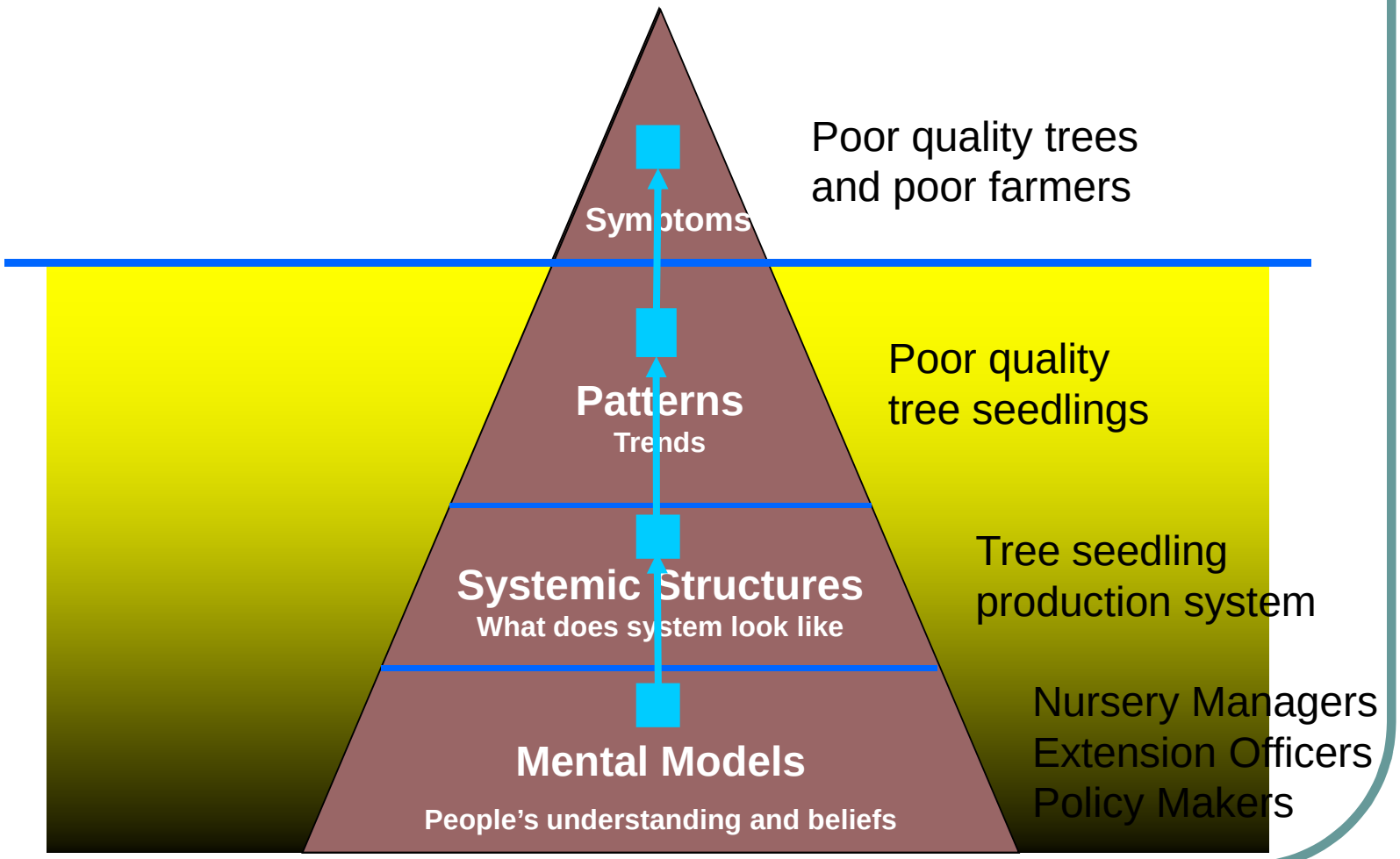
DBL Interactive

Applications of Participatory Systems Analysis and Bayesian Network models

Systems Thinking



Participatory Systems Analysis

- Systems Thinking with Stakeholders

Why?

- Reveal peoples metal models, i.e. how they think
- Expose and share ideas and views – collaborative learning
- Avoid parachuting in solutions and being told to ‘Get-Lost’ – empower stakeholders, improve adoption

Bayesian Networks

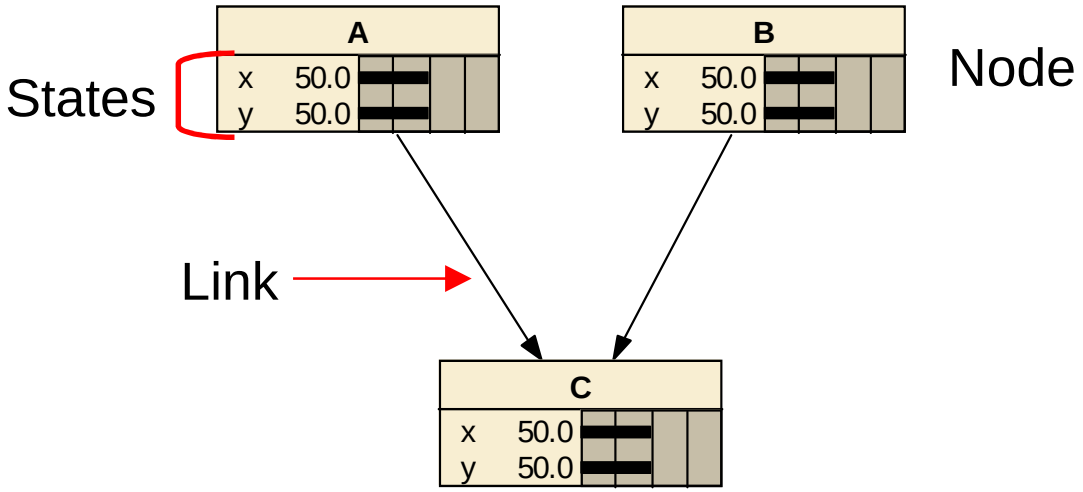
- Quite a handy tool for PSA

Why?

- Visual – easy of non-modellers
- Flexible – can link both qualitative and quantitative factors
- Uncertainty – probabilities
- Scenario, Diagnostic and Sensitivity Analysis – performed rapidly

What is a Bayesian Network?

- Two components
  - Structure (Directed Acyclic Graph): Nodes, States, Links
  - Probabilities
- Links between variables represent causal relationships (as with a conceptual model)
- Probabilities are used to quantify the relationship between variables
- Bayes Theorem



Node: C

Chance | % Probability

A	B	x	y
x	x	80.000	20.000
x	y	50.000	50.000
y	x	50.000	50.000
y	y	20.000	80.000

Conditional Probability Table (CPT)

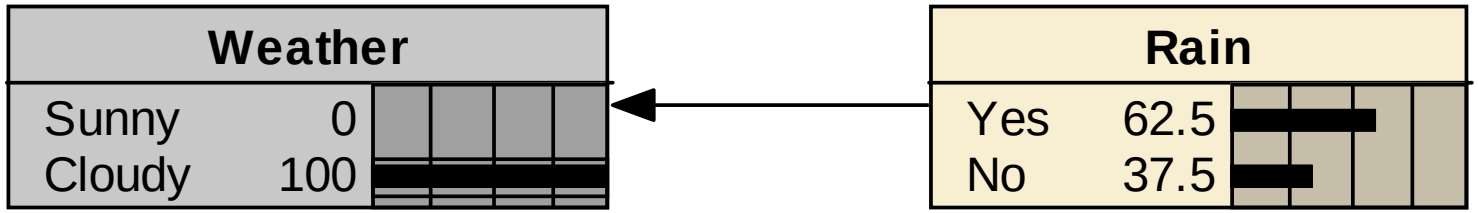
Bayes Theorem

$$P(B|A) \times P(A) = P(A|B) \times P(B)$$

$$P(B|A) = \frac{P(A|B) \times P(B)}{P(A)}$$

$$P(Rain|Cloudy) = \frac{P(Cloudy|Rain) \times P(Rain)}{P(Cloudy)}$$

$$P(Rain|Cloudy) = \frac{100 \times 50}{80} = 5000/80 = 62.5\ \%$$



Rain	Sunny	Cloudy
Yes	0.000	100.00
No	40.000	60.000

Yes	No
50.000	50.000

Bayes

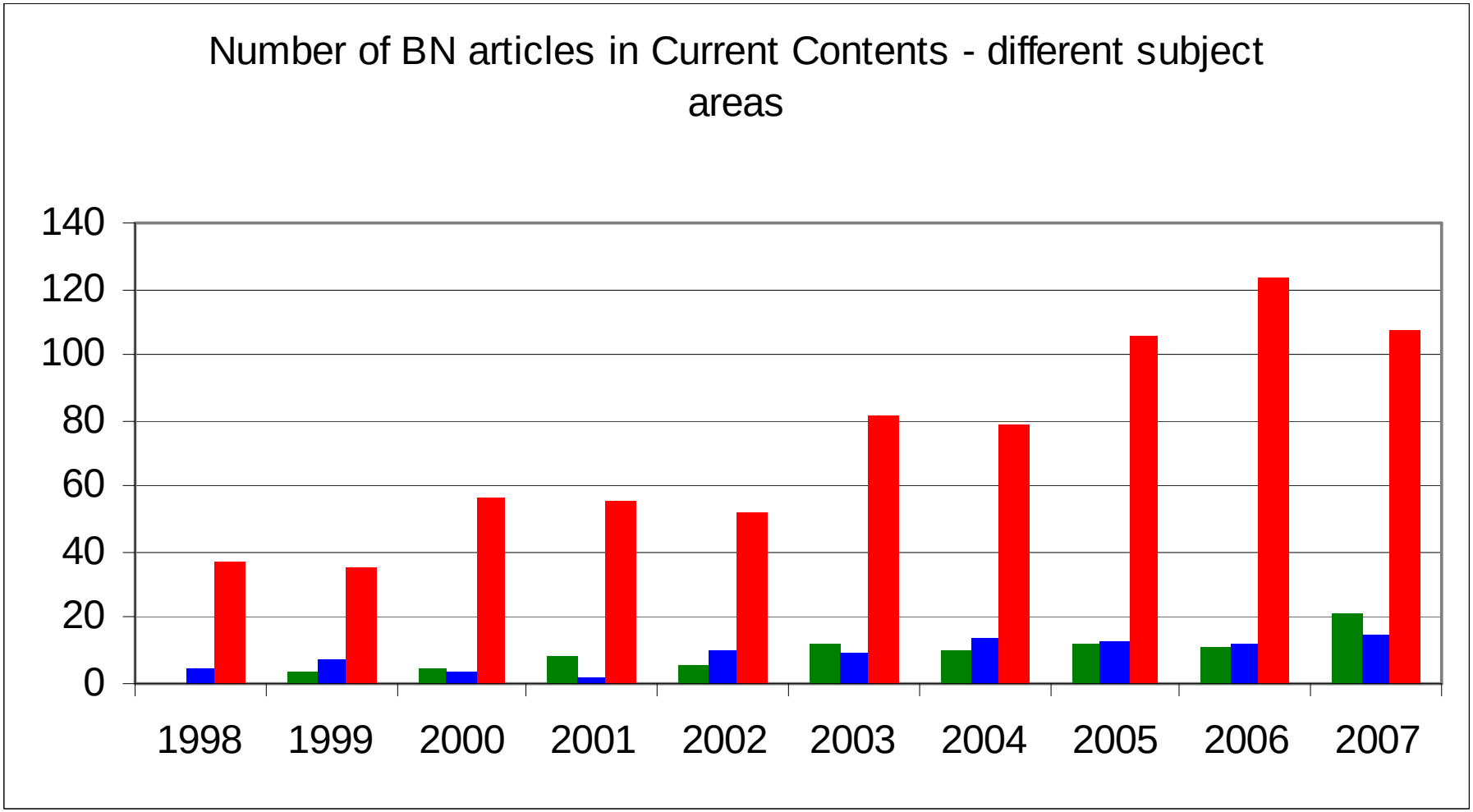
Rev. Thomas Bayes
(1702-1761)

Then

Now

Modelling Issues	Process/ System Dynamic Models	Bayesian Networks	Agent-based Models	Mathematical/ Statistical Models	Expert Systems
Can model cyclical processes and feedback loops?	X		X		
Can model non-linear system dynamics?	X	X	X	X	
Can easily accommodate and represent uncertainty in predictions?		X			X
Can be used to model emergent behaviour and self-organisation?			X		
Can model system dynamics continuously over time?	X		X	X	
Can model interacting processes operating at different temporal and spatial scales?	X		X		
Can be used for prediction and scenario analysis?	X	X		X	X
Can be used for back-casting and diagnostic analysis?		X			X
Can be used in data poor situations?		X	X		X
Are simple for managers and non-modellers to use and interpret?		X			X
Have relatively low development cost?		X			X
Are relatively easy to update?		X			X

Liedloff and Smith 2010, Ecological Modelling, 221: 2565-2575



Red = Engineering and Computer Science
Blue = Clinical Medicine
Green = Ag, Biology and Env. Science

ABNMS2010 Conference Talks

Bayesian network modelling from the **stakeholders perspective**

Bayesian Networks as a **Complex System tool** in the context of a major industry and University project

Predicting a ‘tree change’ in Australia’s tropical savannas: Combining different types of models to understand **complex ecosystem behaviour**

Combining state and transition models with **dynamic Bayesian networks**

BNs for **Anomalous Vessel Detection**

Bayesian modelling for the **Assessment of Proposed Indirect Potable Reuse Schemes**

Is dingo management the key? Using a Bayesian Belief Network to **assess the impact of an apex predator on biodiversity conservation** in the Australian arid zone

Modelling invasive risk of a changing landscape: Using BBNs to **target areas for effective weed management**

Bayes Nets as a method for **analysing return for investment in fire management planning**

Interpreting Risk and Motivational Context: **Importing New Zealand Apples into Australia**

A Bayesian Belief Network for **Legal Decision Support** in Owners Corporation Cases

Consumer Credit Scoring: Building a better predictor using causal Bayesian networks

Object Oriented Bayesian Networks: Designing for simplicity and integration

Build collaborative models or capacity? Reflections from two years on

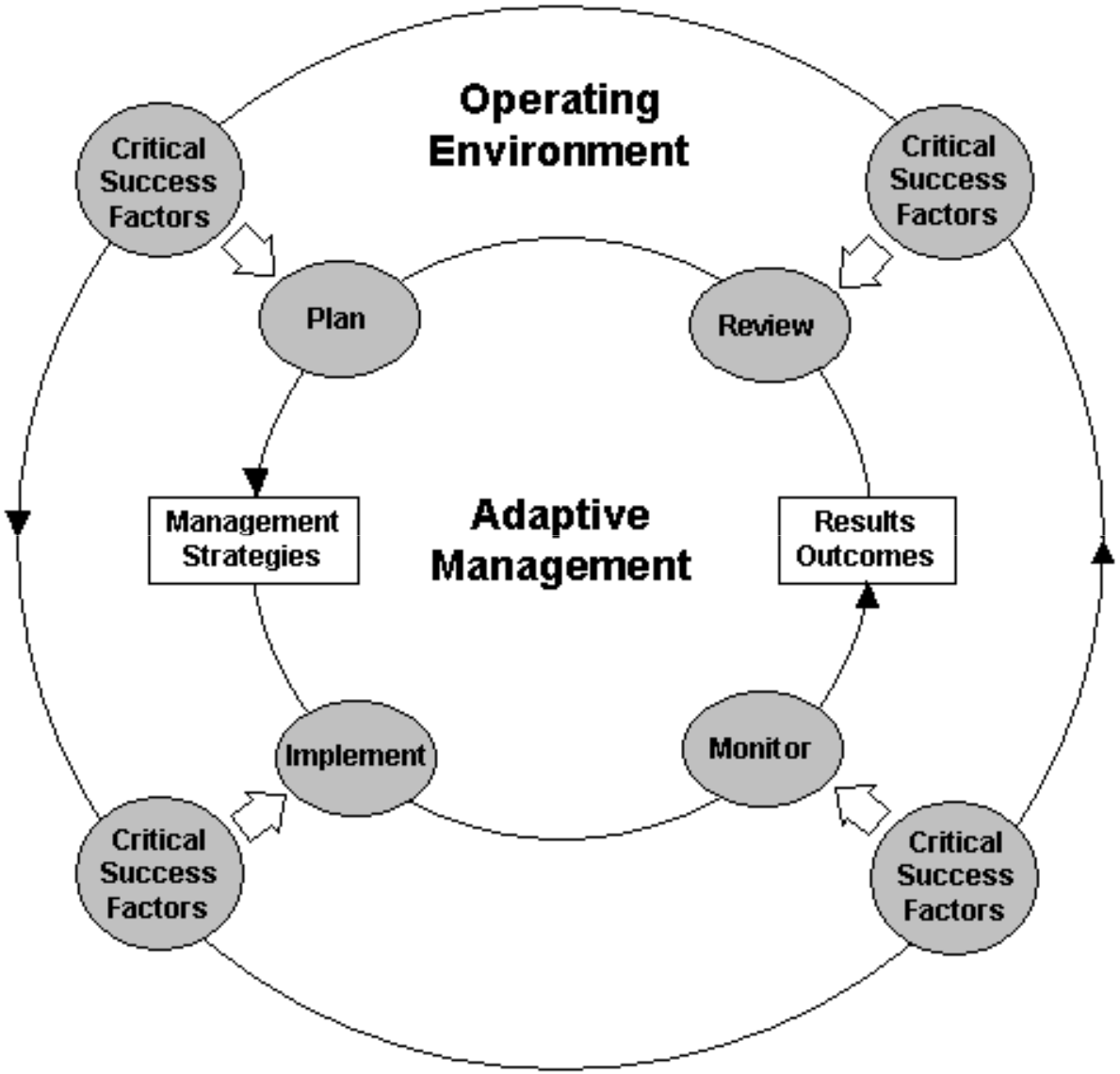
Example 1 - QPWS

The Problem:

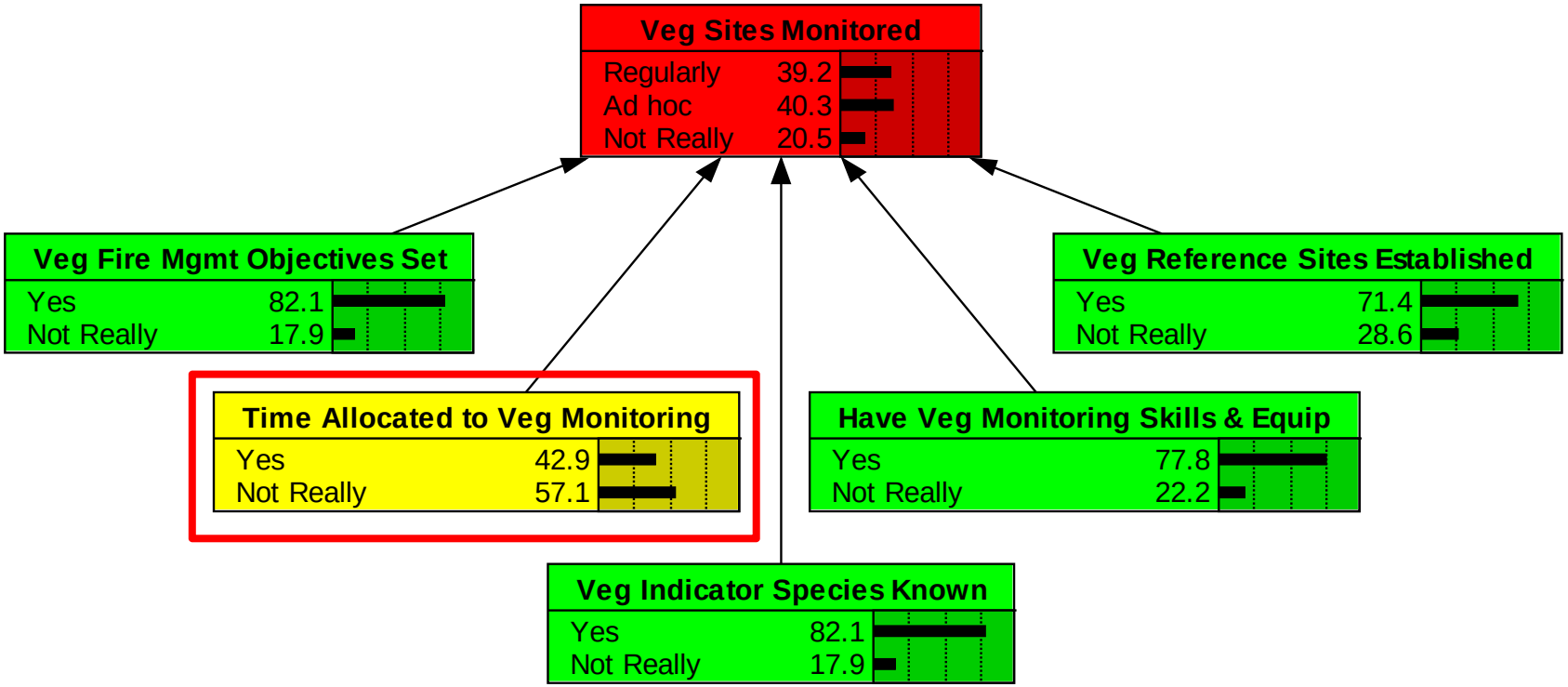
- Had a policy – Adaptive Management of Fire on conservation reserves
- Spent heaps and money on implementing this policy
- But Adaptive Management still wasn't happening

What we did:

- Systems analysis with park rangers

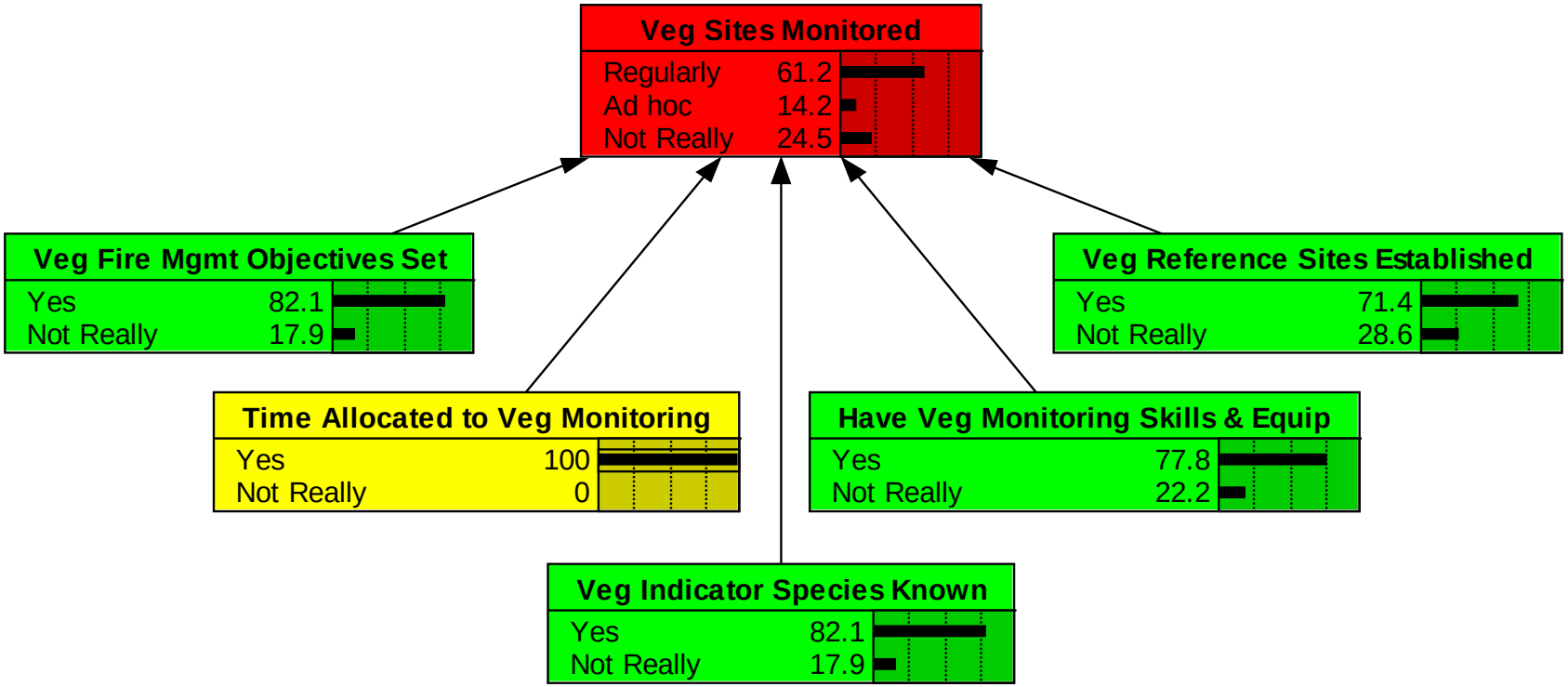

Operating Environment
Critical Success Factors
Critical Success Factors
Plan
Review
Management Strategies
Adaptive Management
Results Outcomes
Implement
Monitor
Critical Success Factors
Critical Success Factors

Performance



Too busy cleaning dunnies

Intervention Assessment



Example 2 – Tree Seedlings Philippines

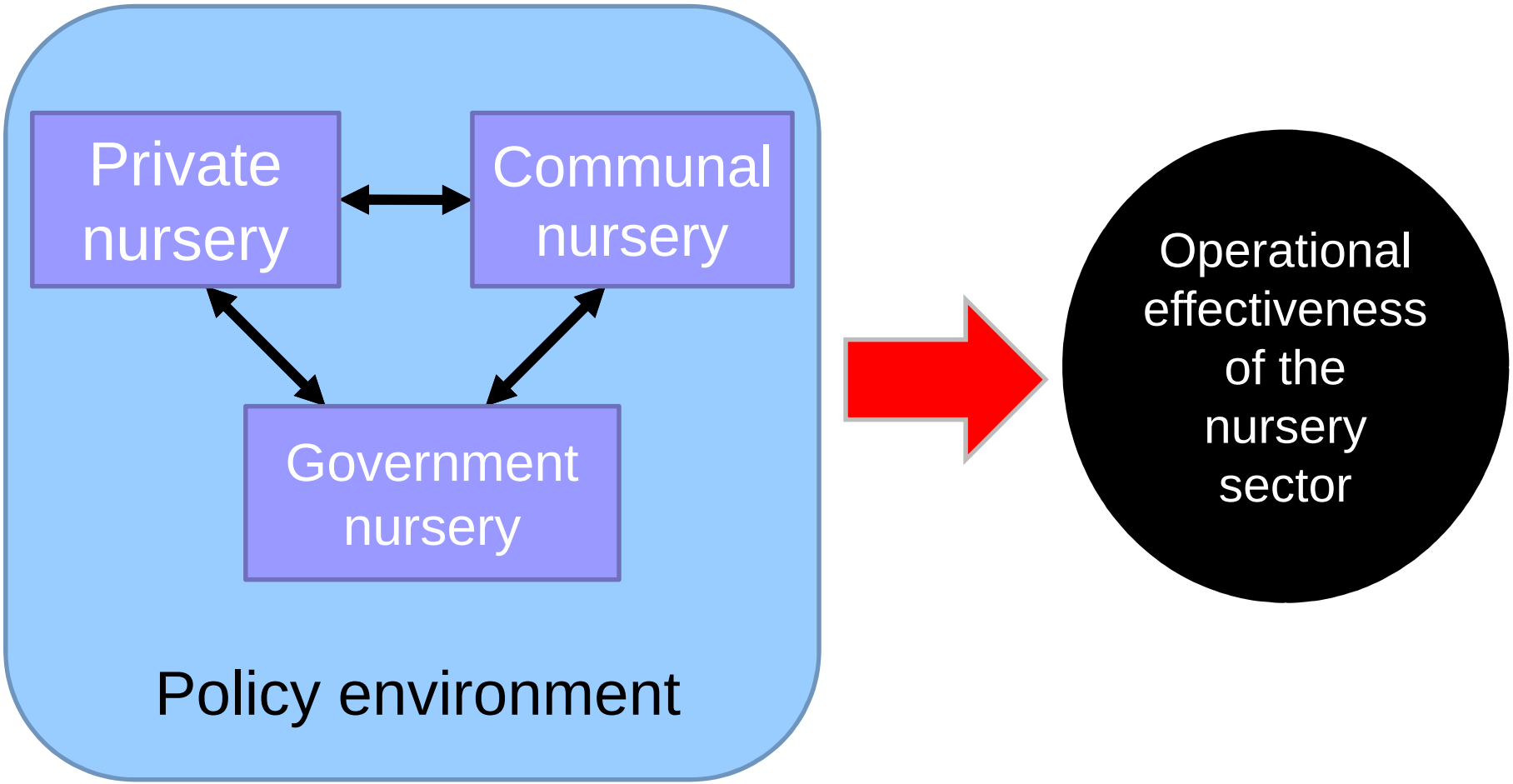
The Problem:

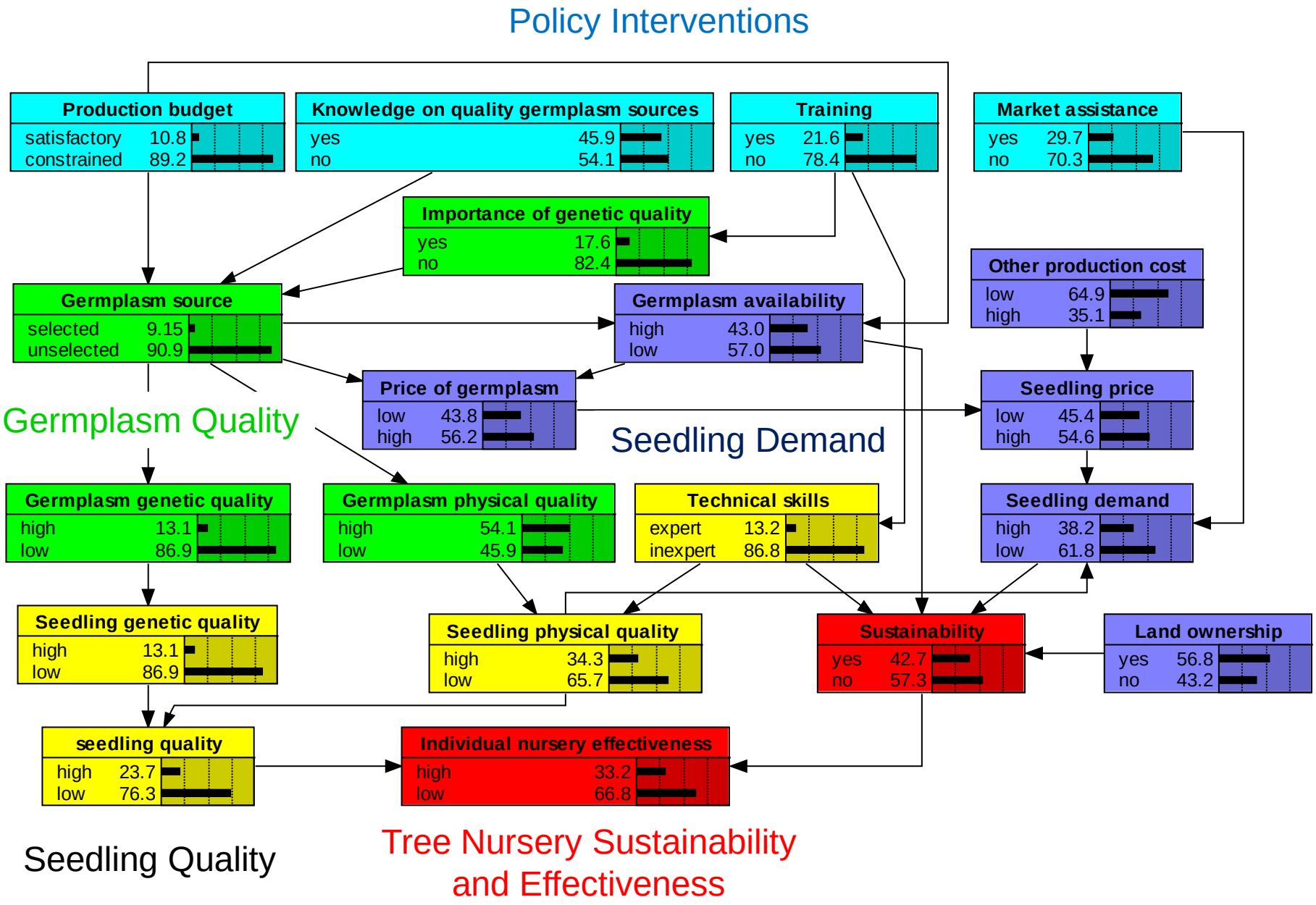
- No quality protocols in most nurseries
- Poor seedlings – poor trees
- Low financial viability – not able to sustain nursery operations

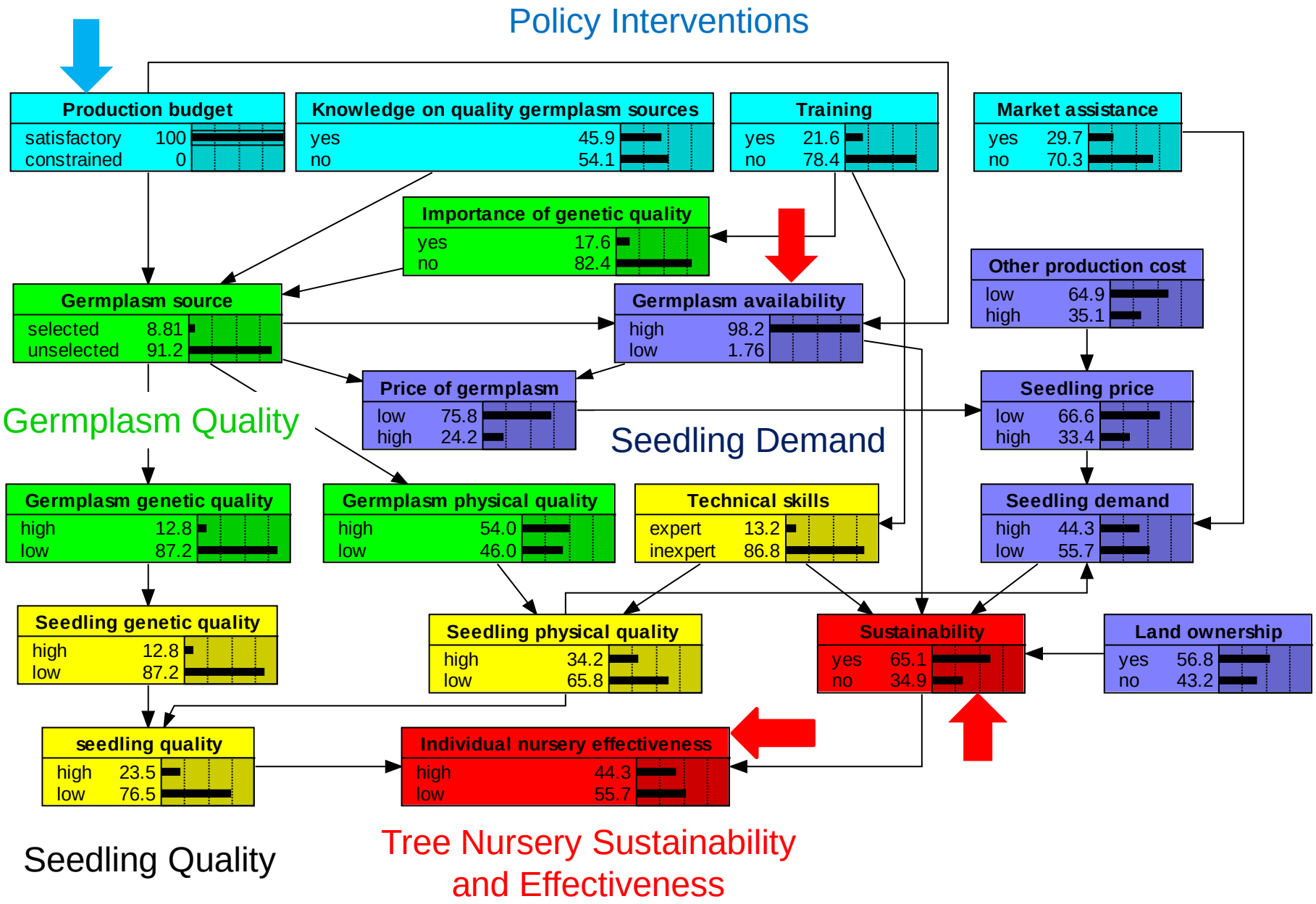
What we did:

- Systems analysis with nursery managers, extension officers and government

Operational effectiveness of the forestry nursery sector




Policy Interventions
Production budget
satisfactory 10.8
constrained 89.2
Knowledge on quality germplasm sources
yes 45.9
no 54.1
Training
yes 21.6
no 78.4
Market assistance
yes 29.7
no 70.3
Importance of genetic quality
yes 17.6
no 82.4
Germplasm source
selected 9.15
unselected 90.9
Germplasm availability
high 43.0
low 57.0
Other production cost
low 64.9
high 35.1
Price of germplasm
low 43.8
high 56.2
Seedling price
low 45.4
high 54.6
Germplasm Quality
Seedling Demand
Germplasm genetic quality
high 13.1
low 86.9
Germplasm physical quality
high 54.1
low 45.9
Technical skills
expert 13.2
inexpert 86.8
Seedling demand
high 38.2
low 61.8
Seedling genetic quality
high 13.1
low 86.9
Seedling physical quality
high 34.3
low 65.7
Sustainability
yes 42.7
no 57.3
Land ownership
yes 56.8
no 43.2
seedling quality
high 23.7
low 76.3
Individual nursery effectiveness
high 33.2
low 66.8
Seedling Quality
Tree Nursery Sustainability
and Effectiveness


Policy Interventions
Production budget
satisfactory 100
constrained 0
Knowledge on quality germplasm sources
yes 45.9
no 54.1
Training
yes 21.6
no 78.4
Market assistance
yes 29.7
no 70.3
Importance of genetic quality
yes 17.6
no 82.4
Germplasm source
selected 8.81
unselected 91.2
Germplasm availability
high 98.2
low 1.76
Other production cost
low 64.9
high 35.1
Price of germplasm
low 75.8
high 24.2
Seedling price
low 66.6
high 33.4
Germplasm Quality
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Germplasm physical quality
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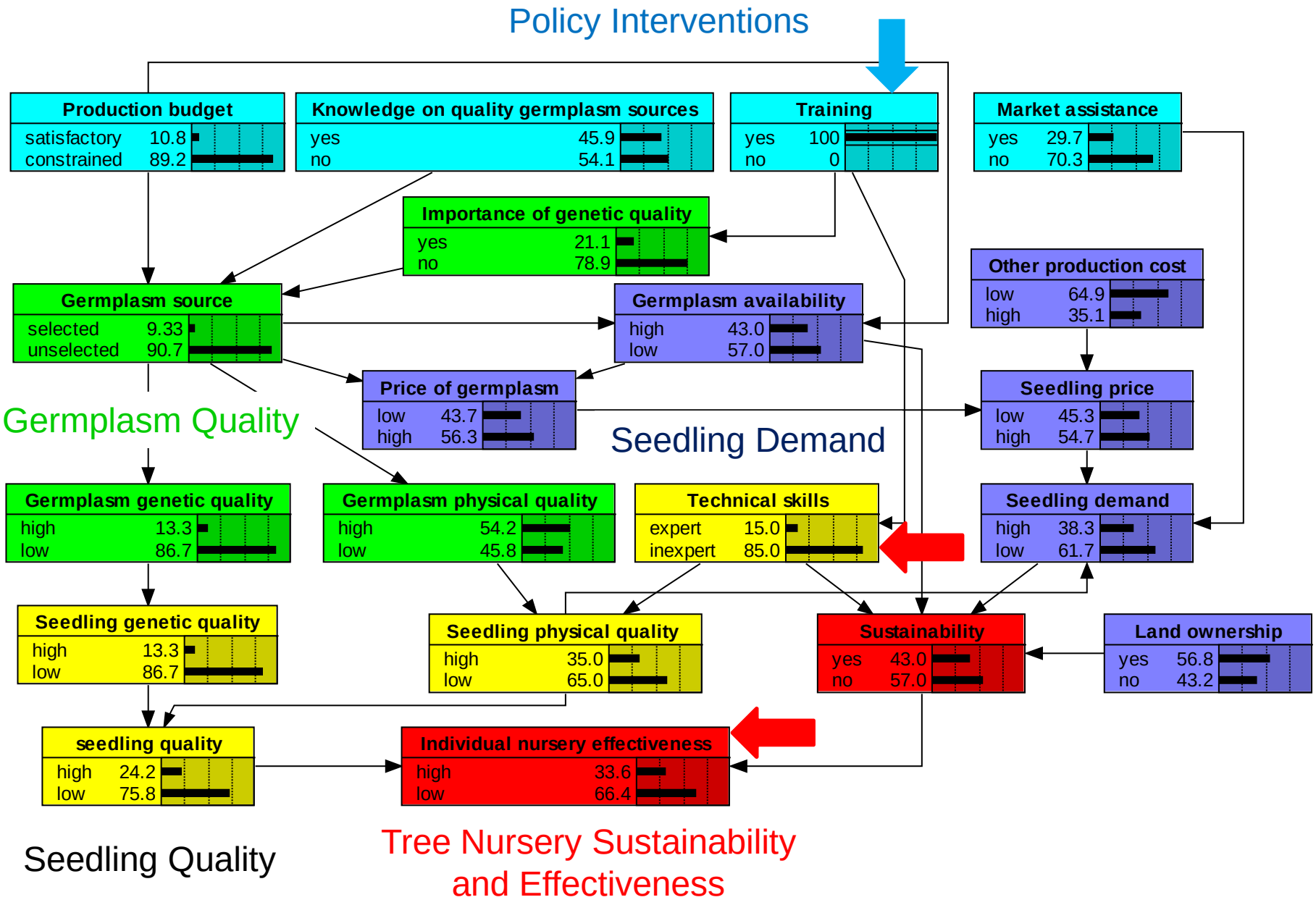
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no 0
Market assistance
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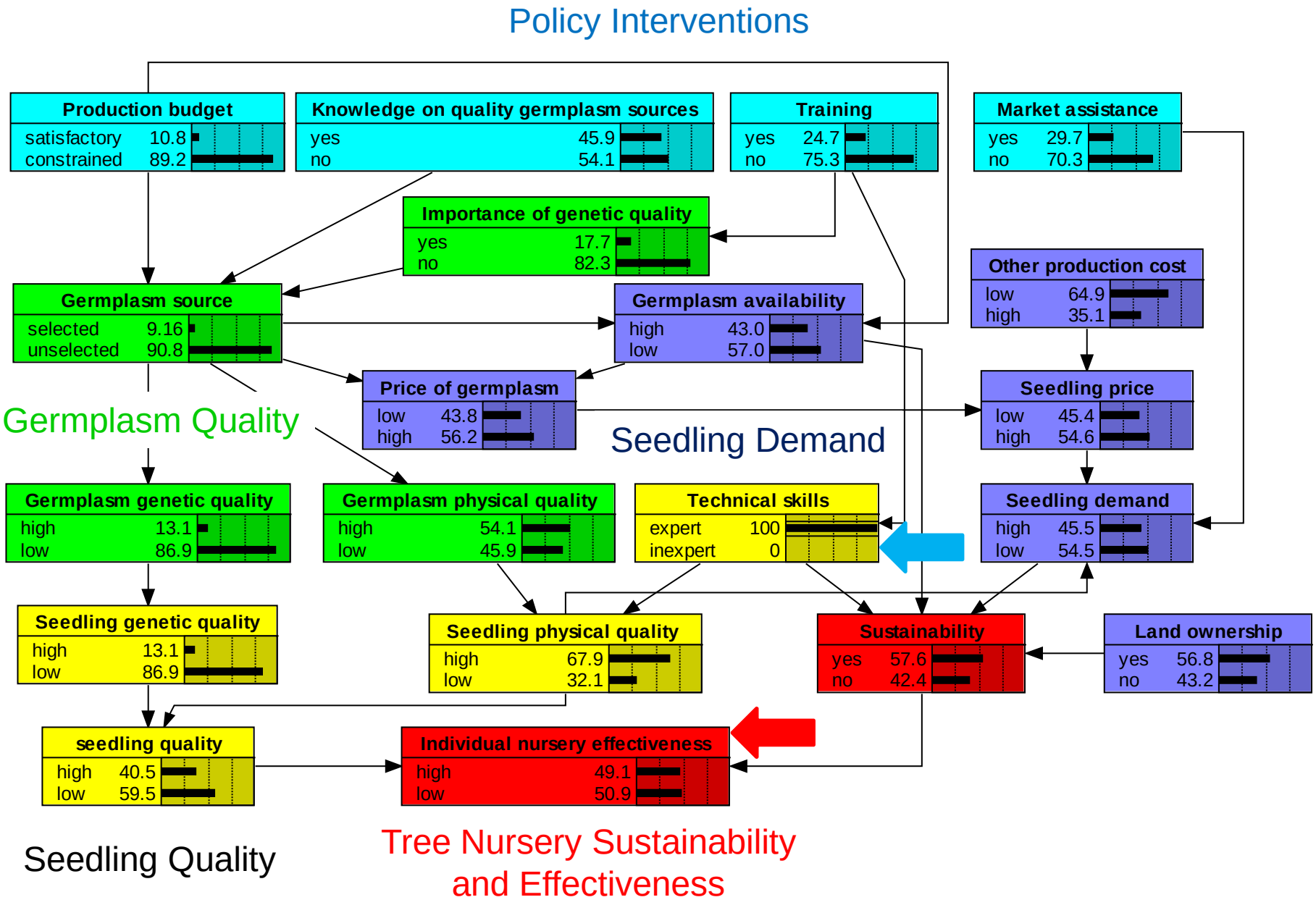
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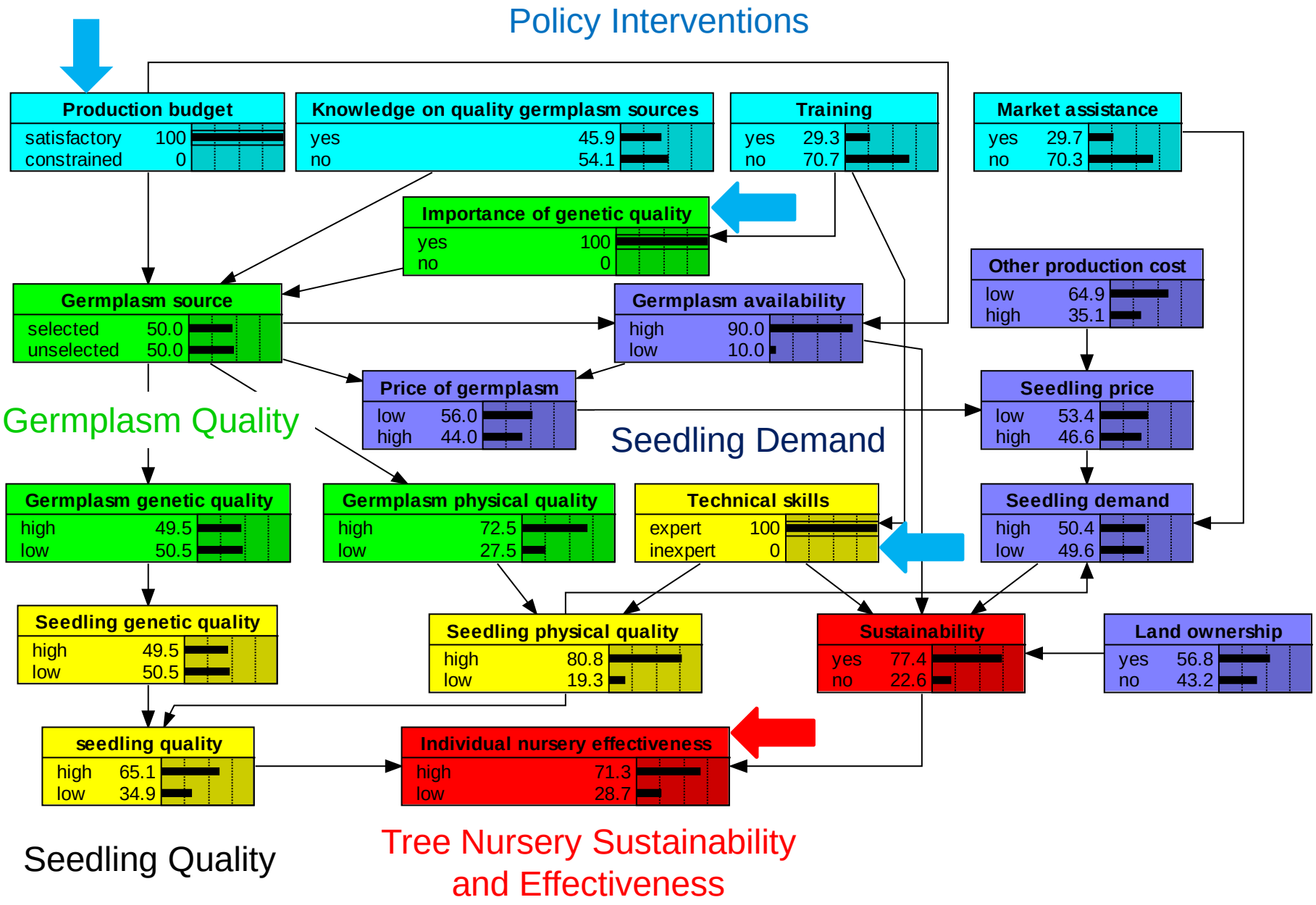
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high 46.6
Germplasm Quality
Seedling Demand
Germplasm genetic quality
high 49.5
low 50.5
Germplasm physical quality
high 72.5
low 27.5
Technical skills
expert 100
inexpert 0
Seedling demand
high 50.4
low 49.6
Seedling genetic quality
high 49.5
low 50.5
Seedling physical quality
high 80.8
low 19.3
Sustainability
yes 77.4
no 22.6
Land ownership
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Tree Nursery Sustainability
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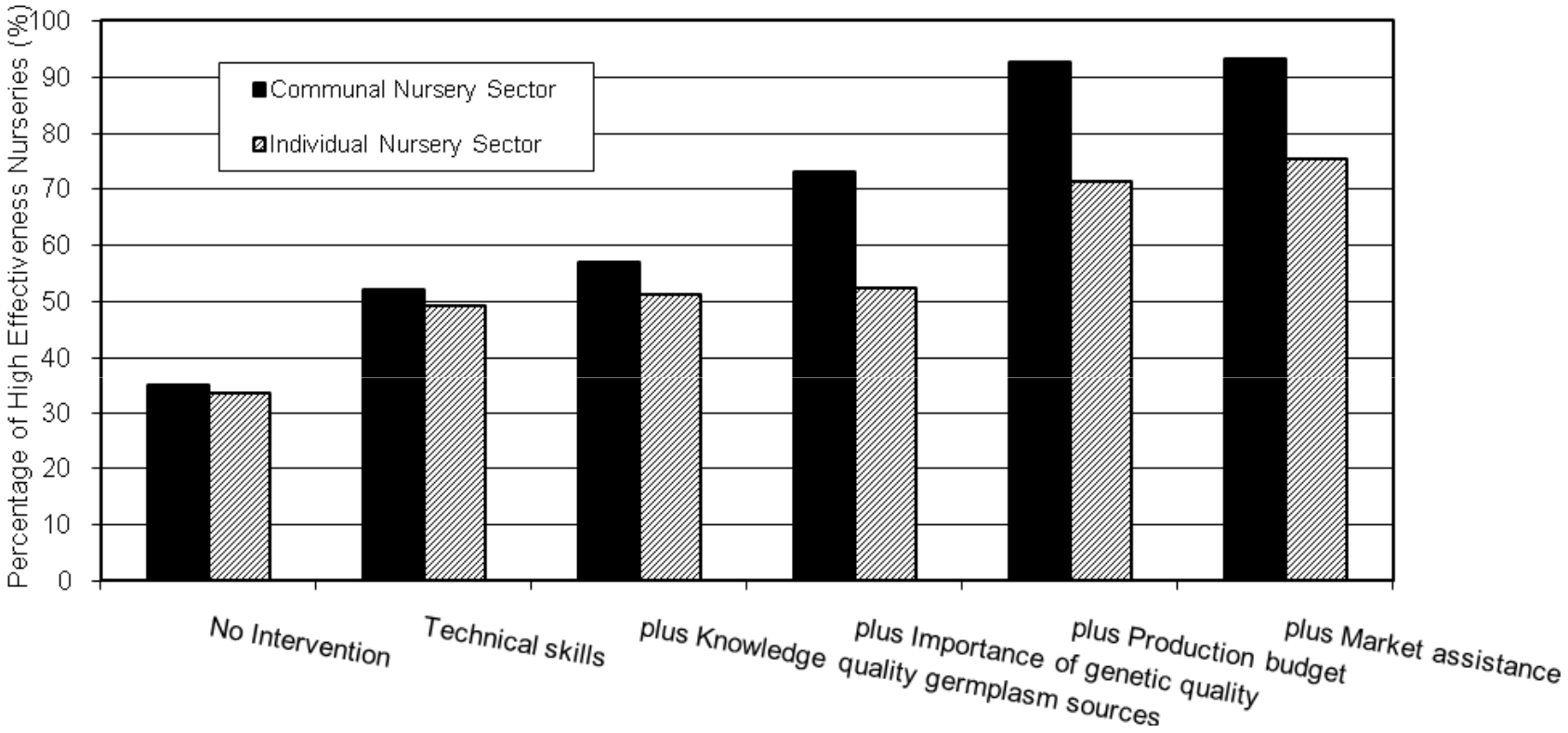
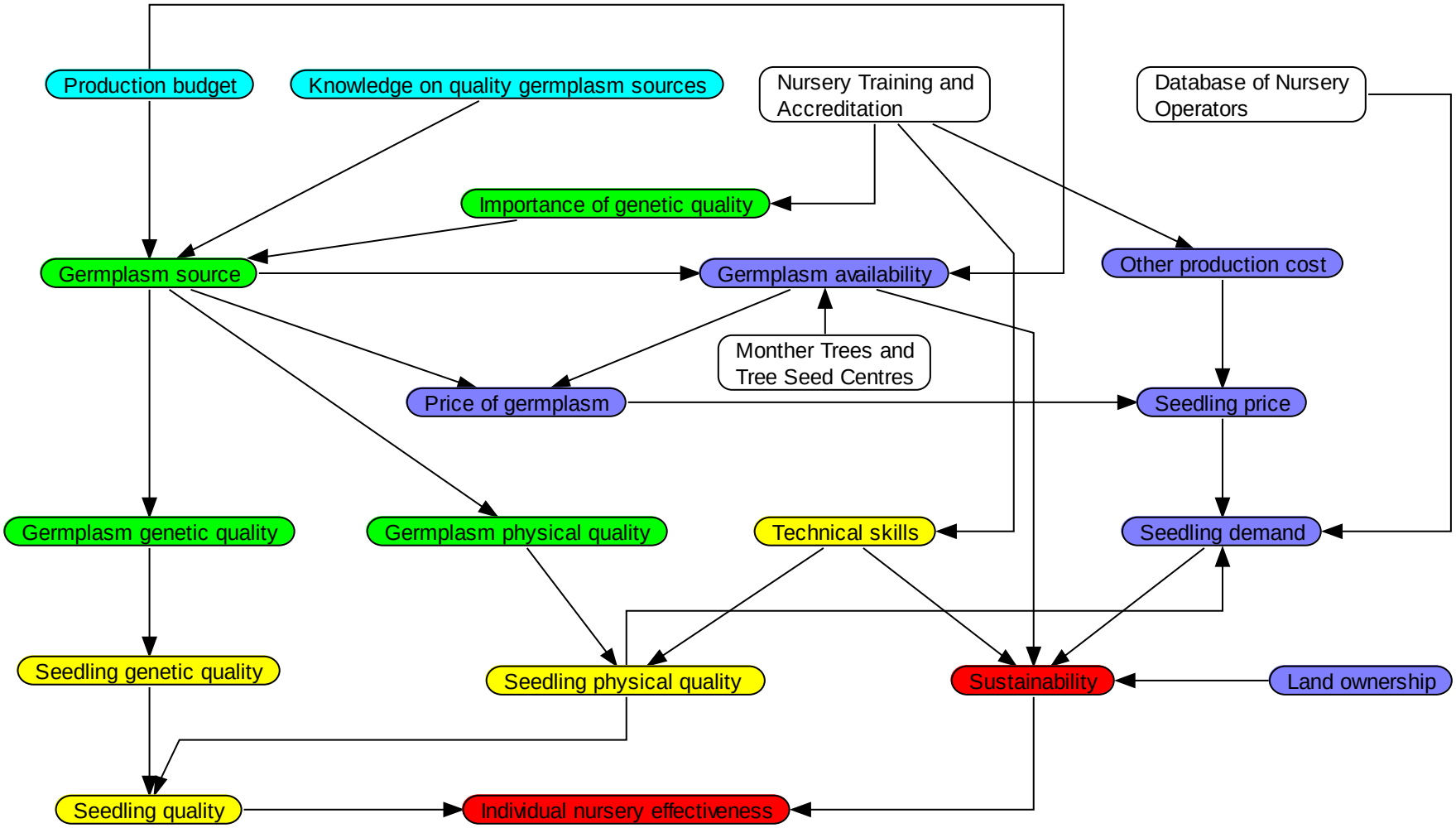

Percentage of High Effectiveness Nurseries (%)
100
90
80
70
60
50
40
30
20
10
0
Communal Nursery Sector
Individual Nursery Sector
No Intervention
Technical skills
plus Knowledge
plus Importance of genetic quality
quality germplasm sources
plus Production budget
plus Market assistance

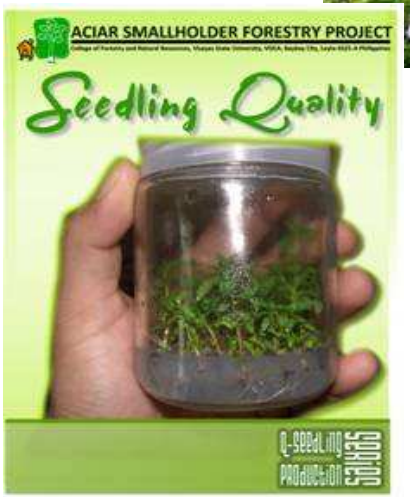

Community
Organization


Budget


Production budget
Knowledge on quality germplasm sources
Nursery Training and Accreditation
Database of Nursery Operators
Importance of genetic quality
Germplasm source
Germplasm availability
Other production cost
Monther Trees and Tree Seed Centres
Price of germplasm
Seedling price
Germplasm genetic quality
Germplasm physical quality
Technical skills
Seedling demand
Seedling genetic quality
Seedling physical quality
Sustainability
Land ownership
Seedling quality
Individual nursery effectiveness

- Interventions
  - Forestry nursery accreditation
    - Participatory research and partnership with LGUs
    - Development of nursery accreditation policy and guidelines

- Nursery accreditation (cont.)
  Capacity building (series of training, nursery manuals and videos, establishment of demo nurseries)



- Improvement of germplasm availability
  - Establishment of tree seed centers
  - Database of germplasm sources
- Developed database of nursery operators
  - Name, contact number, address
  - Species produce and selling price
  - Marketing agreement

Example 3 – Parkinsonia in Queensland

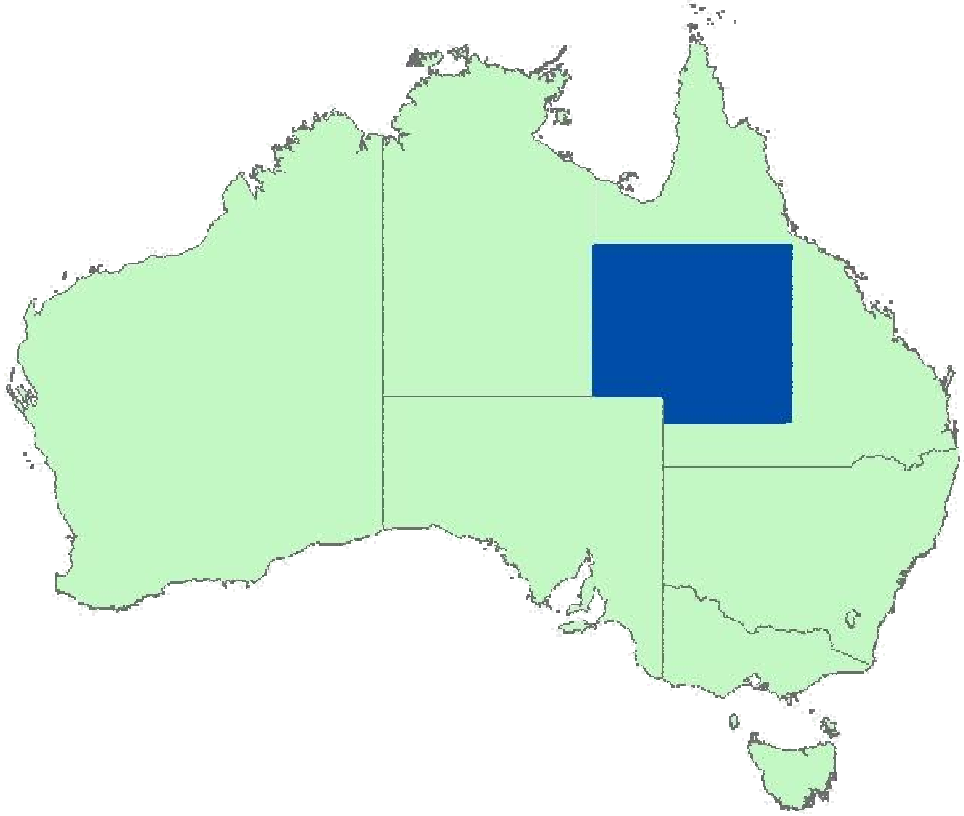
The Problem:

- Parkinsonia is an emerging weed – current models of potential distribution are based on climate matching
- Grows in rangeland and desert areas – coarse and limited data sets
- Need to make management decisions to contain spread

What we did:

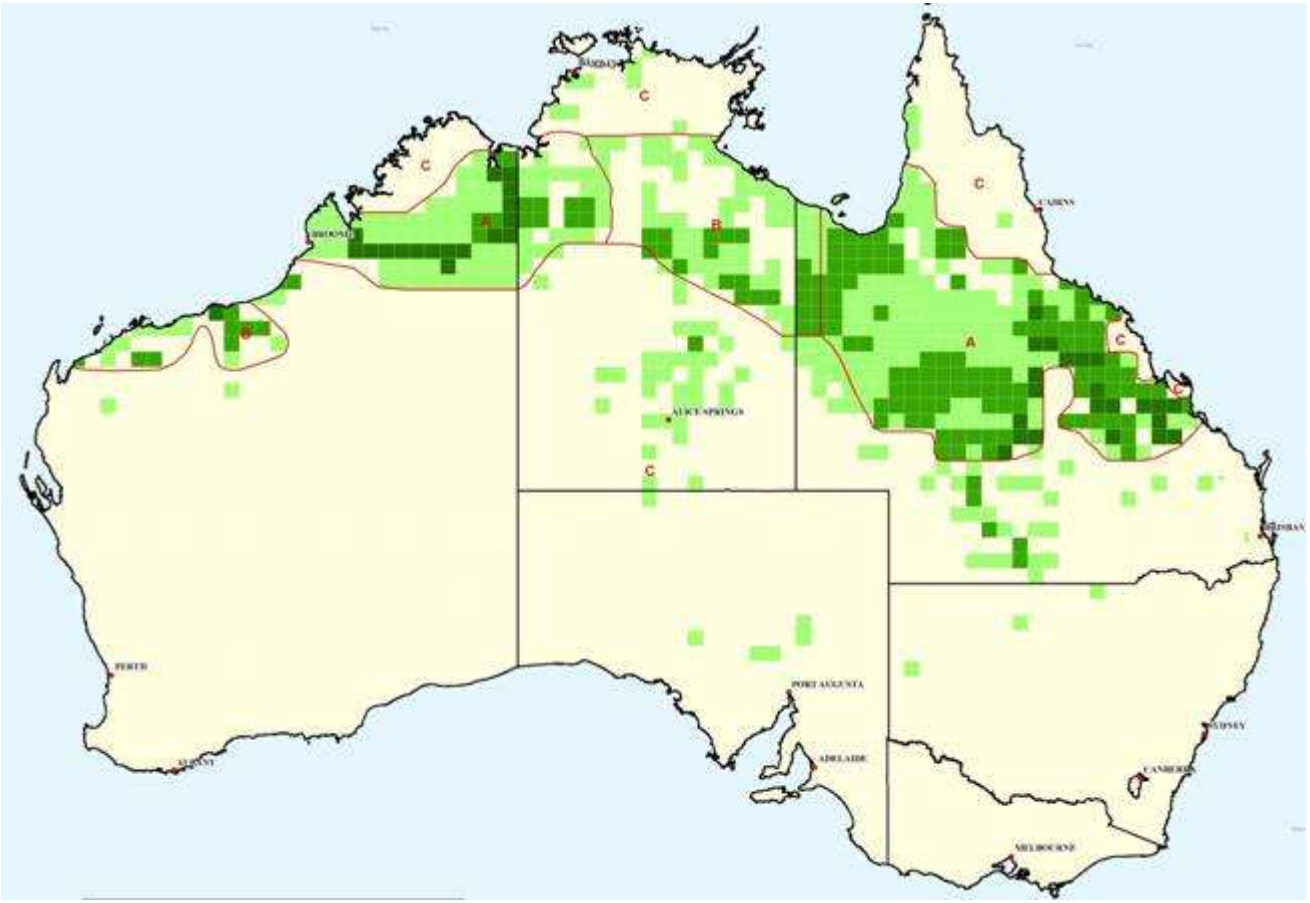
- Systems analysis with weed ecologists, extension officers and graziers

Desert Channels Region

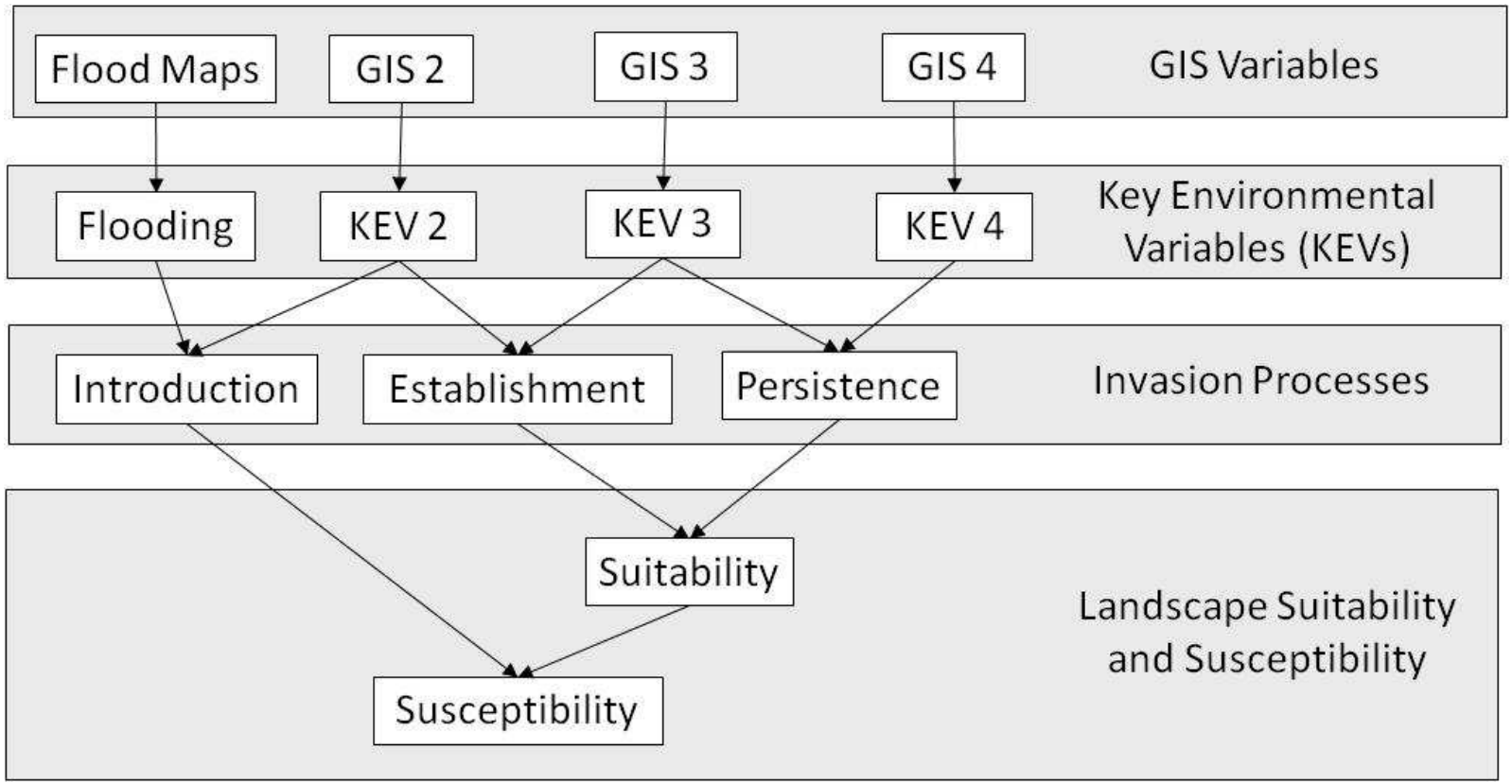


Area = 700 000 km^2 (Area of Austria = 84 000 km^2)

Results from Climate Matching

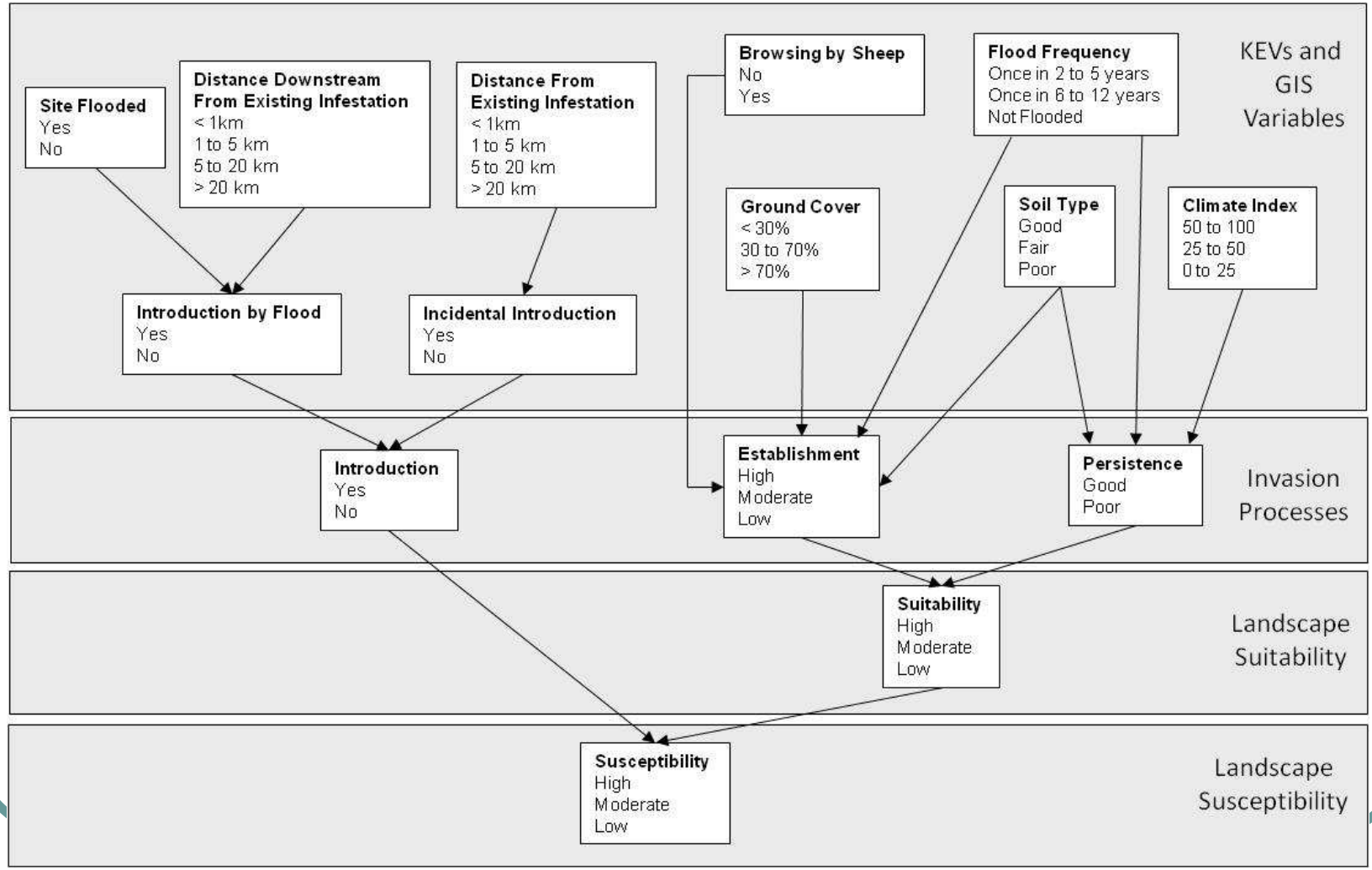


Modelling Approach

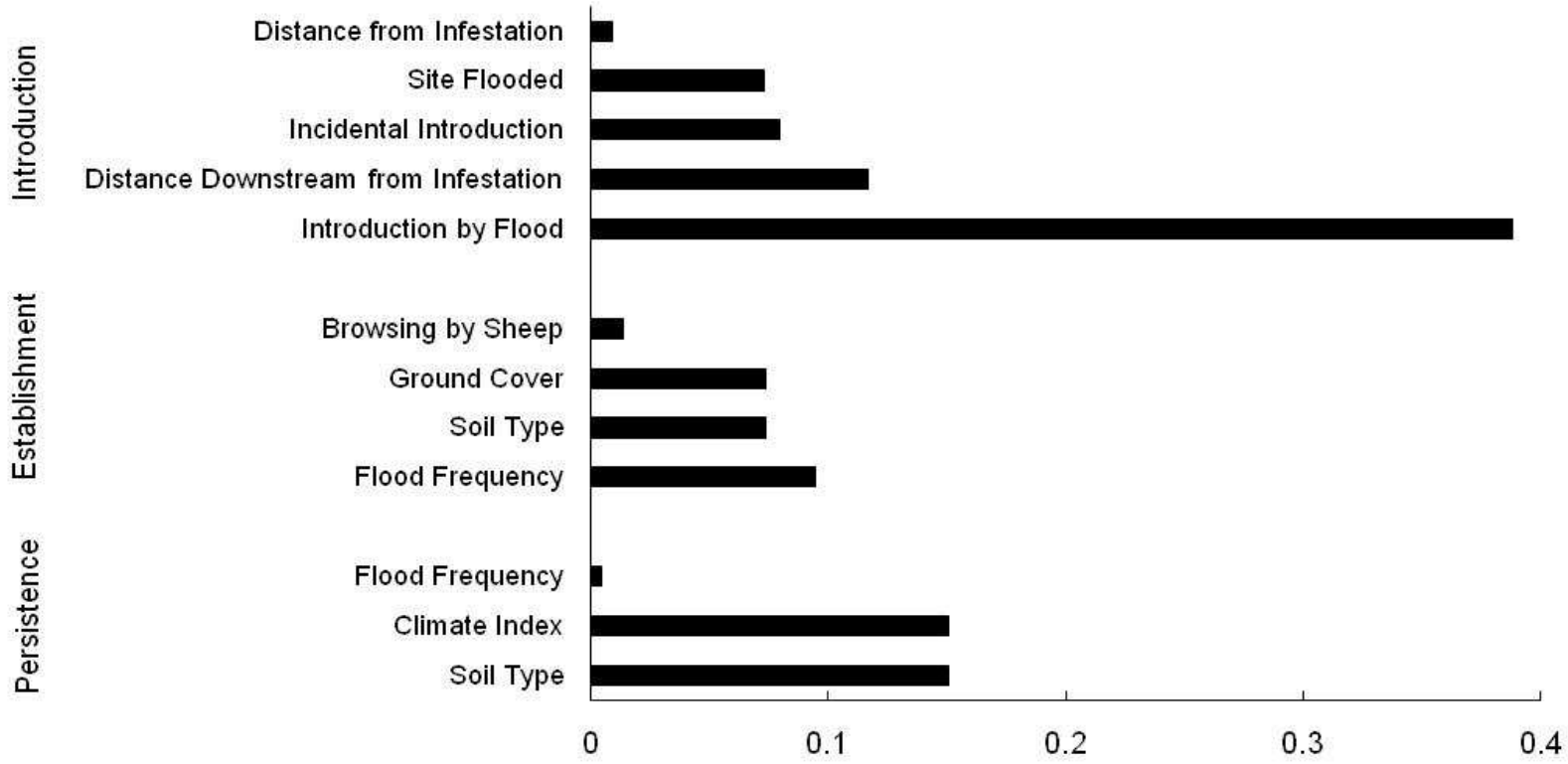



REQUIREMENTS
VARIABLES
INTRODUCTION
ESTABLISHMENT
SURVIVAL

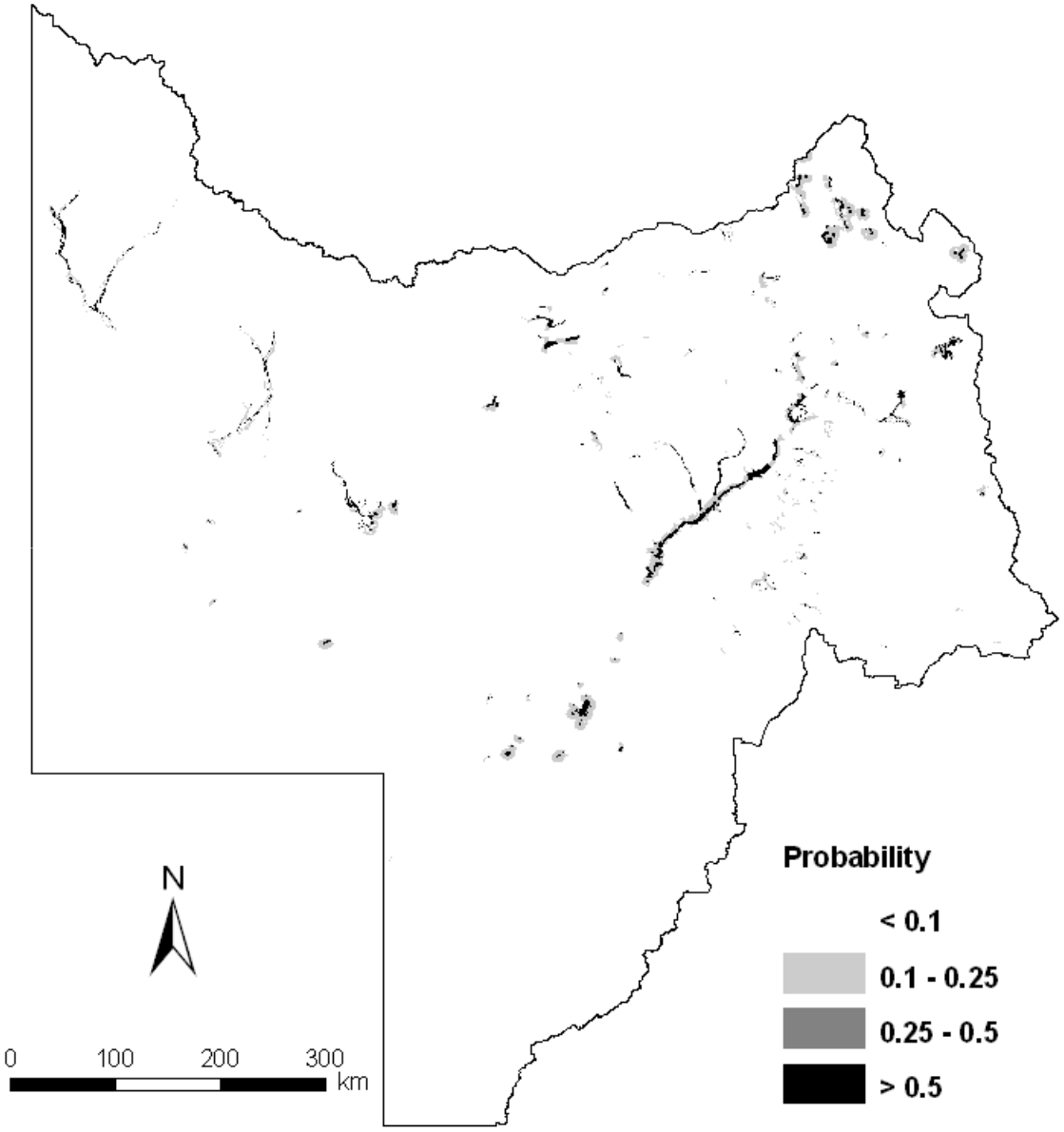
The Model


KEVs and GIS Variables
Site Flooded
Yes
No
Distance Downstream From Existing Infestation
< 1km
1 to 5 km
5 to 20 km
> 20 km
Distance From Existing Infestation
< 1km
1 to 5 km
5 to 20 km
> 20 km
Browsing by Sheep
No
Yes
Flood Frequency
Once in 2 to 5 years
Once in 6 to 12 years
Not Flooded
Ground Cover
< 30%
30 to 70%
> 70%
Soil Type
Good
Fair
Poor
Climate Index
50 to 100
25 to 50
0 to 25
Introduction by Flood
Yes
No
Incidental Introduction
Yes
No
Introduction
Yes
No
Establishment
High
Moderate
Low
Persistence
Good
Poor
Invasion Processes
Suitability
High
Moderate
Low
Landscape Suitability
Susceptibility
High
Moderate
Low
Landscape Susceptibility

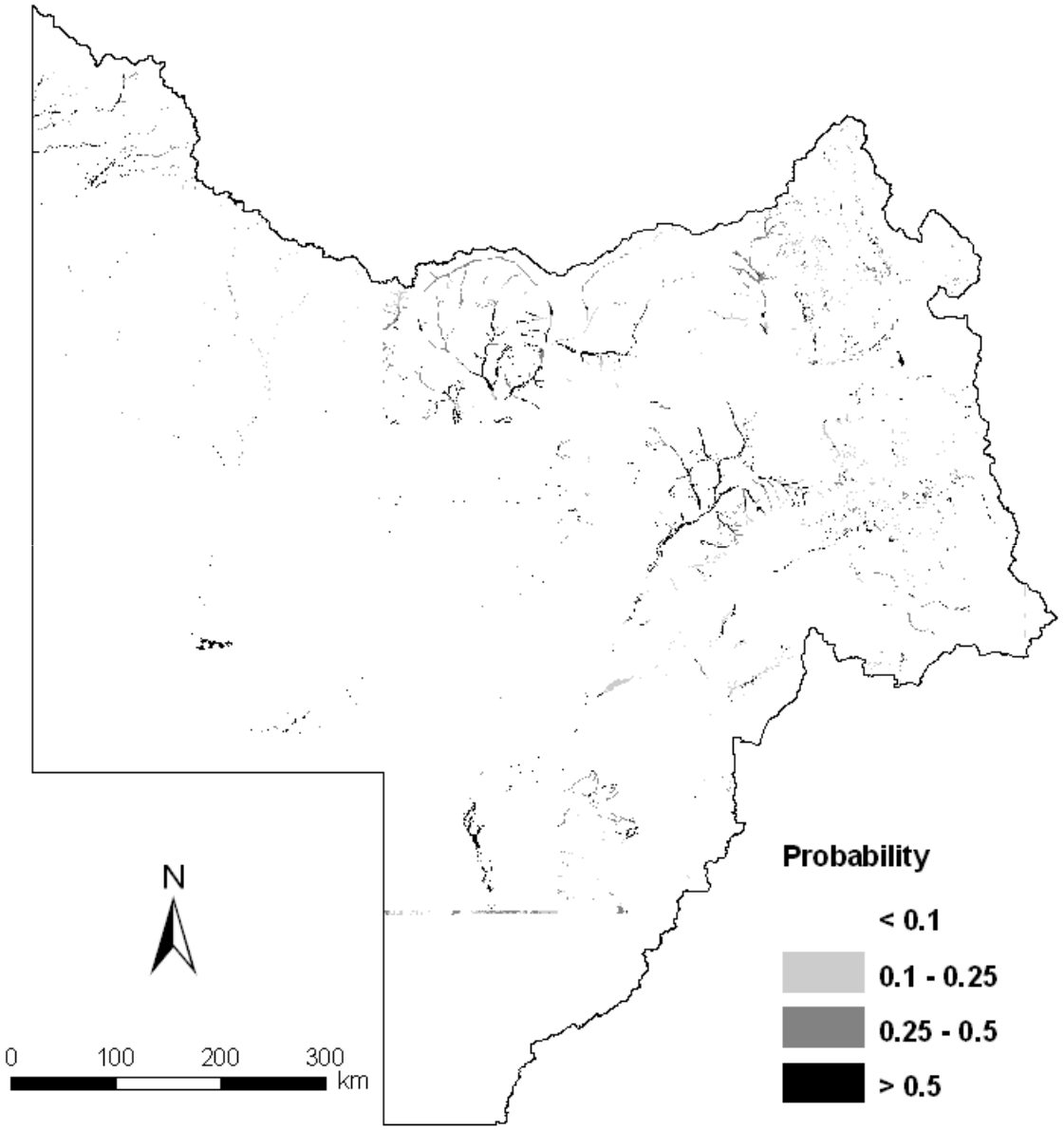
Sensitivity Analysis



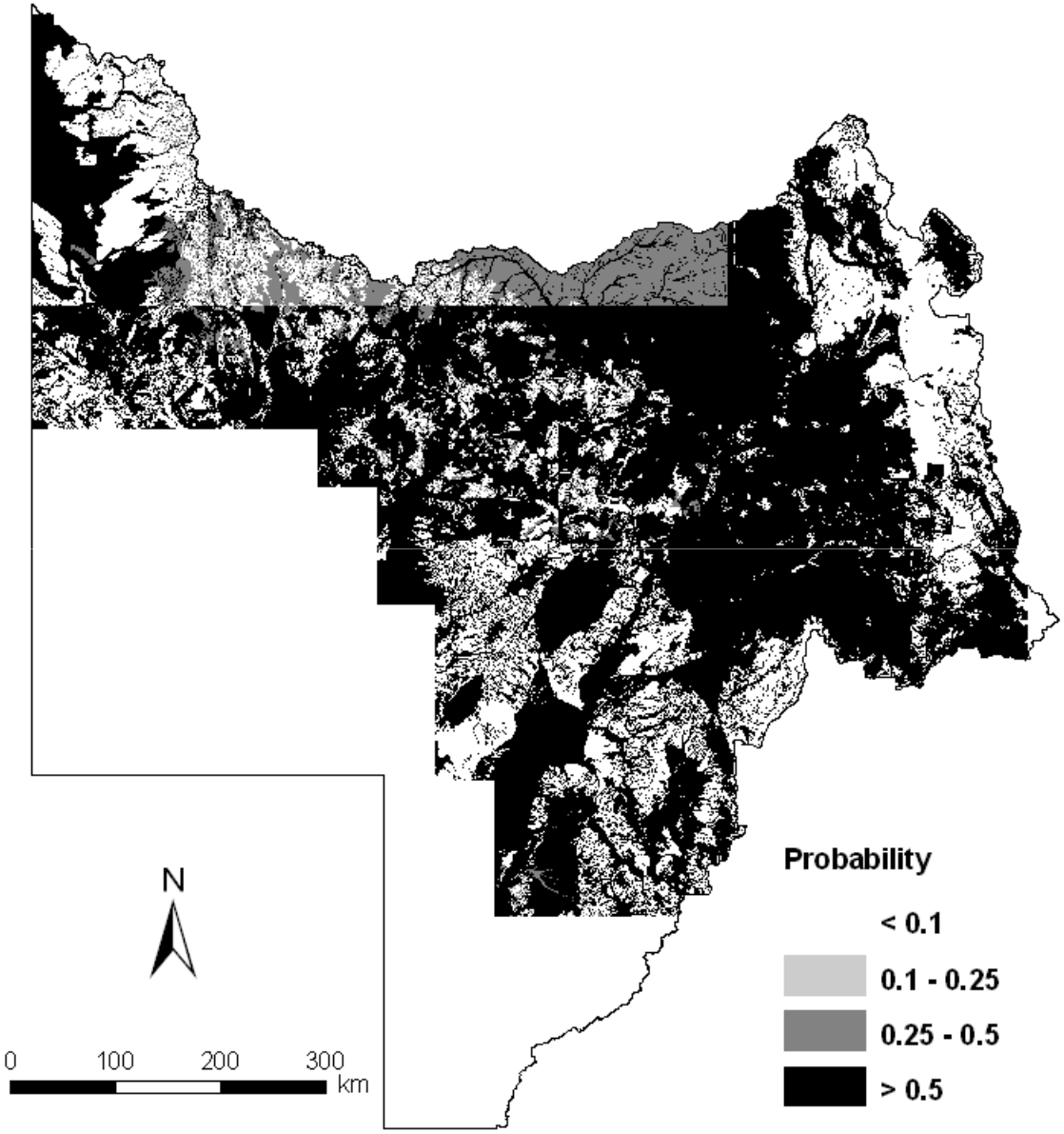
Introduction



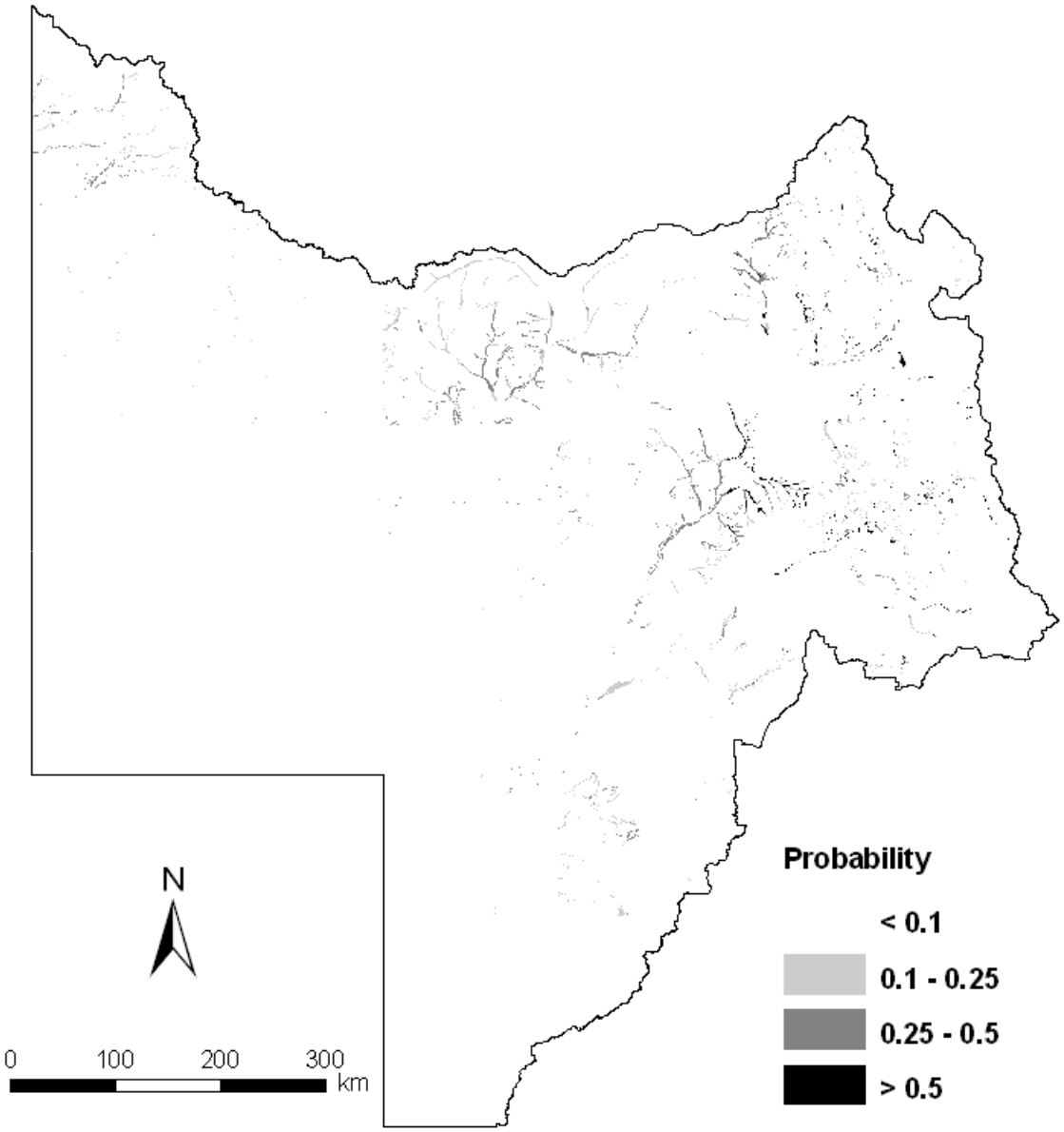
Establishment = High



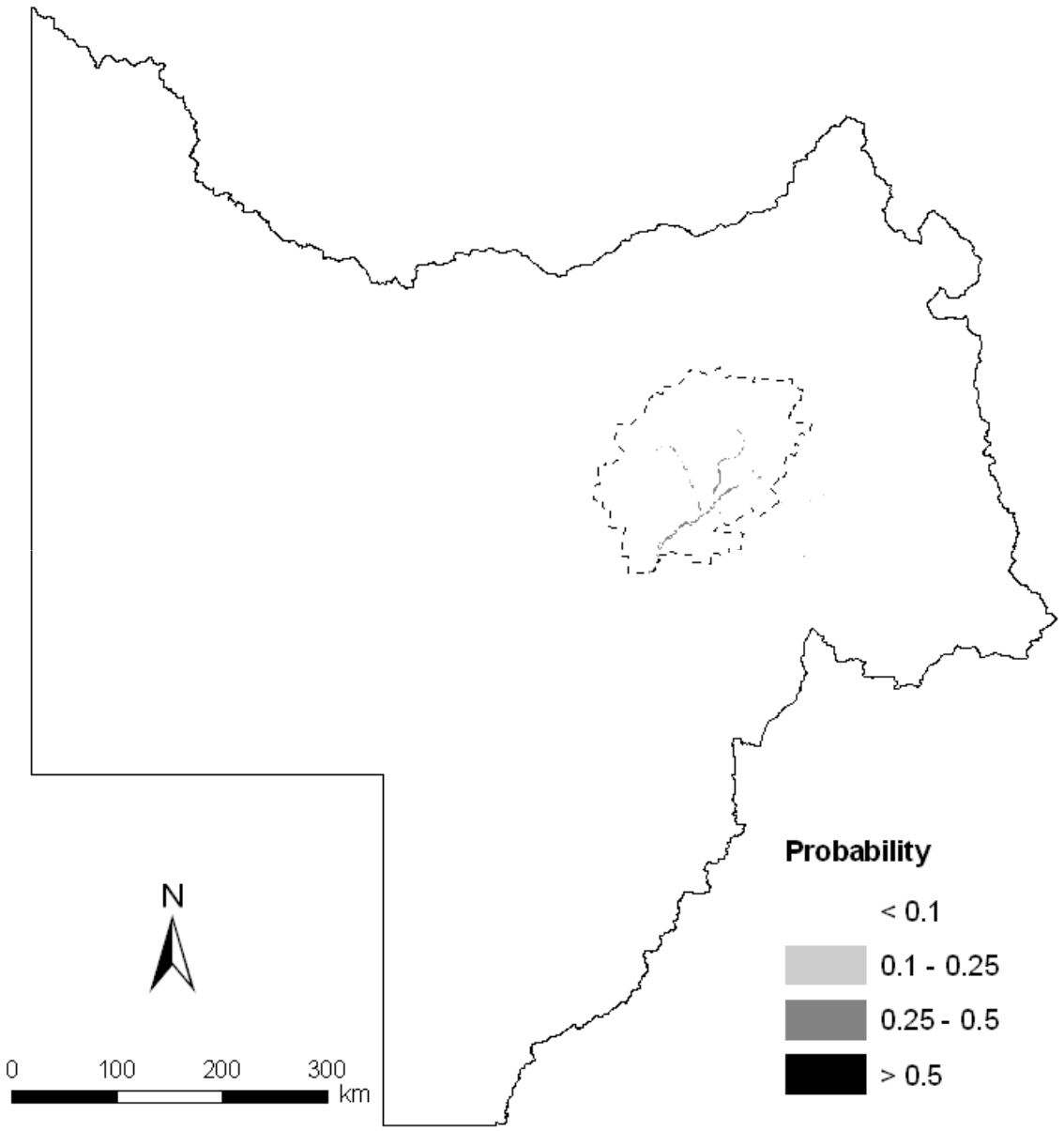
Persistence = Good



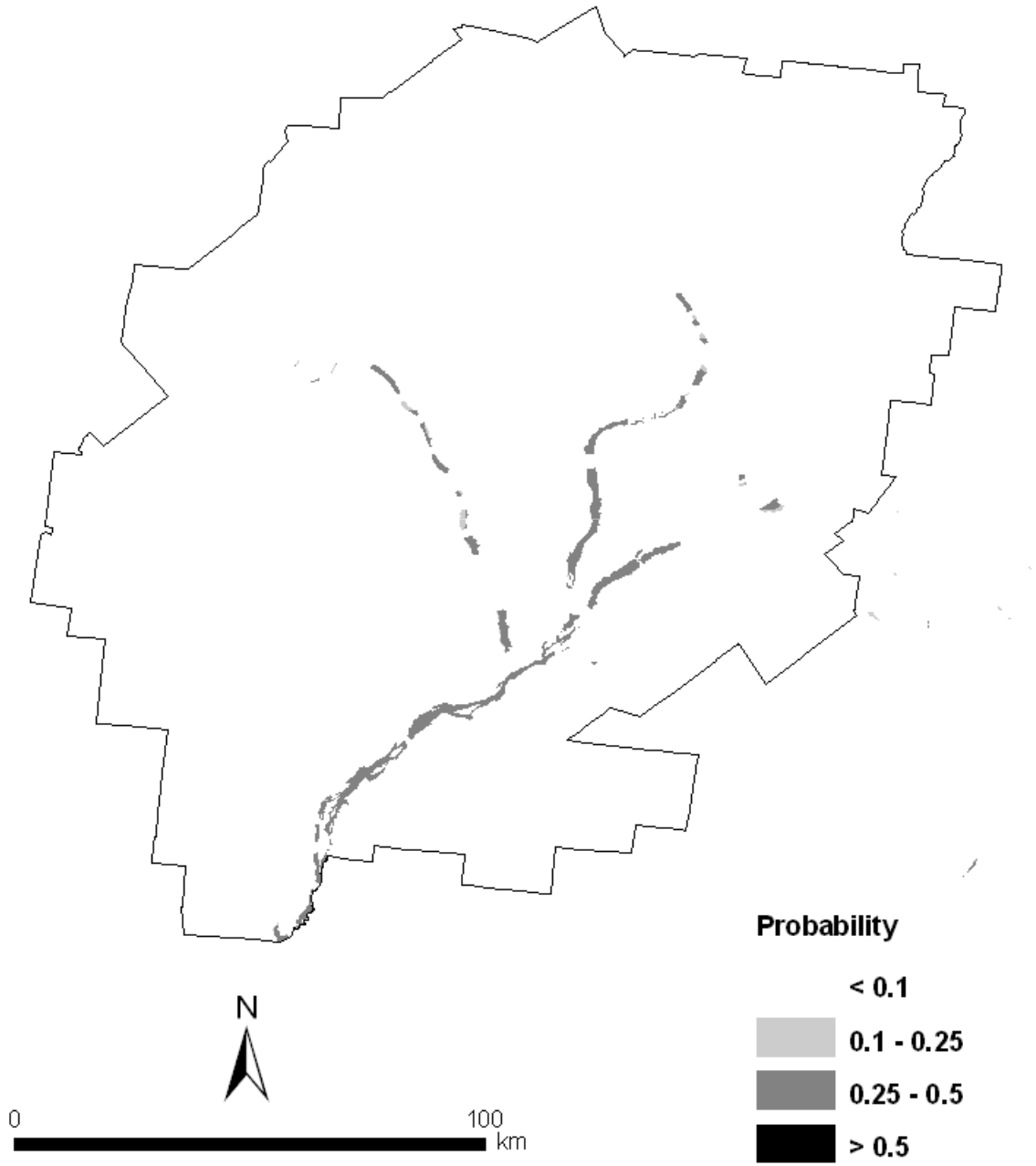
Suitability = High

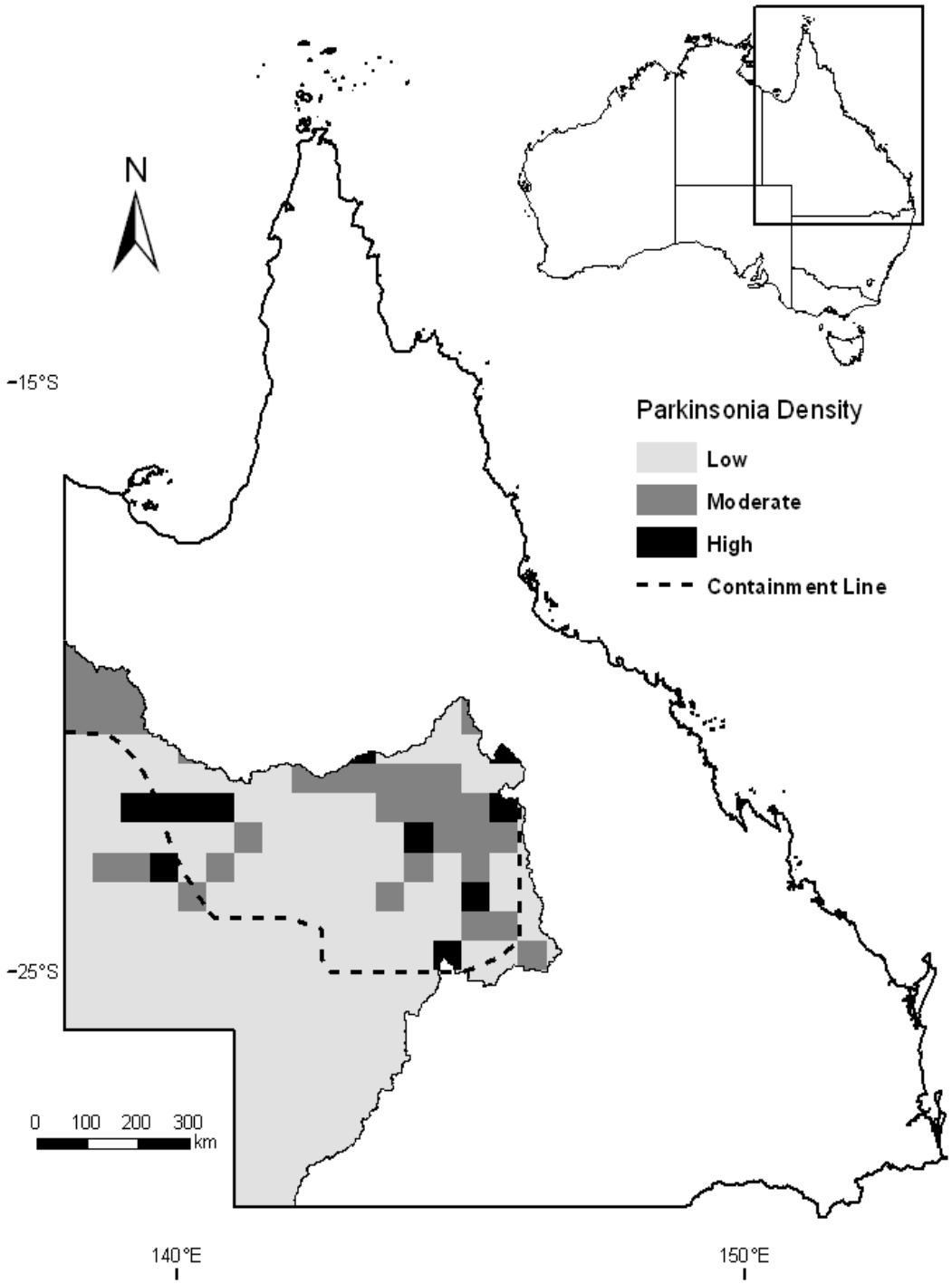


Susceptibility = High



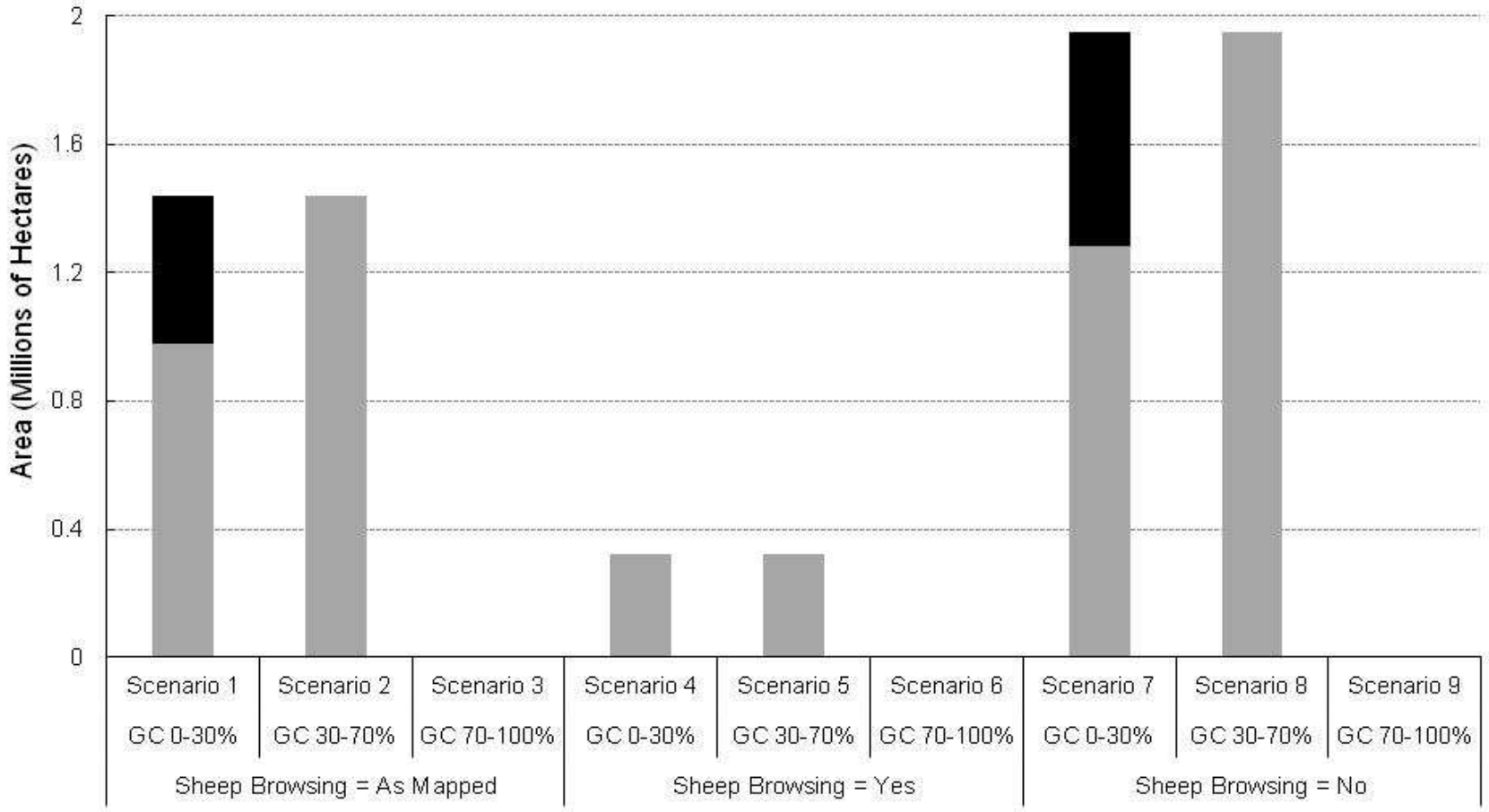
Susceptibility = High




N
Parkinsonia Density
Low
Moderate
High
Containment Line
-15°S
-25°S
0 100 200 300
km
140°E
150°E

Accuracy Assessment

Predicted Suitability	Estimated Density		Accuracy (%)
	Low	Moderate to High	
Low	54	8	87
Moderate to High	103	41	28
Accuracy (%)	34	84	



Area predicted as moderate (grey bars) and high (black bars) suitability for parkinsonia

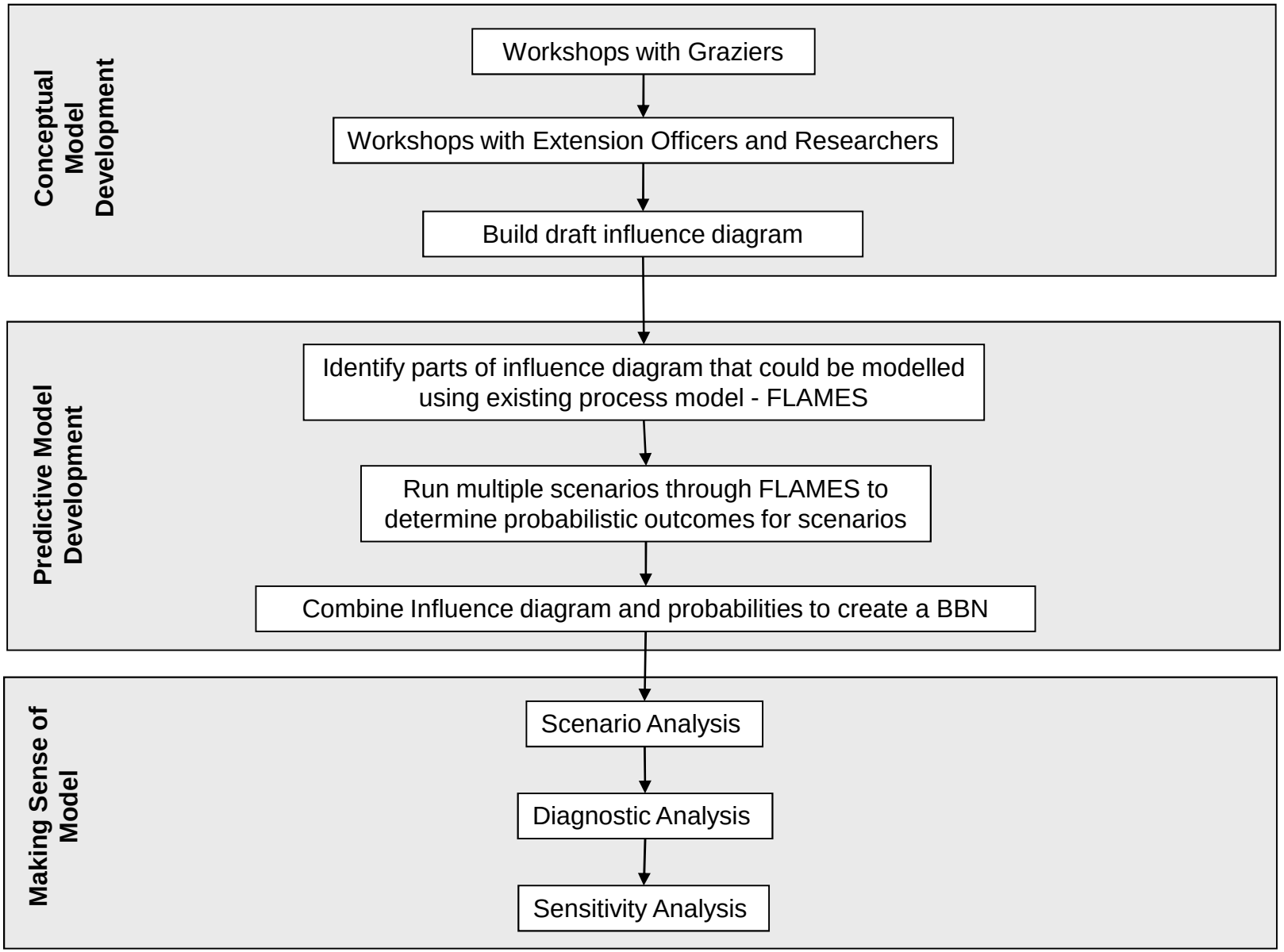
Example 4 – Tree Change in Australia

The Problem:

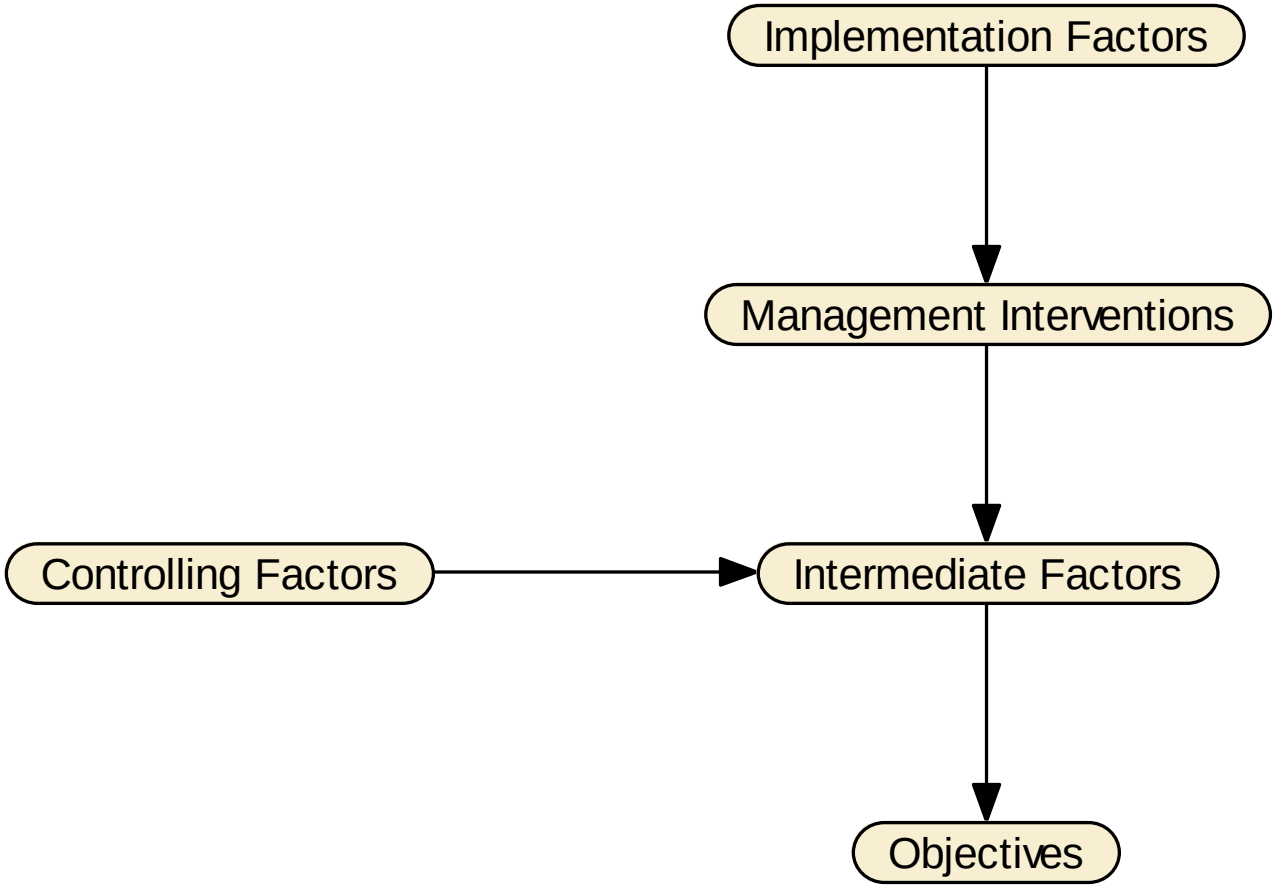
- Recently an increase in tree and shrub density has been reported in Australia's tropical savannas
- This has the potential to change catchment hydrology, carbon stocks, pasture biomass and wildlife habitat

What we did:

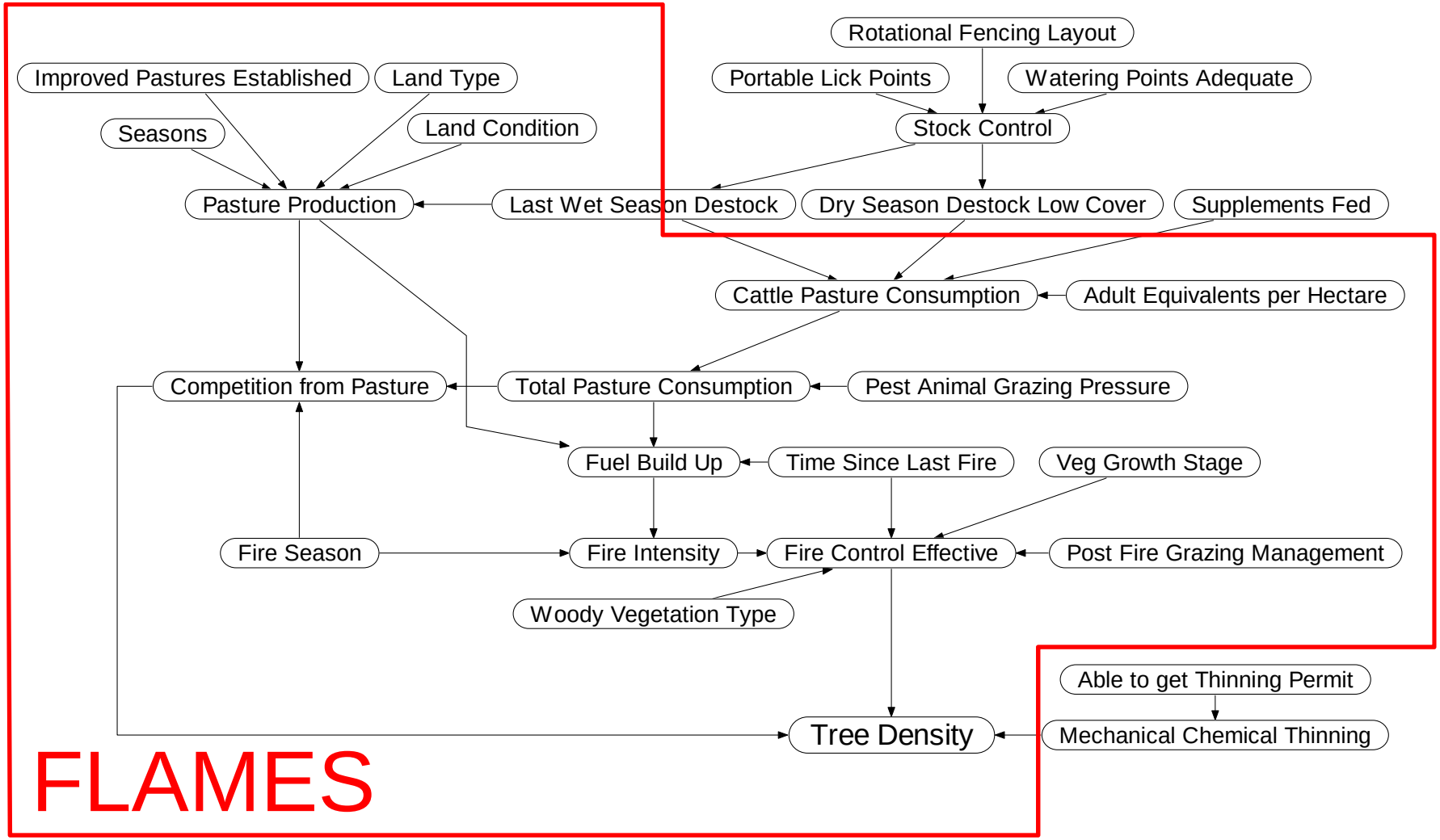
- Systems analysis with ecologists, extension officers and graziers


Conceptual Model Development
Workshops with Graziers
Workshops with Extension Officers and Researchers
Build draft influence diagram
Predictive Model Development
Identify parts of influence diagram that could be modelled using existing process model - FLAMES
Run multiple scenarios through FLAMES to determine probabilistic outcomes for scenarios
Combine Influence diagram and probabilities to create a BBN
Making Sense of Model
Scenario Analysis
Diagnostic Analysis
Sensitivity Analysis

Grazier Workshops



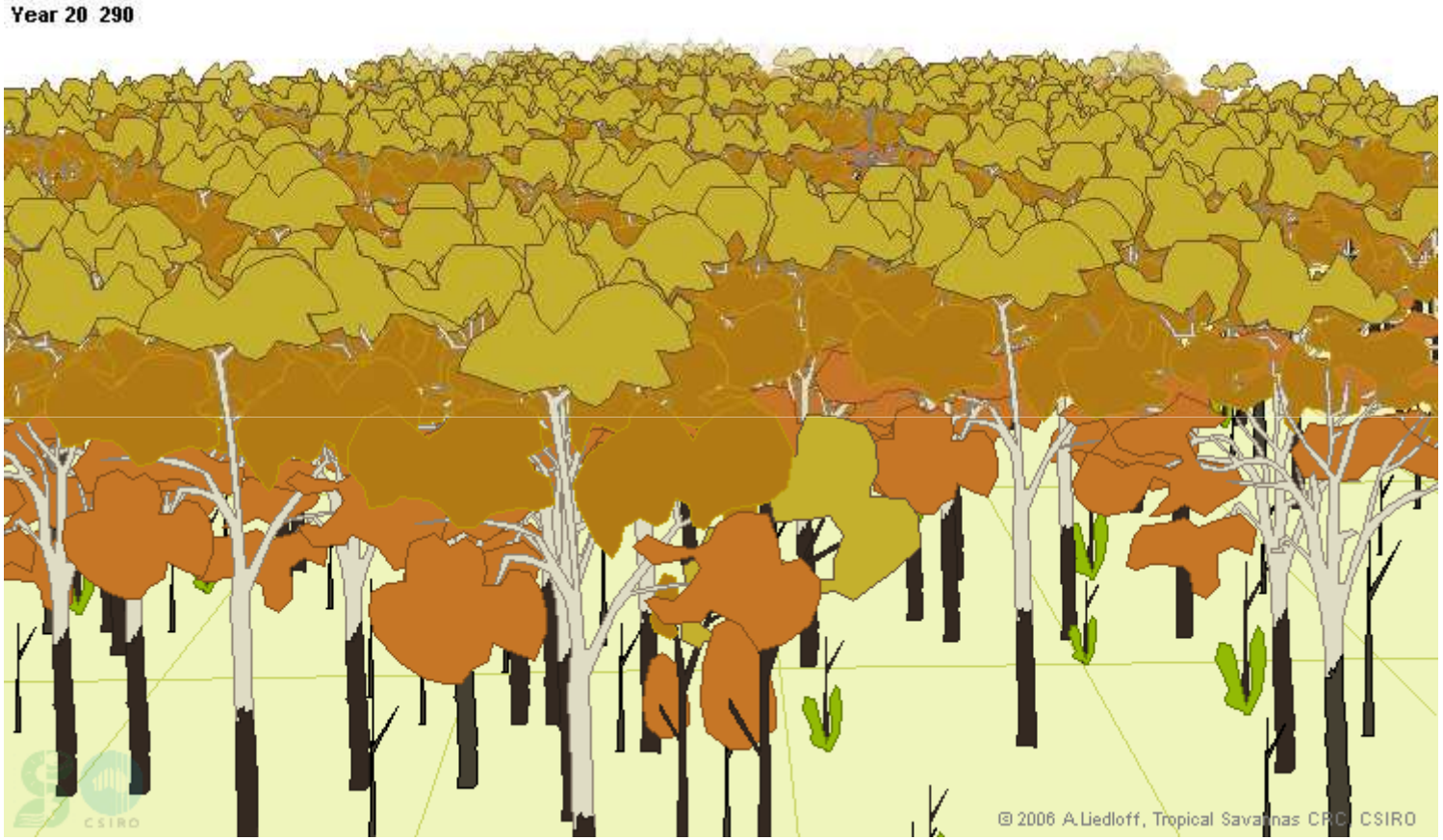
Influence Diagram



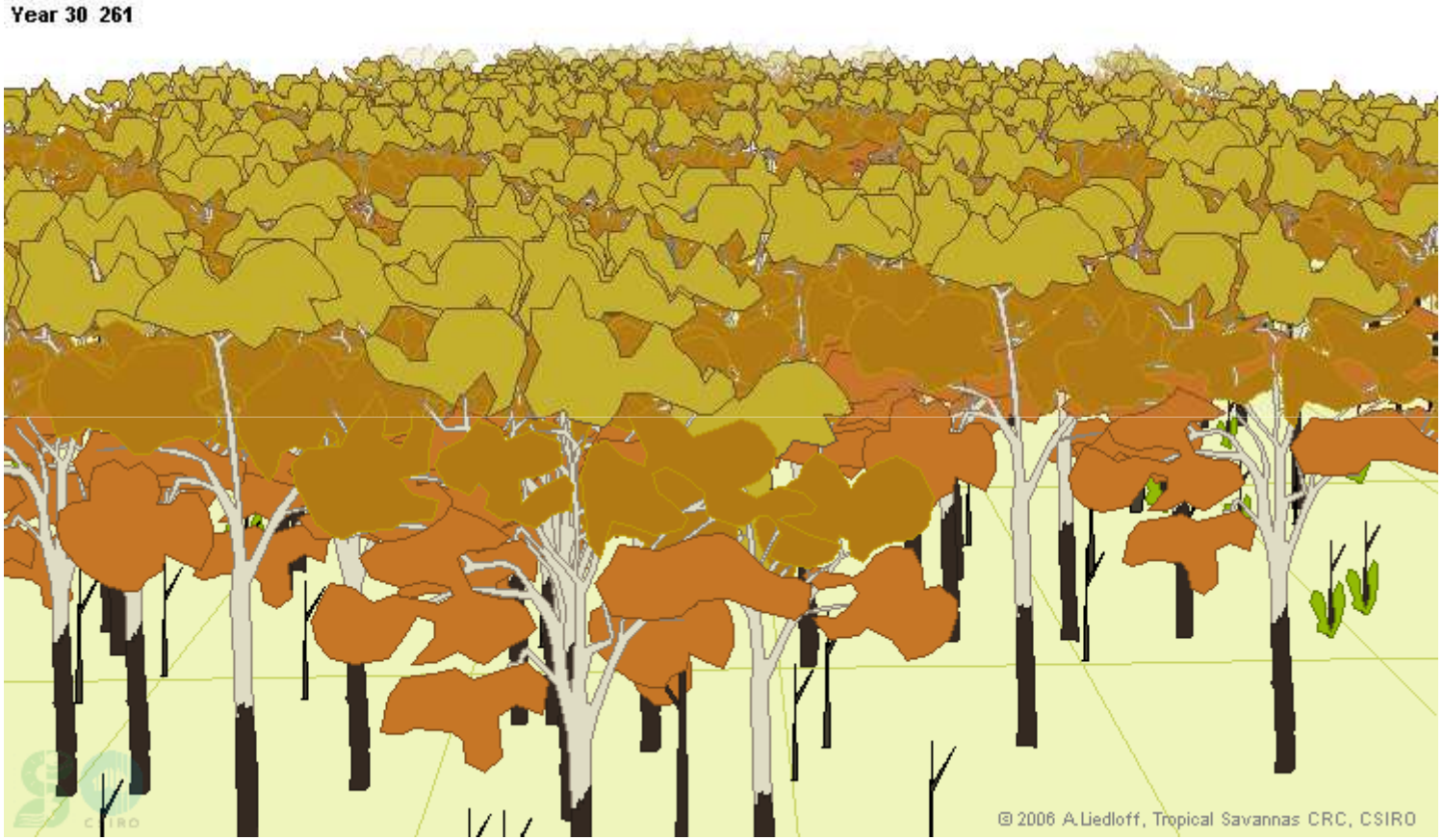
Starting Stand

After 10 Years

After 20 Years



After 30 Years

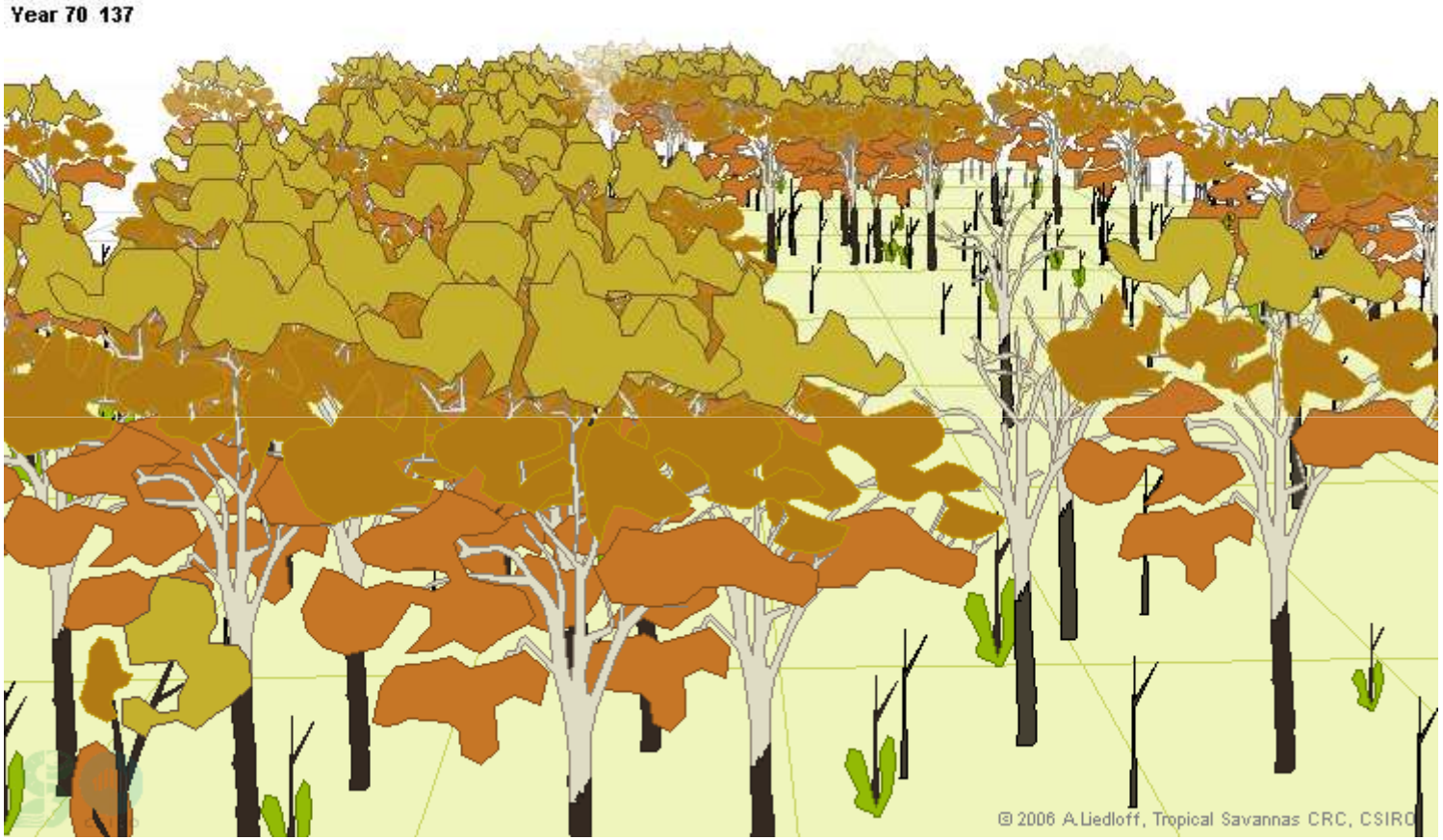


After 40 Years

After 50 Years

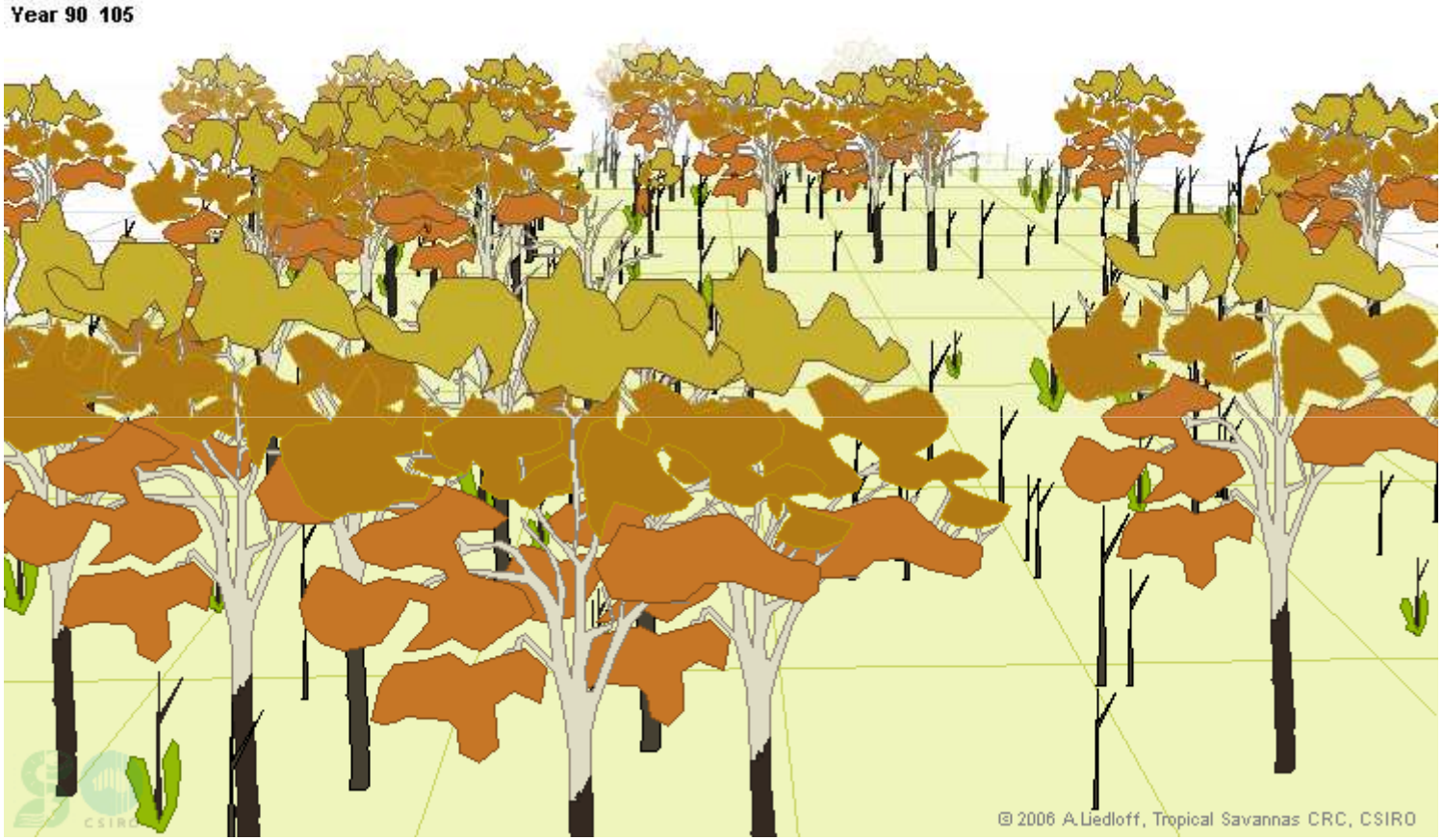
After 60 Years

After 70 Years

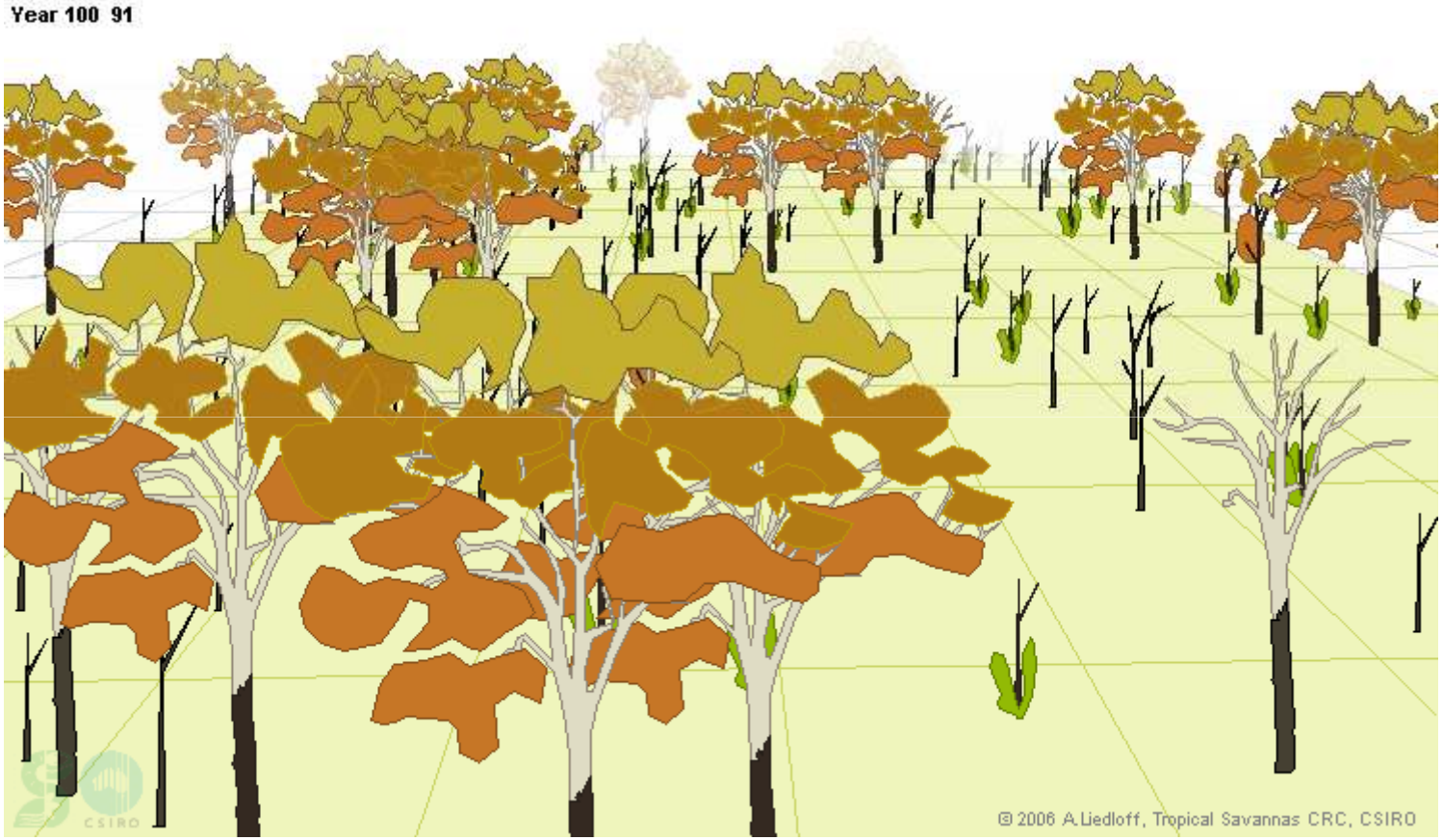


After 80 Years

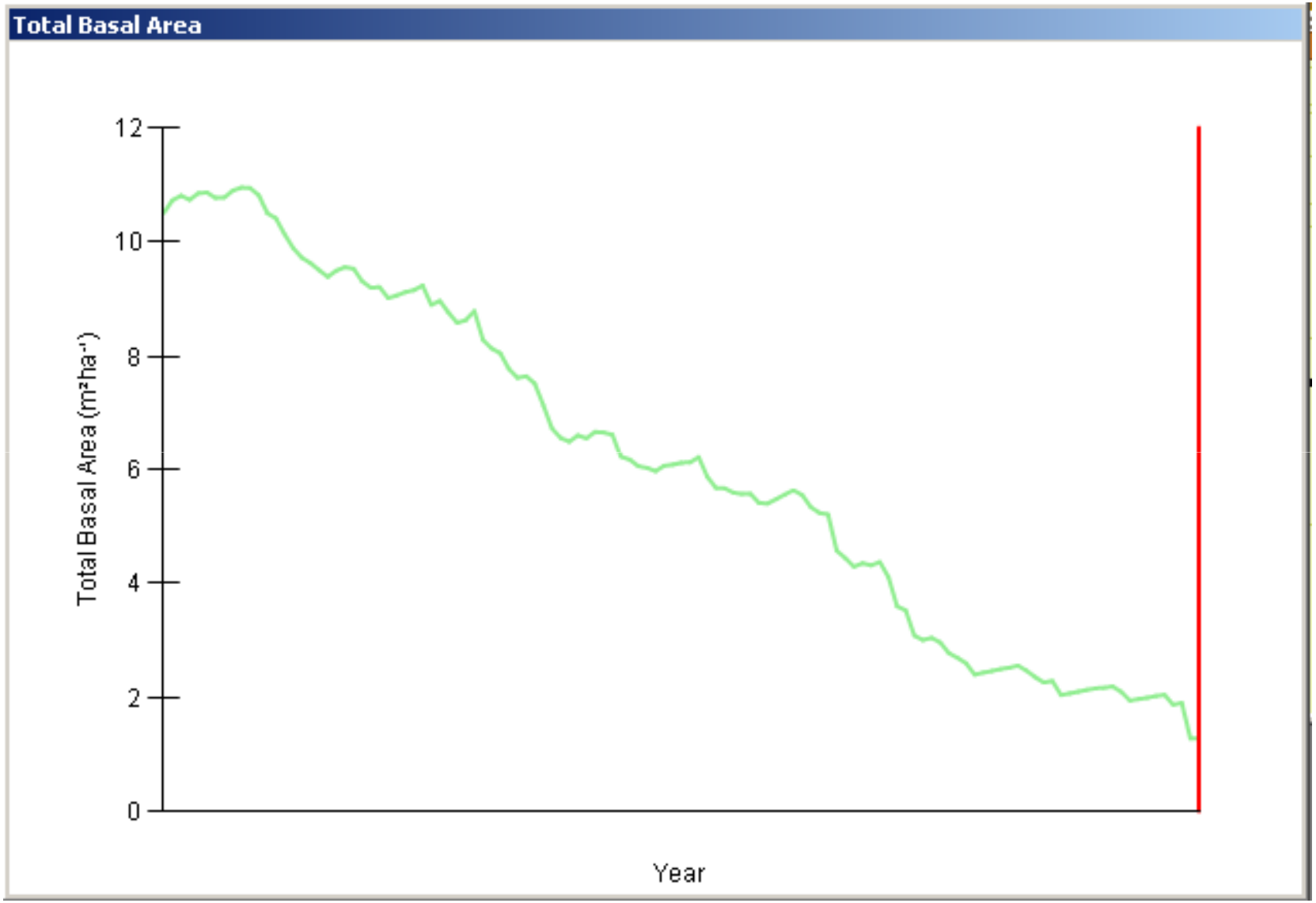
After 90 Years



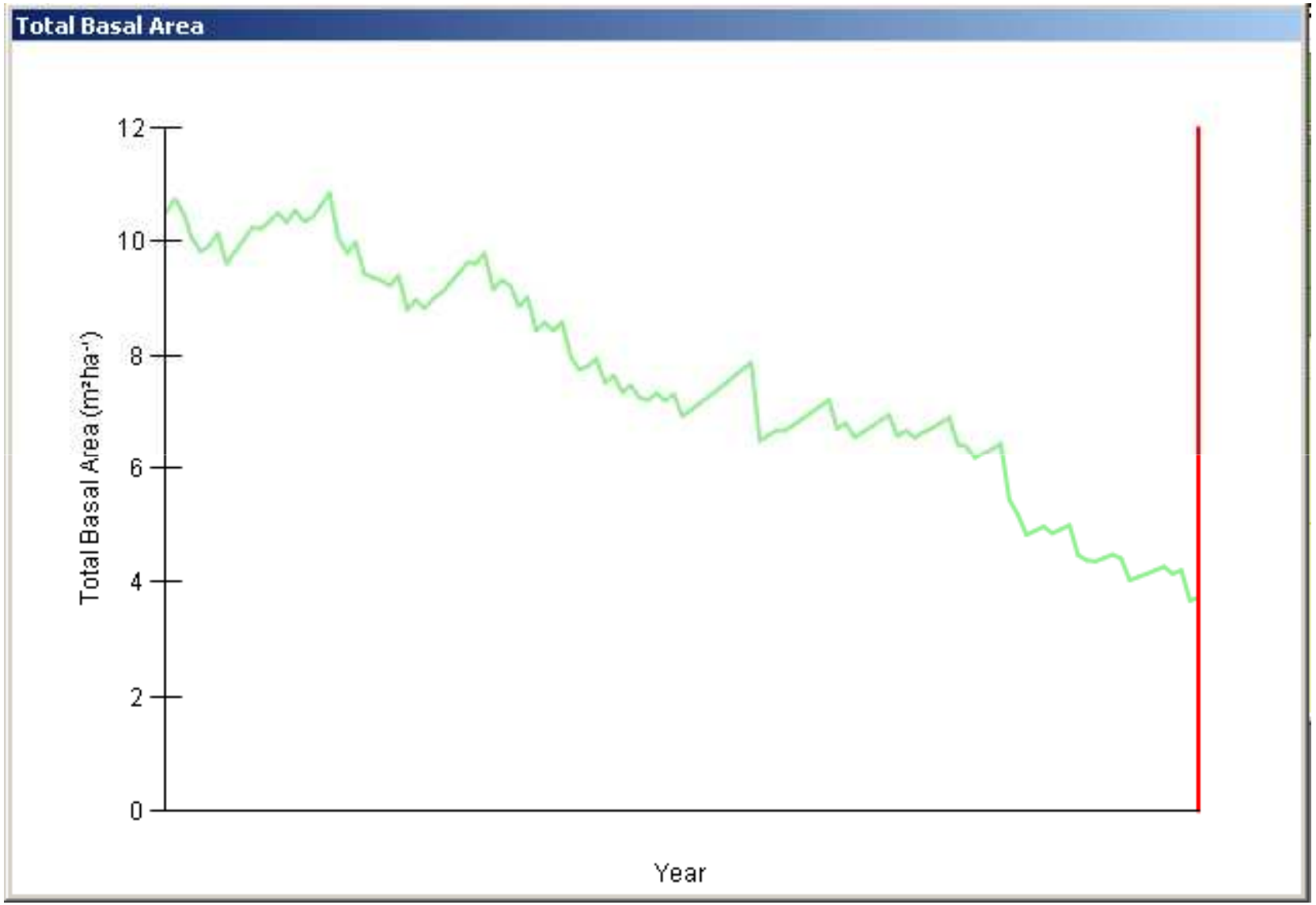
After 100 Years



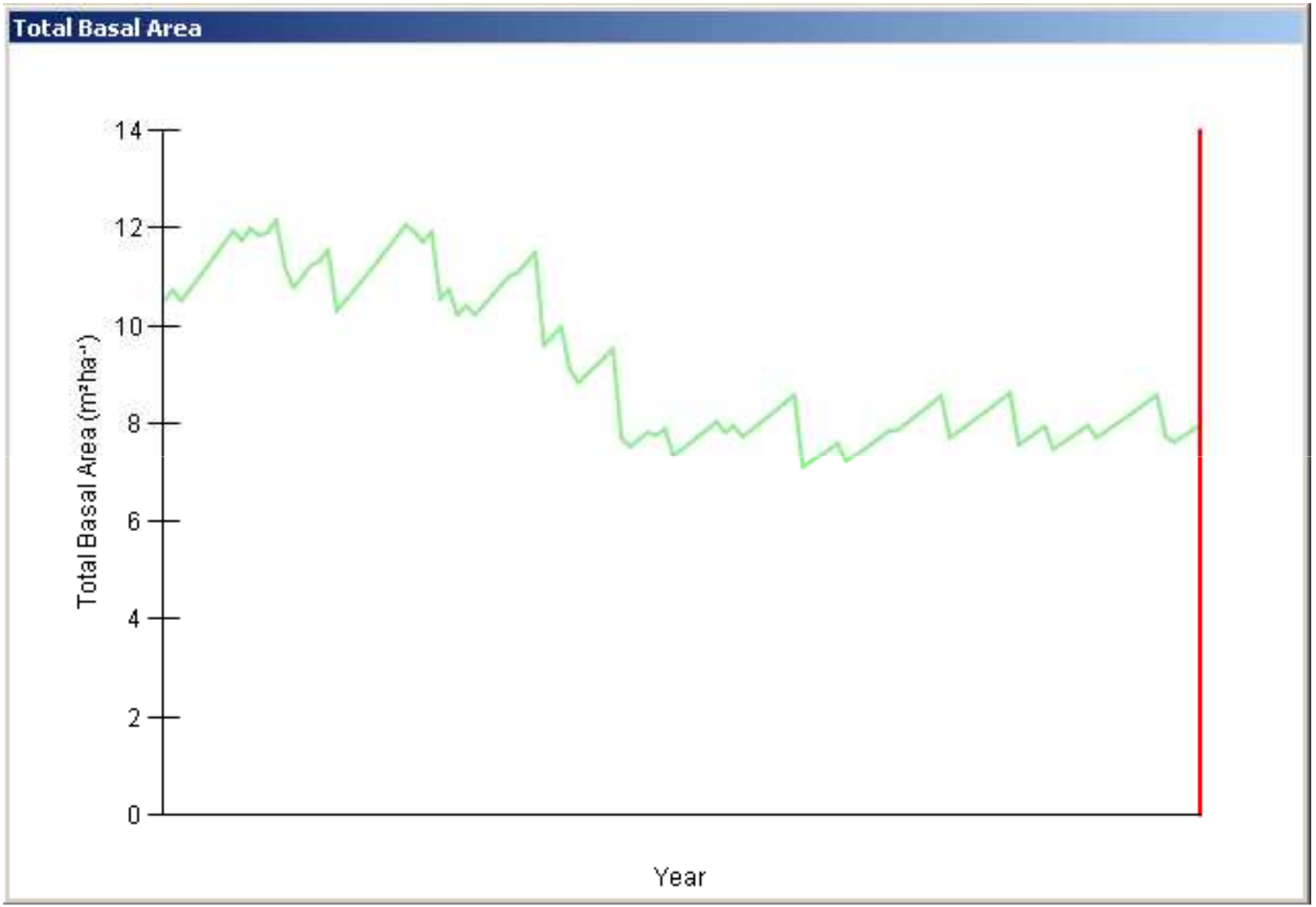
Annual Fires, Kakadu, No Grazing, Mature Staring Stand, E. miniata



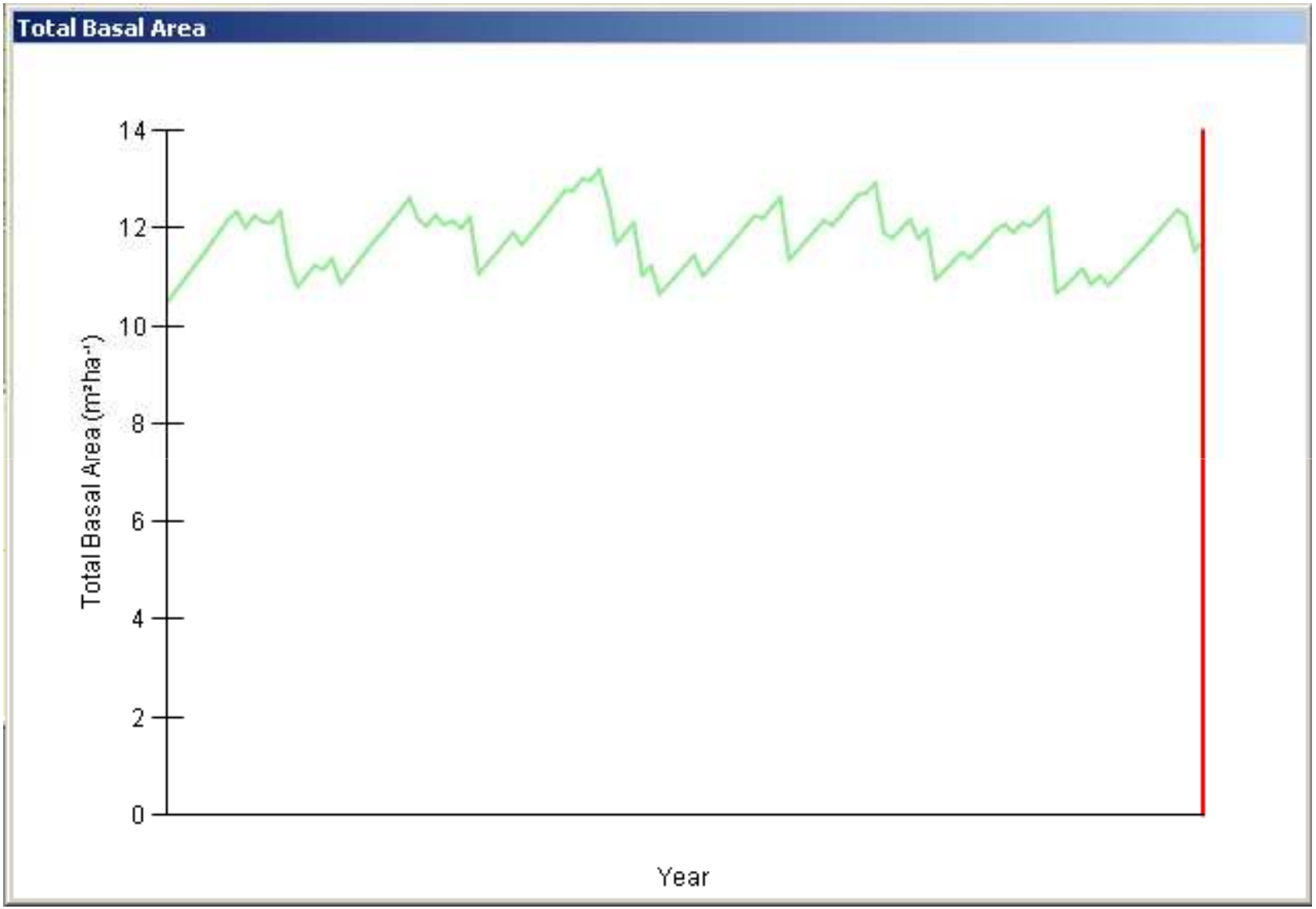
Biennial Fires, Kakadu, No Grazing, Mature Staring Stand, E. miniata

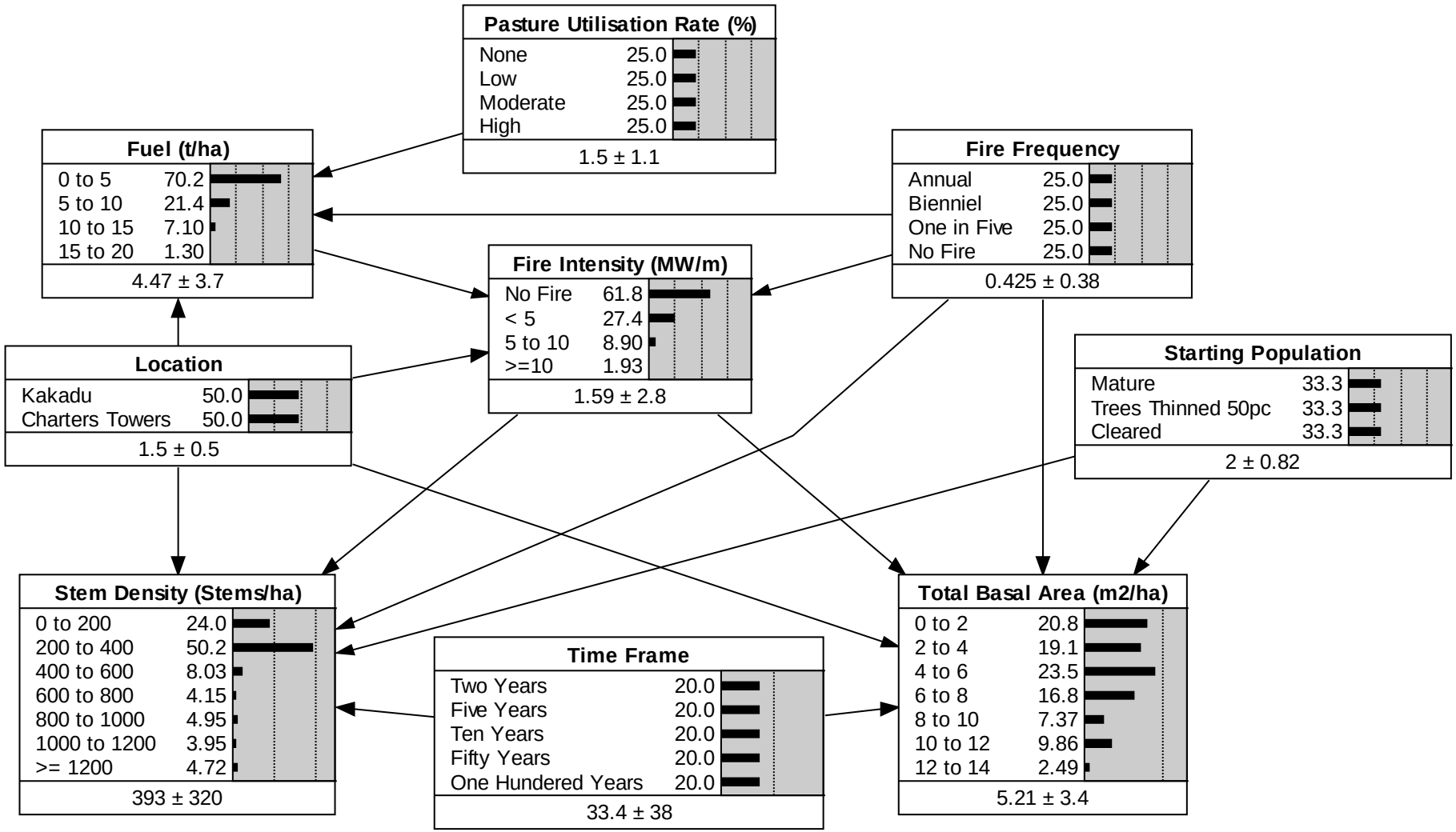


1 in 5 Year Fires, Kakadu, No Grazing, Mature Staring Stand, E. miniata



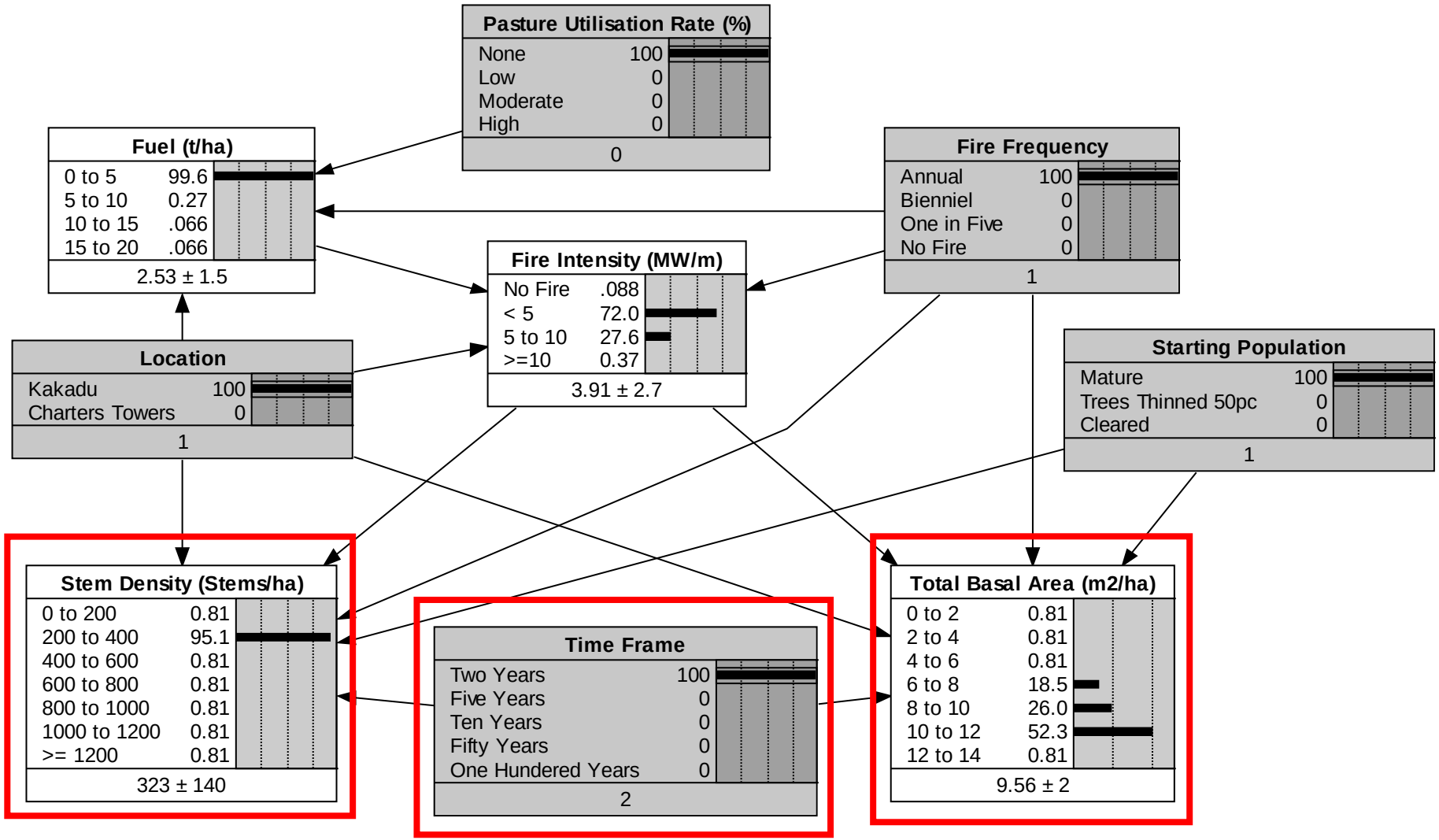
No Fire, Kakadu, No Grazing, Mature Staring Stand, E. miniata



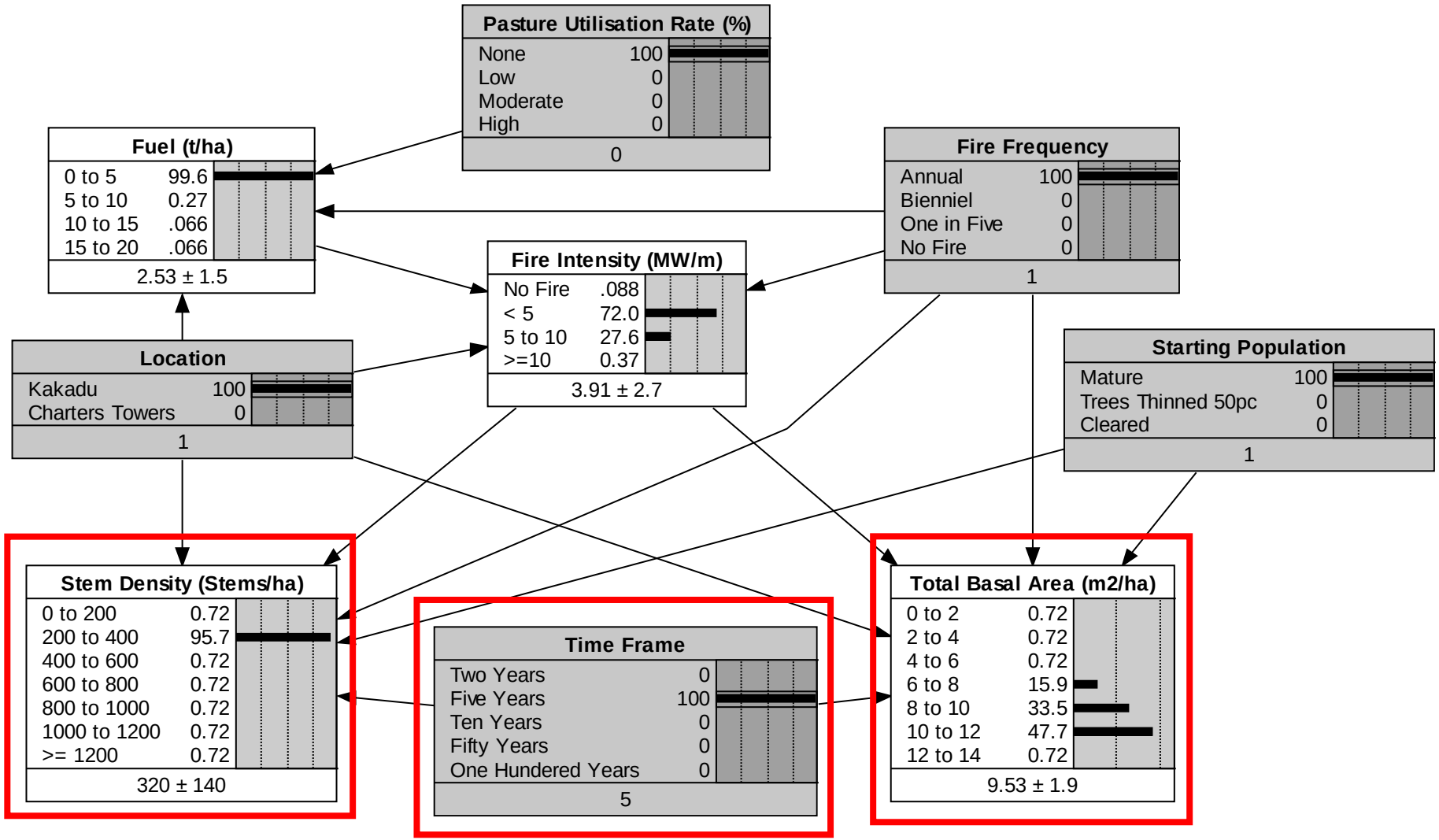

Pasture Utilisation Rate (%)
None 25.0
Low 25.0
Moderate 25.0
High 25.0
1.5 ± 1.1
Fuel (t/ha)
0 to 5 70.2
5 to 10 21.4
10 to 15 7.10
15 to 20 1.30
4.47 ± 3.7
Fire Frequency
Annual 25.0
Bienniel 25.0
One in Five 25.0
No Fire 25.0
0.425 ± 0.38
Fire Intensity (MW/m)
No Fire 61.8
< 5 27.4
5 to 10 8.90
>=10 1.93
1.59 ± 2.8
Location
Kakadu 50.0
Charters Towers 50.0
1.5 ± 0.5
Starting Population
Mature 33.3
Trees Thinned 50pc 33.3
Cleared 33.3
2 ± 0.82
Stem Density (Stems/ha)
0 to 200 24.0
200 to 400 50.2
400 to 600 8.03
600 to 800 4.15
800 to 1000 4.95
1000 to 1200 3.95
>= 1200 4.72
393 ± 320
Time Frame
Two Years 20.0
Five Years 20.0
Ten Years 20.0
Fifty Years 20.0
One Hundered Years 20.0
33.4 ± 38
Total Basal Area (m2/ha)
0 to 2 20.8
2 to 4 19.1
4 to 6 23.5
6 to 8 16.8
8 to 10 7.37
10 to 12 9.86
12 to 14 2.49
5.21 ± 3.4

Annual Fire Frequency in Kakadu

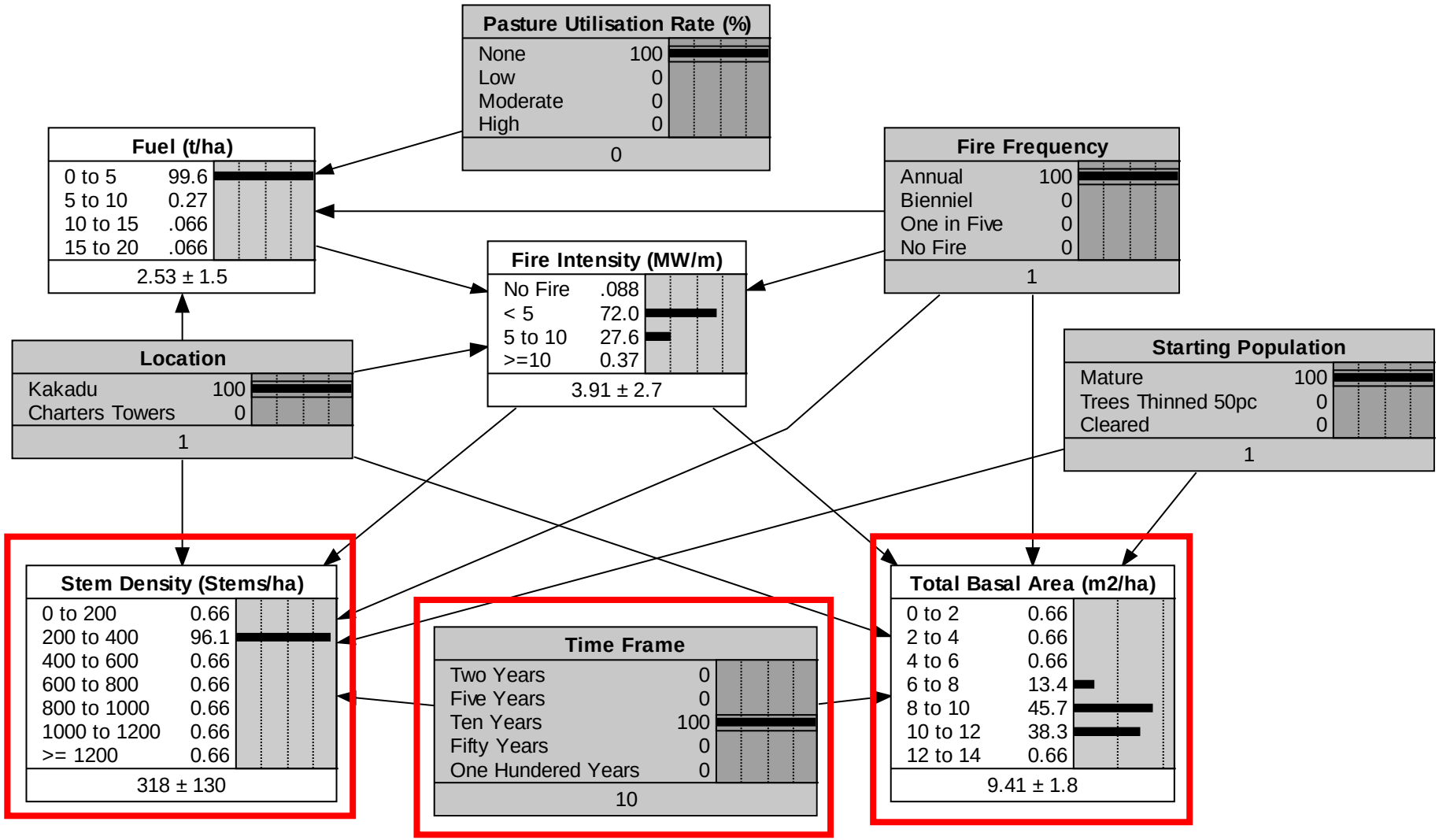
After 2 Years



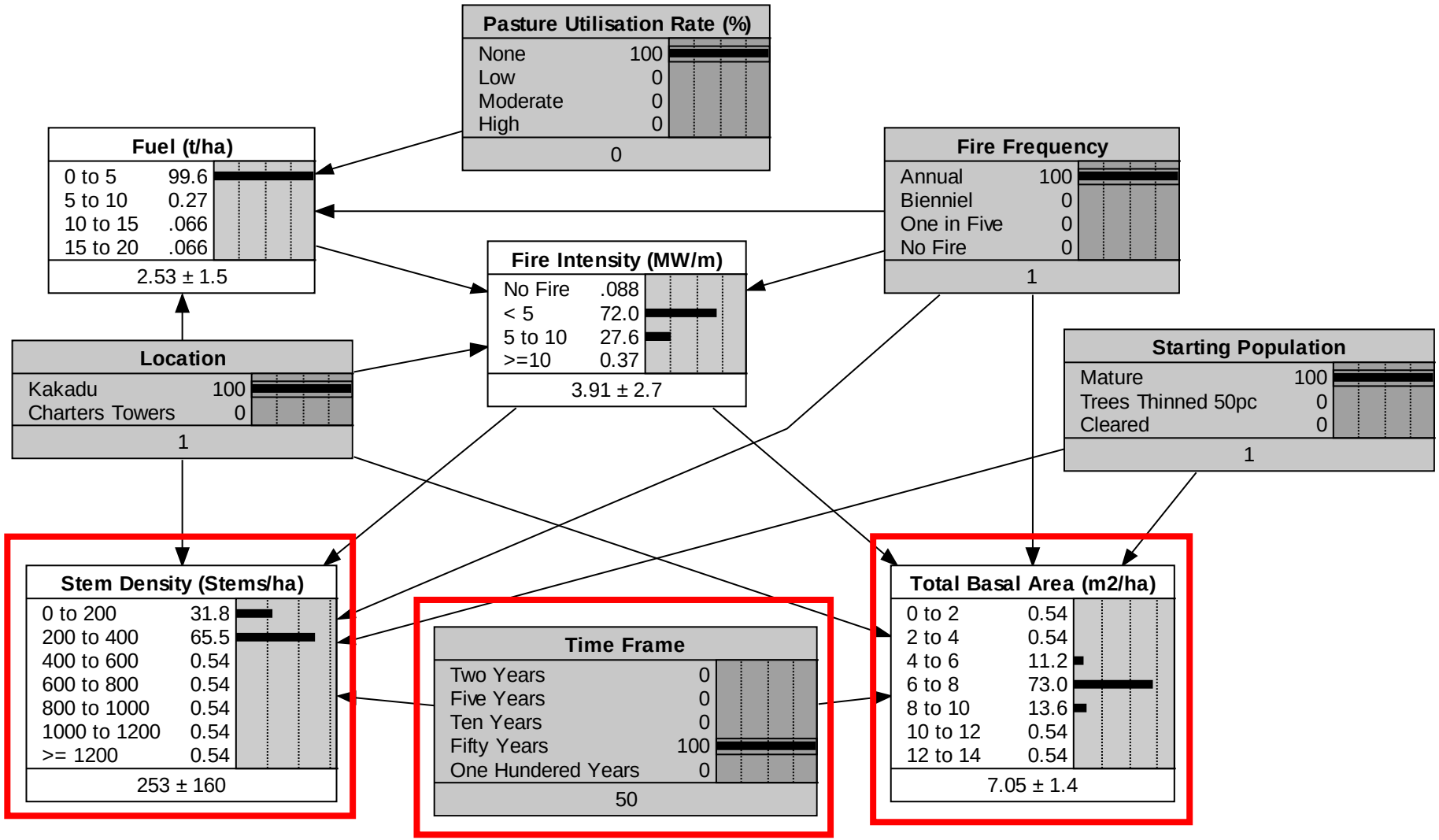
After 5 Years



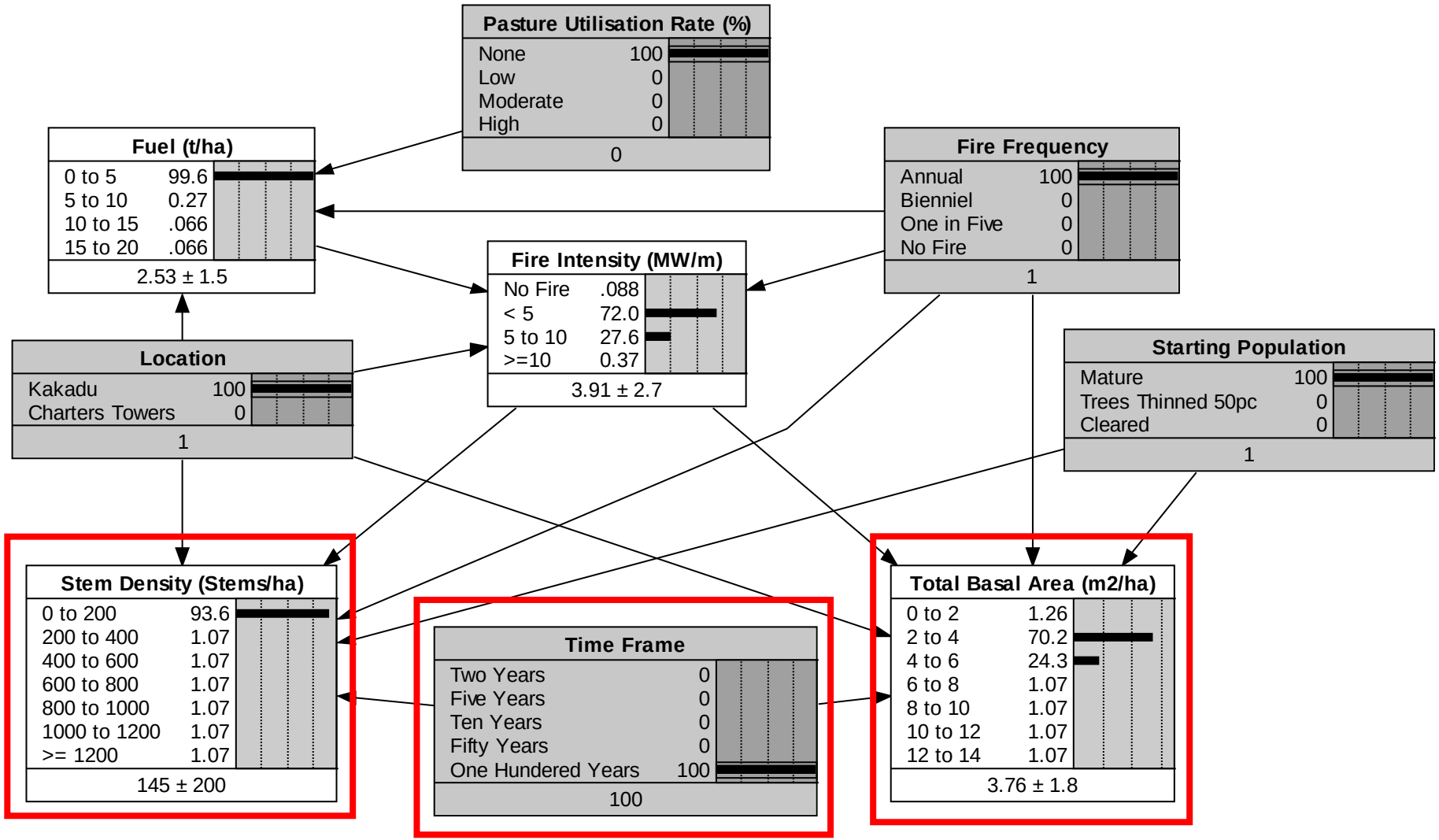
After 10 Years



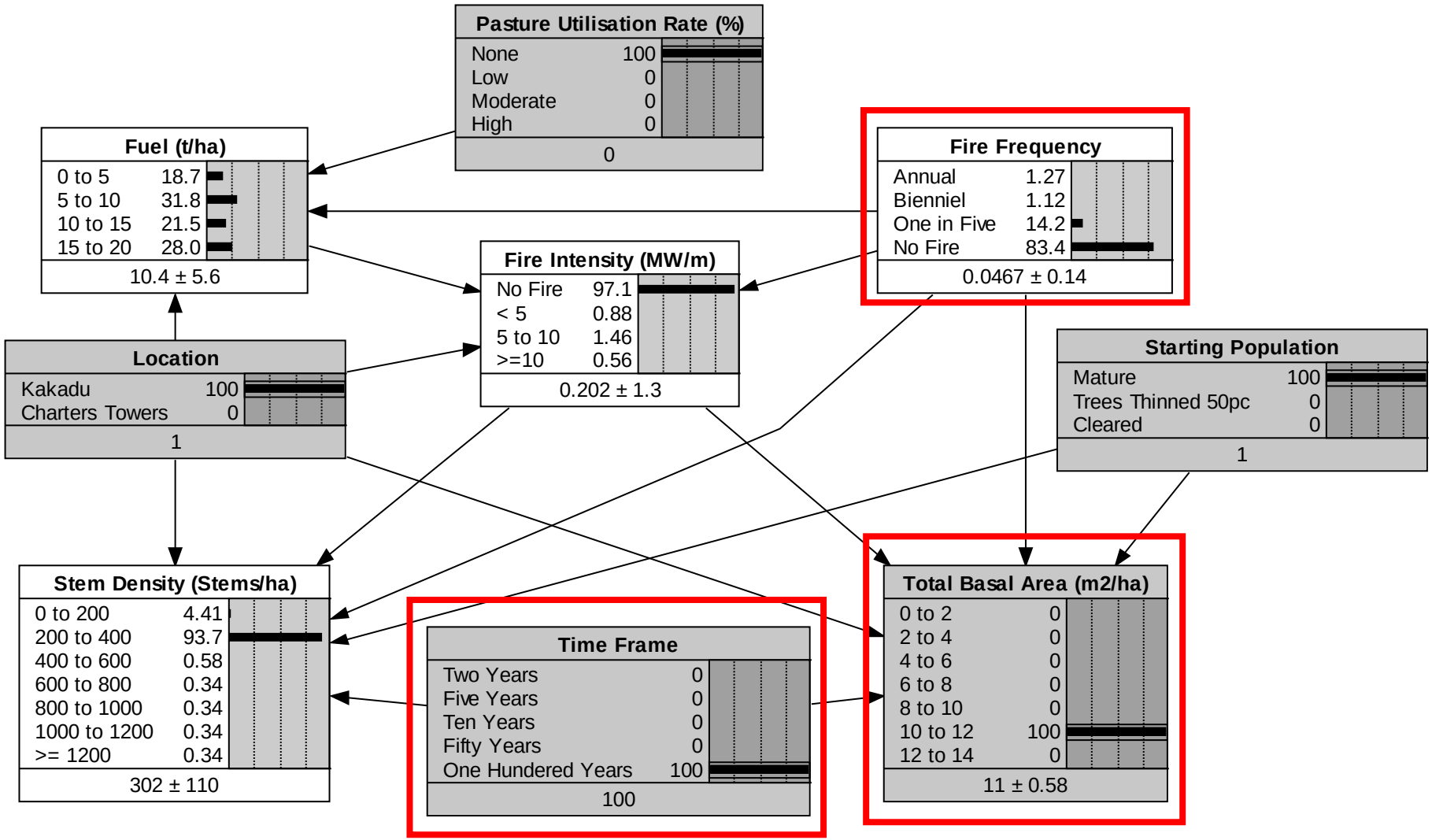
After 50 Years



After 100 Years

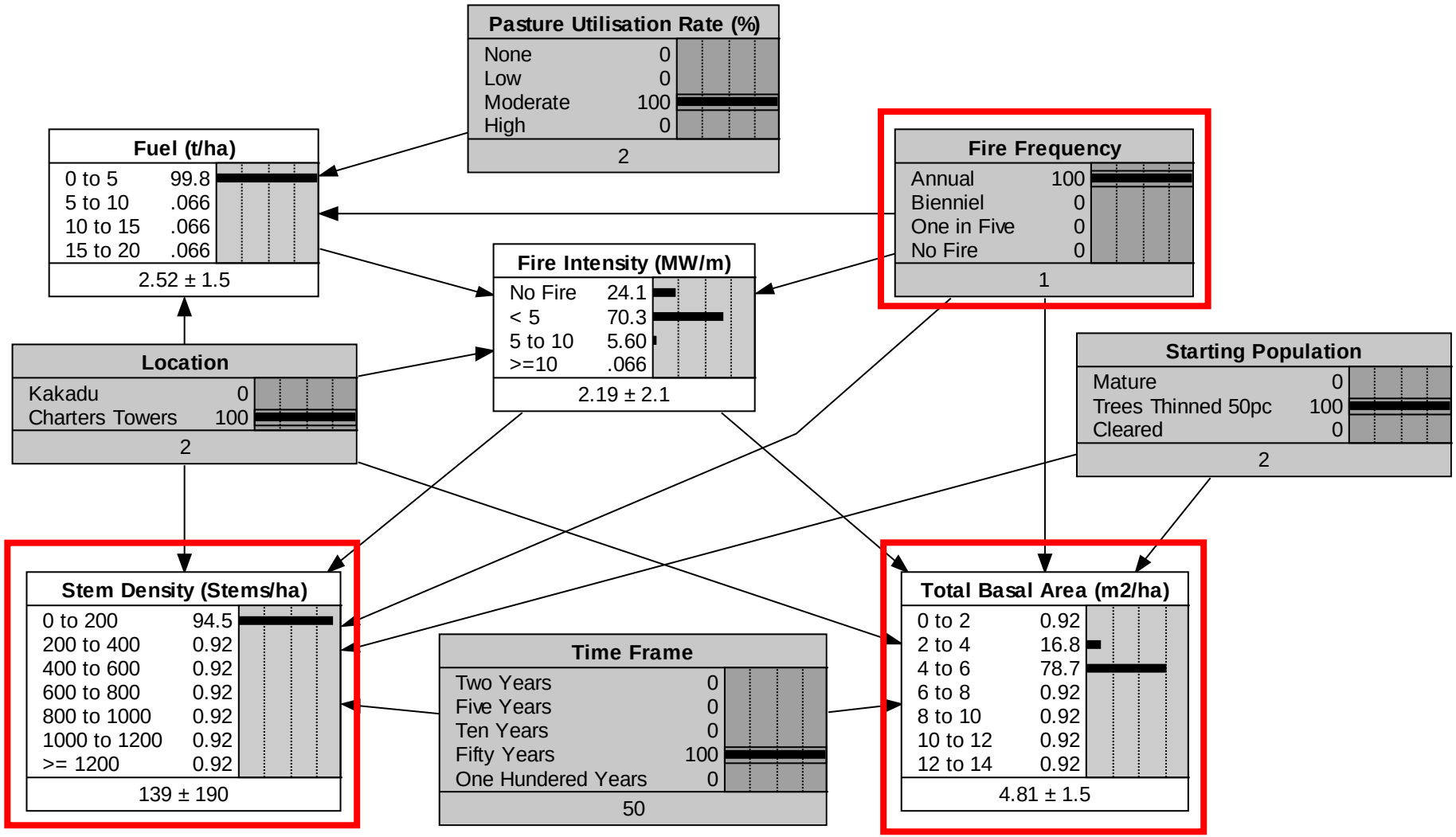


Diagnosing a fire frequency required to maintain a mature stand of trees with large TBA over a 100 year period in Kakadu National Park.

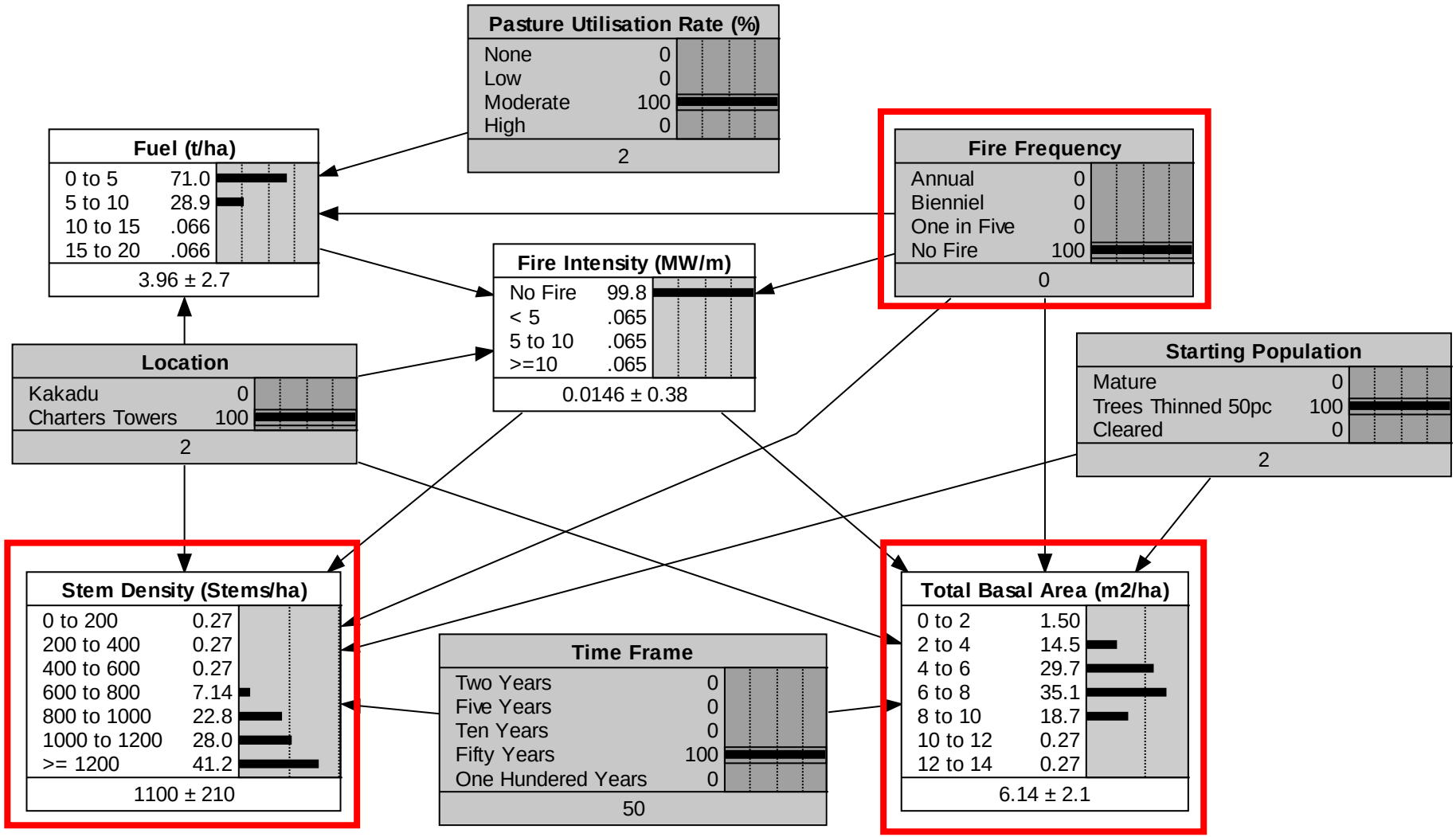

Pasture Utilisation Rate (%)
None 100
Low 0
Moderate 0
High 0
0
Fuel (t/ha)
0 to 5 18.7
5 to 10 31.8
10 to 15 21.5
15 to 20 28.0
10.4 ± 5.6
Fire Frequency
Annual 1.27
Bienniel 1.12
One in Five 14.2
No Fire 83.4
0.0467 ± 0.14
Fire Intensity (MW/m)
No Fire 97.1
< 5 0.88
5 to 10 1.46
>=10 0.56
0.202 ± 1.3
Location
Kakadu 100
Charters Towers 0
1
Starting Population
Mature 100
Trees Thinned 50pc 0
Cleared 0
1
Stem Density (Stems/ha)
0 to 200 4.41
200 to 400 93.7
400 to 600 0.58
600 to 800 0.34
800 to 1000 0.34
1000 to 1200 0.34
>= 1200 0.34
302 ± 110
Time Frame
Two Years 0
Five Years 0
Ten Years 0
Fifty Years 0
One Hundered Years 100
100
Total Basal Area (m2/ha)
0 to 2 0
2 to 4 0
4 to 6 0
6 to 8 0
8 to 10 0
10 to 12 100
12 to 14 0
11 ± 0.58

Predicting the effect of burning on stem density and TBA of a thinned tree stand after fifty years with moderate grazing pressure in Charters Towers.

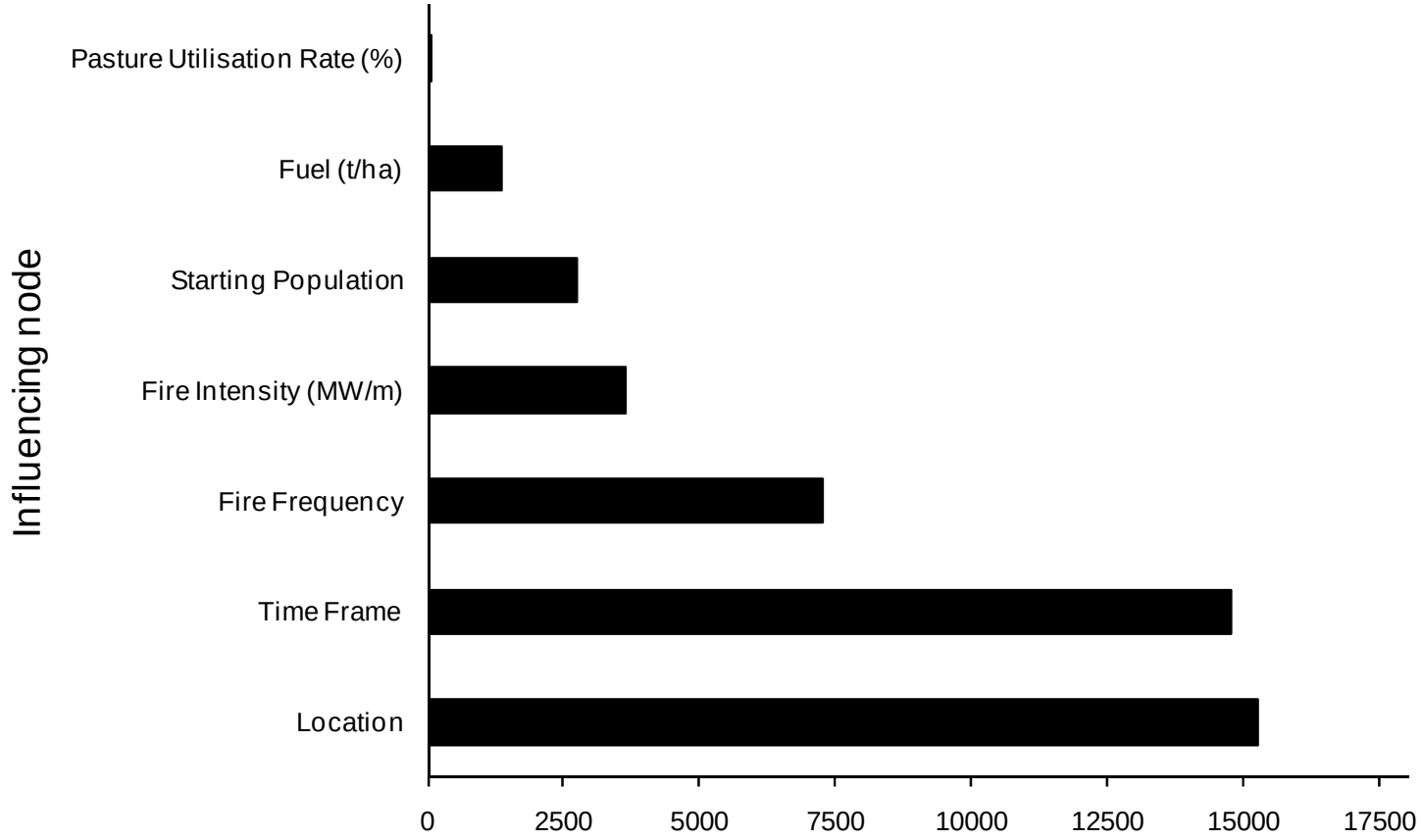
Annual Fires



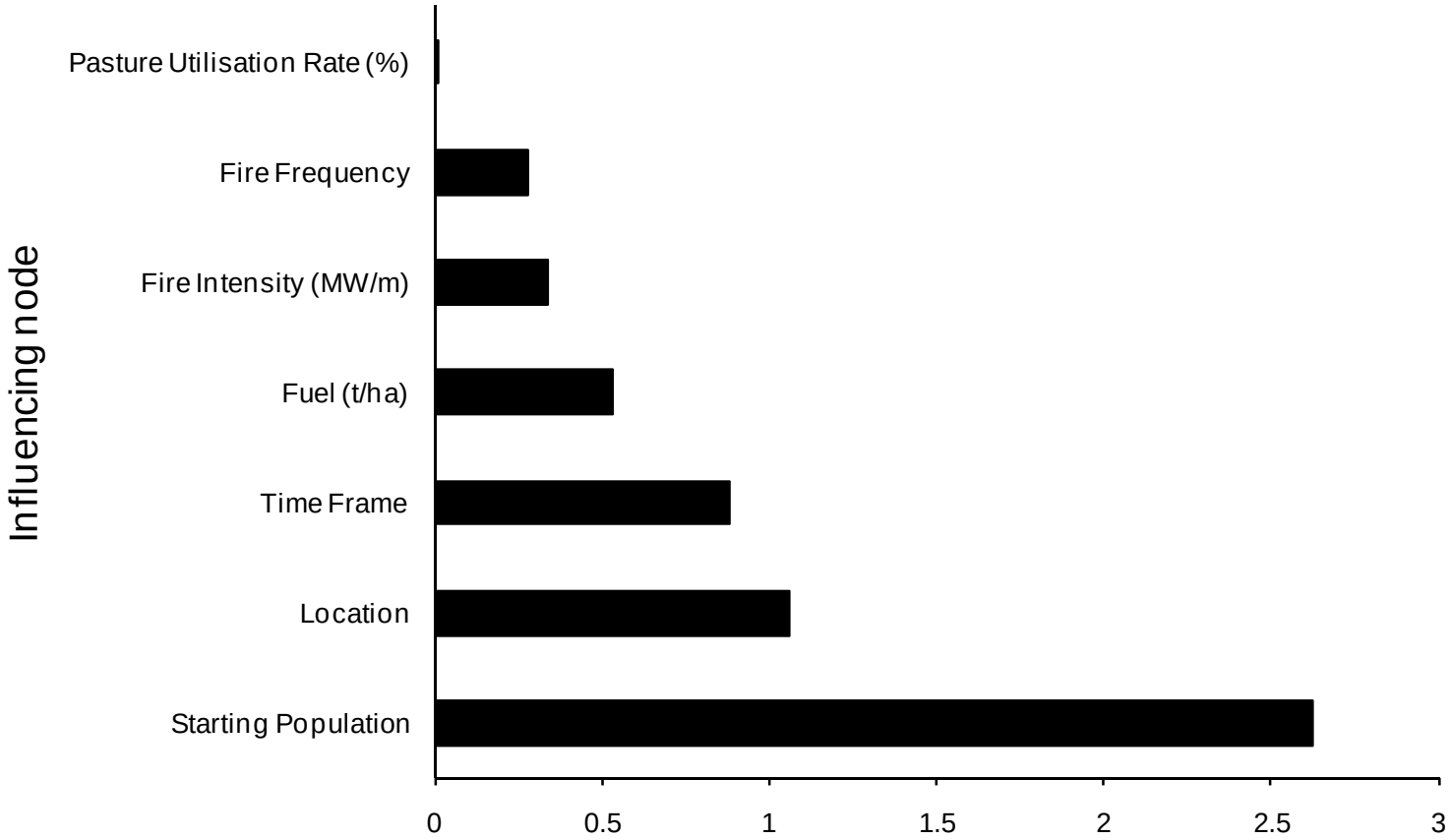
No Fire


Pasture Utilisation Rate (%)
None 0
Low 0
Moderate 100
High 0
2
Fuel (t/ha)
0 to 5 71.0
5 to 10 28.9
10 to 15 .066
15 to 20 .066
3.96 ± 2.7
Fire Frequency
Annual 0
Bienniel 0
One in Five 0
No Fire 100
0
Fire Intensity (MW/m)
No Fire 99.8
< 5 .065
5 to 10 .065
>=10 .065
0.0146 ± 0.38
Location
Kakadu 0
Charters Towers 100
2
Starting Population
Mature 0
Trees Thinned 50pc 100
Cleared 0
2
Stem Density (Stems/ha)
0 to 200 0.27
200 to 400 0.27
400 to 600 0.27
600 to 800 7.14
800 to 1000 22.8
1000 to 1200 28.0
>= 1200 41.2
1100 ± 210
Time Frame
Two Years 0
Five Years 0
Ten Years 0
Fifty Years 100
One Hundered Years 0
50
Total Basal Area (m2/ha)
0 to 2 1.50
2 to 4 14.5
4 to 6 29.7
6 to 8 35.1
8 to 10 18.7
10 to 12 0.27
12 to 14 0.27
6.14 ± 2.1

Sensitivity Analysis - Stems per Hectare



Sensitivity Analysis – Total Basal Area



Conclusions

- In the short term (after 2 years), tree numbers are most influenced by the Starting Point (Mature, Thinned or Cleared stand) followed by Fire Intensity and Fuel
- In the long term (after 100 years), tree numbers are most influenced by Location followed by Fire Frequency and Fire Intensity (assuming the woody vegetation type is Eucalypt)
- This shows that in the long term, climate is the factor driving tree numbers

Take Home Messages

- Systems thinking - mechanism for knowledge integration, stakeholder participation and intervention design
- Bayesian Networks a flexible tool for use in participatory systems analysis – scenario, sensitivity and diagnostic analysis

Take Home Messages

- Embedding these within the Llab cycle – the interventions/actions are implemented and then reviewed (step 7 – reflection)