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FullCAM-generated map layers for carbon emissions resulting from land clearing in the NT

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Acknowledgments

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Summary

- The objective of this project was to support DEPWS to develop a simple, easy to use, spatial tool for allowing users to assess the approximate emissions implications of their planned land management activities. A review of land clearing methods across the NT suggested a single, composite map summarising the average expected emissions associated with a land clearing event would satisfy the requirements for such a tool.
- To generate the mapped products, the FullCAM model was used to estimate per-hectare land clearing emissions across the entire NT, at a spatial resolution of 250 m x 250 m (corresponding to approximately 21 million calculation locations). Predicted emissions in response to land clearing events were calculated as the sum of the four carbon pools assumed to return to the atmosphere as a result of clearing: aboveground biomass, belowground biomass, aboveground debris, aboveground standing dead. To provide a generalised emissions estimate, the average expected outcome was calculated over a 40-year period to include variability associated with historical fire. The assumption was made that tree growth was experiencing average environmental conditions.
- To implement the model, a simple emulation method was developed to address computational constraints, and to prevent excessive accessing of the FullCAM web server. Emulation of the FullCAM model was exact for living biomass, and highly accurate for debris. Overall model efficiency of the emulation was greater than 0.9999, where 1.0 represents complete agreement between FullCAM and emulated model predictions.
- Of the four ecosystem components comprising the total emissions, above-and below-ground living biomass contributed the most to the total, with smaller contributions from the debris and standing dead pools. On average the total predicted post-clearing emissions across the territory were 63.78 tonnes of carbon dioxide equivalent per hectare (tCO_2-e ha^{-1}), with approximately 58% (36.73 tCO_2-e ha^{-1}) comprising above-ground biomass; 30% comprising below-ground biomass (19.35 tCO_2-e ha^{-1}); 8% comprising above-ground debris (5.35 tCO_2-e ha^{-1}); and 4% comprising standing dead (2.35 tCO_2-e ha^{-1}).
- Geographic Information System (GIS) results layers were provided in GeoTIFF GIS format, with five mapped products in total: total emissions, and separate emissions layers for each of the four ecosystem components. Emissions were presented in units of tCO_2-e ha^{-1}.
- A discussion of five keys assumptions underling the analysis is provided, together with consideration for how the products could be improved and enhanced into the future.

1 Introduction

In 2019, CSIRO delivered a discussion paper to the then Northern Territory Department of Environment and Natural Resources (DENR; now Department of Environment, Parks and Water Security, DEPWS) on carbon emissions and land clearing in the Northern Territory (England et al. 2019). The report concluded that the Australian Government's Full Carbon Accounting Model (FullCAM) was the most appropriate tool for estimating land clearing emissions in the NT. This is because FullCAM is widely recognised as the 'industry standard' for greenhouse gas (GHG) accounting in Australia and has been rigorously tested over a number of years, has minimal data requirements, is freely available, and is comprehensive in its calculation of vegetation carbon cycling and land clearing emissions. FullCAM tracks GHG emissions and changes in carbon stocks associated with land use and management in Australian agricultural and forest systems (Richards 2001; Richards and Brack 2004; Richards and Evans 2004; Brack et al. 2006; Waterworth et al. 2007; Roxburgh et al. 2018). DEPWS has accepted this recommendation and are now internally using FullCAM through setting up a plot-file analysis for each clearing application to model emissions.

A second simplified option provided by England et al. (2019) was to pre-run FullCAM scenarios and save the model predictions in a series of look-up tables of carbon emissions resulting from land clearing. Based on this suggestion DEPWS are now interested in complementing their plot-level FullCAM analyses with a web-based option, for use by potential applicants to provide them with a broad indication of the emissions implications of their land clearing plans prior to the formal application process. Discussion between DEPWS and CSIRO around the end-user experience resulted in an agreement for CSIRO to provide DEPWS with FullCAM-generated map layers for land clearing GHG emissions, rather than lookup tables. This will enable DEPWS to design a web-based service where users will be able to click on a map and/or select areas, to estimate emissions arising from land clearing for a desired location.

The current NT Land Clearing Guidelines apply to zoned, unzoned and pastoral land with a range of proposed land uses. As such here carbon emissions are only considered from the clearing of native vegetation, not the proposed use of the land following clearing. The focus of this work is therefore on carbon emissions from a land clearing event on living woody biomass, debris (dead woody biomass on the ground) and standing dead biomass, rather than the post-clearing prolonged (and highly uncertain) legacy effects on debris and soil carbon. Thus, the map layers of carbon emissions generated in this project will not include the greenhouse-gas implications of the subsequent land use.

The aim of this report is to describe:

i) identification and justification of FullCAM modelling scenarios for determining carbon emissions from land clearing in the NT;

ii) the methods used in the FullCAM modelling and generation of carbon emissions outputs as map layers;

iii) a summary of the model outputs; and

iv) recommendations for further work.

2 Land clearing methods in the NT and identification of appropriate scenarios

To inform the identification of model scenarios, two land clearing datasets in the NT for the years 2003-2020 were provided to CSIRO by NT DEPWS:

1. Pastoral land, >300 ha clearing area; and
2. Unzoned land, >50 ha clearing area.

Below we have summarised the datasets for clearing method and post-clearing treatment combinations. The clearing methods provided in the dataset were categorised into the following eight types described in Table 1:

i) pulling (chaining)

ii) pulling + ploughing

iii) pulling + raking

iv) pushing

v) pushing + ploughing

vi) pushing + grading

vii) pushing + raking

viii) slashing + burning

There were 55 proposals of >300 ha on pastoral land from 2003-2020, totalling 128,650 ha, of which 32 (87,443 ha) had data on clearing method. For unzoned land, there were 116 proposals of >50 ha from 2003-2020, totalling 64,177 ha, of which 106 (62,470 ha) had data on clearing method. The most common clearing method based on both the number of proposals and the clearing area was pulling (chaining). However, for pastoral land a broader range of methods were used (Table 1).

The post-clearing treatment methods from the datasets were categorised into five types:

i) Burn

ii) Leave in situ

iii) Mulch

iv) Leave in situ + partial burn

v) Mulch + burn

A summary of the combinations of clearing methods × post-clear treatments for the NT is provided in Table 2. The most common post-clearing treatment was burning.

Table 1 Categorisation and description of the eight categories of clearing methods defined for the NT, and the percentages by number of proposals (*N*) and area (ha) for pastoral and unzoned land.

Clearing method category	Description	Methods included in proposals	Likely soil disturbance	% by *N*		% by area	
				Pastoral[1]	Unzoned[2]	Pastoral[3]	Unzoned[4]
Pulling (chaining)	Involves using a large chain dragged between two bulldozers/tractors to pull woody plants onto and out of the ground.	Bulldozer & chain; tractor & chain; slashing & light chaining	Medium-High	44	81	38	83
Pulling + ploughing	Involves pulling out woody plants and ploughing, often with a blade plough dragged through the ground to sever tree roots.	Bulldozer, chain & plough; Cutter bar/plough & chain	High	3	2	21	6
Pulling + raking	Involves pulling out woody vegetation and stick raking to clear debris (and sometimes unearth roots) including piling into windrows.	Chain & stick rake	High	13	-	7	-
Pushing	Involves using heavy machinery, typically bulldozers, to clear trees by pushing them over.	Bulldozer; tractor & bulldozer; bulldozer & grader to push	Medium	13	10	4	9
Pushing + ploughing	Involves pushing trees over and ploughing using a disc or blade plough to break up tree roots in the soil.	Front end loader & plough; tractor & kelly chain; disc plough & kelly chain	High	16	-	7	-
Pushing + grading	Involves pushing trees over and leveling the ground with a grader.	Front end loader & grader	High	3	6	<1	2
Pushing + raking	Involves pushing trees over and stick raking to clear debris (and sometimes unearth roots) including piling into windrows.	Stick rake; Bulldozer & stick rake; Grubbing & stick rake	Medium-High	6	1	19	<1
Slashing + burning	Involves slashing and control burning to remove woody vegetation.	Slash & control burn	Low	3	-	3	-
Total				**100**	**100**	**100**	**100**

[1] Total *N* = 32
[2] Total *N* = 106
[3] Total area = 87,443 ha
[4] Total area = 62,470 ha

Table 2 Combinations of clearing methods × post-clear treatments defined for the NT, and the percentages by number (*N*) of proposals and area for pastoral and unzoned land.

Clearing method	Post-clearing treatment	% by *N*		% by area	
		Pastoral[1]	Unzoned[2]	Pastoral[3]	Unzoned[4]
Pulling (chaining)	Burn	31	80	20	83
	Leave in situ + partial burn	6	-	13	-
	Mulch + burn	3	-	1	-
	NA	3	1	4	<1
Pulling + ploughing	Burn	-	2	-	6
	NA	3	-	21	-
Pulling + raking	Burn	6	-	5	-
	Mulch + burn	6	-	2	-
Pushing	Burn	9	6	3	2
	Mulch + burn	-	4	-	2
	Leave in situ	-	1	-	5
	NA	3	-	1	-
Pushing + ploughing	Burn	6	-	<1	-
	Mulch	3	-	6	-
	NA	6	-	1	-
Pushing + grading	Burn	3	-	<1	-
	Leave in situ	-	6	-	2
Pushing + raking	Burn	-	1	-	<1
	Mulch	3	-	19	-
	NA	3	-	<1	-
Slashing + burning	Mulch	3	-	3	-
Total		**100**	**100**	**100**	**100**
All methods	Burn	56	88	28	91
	Leave in situ	-	7	-	5
	Mulch	9	-	28	-
	Leave in situ + partial burn	6	-	13	-
	Mulch + burn	9	4	3	2
	NA	19	1	28	<1
Total		**100**	**100**	**100**	**100**

[1] Total *N* = 32
[2] Total *N* = 106
[3] Total area = 87,443 ha
[4] Total area = 62,470 ha

It was initially envisaged that a series of scenarios for land clearing in the NT would be identified that encompassed a range of clearing regimes (i.e., clearing method and post-clearing management of debris) (Table 1). However, following a preliminary analysis of the different clearing methods, it was found that there was negligible loss of accuracy by integrating emissions associated with all types of clearing regimes into a single, mapped, emissions layer. For example, the net emissions associated with tree clearing and combustion of the resulting debris, and the net emissions associated with tree clearing and only partial burning of the debris (leaving the balance to decay *in situ*), are considered the same, with the only difference being the time course over which the emissions occur. This is because complete combustion leads to instantaneous loss, whereas decay of the residual material *in situ* leads to delayed losses.

Whist this assumption holds for the impacts and subsequent losses to biomass and debris pools across the activities in Table 1, it would not hold for soil carbon, where for example, pulling followed by ploughing is likely to have different impacts to pulling alone. However, because of high uncertainty on current stocks of soil carbon, and on future changes in soil carbon under different clearing methods, soil carbon was not included in the emissions estimates, thus allowing simplification of the analysis.

3 Modelling approach

Spatial stratification

Two of the main drivers determining the amount of woody biomass potentially impacted by clearing activity are the vegetation type (varying by e.g., soil type, topography and climate), and fire history (Figure 1a), with both of these varying spatially across the NT. Both of these drivers were included in the FullCAM modelling of emissions.

A key input in FullCAM is a spatial input layer indicating the capacity for storage of biomass carbon in native woody vegetation (‘*M* layer’) across Australia, which was recently revised and verified for many parts of the NT (Roxburgh et al. 2019). Using this input layer, the impacts of fires and mortality on the dynamics of live woody biomass, standing dead, debris and grass pools were calibrated using datasets collated from decades of savanna fire research (Paul and Roxburgh 2020). These growth calibrations, specific to the nine vegetation fuel types mapped in the *Northern Savanna Vegetation Fuel Types Spatial Dataset (Map) (Version 1.0.1)*[1] (Figure 1b), were applied here, noting some simplification in the classification from nine to six fuel classes (Table 3). An additional category ‘Arid/Other’ was also included to represent vegetation outside the savanna fuel types. To simulate locations classified as Arid/Other, the generic FullCAM ‘Eucalyptus open woodland’ vegetation type was used.

To include an approximation of the impacts of historical fire on living and dead biomass, fires were applied at regular intervals from 1900 to 2017 (with 2017 being the current limit of FullCAM climate data), with fire return intervals that ranged from 0 to 20 years, based on the 2000-2020 mapped fire frequency obtained from NAFI[2]. Observed fire frequencies over the 20-year historical record were converted to inter-fire intervals and rounded to the nearest whole year for application within FullCAM (Table 4). In order to provide generalised estimates of potential emissions associated with clearing, no attempt was made to include fire seasonality into the analysis. Although Paul and Roxburgh (2020) calibrated six different types of fire events (early and late dry season, each with three levels of severity), here one of the median fire types in terms of severity was selected to be applied: the early dry season fire with a moderate severity.

To simulate savanna ecosystems, FullCAM plot files were set up to include both woody vegetation and a grassy understory as outlined by Paul and Roxburgh (2020); but with only the woody vegetation components included in the emissions estimate outputs. The combination of seven modelled vegetation fuel type categories (Table 3) and nine observed fire frequencies (no fire, and one fire every 1, 2, 3, 4, 5, 7, 10 and 20 years) (Table 4) gives a total of 63 unique scenarios of vegetation fuel type × fire return interval, distributed spatially across the Territory (Figure 1c). A separate FullCAM template plot file was created to reflect each of these 63 unique combinations.

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[1] https://v3.savbat.environment.gov.au/SavBAT_vegetation_fuel_type_base_map_metadata.pdf

[2] https://firenorth.org.au/nafi3/downloads/firehistory/Since_2000/250m%20pixel%202000-2020_Long%20Term%20Fire%20Frequency_Image%20File.zip

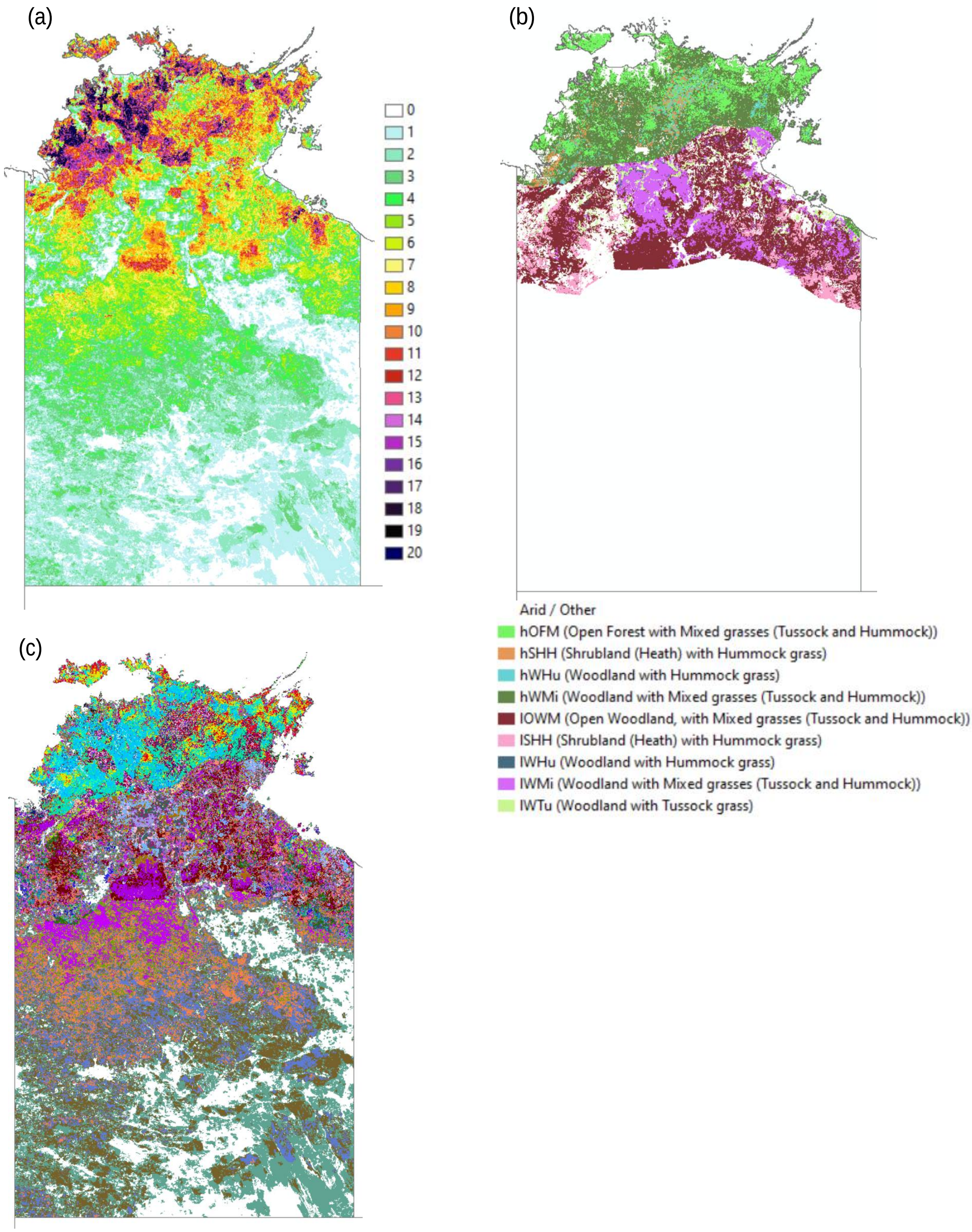

Figure 1 Map of the NT showing the: (a) fire frequency (number of fires observed in the period 2000-2020), (b) vegetation fuel categories in the NT used in the FullCAM model scenarios, and (c) 63 unique combinations of vegetation fuel type and fire return interval used in the modelling of emissions, derived from a classification of the fire frequency data into nine fire return intervals (Table 4), and the simplification of the fuel categories into six classes (Table 3).

Table 3 Carbon Farming Initiative (CFI) vegetation fuel type categories used in the model scenarios.

Fuel type	FullCAM plot file	Description
<u>High rainfall zone</u>		
hWMi	HRZ	Woodland with Mixed grasses (Tussock and Hummock)
hWHu	HRZ	Woodland with Hummock grass
hOFM	HRZ-hOFM	Open Forest with Mixed grasses (Tussock and Hummock)
hSHH	HRZ-hSHH	Shrubland (Heath) with Hummock grass
<u>Low rainfall zone</u>		
lWMi	LRZ	Woodland with Mixed grasses (Tussock and Hummock)
lWHu	LRZ	Woodland with Hummock grass
lWTu	LRZ	Woodland with Tussock grass
lOWM	LRZ-lOWM	Open Woodland with Mixed grasses (Tussock and Hummock)
lSHH	LRZ-lSHH	Shrubland (Heath) with Hummock grass
<u>Unclassified vegetation</u>		
Arid / Other	Arid / Other	Vegetation not classified above

Table 4 Mapping of fire frequency obtained from NAFI data to inter-fire interval. For integration with the FullCAM plot files, inter-fire intervals were rounded to the nearest year.

NAFI fire frequency (number of fires in period 2000-2020)	Inter-fire interval	Inter-fire interval applied in FullCAM
0	No fire	No fire
1	20.00	20
2	10.00	10
3	6.67	7
4	5.00	5
5	4.00	4
6	3.33	3
7	2.86	3
8	2.50	3
9	2.22	2
10	2.00	2
11	1.82	2
12	1.67	2
13	1.54	2
14	1.43	1
15	1.33	1
16	1.25	1
17	1.18	1
18	1.11	1
19	1.05	1
20	1.00	1

FullCAM implementation

FullCAM-predicted average standing stock of biomass and debris carbon over the 40-year period 1977-2017 formed the basis for the calculation of the emissions losses (Figure 2). The included carbon pools were aboveground living tree biomass, belowground living tree biomass, aboveground standing dead tree biomass, and above-ground debris. The emissions losses following clearing were calculated as the sum of these pools, on the assumption these pools would be lost to the atmosphere (as CO_2) following a clearing event. This calculation framework is consistent with the two Emissions Reduction Fund (ERF) methodologies that consider avoided emissions from land clearing (Avoided Deforestation[3], and Avoided Clearing of Native Regrowth[4]). Note that the FullCAM results in Figure 2 are in units of tonnes of carbon per hectare (t C ha^{-1}), whereas the emissions estimates are in units of tonnes of carbon dioxide equivalent per hectare (t CO_2-e ha^{-1}), obtained by multiplying the carbon results by 44/12.

The analysis was run at a 250 m x 250 m resolution, coincident with the FullCAM maximum biomass spatial layer (*M*, Roxburgh et al. 2019) that is the primary determinant of biomass growth in the model[5]. A simulation covering the NT would require 20,974,363 separate runs of the FullCAM model, as each 250 m x 250 m pixel is characterised by its own estimate of *M* and associated historical climate data, in addition to being classified to one of the 63 combinations of vegetation type and fire history.

Running the FullCAM model requires updating, for each pixel, the embedded climate data and *M* through a call to the FullCAM server. This is computationally time-consuming, and for an analysis of the magnitude of the entire NT would not be practical to achieve (with initial experiments suggesting in excess of 100 days of processing time to complete, and with the likelihood of being denied server access through excessive data requests). To overcome this limitation the FullCAM model can be readily emulated using simple linear functions that relate a given FullCAM output to the spatially varying parameter, *M*. In this way a relatively small number of calls to the FullCAM server can be used to develop the relationships of each output variable to *M*, and then those relationships can be applied spatially using the *M* layer, which is available as a downloadable GIS map independent of FullCAM (DISER 2019). Making use of this emulation approach allowed the NT analysis to be completed in less than 8 hours, based on an emulation sample size of 75 randomly selected locations to develop the predictive relationships for each required FullCAM output variable and each of the 63 vegetation type × fire history combinations (a total of 252 separate emulation models).

In addition to selecting 75 random locations to calibrate each emulation model, an additional 75 locations were also selected to independently validate the emulation model predictions. Emulation model fit was quantified, using the validation locations, using three statistics: root mean-squared error (RMSE), Nash-Sutcliffe model efficiency (Nash and Sutcliffe 1970), and Lin's

[3] https://www.legislation.gov.au/Details/F2015L00347

[4] https://www.legislation.gov.au/Details/F2018C00127

[5] https://data.gov.au/dataset/ds-dga-b46c29a4-cc80-4bde-b538-51013dea4dcb/distribution/dist-dga-1e3af98e-967a-4908-882f-2d217b0d0e5a/?q=FullCAM

concordance (Lin 2000). The latter two indices both have a value of 1.0 when the FullCAM and emulation predictions are identical.

The current public release version of FullCAM (ver 6.20.03.0827) is not well suited to the simulation of savanna ecosystems, due to limitations in the representation of the mortality and recovery response of living vegetation following repeated frequent fires (Paul and Roxburgh 2020). Therefore, in this study a pre-release (development) version of FullCAM was used (ver 7.21.03.0825). This version was also used in the northern savanna study of Paul and Roxburgh (2020) and has improved functionality for representing disturbance response.

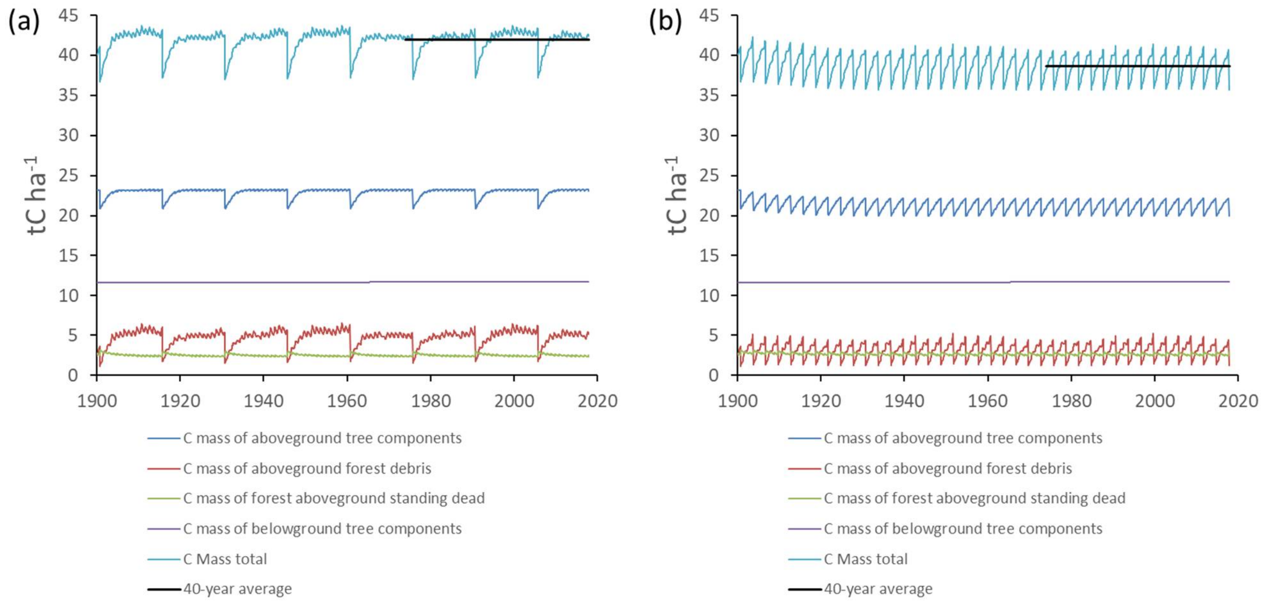

Figure 2 (a) FullCAM results for two HRZ locations with the same growth potential but contrasting fire histories: (a) fire return interval = 15 years, (b) fire return interval = 3 years. The average total carbon mass over the last 40 years of the simulation (black line) is used as the basis for the emissions estimate.

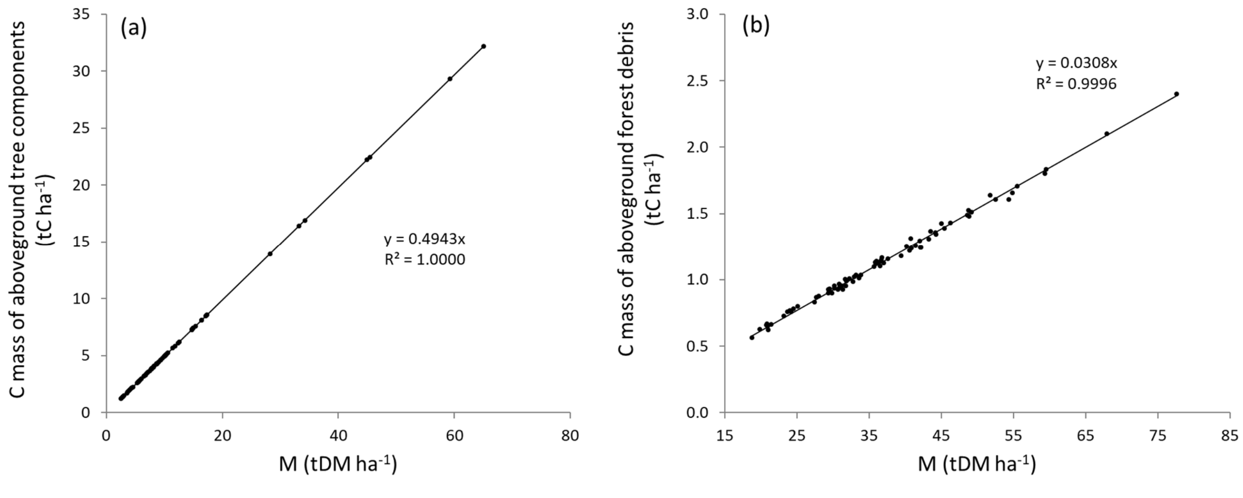

Figure 3 Example FullCAM emulation models for: (a) living biomass and (b) debris, based on a random selection of 75 locations spanning a range of values of *M*.

4 Results

If average growth conditions are assumed, as is the case for this study, then emulation of the FullCAM model is exact for the living biomass components (i.e., the emulation results and the results from running FullCAM directly are identical; Figure 3a), and highly accurate for the debris components (Figure 3b). Because debris is a minor component of the total emissions calculation, the overall accuracy of the emulation is high, with Nash-Sutcliffe and Lin's concordance indices both in excess of 0.9999, and RMSE less than 0.25% on average (Appendix). Individual fit statistics for each of the 252 component emulation models are also provided in the Appendix.

Mapped results are provided in GeoTIFF format (Table 4). Total emissions resulting from land clearing (in units CO_2-e) are calculated as the sum of the four ecosystem components (above- and below-ground living biomass, above-ground debris, and above-ground standing dead). As expected, the spatial distribution of total emissions (Figure 4) shows higher potential emissions arising from clearing in the northern, more productive ecosystems of the NT, and lower potential emissions from more arid regions. The spatial detail evident in Figure 4 largely reflects the distribution of the FullCAM *M* parameter, which masks much of the finer-scale spatial variability arising from differences in fire history (Figure 1a; Figure 2) and vegetation type (Figure 1b). The four ecosystem components comprising the total emissions (Figure 5) show above-and below-ground living biomass contributing the most to the total, with smaller contributions from the debris and standing dead pools. On average the total predicted emissions across the territory were 63.78 tCO_2-e ha^{-1}, with approximately 58% (36.73 tCO_2-e ha^{-1}) comprising above-ground biomass; 30% comprising below-ground biomass (19.35 tCO_2-e ha^{-1}); 8% comprising above-ground debris (5.35 tCO_2-e ha^{-1}); and 4% comprising standing dead (2.35 tCO_2-e ha^{-1}).

Table 4 Map attributes.

Cell size	0.0025 decimal degrees (~250 m)
Coordinate system	Geographic Decimal Degrees, Datum: WGS 84 (GDA Compliant)
Extent	
Number of rows	6246
Number of columns	4078
Lower-left corner	-26.11375, 128.09125
Positional accuracy	Not assessed. However, the results are masked to the FullCAM Maximum Above Ground Tree Biomass data, which has itself been aligned with other FullCAM data layers using a snap raster approach[6]
Map layers provided	CO2e mass of aboveground tree components_tCO2e-ha_12-1977--12-2017.tif CO2e mass of belowground tree components_tCO2e-ha_12-1977--12-2017.tif CO2e mass of aboveground forest debris_tCO2e-ha_12-1977--12-2017.tif CO2e mass of forest aboveground standing dead_tCO2e-ha_12-1977--12-2017.tif CO2e total emissions_tCO2e-ha_12-1977--12-2017.tif

[6] https://data.gov.au/dataset/ds-dga-b46c29a4-cc80-4bde-b538-51013dea4dcb/distribution/dist-dga-1e3af98e-967a-4908-882f-2d217b0d0e5a/details?q=FullCAM

Figure 4 Estimated total emissions (tCO_2-e ha^{-1}) resulting from land clearing across the NT.

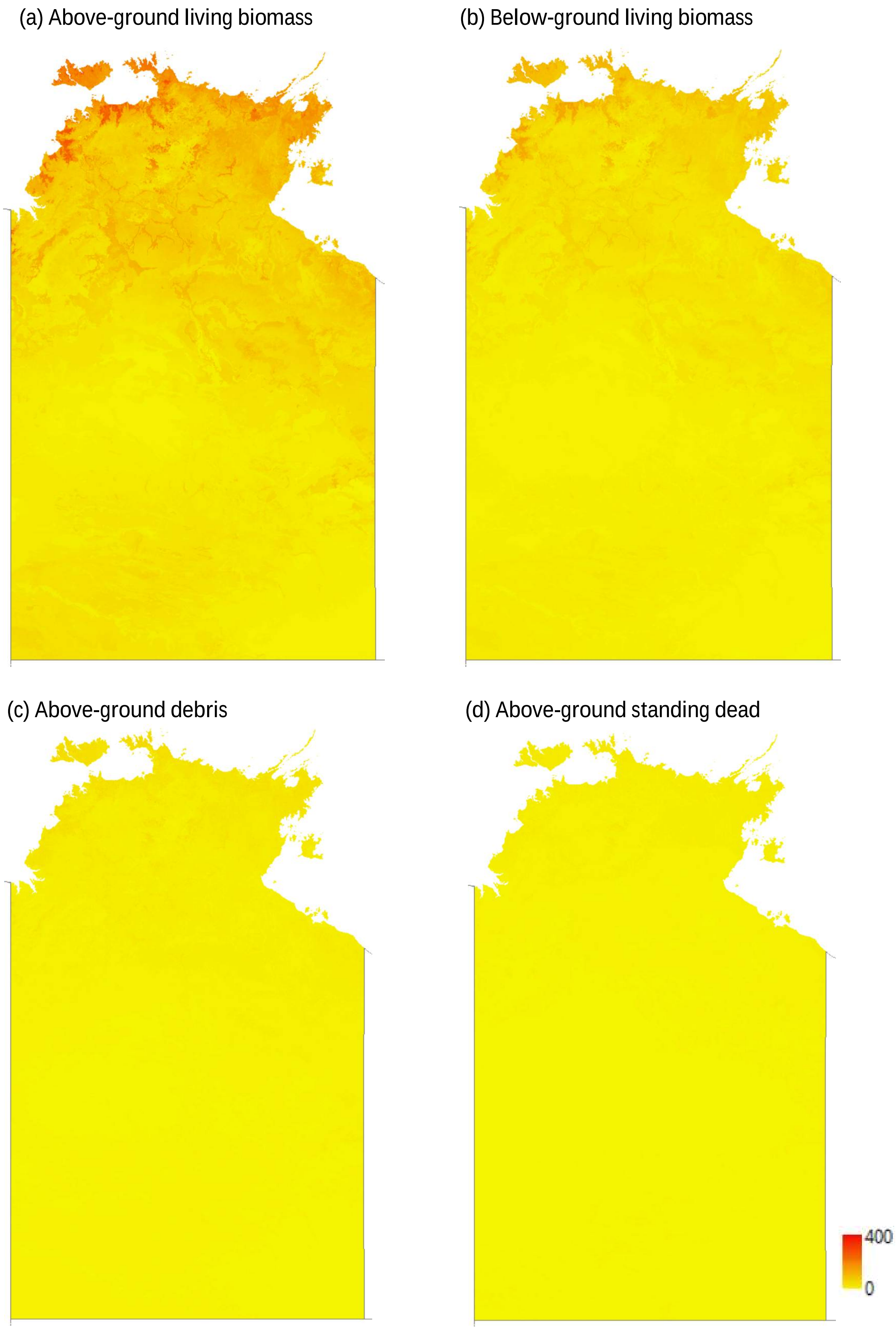

Figure 5 The four ecosystem components contributing to the total emissions estimate (tCO_2-e ha^{-1}).

Summarising total potential emissions for each of the 63 combinations of vegetation type × fire return interval (Figure 6) shows expected patterns of higher emissions associated with the High Rainfall Zone (HRZ) vegetation fuel types, and lower emissions from Low Rainfall Zone (LRZ) and more arid regions. The higher emissions potential under frequent fire (every 1-2 years) for Arid/Other reflects the wide spatial distribution of this vegetation class, with frequent fires limited to the northern, more productive regions of the territory.

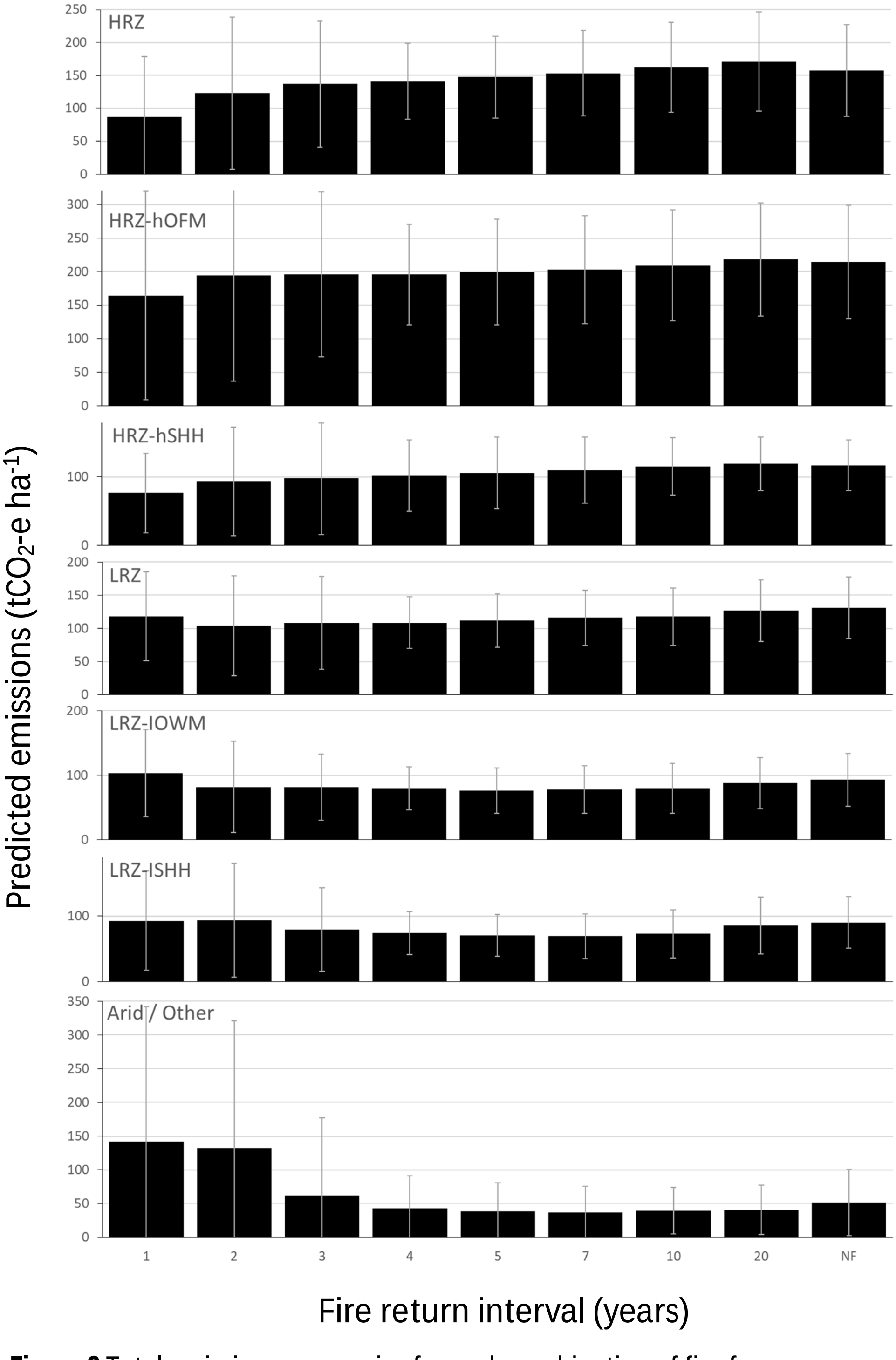

Figure 6 Total emissions summaries for each combination of fire frequency × vegetation type. Bars are spatial standard deviations across each zone shown in Figure 4c. 'NF' represents no fire.

5 Discussion

Five key assumptions underlie the analysis. These are discussed below, together with consideration of how the analyses presented here could be extended and enhanced.

1. Averaging of emissions

Consistent with the calculations underlying the Emissions Reduction Fund (ERF) methodologies, potential emissions in response to land clearing events were calculated as the sum of selected above- and below-ground pools of carbon present in the ecosystem at the time of clearing, on the assumption these pools would be returned to the atmosphere as a result of the clearing event. To provide a generalised emissions estimate, the average expected outcome was calculated over a 40-year period (to include variability associated with repeated fire), and assuming tree growth was experiencing average environmental conditions.

The averaged emissions outcomes provided here could be made more location-specific through embedding the actual pixel-specific historical fire histories, rather than the approximate fire regimes based on average fire return intervals; and growth could be made climate-sensitive. In future years, the emissions estimates could also be updated to include new fire activity and other data as it becomes available. However, the observation that the land clearing emissions estimates are relatively insensitive to changes in fire frequency (Figures 2 & 6), and the modest sensitivity of the FullCAM growth equations to climatic variability, suggests any gains in accuracy might be modest.

2. Exclusion of non-CO_2 gaseous emissions from the calculations

To maintain consistency with the ERF methodologies, non-CO_2 emissions associated with biomass burning were excluded from the estimates. This can be partly justified through uncertainty over the fate of post-harvest debris, where differing assumptions on the fraction of material burnt, and the conditions of that burning, will affect the composition and amount of non-CO_2 GHG emissions generated, thus making generalisation difficult. Non-CO_2 emissions are also a minor emissions component compared to CO_2. Nevertheless, the emissions estimates provided here could be improved upon in the future through providing additional scenarios where different post-clearing burn assumptions are applied, which would require determining emissions under different combustion conditions, and specifying the fraction of material combusted. This would require additional calculations to quantify these additional GHG losses, and it would also require additional information to be provided by users on their planned clearing methods and post-clearing management.

3. Complete loss of carbon associated with the clearing events

The emissions calculations assume that all material in the affected pools will be returned to the atmosphere. In reality, vegetation clearing is rarely 100% effective due to landscape features such as rocky outcrops, farming infrastructure, or other constraints on access. If it was deemed desirable, then the emissions maps provided here could be readily adjusted as part of the web delivery platform to account for user-defined input on the fraction of total area impacted. For example, if a user deemed 10% of their selected area would not be cleared, then the total emissions obtained from the base map could be reduced by 10%. Again, this would require additional user input on the percentage of the selected area actually impacted by clearing.

4. Instantaneous emissions

As described in Section 2, it was decided to integrate (over time) all emissions associated with a clearing event, and to summarise them in a single map layer. For example, burning all debris post-fire, or allowing to decompose *in situ*, will ultimately lead to the same emissions outcome; although in the latter case the emissions will be spread out over time. Although not considered necessary here for use in a simple tool designed to provide an approximate estimate of clearing emissions, if there was interest in the time course of emissions under different clearing methods, then this could be achieved by adding specific clearing events to the FullCAM event queue, and by saving a time-series of emissions to monitor post-clearing changes over time.

5. Soil carbon

A lack of information on the impact of clearing events and post-clearing changes in soil carbon, together with uncertainty over current soil carbon stocks across the NT, required soil carbon dynamics to be excluded from analysis. This is also consistent with all other vegetation-based methodologies within the ERF. Although a much larger and longer-term ambition, improving our understanding of soil carbon responses to different management events, such as land clearing, and improving the current information base on soil carbon stocks across the NT, may in the future allow soil carbon to be considered as part of broader vegetation and land management activities in savanna and arid ecosystems as part of the FullCAM model.

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Appendix

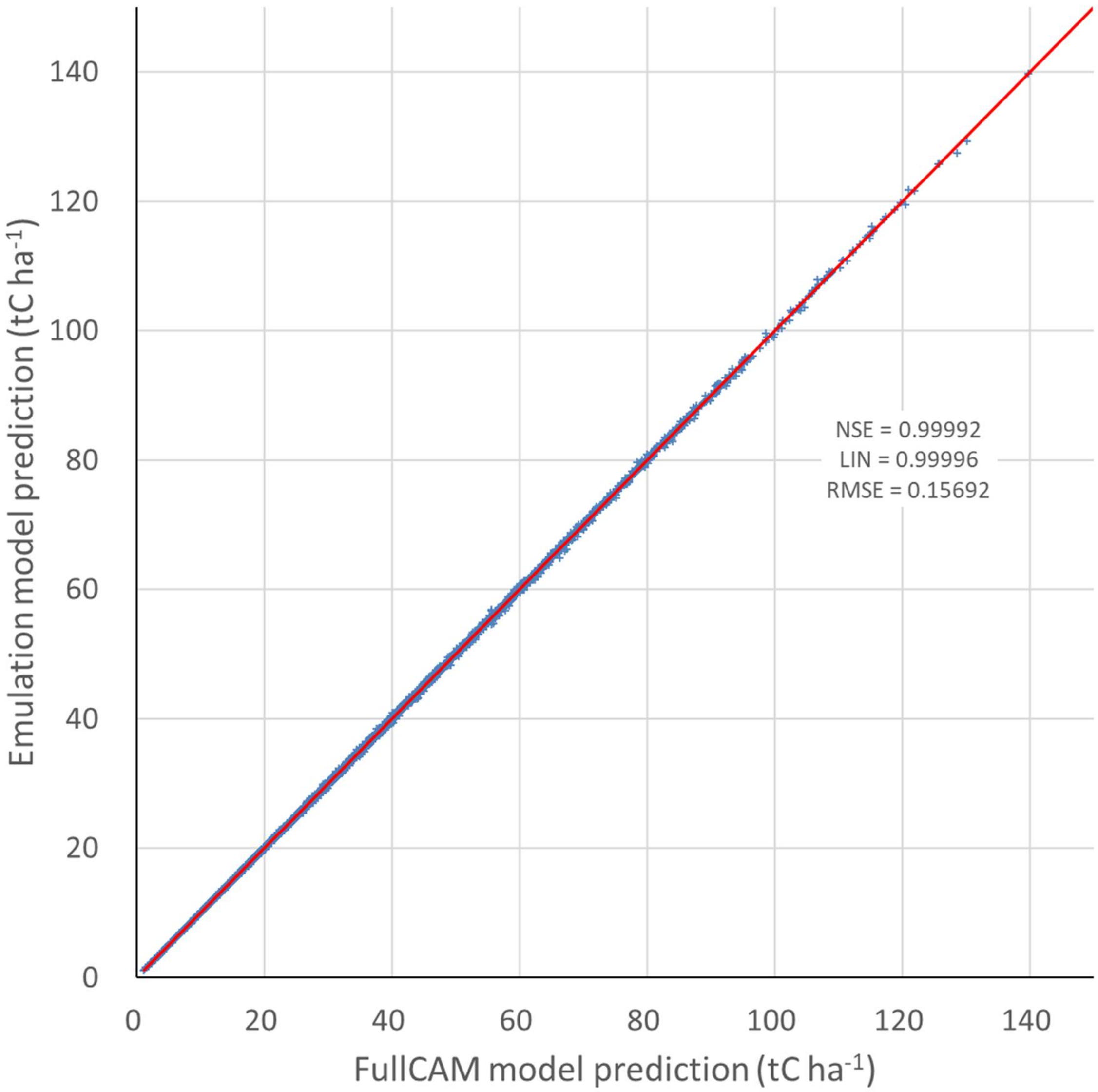

Figure A1 FullCAM predicts vs emulation predictions for all 252 emulation models combined (4 output variables x 63 combinations = 252 separate models (Table A1)). Results shown are based on 75 randomly selected validation locations.

Table A1 Results for each of 252 fitted emulation models used to predict each combination of FullCAM output variable, vegetation type, and fire return interval. Emulation models are fitted to 75 randomly selected calibration locations, and the model fit statistics are based on an independent sample of 75 validation locations. 'Slope' and 'Intercept' are the fitted parameters between each out variable, and maximum above-ground biomass (*M*).

			Emulation model parameters		Emulation model fit statistics		
Output variable	Vegetation type	FI	Slope	Intercept	Nash-Sutcliff model efficiency	RMSE	Lin's concordance
Aboveground biomass	Arid/Other	NF	0.4943	-0.0000	0.99999999992	0.00003871652	0.99999999996
Aboveground biomass	Arid/Other	20	0.4943	-0.0000	0.99999999996	0.00006673920	0.99999999998
Aboveground biomass	Arid/Other	10	0.4943	-0.0000	0.99999999987	0.00004711370	0.99999999993
Aboveground biomass	Arid/Other	7	0.4943	-0.0000	0.99999999978	0.00004029463	0.99999999989
Aboveground biomass	Arid/Other	5	0.4943	0.0000	0.99999999997	0.00002675516	0.99999999999
Aboveground biomass	Arid/Other	4	0.4943	0.0000	0.99999999998	0.00002959084	0.99999999999
Aboveground biomass	Arid/Other	3	0.4943	-0.0000	0.99999999996	0.00003526070	0.99999999998
Aboveground biomass	Arid/Other	2	0.4943	-0.0000	0.99999999996	0.00008825769	0.99999999998
Aboveground biomass	Arid/Other	1	0.4943	-0.0001	0.99999999994	0.00011571029	0.99999999997
Aboveground biomass	HRZ	NF	0.4937	-0.0000	0.99999999990	0.00009780017	0.99999999995
Aboveground biomass	HRZ	20	0.4897	-0.0000	0.99999999981	0.00014776410	0.99999999991
Aboveground biomass	HRZ	10	0.4858	-0.0001	0.99999999991	0.00010660708	0.99999999996
Aboveground biomass	HRZ	7	0.4821	0.0001	0.99999999989	0.00010429336	0.99999999994
Aboveground biomass	HRZ	5	0.4777	0.0000	0.99999999982	0.00014591846	0.99999999991
Aboveground biomass	HRZ	4	0.4708	-0.0000	0.99999999990	0.00006648252	0.99999999995
Aboveground biomass	HRZ	3	0.4503	0.0001	0.99999999986	0.00009175504	0.99999999993
Aboveground biomass	HRZ	2	0.3872	-0.0000	0.99999999991	0.00006300459	0.99999999995
Aboveground biomass	HRZ	1	0.2343	-0.0000	0.99999999993	0.00003184723	0.99999999996
Aboveground biomass	HRZ-hOFM	NF	0.4937	-0.0001	0.99999999973	0.00021030411	0.99999999986
Aboveground biomass	HRZ-hOFM	20	0.4930	0.0000	0.99999999983	0.00016765593	0.99999999992
Aboveground biomass	HRZ-hOFM	10	0.4925	-0.0000	0.99999999961	0.00024477017	0.99999999981
Aboveground biomass	HRZ-hOFM	7	0.4918	-0.0001	0.99999999983	0.00014131598	0.99999999991
Aboveground biomass	HRZ-hOFM	5	0.4909	-0.0000	0.99999999979	0.00015990846	0.99999999989
Aboveground biomass	HRZ-hOFM	4	0.4902	-0.0000	0.99999999991	0.00011422044	0.99999999995
Aboveground biomass	HRZ-hOFM	3	0.4890	0.0000	0.99999999991	0.00010685323	0.99999999996
Aboveground biomass	HRZ-hOFM	2	0.4842	-0.0001	0.99999999989	0.00011655001	0.99999999994
Aboveground biomass	HRZ-hOFM	1	0.4392	-0.0000	0.99999999993	0.00008619164	0.99999999996
Aboveground biomass	HRZ-hSHH	NF	0.4937	-0.0001	0.99999999991	0.00005112115	0.99999999995
Aboveground biomass	HRZ-hSHH	20	0.4915	-0.0000	0.99999999981	0.00007080673	0.99999999991
Aboveground biomass	HRZ-hSHH	10	0.4893	-0.0000	0.99999999990	0.00007092078	0.99999999995
Aboveground biomass	HRZ-hSHH	7	0.4876	-0.0000	0.99999999992	0.00006226900	0.99999999996
Aboveground biomass	HRZ-hSHH	5	0.4850	-0.0000	0.99999999991	0.00006542933	0.99999999996
Aboveground biomass	HRZ-hSHH	4	0.4825	-0.0000	0.99999999995	0.00006222647	0.99999999997
Aboveground biomass	HRZ-hSHH	3	0.4752	-0.0000	0.99999999994	0.00005192640	0.99999999997
Aboveground biomass	HRZ-hSHH	2	0.4440	0.0000	0.99999999985	0.00007093601	0.99999999992
Aboveground biomass	HRZ-hSHH	1	0.2857	0.0000	0.99999999988	0.00002515636	0.99999999994
Aboveground biomass	LRZ	NF	0.4943	0.0000	0.99999999994	0.00005597236	0.99999999997
Aboveground biomass	LRZ	20	0.4943	0.0000	0.99999999994	0.00005363884	0.99999999997
Aboveground biomass	LRZ	10	0.4943	0.0000	0.99999999992	0.00004893429	0.99999999996
Aboveground biomass	LRZ	7	0.4943	0.0000	0.99999999996	0.00004909802	0.99999999998
Aboveground biomass	LRZ	5	0.4943	-0.0000	0.99999999984	0.00005953715	0.99999999992
Aboveground biomass	LRZ	4	0.4943	-0.0000	0.99999999987	0.00006991467	0.99999999993
Aboveground biomass	LRZ	3	0.4943	0.0000	0.99999999989	0.00005817173	0.99999999995
Aboveground biomass	LRZ	2	0.4943	0.0001	0.99999999992	0.00005702854	0.99999999996
Aboveground biomass	LRZ	1	0.4943	-0.0001	0.99999999989	0.00006482400	0.99999999994
Aboveground biomass	LRZ-IOWM	NF	0.4943	-0.0000	0.99999999993	0.00004971288	0.99999999997
Aboveground biomass	LRZ-IOWM	20	0.4943	-0.0000	0.99999999994	0.00004789477	0.99999999997

Table A1 Contd.

Output variable	Vegetation type	FI	Emulation model parameters		Emulation model fit statistics		
			Slope	Intercept	Nash-Sutcliff model efficiency	RMSE	Lin's concordance
Aboveground biomass	LRZ-IOWM	10	0.4943	-0.0000	0.99999999996	0.00003638764	0.99999999998
Aboveground biomass	LRZ-IOWM	7	0.4943	-0.0000	0.99999999993	0.00003980820	0.99999999996
Aboveground biomass	LRZ-IOWM	5	0.4943	-0.0000	0.99999999996	0.00003404209	0.99999999998
Aboveground biomass	LRZ-IOWM	4	0.4943	-0.0000	0.99999999995	0.00003243375	0.99999999997
Aboveground biomass	LRZ-IOWM	3	0.4943	-0.0000	0.99999999996	0.00002772773	0.99999999998
Aboveground biomass	LRZ-IOWM	2	0.4943	0.0000	0.99999999989	0.00004829209	0.99999999994
Aboveground biomass	LRZ-IOWM	1	0.4943	-0.0000	0.99999999990	0.00004593089	0.99999999995
Aboveground biomass	LRZ-ISHH	NF	0.4939	0.0000	0.99999999992	0.00004743472	0.99999999996
Aboveground biomass	LRZ-ISHH	20	0.4930	0.0000	0.99999999991	0.00004811867	0.99999999995
Aboveground biomass	LRZ-ISHH	10	0.4921	-0.0000	0.99999999994	0.00003835428	0.99999999997
Aboveground biomass	LRZ-ISHH	7	0.4914	-0.0000	0.99999999992	0.00003765240	0.99999999996
Aboveground biomass	LRZ-ISHH	5	0.4902	-0.0000	0.99999999993	0.00004177186	0.99999999996
Aboveground biomass	LRZ-ISHH	4	0.4893	0.0000	0.99999999991	0.00005523187	0.99999999996
Aboveground biomass	LRZ-ISHH	3	0.4876	-0.0000	0.99999999993	0.00003572195	0.99999999996
Aboveground biomass	LRZ-ISHH	2	0.4827	0.0000	0.99999999993	0.00004668955	0.99999999997
Aboveground biomass	LRZ-ISHH	1	0.4096	0.0000	0.99999999991	0.00003762639	0.99999999996
Belowground biomass	Arid/Other	NF	0.2490	-0.0000	0.99999999990	0.00002113595	0.99999999995
Belowground biomass	Arid/Other	20	0.2490	-0.0000	0.99999999996	0.00003606610	0.99999999998
Belowground biomass	Arid/Other	10	0.2490	-0.0000	0.99999999985	0.00002563889	0.99999999992
Belowground biomass	Arid/Other	7	0.2490	-0.0000	0.99999999974	0.00002193330	0.99999999987
Belowground biomass	Arid/Other	5	0.2490	0.0000	0.99999999997	0.00001464696	0.99999999998
Belowground biomass	Arid/Other	4	0.2490	0.0000	0.99999999997	0.00001608512	0.99999999999
Belowground biomass	Arid/Other	3	0.2490	-0.0000	0.99999999995	0.00001919282	0.99999999998
Belowground biomass	Arid/Other	2	0.2490	-0.0000	0.99999999995	0.00004817272	0.99999999997
Belowground biomass	Arid/Other	1	0.2490	-0.0000	0.99999999993	0.00006296437	0.99999999996
Belowground biomass	HRZ	NF	0.2489	-0.0000	0.99999999994	0.00003848614	0.99999999997
Belowground biomass	HRZ	20	0.2489	-0.0000	0.99999999988	0.00005862425	0.99999999994
Belowground biomass	HRZ	10	0.2489	-0.0000	0.99999999995	0.00004308830	0.99999999997
Belowground biomass	HRZ	7	0.2489	0.0000	0.99999999993	0.00004256332	0.99999999997
Belowground biomass	HRZ	5	0.2489	0.0000	0.99999999989	0.00006013882	0.99999999994
Belowground biomass	HRZ	4	0.2489	-0.0000	0.99999999994	0.00002760492	0.99999999997
Belowground biomass	HRZ	3	0.2489	0.0000	0.99999999991	0.00004037697	0.99999999996
Belowground biomass	HRZ	2	0.2489	-0.0000	0.99999999994	0.00003261470	0.99999999997
Belowground biomass	HRZ	1	0.2489	-0.0000	0.99999999996	0.00002607435	0.99999999998
Belowground biomass	HRZ-hOFM	NF	0.2489	-0.0000	0.99999999983	0.00008304070	0.99999999992
Belowground biomass	HRZ-hOFM	20	0.2489	0.0000	0.99999999990	0.00006618652	0.99999999995
Belowground biomass	HRZ-hOFM	10	0.2489	-0.0000	0.99999999976	0.00009644128	0.99999999988
Belowground biomass	HRZ-hOFM	7	0.2489	-0.0000	0.99999999989	0.00005587239	0.99999999995
Belowground biomass	HRZ-hOFM	5	0.2489	-0.0000	0.99999999987	0.00006327267	0.99999999994
Belowground biomass	HRZ-hOFM	4	0.2489	-0.0000	0.99999999994	0.00004521884	0.99999999997
Belowground biomass	HRZ-hOFM	3	0.2489	0.0000	0.99999999995	0.00004239073	0.99999999997
Belowground biomass	HRZ-hOFM	2	0.2489	-0.0000	0.99999999993	0.00004655376	0.99999999997
Belowground biomass	HRZ-hOFM	1	0.2489	-0.0000	0.99999999996	0.00003640272	0.99999999998
Belowground biomass	HRZ-hSHH	NF	0.2489	-0.0000	0.99999999995	0.00001950912	0.99999999997
Belowground biomass	HRZ-hSHH	20	0.2489	-0.0000	0.99999999989	0.00002729559	0.99999999994
Belowground biomass	HRZ-hSHH	10	0.2489	-0.0000	0.99999999994	0.00002736627	0.99999999997
Belowground biomass	HRZ-hSHH	7	0.2489	-0.0000	0.99999999996	0.00002414827	0.99999999998
Belowground biomass	HRZ-hSHH	5	0.2489	-0.0000	0.99999999995	0.00002550098	0.99999999997
Belowground biomass	HRZ-hSHH	4	0.2489	-0.0000	0.99999999997	0.00002428745	0.99999999998
Belowground biomass	HRZ-hSHH	3	0.2489	-0.0000	0.99999999996	0.00002069457	0.99999999998
Belowground biomass	HRZ-hSHH	2	0.2489	0.0000	0.99999999990	0.00003233687	0.99999999995

Table A1 Contd.

Output variable	Vegetation type	FI	Emulation model parameters		Emulation model fit statistics		
			Slope	Intercept	Nash-Sutcliff model efficiency	RMSE	Lin's concordance
Belowground biomass	HRZ-hSHH	1	0.2489	0.0000	0.99999999993	0.00001674288	0.99999999997
Belowground biomass	LRZ	NF	0.2489	0.0000	0.99999999997	0.00002081227	0.99999999998
Belowground biomass	LRZ	20	0.2489	0.0000	0.99999999997	0.00002008608	0.99999999998
Belowground biomass	LRZ	10	0.2489	0.0000	0.99999999996	0.00001821488	0.99999999998
Belowground biomass	LRZ	7	0.2489	0.0000	0.99999999998	0.00001837059	0.99999999999
Belowground biomass	LRZ	5	0.2489	-0.0000	0.99999999991	0.00002223351	0.99999999996
Belowground biomass	LRZ	4	0.2489	-0.0000	0.99999999993	0.00002605823	0.99999999996
Belowground biomass	LRZ	3	0.2489	0.0000	0.99999999994	0.00002167737	0.99999999997
Belowground biomass	LRZ	2	0.2489	0.0000	0.99999999996	0.00002122090	0.99999999998
Belowground biomass	LRZ	1	0.2489	-0.0000	0.99999999994	0.00002430658	0.99999999997
Belowground biomass	LRZ-IOWM	NF	0.2489	-0.0000	0.99999999996	0.00001851618	0.99999999998
Belowground biomass	LRZ-IOWM	20	0.2489	-0.0000	0.99999999997	0.00001790529	0.99999999998
Belowground biomass	LRZ-IOWM	10	0.2489	-0.0000	0.99999999998	0.00001359922	0.99999999999
Belowground biomass	LRZ-IOWM	7	0.2489	-0.0000	0.99999999996	0.00001493713	0.99999999998
Belowground biomass	LRZ-IOWM	5	0.2489	-0.0000	0.99999999998	0.00001278464	0.99999999999
Belowground biomass	LRZ-IOWM	4	0.2489	-0.0000	0.99999999997	0.00001208073	0.99999999999
Belowground biomass	LRZ-IOWM	3	0.2489	-0.0000	0.99999999998	0.00001041845	0.99999999999
Belowground biomass	LRZ-IOWM	2	0.2489	0.0000	0.99999999994	0.00001795361	0.99999999997
Belowground biomass	LRZ-IOWM	1	0.2489	-0.0000	0.99999999994	0.00001717862	0.99999999997
Belowground biomass	LRZ-ISHH	NF	0.2489	0.0000	0.99999999995	0.00001818068	0.99999999998
Belowground biomass	LRZ-ISHH	20	0.2489	0.0000	0.99999999995	0.00001837048	0.99999999997
Belowground biomass	LRZ-ISHH	10	0.2489	-0.0000	0.99999999997	0.00001463923	0.99999999998
Belowground biomass	LRZ-ISHH	7	0.2489	-0.0000	0.99999999995	0.00001446999	0.99999999998
Belowground biomass	LRZ-ISHH	5	0.2489	-0.0000	0.99999999996	0.00001600564	0.99999999998
Belowground biomass	LRZ-ISHH	4	0.2489	0.0000	0.99999999995	0.00002127075	0.99999999998
Belowground biomass	LRZ-ISHH	3	0.2489	-0.0000	0.99999999996	0.00001381794	0.99999999998
Belowground biomass	LRZ-ISHH	2	0.2489	0.0000	0.99999999996	0.00001826923	0.99999999998
Belowground biomass	LRZ-ISHH	1	0.2489	0.0000	0.99999999995	0.00001783197	0.99999999997
Forest debris	Arid/Other	NF	0.0691	0.0851	0.96646337331	0.12162981271	0.98123521180
Forest debris	Arid/Other	20	0.0708	-0.0236	0.99102447355	0.14112794185	0.99573873068
Forest debris	Arid/Other	10	0.0673	-0.0219	0.96828501037	0.10094226228	0.98391088591
Forest debris	Arid/Other	7	0.0638	0.0391	0.96439106163	0.06745857896	0.98173530127
Forest debris	Arid/Other	5	0.0643	-0.0025	0.99542576355	0.04432294223	0.99768516388
Forest debris	Arid/Other	4	0.0648	-0.0306	0.99507554100	0.05518909431	0.99756605894
Forest debris	Arid/Other	3	0.0586	-0.0009	0.99226641115	0.05777749142	0.99604201733
Forest debris	Arid/Other	2	0.0505	0.0726	0.99021980183	0.13179765341	0.99519565625
Forest debris	Arid/Other	1	0.0410	0.0359	0.99368381425	0.09828610050	0.99683958068
Forest debris	HRZ	NF	0.1070	0.3366	0.97074332959	0.37085928635	0.98505842620
Forest debris	HRZ	20	0.1050	-0.0887	0.95275730403	0.47255880195	0.97777395061
Forest debris	HRZ	10	0.0964	0.0098	0.97633724825	0.35438479699	0.98806289536
Forest debris	HRZ	7	0.9705	-2.3089	0.96914184936	0.30861151940	0.98462740571
Forest debris	HRZ	5	0.0810	0.0340	0.98009961814	0.25701350137	0.99017417454
Forest debris	HRZ	4	0.0714	0.1606	0.97866347764	0.15470924480	0.98908612018
Forest debris	HRZ	3	0.0650	0.0458	0.98505967878	0.13530869272	0.99271815435
Forest debris	HRZ	2	0.0494	-0.0396	0.98399558488	0.10194109400	0.99233682661
Forest debris	HRZ	1	0.0177	0.0147	0.99339538099	0.02230393401	0.99683472069
Forest debris	HRZ-hOFM	NF	0.1046	0.4052	0.96377675512	0.54328044500	0.98095432539
Forest debris	HRZ-hOFM	20	0.1074	-0.0711	0.97008405239	0.48270818821	0.98524722771
Forest debris	HRZ-hOFM	10	0.0958	0.2123	0.96298415998	0.48192507627	0.98081630411
Forest debris	HRZ-hOFM	7	0.0888	0.2397	0.96825588349	0.36268073543	0.98335580852
Forest debris	HRZ-hOFM	5	0.0837	0.1917	0.96654824496	0.34836845129	0.98303556215

Table A1 Contd.

Output variable	Vegetation type	FI	Emulation model parameters		Emulation model fit statistics		
			Slope	Intercept	Nash-Sutcliff model efficiency	RMSE	Lin's concordance
Forest debris	HRZ-hOFM	4	0.0774	0.2967	0.98076352923	0.27313558813	0.98989217463
Forest debris	HRZ-hOFM	3	0.0740	0.0305	0.98020891499	0.24134206313	0.99009698150
Forest debris	HRZ-hOFM	2	0.0643	-0.0762	0.99042370265	0.14175547650	0.99526597636
Forest debris	HRZ-hOFM	1	0.0353	0.0568	0.99361431187	0.06593626026	0.99674661084
Forest debris	HRZ-hSHH	NF	0.1147	0.0707	0.96690210741	0.22165869374	0.98374838227
Forest debris	HRZ-hSHH	20	0.1037	0.0929	0.96588191596	0.19932421896	0.98302725448
Forest debris	HRZ-hSHH	10	0.0967	0.0734	0.98193315239	0.18635498467	0.99103309257
Forest debris	HRZ-hSHH	7	0.0914	0.0796	0.98654845658	0.15413139052	0.99329186647
Forest debris	HRZ-hSHH	5	0.0840	0.1250	0.99195865732	0.10897584789	0.99597946369
Forest debris	HRZ-hSHH	4	0.0791	0.1047	0.99419931256	0.10882917436	0.99702885439
Forest debris	HRZ-hSHH	3	0.0722	0.0853	0.99045295081	0.09882106276	0.99518141163
Forest debris	HRZ-hSHH	2	0.0653	0.0322	0.98647731019	0.09784333555	0.99324781670
Forest debris	HRZ-hSHH	1	0.0308	0.0094	0.99144662011	0.02308441120	0.99573096162
Forest debris	LRZ	NF	0.1181	-0.0405	0.97962255278	0.25360433249	0.98986450655
Forest debris	LRZ	20	0.1092	0.0106	0.97643373544	0.23905682960	0.98807353903
Forest debris	LRZ	10	0.0992	0.1002	0.96672932534	0.20760778707	0.98294035909
Forest debris	LRZ	7	0.0937	0.0917	0.97914122447	0.20904940238	0.98927963671
Forest debris	LRZ	5	0.9549	-2.2727	0.93556652742	0.21539248489	0.96639285662
Forest debris	LRZ	4	0.9478	-2.2871	0.95660676853	0.21616318674	0.97717556649
Forest debris	LRZ	3	0.0714	0.1811	0.95553939667	0.17300550767	0.97733771449
Forest debris	LRZ	2	0.0660	0.1226	0.97677035323	0.13011970068	0.98831916506
Forest debris	LRZ	1	0.0480	0.1211	0.97467101407	0.09926074982	0.98667912507
Forest debris	LRZ-IOWM	NF	0.1125	0.0465	0.98695580887	0.15908639793	0.99337440280
Forest debris	LRZ-IOWM	20	0.1090	-0.0360	0.98177601190	0.18873710761	0.99075020593
Forest debris	LRZ-IOWM	10	0.1054	-0.0863	0.97035268776	0.20389768340	0.98572790317
Forest debris	LRZ-IOWM	7	0.0966	-0.0158	0.98563578760	0.11330566897	0.99262871068
Forest debris	LRZ-IOWM	5	0.0913	-0.0280	0.98046657967	0.13650011092	0.99037578039
Forest debris	LRZ-IOWM	4	0.0876	-0.0536	0.95842721405	0.15719823959	0.98033456072
Forest debris	LRZ-IOWM	3	0.0766	0.0447	0.97168377276	0.11406685777	0.98524524431
Forest debris	LRZ-IOWM	2	0.0679	0.0420	0.98306993256	0.08332591011	0.99138181639
Forest debris	LRZ-IOWM	1	0.0513	0.0175	0.98864186212	0.05006495082	0.99428015358
Forest debris	LRZ-ISHH	NF	0.1151	-0.0419	0.98666703265	0.13567527259	0.99362142242
Forest debris	LRZ-ISHH	20	0.1050	0.0798	0.98932318983	0.11722916135	0.99438700495
Forest debris	LRZ-ISHH	10	0.1016	0.0028	0.98986686605	0.10709883131	0.99491118007
Forest debris	LRZ-ISHH	7	0.0964	-0.0057	0.98911027014	0.08630216190	0.99449882415
Forest debris	LRZ-ISHH	5	0.0917	-0.0342	0.99021736050	0.09151156229	0.99512308499
Forest debris	LRZ-ISHH	4	0.0870	-0.0176	0.99282596016	0.09151507260	0.99632663972
Forest debris	LRZ-ISHH	3	0.0790	-0.0051	0.99064157804	0.06529154441	0.99532154977
Forest debris	LRZ-ISHH	2	0.0723	-0.0479	0.98891128708	0.08597909293	0.99460860395
Forest debris	LRZ-ISHH	1	0.0488	0.0268	0.99508634064	0.03377444219	0.99751882299
Standing dead	Arid/Other	NF	0.0276	0.0005	0.99999999993	0.00000202553	0.99999999996
Standing dead	Arid/Other	20	0.0261	0.0003	0.99999999997	0.00000290893	0.99999999999
Standing dead	Arid/Other	10	0.0247	0.0002	0.99999999989	0.00000218957	0.99999999994
Standing dead	Arid/Other	7	0.0236	0.0001	0.99999999983	0.00000169918	0.99999999991
Standing dead	Arid/Other	5	0.0223	0.0001	0.99999999998	0.00000111593	0.99999999999
Standing dead	Arid/Other	4	0.0213	0.0000	0.99999999998	0.00000121475	0.99999999999
Standing dead	Arid/Other	3	0.0197	0.0000	0.99999999996	0.00000135863	0.99999999998
Standing dead	Arid/Other	2	0.0173	0.0000	0.99999999996	0.00000295402	0.99999999998
Standing dead	Arid/Other	1	0.0126	-0.0000	0.99999999994	0.00000295403	0.99999999997
Standing dead	HRZ	NF	0.0500	0.0008	0.99999999989	0.00001056806	0.99999999994
Standing dead	HRZ	20	0.0523	0.0001	0.99999999977	0.00001749693	0.99999999988

Table A1 Contd.

Output variable	Vegetation type	FI	Emulation model parameters		Emulation model fit statistics		
			Slope	Intercept	Nash-Sutcliff model efficiency	RMSE	Lin's concordance
Standing dead	HRZ	10	0.0544	0.0000	0.99999999990	0.00001318905	0.99999999995
Standing dead	HRZ	7	0.0560	0.0000	0.99999999986	0.00001358781	0.99999999993
Standing dead	HRZ	5	0.0576	0.0000	0.99999999976	0.00002014823	0.99999999988
Standing dead	HRZ	4	0.0580	-0.0000	0.99999999988	0.00000932906	0.99999999994
Standing dead	HRZ	3	0.0556	0.0000	0.99999999981	0.00001333150	0.99999999991
Standing dead	HRZ	2	0.0478	-0.0000	0.99999999987	0.00000916852	0.99999999994
Standing dead	HRZ	1	0.0332	-0.0000	0.99999999991	0.00000513562	0.99999999995
Standing dead	HRZ-hOFM	NF	0.0500	0.0017	0.99999999971	0.00002211179	0.99999999985
Standing dead	HRZ-hOFM	20	0.0478	0.0006	0.99999999979	0.00001810433	0.99999999990
Standing dead	HRZ-hOFM	10	0.0464	0.0003	0.99999999953	0.00002539448	0.99999999976
Standing dead	HRZ-hOFM	7	0.0450	0.0001	0.99999999978	0.00001470340	0.99999999989
Standing dead	HRZ-hOFM	5	0.0439	0.0000	0.99999999974	0.00001593496	0.99999999987
Standing dead	HRZ-hOFM	4	0.0431	0.0000	0.99999999988	0.00001121514	0.99999999994
Standing dead	HRZ-hOFM	3	0.0421	0.0000	0.99999999989	0.00001039061	0.99999999994
Standing dead	HRZ-hOFM	2	0.0407	-0.0000	0.99999999985	0.00001117062	0.99999999993
Standing dead	HRZ-hOFM	1	0.0368	-0.0000	0.99999999991	0.00000780296	0.99999999996
Standing dead	HRZ-hSHH	NF	0.0500	0.0001	0.99999999989	0.00000561155	0.99999999995
Standing dead	HRZ-hSHH	20	0.0537	0.0000	0.99999999978	0.00000839875	0.99999999989
Standing dead	HRZ-hSHH	10	0.0569	0.0000	0.99999999989	0.00000880258	0.99999999994
Standing dead	HRZ-hSHH	7	0.0593	0.0000	0.99999999991	0.00000837949	0.99999999995
Standing dead	HRZ-hSHH	5	0.0620	0.0000	0.99999999990	0.00000916169	0.99999999995
Standing dead	HRZ-hSHH	4	0.0639	-0.0000	0.99999999993	0.00000919393	0.99999999997
Standing dead	HRZ-hSHH	3	0.0655	-0.0000	0.99999999992	0.00000815859	0.99999999996
Standing dead	HRZ-hSHH	2	0.0622	0.0000	0.99999999981	0.00001113296	0.99999999990
Standing dead	HRZ-hSHH	1	0.0440	0.0000	0.99999999984	0.00000447115	0.99999999992
Standing dead	LRZ	NF	0.0276	0.0005	0.99999999991	0.00000400778	0.99999999995
Standing dead	LRZ	20	0.0261	0.0003	0.99999999992	0.00000327462	0.99999999996
Standing dead	LRZ	10	0.0247	0.0002	0.99999999989	0.00000283991	0.99999999995
Standing dead	LRZ	7	0.0236	0.0001	0.99999999994	0.00000277234	0.99999999997
Standing dead	LRZ	5	0.0223	0.0001	0.99999999978	0.00000319006	0.99999999989
Standing dead	LRZ	4	0.0213	0.0000	0.99999999981	0.00000363058	0.99999999990
Standing dead	LRZ	3	0.0197	0.0000	0.99999999984	0.00000283018	0.99999999992
Standing dead	LRZ	2	0.0173	0.0000	0.99999999987	0.00000249929	0.99999999994
Standing dead	LRZ	1	0.0126	-0.0000	0.99999999981	0.00000214459	0.99999999990
Standing dead	LRZ-lOWM	NF	0.0276	0.0003	0.99999999989	0.00000348069	0.99999999995
Standing dead	LRZ-lOWM	20	0.0261	0.0002	0.99999999991	0.00000319823	0.99999999995
Standing dead	LRZ-lOWM	10	0.0247	0.0001	0.99999999994	0.00000231524	0.99999999997
Standing dead	LRZ-lOWM	7	0.0236	0.0001	0.99999999989	0.00000240691	0.99999999994
Standing dead	LRZ-lOWM	5	0.0223	0.0000	0.99999999993	0.00000206562	0.99999999996
Standing dead	LRZ-lOWM	4	0.0213	0.0000	0.99999999992	0.00000180652	0.99999999996
Standing dead	LRZ-lOWM	3	0.0197	0.0000	0.99999999992	0.00000149673	0.99999999996
Standing dead	LRZ-lOWM	2	0.0173	0.0000	0.99999999980	0.00000227815	0.99999999990
Standing dead	LRZ-lOWM	1	0.0126	-0.0000	0.99999999981	0.00000156273	0.99999999991
Standing dead	LRZ-lSHH	NF	0.0414	0.0001	0.99999999990	0.00000449965	0.99999999995
Standing dead	LRZ-lSHH	20	0.0462	0.0001	0.99999999988	0.00000514536	0.99999999994
Standing dead	LRZ-lSHH	10	0.0506	0.0000	0.99999999993	0.00000434946	0.99999999997
Standing dead	LRZ-lSHH	7	0.0541	0.0000	0.99999999990	0.00000458554	0.99999999995
Standing dead	LRZ-lSHH	5	0.0581	0.0000	0.99999999992	0.00000528377	0.99999999996
Standing dead	LRZ-lSHH	4	0.0614	0.0000	0.99999999989	0.00000763528	0.99999999995
Standing dead	LRZ-lSHH	3	0.0661	0.0000	0.99999999991	0.00000530126	0.99999999996
Standing dead	LRZ-lSHH	2	0.0730	0.0000	0.99999999991	0.00000789943	0.99999999996
Standing dead	LRZ-lSHH	1	0.0687	0.0000	0.99999999988	0.00000733377	0.99999999994

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