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School of Life Sciences

Reconnecting river Country – Floodplain Vegetation Condition Predictive Modelling

Part 1: Murray River floodplain

Prepared for the Department of Planning and Environment NSW

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Executive Summary

Improving the health of floodplain vegetation communities impacted by river regulation and modified flow regimes is one of the key goals of the Reconnecting River Country program. Floodplain vegetation consists of multiple community types (e.g. river red gum forest, emergent wetland communities), which may benefit from a relaxation of constraints on water for the environment deliveries (i.e. raising flow limits). This report summarises the predicted vegetation outcomes in the Murray valley between Hume Dam and the Darling River junction under a current conditions scenario and four relaxed constraint scenarios to identify impacts to the health of the community under alternative constraint relaxation scenarios.

Vegetation responses were modelled using the Floodplain Vegetation Condition Model (FVCM) a newly developed state and transition simulation model (STSM) applied to rasterised layers of vegetation community type and condition. The STSM approach provides dynamic time-series of vegetation condition in response to different inundation sequences (defined in terms of frequency, timing and duration) for individual pixels in the vegetation rasters. Inundation levels were based on two inundation models of the Murray catchment floodplain: the River Murray Floodplain Inundation Model (RiM-FIM) and the Edward Wakool Floodplain Inundation Model (EW-FIM).

Combining the STSM with hydrologic time-series and associated inundation sequences allowed projection of the initial vegetation state (veg type and veg condition) across 124 year hydrologic time series representing different constraint relaxation scenarios.

Vegetation condition was quantified on an ordinal scale (*critical*, *poor*, *intermediate*, *moderate*, and *good*), with numeric values for condition ranging from 0-1. Outputs from the model consist of annual (n=124) rasters describing vegetation type and condition within each pixel (125 m resolution) across the floodplain area. Individual raster extents were aligned with zones in the inundation models. In total there are over 763,000 individual “pixels” modelled over the 124 years and the results stored from each scenario/model-run (n = 6).

Six key outputs were produced for the purposes of comparing between scenarios;

1. Maps showing proportion of years that the vegetation was predicted to be in ‘good’ condition under each scenario.
2. Difference maps showing the change in proportion of years that vegetation condition was predicted to be in ‘good’ condition relative to the baseline scenario.

3. Cumulative density plots showing the proportion of years individual pixels were in good condition
4. Density plots showing the changes in the proportion of time that pixels were in good condition relative to the baseline scenario.
5. Time series projections of the total annual area of vegetation for floodplain areas of interest.
6. Tables summarising the total floodplain area that showed either a) no change, b) an increase, or c) a decrease in the proportion of time that vegetation was in good condition. The net outcome from these changes was also tabulated.

In order to provide a succinct summary for comparing outcomes, the main body of this report relies on the summary tables only, with graphical outputs (maps and plots) included as appendices.

The key findings from the modelled outcomes were as follows:

- Overall, there was a net decline in the area of vegetation in good condition when comparing the base case (Y15D25) with the pre-development scenario (Modelled without development flows - similar to modelled natural conditions). This is in line with expectations given the significant decline in floodplain connectivity that has occurred as a result of river regulation.
- Most constraints relaxation scenarios deliver net increases to the area of good condition vegetation compared to the base case scenario. However, there are some key differences between scenarios in the magnitude of response (net area of vegetation positively affected) for different vegetation types.
- Overall, black box woodland showed the smallest improvements which is likely due to this vegetation type being largely beyond the floodplain extents that can be influenced by constraints relaxation. This is likely due to variability in the spatial distribution of vegetation at the catchment scale, with respect to inundation thresholds, and how each vegetation unit experienced inundation events
- Generally, the response of river red gum forests and woodlands to the relaxation of constraints was a net improvement in good condition area. However, this net improvement with constraint relaxation was not uniform across constraint scenarios or locations of interest within the catchment likely due to variability in the area and distribution of vegetation across the floodplain inundation thresholds between areas.
- Differences between key sites were also evident. Overall, the larger relative proportion of low-lying floodplain at the Barmah-Millewa Forest meant that greater improvements in vegetation condition are predicted to occur there relative to other sites including the

response of river red gum downstream of Euston weir being largely net decline between constraint relaxation options.

- The impact of relaxed flow constraints appears to be temporally variable, with improvements in some vegetation types (e.g. river red gum) under higher flow limits being observed during drier periods across the modelled hydrological scenarios.
- Further investigation of the distribution of vegetation types across inundation areas influenced by hydrological spells with constraint relaxation will elucidate greater understanding of the support of vegetation condition possible via this method of management.

In summary, the FVCM provides a step-change in the ability to model and assess floodplain vegetation responses to changes in floodplain inundation. It shows an overall positive outcome from constraints relaxation, with the largest improvements under the 'Y45D40' scenario when considering the whole catchment scale and multiple vegetation types. These predictions align with expert opinion of the influence inundation has on vegetation condition response and facilitates the comparison of impacts alternate flow constraints has on native vegetation condition. The FVCM model improves upon expert opinion alone by providing a spatially and temporally explicit framework for comparing alternate management scenarios and quantifying outcomes in ways that have not previously been possible.

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Introduction and context for study

Globally, floodplain vegetation communities have been heavily impacted by altered flow regimes due to river regulation and water extraction for off-stream use. Floodplain vegetation communities require specific inundation regimes (extent, duration, timing and frequency) to persist (Roberts & Marston, 2011), but in many regions those inundation regimes no-longer occur, leading to declines in vegetation condition. Projected climate change will exacerbate hydrologic change and is predicted to cause further declines in the 'hydrological health' of river ecosystems (Peterson, Saft, Peel, & John, 2021). As a mitigating measure, environmental watering is possibly an effective way of maintaining and improving the health of floodplain vegetation communities, although determining the flow-regime required to reverse declines in health, as well as assess the feasibility of delivering such flows is a major management challenge.

The Reconnecting River Country program aims to improve wetland and floodplain connectivity through investigating relaxing or removing some of the constraints or physical barriers that impact delivering water for the environment. Flood-dependant native vegetation communities, including riparian and floodplain forests and woodlands, shrublands and non-woody wetland vegetation, will likely benefit from an improved flow regime when flow limits on water for the environment are relaxed. These relaxed flow limits are expected to improve the hydrological conditions that will promote the recovery of vegetation communities in low-lying floodplain and wetland habitats including the Barmah-Millewa forest and Koondrook-Perricoota forest, while also benefiting broader riparian water-dependant forests such as the floodplain downstream of Euston weir and woodlands along the Murray River corridors. To model the dynamic ecological response of vegetation communities to the variable hydrologic conditions we have refined (details below) the vegetation condition state-and-transition models developed for the SDLAM ecological elements method (N. R. Bond et al., 2018; Overton et al., 2014). These models simulate units called 'states' in response to a transition event occurring, for example the condition of vegetation communities (i.e., 'vegetation state') in response to inundation events (i.e. 'inundation transitions') on the floodplain. The vegetation condition models are applied using flow timeseries from constraints program 'Source river system modelling' to compare predicted vegetation response between 'base case' (current flow limits) and 'constraints relaxed' scenarios (Table 1), and between 'base case' and 'without development' scenarios, over the historic climate record.

Table 1: Project areas in the River Murray, and proposed flow limit options, included in the Reconnecting River Country Program.

	Flow limit for each relaxed constraint scenario by project area	
Scenario name	Flow limit at Doctors Point (409017; Hume to Yarrawonga reach) ML/day	Flow limit at d/s Yarrawonga Weir (409025; Yarrawonga to Wakool reach) ML/day
Y15D25 (base case)	25,000	15,000
Y25D25	25,000	25,000
Y30D30	30,000	30,000
Y40D40	40,000	40,000
Y45D40	40,000	45,000

This report focuses on the results of modelled vegetation states within the floodplain inundation extent of the Murray River between Hume Dam and the Darling River junction. The modelling was based on previously developed vegetation condition state-and-transition models. This approach extends previously developed models (N. R. Bond et al., 2018; Overton et al., 2014) through expert elicitation to develop ‘rules’ describing the response of multiple vegetation types to inundation spells. This approach models spatially discrete vegetation condition at discrete annual time intervals in response to the antecedent hydrological conditions. Changes in vegetation state over time are thus themselves conditional on both environmental conditions (e.g. inundation/drying spells) as well as the prevailing state (community type and condition) of the vegetation. Incorporating both of these antecedent conditions (vegetation state and antecedent inundation regime) we have developed a set of customised functions within the R for statistical computing software (R Development Core Team, 2020) to run matrix projections of vegetation state (i.e. vegetation type and condition). Using this model we generated a time series of state transitions (vegetation condition change) over a 124 year period of flows.

Methodology

Model inputs

To our knowledge this is the first implementation of state and transition frameworks to describe changes to the floodplain vegetation of the Murray River catchment. We have modelled a single driver of changes to vegetation condition, inundation spell (duration and frequency), as an initial assessment of the approach given altered hydrology is a primary driver of wetland change (Catford, Downes, Gippel, & Vesk, 2011). The modelling framework considers the joint effects of antecedent vegetation state, and antecedent inundation conditions after each annual time-step. We largely followed the methodology of Bond et al. (N. R. Bond et al., 2018). The model is informed by the following data sources:

- Inundation maps of the floodplain area (RiM-FIM; Overton, McEwan, Gabrovsek, and Sherrah (2006), EW-FIM; Sims et al. (2014),
- Daily timeseries of flows for the duration of model projections that are from gauges representative of inundation within each inundation map,
- Map of vegetation types for the inundation map extents and their initial state,
- State-transition matrices which project state changes at each time-step given a series of state transitions (hereafter referred to as 'transition rules'), different combinations of antecedent hydrological and ecological states, and
- Rule set of the inundation requirements for transitions between vegetation states for each vegetation type.

These data sources are described in detail below.

Inundation maps

Floodplain inundation maps of the Murray River between the outlet of Hume dam, the furthest upstream extent, to the Lock 8 weir beyond the junction of the Murray and Darling systems, furthest downstream extent, were used to model the inundation of vegetation. In total there were 22 zones where projections were completed for the Murray catchment drawn from the Edward-Kolety-Wakool Floodplain inundation model (EW-FIM, Sims et al. (2014)) and the River Murray floodplain inundation model (RiM-FIM, Overton et al. (2006)).

Both the RiM-FIM and EWFIM, layers are based on commence to fill flow volumes at a gauge in the main river channel and as data sources were *raster* files with a resolution of 5 m up to 15 m square pixels. Due to hardware constraints to modelling pixels at this resolution, pixels were aggregated into 125 m square pixels and the mode value of all aggregated cells was used as the new value for the larger pixel. This was based on a sensitivity analysis of various averaging techniques as an earlier part of this project (McPhan and Bond, 2022; Milestones 3e and 3f). Additionally, the inundation volumes of these maps were binned to 1000 ML day^{-1} increments between 0 and 308,000 ML day^{-1} (Table 2). Due to some inaccuracies across the inundation maps of the RiM-FIM some rasters have been updated or modified from the original (Table 2). For every inundation map the highest flow value was removed from the modelling procedure as these highest flow pixels represent a fill of the space between the observed/satellite imagery highest flow and the bounding box of the RiM-FIM zone set out in Overton et al. (2006). Finally, some rasters were 'clipped' to allow the use of the more recently developed EW-FIM model where both models existed.

We have two important notes in relation to the inundation modelling approach. First, RiM-FIM and EW-FIM were used in preference to more detailed hydrodynamic models that exist for some areas so as to align with the hydrologic input scenarios that were provided. However, these layers lack details regarding the operation of local infrastructure, which must be considered when running the hydrodynamic models for flows in the range of 3,000-15,000 ML/day. Second, we modelled vegetation outcomes across the entire floodplain, not just the areas affected by 'operational' flows, so as to assess whether improvements in the areas affected by operating rules and releases caused any declines in areas above the operational range of flow releases (e.g. by changes in operational flows influencing the frequency of uncontrolled spills from storage, which could then affect other parts of the floodplain).

Flow constraint timeseries and spells analysis

Multiple hydrological scenarios were assessed to determine the influence of different constraint relaxations on various outcomes across the multiple themes of the *Reconnecting River Country* project. For the responses of vegetation these scenarios simulated flows that were processed into spells of inundation on the floodplain when combined with the inundation maps described in the previous section. To generate these flow options personnel from DPIE EES used 'Source Murray Model' software (version 5.10) to generate five constraint relaxation scenarios (See RRC Synthesis Report DPE (2022) for a greater explanation of the constraint scenarios with respect to hydrology and inundation extents specifically). These constraint volumes of daily discharge were parameterised by flow constraints at 2 locations, Yarrawonga (Y) and Doctors Point (D). For example, the base case of constraints, the current operational limits of 15 GL day^{-1} at Yarrawonga and 25 GL day^{-1} would be expressed as 'Y15D25'. The 4 remaining scenarios were names Y25D25, Y30D30, Y40D40, Y45D40 using this convention to describe relaxation of the flow constraints at each location. For each scenario simulated flows at corresponding gauges for the 22 inundation maps were generated for a

124 year period from the 1/07/1895 to 30/06/2020. These hydrological time series were analysed using the *hydrostats* package (v0.2.8 N. Bond (2021)) to determine the hydrological year (*hydro.year*) across the entire time series. This resulted in a 123 year time series (and 1 initial state, n = 124) after flows were standardised to the hydrological year (i.e. start/finishing in the average annual driest conditions) between April 1st to March 30th.

Within these annual windows a spells analysis determined the durations of both inundation and drying spells at all unique levels of inundation on the floodplain for each of the inundation maps. To parameterise these spell durations, we consulted with vegetation experts external to the project and the steering committee for the "Reconnecting river country" program through both workshops and regular meetings. Spells of appropriate duration were then summarised as a binary time series of a specific spell occurring in a year which was then used to inform transitions of vegetation based on its expected response (transition) to inundation by a flow event (see "rules" in the "State and transition simulation modelling" section). This usually takes the form of a sum of spells across a period of one or more years at each unique inundation threshold of the inundation map.

One aspect of these inundation maps is that they are based on commence to fill volumes and not correlations of observed inundation extents on the floodplain and antecedent flow in the river. This means that water on the floodplain will rise and fall on the floodplain as rapidly as it changes in the main channel or wherever the gauge point for that inundation map is located. To incorporate some aspect of water residence time on the floodplain we included a tuning parameter in our spells analysis. This was a similar approach that is implemented in several functions of the *hydrostats* package (N. Bond, 2021) that allows spells that occur within a short enough period of one another to be counted as the same spell and their durations of inundation added together. As mentioned, when describing the averaging of our inundation maps a previous sensitivity analysis (McPhan and Bond, 2021; Milestones 3e and 3f) allowed us to assess the validity of values that were suggested by expert elicitation via workshops. We found that a 'between spells duration' of 15 days was adequate to better represent the inundation durations occurring on the floodplain showing a greatly reduced decline in the mean condition of most vegetation types.

Table 2. Inundation extents for each of the modelled floodplain areas from the Edward-Kolety-Wakool Floodplain inundation model (EW-FIM) and the River Murray floodplain inundation model (RiM-FIM). The names within 'Raster' have short codes of "ud" for zones that were updated with more recent data by DPIE EES and "clip" for those zones that were clipped by DPIE EES. Maximum values presented are modified to remove the highest threshold.

Source	Raster	Gauge code	Minimum Volume ($ML.day^{-1}$)	Maximum Volume ($ML.day^{-1}$)
EW-FIM	ew_zone1	Edward River, DS Stevens Weir (409023)	3000	37000
	ew_zone2	River Murray, Tocumwal (409202)	13000	237000
	ew_zone3	Edward River, Liewah (409035)	3000	19000
	ew_zone3a	Edward River, Liewah (409035)	0	12000
	ew_zone4	Wakool River, Wakool-Deniliquin Road (409072)	1000	17000
	ew_zone5	Wakool River, Stoney Crossing (409013)	1000	102000
	ew_zone6	Niemur River, Barham-Wakool Rd (409048)	0	34000
	ew_zone7	Wakool River, Wakool-Deniliquin Road (409072)	1000	17000
RiM-FIM	zone1_ud	River Murray, Corowa (409002)	3000	192000
	zone2	River Murray, Tocumwal (409202)	3000	206000
	zone3_clip	River Murray, Tocumwal (409202)	3000	236000
	zone4	River Murray, Barmah (409215)	3000	212000
	zone5	River Murray, Barmah; Goulburn River, McCoys Bridge (409215 & 405232)	3000	207000
	zone6_ud	River Murray, Barmah; Goulburn River, McCoys Bridge; Campaspe River, Rochester (409215; 405232; 406202)	3000	227000
	zone7_clip	River Murray, DS Torrumbarry (409207)	3000	231000
	zone8_clip	River Murray, DS Torrumbarry (409207)	3000	93000
	zone9_clip	River Murray, Swan Hill (409204)	3000	93000
	ud_zone10_clip	River Murray, Wakool Junction (414200)	3000	223000
	ud_zone11	River Murray, Wakool Junction & Murrumbidgee River, Balranald (414200 & 410130)	3000	308000
	zone12	River Murray, DS Euston (414203)	3000	300000
	zone13	River Murray, Lock 9 US (426501)	3000	308000
	ud_zone14	River Murray, Lock 8 US (426506)	3000	307000

Vegetation layers

High quality vegetation layers were generated from both Victorian and New South Wales data sources across the Murray and Murrumbidgee catchments. Victorian EVC classes and NSW PCT classes were consolidated to the vegetation states modelled here to ensure that the same vegetation type was being represented on either side of the Murray River. A detailed description of this approach can be found in Appendix 5. In aggregating these many classes 28 sub-categories of vegetation type within 12 broad categories were derived for future work using these vegetation layers (Table 3). Of the 12 broad categories, being that we are modelling floodplain vegetation we have focussed on six of the broad categories to parameterise our states: river red gum woodland, river red gum forest, black box woodland, lignum shrublands, perennial wetland grass, sedge and rush lands, and wetland herblands. Modelling vegetation in this report has focussed strongly on 3 of the broad categories (river red gum woodland [RRGW], river red gum forest [RRGF], black box woodland [BBW]).

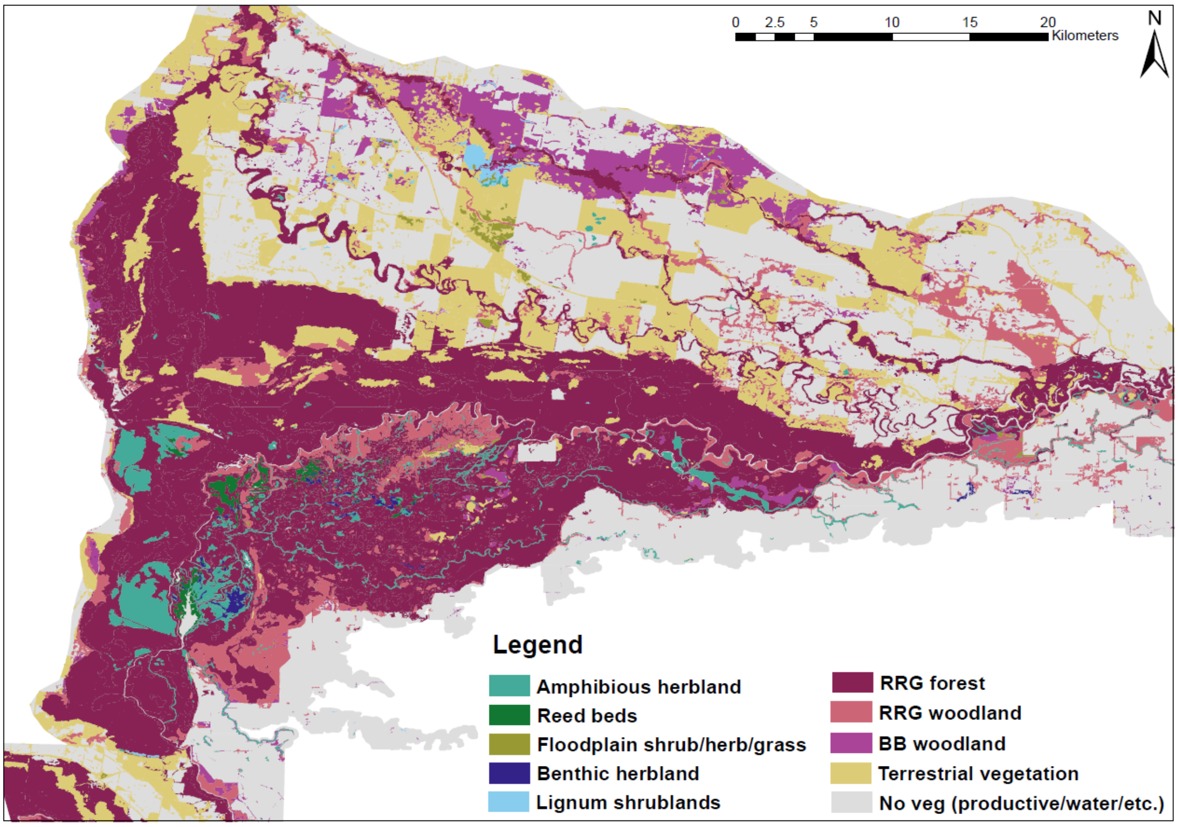


Figure 1. An example of the vegetation data used in the condition modelling of multiple vegetation types. Presented here is the Barmah-Millewa Forest region of the Murray River system.

*Table 3. Vegetation groupings resulting from grouping of EVC and PCT codes to broad categorical and sub-categorical vegetation groups. Broad categories denoted with an * are those assessed in this report, and those with + have rules under review for future reports.*

Broad category	**Subcategory**
River red gum woodland*	RRG woodland lignum understorey
River red gum woodland*	RRG woodland grassy understorey
Black box woodland*	BB woodland chenopod understorey
Black box woodland*	BB woodland grassy understorey
Black box woodland*	BB woodland lignum understorey
Terrestrial grasslands	Terrestrial grasslands
Wetland herblands+	Amphibious herbland - grassland/forbland
River red gum forest*	RRG forest sedge understorey
River red gum forest*	RRG forest herb-grass understorey
Terrestrial woodlands	Terrestrial woodlands
Terrestrial woodlands	Floodplain transition woodlands
River red gum forest*	RRG forest lignum understorey
Lignum shrublands+	Lignum shrublands
Perennial wetland grass, sedge and rush lands+	Common Reed
Wetland herblands+	Floodplain terrestrial herbland/grassland
Perennial wetland grass, sedge and rush lands+	Tall GSR
Terrestrial shrublands	Chenopod shrublands
Terrestrial shrublands	Terrestrial shrublands
River red gum woodland*	RRG woodland mixed understorey
Wetland herblands+	Amphibious herbland - low-mid sedgeland
Wetland herblands+	Benthic perennial herbland 2
Wetland herblands+	Floodplain shrublands
Terrestrial shrublands	Saltbush forbland
Saline wetlands	Saline wetlands
Wetland herblands+	Benthic perennial herbland 1
River red gum woodlands*	RRG woodland sedge understorey
Terrestrial grasslands	Chenopod grasslands
Wetland herblands+	Terrestrial shrublands

State and transition simulation modelling

In recent years there has been a strong push for the development and adoption of modelling approaches to assist with environmental flows planning that are better able to replicate the response of ecosystems to specific flow sequences (e.g. Horne et al., 2019; Shenton, Bond, Yen, & Mac Nally, 2012; Tonkin et al., 2019). This motivated our use of a state and transition framework for projecting likely responses of vegetation in flood dependent ecosystems. In their most basic form state-and-transition models (STMs) assume transition probabilities adhere to a constant first-order Markov process (e.g. Figure 4). This means looking only one time step back to determine if a transition occurs. However, this assumption can easily be relaxed to consider higher-order lag effects or the influence of exogenous variables such as disturbances that alter transition probabilities over time (Baker, 1989; Daniel, Frid, Sleeter, & Fortin, 2016).

While we haven't implemented probabilistic aspects to state transitions in our framework being fully deterministic, with respect to the relationship between a transition parameter (spell rule) and the state change, we have generated very high-order lags e.g. 30 years of 365 day dry spells for the decline from black box woodland in a "good" state to a "dead" state. This allows a significant amount of model "memory" for individual units of simulation and in simulating many millions of pixels across the Murray floodplain these models can be very powerful with respect to antecedent conditions. This antecedent memory is generated when the spells analysis is used to cross reference which rules occur within a year. This time series of rule transitions is used to construct annual transition matrices for each inundation threshold specific to that inundation map. Initialising the vegetation layer as "good" for their relevant type and storing this value as a binary vector of all possible states, the projections are a simple process of multiplying the initial state vector by these transition matrices.

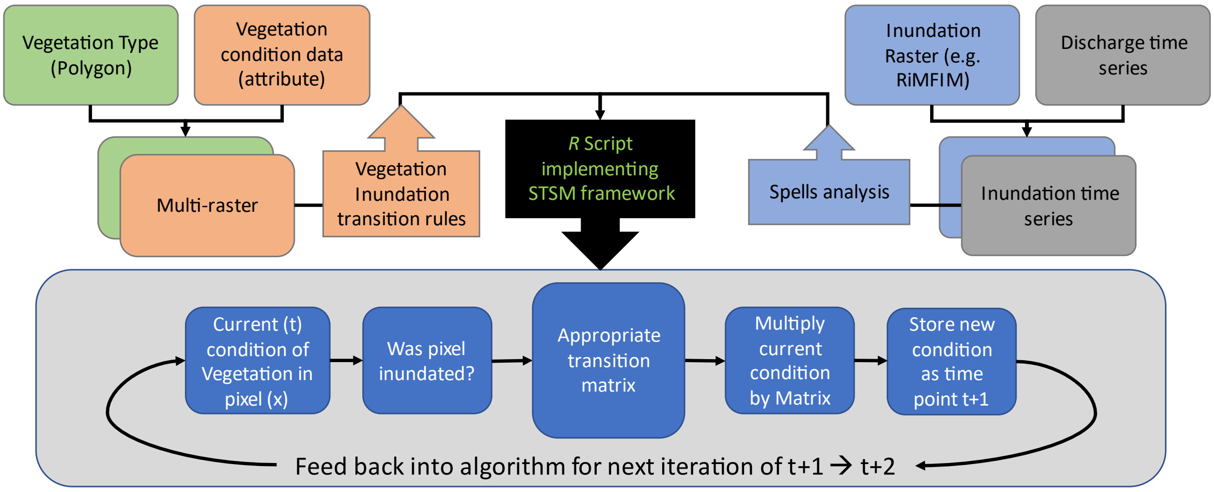


Figure 2 - Visual representation of workflow for the data sources and computing that needs to be completed for the vegetation condition projection. The top left pannels of the diagram show vegetation data preprocessing (Polygons and condition attributes to raster layers). The top right panels show where the hydrological spells analysis/preprocessing occurs prior to being piped into a script that performs the state transitions for vegetation condition projection.

Rules

To determine the rules of state transitions three aspects of the current time point were necessary: 1) the current state of the vegetation, 2) the antecedent inundation time series of spells, 3) the duration, across which a rule would function (Figure 3). The first two are explained in previous sections but the third aspect is one that required fair consideration of the species tolerance to both drought and prolonged inundation. Initial parameterisation of some of our rules was based largely on the following research:

- N. R. Bond et al. (2018). "Assessment of environmental flow scenarios using state-and-transition models." Freshwater Biology 63(8): 804-816.
- Casanova (2015). "Review of Water Requirements for Key Floodplain Vegetation for the Northern Basin." Literature Review and expert knowledge assessment. Report to the Murray–Darling Basin Authority, Charophyte Services, Lake Bolac.
- Telfer, Charles, and Jensen (2015). "black box health and management options." Prepared for the Commonwealth Environmental Water Office. Adelaide: Australian Water Environments.
- Roberts and Marston (2011). Water regime for wetland and floodplain plants: a source book for the Murray-Darling Basin, National Water Commission Canberra.
- Overton et al. (2014). "Development of the Murray-Darling Basin Plan SDL adjustment ecological elements method." Report prepared by CSIRO for the Murray-Darling Basin Authority, Canberra: 45-54.

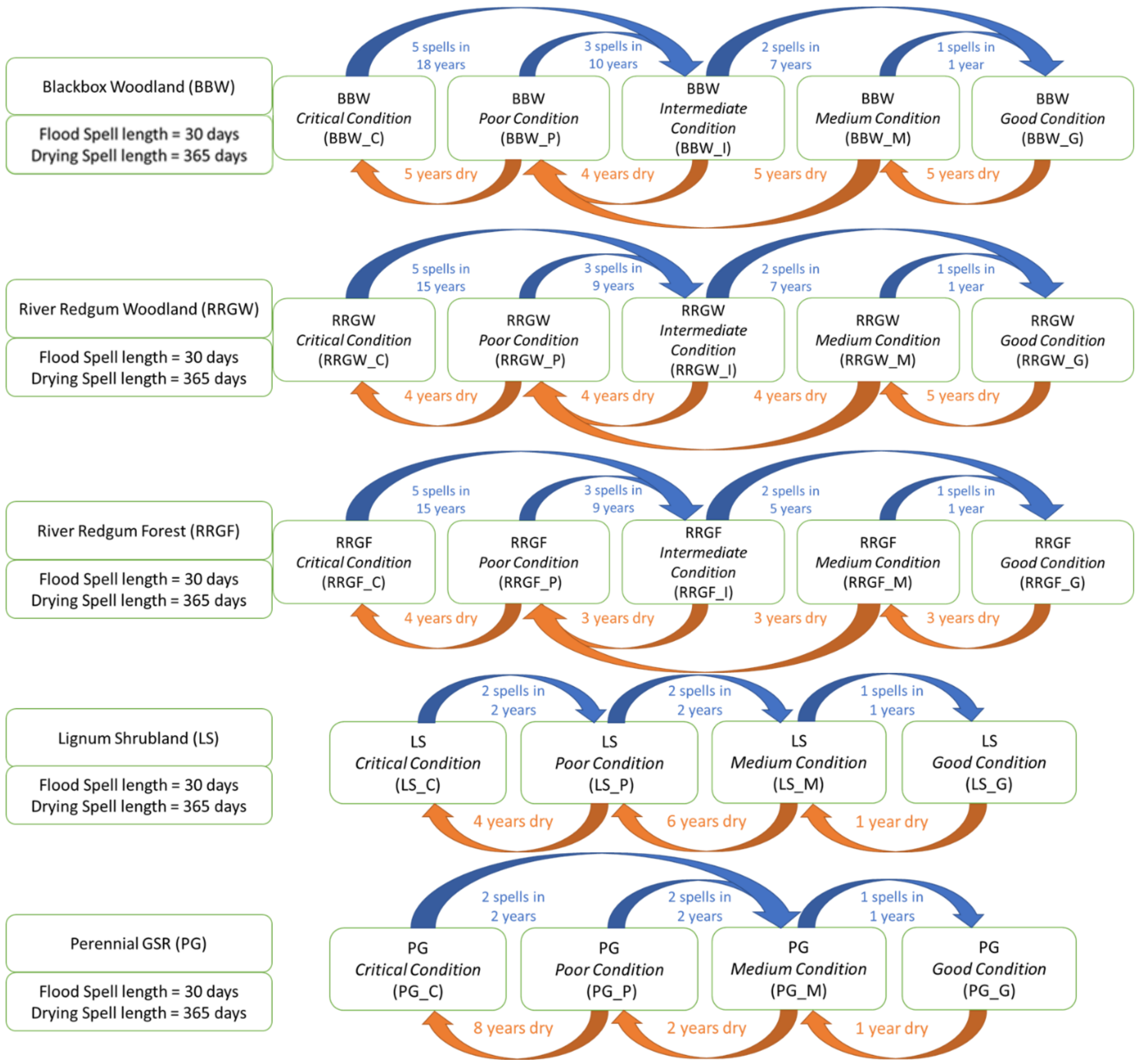


Figure 3. Visual representation of a subset of transition rules for inundation frequency of broad vegetation categories. Blue arrows show the pathway of state transitions in response to flood spells. Orange arrows show the state transitions in response to 365 day extended dry periods (Based on rules from N. R. Bond et al. (2018)).

- Capon, James, Williams, and Quinn (2009). "Responses to flooding and drying in seedlings of a common Australian desert floodplain shrub: *Muehlenbeckia florulenta* Meisn. (tangled lignum)." Environmental and Experimental Botany 66(2): 178-185.
- Jensen, Walker, and Paton (2008). "The role of seedbanks in restoration of floodplain woodlands." River Research and Applications 24(5): 632-649.

In addition, workshops were arranged with external vegetation experts consulted to give feedback on the pathways that had been identified from work above and assess the hydrological conditions that caused rules to project vegetation states into the future. Feedback from these experts included advising that we should focus on:

- Trial mean, mode, max and min inundation values when averaging inundation maps

- Assess multiple durations for inundation spells.
- Test the sensitivity of the period in between spells.

Model results evaluation

The results from a dynamic model such as this are challenging to summarise in a single metric because the condition of the vegetation is changing in multiple dimensions – in two dimensions across the floodplain and along a third dimension of time. Two enable comparison of the multiple constraint options we derived a simple response metric at the pixel level, which was the proportion of years (n=124) during which the vegetation state for that pixel were in a “good” condition. This provided a simple summary metric that could be mapped for each scenario, and which also allowed for differences between scenarios to be visualised and summarised in both a graphical and tabular format ((Figure 4; Figure 5). We also combined river red gum woodland and river red gum forest areas into a single ‘river red gum’ vegetation class due to a significantly smaller extent of RRG woodland.

We present results at several different scales. These include for the River Murray between Hume and Yarrawonga, and separately from Yarrawonga to the Wakool Junction. Following this we have selected 3 areas: Barmah-Millewa Forest (ew_zone2 and Zone3_clip), Koondrook-Perricoota and Gunbower Forest (zone7_clip), and the floodplain area downstream of Euston weir (zone12), to provide spatial representation of selected areas with significant areas of river red gum and black box woodland vegetation (See sections: river red gum outputs and black box outputs). In addition to the tabular results in the main body of the report, we also derived a range of other summary outputs, including time-series of vegetation condition and more detailed comparisons of the changes in condition under individual scenarios (see Appendices).

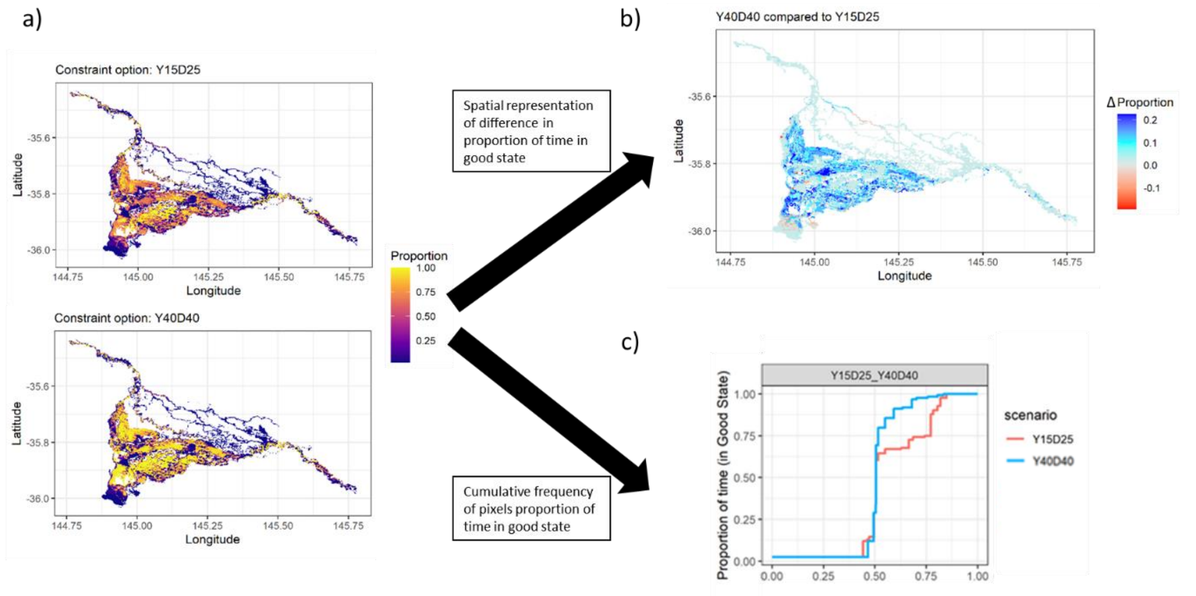
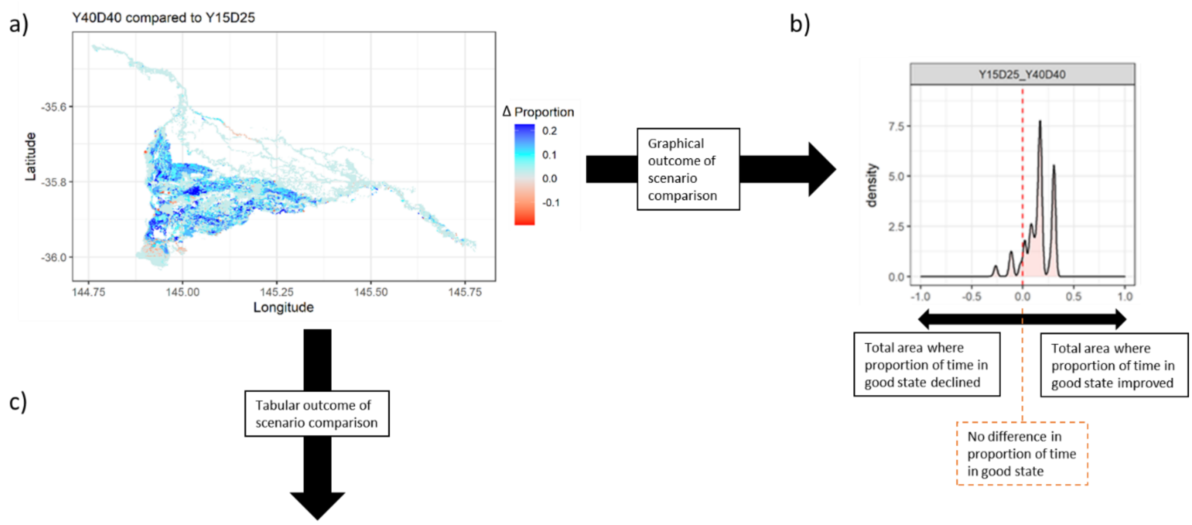


Figure 4. Spatial assessment of results shown for Barmah-Millewa Forest (Zone 3 clip) comparing 2 constraint options a) the base case (Y15D25) to Y40D40 and b) comparing these spatially to show differences between proportion of time in a good state between constraint options in (a) and c) the cumulative frequency of all pixels as proportion of time in a good state for both constraint options.



Vegetation	Zone of interest	Scenario	No change (ha)	Improve (ha)	Decline (ha)	Net Change (ha)
RRG_G	Barmah-Millewa Forest *(RiM-FIM: Zone 3 Clip; EW-FIM: zone 2)*	Y15D25_Y40D40	46565.63	27310.94	3310.94	24000.00

Figure 5. Derivation of summary metrics from the constraint comparisons of proportion of time in good state between a) the base case scenario and Y40D40 and b) a distribution of the difference in proportion of time, positive values are areas of net increase in condition and negative are areas of net decline, that are then c) represented in a tabular format of all modelled pixels.

While the transitions between states is a large part of the analysis, assessing the changes to states at the best possible condition ("Good") will better elucidate the differences between flow scenarios. Below are the key findings and reference to relevant tables and figures for greater spatial context in specific locations.

Table 4. Area of canopy species black box and river red gum (RRG) as the model is initially parameterised. These values are broken down by each inundation map (Raster) and the total area of the raster is shown.

Source	Raster	Raster area (ha)	Black box Area (%)	RRG Area (%)
EW-FIM	ew_zone1	297508	7908 (2.66)	17200 (5.78)
	ew_zone2	421875	9797 (2.32)	46678 (10.00)
	ew_zone3	130650	3986 (3.05)	5692 (4.36)
	ew_zone3a	94688	564 (0.60)	466 (0.49)
	ew_zone4	243950	12830 (5.26)	8188 (3.36)
	ew_zone5	694097	16448 (2.37)	31559 (4.55)
	ew_zone6	453578	21941 (4.84)	14517 (3.20)
	ew_zone7	94219	3773 (4.00)	9819 (10.42)
RiM-FIM	zone1_ud	167813	180 (0.11)	8158 (3.92)
	zone2	20367	150 (0.74)	3747 (18.40)
	Zone3_clip	292570	1272 (0.43)	30509 (10.43)
	zone4	33211	1572 (4.73)	4978 (14.99)
	zone5	21289	253 (1.19)	631 (2.97)
	Zone6_ud	70125	2119 (3.02)	3453 (4.92)
	zone7_clip	288984	8606 (2.98)	39986 (13.84)
	zone8_clip	129844	1309 (1.01)	2764 (2.13)
	zone9_clip	159359	2027 (1.27)	4928 (3.09)
	ud_zon10_clip	35156	1616 (4.60)	2561 (7.28)
	ud_zone11	136250	27084 (19.88)	10694 (7.85)
	zone12	664219	46497 (7.00)	17048 (2.57)
	zone13	63038	10234 (16.24)	3133 (4.97)
	ud_zone14	45533	8925 (19.60)	3911 (10.36)
	Totals	**4558323**	**189091**	**270620**

- Across the Murray River floodplain, a total of 4.56 million ha of floodplain vegetation was modelled where BBW covered 189,091 ha and RRG 270,620 ha (Table 4). From the inundation zones of the Murray catchment the largest area of BBW within a reach was in the floodplain area downstream of Euston weir (46,497 ha, zone 12) and the largest RRG stands were in the Barmah-Millewa Forest (77,187 ha, rasters ew_zone2 and Zone_3 clip were aggregated for this location) followed by the Koondrook-Perricoota and Gunbower forest reaches (39,986 ha, zone7_clip).
- When comparing constraint scenarios, areas where there was no change in the proportion of time RRG was in a good state were far larger than areas positively influenced by constraint scenarios (Table 5). Between alternative constraint options and the base case, the total catchment area where the time RRG was in good condition improved, was greater with higher limit constraint options (e.g. Y15D25_Y45D40, Table 5) and the areas where time in good state declined, decreased considerably above the Y40D40 constraint option. There was no clear trend for BBW areas between constraint options with regard to altered proportion of time in a good condition state.

Table 5. Total area (ha) changes for the Murray catchment (no change, improvement, declined and net change) to time in good condition comparing Constraint relaxation scenarios with the base case of Y15D25 for good states of river red gum (RRG_G) and black box woodland (BBW_G). Darker red shading shows larger declines, darker blue shading shows larger improvements, darker shades of grey indicate larger areas where there was no difference in the time in good state.

Vegetation	Scenario	No change	Improve	Decline	Net change
RRG_G	WOD_Y15D25	133021.90	10793.74	126804.70	-116011.00
	Y15D25_Y25D25	203698.43	39718.77	27203.12	12515.65
	Y15D25_Y30D30	189535.93	40671.87	40412.49	259.38
	Y15D25_Y40D40	194828.11	53892.20	21900.00	31992.20
	Y15D25_Y45D40	187496.88	61196.87	21926.56	39270.31
BBW_G	WOD_Y15D25	131828.10	665.61	56596.88	-55931.30
	Y15D25_Y25D25	165623.42	10220.31	13246.88	-3026.57
	Y15D25_Y30D30	166378.12	8664.07	14048.45	-5384.38
	Y15D25_Y40D40	164589.07	5970.29	18531.26	-12560.97
	Y15D25_Y45D40	163703.14	11173.43	14214.08	-3040.65

- Comparing constraint scenarios across the Murray catchment, the largest areas where time in good condition declined for RRG were found between the base case constraint scenario (Y15D25) to the Y30D30 scenario (40,413 ha, Table 5). For BBW, the largest areas where time in good condition declined were between the base case and Y40D40 scenario (18,531 ha, Table 5). For both RRG and BBW the largest areas experienced improvements in the time in good state (61,197 and 11,173 ha respectively, Table 5) under the Y45D40 scenario when compared to the base case (Y15D25).

- Comparing the base case to without development (WOD) flows, showed large areas where time RRG was in good condition declined across the Murray catchment (approximately ~47% of total river red gum area, 126805 ha, Table 5). For BBW the base case to WOD comparison showed predominantly areas declined in their time in good condition or were not changed (56,596 ha decline, Table 5).
- Areas of improvement to the time spent in good condition for RRG were greatest in the Y40D40 and Y45D40 (53,892 ha and 61,197 ha respectively Table 5). For BBW improvements in the time spent in good condition were greatest from the base case to the Y45D40 (11,173 ha), this was closely followed by the Y25D25 option (10,220 ha).

- For the areas of interest:
    - Hume to Yarrawonga Weir (HYW; RiM-FIM: Zone 1) and
    - Yarrawonga Weir to Wakool Junction (YWJ; RiM-FIM: Zone 2 – Zone 9 & all EW-FiM Zones)

Table 6. Mean percentage (with Standard deviation) of time (% of years) river red gum (RRG_G) and black box woodland (BBW_G) were in a good state over modelled time periods. Coloured shading has been included to allow comparison of the constraint options within selected areas of interest (Barmah-Millewa Forest, Koondrook-Perricoota and Gunbower Forest and Downstream Euston weir). The darkest red shading shows the shortest accumulated time, and darkest blue shading shows the longest accumulated time in a good state.

Vegetation	Zone of interest	WOD	Y15D25	Y25D25	Y30D30	Y40D40	Y45D40
RRG_G	*Hume to Yarrawonga*	25.85 (28.81)	32.58 (44.58)	32.72 (44.69)	34.15 (45.29)	40.39 (45.32)	42.16 (46.16)
	Yarrawonga Weir to Wakool Junction	51.00 (41.00)	33.60 (40.70)	34.70 (42.30)	35.20 (42.70)	36.50 (44.30)	42.20 (46.20)
	Barmah-Millewa Forest	65.65 (42.29)	42.89 (40.67)	44.04 (42.10)	45.45 (43.11)	48.65 (45.91)	50.52 (43.98)
	Koondrook-Perricoota and Gunbower Forest	71.96 (42.91)	49.58 (42.14)	53.23 (44.09)	52.86 (43.94)	53.40 (44.45)	53.42 (44.3)
	Downstream Euston weir	57.36 (41.45)	30.93 (40.06)	31.13 (40.16)	31.14 (40.12)	31.18 (40.33)	31.71 (40.56)
BBW_G	*Hume to Yarrawonga*	34.06 (38.5)	24.39 (37.42)	23.56 (37.04)	24.24 (39.1)	31.91 (43.26)	33.10 (44.15)
	Yarrawonga Weir to Wakool Junction	26.3 (36.7)	8.66 (17.90)	9.84 (20.30)	9.81 (20.50)	9.97 (21.00)	9.97 (21.00)
	Barmah-Millewa Forest	38.79 (32.05)	6.17 (13.00)	6.30 (13.44)	6.09 (12.9)	6.16 (13.53)	6.56 (15.19)
	Koondrook-Perricoota and Gunbower Forest	34.9 (44.33)	16.61 (27.38)	21.28 (33.57)	21.51 (33.95)	21.72 (34.39)	21.47 (33.92)
	Downstream Euston weir	29.89 (39.04)	8.03 (14.58)	7.52 (14.61)	7.32 (14.13)	7.03 (13.64)	7.71 (15.19)

  - Barmah-Millewa Forest (BMF; ew_zone2 and Zone3_clip),
  - Koondrook-Perricoota and Gunbower Forest (KPG; zone7_clip),
  - Downstream of Euston weir (DSE; zone12),

  the mean time spent in good condition for the alternative constraint options and without development scenario were compared to the base case. For RRG the highest mean proportion of time in a good state was under the WOD scenario at 72% of the modelled time period in the KPG (Table 6). When assessing the constraint and without development options Y15D25 consistently had the lowest percentage of time in good state (Table 6) with one exception being for RRG in the HYW reach where the Y45D40 constraint option has a higher mean percentage than the WOD scenario.

- Within the proposed constraint options (not including WOD) Y45D40 had the highest percentage of time in good condition of all constraint options (Table 6), although, trends

Table 7. Total area (ha) changes for selected zones of interest (decline, improvement, net change and No change) to time in good condition comparing constraint scenarios to base Constrain scenario for good states of river red gum (RRG_G). Darker red shading shows larger declines, darker blue shading shows larger improvements, shades of yellow (smallest net improvement) and green (largest net improvement) indicate net the area where time in good state improved and Darker shades of grey indicate larger areas where there was no difference in the time in good state.

Vegetation	Zone of interest	Scenario	No change	Improve	Decline	Net Change
RRG_G	Barmah-Millewa Forest	WOD_Y15D25	31803.12	325	45059.37	-44734.4
	(RiM-FIM: Zone 3 Clip;	Y15D25_Y25D25	53573.43	14779.69	8834.37	5945.32
	EW-FIM: zone 2)	Y15D25_Y30D30	45889.06	15364.06	15934.37	-570.31
		Y15D25_Y40D40	46565.63	27310.94	3310.94	24000
		Y15D25_Y45D40	45107.81	32054.68	25	32029.68
	Koondrook-Perricoota and	WOD_Y25D25	12150	1629.69	26206.25	-24576.6
	Gunbower Forest	Y15D25_Y25D25	20364.06	13559.38	6062.5	7496.88
	(RiM-FIM: Zone 7)	Y15D25_Y30D30	16982.81	12657.81	10345.31	2312.5
		Y15D25_Y40D40	23157.81	12359.38	4468.75	7890.63
		Y15D25_Y45D40	17064.06	10910.94	12010.94	-1100
	Downstream Euston weir	WOD_Y15D25	8837.5	70.31	8140.62	-8070.31
	(RiM-FIM: Zone 12)	Y15D25_Y25D25	13092.19	1325	2631.25	-1306.25
		Y15D25_Y30D30	13262.5	1259.38	2526.56	-1267.18
		Y15D25_Y40D40	13239.06	1596.88	2212.5	-615.62
		Y15D25_Y45D40	13825	2017.19	1206.25	810.94
	Hume to Yarrawonga	WOD_Y15D25	2957.81	2406.25	2793.75	-387.5
	(RiM-FIM: Zone 1)	Y15D25_Y25D25	7995.31	62.5	100	-37.5
		Y15D25_Y30D30	7693.75	215.62	248.44	-32.82
		Y15D25_Y40D40	7050	1107.81	0	1107.81
		Y15D25_Y45D40	7078.12	1079.69	0	1079.69
	Yarrawonga Weir to	WOD_Y15D25	116190.6	5967.18	102957.8	-96990.64
	Wakool Junction	Y15D25_Y25D25	170384.4	34534.39	20196.86	14337.53
	(RiM-FIM: Zone 2 – Zone 9)	Y15D25_Y30D30	155728.1	35662.5	33724.99	1937.51
		Y15D25_Y40D40	124960.9	33350.01	10064.05	23285.96
		Y15D25_Y45D40	122859.4	41570.31	3945.31	37625

across options from the base case through higher volume options were not consistent between areas of interest. For BBW the highest mean proportion of time in a good state was under the WOD scenario at 39% of the modelled time period at BMF (Table 6). When assessing the response of BBW time in good condition to constraint options, trends were highly variable and site specific.

- Comparing the area where time in a good condition improved or declined between the base case and other scenarios showed a general trend for net change to increase as flow constraints were relaxed (Table 7 and 8) though this also was highly variable between scenarios, zones of interest and vegetation type.

Table 8. Total area (ha) changes for selected zones of interest (decline, improvement, net change and No change) to time in good condition comparing constraint scenarios to base Constrain scenario for good states of black box woodland (BBW_G). Darker red shading shows larger declines, darker blue shading shows larger improvements, shades of yellow (smallest net improvement) and green (largest net improvement) indicate net the area where time in good state improved and Darker shades of grey indicate larger areas where there was no difference in the time in good state.

Vegetation	Zone of interest	Scenario	No change	Improve	Decline	Net Change
BBW_G	Barmah-Millewa Forest	WOD_Y15D25	4806.25	1.56	6260.94	-6259.38
	(RiM-FIM: Zone 3 Clip;	Y15D25_Y25D25	10925	104.68	39.06	65.62
	EW-FIM: zone 2)	Y15D25_Y30D30	10860.93	93.76	114.07	-20.31
		Y15D25_Y40D40	10850	168.74	50	118.74
		Y15D25_Y45D40	10842.19	198.44	28.13	170.31
	Koondrook-Perricoota and	WOD_Y15D25	5939.06	59.38	2607.81	-2548.43
	Gunbower Forest	Y15D25_Y25D25	6960.94	1445.31	200	1245.31
	(RiM-FIM: Zone 7)	Y15D25_Y30D30	6846.88	1584.38	175	1409.38
		Y15D25_Y40D40	6743.75	1640.62	221.88	1418.74
		Y15D25_Y45D40	6710.94	1673.44	221.88	1451.56
	Downstream Euston weir	WOD_Y15D25	32395.31	6.25	14095.31	-14089.1
	(RiM-FIM: Zone 12)	Y15D25_Y25D25	39225	940.62	6331.25	-5390.63
		Y15D25_Y30D30	39745.31	315.62	6435.94	-6120.32
		Y15D25_Y40D40	38306.25	301.56	7889.06	-7587.5
		Y15D25_Y45D40	38396.88	1601.56	6498.44	-4896.88
	Hume to Yarrawonga	WOD_Y15D25	92.19	28.12	59.38	-31.26
	(RiM-FIM: Zone 1)	Y15D25_Y25D25	170.31	0	9.38	-9.38
		Y15D25_Y30D30	162.5	6.25	10.94	-4.69
		Y15D25_Y40D40	157.81	21.88	0	21.88
		Y15D25_Y45D40	156.25	23.44	0	23.44
	Yarrawonga Weir to	WOD_Y15D25	68906.25	412.5	25235.94	-24823.4
	Wakool Junction	Y15D25_Y25D25	74020.3	3278.13	1370.3	1907.83
	(RiM-FIM: Zone 2 – Zone 9)	Y15D25_Y30D30	73989.05	2514.07	2165.64	348.43
		Y15D25_Y40D40	74623.44	2537.48	1507.82	1029.66
		Y15D25_Y45D40	73885.94	3017.19	1765.63	1251.56

- Significant declines in time in good condition marked the only real difference for both RRG and BBW with respect to the WOD scenario (Tables 7 and 8). The greatest net change in time spent in a good condition for both RRG and BBW when compared to the without development case in most cases was the Y45D40 constraint, the exception was for RRG areas at KPG under the Y40D40 constraint.

- When comparing the constraint options to the base case at each of these locations, with the exception of RRG at KPG, Y45D40 showed the largest areas of improvement to time in good condition for all locations and both RRG and BBW (Table 7). The RRG at KPG showed a trend of decreasing area of increased time in good condition as constraints lifted from Y25D25 to

Y45D40. This meant the areas of net improvement were within 5% of one another for the Y25D25 to Y45D40 scenarios when compared to base constraints.

Discussion

The health of floodplain vegetation communities along the Murray River has declined considerably as a result of river regulation and altered flow regimes. The Reconnecting River Country Program is assessing options for raised flow limits for water for the environment to improve the condition of floodplain vegetation communities. This report summarises the predicted vegetation outcomes in the Murray valley between Hume Dam and the Darling River junction under five scenarios of constraint relaxation to identify impacts to the health of the community under alternative constraint relaxation scenarios.

Vegetation responses were modelled using the Floodplain Vegetation Condition Model (FVCM) a newly developed state and transition simulation model (STSM) applied to rasterised layers of vegetation community type and condition. The STSM approach provides dynamic time-series of vegetation condition in response to different inundation sequences (defined in terms of frequency, and duration). Vegetation condition was quantified on an interval scale (*critical*, *poor*, *intermediate*, *moderate*, and *good*), with numeric values for condition ranging from 0-1.

The model provides an estimate of expected vegetation condition at each time-step, which can be mapped across the floodplain and summarised by aggregating results in space and/or time. The overall finding from the modelling is that relaxation of operational constraints on river flows has the potential to improve outcomes for floodplain vegetation, although there were some notable differences between the five scenarios in long-term outcomes. The findings can be summarised as follows:

- The model was able to capture the dynamic nature of vegetation condition over time (Appendix 1), in particular capturing declines in condition associated with drought sequences.
- While temporally variable, the benefits of higher levels of constraint relaxation on areas of modelled vegetation in good condition (Appendix 1. Figures 6-9) were most visible during periods of particularly dry climate conditions (e.g. 1914-15, 1937-45, 1982-83 & 1997-2009), suggesting constraints relaxation has its greatest influence during dry conditions.
- Overall, black box woodland showed the smallest improvements, which is in part due to this vegetation type being largely beyond the floodplain extents that can be influenced by constraints relaxation.
- Generally, the response of river red gum forests and woodlands to the relaxation of constraint options was a net improvement in good condition area. However, this net

improvement with constraint relaxation was not observed across all constraint scenarios or locations of interest. This is likely due to variability in the spatial distribution of vegetation at the catchment scale, with respect to inundation thresholds, and how each vegetation unit experienced inundation events.

- Comparing each scenario to the base case, overall Y45D40 delivered the best outcomes. The highest mean time in good condition (Table 6) and the largest increases in the area of river red gum in good condition, and only moderate declines in the area of black box woodland in good condition were seen in this scenario.
- Differences between key sites were also evident. Overall, the larger relative proportion of low-lying floodplain at the Barmah-Millewa Forest meant that greater improvements in vegetation condition are predicted to occur there relative to other sites.
- Larger influences of flow constraint relaxation on vegetation condition were seen in reaches further upstream in the catchment. This may indicate that the attenuation of flows across the catchment will result in a decreasing impact of constraint relaxation as water reaches sites further downstream.

In summary, the FVCM provides a step-change in the ability to assess floodplain vegetation responses to changes in floodplain inundation. It shows an overall positive outcome from constraints relaxation, with the largest improvements under the 'Y45D40' scenario when considering the whole catchment scale and multiple vegetation types. While the model will benefit from further refinement, the current predictions align with expert opinion of the impacts of alternate flow constraints though improve upon this by providing a spatially and temporally explicit framework for quantifying outcomes in ways that have not previously been possible.

Future directions

At the time of development of Version 1.0 of the FVCM, presented here, inundation/drying period experienced by floodplain vegetation was the sole metric able to be derived from supplied 'commence-to-fill' inundation maps (RIMFiM and EW-FiM) and modelled hydrology ('Source river system modelling'). Additionally, our derivation of the response of vegetation to inundation spells was completed via expert elicitation which while a positive first step requires some refinement.

The following 'future directions' are a summary of multiple workshops and meetings around future functionality of the FVCM:

- There are vegetation condition responses that may rely on other sources of water (i.e. ground water and rainfall) that were not available to be incorporated into the current model projections.
- A more useful representation of basin wide soil moisture index and floodplain residence time of water in a spatially explicit format would improve the accuracy of the inundation events modelled in the FVCM currently as 'commence-to-fill' derivations.
- Definitions and understanding of individual plant health (in the case of canopy species) or vegetation community condition (i.e. "Healthy river red gum forest" vs "Healthy river red gum woodland") would improve the current models approach to modelling "Vegetation condition" outcomes.
- The early stages of modelling floodplain vegetation empirically to derive "state transition rules" has been completed by staff from La-Trobe to assess if condition responses to inundation should be completed across a floodplain gradient for vegetation community types. This will eventually help to determine if responses are uniform to flooding, or spatial context of vegetation influences the inundation/drought response.
- Finally, Transitions in vegetation community type, e.g. between dead wetland herbland and an establishing river red gum thicket, has been identified as a future direction for addressing issues associated with woody-vegetation encroachment and floodplain community scale transitions.

Acknowledgments

Thanks to the following people that participated in and formed the workshop group of experts that that helped determine the transition rules for the State and Transition framework for floodplain vegetation: Cherie Campbell, Tanya Mason, Thomas Job, Keith Ward, Rachael Thomas, Susan Gehrig, Mark Henderson, Samantha Dawson, Paul Doyle, Ian Burns and Iwona Conlan.

Appendix 1. Time-series of floodplain area in ‘good’ condition

Catchment scale

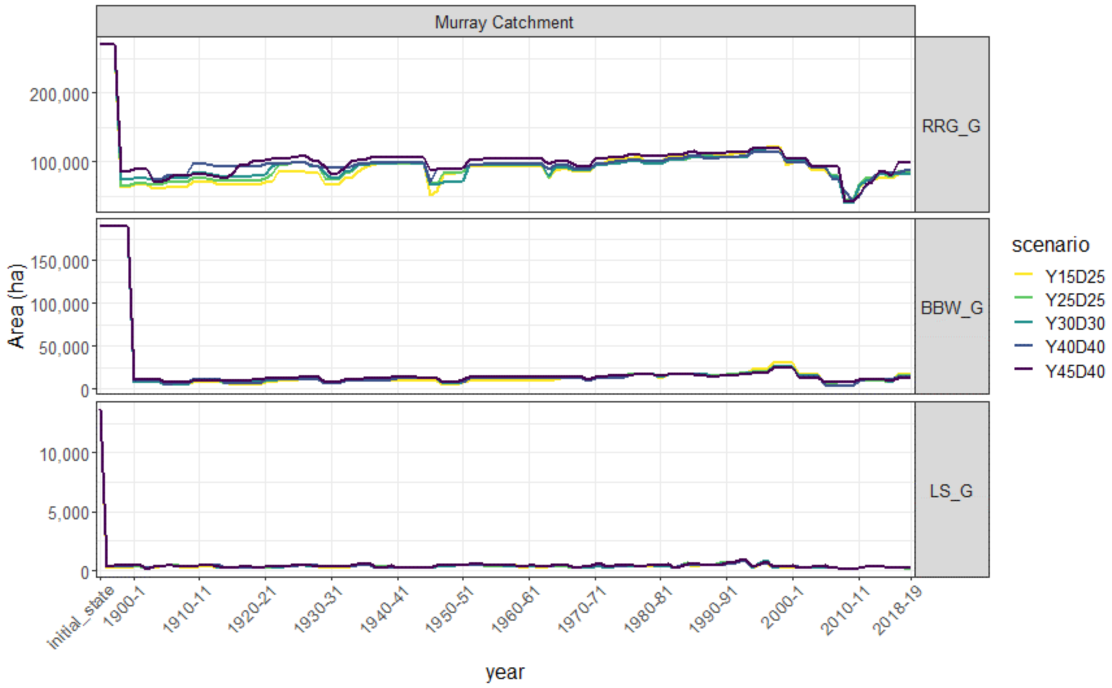


Figure 6. Time series of the area of each vegetation type (RRG_G- river red gum; BBW- black box woodland; LS_G - lignum shrubland) in good condition in each year. “initial_state” represents the total area of the vegetation type in the Murray catchment.

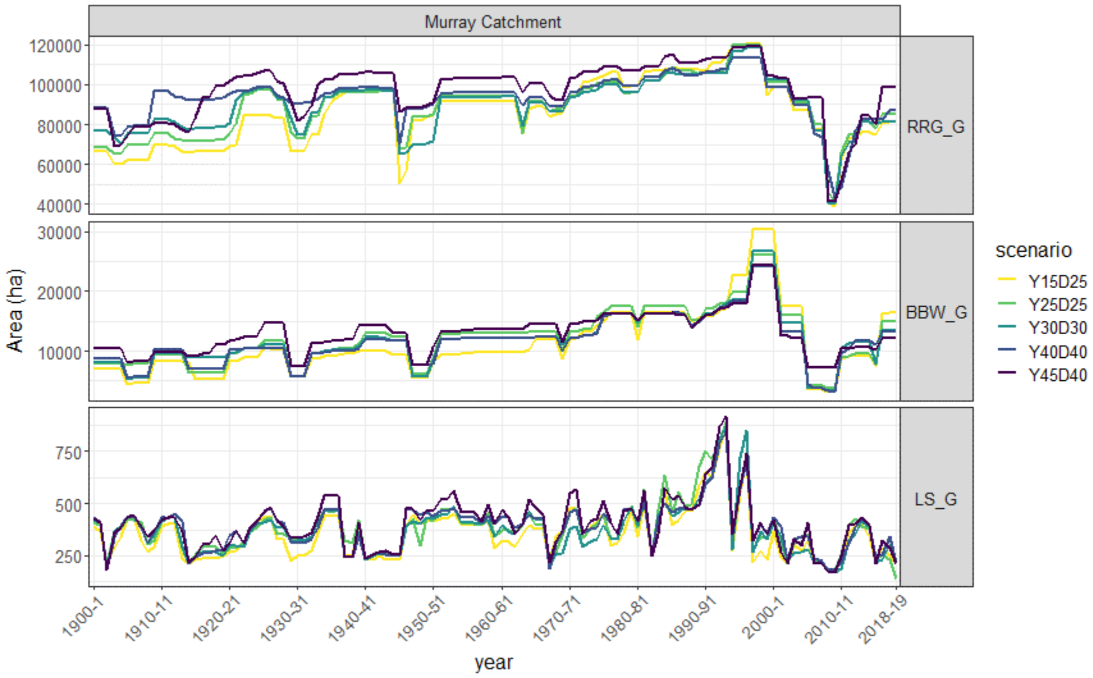


Figure 7. Truncated time series (1900-1 – 2018-19) to remove large declines in original areas of vegetation stand. Time series shows the area of each vegetation type (RRG_G- river red gum; BBW- black box woodland; LS_G - lignum shrubland) in good condition in each year.

Zone 1: Hume Dam to Yarrawonga Weir

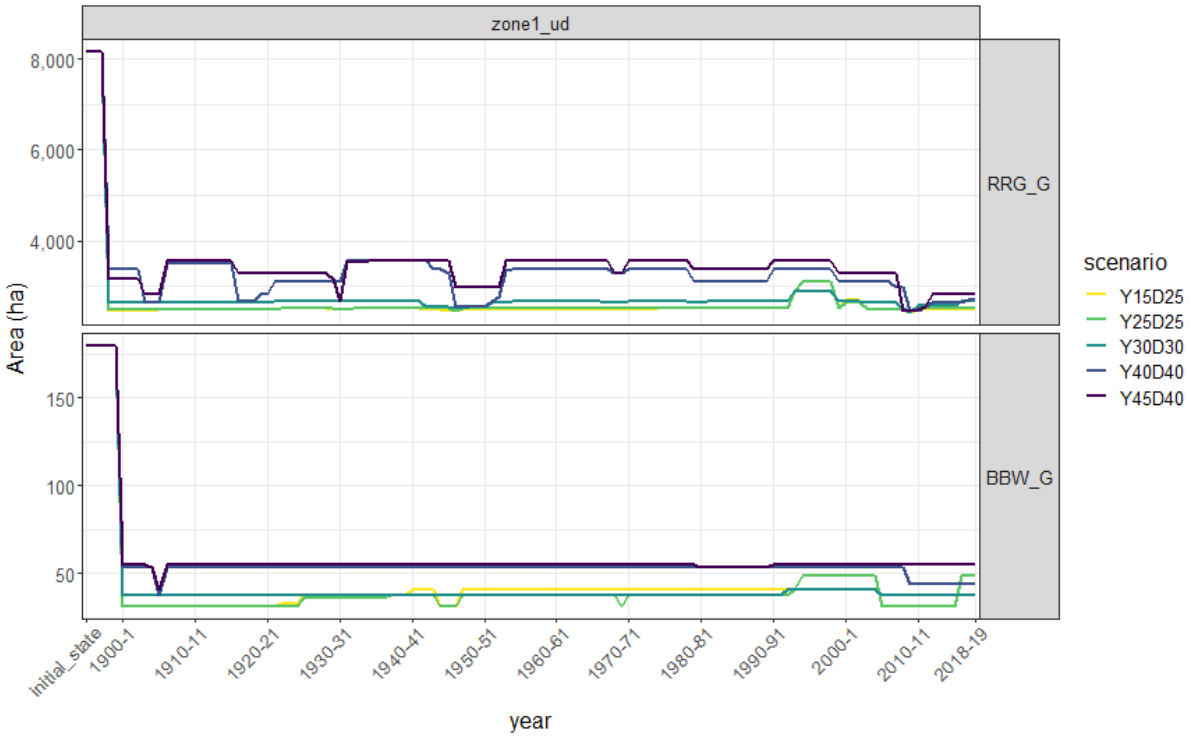


Figure 8. Time series of the area of each vegetation type (RRG_G- river red gum; BBW- black box woodland; LS_G - lignum shrubland) in good condition in each year for Hume Dam to Yarrawonga Weir (Zone 1; zone1_ud). "initial_state" represents the total area of the vegetation type in the Murray catchment at the point of model initialisation.

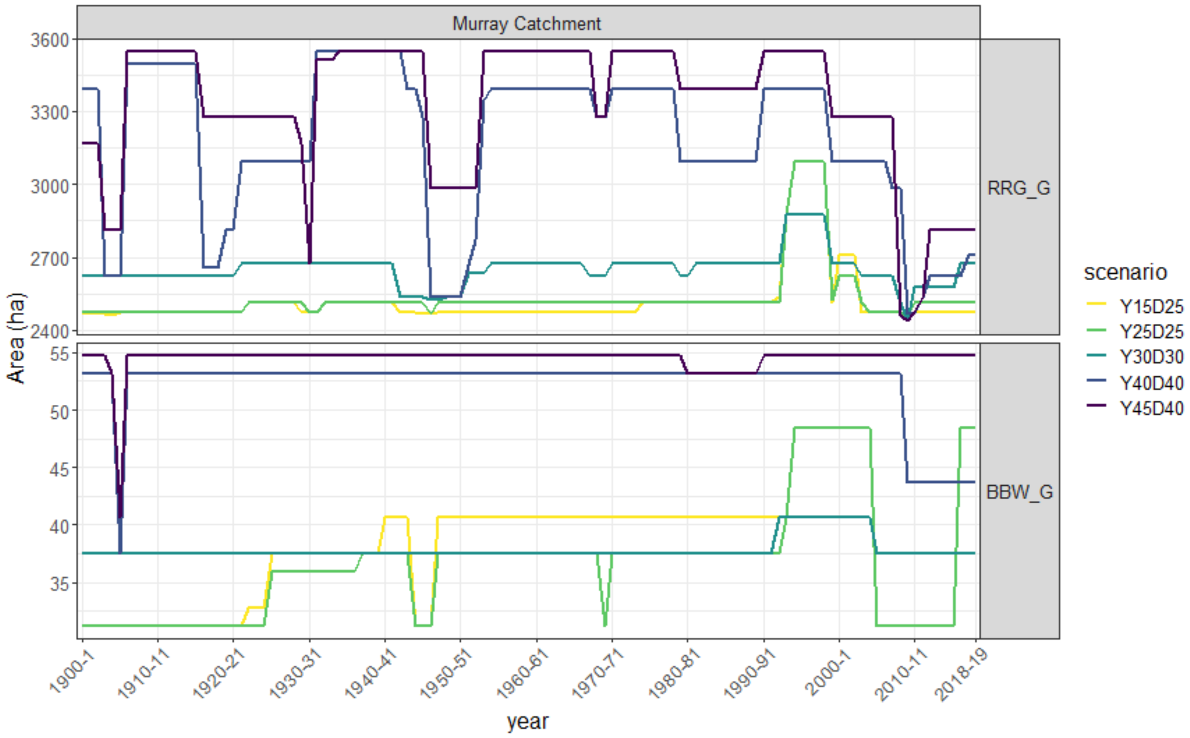


Figure 9 Truncated time series (1900-1 – 2018-19) to remove large declines in original areas of vegetation stand. Time series shows the area of each vegetation type (RRG_G- river red gum; BBW- black box woodland; LS_G - lignum shrubland) in good condition in each year for Hume Dam to Yarrawonga Weir (Zone 1).

Zone 2 – Zone 9: Yarrawonga Weir to Wakool Junction

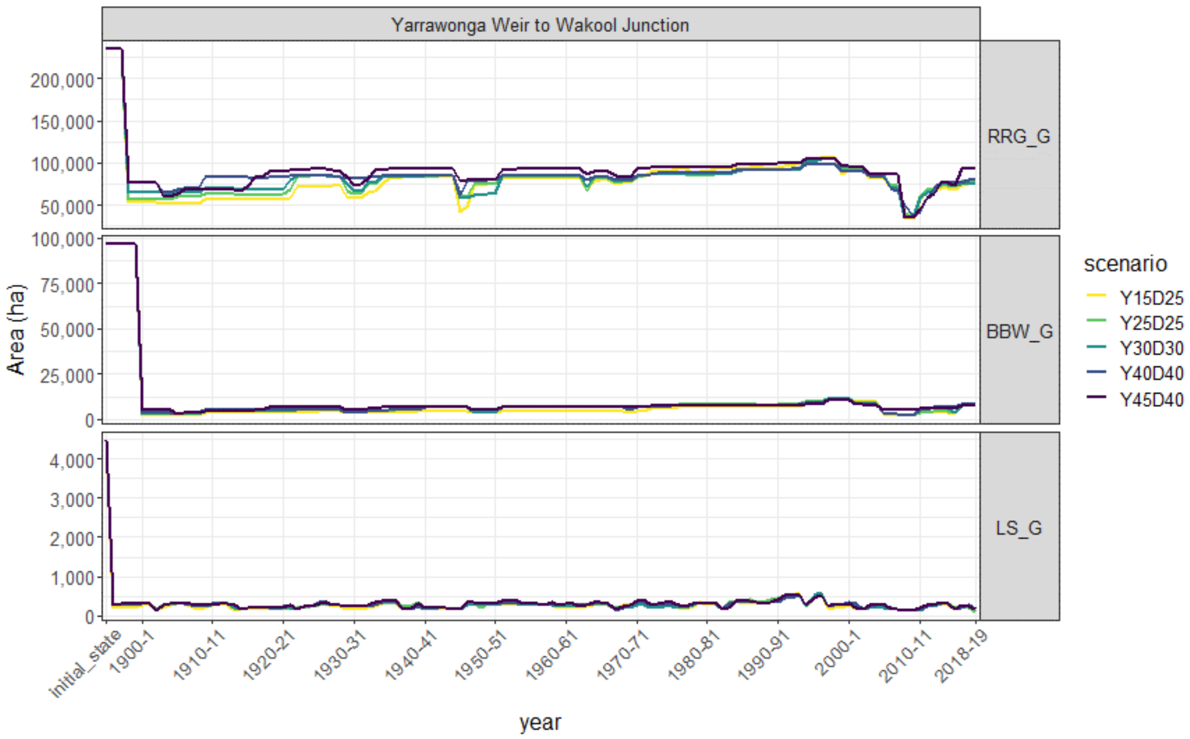


Figure 10. Time series of the area of each vegetation type (RRG_G- river red gum; BBW- black box woodland; LS_G - lignum shrubland) in good condition in each year for Yarrawonga Weir to Wakool Junction (Zone 2 - 9). "initial_state" represents the total area of the vegetation type in the Murray catchment.

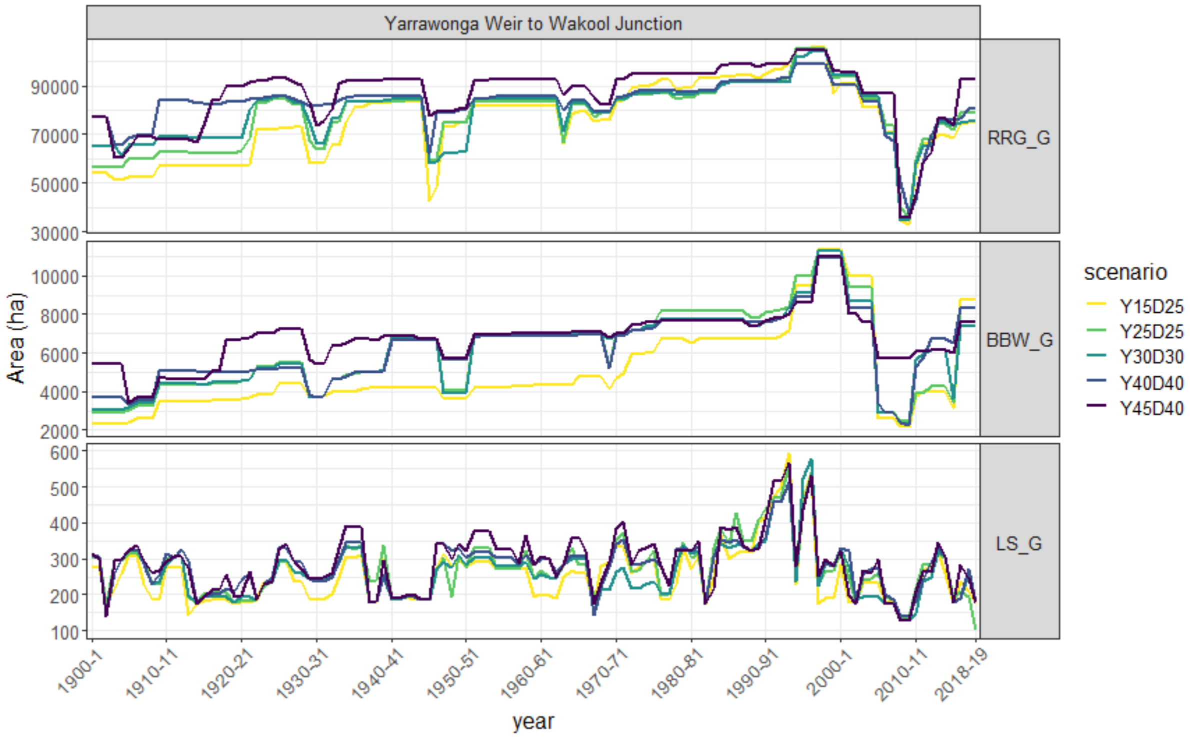


Figure 11. Truncated time series (1900-1 – 2018-19) to remove large declines in original areas of vegetation stand. Time series shows the area of each vegetation type (RRG_G- river red gum; BBW- black box woodland; LS_G - lignum shrubland) in good condition in each year for Yarrawonga Weir to Wakool Junction (Zone 2-9).

Appendix 2. River red gum outputs

Accumulation plots

Comparisons of constraint relaxation scenarios with the base case (Y15D25)

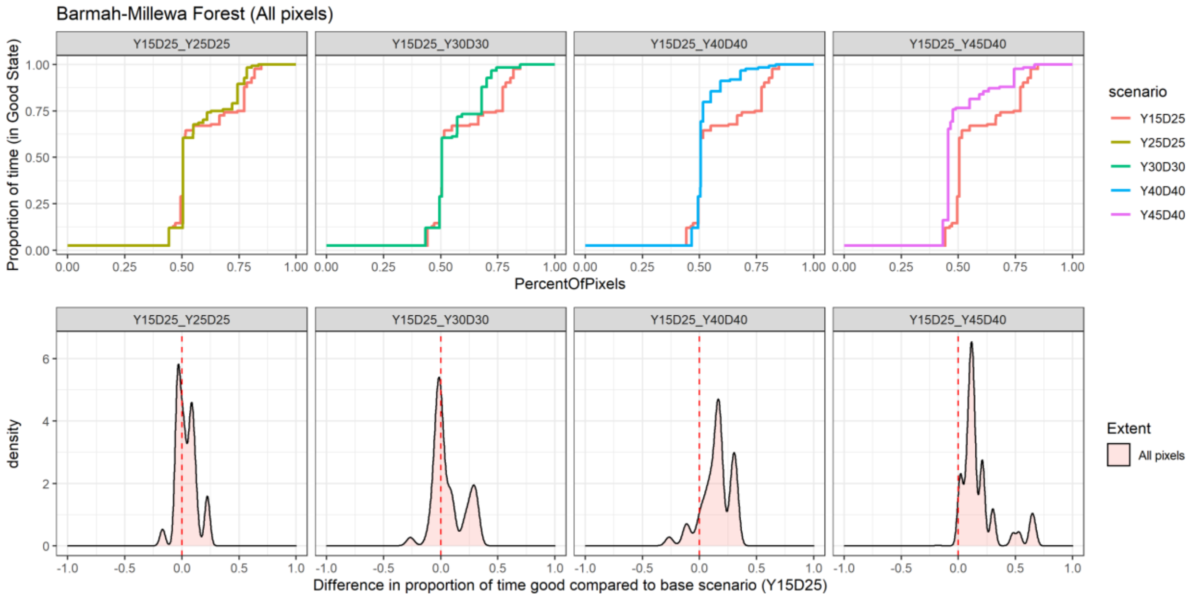


Figure 12. BMF All pixels, Difference in proportion of time in a good state between constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). Top panels show the cumulative distribution of Proportion of time in a good state for RRG pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for BMF (zone2 EW-FIM and zone3 RIMFIM)

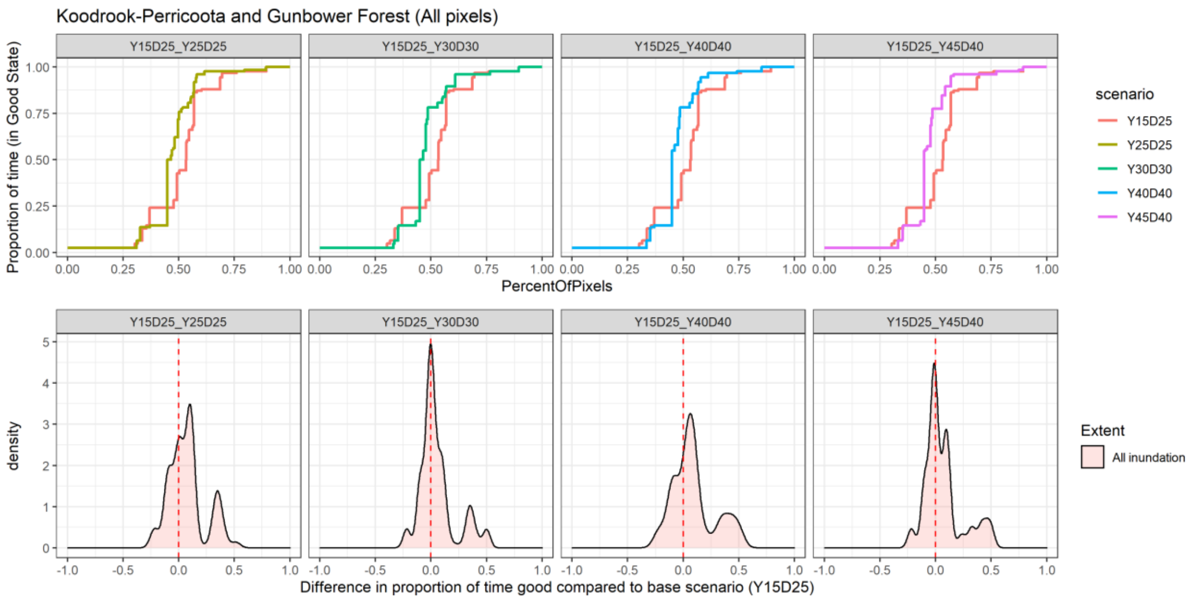


Figure 13. KP-GB All pixels, Difference in proportion of time in a good state between constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). Top panels show the cumulative distribution of Proportion of time in a good state for RRG pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for KP-GF (zone7 RIMFIM)

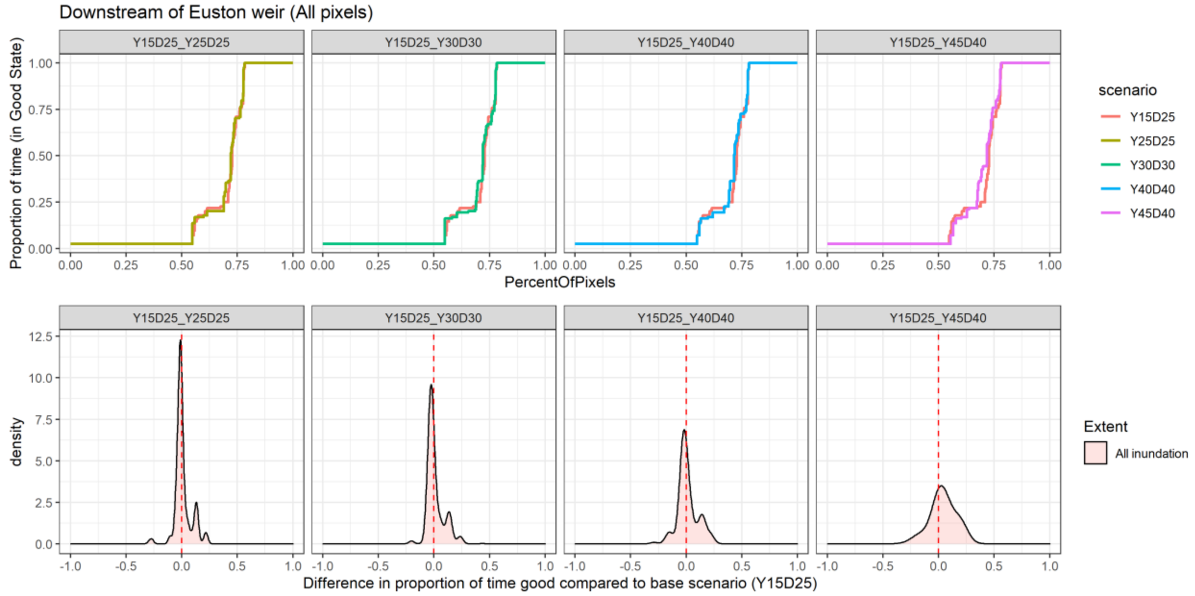


Figure 14. DS Euston weir All pixels, Difference in proportion of time in a good state between constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). Top panels show the cumulative distribution of Proportion of time in a good state for RRG pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for DS Euston weir (zone12)

Comparison of constraint relaxation scenarios to the without development scenario

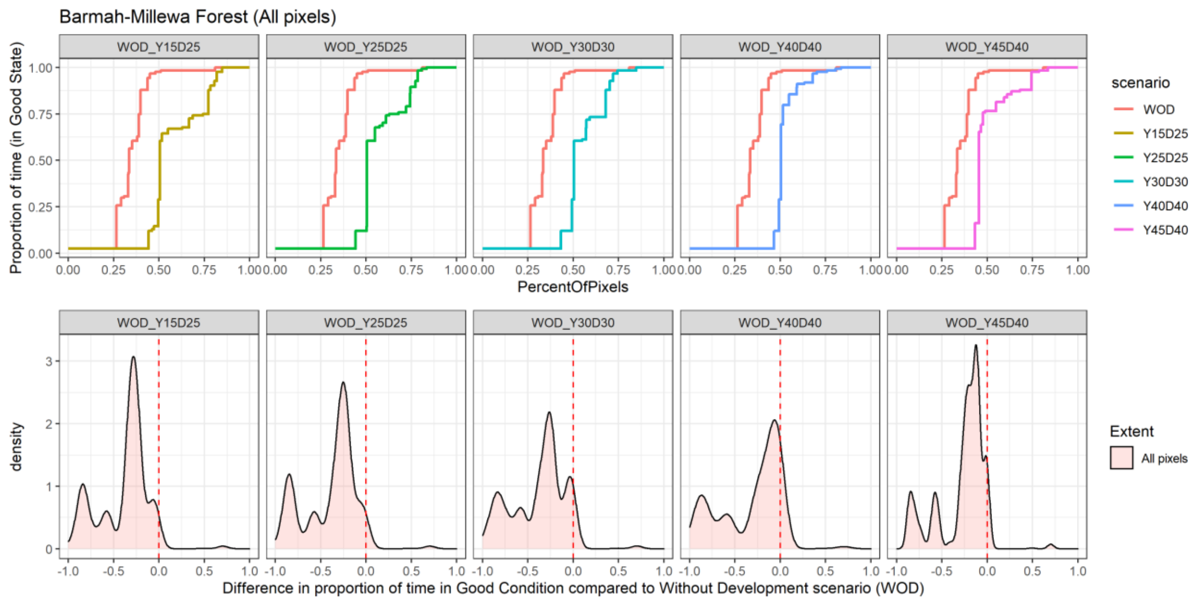


Figure 15. BMF All pixels, Difference in proportion of time in a good state between without development scenario (WOD) and constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). Top panels show the cumulative distribution of Proportion of time in a good state for RRG pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for BMF (zone2 EW-FIM and zone3 RIMFIM)

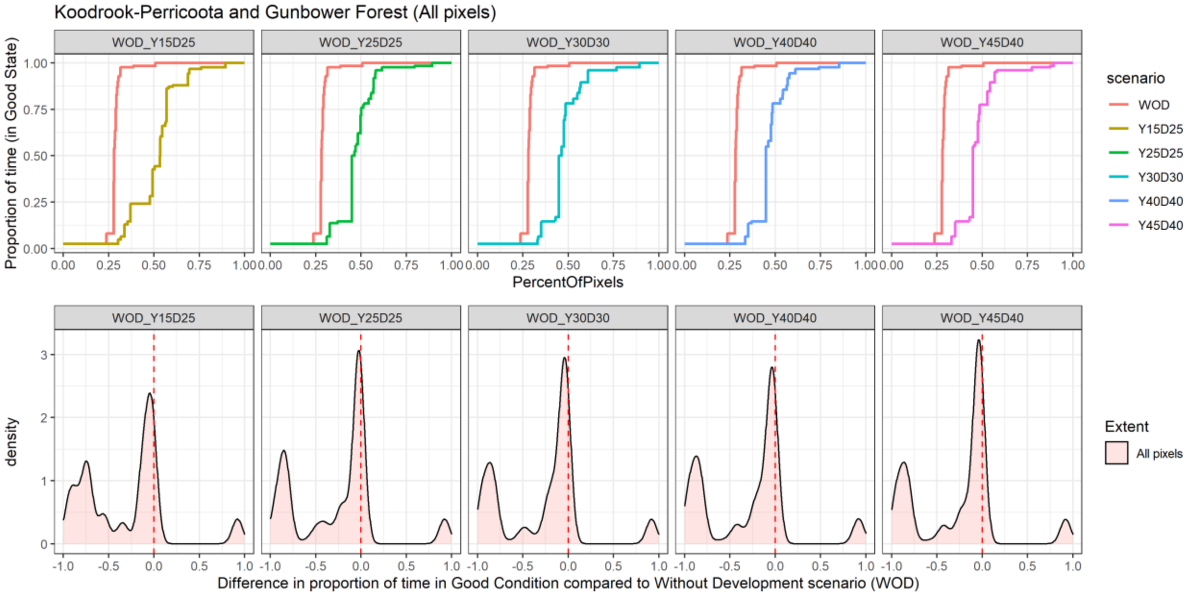


Figure 16. KP-GB All pixels, Difference in proportion of time in a good state between without development scenario (WOD) and constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). Top panels show the cumulative distribution of Proportion of time in a good state for RRG pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for KP-GF (zone7 RIMFIM)

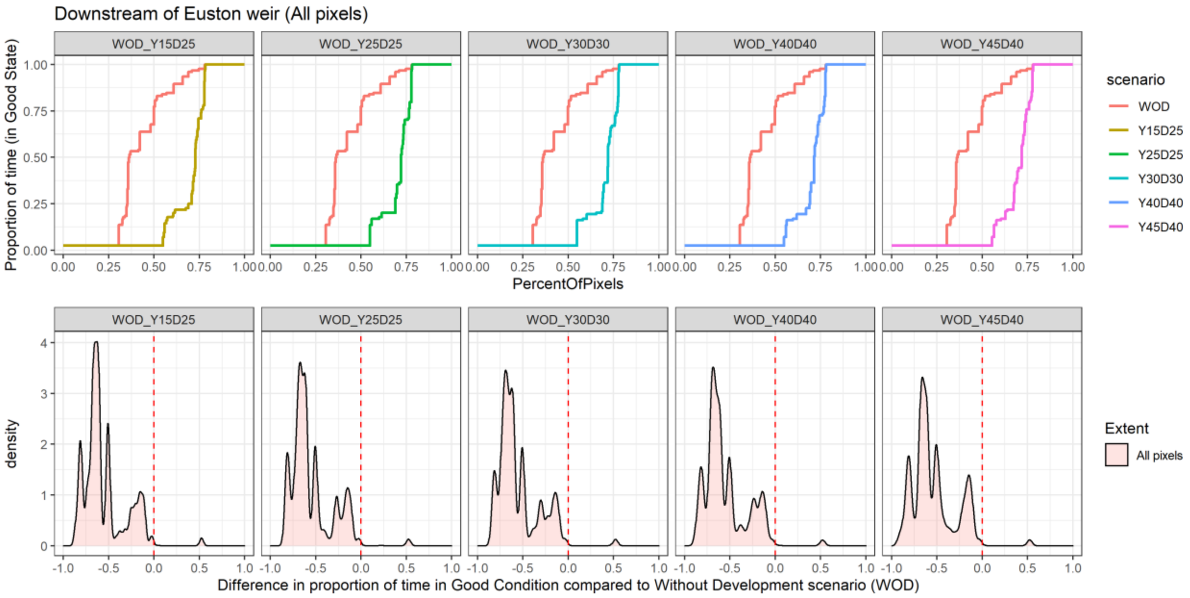


Figure 17. DS Euston weir (all pixels) Difference in proportion of time in a good state between without development scenario (WOD) and constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). Top panels show the cumulative distribution of Proportion of time in a good state for RRG pixels and the bottom pannels show the difference in the proportion of time in good state between WOD and each Constraint scenario for DS Euston weir (zone12 RIMFIM)

Spatial plots of proportion good condition

Proportion good by constraint option

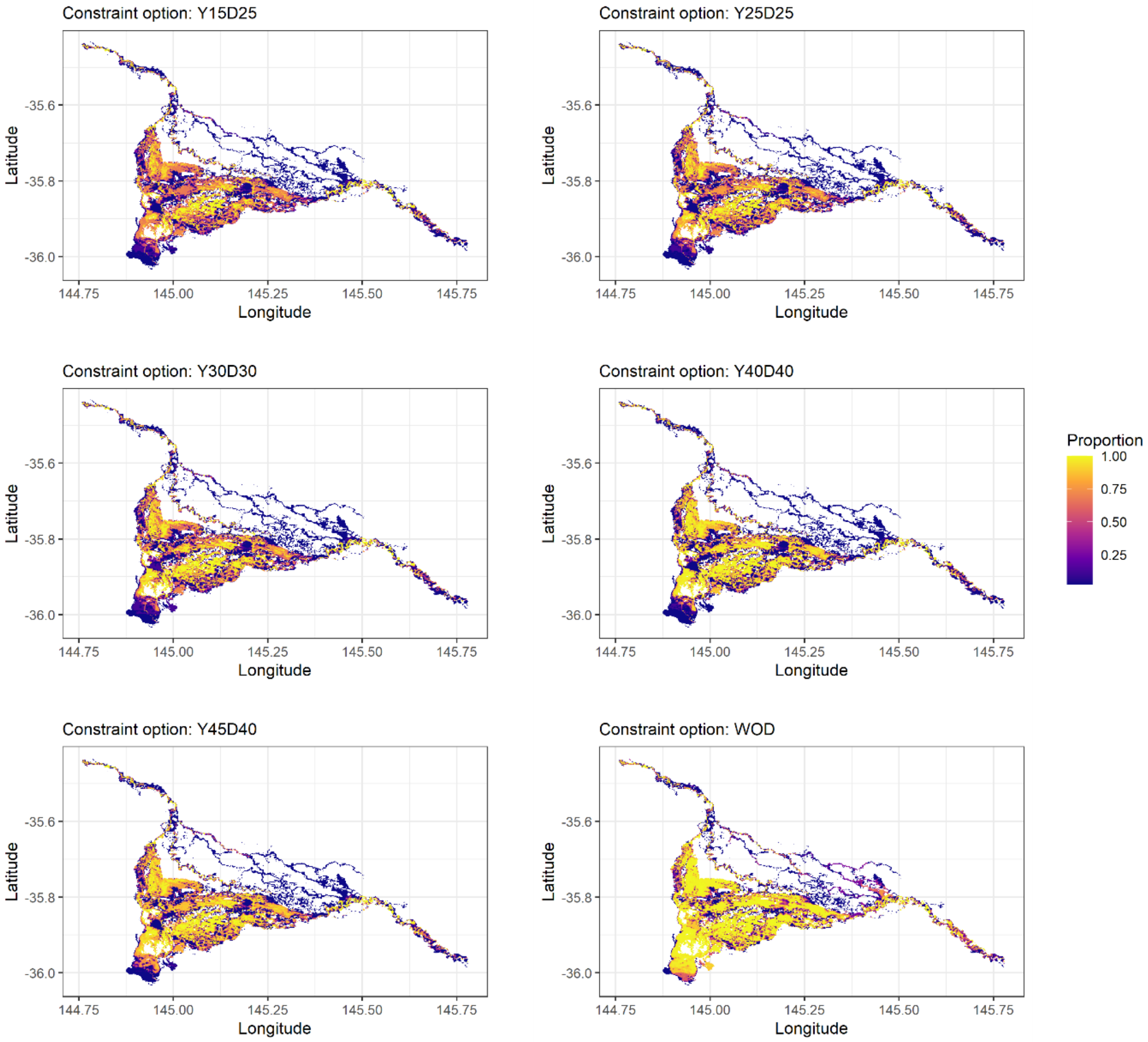


Figure 18. Barmah-Millewa forest (RIMFIM Zone3_clip and EW-FIM zone2) showing the proportion of time river red gum is in a good condition in each constraint option (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40) and the Without Development (WOD) scenario.

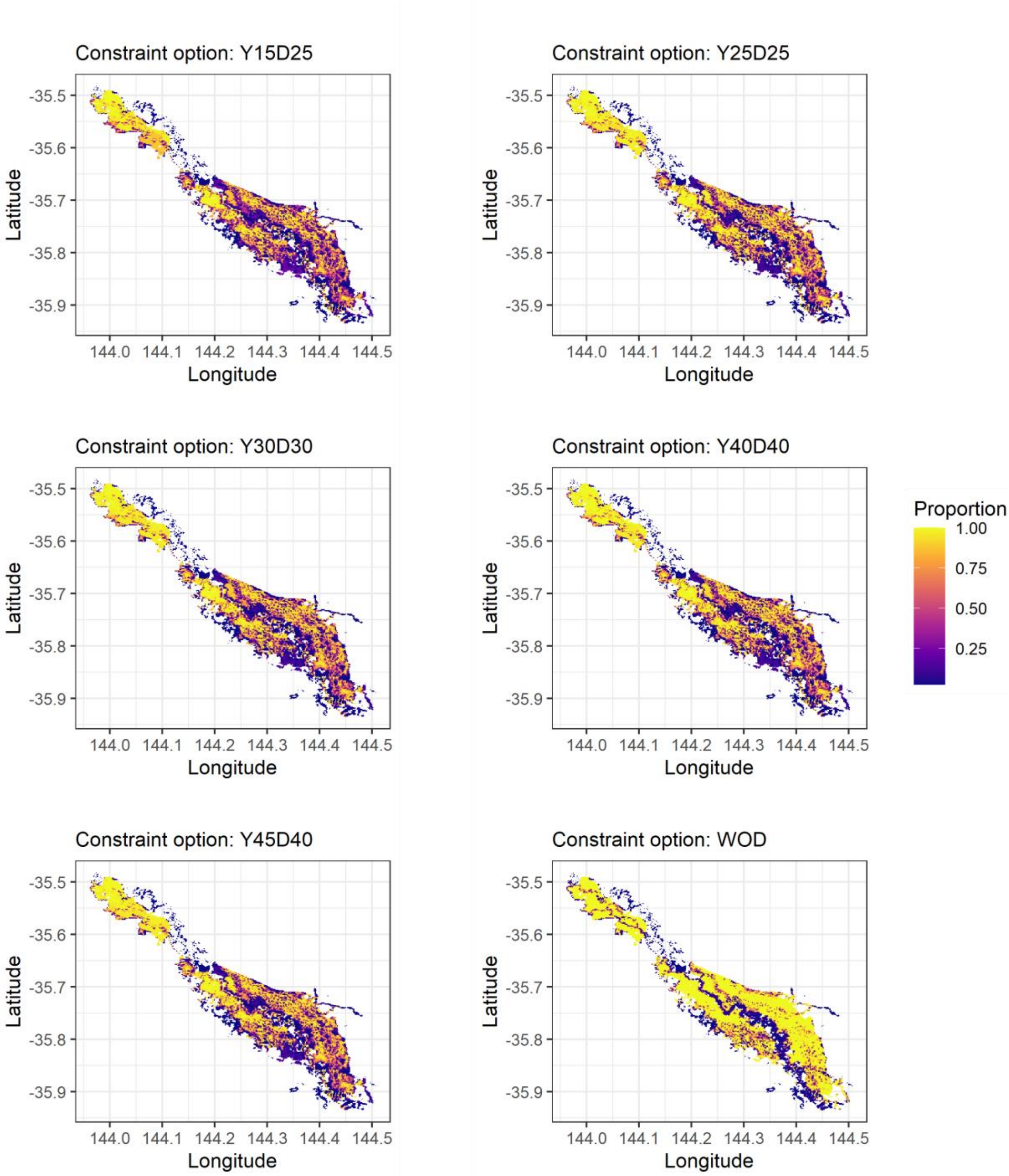


Figure 19. Koondrook-Perricoota and Gunbower forest (RIMFIM zone 7) showing the proportion of time river red gum is in a good condition in each constraint option (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40) and the Without Development (WOD) scenario.

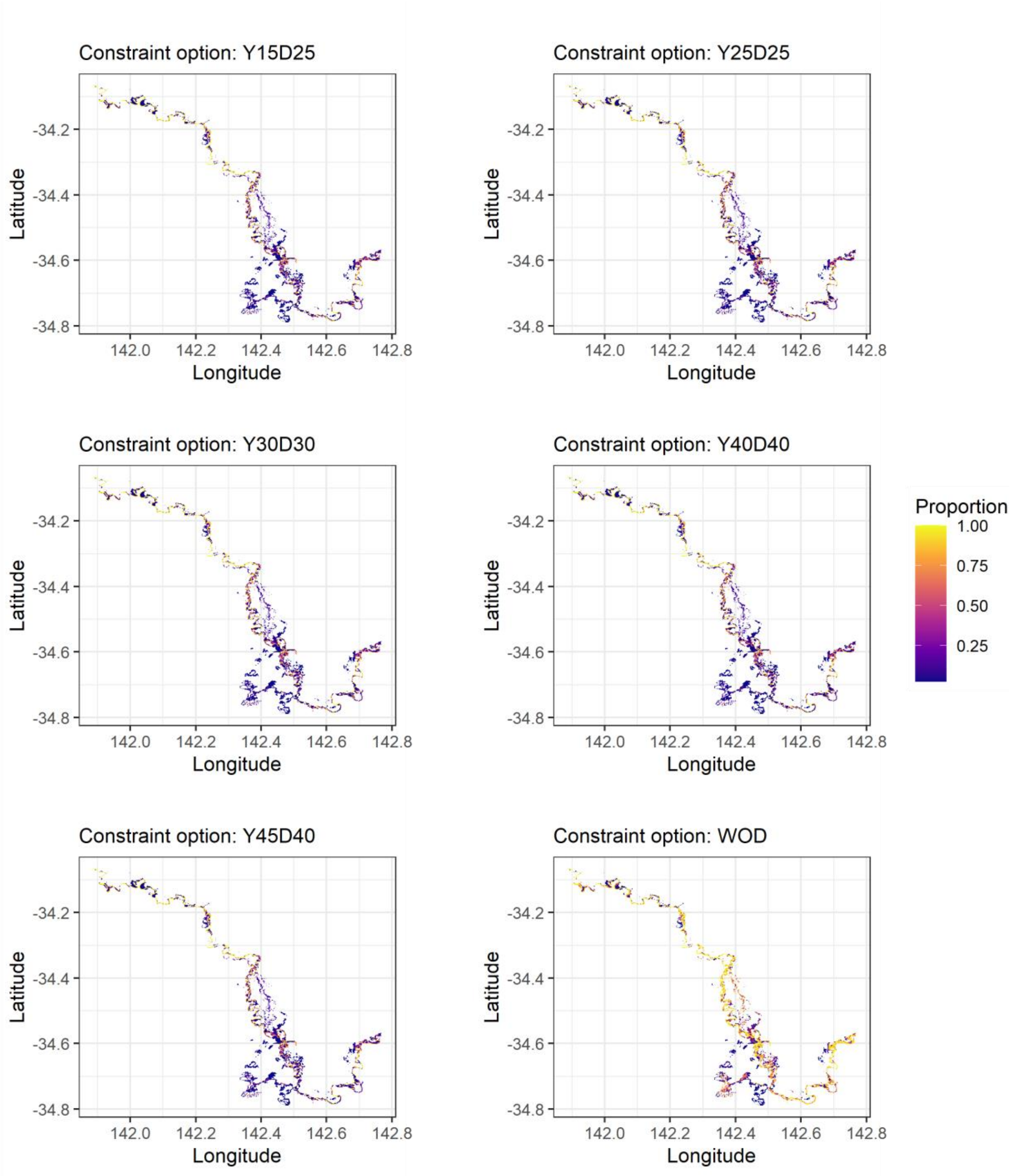


Figure 20. Downstream of Euston weir (RIMFIM zone12) showing the proportion of time river red gum is in a good condition in each constraint option (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40) and the Without Development (WOD) scenario.

Change in proportion good between constraint relaxation scenarios and the base case (Y15D25)

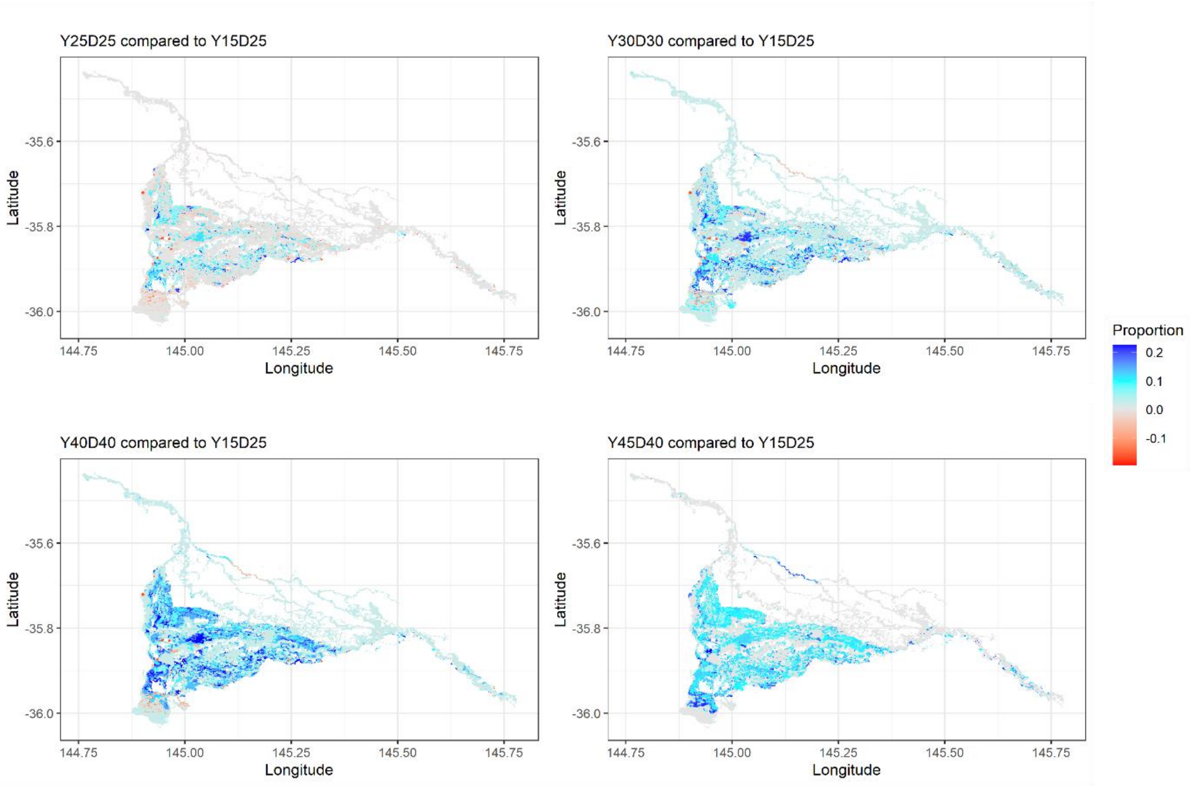


Figure 21. Barmah-Millewa forest (RIMFIM zone3 EWFIM zone2) showing the difference in proportion of time river red gum is in a good state between the baseline constraints scenario (Y15D25) and each constraint relaxation option (Y15D25_Y25D25, Y15D25_Y30D30, Y15D25_Y40D40, Y15D25_Y45D40). Colour shows areas where constraint relaxation, from baseline increased (darker blues correlate with greater increase) or decreased (reds correlate with greater increase) the proportion of time a pixel was in a good condition.

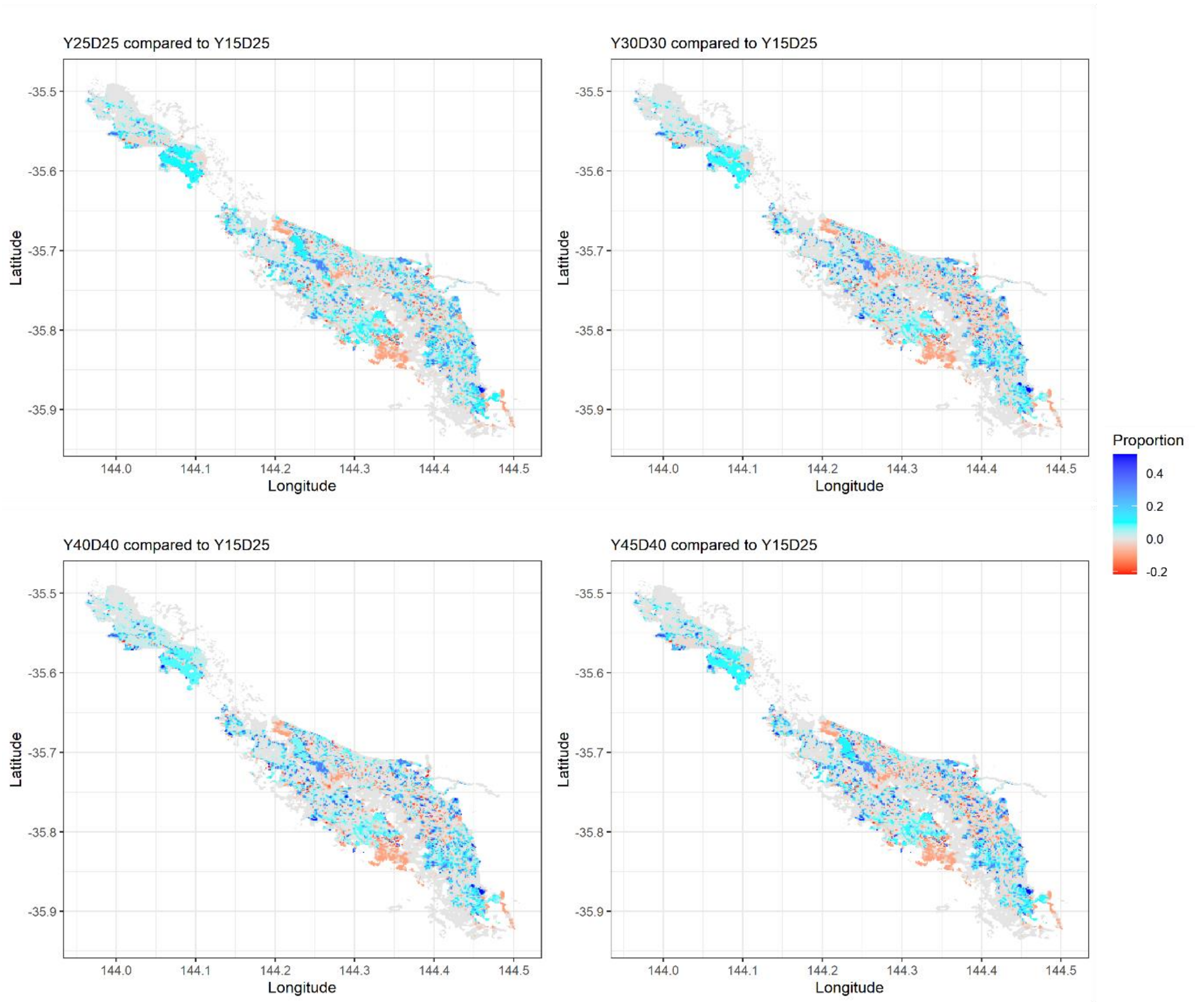


Figure 22. Koondrook-Perricoota and Gunbower forest (RIMFIM zone 7) showing the difference in proportion of time river red gum is in a good state between the baseline constraints scenario (Y15D25) and each constraint relaxation option (Y15D25_Y25D25, Y15D25_Y30D30, Y15D25_Y40D40, Y15D25_Y45D40). Colour shows areas where constraint relaxation, from baseline increased (darker blues correlate with greater increase) or decreased (reds correlate with greater increase) the proportion of time a pixel was in a good condition.

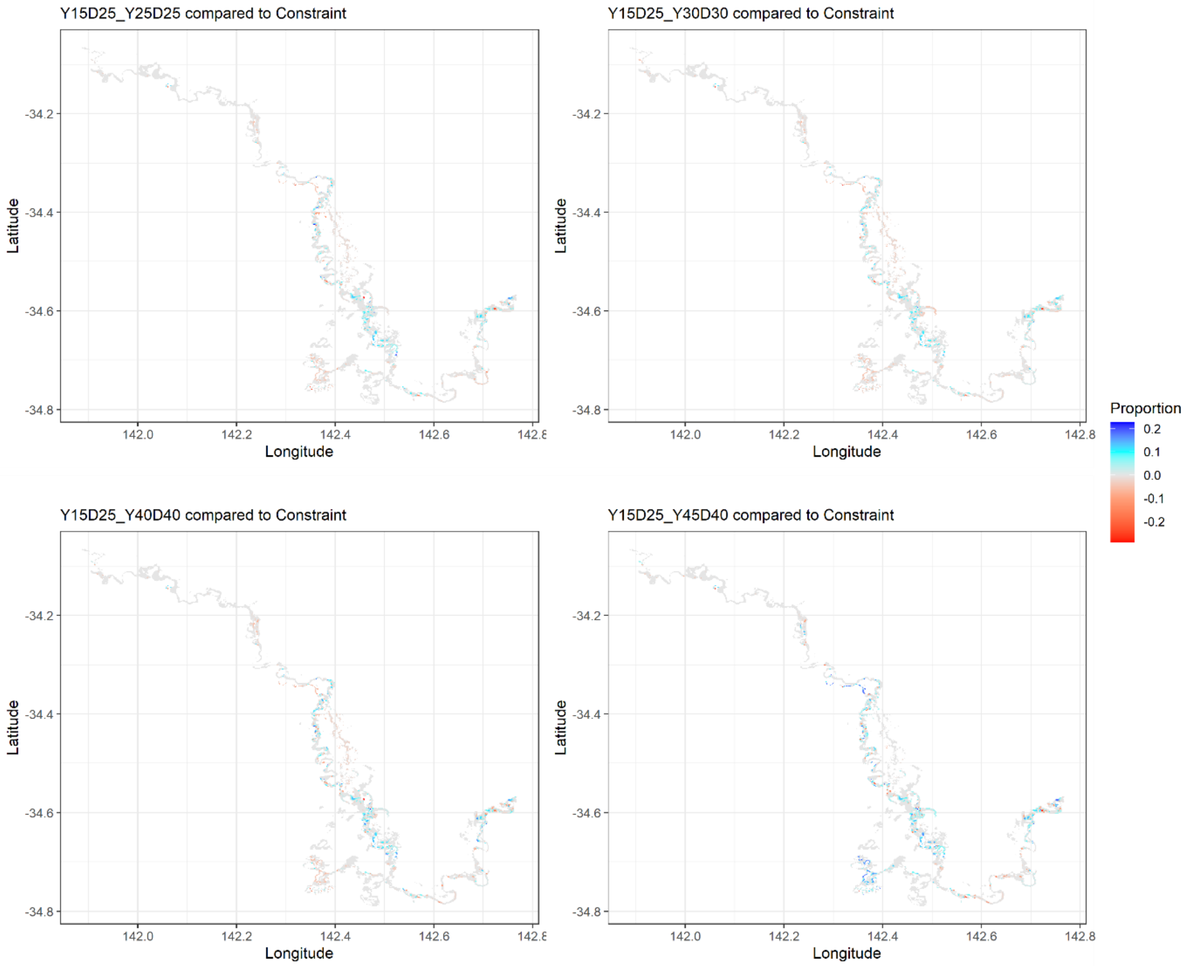


Figure 23. Downstream of Euston weir (zone 12) showing the change in proportion of time river red gum is in a good state between the without development scenario and each constraint relaxation option (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40).

Change in proportion good between base case and without development scenarios

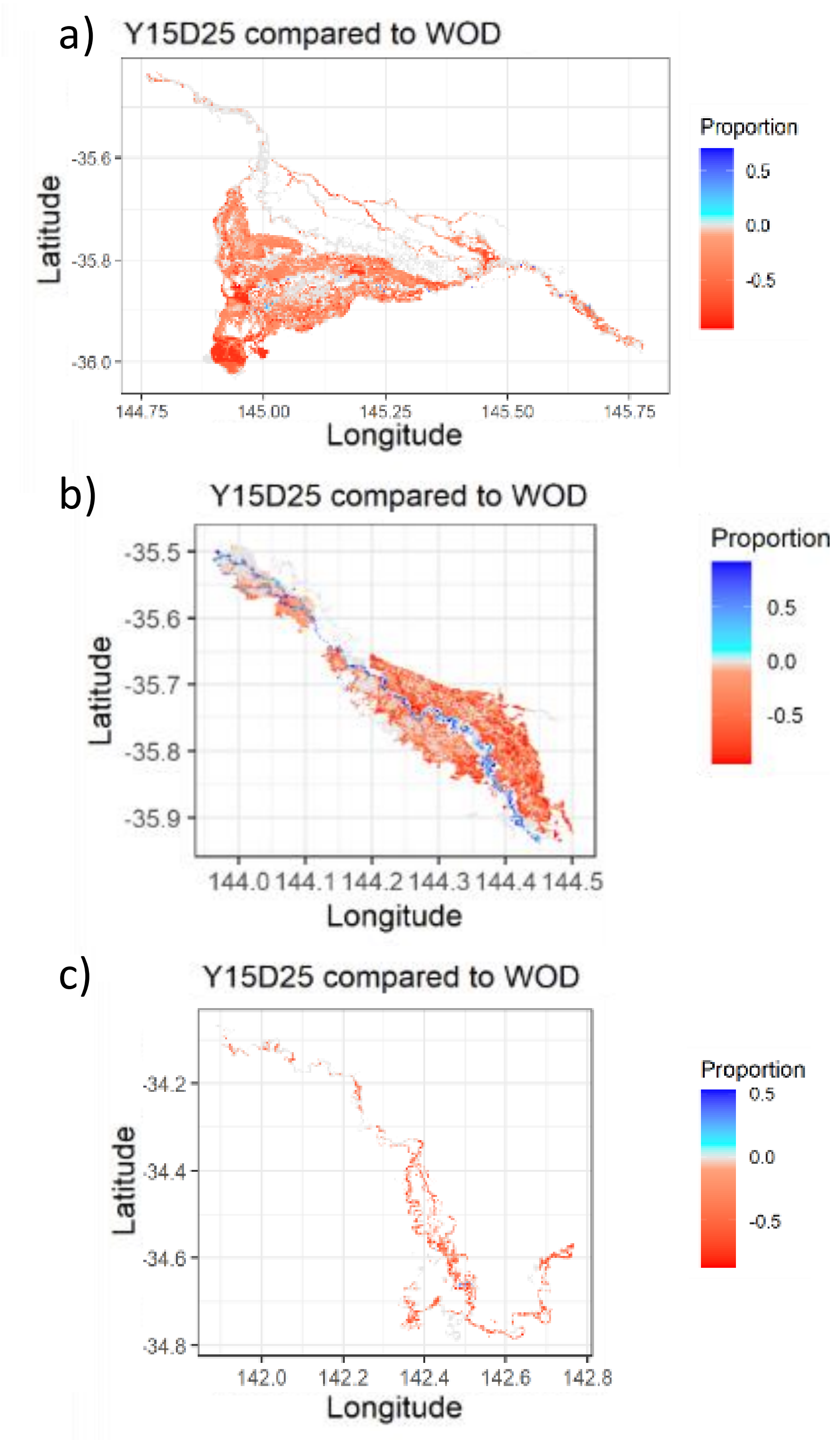


Figure 24. Each region of interest a) Barmah- Millewa Forest, b) Koondrook-Perricoota and Gunbower forest and c) Downstream of Eustons weir, showing the change in proportion of time river red gum is in a good state between the without development scenario and the base case constraint option (Y15D25).

Appendix 3. Black box outputs

Accumulation plots

Comparisons of constraint relaxation scenarios with the base case (Y15D25)

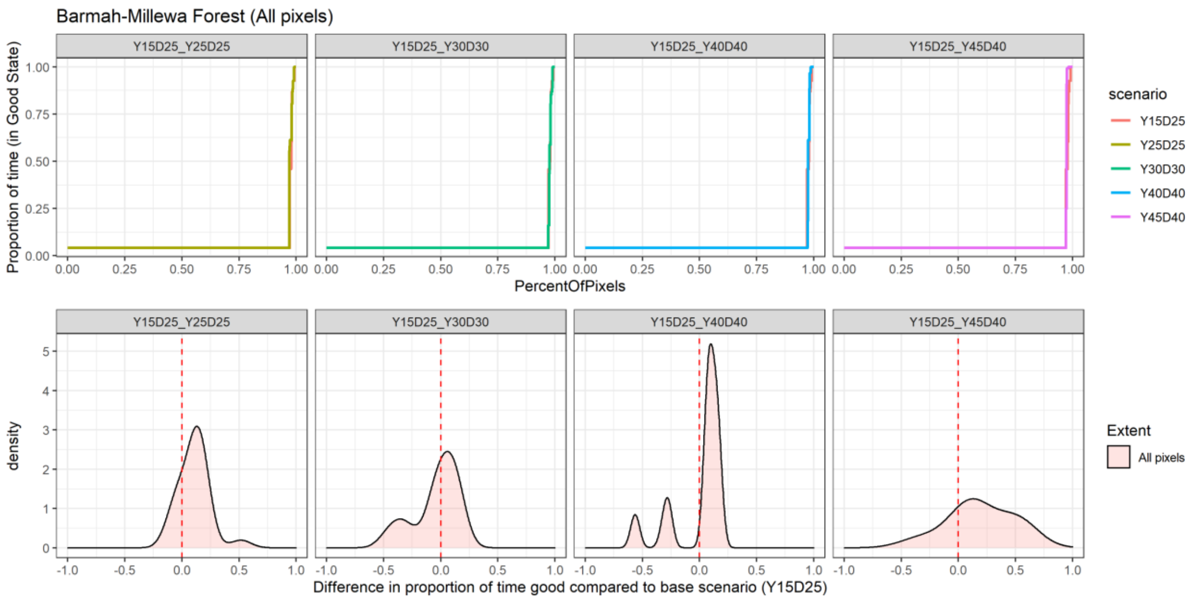


Figure 25. BMF All pixels, Difference in proportion of time in a good state between constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). top panels show the cumulative distribution of Proportion of time in a good state for black box pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for BMF (zone2 EW-FIM and zone3 RIMFIM)

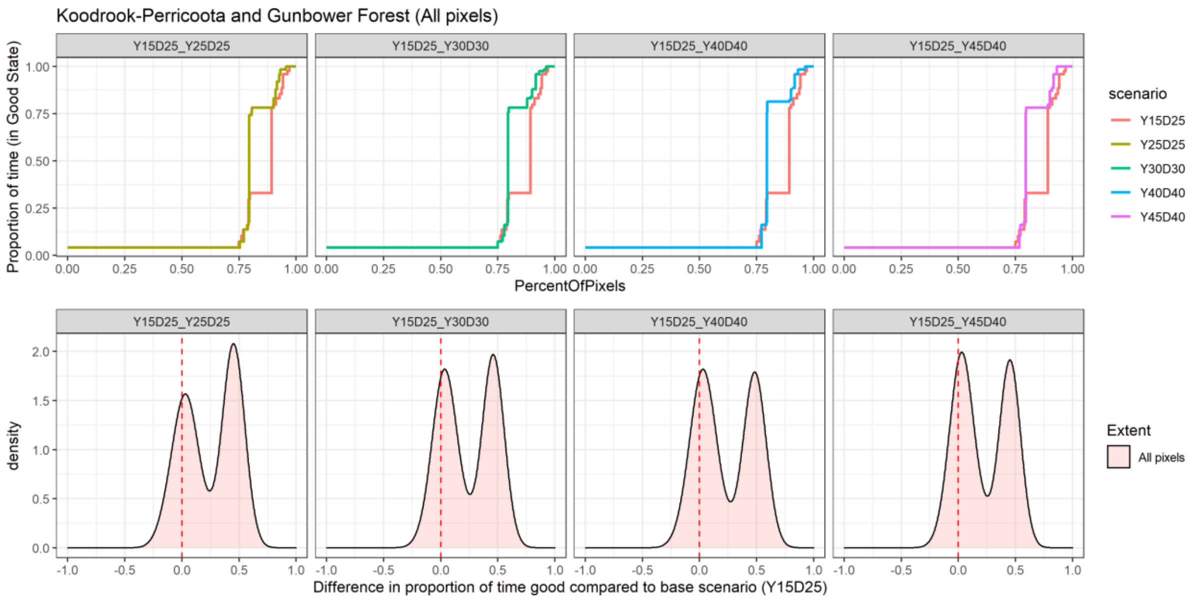


Figure 26. KP-GB All pixels, Difference in proportion of time in a good state between constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). top panels show the cumulative distribution of Proportion of time in a good state for black box pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for KP-GF (zone7 RIMFIM)

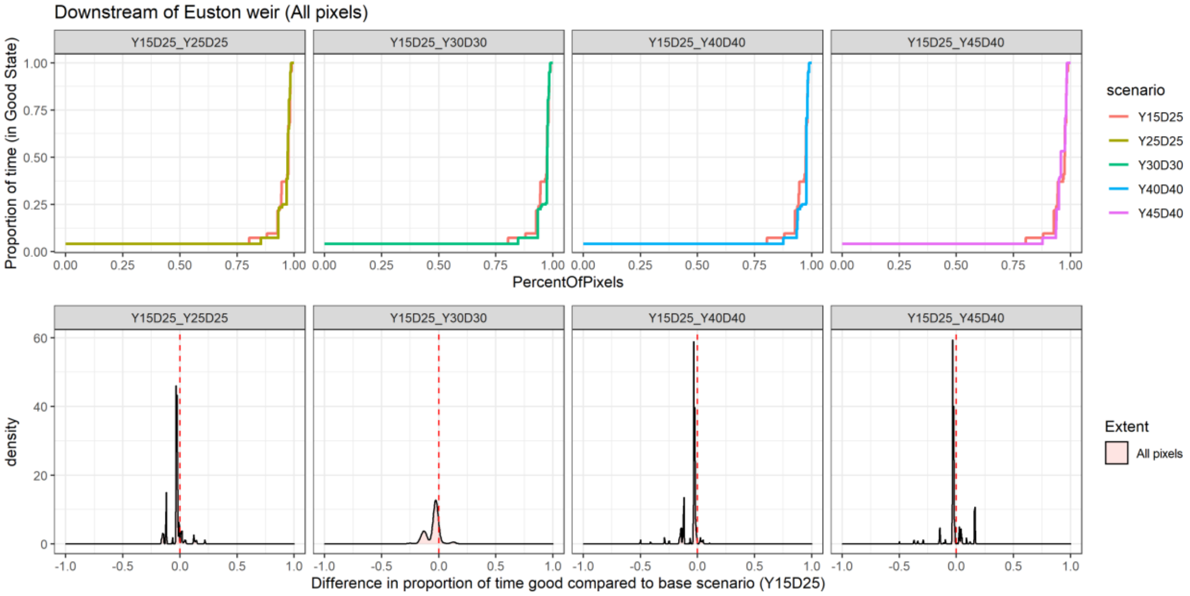


Figure 27. DS Euston weir All pixels, Difference in proportion of time in a good state between constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). top panels show the cumulative distribution of Proportion of time in a good state for black box pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for DS Euston weir (zone12)

Comparison to without development scenario

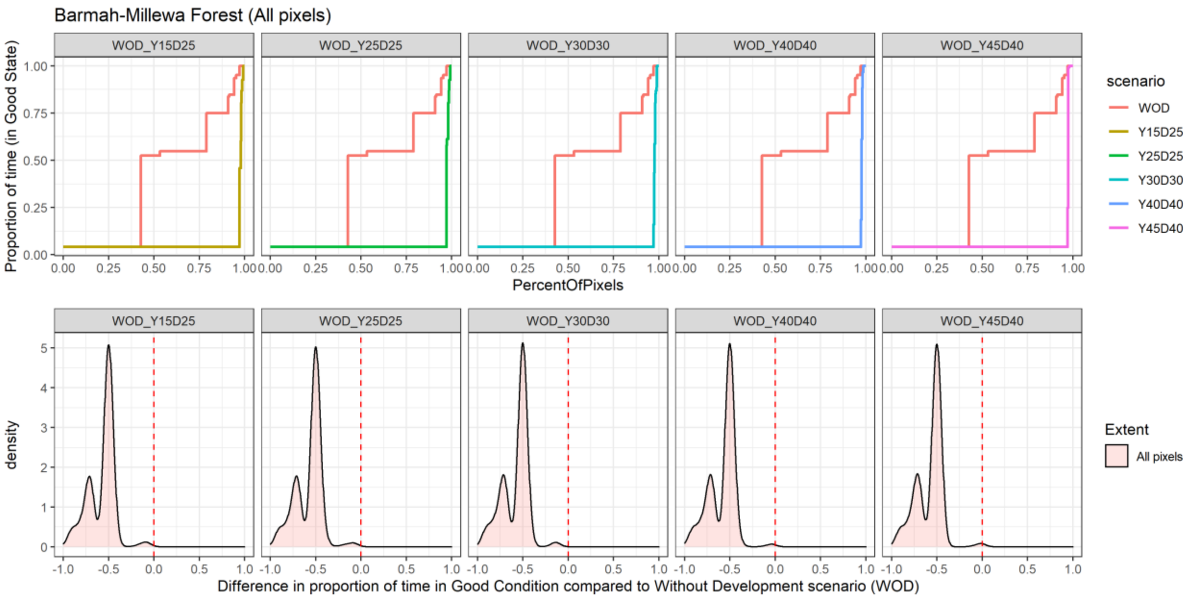


Figure 28. BMF All pixels, Difference in proportion of time in a good state between without development scenario (WOD) and constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). top panels show the cumulative distribution of Proportion of time in a good state for black box pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for BMF (zone2 EW-FIM and zone3 RIMFIM)

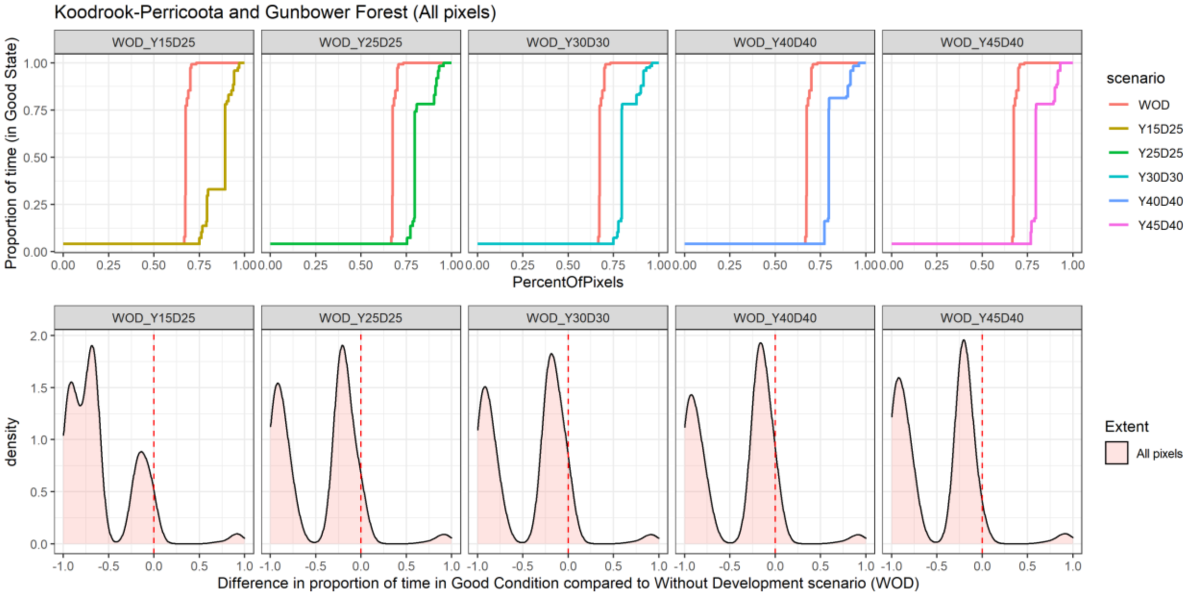


Figure 29. KP-GB All pixels, Difference in proportion of time in a good state between without development scenario (WOD) and constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). top panels show the cumulative distribution of Proportion of time in a good state for black box pixels and the bottom pannels show the difference in the proportion of time in good state between Y15D25 and each other Constraint scenario for KP-GF (zone7 RIMFIM)

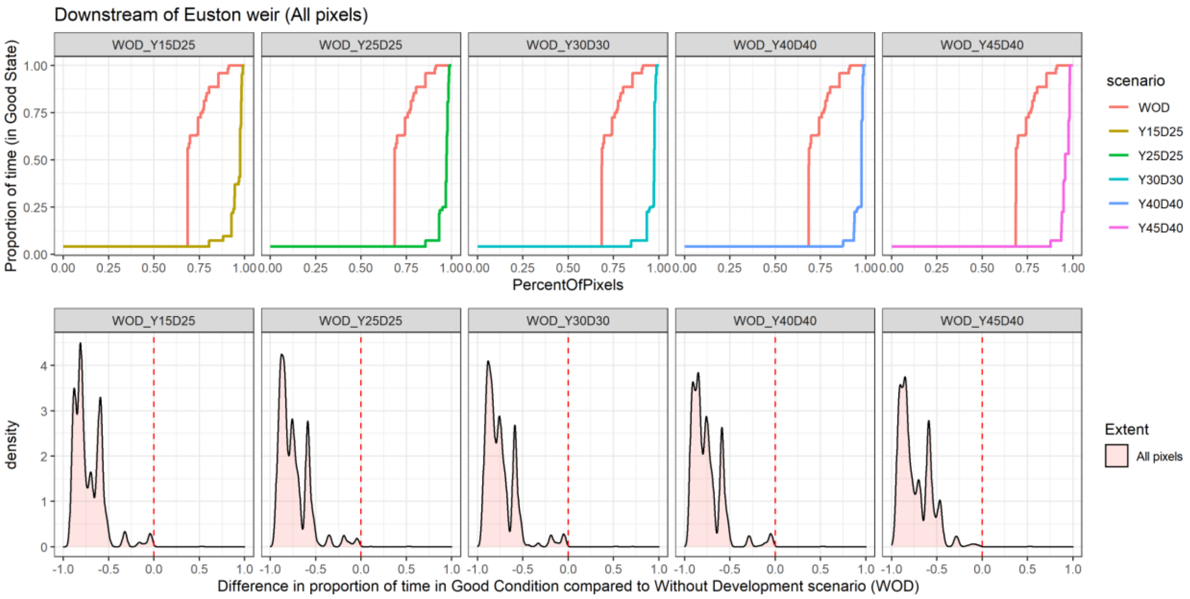


Figure 30. DS Euston weir (all pixels) Difference in proportion of time in a good state between without development scenario (WOD) and constraint options (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40). top panels show the cumulative distribution of Proportion of time in a good state for black box pixels and the bottom pannels show the difference in the proportion of time in good state between WOD and each Constraint scenario for DS Euston weir (zone12 RIMFIM)

Spatial plots of proportion good condition

Proportion good by constraint option

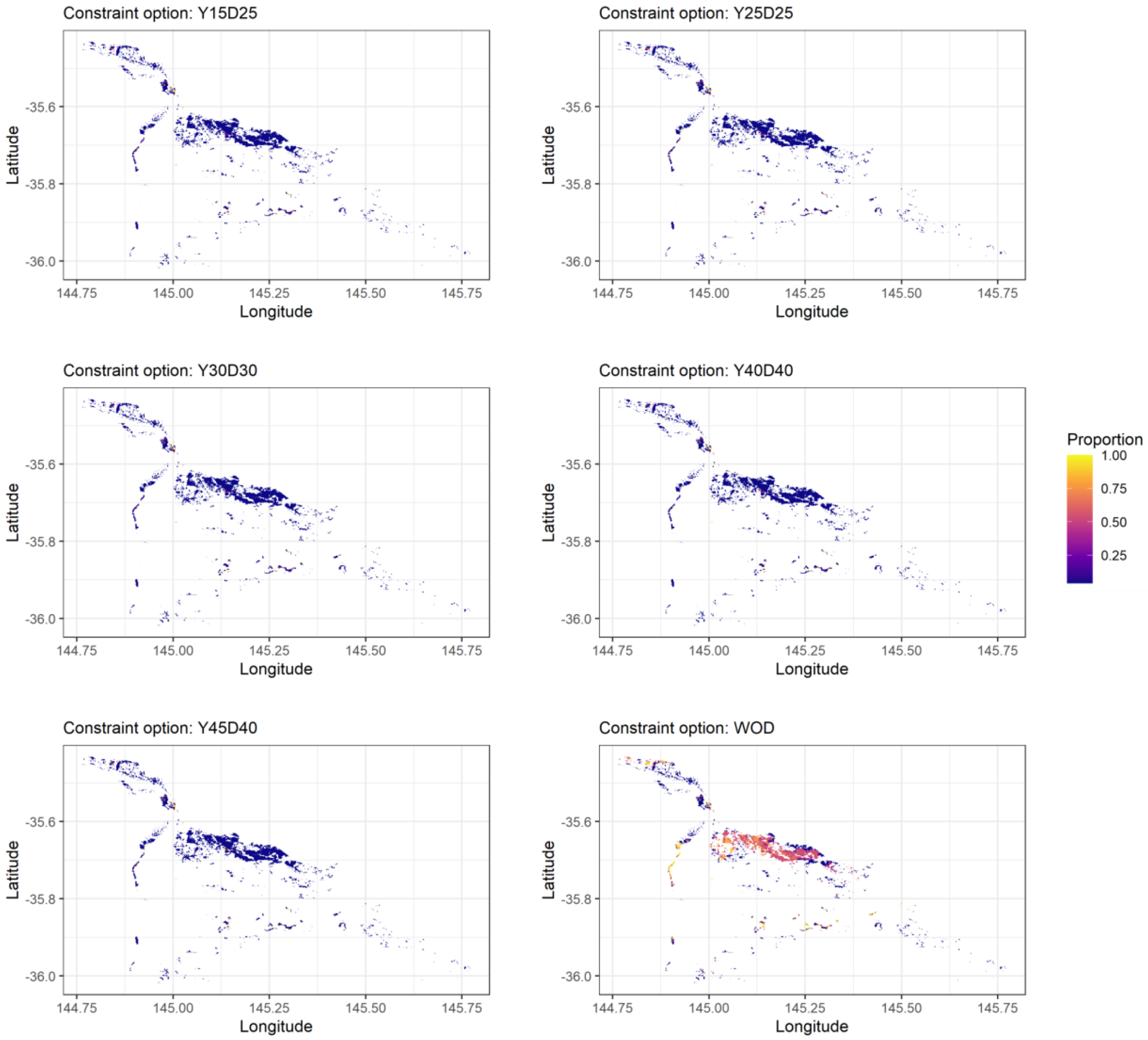


Figure 31. Barmah-Millewa forest (RIMFIM Zone3_clip and EW-FIM zone2) showing the proportion of time Black box is in a good condition in each constraint option (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40) and the Without Development (WOD) scenario.

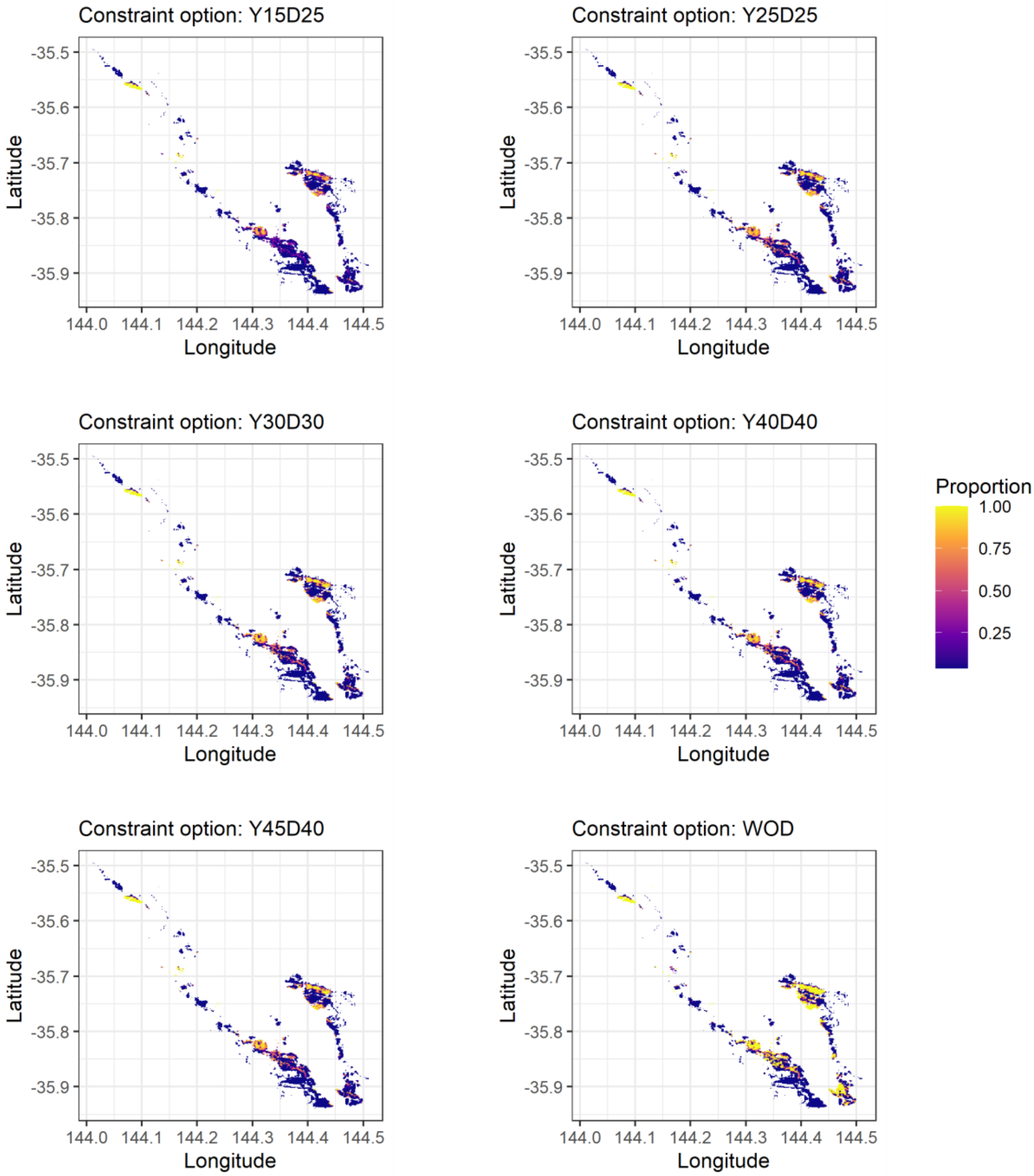


Figure 32. Koondrook-Perricoota and Gunbower forest (RIMFIM zone 7) showing the proportion of time Black box is in a good condition in each constraint option (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40) and the Without Development (WOD) scenario.

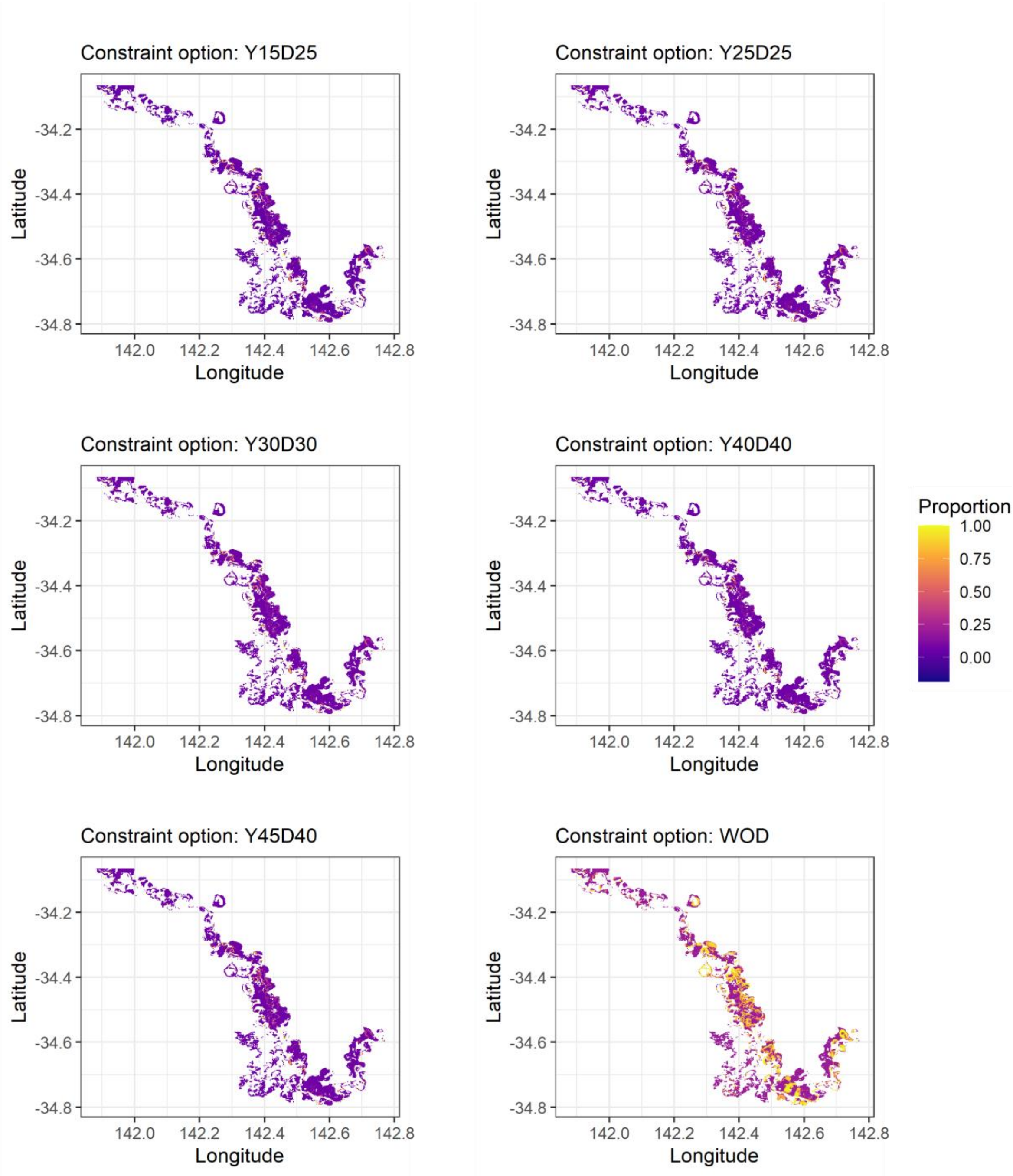


Figure 33. Downstream of Euston weir (RIMFIM zone12) showing the proportion of time black box is in a good condition in each constraint option (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40) and the Without Development (WOD) scenario.

Change in proportion good between constraint options

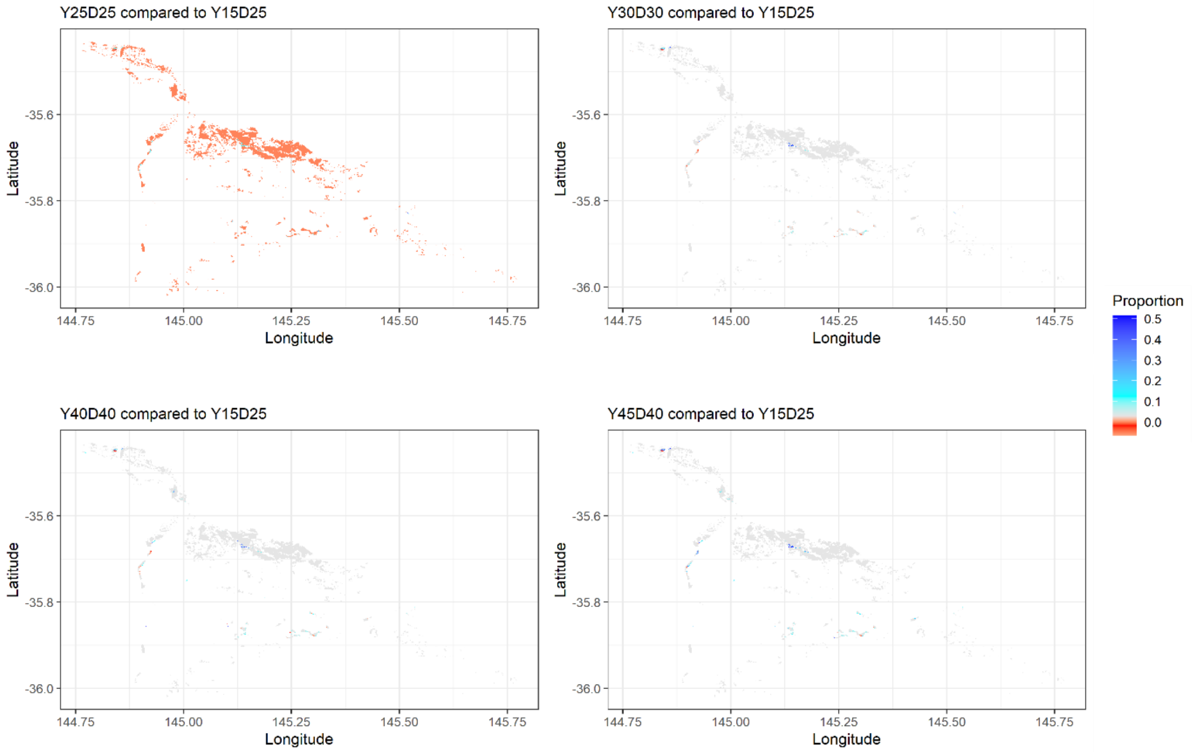


Figure 34. Barmah-Millewa forest (RIMFIM zone3 EWFIM zone2) showing the difference in proportion of time Black box is in a good state between the baseline constraints scenario (Y15D25) and each constraint relaxation option (Y15D25_Y25D25, Y15D25_Y30D30, Y15D25_Y40D40, Y15D25_Y45D40). Colour shows areas where constraint relaxation, from baseline increased (darker blues correlate with greater increase) or decreased (reds correlate with greater decrease) the proportion of time a pixel was in a good condition.

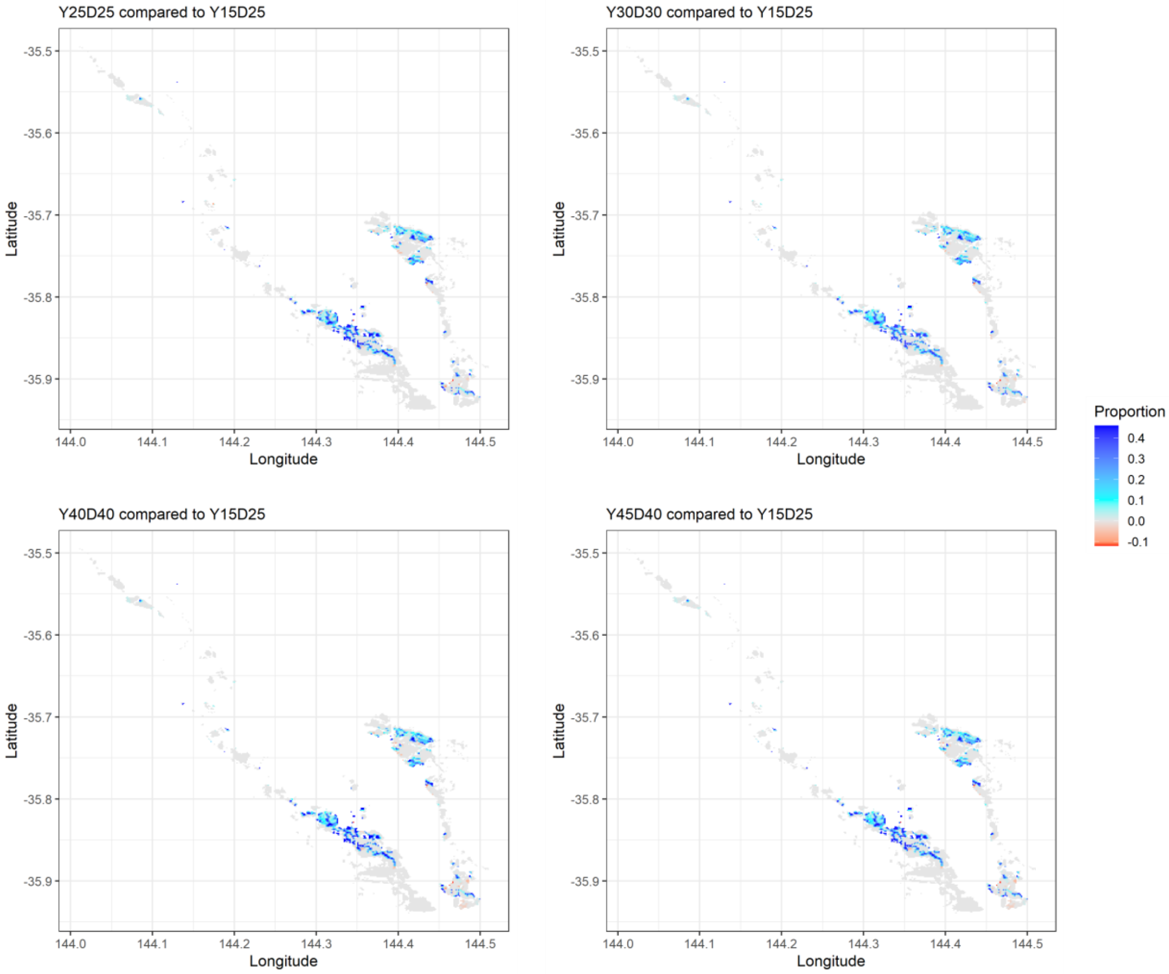


Figure 35. Koondrook-Perricoota and Gunbower forest (RIMFIM zone 7) showing the difference in proportion of time Black box is in a good state between the baseline constraints scenario (Y15D25) and each constraint relaxation option (Y15D25_Y25D25, Y15D25_Y30D30, Y15D25_Y40D40, Y15D25_Y45D40). Colour shows areas where constraint relaxation, from baseline increased (darker blues correlate with greater increase) or decreased (reds correlate with greater decrease) the proportion of time a pixel was in a good condition.

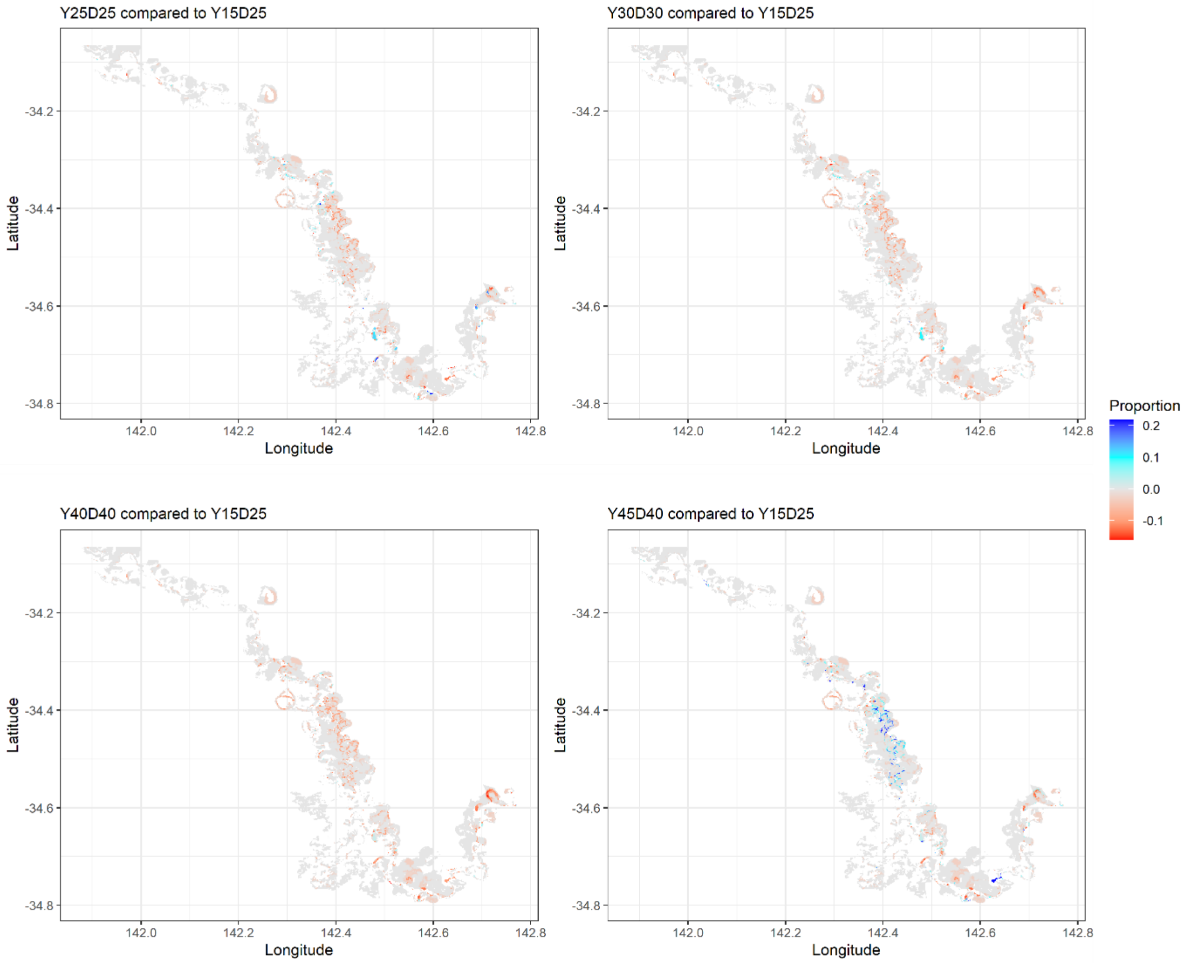


Figure 36. Downstream of Euston weir (zone 12) showing the change in proportion of time Black box is in a good state between the without development scenario and each constraint relaxation option (Y15D25, Y25D25, Y30D30, Y40D40, Y45D40).

Change in proportion good between constraint options and without development scenarios

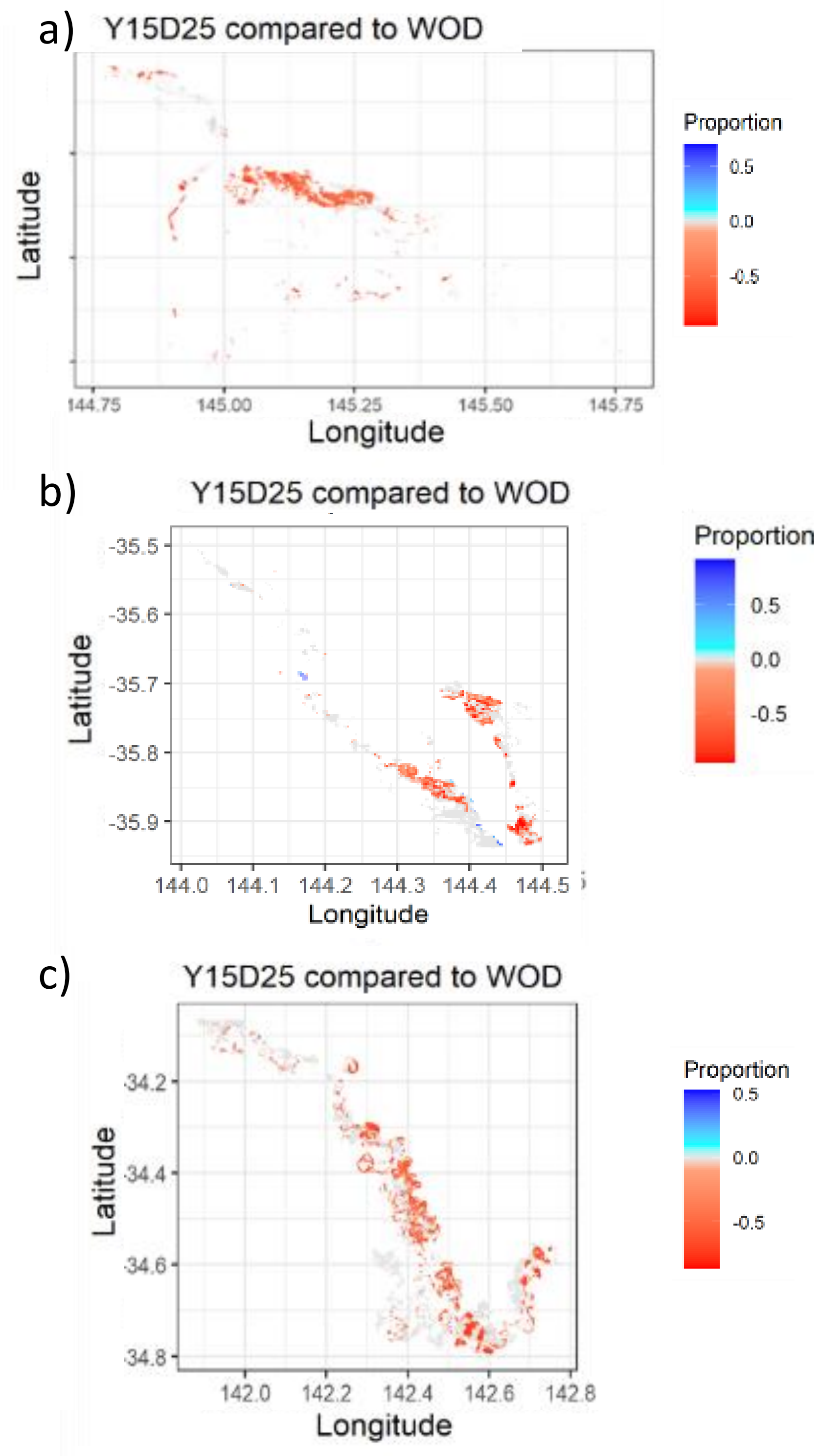


Figure 37. Each region of interest a) Barmah- Millewa Forest, b) Koondrook-Perricoota and Gunbower forest and c) Downstream of Eustons weir, showing the change in proportion of time Black box is in a good state between the without development scenario and the base case constraint option (Y15D25).

Appendix 4. State transition rules

In this appendix the hydrological rules for each of the vegetation classes have been represented in separate tables. Below is a list of terms and a brief description of each that will assist in the interpretation of the response of vegetation to inundation spells. As some states of condition (e.g. poor and Critical) can result from declines in condition from multiple states or improvements the states of these models store the previously modelled states in these instances. For example as a river red gum that is good condition (Table 10., RRGW_G) declines to critical condition (RRG_C) via Moderate (RRG_M) and Poor (RRG_P) the transitions are stored at the end of the state name. In our example the transition from Good to critical would result in the state RRGW_C_GMP. This is not required where there is only one improvement and/or decline transition path (Figure 3.) for the state.

Rule variables

initial_state_t0

This is the current state of the unit being simulated after the previous time step/matrix multiplication. It is stored in the model as a binary vector of all states and is the input vector to the next matrix multiplication for projecting the state.

future_state_t1

This is the resulting state from the matrix multiplication of the of the *initial_state_t0* unit and is the next state in the simulated state transition time series. Under iteration, once the future state is determined after 1 or many years, the recorded state becomes the *initial_state_t0* for the subsequent matrix multiplication.

rule_number

This is a value identifying each unique rule.

spell_duration

This is the number of uninterrupted days that will be required to have a 'spell' of a specific type recorded. In the case where a spell is interrupted, e.g. in a 365 day dry spell there is a period of 16 days of inundation (one more than out spell gap of 15) then the 365 day transition does not occur and the unit stays in the initial_state_t0.

spell_type

This determines whether the rule is to do with an inundation ('inun') or drying ('dry') spell.

spell_count

This is the number of spells that must occur within the antecedent 'annual window'

annual_window

This is a value determining the maximum number of years within which the spell count must occur. For example if the rule states spell_count = 5 and annual window = 5 if any one year of the previous 5 years does not include a spell the spell count would be 4 and the transition does not occur.

Black box woodland Transitions

Table 9.Transitions rules for states of Black box woodland

initial_state_t0	future_state_t1	rule_number	spell_duration	spell_type	spell_count	annual_window
BBW_G	BBW_M	1	365	dry	5	5
BBW_G	BBW_Inun	2	300	inun	5	7
BBW_M	BBW_G	3	30	inun	1	1
BBW_M	BBW_P_GM	4	365	dry	10	10
BBW_P_GM	BBW_P	5	30	inun	1	1
BBW_P_GM	BBW_C_GMP	6	365	dry	15	15
BBW_P_I	BBW_C_IP	7	365	dry	9	9
BBW_P_I	BBW_P	8	30	inun	1	1
BBW_P	BBW_I	9	30	inun	3	10
BBW_P	BBW_C_P	10	365	dry	5	5
BBW_I	BBW_G	11	30	inun	2	7
BBW_I	BBW_P_I	12	365	dry	4	4
BBW_C_GMP	BBW_Dry	13	365	dry	45	45
BBW_C_GMP	BBW_C	14	30	inun	1	1
BBW_C_IP	BBW_Dry	15	365	dry	39	39
BBW_C_IP	BBW_C	16	30	inun	1	1
BBW_C_P	RRG_Dry	17	365	dry	35	35
BBW_C_P	BBW_C	18	30	inun	1	1
BBW_C	BBW_I	19	30	inun	5	18
BBW_C	BBW_Dry	20	365	dry	30	30
BBW_Inun	BBW_Recruit	21	245	dry	2	5
BBW_Dry	BBW_Recruit	22	30	inun	2	5
BBW_Dry	BBW_Dead	23	365	dry	5	5
BBW_Recruit	BBW_I	24	30	inun	2	2
BBW_Recruit	BBW_Dry	25	365	dry	3	3
BBW_Recruit	BBW_Dead	26	90	inun	1	1
BBW_Dead	TV	27	30	inun	3	10

River red gum woodland transition rules

Table 10. Transition rules for states of river red gum woodland

initial_state_t0	future_state_t1	rule_number	spell_duration	spell_type	spell_count	annual_window
RRGW_G	RRGW_M	28	365	dry	3	3
RRGW_G	RRG_Inun	29	300	inun	5	7
RRGW_M	RRGW_G	30	30	inun	1	1
RRGW_M	RRGW_P_GM	31	365	dry	9	9
RRGW_P_GM	RRGW_C_GMP	32	365	dry	13	13
RRGW_P_GM	RRGW_P	33	30	inun	1	1
RRGW_P_I	RRGW_C_IP	34	365	dry	8	8
RRGW_P_I	RRGW_P	35	30	inun	1	1
RRGW_P	RRGW_I	36	30	inun	3	9
RRGW_P	RRGW_C_P	37	365	dry	4	4
RRGW_I	RRGW_G	38	30	inun	2	7
RRGW_I	RRGW_P_I	39	365	dry	4	4
RRGW_C_GMP	RRG_Dry	40	365	dry	28	28
RRGW_C_GMP	RRGW_C	41	30	inun	1	1
RRGW_C_IP	RRG_Dry	42	365	dry	23	23
RRGW_C_IP	RRGW_C	43	30	inun	1	1
RRGW_C_P	RRG_Dry	44	365	dry	19	19
RRGW_C_P	RRGW_C	45	30	inun	1	1
RRGW_C	RRGW_I	46	30	inun	5	15
RRGW_C	RRG_Dry	47	365	dry	15	15

River red gum forest transition rules

Table 11. Transition rules for states of river red gum forest

initial_state_t0	future_state_t1	rule_number	spell_duration	spell_type	spell_count	annual_window
RRGF_G	RRGF_M	48	365	dry	3	3
RRGF_G	RRG_Inun	49	300	inun	5	7
RRGF_M	RRGF_G	50	30	inun	1	1
RRGF_M	RRGF_P_GM	51	365	dry	6	6
RRGF_P_GM	RRGF_C_GMP	52	365	dry	10	10
RRGF_P_GM	RRGF_P	53	30	inun	1	1
RRGF_P_I	RRGF_C_IP	54	365	dry	7	7
RRGF_P_I	RRGF_P	55	30	inun	1	1
RRGF_P	RRGF_I	56	30	inun	3	9
RRGF_P	RRGF_C_P	57	365	dry	4	4
RRGF_I	RRGF_G	58	30	inun	2	5
RRGF_I	RRGF_P_I	59	365	dry	3	3
RRGF_C_GMP	RRG_Dry	60	365	dry	25	25
RRGF_C_GMP	RRGF_C	61	30	inun	1	1
RRGF_C_IP	RRG_Dry	62	365	dry	22	22
RRGF_C_IP	RRGF_C	63	30	inun	1	1
RRGF_C_P	RRG_Dry	64	365	dry	19	19
RRGF_C_P	RRGF_C	65	30	inun	1	1
RRGF_C	RRGF_I	66	30	inun	5	15
RRGF_C	RRG_Dry	67	365	dry	15	15
RRG_Inun	RRG_Recruit	68	245	dry	2	5
RRG_Dry	RRG_Recruit	69	30	inun	2	5
RRG_Dry	RRG_Dead	70	365	dry	5	5
RRG_Recruit	RRGF_I	71	30	inun	2	2
RRG_Recruit	RRG_Dry	72	365	dry	3	3
RRG_Recruit	RRG_Dead	73	90	inun	1	1
RRG_Dead	TV	74	30	inun	3	10

Lignum shrubland transition rules

Table 12. Transition rules for states of Lignum shrubland

initial_state_t0	future_state_t1	rule_number	spell_duration	spell_type	spell_count	annual_window
LS_G	LS_Inun	75	90	inun	15	15
LS_G	LS_M_G	76	365	dry	1	1
LS_M_G	LS_G	77	30	inun	1	1
LS_M_G	LS_P_GM	78	365	dry	7	7
LS_M	LS_G	79	30	inun	1	1
LS_M	LS_P_M	80	365	dry	6	6
LS_P_GM	LS_P	81	30	inun	1	1
LS_P_GM	LS_C_GMP	82	365	dry	11	11
LS_P_M	LS_P	83	30	inun	1	1
LS_P_M	LS_C_MP	84	365	dry	10	10
LS_P	LS_M	85	30	inun	2	2
LS_P	LS_C_P	86	365	dry	4	4
LS_C_GMP	LS_C	87	30	inun	1	1
LS_C_GMP	LS_Dry	88	365	dry	21	21
LS_C_MP	LS_C	89	30	inun	1	1
LS_C_MP	LS_Dry	90	365	dry	20	20
LS_C_P	LS_C	91	30	inun	1	1
LS_C_P	LS_Dry	92	365	dry	14	14
LS_C	LS_P	93	30	inun	2	2
LS_C	LS_Dry	94	365	dry	10	10
LS_Inun	LS_Recruit	95	245	dry	2	5
LS_Dry	LS_Recruit	96	30	inun	2	5
LS_Dry	LS_Dead	97	365	dry	5	5
LS_Recruit	LS_M	98	30	inun	2	2
LS_Recruit	LS_Dead	99	120	inun	3	5
LS_Dead	TV	100	30	inun	3	10

Perennial grass, sedge and rush lands transition rules

Table 13. Transition rules for states of Perennial grass, sedge and rush lands

initial_state_t0	future_state_t1	rule_number	spell_duration	spell_type	spell_count	annual_window
PG_G	PG_M_G	101	365	dry	1	1
PG_M_G	PG_G	102	30	inun	1	1
PG_M_G	PG_P_GM	103	365	dry	3	3
PG_M	PG_G	104	30	inun	1	1
PG_M	PG_P_M	105	365	dry	2	2
PG_P_GM	PG_P	106	30	inun	1	1
PG_P_GM	PG_C_GMP	107	365	dry	11	11
PG_P_M	PG_P	108	30	inun	1	1
PG_P_M	PG_C_MP	109	365	dry	10	10
PG_P	PG_M	110	30	dry	2	2
PG_P	PG_C_P	111	365	dry	8	8
PG_C_GMP	PG_C	112	30	inun	1	1
PG_C_GMP	PG_Dry	113	365	dry	21	21
PG_C_MP	PG_C	114	30	inun	1	1
PG_C_MP	PG_Dry	115	365	dry	20	20
PG_C_P	PG_C	116	30	inun	1	1
PG_C_P	PG_Dry	117	365	dry	18	18
PG_C	PG_M	118	30	inun	2	2
PG_C	PG_Dry	119	365	dry	10	10
PG_Dry	PG_Recruit	120	30	inun	2	5
PG_Dry	PG_Dead	121	365	dry	5	5
PG_Recruit	PG_M	122	30	inun	2	2
PG_Recruit	PG_Dead	123	120	inun	3	5
PG_Dead	TV	124	30	inun	3	10
TV	TV_Dead	125	365	dry	35	35
TV_Dead	TV	126	30	inun	3	10

Appendix 5. Methods for classification of PCT and EVC into vegetation categories for state and transition modelling

Process lead by Samantha Dawson (DPIE EES Water for the Environment)

Contributors: Rachael Thomas (DPIE Science), Tanya Mason (DPIE Science), Tim Barlow (Vic DSE; ran by Keith Ward, other Vic folk), Mark Henderson (DPIE), Susan Gehrig (Flora, Flow & Floodplains), Cherie Campbell (employer)

The purpose of reclassifying existing vegetation mapping was two-fold: first, to implement the categories that are defined in the state and transition models; second, to match the vegetation layers on the NSW and Victorian sides of the Murray River to enable a single model to be run. State and transition (S&T) models developed by consultants at La Trobe University and Griffith University were based on published literature and expert opinion and delineated a set of rules for riverine and floodplain vegetation types outlining expected vegetation condition and transition between vegetation communities based on flooding regimes. The vegetation categories they identified consisted of two tiers: a broader category between which transitions occur and PCT/EVC based categories which, in the case of non-woody vegetation, defined phases of vegetation across a wetting/drying spectrum (Table 14). Files on the various stages with comments attached can be found in the Teams drive: C:\Users\dawsons\DPIE\SDLAM Constraints projects - Vegetation benefits - Vegetation benefits\Vegetation mapping\PCT and EVC groupings for veg mapping. The ones starting with 'Comments_final' show the reasoning behind the final categorisation.

To extract the PCT/EVC polygons of interest, we used a polygon that defined the floodplain for the Murray River (below Hume Dam), Murrumbidgee River (including Tumut River and Yanco/Billabong Creek system) and the lower Darling and Darling Anabranch. The polygon defines the area of interest and is based on the RIMFIM boundary (1956 flood extent). PCT and EVC spatial polygon layers were then clipped to this boundary for all NSW and Victorian bioregions that covered the extent. From the attribute tables of the clipped polygon layer we were able to extract a list of the PCT and EVC classes that were present in our area of interest. This list formed a table by which we could then attribute S&T categories to various vegetation classes. Note: we used spatial information to extract a table

Table 14 Vegetation categories used in the state and transition models.

<u>**Revised Broad Wetland Vegetation Types**</u>	**Other/understorey vegetation groups to consider (see literature for common transitions) - PCT/EVC BASED CLASSES**
Wetland herblands (WH)	
Benthic perennial herbland with low - moderate biomass, moderate - high diversity (WH_BPH1) *Benthic perennial herbland with high biomass, low – moderate diversity (WH_BPH2)*	Benthic herbland
Amphibious herbland with low - moderate biomass, high diversity (WH_AH_LS)	Low-mid sedgeland
(WH_AH_GF)	Grassland/forbland wetland
Floodplain terrestrial herbland with low - moderate biomass, low - moderate diversity (WH_TH)	Floodplain grasslands
Floodplain chenopod shrubland – high biomass, low diversity (WH_CS)	Floodplain shrublands
Perennial wetland grasslands, sedgelands and rushlands (PG) N.B. This class distinguished by persistent dominant canopy.	
	Pseudoraphis spinescens grasslands (in Barmah-Millewa)
	Giant rush (Juncus ingens)
	Common reed (Phragmites)
	Tall GSR
River red gum forests (RRGF)	
	RRG forest sedge understorey
	RRG forest herb-grass understorey
River red gum woodlands (RRGW)	
	RRG woodland grassy understorey
	RRG woodland lignum understorey
	RRG woodland sedge understorey
Lignum shrublands (LS)	
Black box woodlands (BBW)	
	Black box woodland chenopod understorey
	Black box woodland grassy understorey
	Black box woodland lignum understorey

and the table was used in the categorisation – this was not a spatially informed categorisation process.

There were in total 147 PCT classes and 146 EVC classes that were identified as occurring in the area of interest. As a first pass, SD used the table of classes and the following information to allocate each PCT/EVC class to S&T categories:

PCT: The details of the PCT attribute table could be used by and large alone. They include extra details not in the EVC classes attribute tables such as dominant species in each storey

EVC – details of the EVCs including specialist wetland reports:

https://www.environment.vic.gov.au/__data/assets/pdf_file/0027/48753/VRiv_EVCs_combined.pdf

https://www.environment.vic.gov.au/__data/assets/pdf_file/0024/48732/MuF_EVCs_combined.pdf

https://www.environment.vic.gov.au/__data/assets/pdf_file/0022/48730/MSB_EVCs_combined.pdf

https://www.environment.vic.gov.au/__data/assets/pdf_file/0030/48747/RobP_EVCs_combined.pdf

https://www.environment.vic.gov.au/__data/assets/pdf_file/0026/48734/MuM_EVCs_combined.pdf

https://www.environment.vic.gov.au/__data/assets/pdf_file/0028/48709/LoM_EVCs_combined.pdf

https://www.environment.vic.gov.au/__data/assets/pdf_file/0028/48736/NIS_EVCs_combined.pdf

https://www.water.vic.gov.au/__data/assets/pdf_file/0023/52763/Final-for-publicatn-Wetland-Classification-Report-8Mar16.pdf

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