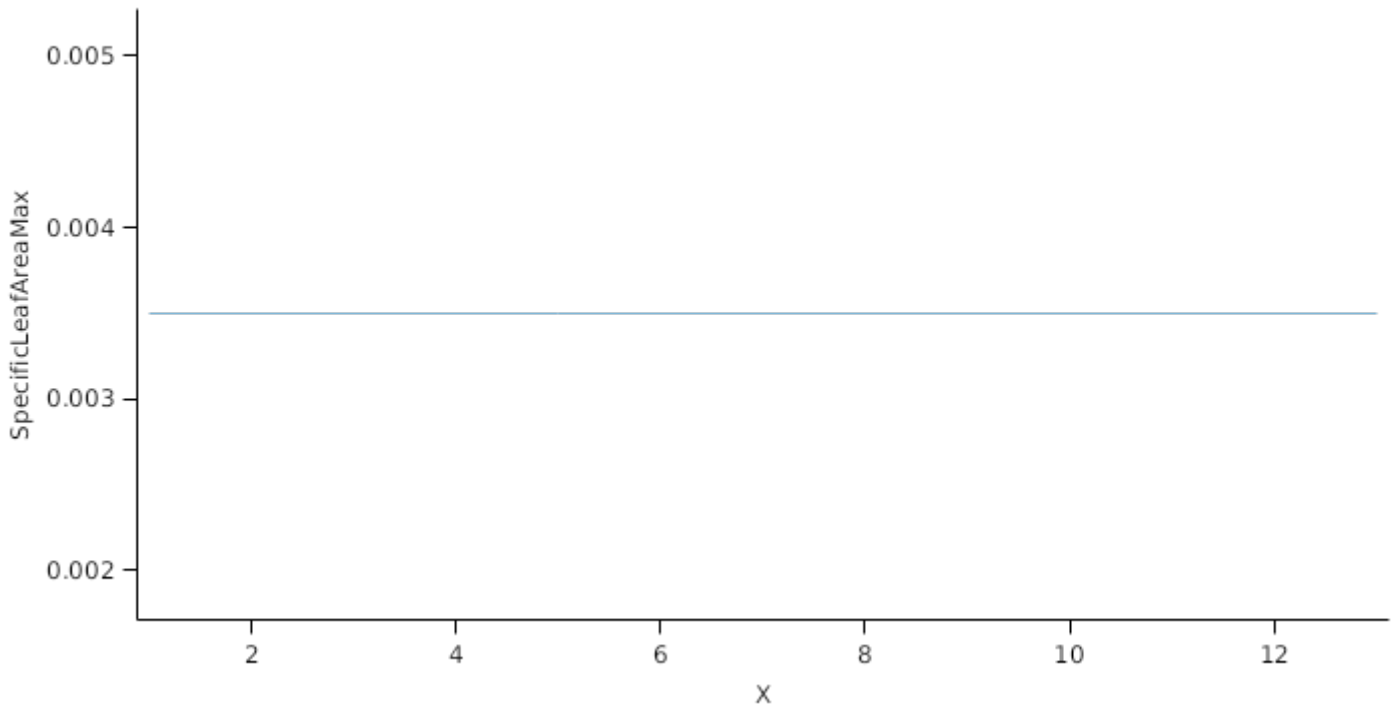


## 1.13 SpecificLeafAreaMax

*SpecificLeafAreaMax* is calculated using linear interpolation

X	SpecificLeafAreaMax
1.0	0.0
5.0	0.0
13.0	0.0

## SpecificLeafAreaMax

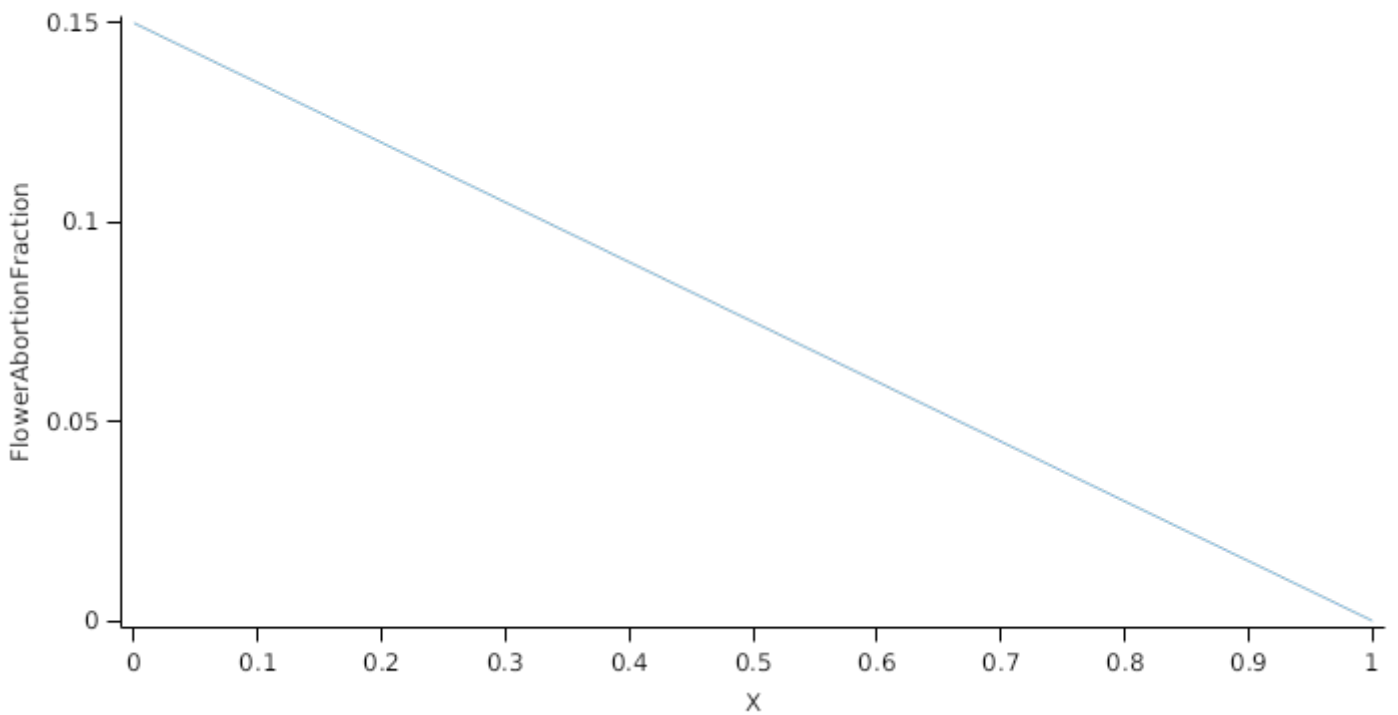


## 1.14 FlowerAbortionFraction

*FlowerAbortionFraction* is calculated using linear interpolation

X	FlowerAbortionFraction
0.0	0.1
1.0	0.0

## FlowerAbortionFraction



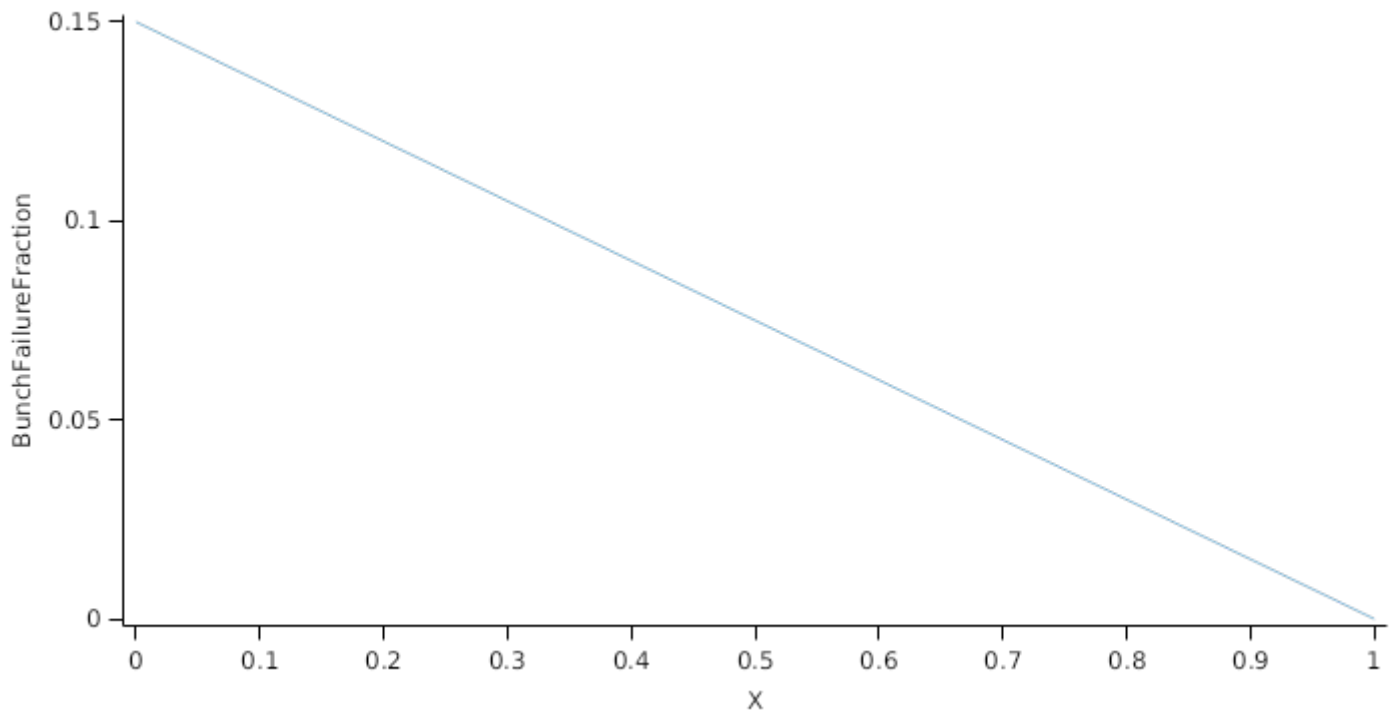
## 1.15 BunchFailureFraction

*BunchFailureFraction* is calculated using linear interpolation



X	BunchFailureFraction
0.0	0.1
1.0	0.0

### BunchFailureFraction

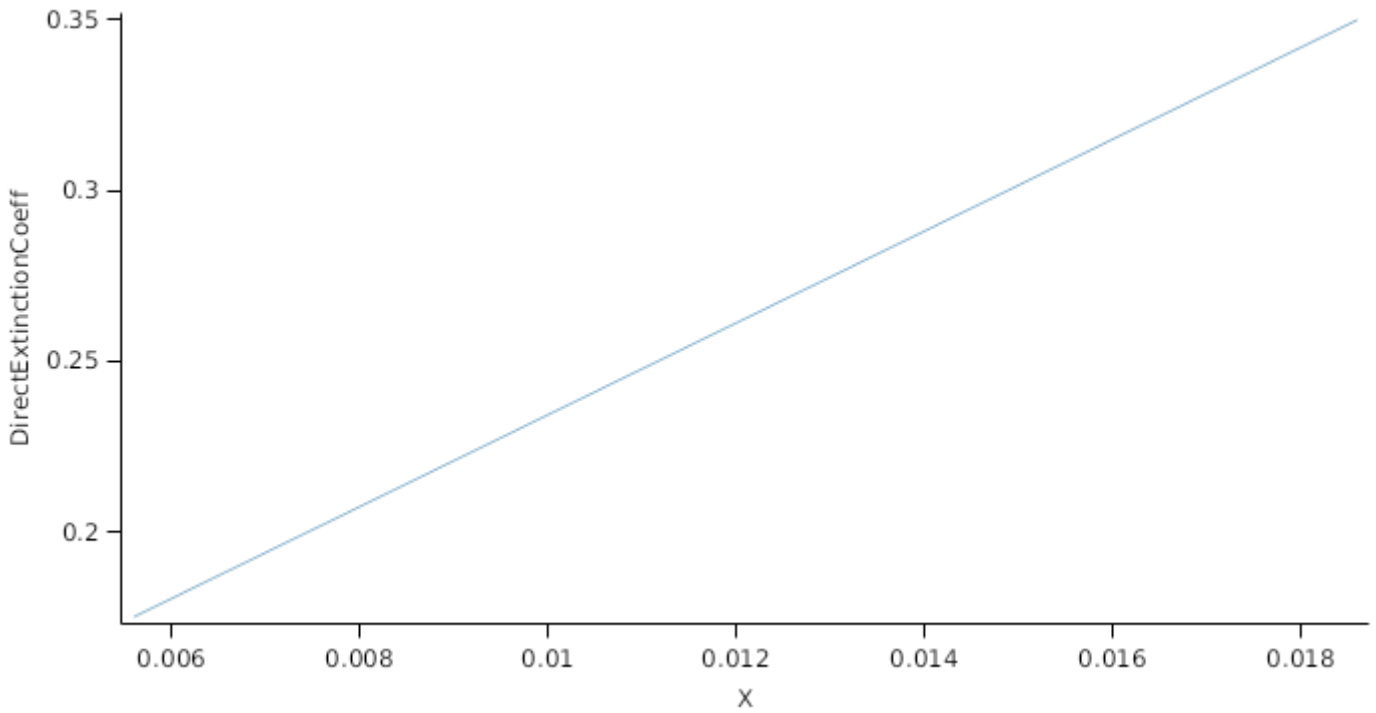


### 1.16 DirectExtinctionCoeff

*DirectExtinctionCoeff* is calculated using linear interpolation

X	DirectExtinctionCoeff
0.0	0.2
0.0	0.3

## DirectExtinctionCoeff

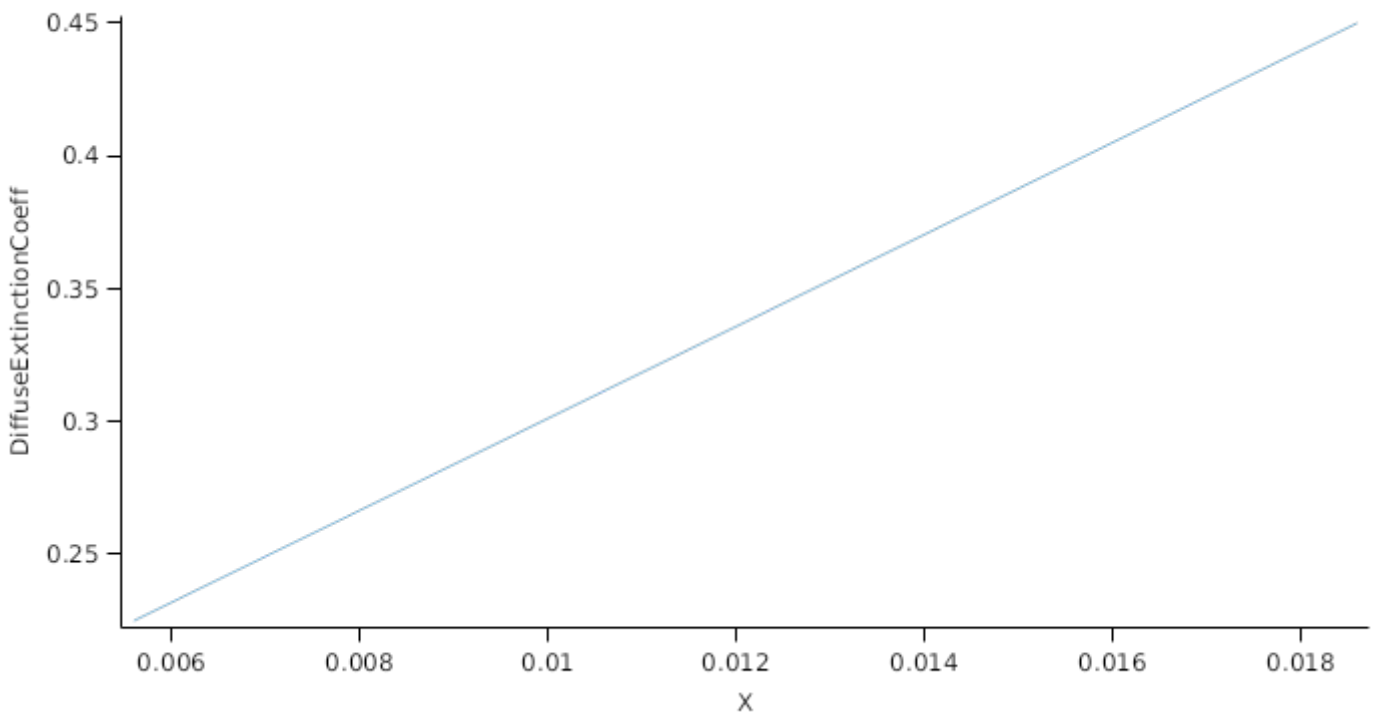


### 1.17 DiffuseExtinctionCoeff

*DiffuseExtinctionCoeff* is calculated using linear interpolation

X	DiffuseExtinctionCoeff
0.0	0.2
0.0	0.5

## DiffuseExtinctionCoeff



Photosynthesis is calculated using a radiation use efficiency (RUE) of 1.22 g MJ<sup>-1</sup> of intercepted direct beam total short wave radiation. RUE for diffuse light increases from this direct beam value by up to 33%, in proportion to the fraction of daily intercepted radiation, corresponding with the observed impact of diffuse light penetration on forest growth (Alton et

al., 2007). Daily average RUE is calculated as the average of the direct and diffuse beam RUE values, weighted toward the diffuse light RUE using the square of the daily diffuse light fraction (van Kraalingen et al., 1989). This approach yields a value of 1.35 for a clear day with approximately 30% diffuse light which matches estimates provided by Henson and Dolmat (2003) assuming a density of 140 palms ha<sup>-1</sup>.

RUE = 1.22

Fixed root front velocity taken from Carr(2011).

RootFrontVelocity = 30

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## 2 Validation

Data from three sites across PNG with different climate and soils were used for model testing. Soils ranged from sandy clay (volcanic ash) to alluvial clay. Mean annual rainfall ranged from 2400 mm at Sagarai (1990-2008) and Sangara (1986-2009) to 4350 mm at Hargy(1989-2008) with annual rainfall variability larger at Sagarai than the other two sites. Whilst there is only a small difference in temperature across the sites, rainfall patterns do impact on both annual (Hargy 15.9 MJ; Sangara 17.0 MJ; Sagarai 18.1 MJ) and monthly variation in mean daily solar radiation.

Fertiliser trial data were obtained for each location from the PNG Oil Palm Research Association trial database (Table Below). All trials had the same commercial dura x pisifera palms planted in an equilateral triangular pattern. Trials included multiple rates of nitrogen including a control in which no nitrogen was applied. Fertilisers were applied in two to three applications per year. Trial 324 evaluated the effect of nitrogen rate and source (five sources). There was no effect of nitrogen source and so these data have been combined in this study as there was no effect of nitrogen source. Trial 504 investigated nutrient interactions (N x K). Data from treatments for which potassium was not limiting were combined. Trial 212 investigated nitrogen rate only. All other macro- and micronutrients were maintained at sufficient levels in all trials. Plots in each trial consisted of 16 to 30 palms surrounded by guard rows between neighbouring plots. Levels of replication ranged from two to four. In trials 324 and 504, trenches were dug around plots to minimise poaching of nutrients by palms from neighbouring plots.

### Description of fertiliser trials and selected treatments used in model development and testing.

Location: **Hargy**

Trial number: 212

Previous land use: Oil Palm

Year planted: 1996

Treatment commenced: 2002

Population: 140 (palms/ha)

NRates: 0, 1.0, 2.0 (kg/palm/ha/y)

Location: **Sangara**

Trial number: 324

Previous land use: Oil Palm  
Year planted: 1996  
Treatment commenced: 2001  
Population: 135 (palms/ha)  
NRates: 0, 0.42, 1.68 (kg/palm/ha/y)

Location: **Sagarai**  
Trial number: 504  
Previous land use: Forest / Rubber plantation  
Year planted: 1991  
Treatment commenced: 1995  
Population: 127 (palms/ha)  
NRates: 0, 0.42, 1.26 (kg/palm/ha/y)

Harvested ripe bunches were counted and weighed (together with loose fruits) fortnightly for every palm. Leaf samples were collected from frond 17 from selected palms in all plots at least once a year and were oven dried and analysed for nitrogen content. Petiole cross-sectional area, leaflet lengths and frond length of frond 17 was measured to allow calculation of leaf area and mass (Corley et al., 1971). The total number of fronds on each palm was counted, and the first frond was marked twice a year to determine frond production rate. Stem heights of selected palms were measured periodically in two of the trials, and these were combined with a single measurement of stem diameter to calculate stem mass, assuming a linear increase in stem density with plantation age (Corley et al., 1971).

Parameterisation of soil process models used information from a variety of sources. Soil hydraulic properties were derived from pressure plate water retention data. Runoff curve number (Hawkins, 1996) was estimated to 72 for clay soils and 50 for ash soils using runoff data from PNG oil palm plantations (Banabas et al., 2008b). Soil organic carbon data were available for Trials 324 and 504. Simulations of Trial 212 utilised carbon measurements available for a nearby planting. The fractionation of soil organic carbon into the various model pools is very important for model accuracy. It has been shown that it is possible to deduce, a priori, the apparent soil organic matter composition from observed patterns (Huth et al., 2010). The inert fraction of the total soil organic matter is an important parameter and methods for its determination for the volcanic soils in PNG have not been developed. In this study, we have assumed that the inert carbon content does not vary significantly with depth and that it can be approximated using the carbon content at a depth of approximately 0.5 m. Most carbon cycling occurs above this depth and carbon contents vary less below this depth. Therefore we assumed that carbon above this value is available for decomposition. Finally, as trials 212 and 324 were planted after felling of existing plantations, we initialised the surface organic matter pools to consist of 24 t/ha of fronds with a C:N of 39 and 63 t/ha of stems with a C:N of 145. In the absence of other information, the same initial surface organic matter was used for trial 504.

Daily meteorological data (rainfall, sunshine hours, temperature) for Trial 324 were taken from the nearby research station of the PNG Oil Palm Research Association. Sunshine hour data was used to calculate incoming global shortwave radiation as described by Banabas (2007). Complete daily meteorological datasets were not available for the other two sites apart from a limited number of monthly totals for sunshine hours and rainfall. Daily estimates of the required climate weather data for these sites were derived from estimates obtained from the NASA Langley Research Center POWER Project funded through the NASA Earth Science Directorate Applied Science Program (<http://power.larc.nasa.gov/>). Adequacy of this dataset was tested via comparison of satellite-derived estimates of monthly mean solar radiation with that calculated from measured monthly sunshine hours for Hargy (data not shown). No data on sunshine hours were available for Sagarai and neither site had measured temperature data for comparison. Satellite-derived estimates of monthly rainfall proved inadequate when compared to available monthly data. Therefore, observed monthly rainfall totals were disaggregated into daily data using the satellite-derived daily rainfall estimates. Satellite-derived estimates of daily temperatures were used for these two sites but could not be tested for accuracy.

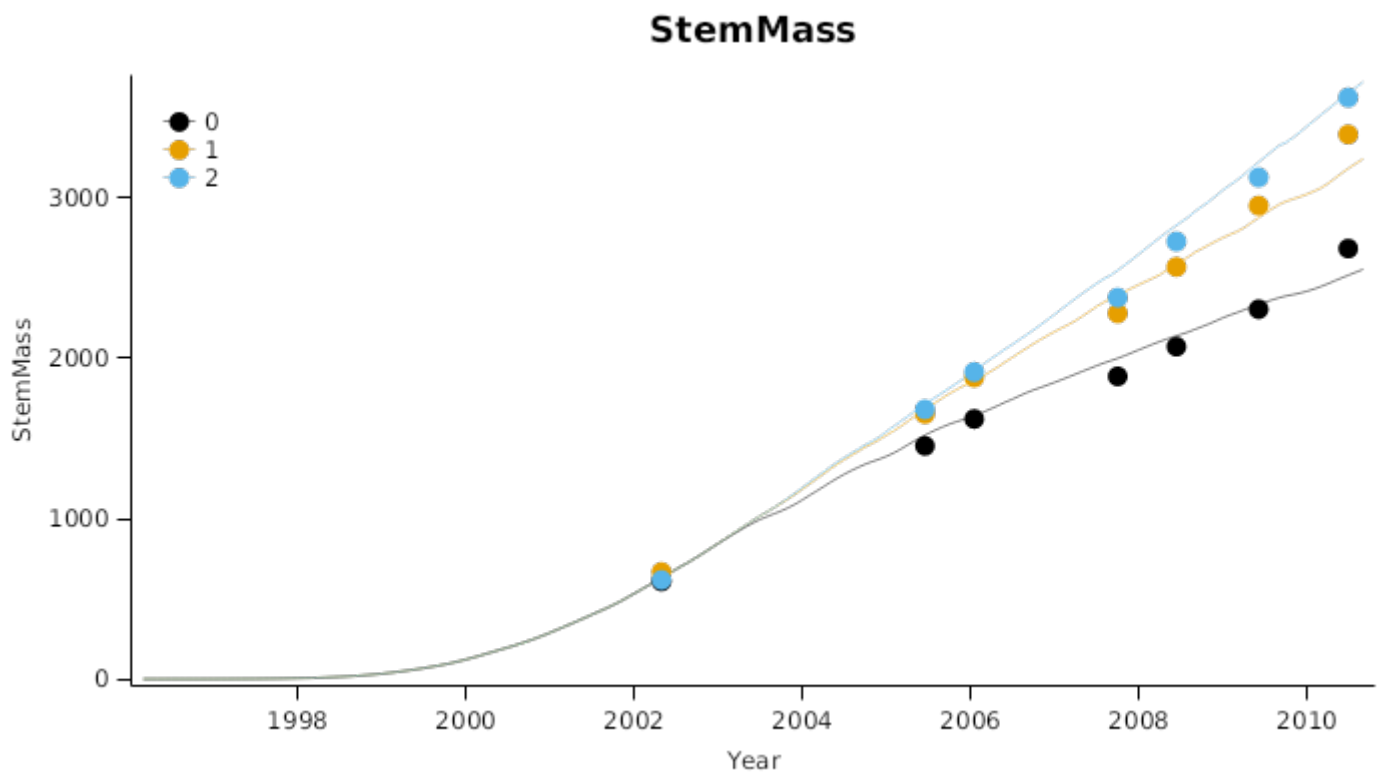
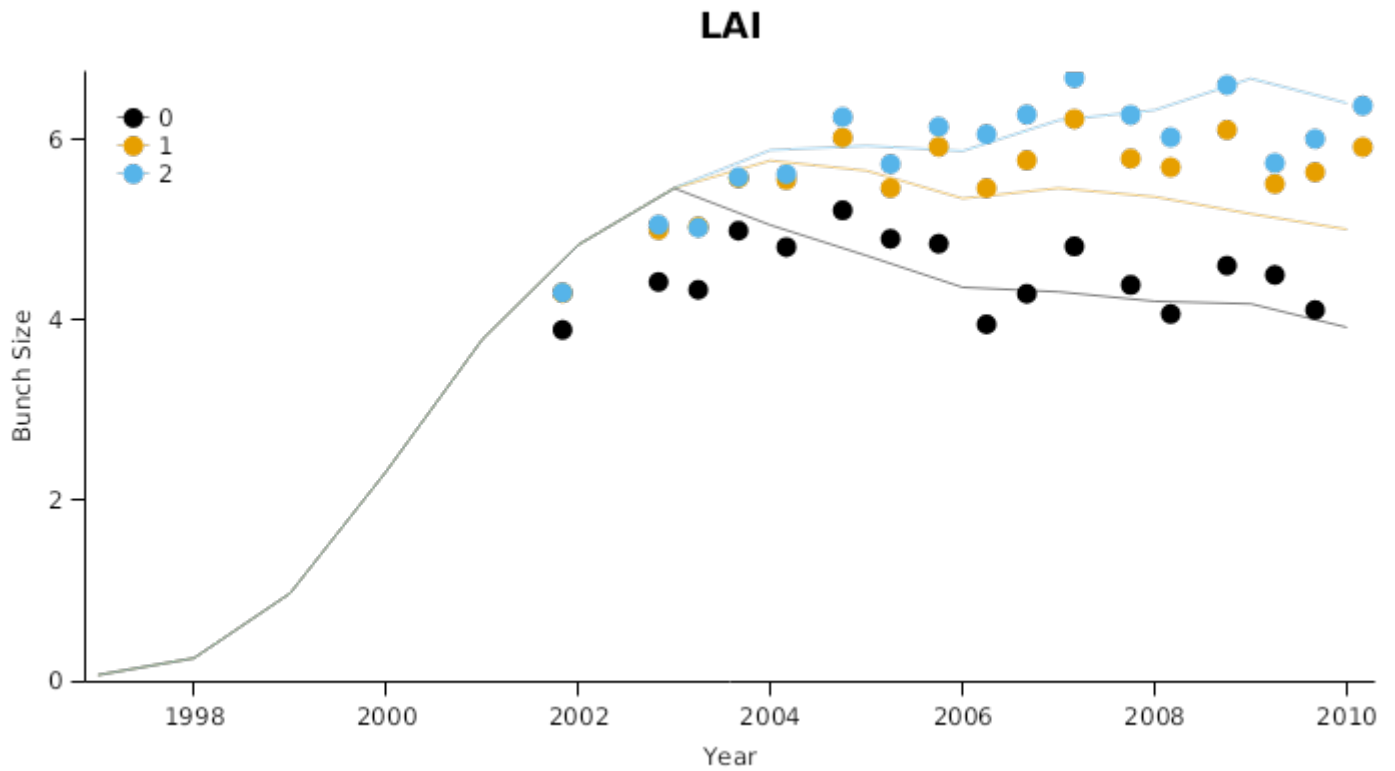
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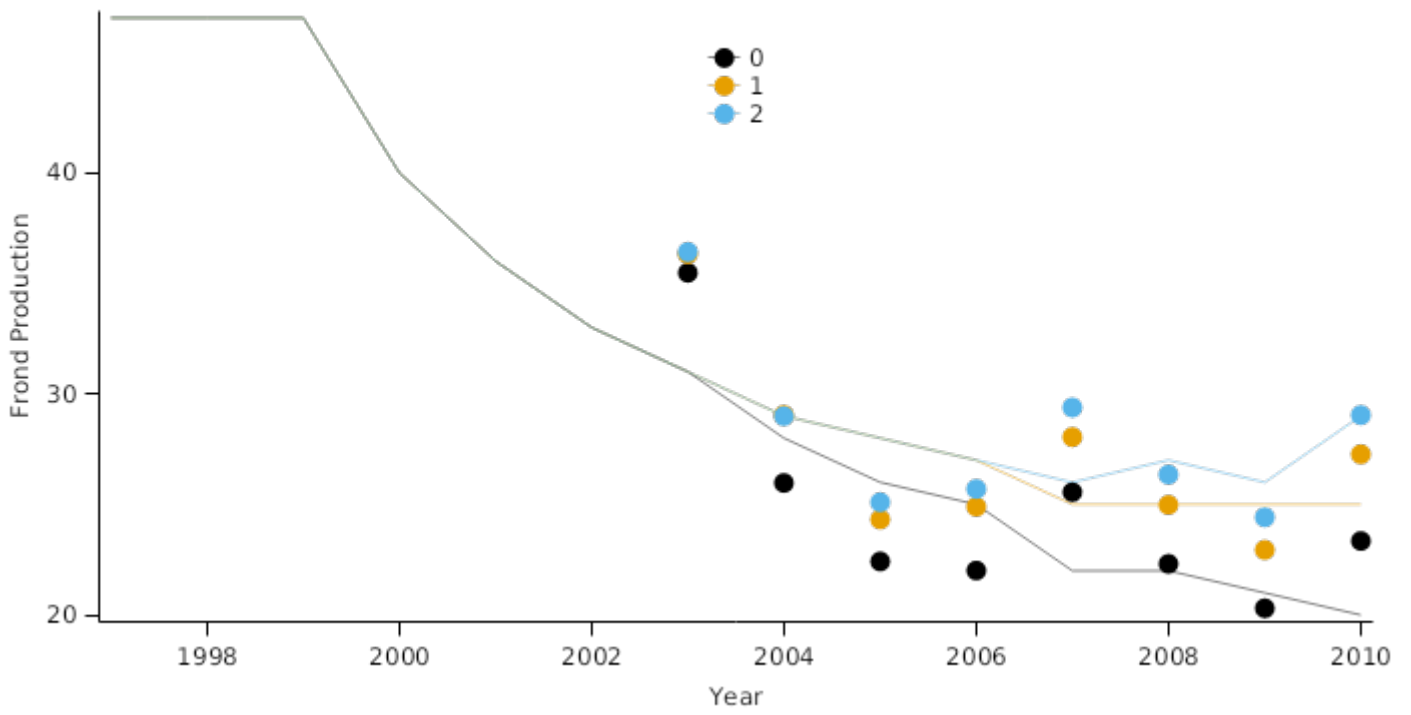
## List of experiments.

Experiment Name	Design (Number of Treatments)
Sangara	N (3)
Hargy	N (3)
Sagarai	N (3)

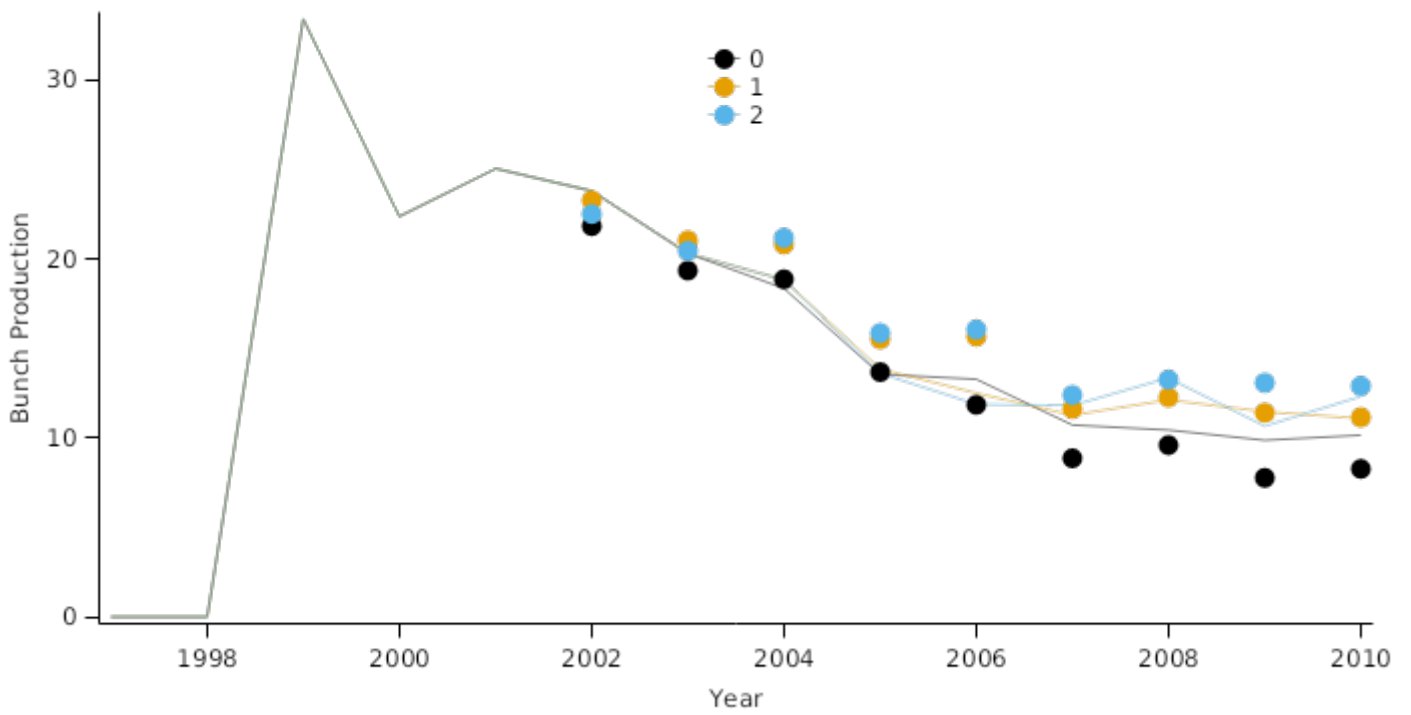
### 2.1 Sangara



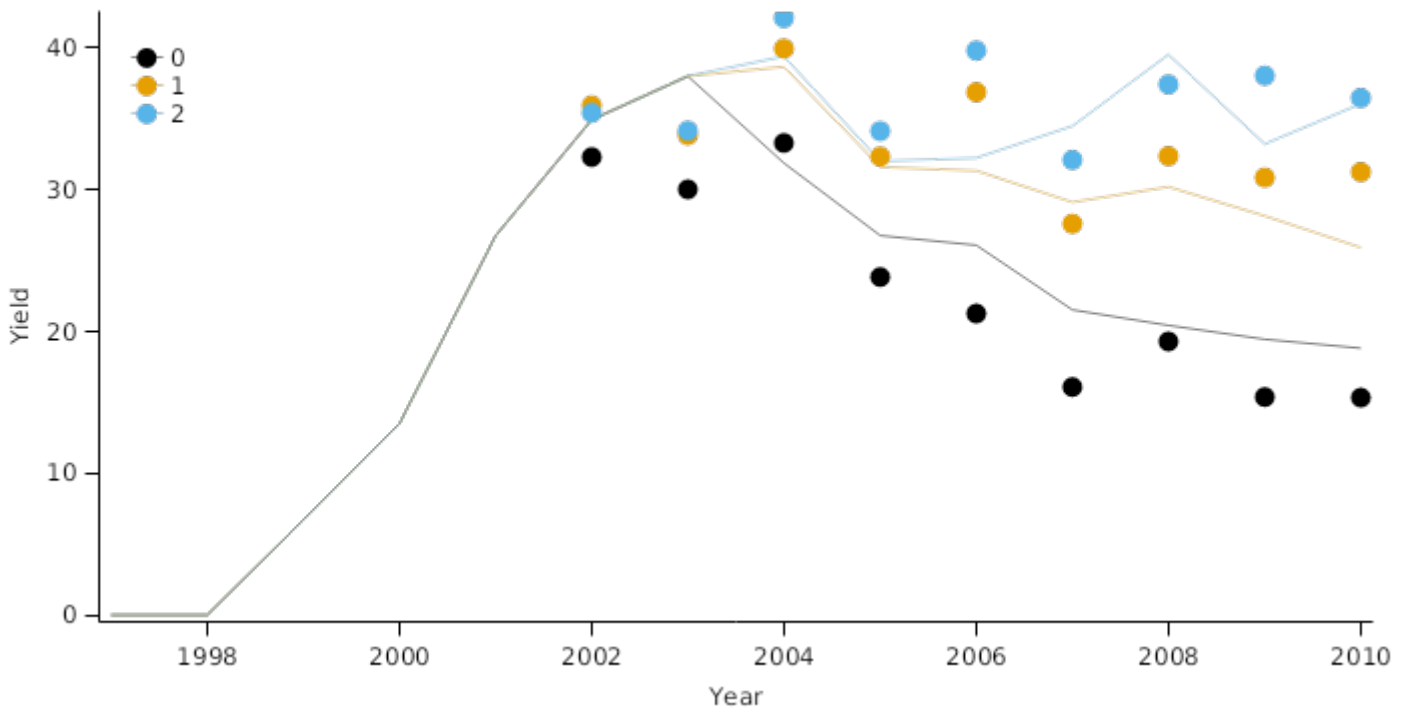
### FronndProduction



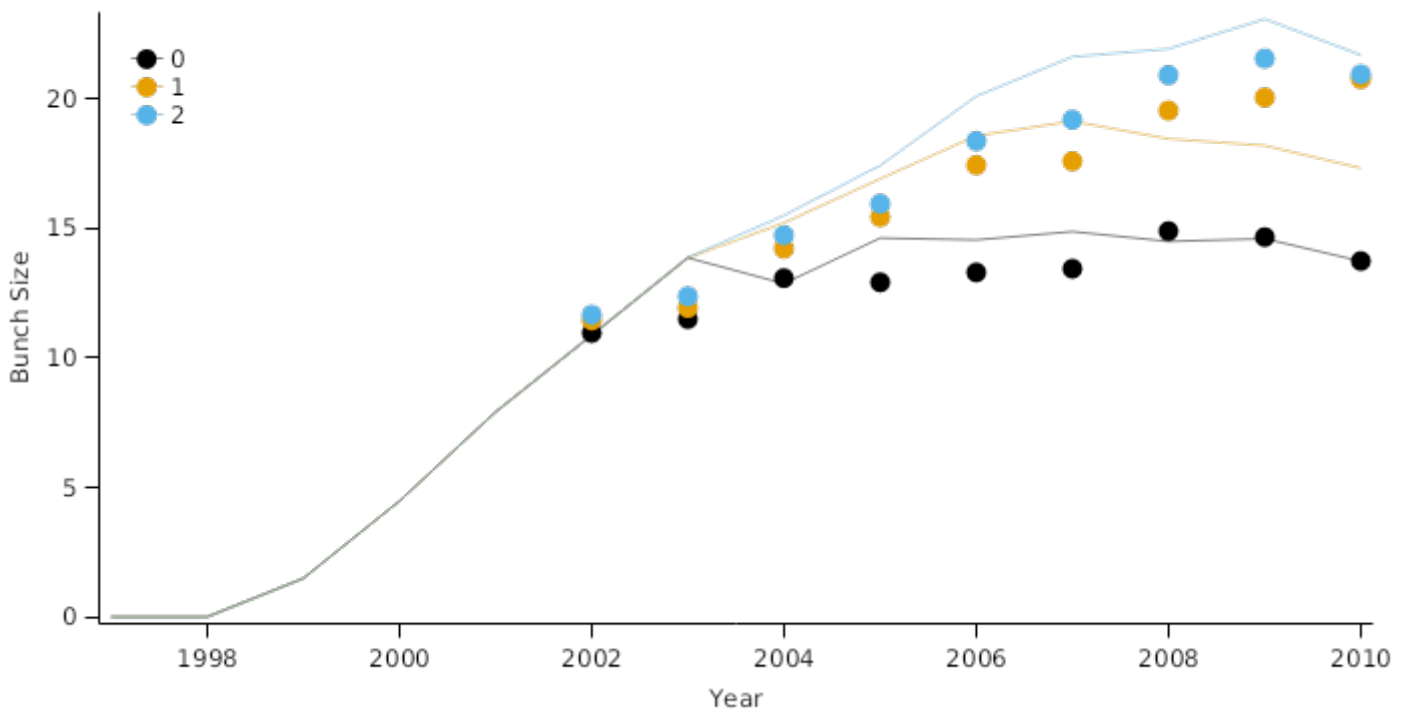
### BunchProduction



### Annual IFFB



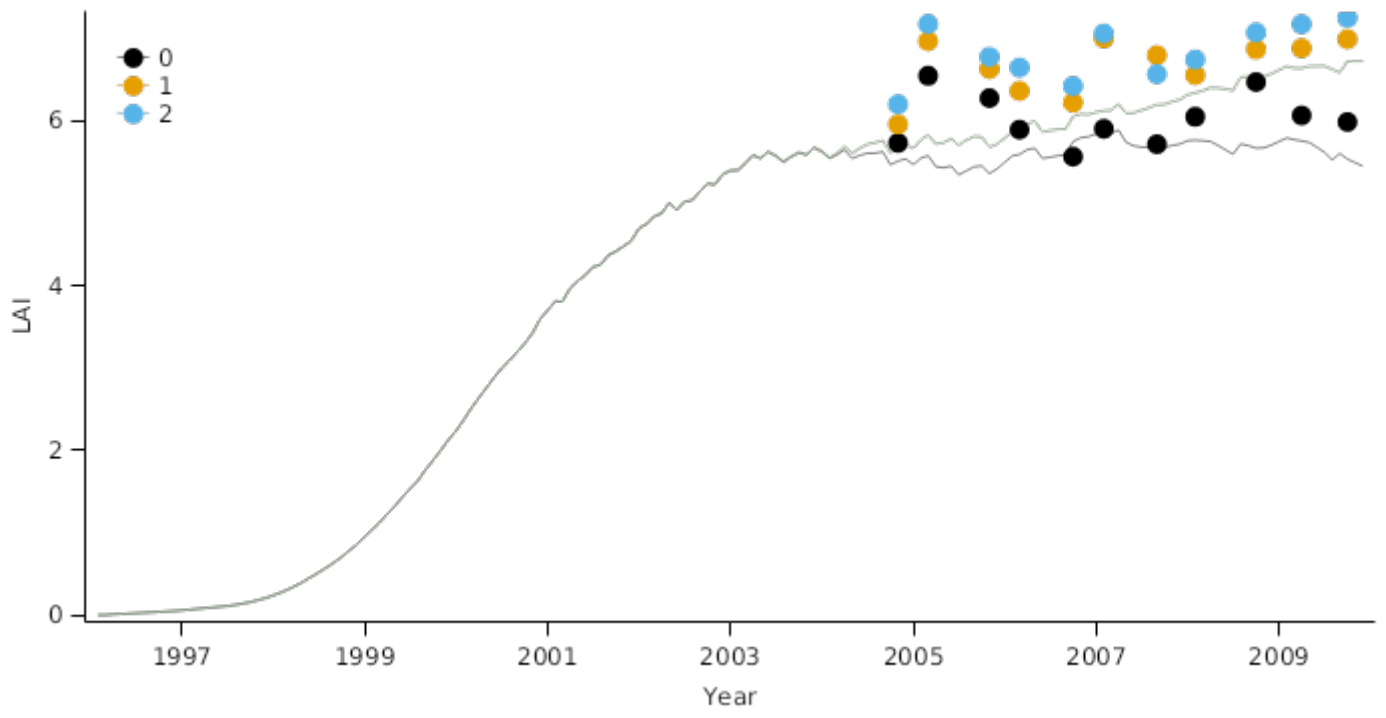
### Annual Bunch Size



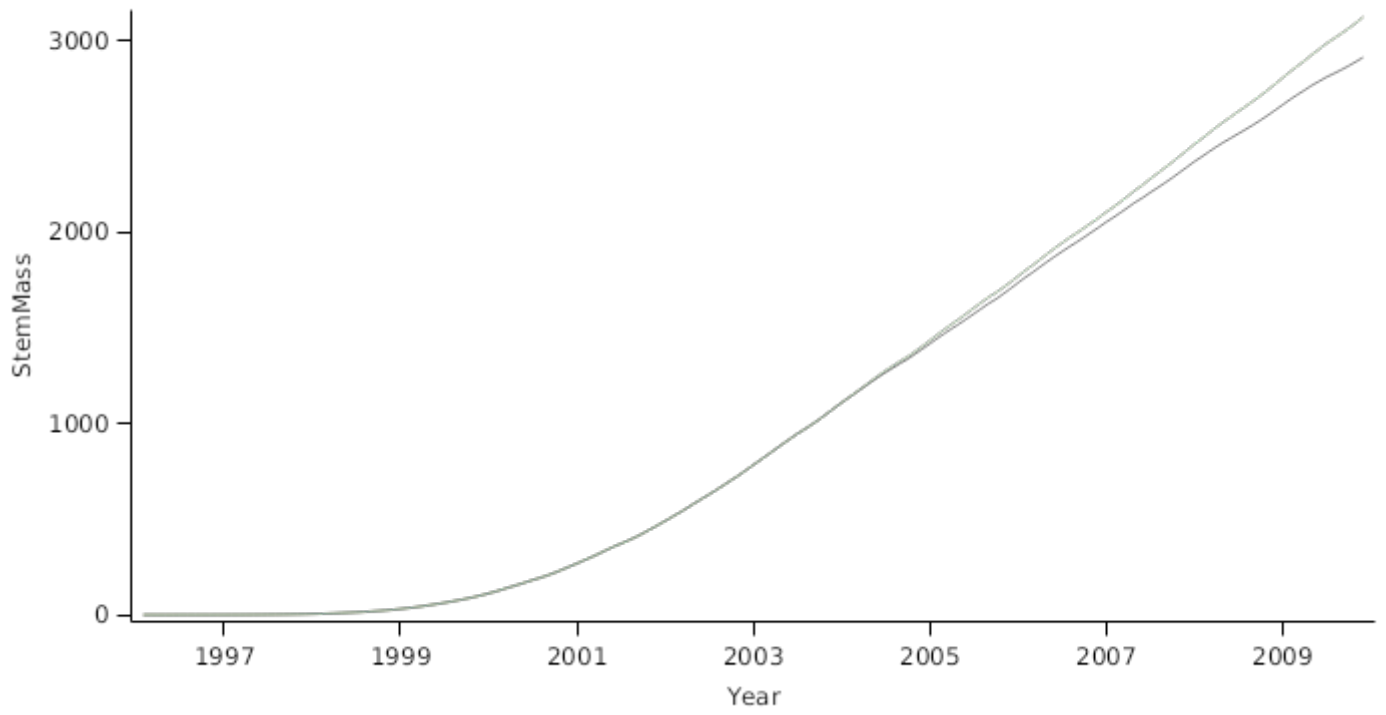
## 2.2 Hargy



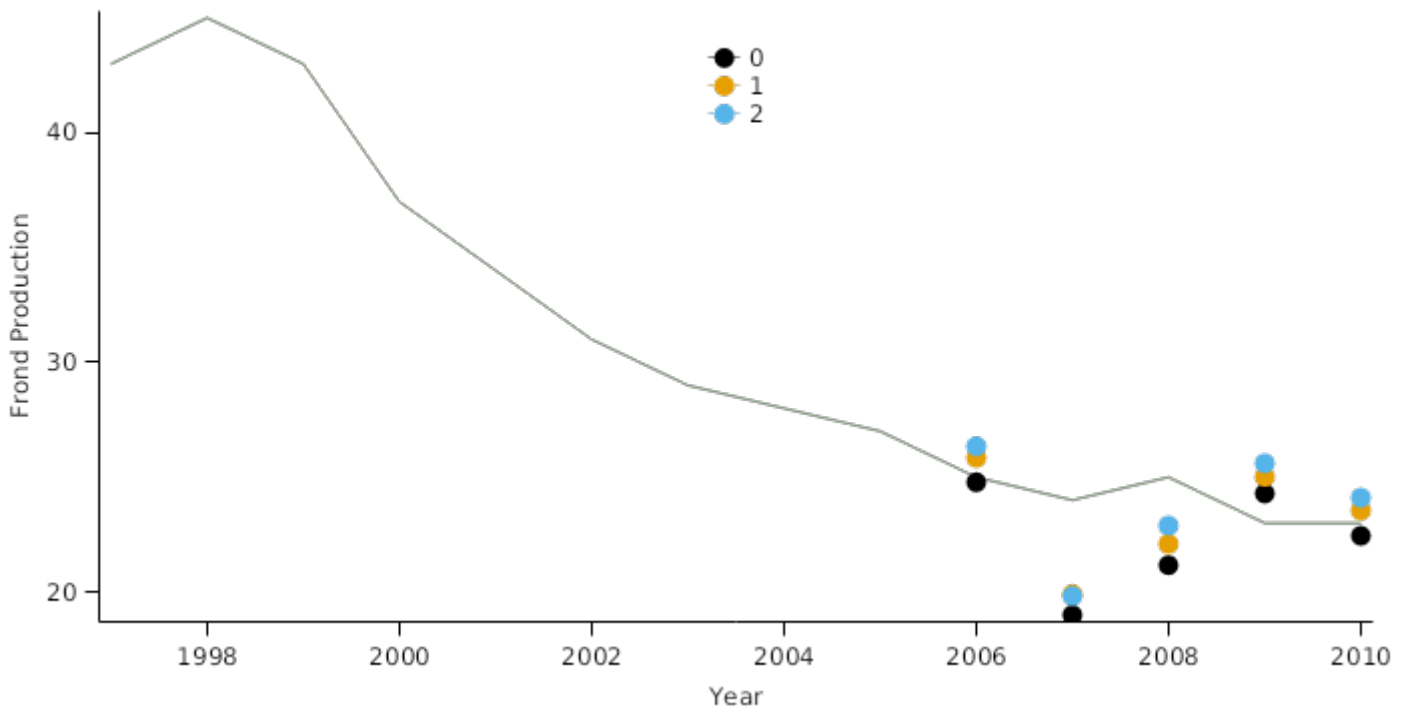
### LAI



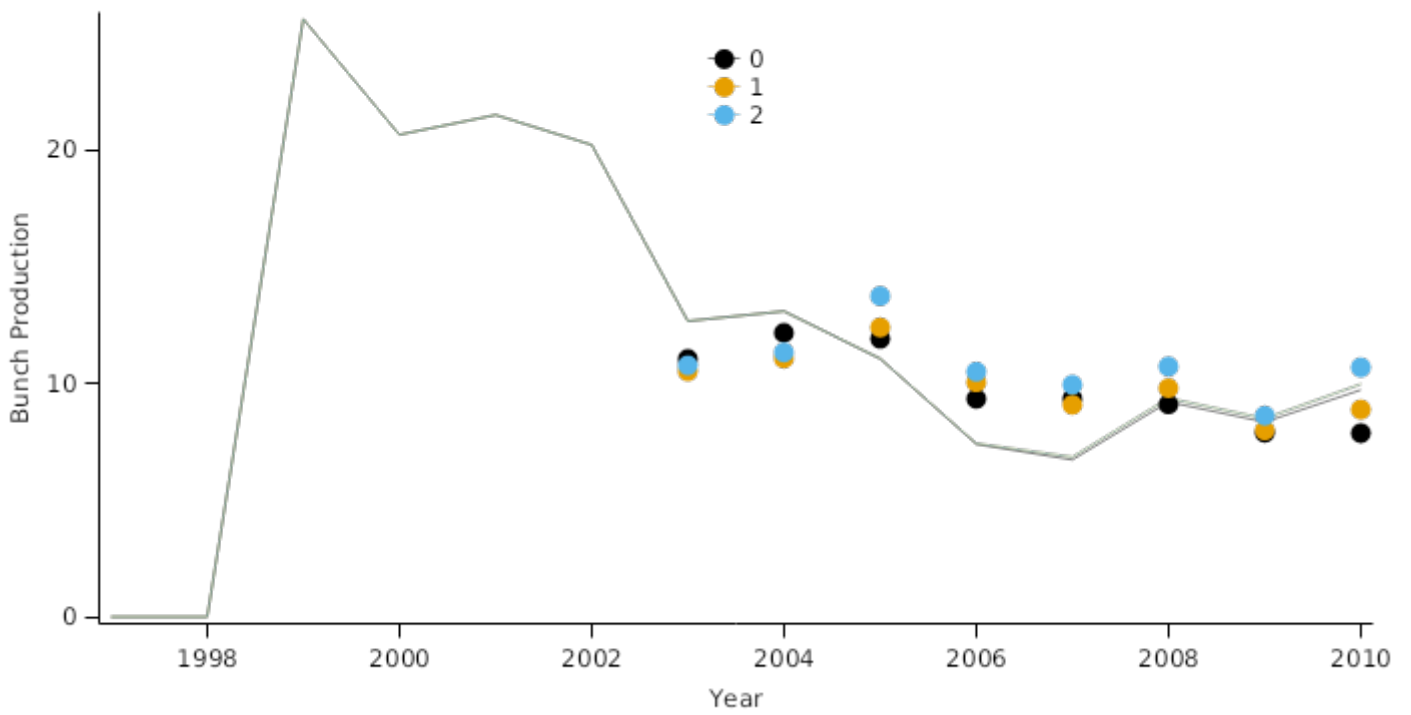
### StemMass



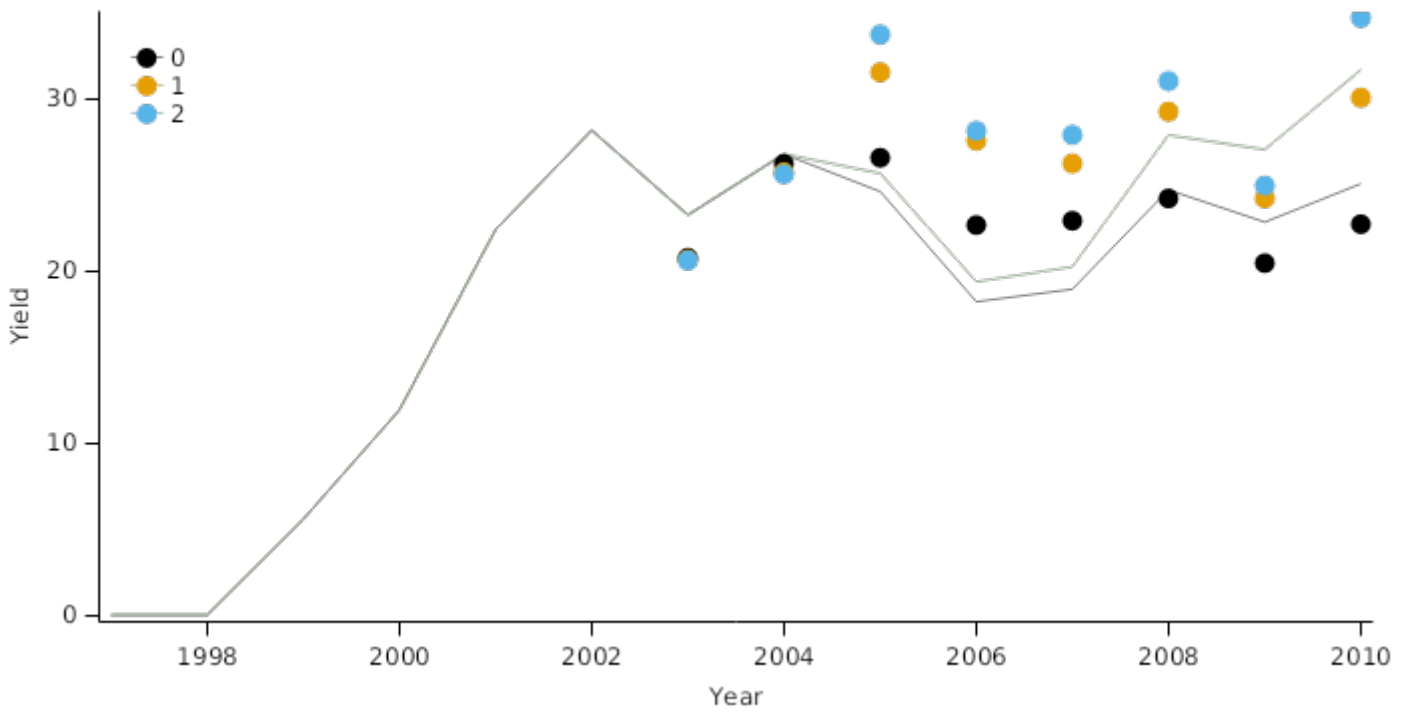
### FronndProduction



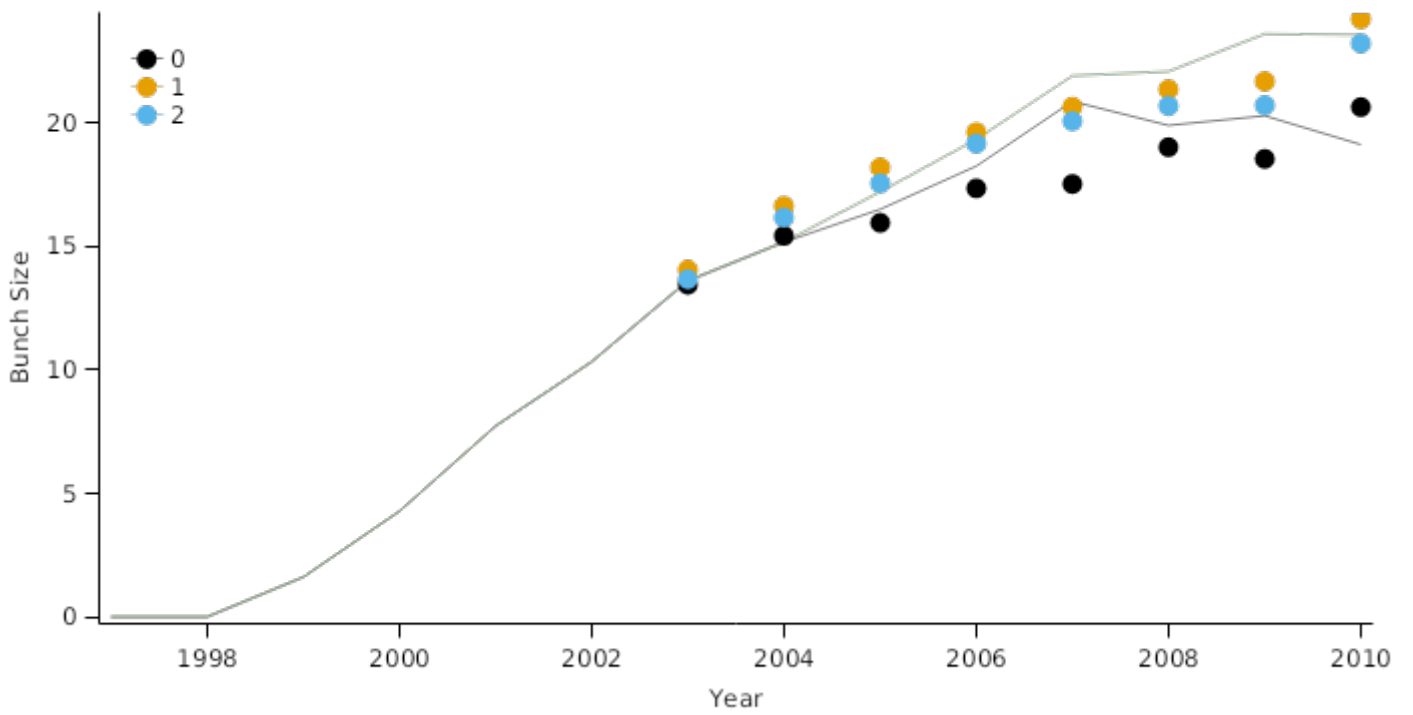
### BunchProduction



### AnnualYield

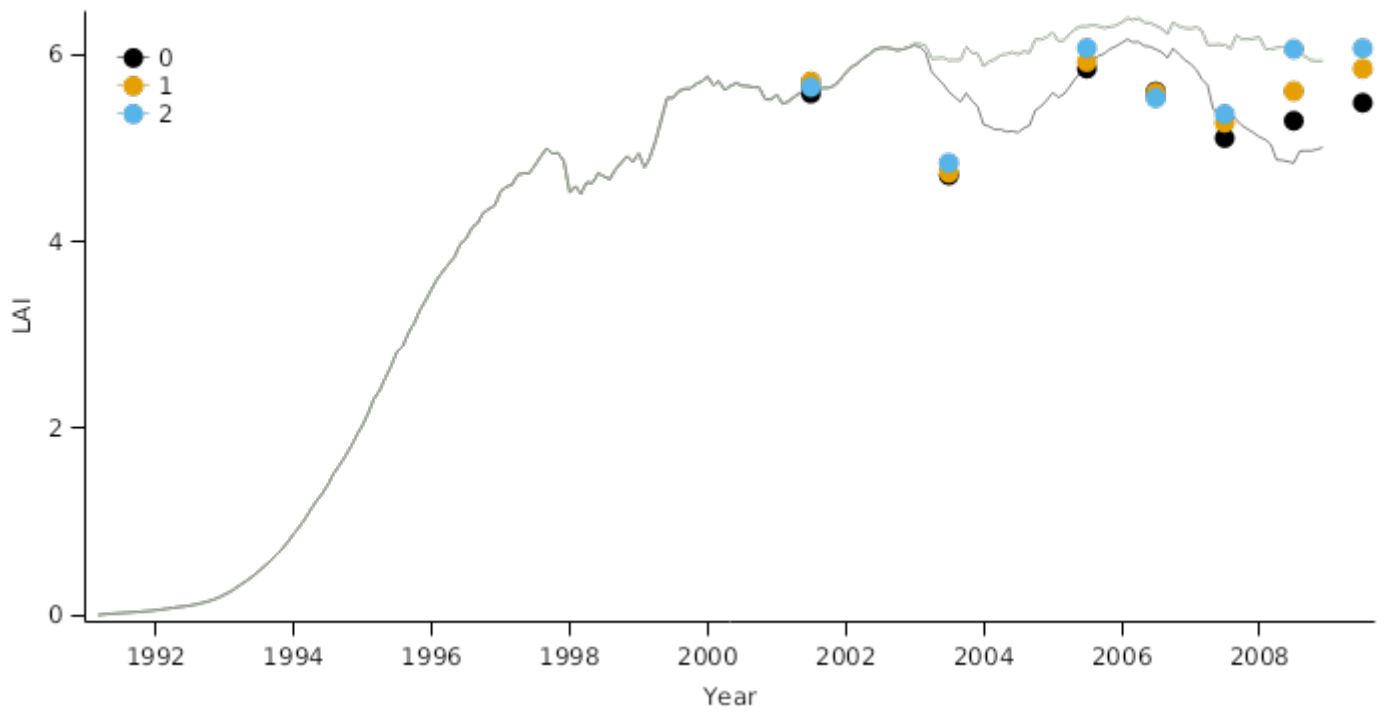


### AnnualBunchSize

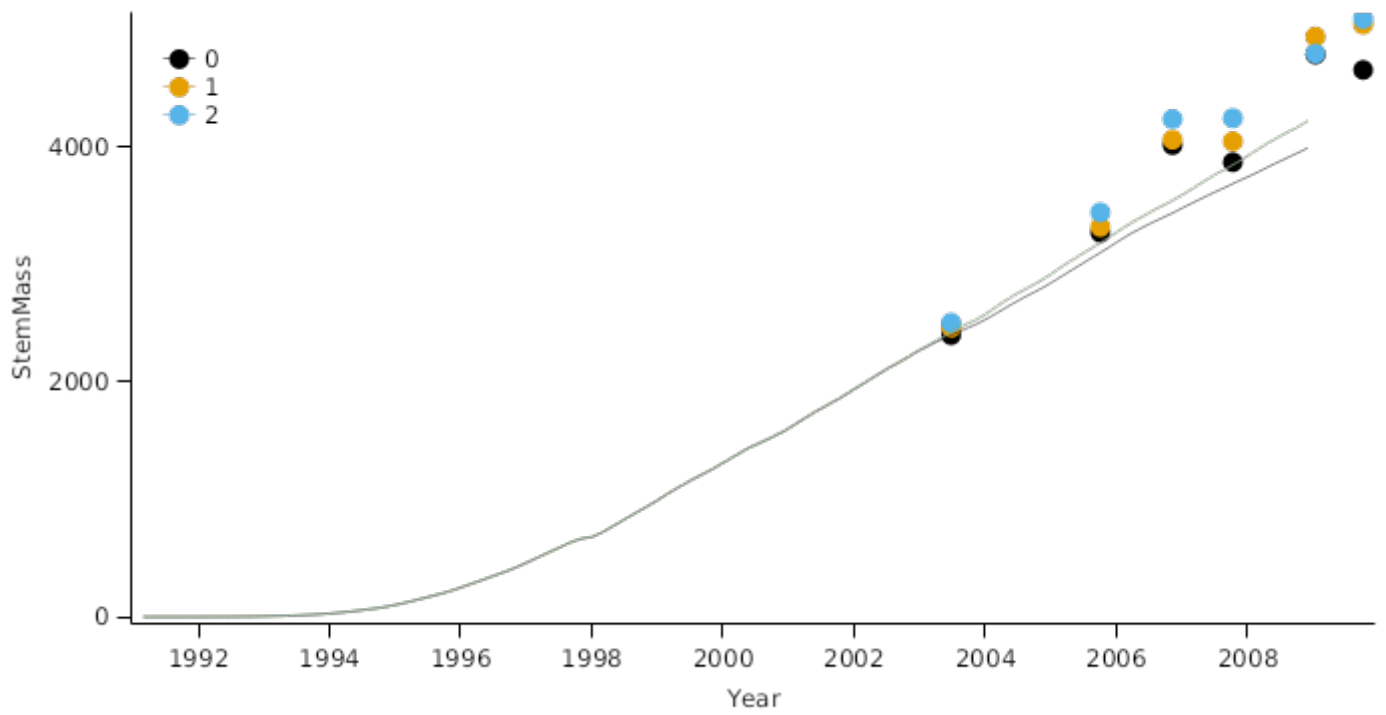


## 2.3 Sagarai

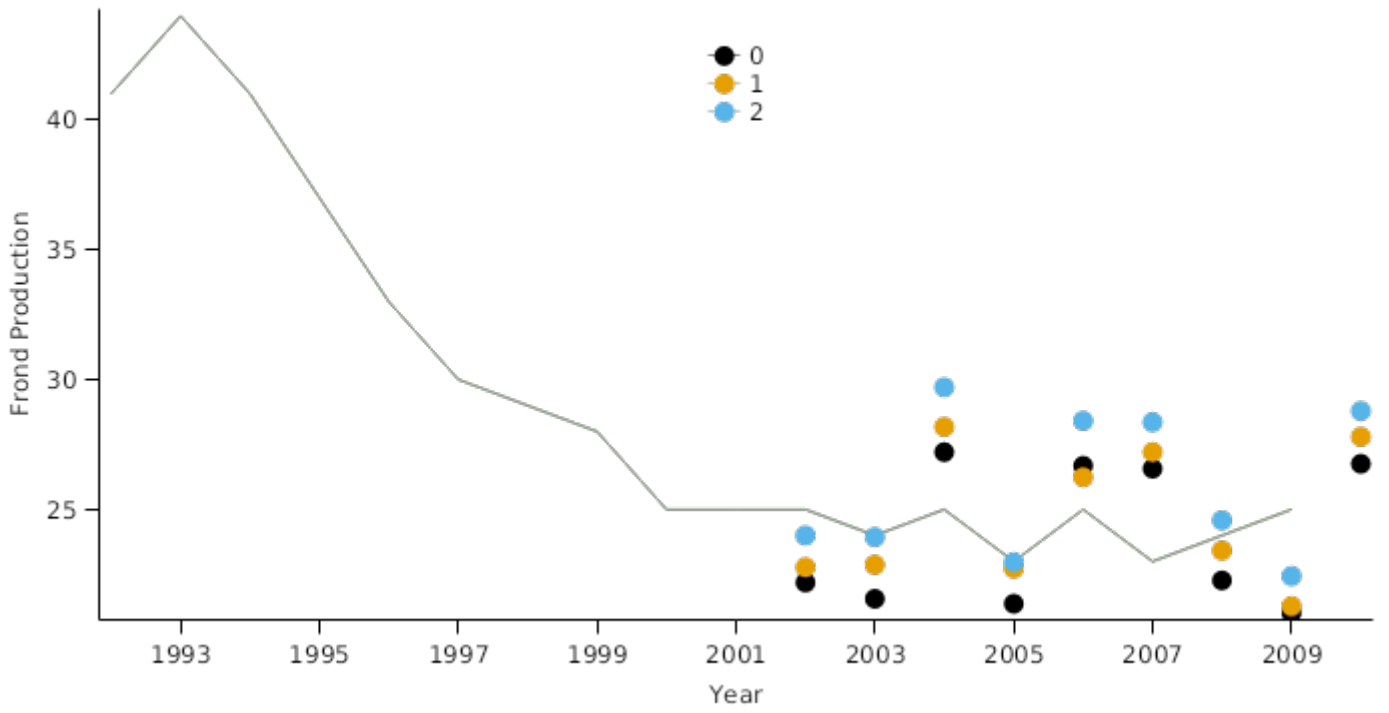
## LAI



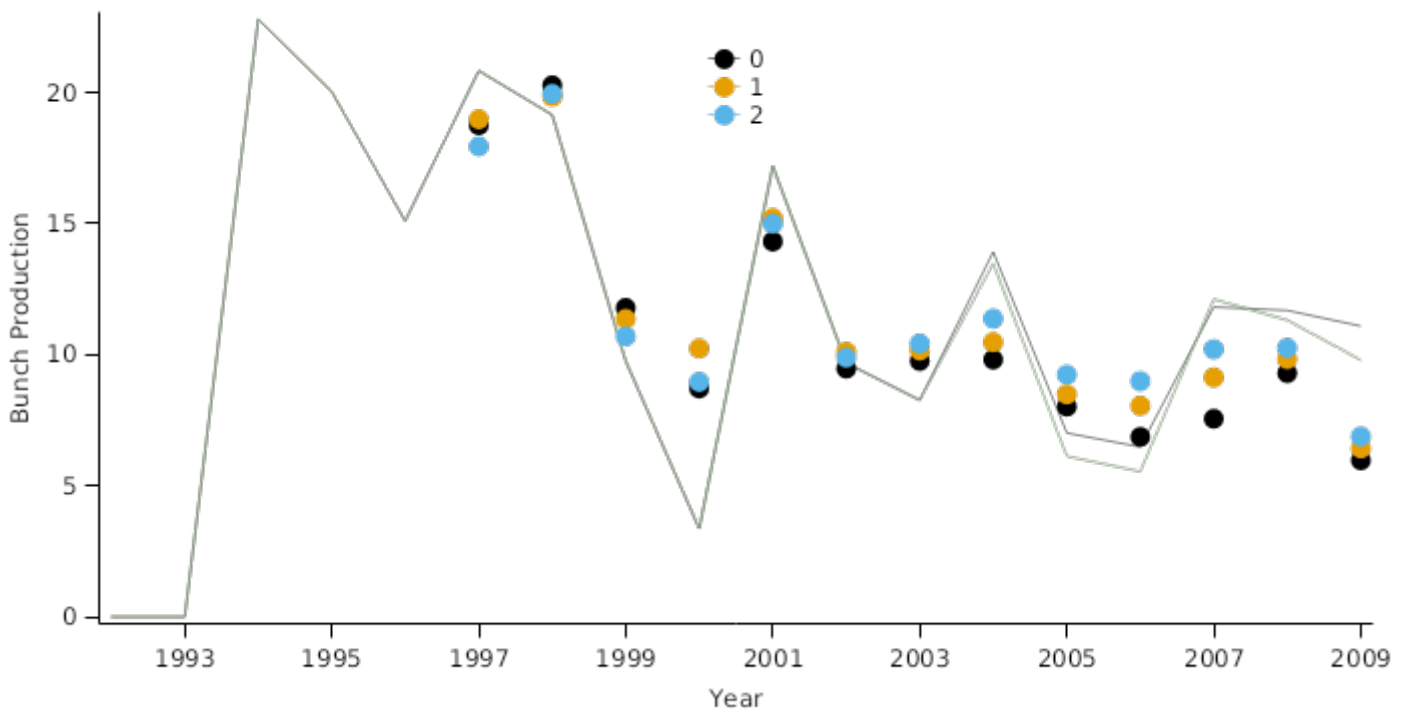
## StemMass



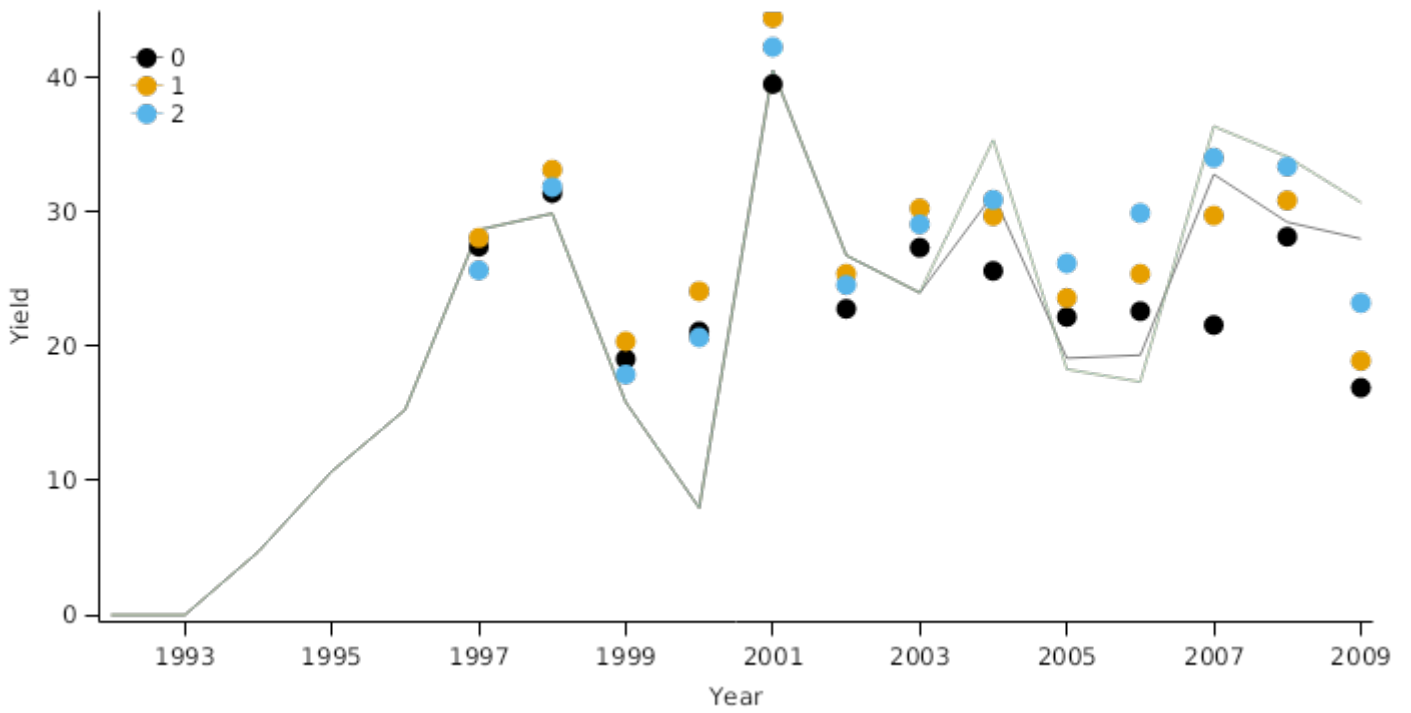
### FronndProduction



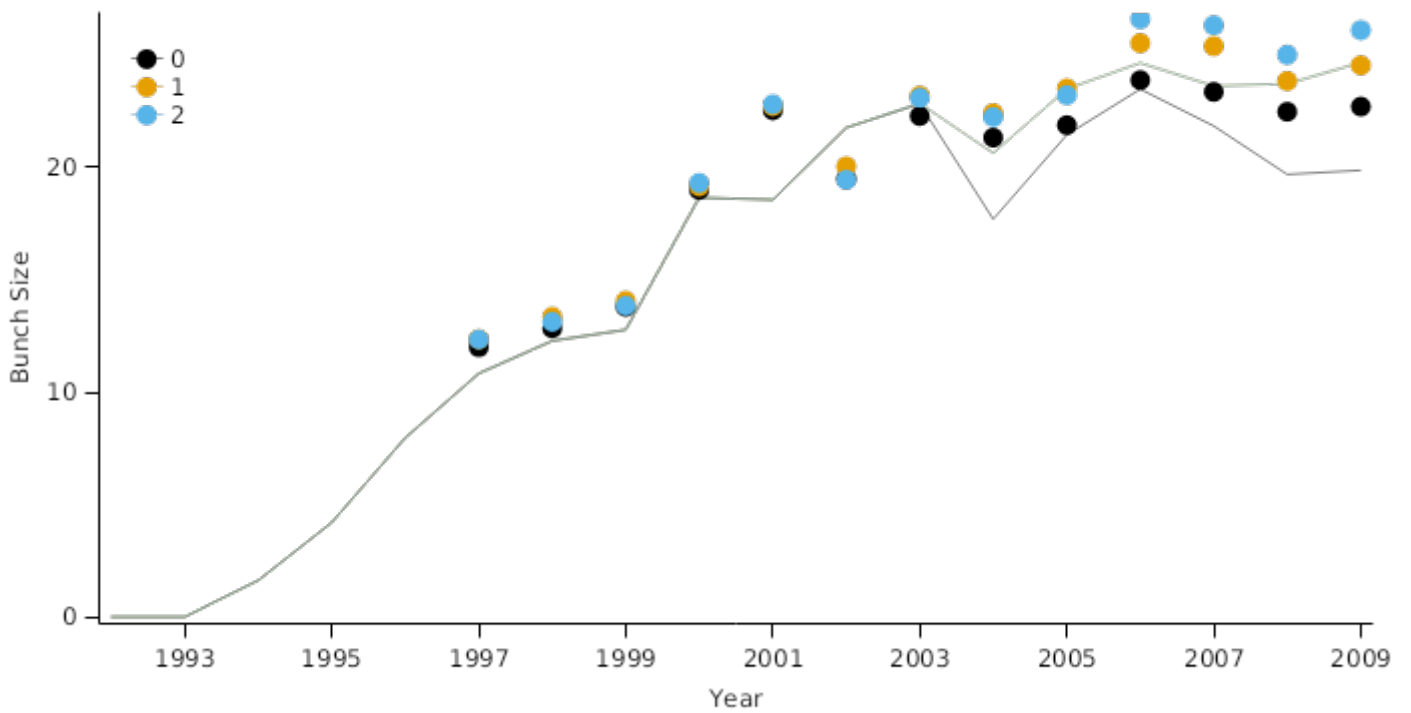
### BunchProduction



### AnnualYield

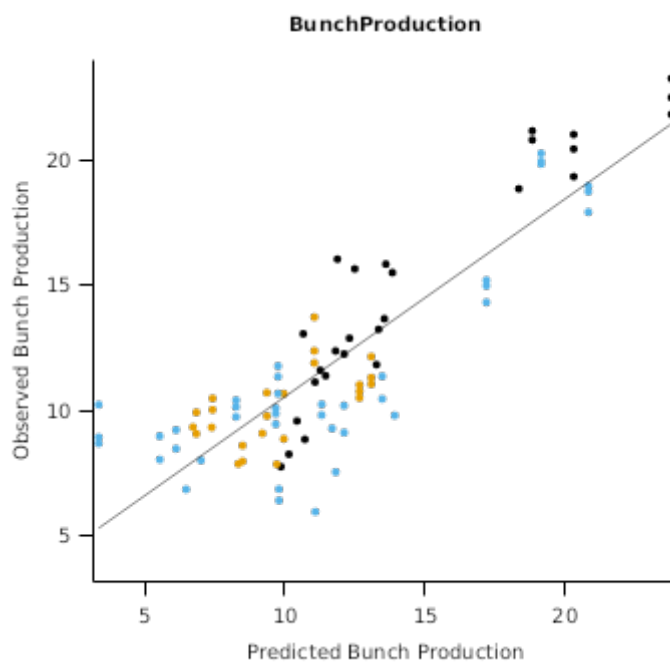
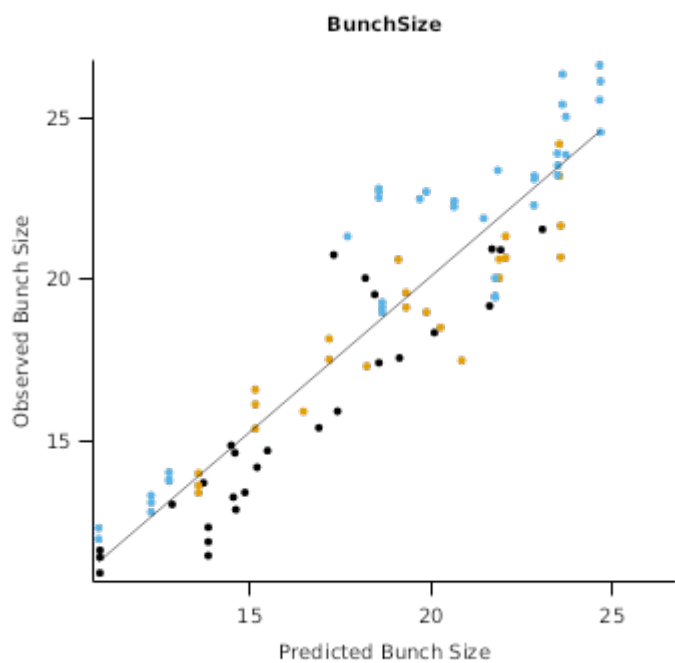
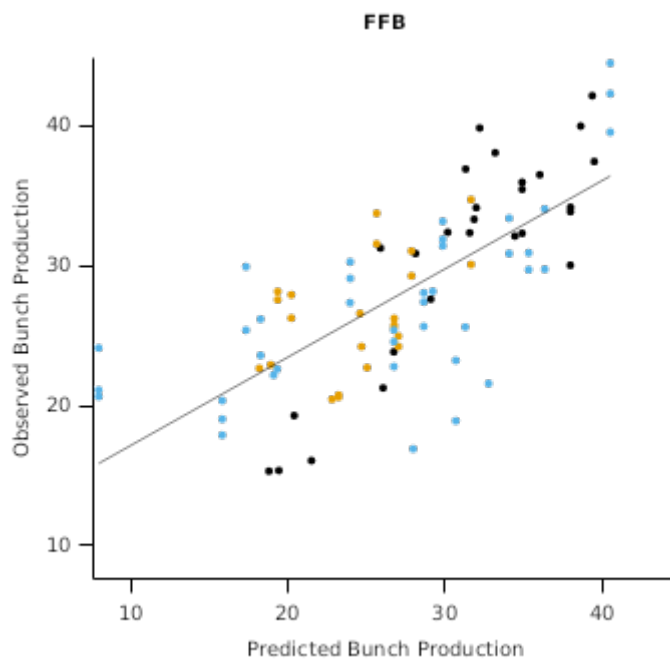
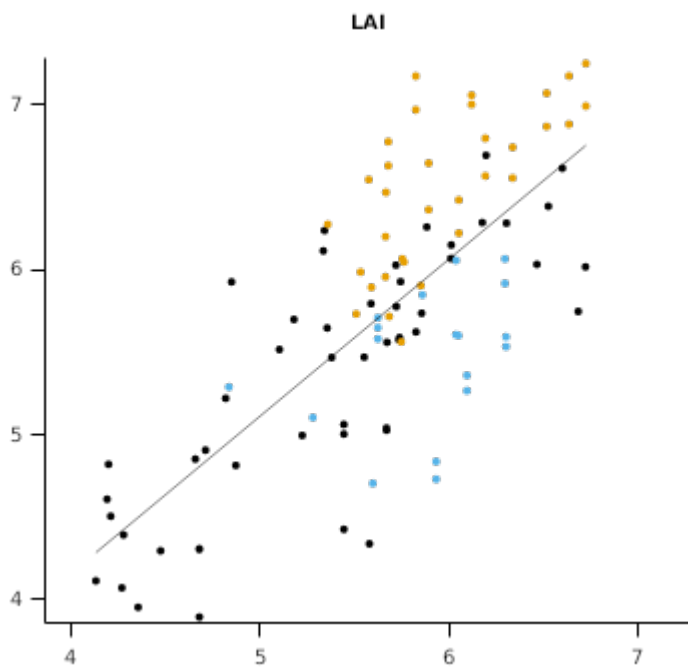


### AnnualBunchSize



## 2.4 Combined Results

Simulation results for the combined datasets from the various countries are shown in the following graphs. The model is able to adequately capture the influence of growing conditions (soil, climate) and management (Nitrogen)



### 3 References

Jones, C.A., Kiniry, J.R., Dyke, P.T., 1986. CERES-Maize: a simulation model of maize growth and development..