Program	Understanding Risk
Project Title	Northern Fire Mapping: Developing robust fire extent and severity mapping products for the tropical savannas
Project Leaders	Prof. **Jeremy Russell-Smith** and Dr **Mick Meyer**
Lead End User	Dr **Neil Burrows**
Researcher	Dr **Andrew Edwards**

This project will examine some of the key environmental aspects of fire management in relation to ***biodiversity***, and ***carbon*** in the northern parts of Australia.

In particular, getting a better understanding of ***fire severity***.

This information will help to inform the ***emissions debate*** across the whole of the country.

Presentation outline:

1. What's the risk?
   - *Assessment of the risks to Biodiversity and Carbon (including greenhouse gas emissions);*

2. What information do we need?
   - *burnt area mapping, fire severity mapping, other;*

3. What is fire severity and how can we measure it?
   - *as compared to fire intensity and other measures,*
   - *how we can measure it,*
   - *how we classify fire severity, for whom and what purpose/s.*

1. *Savanna burning emissions abatement*

Detailed estimates of accountable (methane, nitrous oxide) greenhouse gas (GHG) emissions, derived using the formally approved (Australian Govt's Carbon Farming Initiative) methodology for "Savanna burning emissions abatement" methodology for regions with rainfall >1,000 mm p.a.

(refer: http://www.climatechange.gov.au/en/government/initiatives/carbon-farming-initiative/methodology-development/approved-methodologies/~/media/government/initiatives/cfi/methodology-development/methodologies-approved/savanna-burning-methodology-approved.pdf)

2. *Savanna burning biosequestration*

Generalised but robust estimates of achievable sequestration in above- and below-ground living biomass, based on a comprehensive assessment of relationships between fire regime parameters (especially frequency of severe fires) and biosequestration derived from 10 years of observations from plots in Kakadu, Litchfield & Nitmiluk National Parks (Murphy et al. 2010).

3. Effects of fire regimes on fire-vulnerable fauna and flora

based on published relationships (fire frequency, fire severity) between fire regime parameters and small mammal diversity and abundance (Woinarski et al. 2010), and vegetation types (Russell-Smith et al. 2012), derived from observations from monitoring plots in Kakadu National Park.

4. Effects of fire regimes on hill-slope erosion

based on relationships between LDS fires and hill-slope erosional and depositional processes (Russell-Smith et al. 2006). Note that while savanna landscapes are notoriously erosive given seasonal rainfall conditions alone (Lu et al. 2003), LDS fires afford additional erosional potential given their impact on surface cover (vegetation, litter). EDS fires on the other hand typically result in far less erosion (especially if they are low severity and patchy) given reduced impact on surface cover and leaf fall inputs through the dry season (Townsend & Douglas 2000).

Other ancillary datasets used for analyses

- Land tenure, depicting Indigenous and other lands;

- Generalised Land use, loosely depicting 'natural' vs. modified environmental conditions;

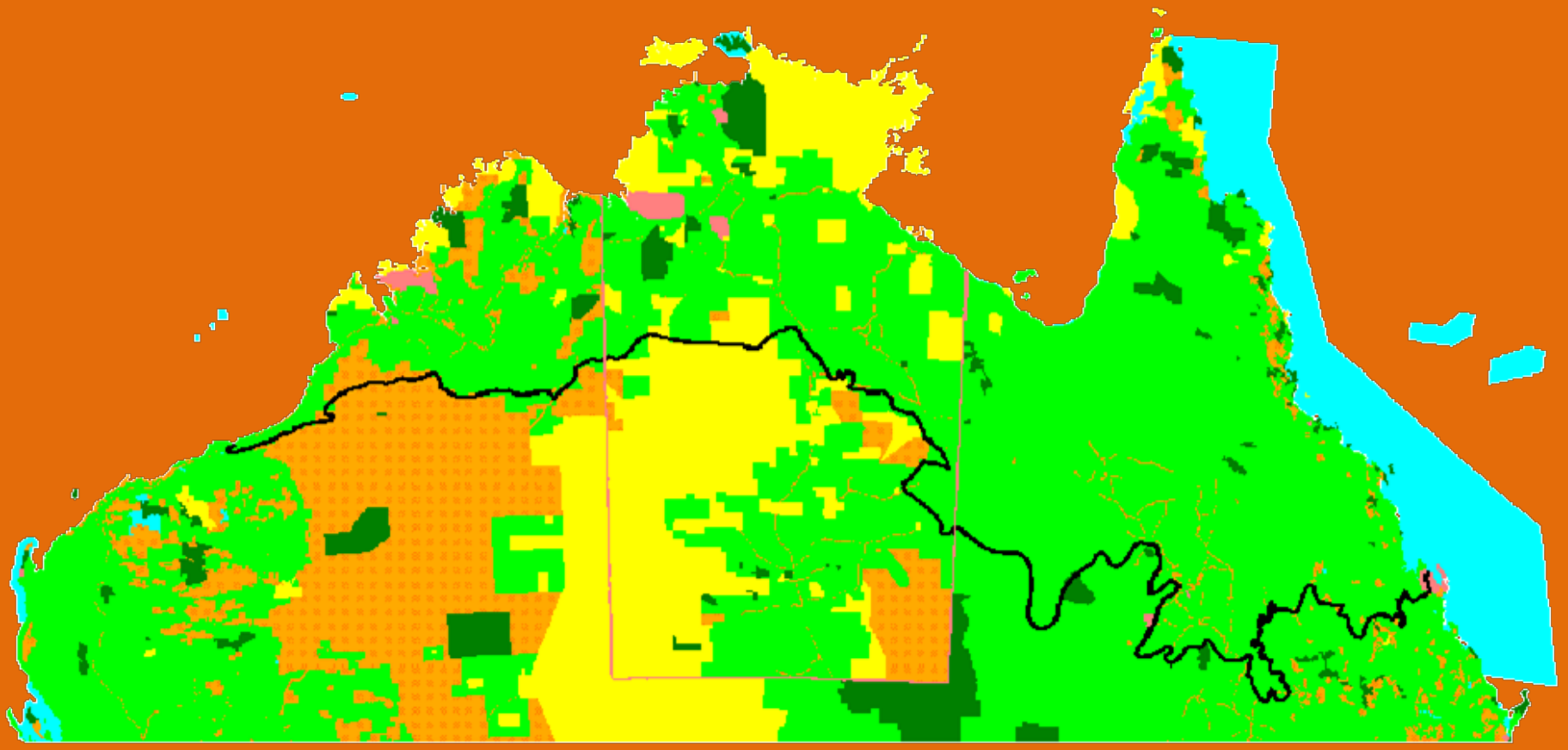
- 1:250k topographic data, includes roads, surface hydrology, population centres;

- North Australian Vegetation mapping (1: 250K,1:1M), for deriving major fuel types (refer Edwards & Russell-Smith 2009; approved 'savanna burning emissions abatement' methodology) ;

- Digital Elevation Model (DEM), 90 m pixels, from which also we can derive slope and 'topographic roughness' (a measure of the elevation range in a focal window, depicting topographic heterogeneity;)

- Mean rainfall interpolated rainfall surface, (derived from rainfall observations 1969-2009).

Land Use of Northern Australia



Aboriginal Land

Marine Conservation

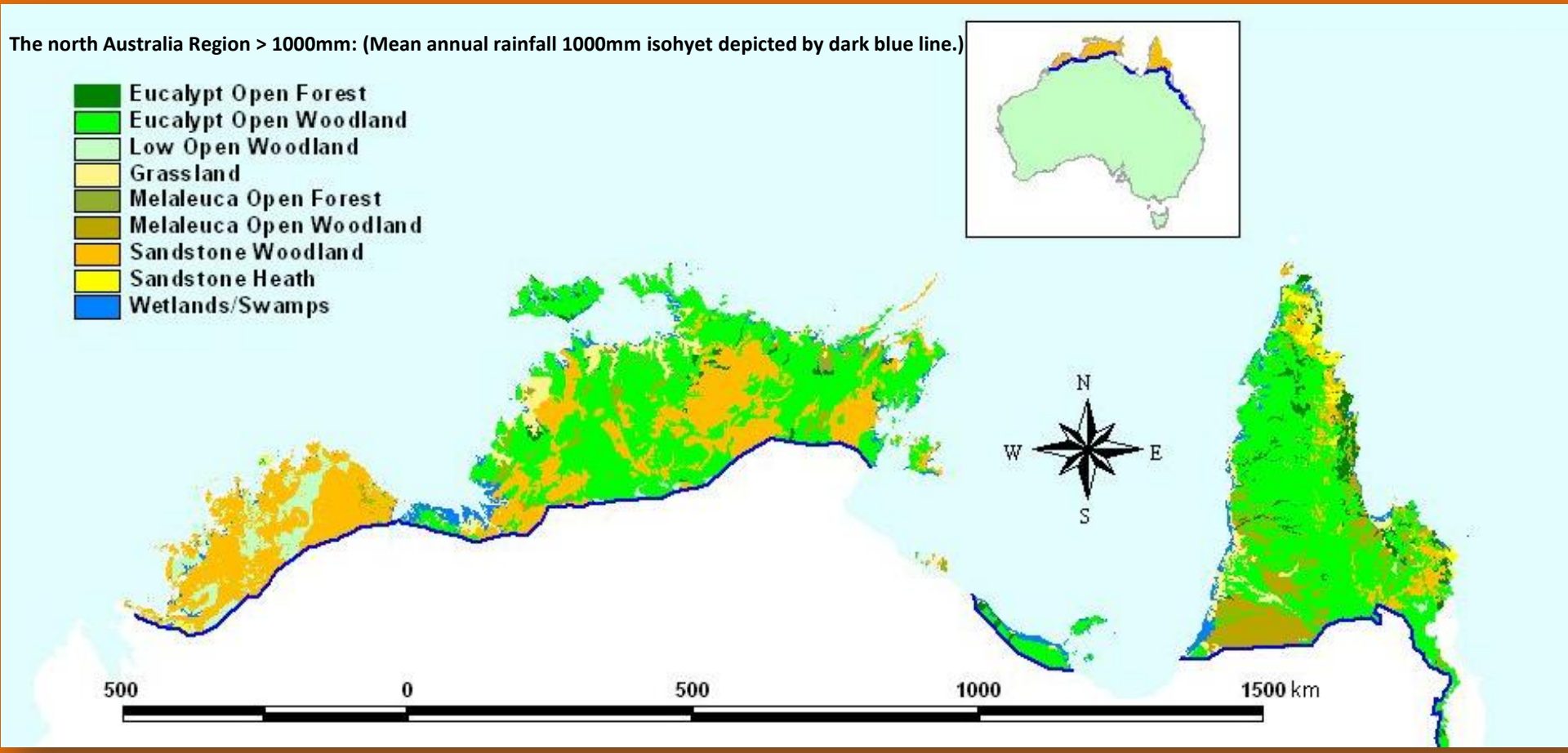
Pastoral Land

Defence Land

Crown Land

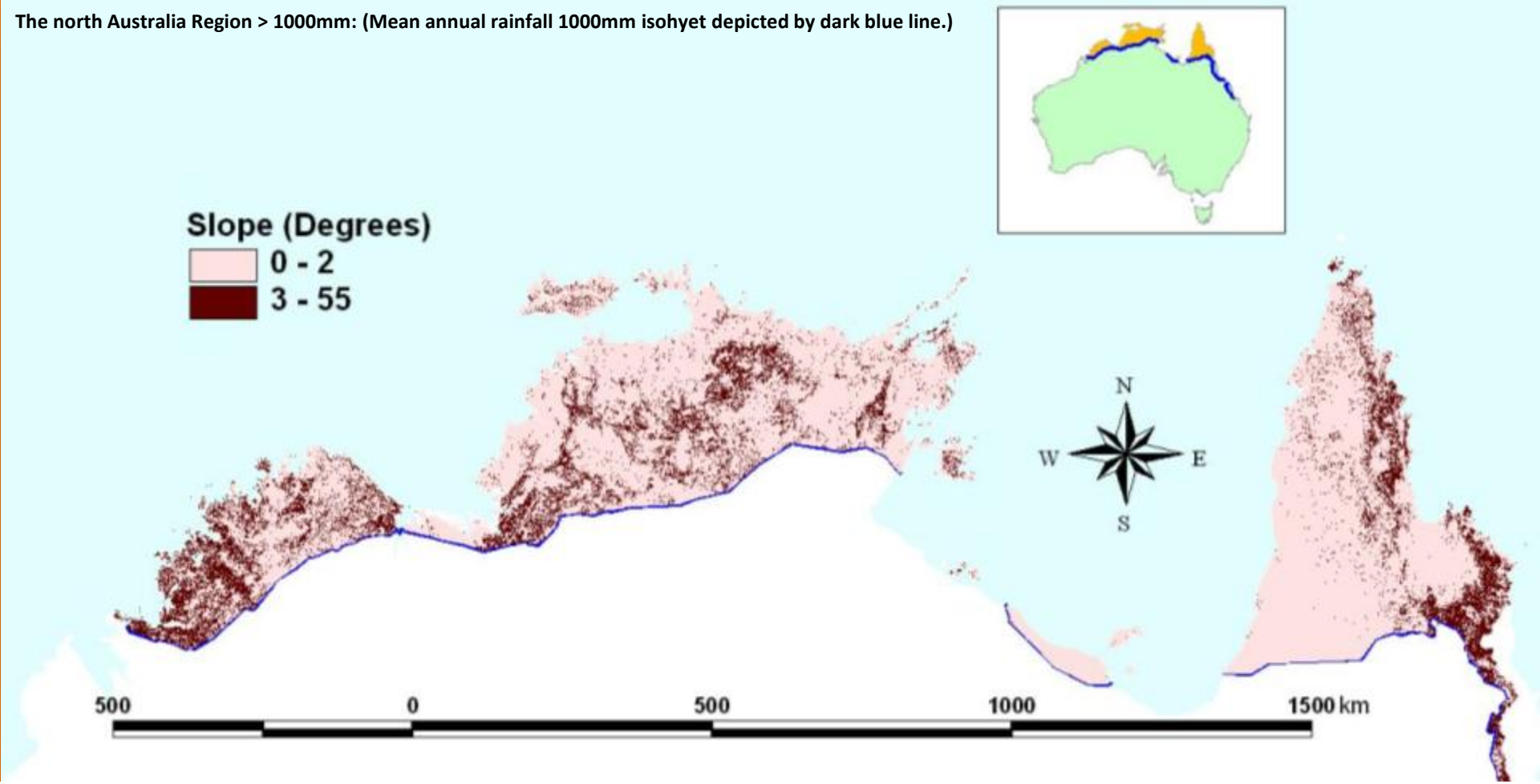
Conservation Land

Vegetation mapping ➔ fuels



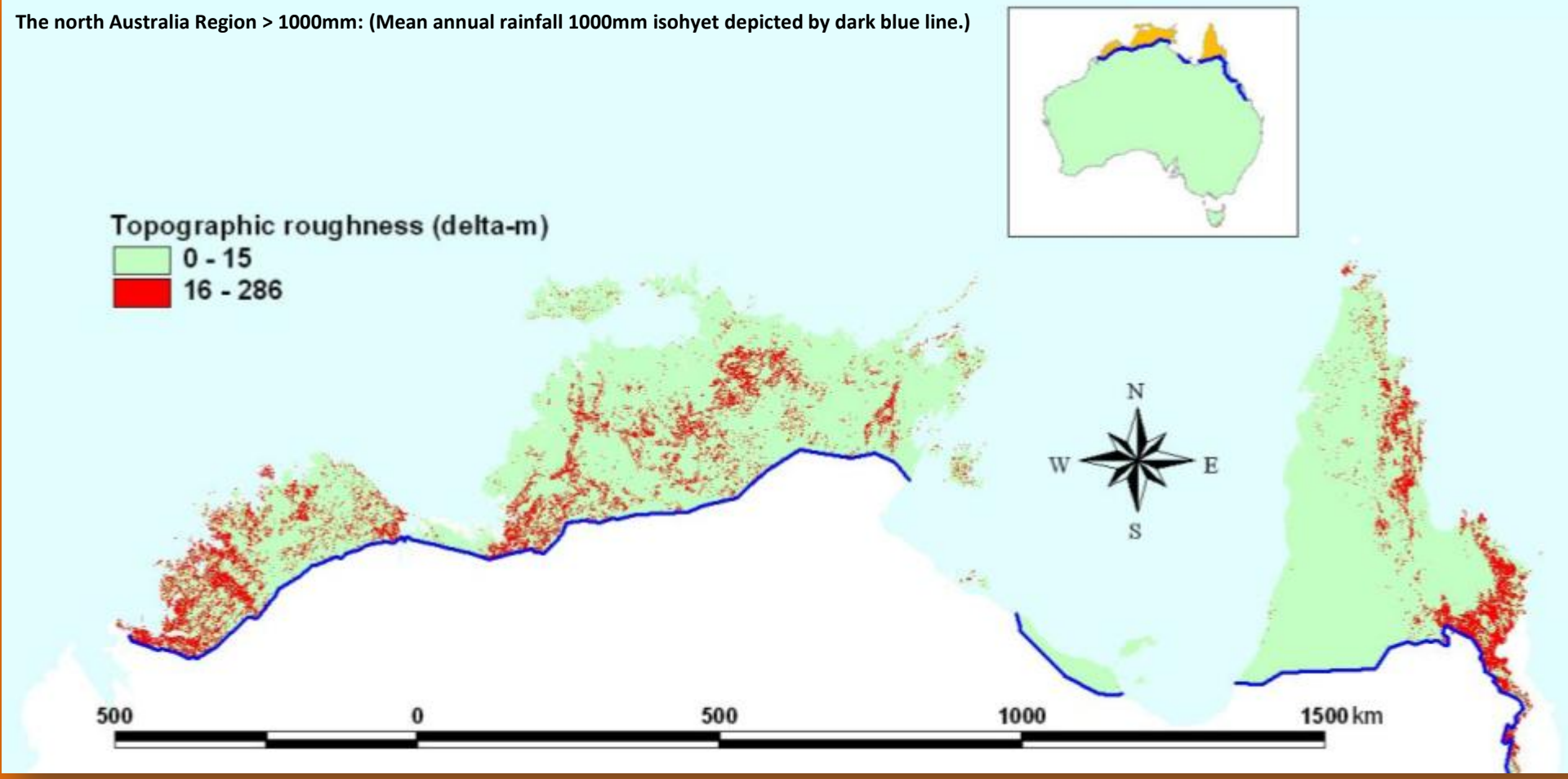
Slope

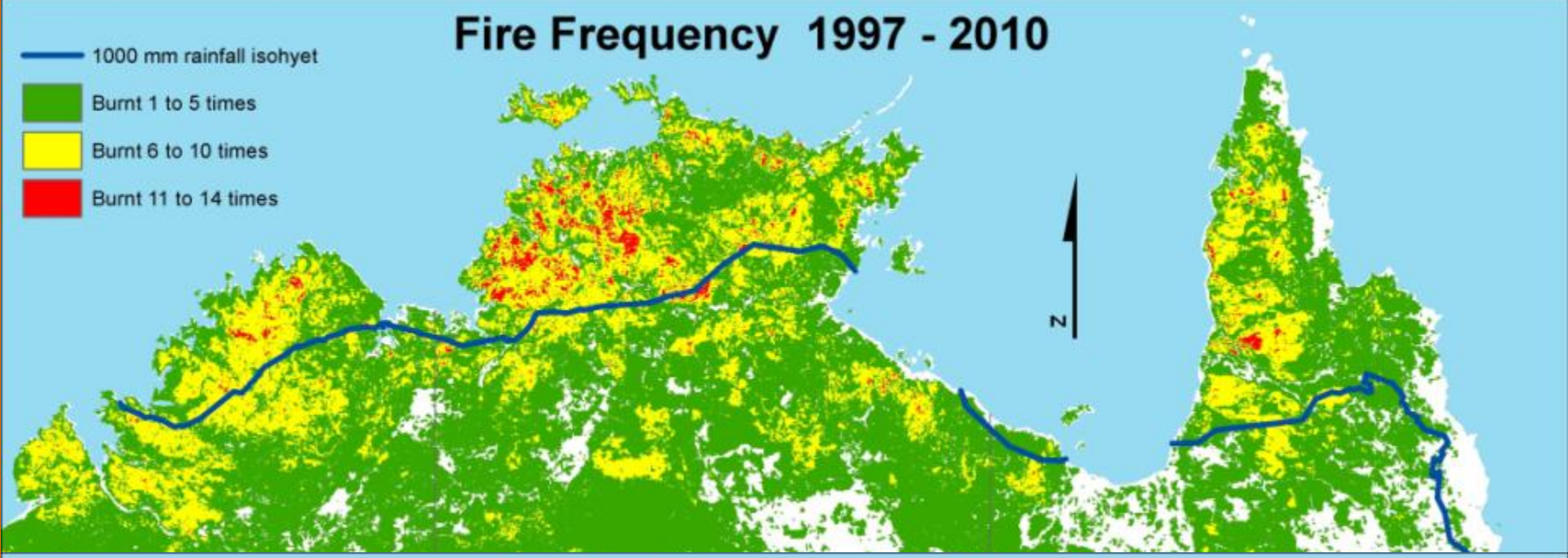
The north Australia Region > 1000mm: (Mean annual rainfall 1000mm isohyet depicted by dark blue line.)

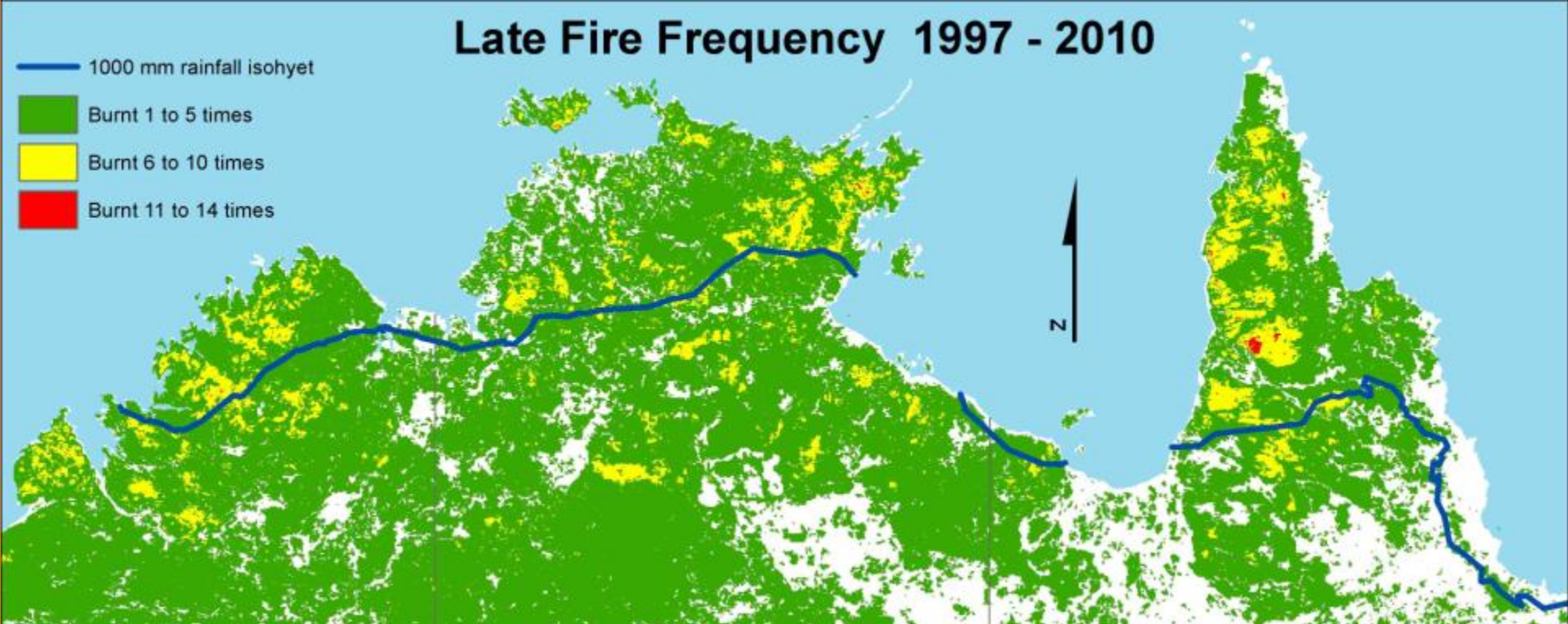


Topographic roughness

The north Australia Region > 1000mm: (Mean annual rainfall 1000mm isohyet depicted by dark blue line.)




Fire Frequency 1997 - 2010
1000 mm rainfall isohyet
Burnt 1 to 5 times
Burnt 6 to 10 times
Burnt 11 to 14 times
N


Late Fire Frequency 1997 - 2010
1000 mm rainfall isohyet
Burnt 1 to 5 times
Burnt 6 to 10 times
Burnt 11 to 14 times
N

North Australian Scenarios:

- period of scenarios for next 20 years;

- comparison between Indigenous and non-Indigenous held lands.

Scenario definitions

Business as usual (BAU)
maintaining similar fire regime patterns across the savannas as per unmanaged landscapes 2003-2011, i.e. at an annual frequency of 0.39 (comprising 0.14 in EDS, 0.25 in LDS) and at severity frequencies generally of 0.18 mild, 0.14 moderate, 0.07 high.

Improved fire management (IFM)
reducing fire frequency overall by 25%, but incorporating a 50% reduction in LDS fires. In effect, this results in fire severity frequencies of 0.18 for mild fires, 0.11 for moderate fires, 0.05 for severe fires. These modest targets are highly realistic based on the WALFA experience (Whitehead et al. 2009).

Climate change impacts (CCI)
it is predicted that climate change will result in ever-increasing numbers of days with extreme fire-weather conditions, essentially number of days with >35^{o} temperature (CSIRO & Bureau of Meteorology 2007). We account for this by increasing high severity fire frequency by 0.1, both for BAU and IFM.

Parameters / variables	Business as usual (BAU)	BAU with climate change (BAU / CC)	Improved fire management (IFM)	IFM with climate change (IFM / CC)
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Fire severity—frequency of low, moderate, high severity fires (as a proportion of the total proportion of area burnt)	Low = 0.18 Moderate = 0.14 High = 0.07	Low = 0.18 Moderate = 0.14 High = 0.17	Low = 0.18 Moderate = 0.11 High = 0.05	Low = 0.18 Moderate = 0.11 High = 0.15
Savanna burning emissions abatement—applying formal CFI methodological approach	Baseline scenario—effectively no change	Baseline scenario with worsening fire-weather conditions	Reduced GHG emissions through strategic burning	Attempted reduced GHG emissions, but with worsening fire weather conditions
Savanna burning biosequestration—applying modelling approach as per Murphy et al. (2009, 2010)	Baseline scenario—effectively no change	Baseline scenario with worsening fire-weather conditions	Increased biosequestration associated with milder fire regime	Attempted increased biosequestration, but encountering worsening fire-weather conditions
Biodiversity effect: (1) small mammal fauna—applying fire frequency models models as per Woinarski et al. 2010	Ongoing precipitous decline	Ongoing precipitous decline, exacerbated by climate change	Attempt to impose (slightly) more sustainable fire regime	Attempt to impose (slightly) more sustainable fire regime, but encountering worsening fire-weather conditions
Biodiversity effect: (2) fire-vulnerable obligate seeder vegetation—applying fire frequency models as per Russell-Smith et al. 2012	Ongoing decline, especially in more rugged terrain	Ongoing decline, exacerbated by climate change	Attempt to impose (slightly) more sustainable fire regime	Attempt to impose (slightly) more sustainable fire regime, but encountering worsening fire-weather conditions
Erosion effect—applying erosivity relationships as per Russell-Smith et al. (2006)	Ongoing high erosion rate, especially in rugged terrain	Ongoing high erosion rate, exacerbated by climate change	Attempt to impose (slightly) more sustainable fire regime	Attempt to impose (slightly) more sustainable fire regime, but encountering worsening fire-weather conditions
Ecosystem services generally	Deteriorating	Deteriorating, exacerbated by climate change	Positive intervention	Positive intervention, but encountering worsening fire-weather conditions
Ecosystem services, on Indigenous lands specifically	Deteriorating, likely at greater rate than for north Australia generally	Deteriorating, exacerbated by climate change	Positive intervention, with potential for enhanced benefits relative to north Australia generally	Positive intervention, but encountering worsening fire-weather conditions

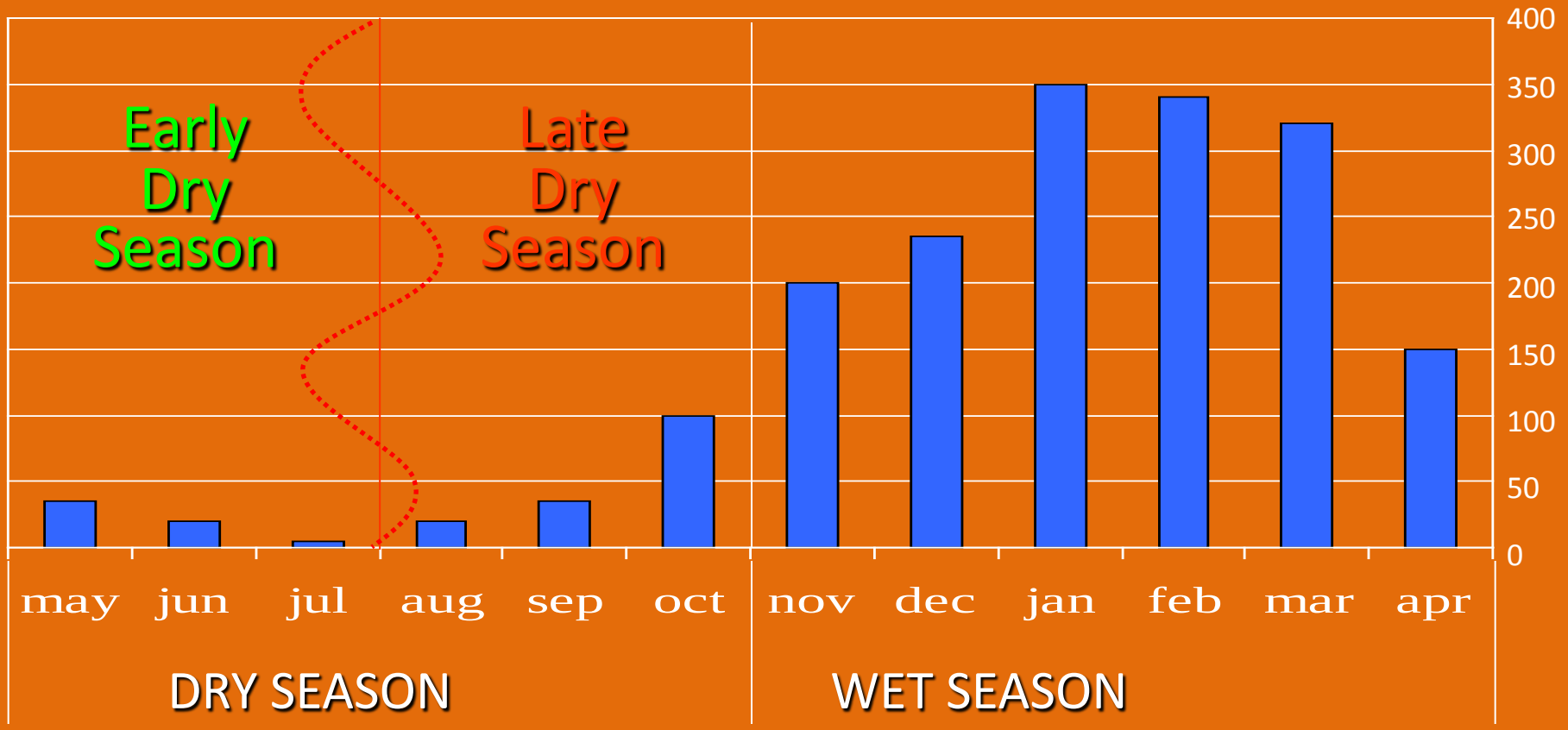
Fire Severity

FIRE SEVERITY CATEGORIES FOR THE TROPICAL SAVANNA WOODLANDS OF NORTHERN AUSTRALIA

A savanna is a tropical / subtropical woodland ecosystem.

Tropical savannas cover 12 % of the world's land surface.

Savannas are characterised by seasonal water availability, with the majority of rainfall being confined to one season of the year.

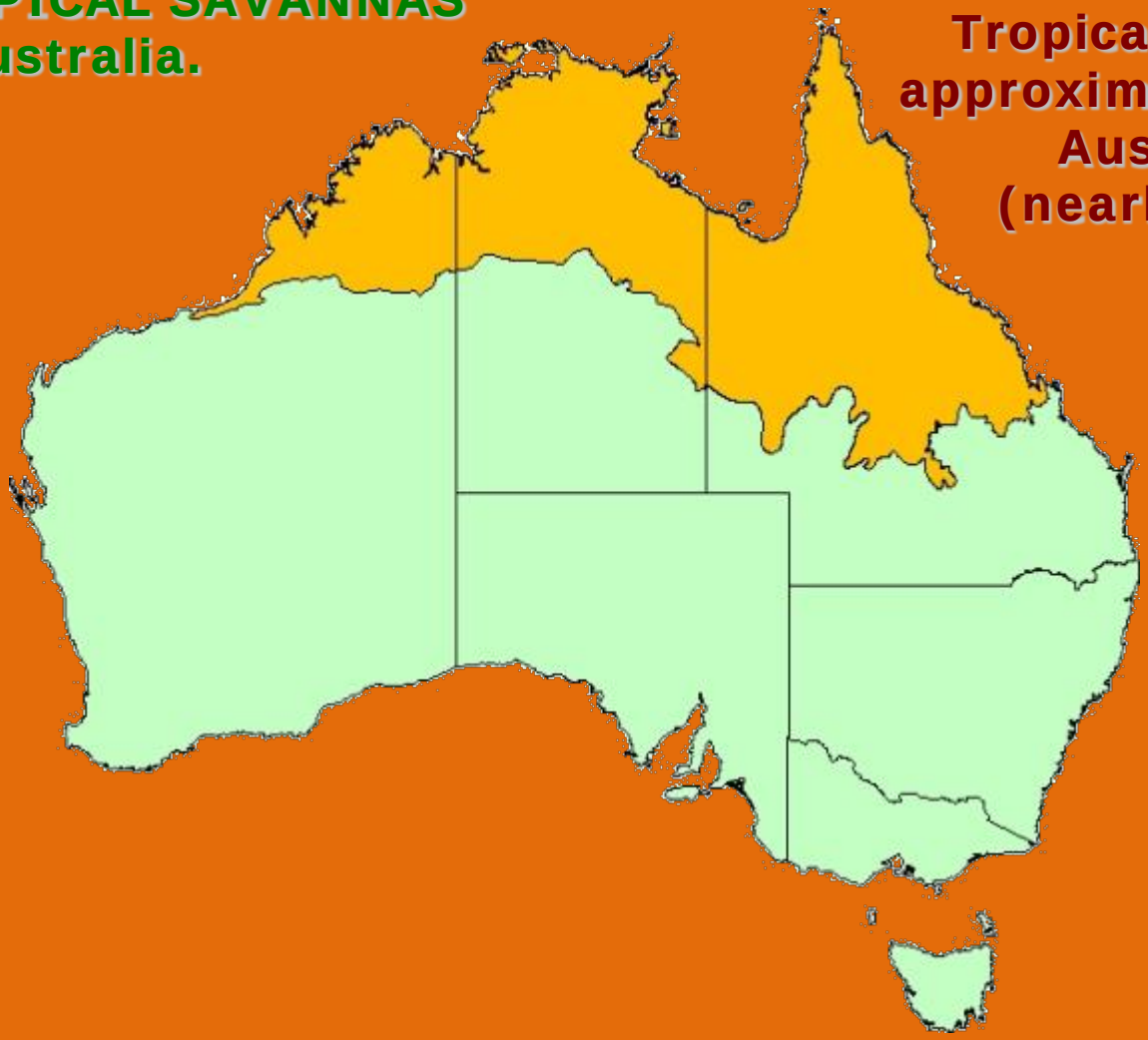


YEKKE	WURRKENG	KURRUNG	KUNUMELENG	KUDJEWK	BANGKERRENG
Early DRY	LATE DRY	BUILD UP	FIRST STORMS	WET	LATE WET

Mean Average Monthly Rainfall (mm) for Darwin, Northern Territory (~100 years) (Source: Bureau of Meteorology, Commonwealth of Australia)


Tropical savannas are landscapes
with a continuous
grass layer below and regular
tree cover above.
26.04 15:15

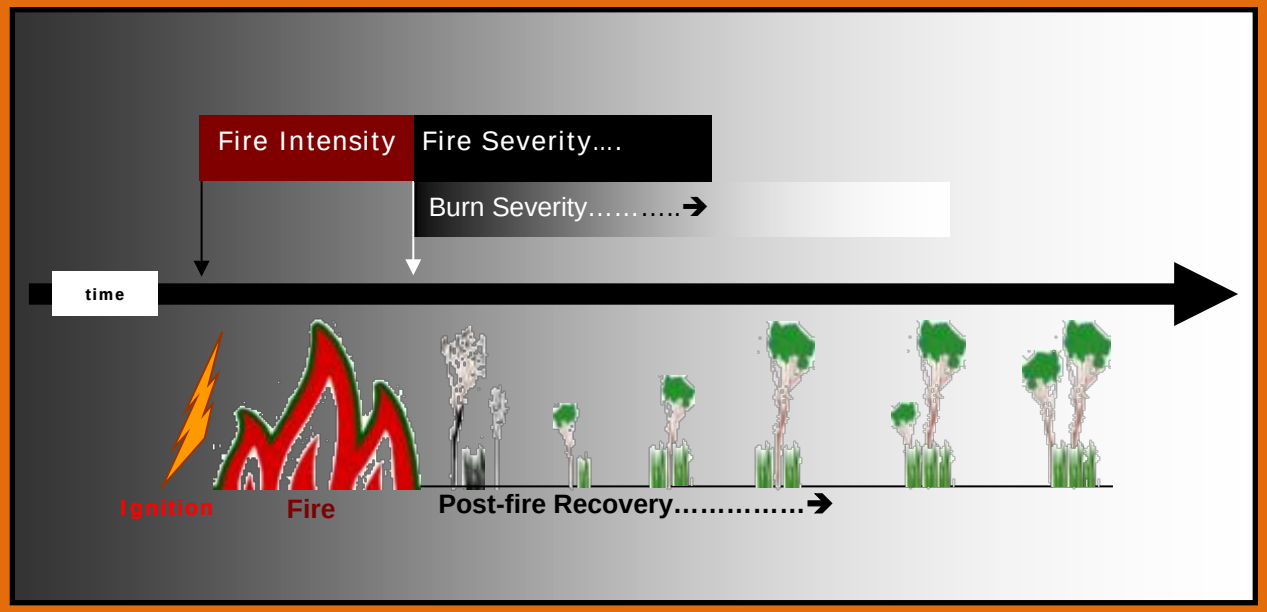
The Extent of TROPICAL SAVANNAS in Australia.



Tropical Savannas cover approximately 25% of the Australian continent (nearly 2 million km^2).

What is Fire Severity?

Fire **intensity**, is a directly measurable quantity of the energy released by fire (usually in kWm^{-1})



Unlike fire intensity, measures of fire severity **vary** based on the ecosystem and for various sectors of the community.

Scorch Height
is the height to which former green leaves *still suspended* on plants are turned brown by the heat of a fire.

Char Height
is the height to which former green leaves *still suspended* on plants are turned black by the flame of the fire.
NB This can **not** be measured on the stems of plants as fire "climbs" the bark.

Patchiness
a percentage or proportion of the ground layer vegetation (grasses, herbs and trees/shrubs < 1m) **not** affected by fire.
i.e. 20% patchiness = 80% burnt.

Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: PATCHY

Fire Severity Class:	**PATCHY**
Scorch height:	≤ 2 m
Patchiness:	YES
Fire Intensity:	<< 100 kWm^{-1}

Category Description: A patchy fire of low severity where:
- the ground material is not all affected by the fire;
- the height of scorched leaves is no higher than 2 metres.

Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: PATCHY

Fire Severity Class:	**PATCHY**
Scorch height:	$\leq$ 2 m
Patchiness:	YES
Fire Intensity:	<< 100 kWm^{-1}

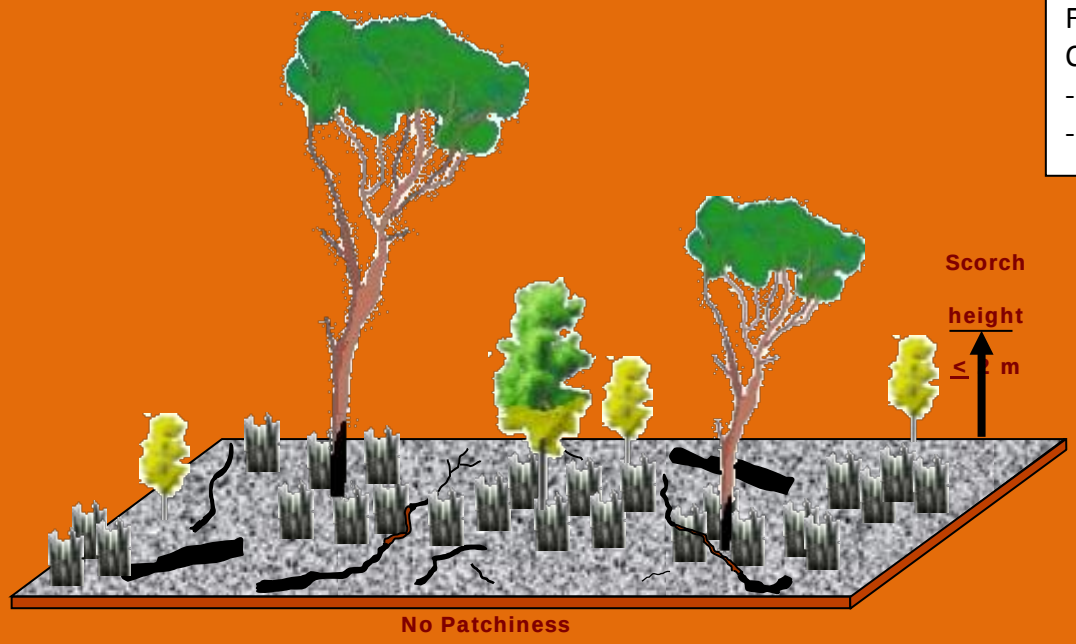
Category Description: A patchy fire of low severity where:
- the ground material is not all affected by the fire;
- the height of scorched leaves is no higher than 2 metres.

Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: LOW

Fire Severity Class:	**LOW**
Scorch height:	≤ 2 m
Patchiness:	NO
Fire Intensity:	< 100 kWm^{-1}

Category Description:
- all of the ground material is affected by the fire;
- the height of scorched leaves is no higher than 2m.



Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: LOW

Fire Severity Class:	**LOW**
Scorch height:	≤ 2 m
Patchiness:	NO
Fire Intensity:	< 100 kWm^{-1}

Category Description:

- all of the ground material is affected by the fire;
- the height of scorched leaves is no higher than 2m.

Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: MODERATE

Fire Severity Class:	**MODERATE**
Scorch height:	2 to 5 m
Patchiness:	NO
Fire Intensity:	100 - 500 kWm^{-1}

Category Description:

- all of the ground material is affected by the fire;
- Leaf scorch height is >2m but $\leq$ 5m;
- all or most mid-storey canopy leaves were scorched;
- upper canopy leaves may be partly scorched.

Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: MODERATE

Fire Severity Class:	**MODERATE**
Scorch height:	2 to 5 m
Patchiness:	NO
Fire Intensity:	100 - 500 kWm^{-1}

Category Description:

- all of the ground material is affected by the fire;
- Leaf scorch height is >2m but $\leq$ 5m;
- all or most mid-storey canopy leaves were scorched;
- upper canopy leaves may be partly scorched.

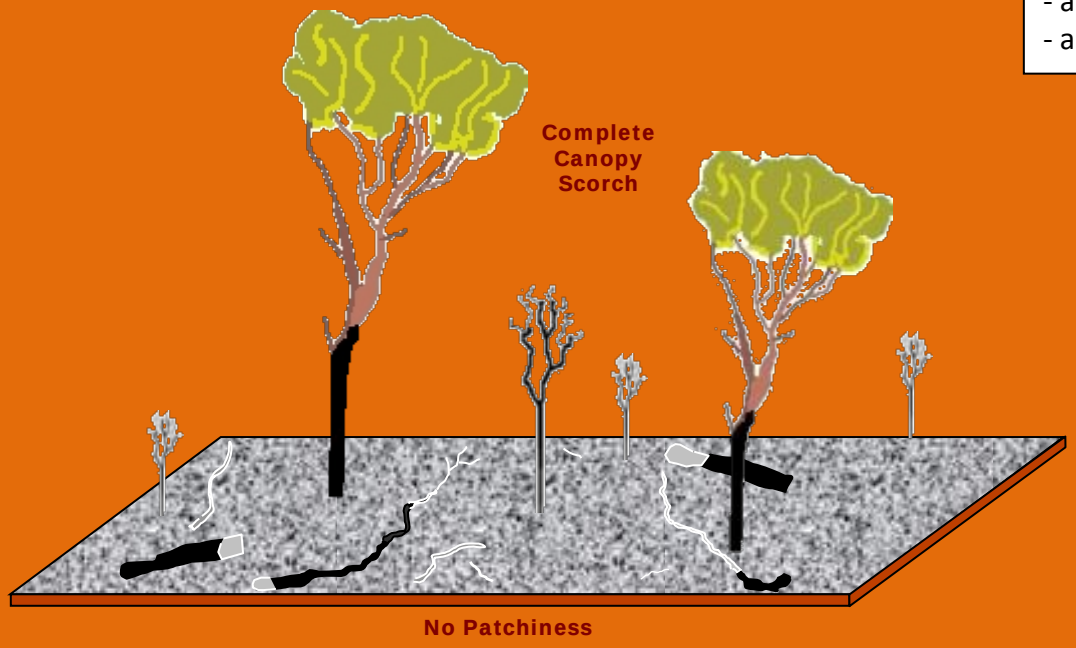
Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: HIGH

Fire Severity Class:	**HIGH**
Scorch height:	Complete canopy scorch
Patchiness:	NO
Fire Intensity:	500 – 10,000 kWm^{-1}

Category Description:

- all ground material was affected by the fire;
- all mid-storey canopy leaves were scorched;
- all upper canopy leaves were charred/scorched.



Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: HIGH

Fire Severity Class:	**HIGH**
Scorch height:	Complete canopy scorch
Patchiness:	NO
Fire Intensity:	500 – 10,000 kWm^{-1}

Category Description:

- all ground material was affected by the fire;
- all mid-storey canopy leaves were scorched;
- all upper canopy leaves were charred/scorched.

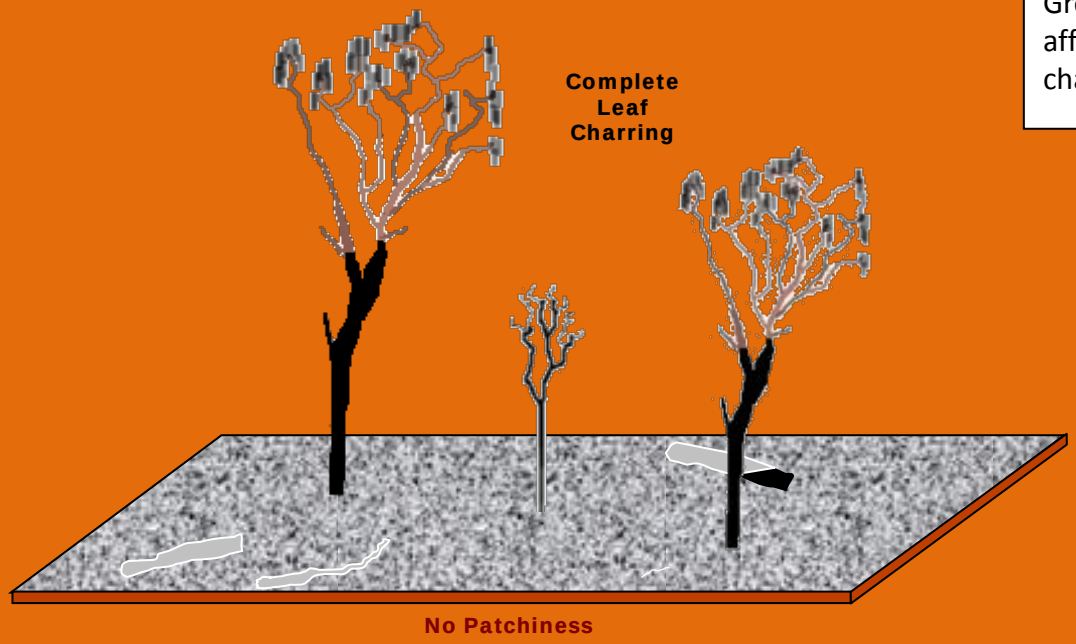
Simplified models of fire severity: tropical savanna woodland/open forest example

Fire severity: EXTREME

Fire Severity Class:	**EXTREME**
Scorch height:	Completely Charred
Patchiness:	NO
Fire Intensity:	> 10,000 kWm^{-1}

Field Description:

Ground, mid-storey and upper-canopy are completely affected by the fire, most leaf material is removed or charred.



Simplified models of fire severity: tropical savanna woodland/open forest example

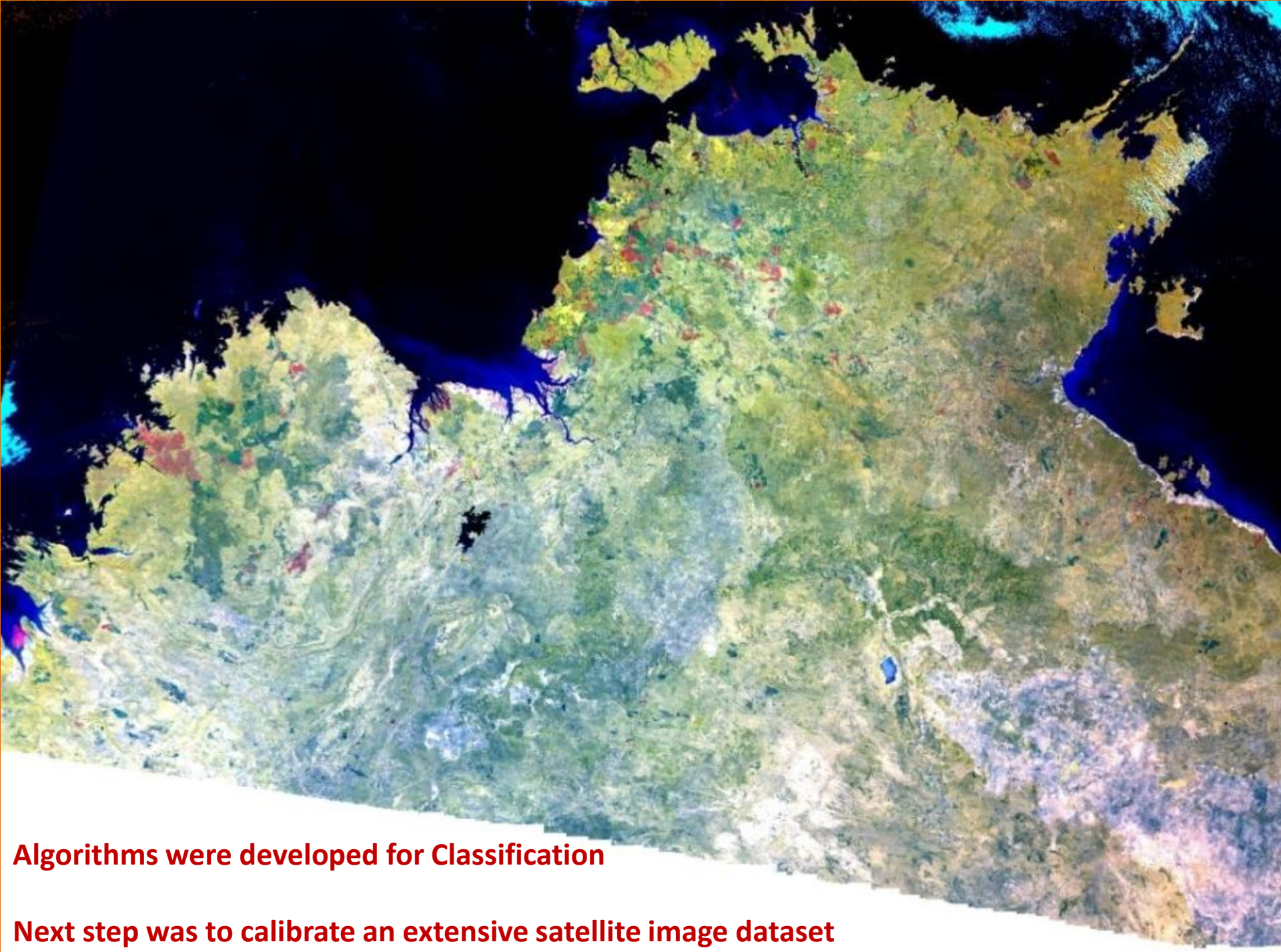
Fire severity: EXTREME

Fire Severity Class:	**EXTREME**
Scorch height:	Completely Charred
Patchiness:	NO
Fire Intensity:	> 10,000 kWm^{-1}

Field Description:

Ground, mid-storey and upper-canopy are completely affected by the fire, most leaf material is removed or charred.

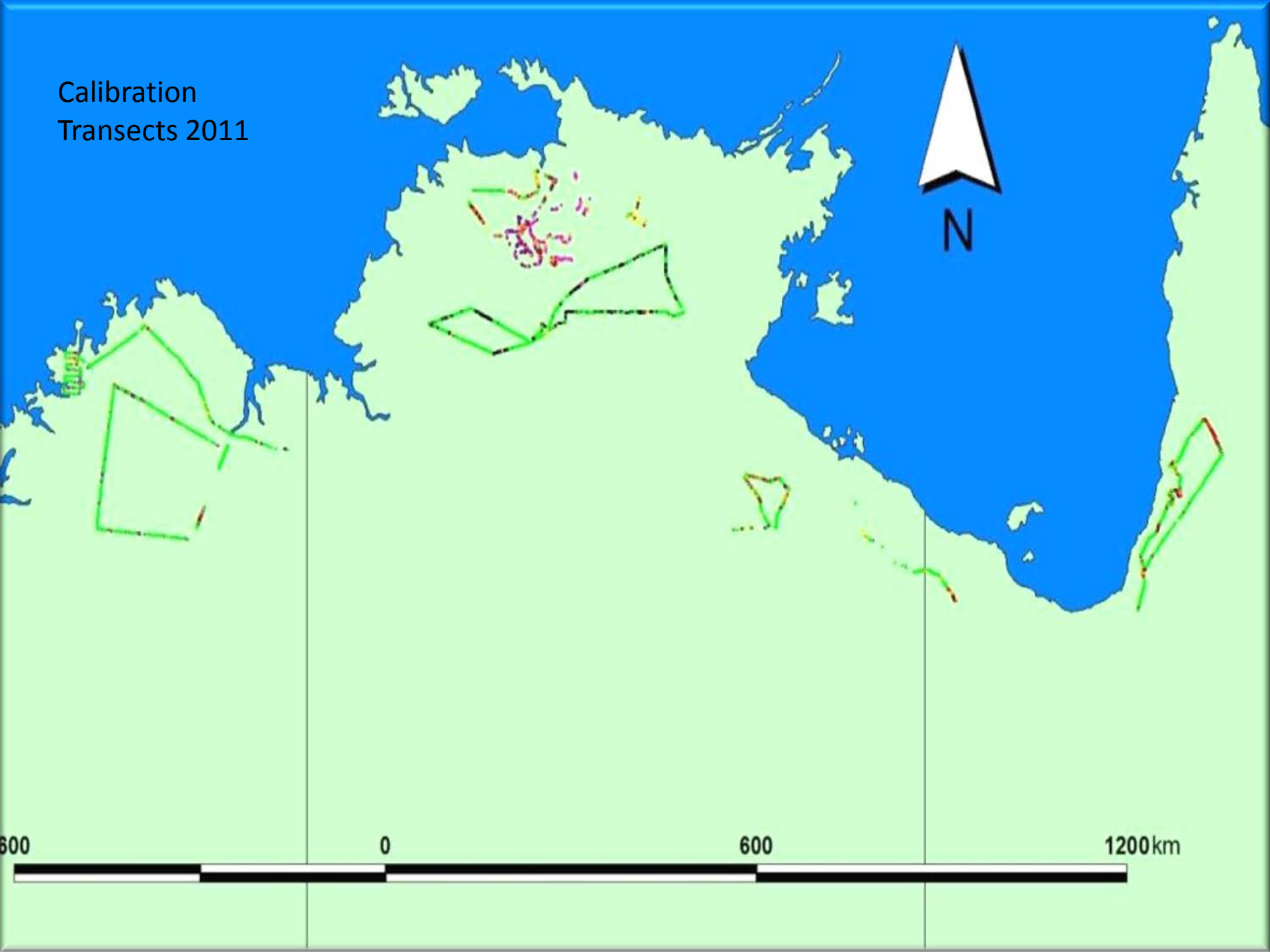
Fire Severity and Remote Sensing

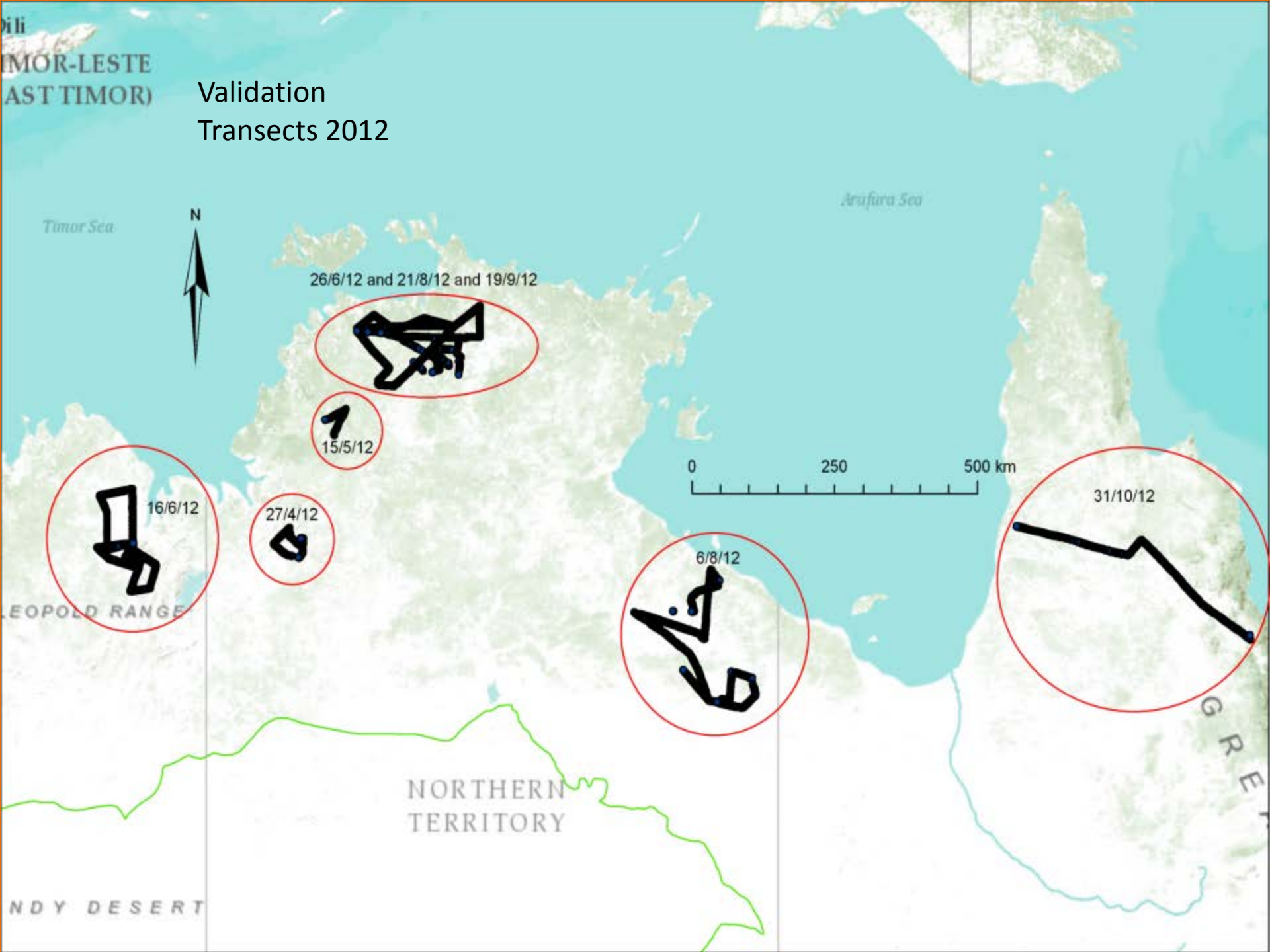


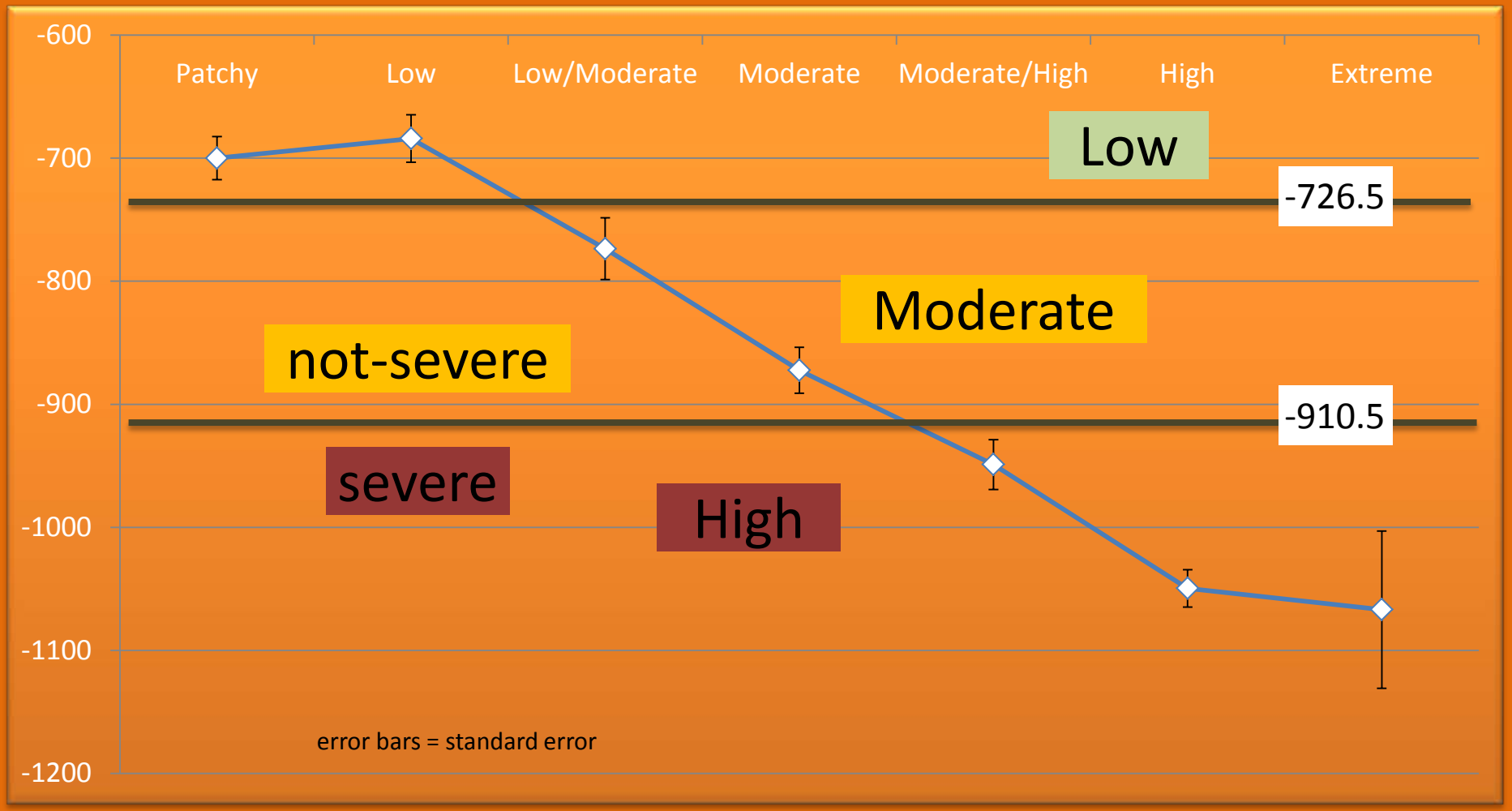
Algorithms were developed for Classification

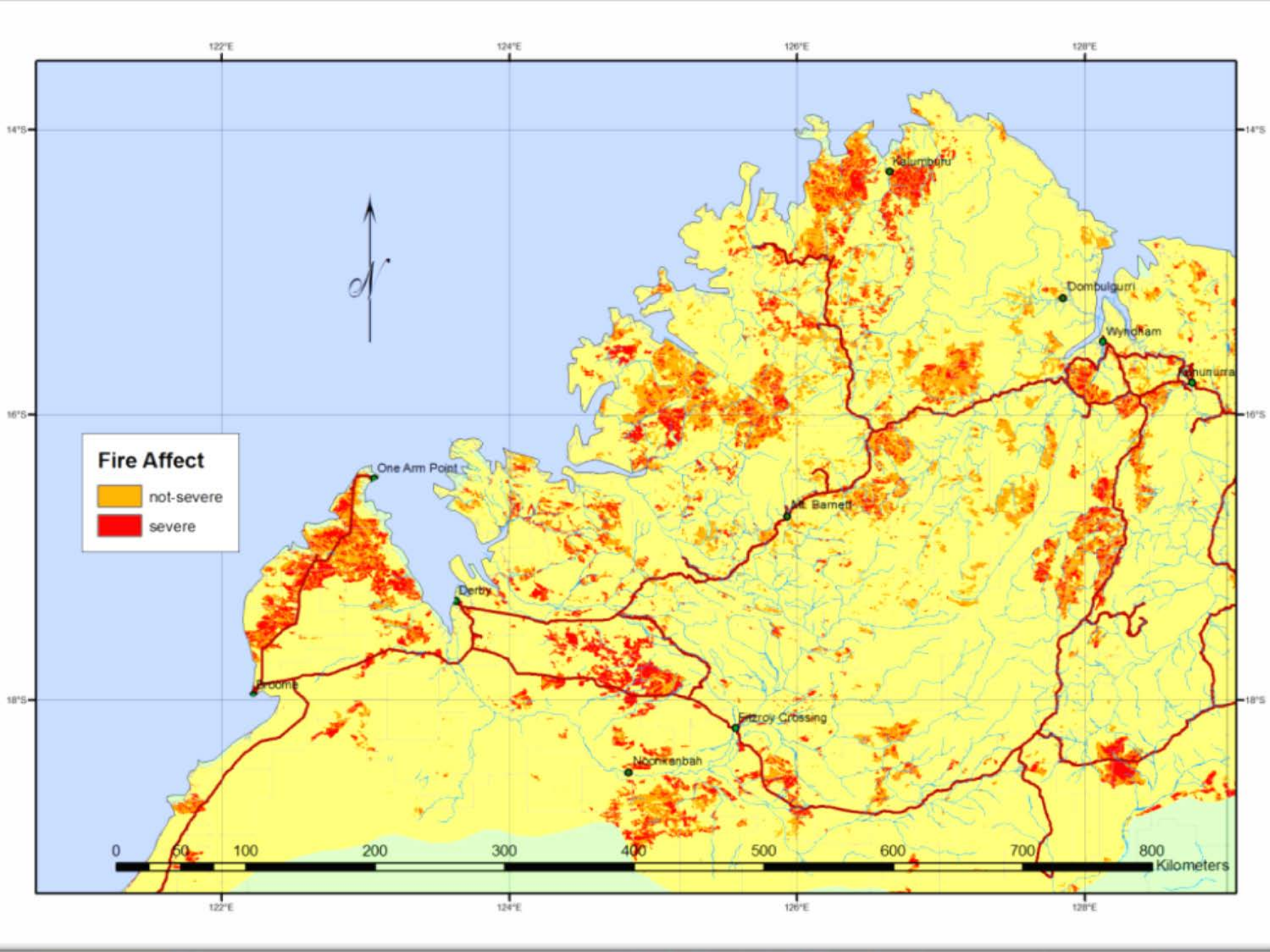
Next step was to calibrate an extensive satellite image dataset

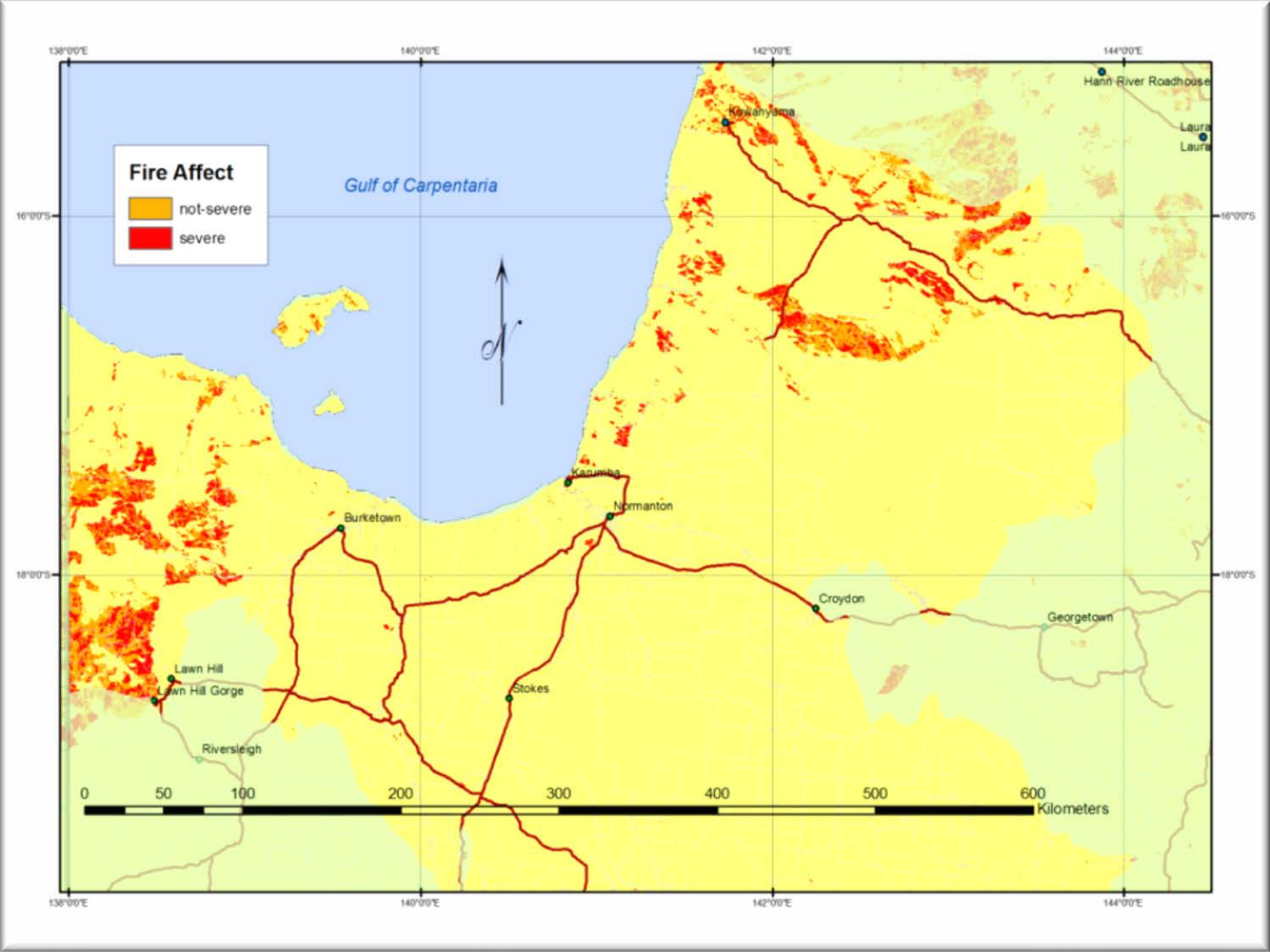
Date	Place	Type	Total Count	Count (Fire Severity)
17-18/ Apr	Kakadu NP, NT	chopper	526	282
18 Apr	Kakadu NP, NT	foot	18	18
22 May	Kakadu NP, NT	chopper	159	159
3 Jun	Kimberley, WA	chopper	1144	367
4 Jun	Karrunjie Station, WA	foot	21	21
11 Jun	Karrunjie Station, WA	foot	36	36
20 Jul	Adelaide River Region/Kakadu NP,NT	chopper	690	531
26 Jul	Delta Downs	foot	54	54
27 Jul	Normanton/SW Cape York, Qld	chopper	1430	683
28/29 Jul	Gulf (nr QLD border), NT	foot	60	60
29 Jul	Cape Crawford, NT	chopper	561	337
9 Aug	Kimberley, WA	chopper	275	38
12 Aug	Prince Regent, WA	chopper	453	251
14 Aug	Ellenbrae Station, WA	foot	39	39
15 Aug	Kalumburu Rd, WA	car	171	41
23 Aug	west Arnhem Land, NT	chopper	56	46
13-16 Sep	Robinson River station, NT	foot	92	92
16 Sep	Robinson River region, NT	chopper	112	85
20-22 Sep	Nicholson Block, NT	foot	11	11
26 Sep	Doomadgee, Qld	foot	60	60

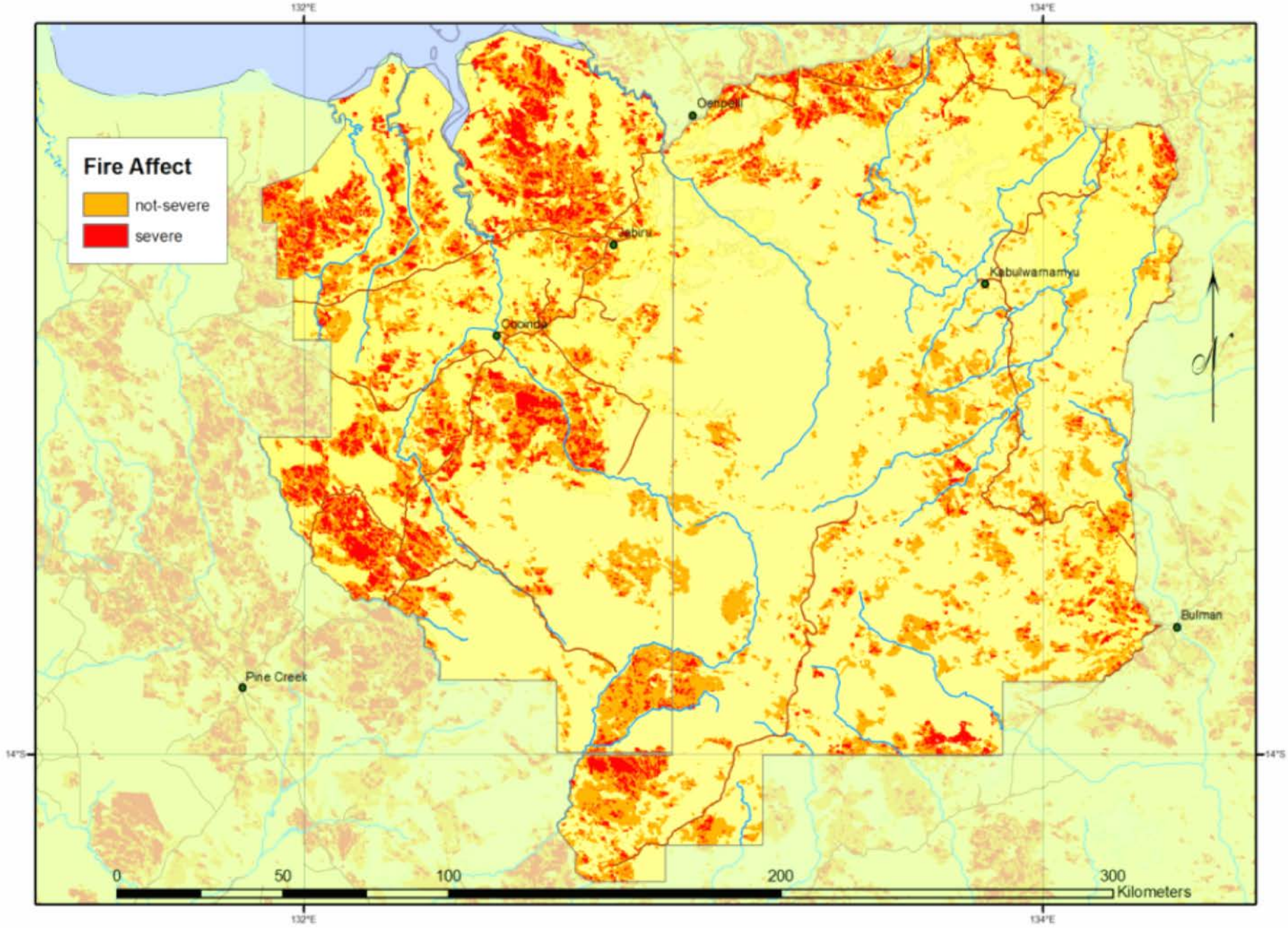

Calibration
Transects 2011
N
600
0
600
1200km


Validation
Transects 2012
N
26/6/12 and 21/8/12 and 19/9/12
15/5/12
16/6/12
27/4/12
6/8/12
31/10/12
0
250
500 km
Timor Sea
Arafura Sea
NORTHERN
TERRITORY


-600
-700
-800
-900
-1000
-1100
-1200
Patchy
Low
Low/Moderate
Moderate
Moderate/High
High
Extreme
Low
-726.5
Moderate
not-severe
-910.5
severe
High
error bars = standard error


122°E
124°E
126°E
128°E
14°S
16°S
18°S
Kalumburu
Dombulgurri
Wyndham
Kununurra
One Arm Point
Mt. Barnett
Derby
Broome
Fitzroy Crossing
Noonkanbah
Fire Affect
not-severe
severe
0
50
100
200
300
400
500
600
700
800
Kilometers


Fire Affect
not-severe
severe
Gulf of Carpentaria
Kowanyama
Hann River Roadhouse
Kanumba
Normanton
Burketown
Croydon
Georgetown
Lawn Hill
Lawn Hill Gorge
Stokes
Riversleigh
0 50 100 200 300 400 500 600
Kilometers
138°0'0"E
140°0'0"E
142°0'0"E
144°0'0"E
16°0'0"S
18°0'0"S

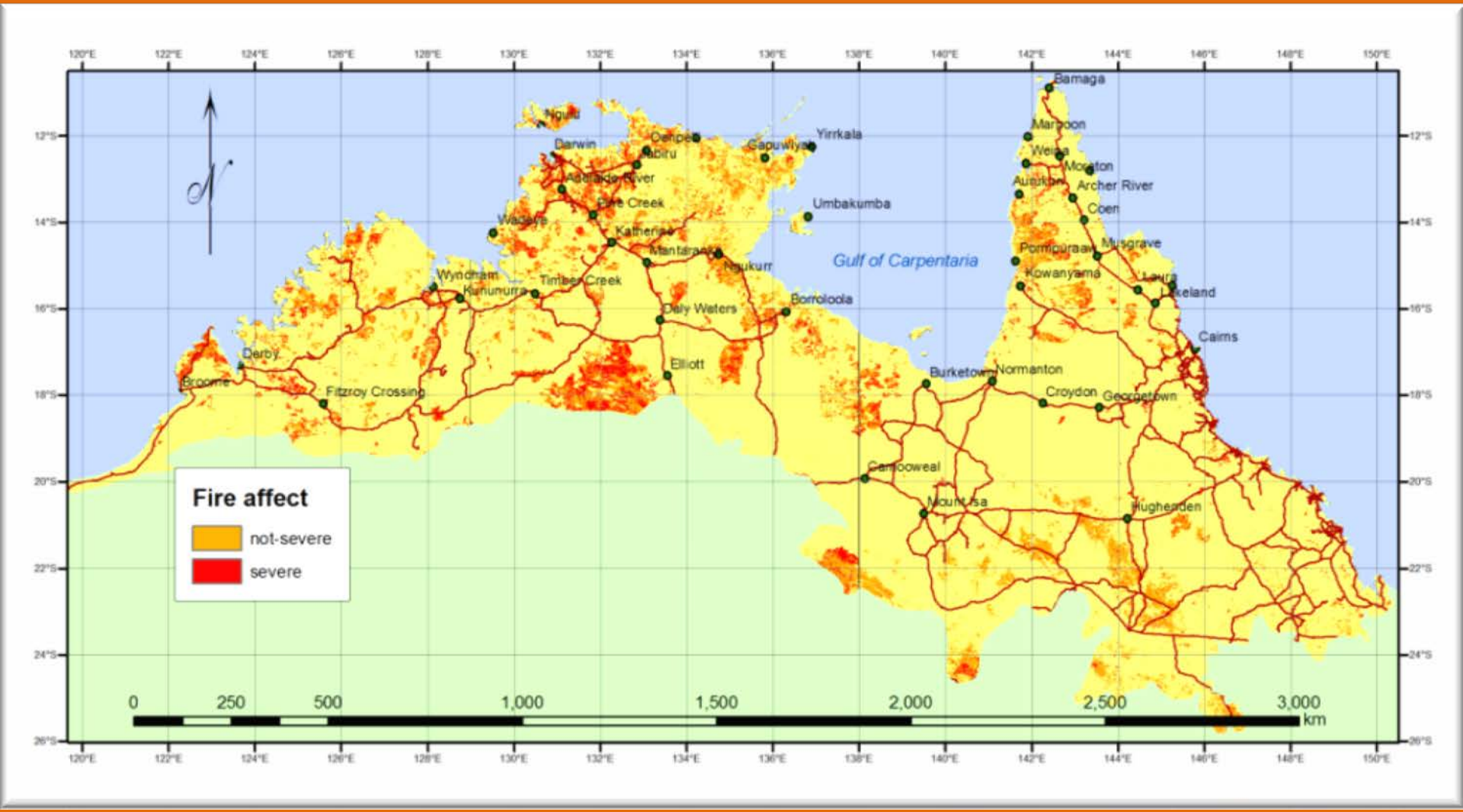

132°E
134°E
14°S
Fire Affect
not-severe
severe
Oenpelli
Jabiru
Kabulwarnamyu
Oenpelli
Bulman
Pine Creek
0
50
100
200
300
Kilometers

Validation assessment.

Statistic	7 Categories	3 Categories	2 Categories
Overall Accuracy	0.23	0.62	0.75
Omission error	0.14	0.57	0.82
Commission error	0.15	0.56	0.81


Tropical
Savannas
Rangelands

Tropical savanna fire severity map ➔ Rangelands mapping



[Northern Fire Mapping: Developing robust fire extent and severity mapping products for the tropical savannas]