RECONNECTING RIVER COUNTRY: WEED RISKS AND BENEFITS ASSESSMENT

TECHNICAL REPORT

PREPARED FOR THE DEPARTMENT OF PLANNING AND ENVIRONMENT

MARCH 2022

Prepared by: Samantha Capon, Rebekah Grieger, Ali Chauvenet, Jaiden Johnston-Bates, Hannah Franklin and Hannah Burgoyne

Summary

The presence and consequences of exotic plant species is a major concern for land managers and other stakeholders in the Murray and Murrumbidgee River regions. Particular concerns have been raised in relation to the potential for changes in weed distribution resulting from the relaxation of flow constraints proposed under the Reconnecting River Country program (previously the Constraints Measures Program). This program, run by the New South Wales (NSW) Department of Planning and Environment (DPE), 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. It focuses on the following areas in the southern-connected Murray Darling Basin (the basin), including:

• Hume to Yarrawonga (River Murray)
• Yarrawonga to Wakool (River Murray)
• Murrumbidgee River

As part of this program, NSW DPE contracted Griffith University to conduct an assessment of current weed distributions and consequences and assess potential risks and benefits associated with constraints relaxation.

The aims of this project were to:

- describe the current invasive weed distribution and consequences in the project areas through a compilation and synthesis of existing knowledge;
- evaluate the likelihood and consequences of various flow constraint relaxation options changing invasive weed extent and impacts in the project area; and
- develop a risk framework for invasive plant species in relation to each flow scenario.

A comprehensive review of published literature and internet resources was conducted in the first stage of this project to address the first aim. This review identified over 80 weed species of concern and described the current invasive weed distribution and consequences in the project area (see Capon et al., 2021).

To explore the current distributions of weeds in the project areas, as well as potential changes to these under the inundation scenarios, species distribution models (SDMs) were developed for each catchment (i.e., Murray and Murrumbidgee) under a base case and in relation to each inundation scenario. Seven weed species and two plant functional groups (comprising an additional 38 species) were the focus of this investigation. To build these SDMs, we used species observation data from Atlas of Living Australia and additional data held by the NSW government. Climatic data (i.e. annual rainfall, temperature range), environmental data (i.e., land use, vegetation, and wetland mapping), and inundation metrics were included as predictor variables in the models. The SDMs generated map outputs of the likelihood of the presence/absence of the weed species examined in the Murray and Murrumbidgee project areas under each scenario from which we delineated areas of suitable habitat and highly suitable habitat (i.e. top 20% of suitable habitat). To determine the land uses, vegetation types and wetland classes with most suitable habitat for the weed species considered in each scenario and the changes predicted under these from the base case we conducted a range of spatial data analyses.

The results of the SDMs and spatial analyses are summarised below:

- Most of the species and functional groups investigated exhibited potential basecase distributions of suitable habitat between 10,000 and 60,000 hectares over the whole project area. The basecase distribution of Phyla (lippia) was much larger, covering approximately 300,000 hectares of potential suitable habitat, which mostly occurred in the Murray

catchment. Suitable habitat for Sagittaria (arrowheads) only occurred in the Murray catchment. Salix (willows) had minimal suitable habitat throughout the project area.

- Climatic variables were the most important predictors in all SDMs and annual rainfall was the most important predictor in five of seven models. Inundation metrics were moderately important for all taxa, but metrics associated with longer dry periods were particularly important for terrestrial weed taxa, e.g. Marrubium (Horehounds), Lycium (African boxthorn).

- Weed hotspots (defined here as areas comprising suitable habitat for four or more modelled weed taxa) occupied less than 1 % of the project area and tended to occur in the vicinity of all the major towns in the project area (Wagga Wagga, Hay, Albury, Echuca, Denliquin and Swan Hill) as well as along the Murrumbidgee Rivers south of Griffith.

- Distribution of suitable habitat area for amphibious or aquatic weed species (i.e. species which require flooding for their lifecycle, e.g. Phyla (lippia), Sagittaria (arrowheads) tended to decrease under relaxed constraints scenarios, particularly in the Murray but also in the Murrumbidgee, albeit to a lesser extent. Amphibious species which have thrived in some low-lying habitats under recent reduced flow conditions, appear likely to be 'drowned out' by the increased duration, frequency, and permanence of inundation events proposed under constraints relaxation scenarios.

- Terrestrial species (i.e. species which do not require flooding for their lifecycle), particularly the widespread Marrubium (horehounds) and Lycium (African boxthorn), exhibited increased potential suitable habitat area under relaxed constraints scenarios in both study catchments. The potential increase in fringing areas (i.e. where moisture is readily available more frequently but where inundation does not occur for longer periods of time) would likely favour the germination and establishment of terrestrial species under a more frequent occurrence of wetter conditions.

- Although modelled changes in weed distributions were often substantial between the basecase and flow scenarios, minimal differences in projected species distribution occurred between inundation scenarios. Where differences were notable, Salix (willows) for example, greater potential weed extents were predicted under lower constraint relaxation scenarios, suggesting that the higher flooding conditions resulting from greater constraint relaxation will be unsuitable for this species.

- Results of the expert elicitation activities largely aligned with the model findings, although experts generally noted low to moderate confidence in their responses and suggested minimal changes to weed distributions under proposed inundation changes. Model outputs showed varying directions and magnitudes of changes, however, there was little variation between constraint relaxation scenarios for each taxa.

- The weed risk assessment framework considered the potential changes in species distribution under each constraint relaxation scenario overall and in land uses, vegetation types, wetland types. Total risk scores for each species were largely consistent between constraint relaxation scenarios with an overall negative score for all scenarios in the Murray River project area corresponding to a slight overall benefit in this region. In the Murrumbidgee, the lowest constraint relaxation scenario (32GL) had an overall positive score, corresponding to a slight overall risk in this region, while the two higher constraint relaxation scenarios had an overall negative score, corresponding to a slight overall benefit in this region.

Summary of weed risk assessment framework scores for each constraint relaxation scenario in the Murray and Murrumbidgee study areas (full table in table 12).

Study area	***Murray River***				***Murrumbidgee River***		
Constraint relaxation scenario	***Y25D25***	***Y30D30***	***Y40D40***	***Y45D40***	***32GL***	***36GL***	***40GL***
Total	***-636***	***-667***	***-708***	***-627***	***261***	***-339***	***-517***
Standardised score (-100 to +100)	***-2.8***	***-3.0***	***-3.2***	***-2.8***	***1.2***	***-1.5***	***-2.3***
Overall risk	***Likely overall slight benefit***	***Likely overall slight benefit***	***Likely overall slight benefit***	***Likely overall slight benefit***	***Likely overall slight risk***	***Likely overall slight benefit***	***Likely overall slight benefit***

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Acknowledgements

We acknowledge the significant assistance and contributions to this project from NSW DPE personnel, Carmen Amos, Iwona Conlan, Samantha Dawson, Thomas Job, and Miah Kesby. We are also grateful to the project steering committee, Stephen Johnson, Tanya Mason, Hillary Cherry and Paul Doyle, for their assistance and expert knowledge input through all stages of this project.

We acknowledge the Traditional Custodians of the land where we work, the Yuggera, and Turrbal people, and the land which is the focus of this work, the people of the Murrumbidgee and Murray Rivers. We show our respect for Elders past, present and emerging and extent that respect to all Indigenous Australian and Torres Strait peoples.

We also thank the many other people that contributed to this project by providing data, sharing their knowledge, participating in our survey and expert workshops, and providing revisions to this report.

Glossary

Common acronyms

DPE New South Wales Department of Planning and Environment

RRC Reconnecting River Country Program

DPI New South Wales Department of Primary Industry

SDM Species Distribution Model

RIMFIM River Murray Floodplain Inundation Model

Common phrases

Weeds Exotic plant species which are regarded as pests in the study region

Project area Boundary of floodplain inundation area defined by RIMFIM

Inundation / flow scenario Constraints relaxation scenarios (outlined in table 2) used for modelling changes in species distribution

Suitability Areas of habitat deemed suitable by species distribution model outputs based on suitability threshold calculated with each model run. A cell must be suitable in all five model runs to be classed as suitable.

Highly suitable areas are the top 20% of suitable habitat which is, in theory, a subset of suitability, however greater areas of high suitability are possible as cells do not have to fit the criteria in each of the model runs to classify.

Likelihood In SDMs likelihood is the chance that a species can occur in a cell based on the initial occurrence data and environmental predictor variables.

For risk assessment likelihood refers to the magnitude of change predicted by SDMs

Introduction

Background

The New South Wales (NSW) Department of Planning and Environment (DPE) is currently conducting a range of assessments to understand the benefits and risks associated with various flow management options in the Murray and Murrumbidgee River catchments – the Reconnecting River Country (RCC) program. The RRC program seeks to use the best available data, knowledge, and techniques to investigate ecological outcomes of a suite of inundation scenarios representing different levels of relaxation in existing physical and/or human constraints to flow in these catchments.

The flows being considered under relaxed constraints aim to inundate low-lying wetlands, billabongs, flood runners (with a small portion of floodplain) at an increased frequency. These additional inundations would likely occur in winter/ spring.

As part of the RRC program, Griffith University was tasked with evaluating the risks and benefits of these inundation scenarios for weeds in the project area (Figure 1). This evaluation is needed to inform decisions regarding environmental water delivery as well as to better inform affected landholders about the likely risks and to allow the Program team to develop appropriate mitigation measures to address these.

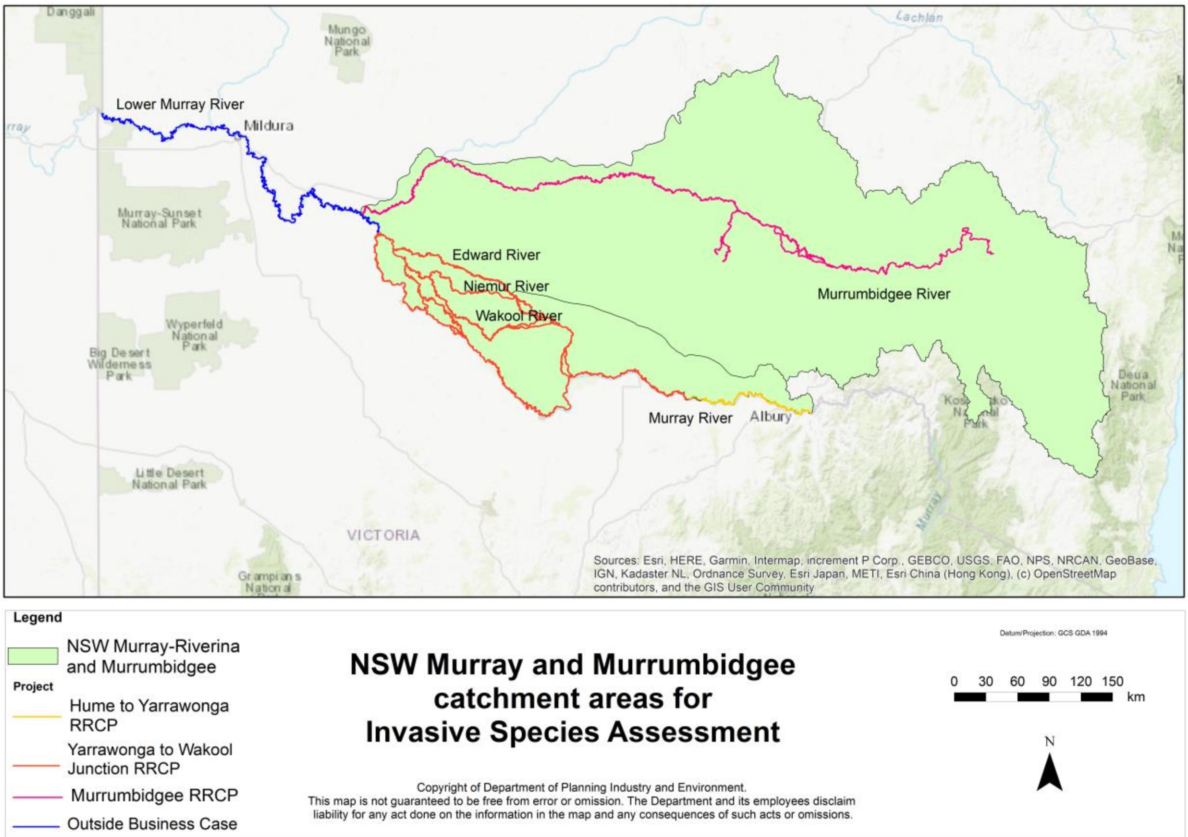

Figure 1. Project area map showing focus catchment areas and the constrained project area (in green) in the context of the Murray-Darling Basin and eastern Australia.

The overall aims of this project were to:

- describe the current invasive weed distribution and consequences in the project areas through a compilation and synthesis of existing knowledge;
- evaluate the likelihood and consequences of various flow constraint relaxation options changing invasive weed extent and impacts in the project area; and
- develop a risk framework for invasive plant species in relation to each inundation scenario.

Purpose of this report

This report presents the detailed results of this project in relation to the second and third project aims described above. An initial report addressing the first aim and describing the current invasive weed distribution and consequences in the project areas, based on a knowledge review, has previously been provided to DPE (see Capon et al., 2021).

More specifically, this report provides:

- results of species distribution modelling undertaken to describe the current extents of selected priority weed taxa and the changes predicted under each inundation scenario;
- results of an expert knowledge elicitation process (survey and workshops) to assess weed risks and benefits under current conditions and in relation to potential increased floodplain inundation;
- an overall risk assessment for each inundation scenario.

A summary report presenting the key findings of this project accompanies this technical report.

Structure of this report

This report presents a detailed presentation of the methods and results of this project. Methods are presented for both the species distribution modelling that was undertaken as well as the expert elicitation conducted. The Methods section also outlines the approach taken to developing the risk assessment framework. Summary results for each component are then presented followed by overall conclusions. Detailed data summaries for key project components are provided in the report Appendices.

Methods

Species distribution modelling

Overview

To explore the current potential distributions of weeds in the project areas (Figure 1) as well as potential changes to these under the RRC inundation scenarios, we developed species distribution models (SDMs) for each catchment (i.e., Murray and Murrumbidgee) under a base case and in relation to each RRC inundation scenario. To build these SDMs, we used a range of available climatic and environmental data (i.e., land use, vegetation, and wetland mapping), coupled with a range of calculated inundation metrics as predictor variables. The SDMs generated map outputs of the likelihood of the presence/absence of the weed species examined in the Murray and Murrumbidgee project areas under each scenario. We also conducted a range of spatial data analyses to determine the land uses, vegetation types and wetland classes with most suitable habitat for the weed species considered in each scenario and the changes predicted under these from the base case.

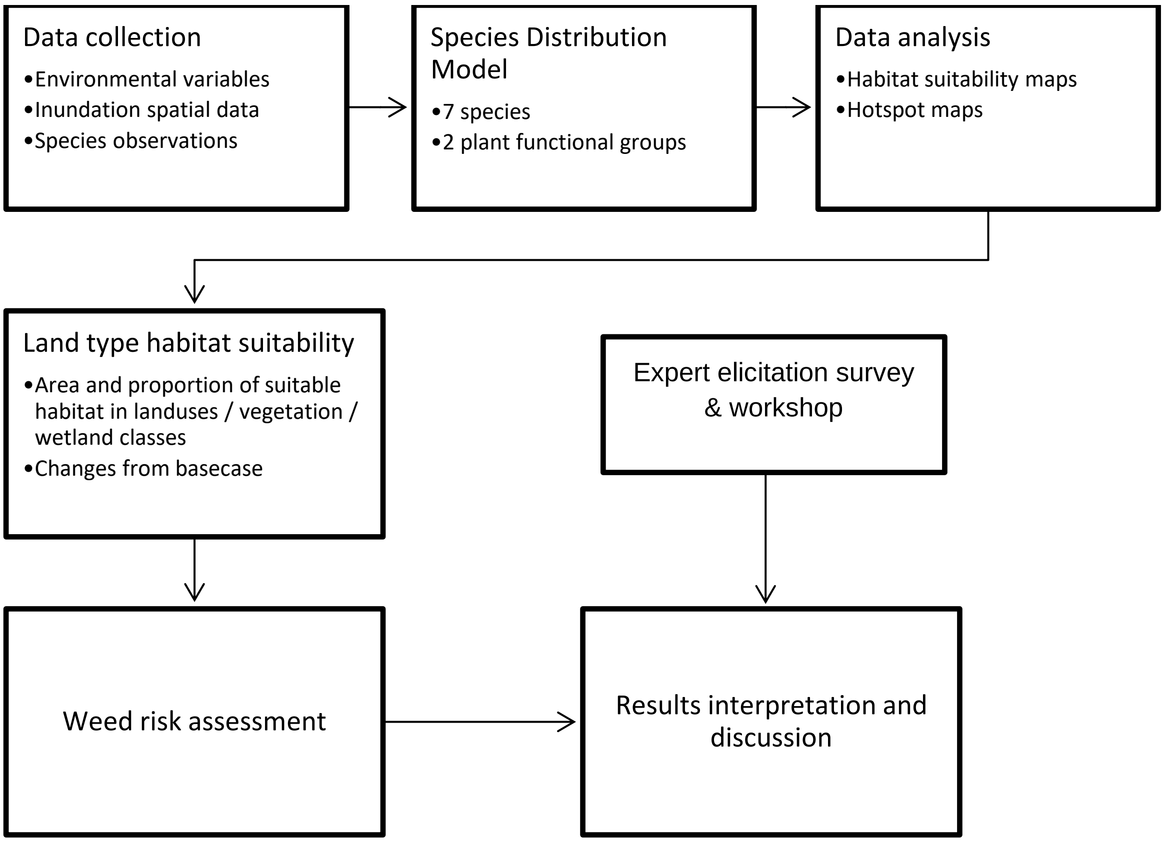

Figure 2. Flow chart of data collection, analysis, and interpretation methods used for this reconnecting river country program invasive species risk assessment project.

Species data

Twenty-nine of the 96 weed species shortlisted in the initial phase of this project (see Capon et al., 2021) were identified as priority species for SDMs through consultation with the steering committee which is comprised of invasive species and weed management experts from the NSW Department of Planning and Environment (DPE), the NSW Department of Primary Industry (DPI), NSW Parks and Wildlife Service. Species presence data were then obtained by extracting data from the Atlas of Living Australia (see Capon et al., 2021). Additional species data, collected during routine surveys and site inspections (N=433,434), was provided by NSW DPI. Only points that overlapped with the predictor variables were retained for analysis (N= 4,541). Some taxa did not have enough unique presence points (at least 5) overlapping with predictor variables (Tables 1 and 2) to run models and were therefore abandoned. Five observations were chosen as a conservative cutoff to potentially include a large number of species, although, the minimum number of observations for the selected species was 107. Seven priority weed species had sufficient available data for running the species distribution model analysis (Table 3).

Additionally, we generated SDMs for water plant functional groups (Brock and Casanova 1997) for which there was sufficient species distribution data – four of the seven plant groups. Two of these plant groups (i.e, Arp and Atl) were represented by a single species each, which were also modelled as individual species. Here we only present the findings for the individual species models. Consequently, SDMs were generated for nine taxa overall: seven individual species and two water plant functional groups (Tda – terrestrial damp species; Tdr – terrestrial dry species; Table 3).

Spatial data extraction

Extents of each bioclimatic variable were extracted for the project areas from global rasters (Table 1) through the ‘extract by mask’ tool in ArcGIS. We selected six of the bioclimatic variables based on our knowledge of weeds: i) mean annual temperature (Bio1); ii) max temp in warmest month (Bio5); iii) temperature range (Bio7); iv) minimum temp in coldest month (Bio6); v) annual precipitation (Bio12); vi) precipitation seasonality (Bio15). Similar combinations of bioclimatic variables have been used in global and Australian assessments of weed distribution (O'Donnell et al. 2012; Shabani et al. 2020).

Land use, vegetation, and wetland mapping shapefile layers (Table 1) were initially clipped to the project area polygon and then converted into rasters through the ‘polygon to shapefile’ tool in ArcGIS. We used the maximum combined area cell assignment type for resolving cells where more than one value existed and where multiple of the same value existed, assigning the output cell the value which was most dominant in the input. When converting shapefiles to rasters, we chose an output cell size of 5 x 5 m to align with the resolution of the inundation data (RIMFIM: see below).

Table 1. Summary of spatial data sources and group categorisation

Data	Resolution	Categorisation	Source
Bioclimatic variables suite (WorldClim v2)	30 sec (~1 km^2)	Mean annual temperature Maximum temperature in the warmest month Temperature range Minimum temperature in the coldest month Annual precipitation Precipitation seasonality	Fick, S.E. and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302-4315. Downloaded from the WorldClim data portal
Land use (Catchment scale Land Use Mapping Australia)	50 x 50 m Converted to 5 x 5 m aligning with RIMFIM data	<u>Primary land uses</u> Dryland agriculture and plantations Conservation and natural environments Intensive uses Irrigated agriculture and plantations Water/ Wetlands Production from relatively natural environments	ABARES 2021, Catchment Scale Land Use of Australia – Update December 2020, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, February, CC BY 4.0, DOI: 10.25814/aqjw-rq15.
Wetlands (ANAE wetland mapping)	1:25,000 to 1:250,000 Converted to 5 x 5m aligning with RIMFIM data	<u>Broad categorisation (as defined in Capon et al. 2021)</u> Temporary woodland Clay pan Freshwater herbaceous Temporary shrubland Permanent wetland Temporary waterbody Permanent waterbody Permanent herbaceous Temporary herbaceous Floodplain woodland Floodplain shrubland Saline herbaceous Waterhole Temporary wetland Unspecified river	Brooks S., Cottingham P., Butcher R. and Hale J. (2013). Murray-Darling Basin aquatic ecosystem classification: Stage 2 report. Peter Cottingham & Associates report to the Commonwealth Environmental Water Office and Murray-Darling Basin Authority, Canberra.
Vegetation (mapping and typology a combined output of the vegetation state and transition RRC project)	Converted to 5 x 5 m aligning with RIMFIM data	<u>Broad categories (as defined in Capon et al. 2021</u>) Blackbox woodland Lignum shrubland No vegetation River redgum forest River redgum woodland Terrestrial grassland Terrestrial shrubland Terrestrial woodland Wetland herbland Perennial wetland grass, sedge, herbland Saline wetlands	
RIMFIM	5 x 5 m	Inundation flow thresholds by zone for Murray Reconnecting	Cuddy SM, Penton D, Chen Y, Davies P and Ren Y (2012)

		River country areas and select Murrumbidgee areas where covered	MD2026: to rectify four flood inundation zones of Rim-FIM. Final report to Murray-Darling Basin Authority. CSIRO Water for a Healthy Country Flagship, Australia Overton, IC, McEwan, K, and Sherrah, JR (2006) The River Murray Floodplain Inundation Model – Hume Dam to Lower Lakes. CSIRO Water for a Healthy Country Technical Report 2006. CSIRO: Canberra. Sims, N.C., Warren, G., Overton, I.C., Austin, J., Gallant, J., King, D J., Merrin, L.E., Donohue, R., McVicar, T.R., Hodgen, M.J., Penton D.J., Chen, Y., Huang, C. & Cuddy, S. (2014). RiM-FIM Floodplain Inundation Modelling for the Edward-Wakool, Lower Murrumbidgee and Lower Darling River Systems. Report prepared for the Murray-Darling Basin Authority. CSIRO Water for a Healthy Country Flagship, Canberra.
CARM	5 x 5 m	Inundation flow thresholds for Burrinjuck Dam to Hay Weir	DPI (2015), Computer Aided River Management system for the Murrumbidgee River. Department of Primary Industries (Water)
Lowbidgee Zone 2	25 x 25 m	30 cumulative volume as predictor variable for inundation	DPE-EHG (2022), Lowbidgee Zone 2 Floodplain Inundation Model [an inundation model for the lower Murrumbidgee River floodplain between Maude Weir and Balranald developed using hydrological and remotely sensed data]. NSW Department of Planning and Environment, Environment and Heritage Group, Water for the Environment, Unpublished.

Inundation scenarios and data

Inundation scenario data provided by DPE was used to explore the species distribution response to inundation changes. Relaxation of constraints aims to restore historic flow regimes by increasing the frequency of events which inundate low-lying wetlands, billabongs, flood runners (with a small portion of floodplain). The inundation scenarios are modelled separately for the Murray and Murrumbidgee Rivers (Table 2) where the Murray is further considered in two sections; Hume to Yarrawonga and Yarrawonga to Wakool Junction.

Table 2. Inundation scenario and associated flow limit options for the Murray and Murrumbidgee Rivers

Murray		
Hume to Yarrawonga *Flow limit option at Doctors Point (ML/d)*	Yarrawonga to Wakool Junction *Flow limit option at downstream Yarrawonga Weir (ML/d)*	Scenario name
25,000 (current operational flow limit)	15,000 (current operational flow limit)	Y15D25 (basecase)
25,000	25,000	Y25D25
30,000	30,000	Y30D30
40,000	40,000	Y40D40
40,000	45,000	Y45D40
Murrumbidgee		
Flow limit option at Wagga Wagga (ML/d)		Scenario name
22,000 (current operational flow limit)		W22 (hereafter 22GL basecase)
32,000		W32 (hereafter 32GL)
36,000		W36 (hereafter 36GL)
40,000		W40 (hereafter 40GL)

We used the flow time series spells analysis data provided by DPE to calculate nine inundations metrics for each inundation threshold in each inundation model (Table 3). We then used the ‘reclassify by table’ tool in ArcGIS to join each metric to the corresponding inundation raster of commence-to-flow data, based on the inundation threshold (for each scenario). We then used the ‘mosaic to new raster’ tool in ArcGIS to join all rasters in the Murray and Murrumbidgee respectively, for each metric, to create one complete raster for each of the nine inundation metrics per scenario for each Reconnecting River Country Project area. The values for each metric ranged from 0 – 125, representing the number of years each metric is met.

Table 3. Description of inundation summary metrics derived from spells analysis outputs

ID	Metric	Description
N1	<30 Total Inundation	Number of years that cell is inundated less than 30 days in a year
N2	>30 Total Inundation	Number of years that cell is inundated more than 30 days in a year
N3	>60 Total Inundation	Number of years that cell is inundated more than 60 days in a year
N4	<30 Total NO Inundation	Number of years that cell is **not** inundated less than 30 days in a year
N5	>30 Total NO Inundation	Number of years that cell is **not** inundated more than 30 days in a year
N6	>60 Total NO Inundation	Number of years that cell is **not** inundated more than 60 days in a year
N7	Maximum Inter Flood <30	Maximum number of consecutive years that cell is not inundated less than 30 days in a year (number of consecutive 0s)
N8	Maximum Inter Flood >30	Maximum number of consecutive years that cell is not inundated more than 30 days in a year
N9	Maximum Inter Flood >60	Maximum number of consecutive years that cell is not inundated more than 60 days in a year

Species Distribution Models

For each of the nine selected weed taxa, we ran and compared two SDM algorithms, Maxent and Random Forest, to predict the likelihood of presence of species in each water functional group and in the priority species list (Table 4). Due to time and computational power required to predict with each model at the 5 m x 5 m resolution and current project time-constraints, we aggregated the predictor variables and model outputs to 100 m x 100 m resolution. Therefore, interpretation of model outputs needs to be considered at the 100 x 100 m scale which is a standard scale for analysis of broad scale vegetation patterns in arid/semi arid environments such as the Murray-Darling Basin.

The models were built on the base case scenario data (Y15D25 for Murray and 22GL) for Murrumbidgee) which included all predictor variables. We then predicted likelihood of presence on the basecase, and other scenarios (by replacing the basecase inundation metrics with each scenario inundation metrics), using the best algorithm. The best algorithm (i.e., Maxent or Random Forest) was identified using the Area Under the Curve (AUC), which indicates how good a model is at predicting known presence and absence. An AUC value of 0.5 means that the model is no better than random at predicting absence and presence, while an AUC of 1 (the maximum) indicates perfect prediction.

Calculating the AUC was made possible by randomly selecting background points to use as pseudo-absence in the models from cells with no presence points as well as splitting the data for each group into training (80%) and testing (20%) subsets five times (holding back a different 20% every time). This step yielded five predicted likelihoods of presence maps, with associated AUC, for each scenario for each group and taxa, allowing us to account for the uncertainty associated with the data.

For each taxa under each scenario, we calculated AUC-weighted average likelihood of presence $Pmean_j$ using the following method. For each run *i* of each scenario *j*, we calculated the weight of model run as w_{ij} = (AUC_{ij} – 0.5)^2, which give greater weight to the better performing models (with greater AUCs), and then calculated the weighted average likelihood of presence as:

$$Pmean_j = \frac{\sum_{i=1}^{i=5} P_{ij}\ x\ w_{ij}}{5}$$

One output of both Maxent and Random Forest is a threshold value (maximizing the sum of sensitivity and specificity) that allows conversion of the continuous likelihood of presence output into a binary unsuitable / suitable categorisation of the landscape. For each run of each scenario, we converted the continuous map into a binary map using this threshold to produce a binary map by scenario by identifying cells in the landscape that all five model runs agreed were suitable (agreement binary map).

Finally, the importance or contribution of each predictor variable to each SDM was noted from the model outputs. Random Forest values represent the relative variable importance (does not sum to 100) while Maxent values represent the percentage contribution of the variables (sums to 100). These were averaged across the five runs for each scenario (for each group and priority species) too. High numbers indicate a greater relative contribution to the results.

Table 4. List of taxa and plant functional groups used for species distribution modelling, the model algorithm used, the area under the curve (AUC) and the number of observations available.

Group	Species list (common name)	Selected model	Average AUC	Available observations
Lycium species (Tdr)	*Lycium ferocissimum* (African boxthorn)	MaxEnt	0.80	617
Marrubium species (Tdr)	*Marrubium vulgare* (Horehound)	MaxEnt	0.87	1132
Phyla species (Atl)	*Phyla canescens* (Lippia)	MaxEnt	0.64	107
Rubus species (Tdr)	*Rubus fruticosus spp. Aggregate* (Blackberries) *(Rubus anglocandicans* *Rubus leucostachys* *Rubus ulmifolius* var. *ulmifolius* *Rubus ulmifolius* var. *anoplothyrsus* *Rubus leightonii* *Rubus phaeocarpus)*	Random forest	0.99	473
Sagittaria species (Arp)	*Sagittaria platyphyla* (Arrowheads)	Random forest	0.98	363
Xanthium species (Tdr)	*Xanthium spinosum* (Bathurst burr)	Random forest	0.84	320
Salix species (Tda)	*Salix nigra* (Black willow)	Random forest	0.99	122
Tda (Terrestrial damp water plant functional group)	*Centaurea calcitrapa* (Star thistle) *Cestrum parqui* (Green cestrum) *Salix nigra* (Black willow) *Tamarix ramosissima* (Saltcedar)	Random forest	0.98	130
Tdr (Terrestrial dry water plant functional group)	*Ailanthus altissima* (Tree of heaven) *Alhagi maurorum* (Camel thorn) *Alternanthera pungens* (Kahki weed) *Asparagus asparagoides* (Bridal creeper) *Cenchrus longispinus* (Spiny burr grass) *Centaurea solstitialis* (St Barnaby's thistle) *Cuscuta campestris* (Golden dodder) *Cytisus scoparius* (Scotch broom) *Eragrostis curvula* (African lovegrass) *Galenia pubescens* (Galenia / Carpet weed) *Genista monspessulana* (Cape broom) *Gleditsia triacanthos* (Honey locust) *Heliotropium amplexicaule* (Blue heliotrope) *Hypericum perforatum* (St John's wort) *Ligustrum lucidum* (Broad-leaved privet) *Ligustrum sinense* (Narrow-leaved privet) *Lycium ferocissimum* African boxthorn) *Marrubium vulgare* (Horehound) *Nassella hyalina* (Cane needlegrass) *Nassella neesiana* (Chilean needlegrass) *Nassella* (Serrated tussock grass) *Onopordum* *Onopordum acanthium* (Scotch thistle)	MaxEnt	0.86	3503

	Onopordum acaulon (Stemless thistle) *Onopordum Illyricum* (Illyricum thistle) *Opuntia stricta* (Prickly pear) *Physalis hederifolia* (Sticky ground cherry) *Prosopis glandulosa* (Honey mesquite) *Rhaponticum repens* (Creeping knapweed) *Rosa rubiginosa* (Sweet briar) *Sclerolaena birchii* (Galvenised burr) *Senecio madagascariensis* (Fireweed) *Solanum elaeagnifolium* (Silver-leaf nightshade) *Solanum rostratum* (Buffalo burr) *Sorghum halepense* (Johnson grass) *Tamarix aphylla* (Athel pine) *Tribulus terrestris* (Caltrop) *Ulex europaeus* (Gorse) *Xanthium spinosum* (Bathurst burr)			

Summary statistics

Area of suitable habitat

For each taxon under each scenario, we recorded the number of cells classified as 'suitable' from the agreement binary map. Each cell represents 100 m x 100 m which is equivalent to 1 hectare thus a count of cells is equivalent to hectares of suitable habitat. To assess the distribution of taxa with respect to land use, vegetation, and wetland categories we first created polygon layers of each habitat classification where like categories were dissolved to output one multipart polygon for each category in ArcGIS. We then used the exact_extract (package = exactextractr) function in R to identify the presence and area covered by each species group in each category. We then calculated the proportion of the categories' total area that the species group occupied. We also calculated summary statistics using the same approach for areas classified as 'highly suitable' for each weed taxa using a higher threshold value (i.e., the top 20 % of the range of values above the mean 'suitable' habitat threshold).

It is important to note that it is possible to have greater areas of highly suitable habitat compared to suitable habitat as the high suitability threshold value was calculated as the top 20 % of the mean suitability threshold from all five model runs (i.e,. 1 - mean suitability*0.2). This compares to the more conservative suitable habitat which only counts cells which were suitable in all of the five model runs.

Weed hotspots

To explore spatial patterns in the richness of weed taxa in the project area under each flow scenario, we used the cellStats (package = raster) function in R to calculate the number of modelled taxa present in each cell (i.e., a count of the raster layers which had suitable habitat in a given cell) and generated a raster of the output. To assess species distribution in relation to land use, vegetation, and wetland categories we again used the exact_extract function to identify the number of weed taxa in each category and the total area occupied.

To identify areas of high occupancy by weeds (i.e., a weed hotspot), we visually inspected the output of the cell statistics tool, noting regions where suitable habitat for four or more weed taxa overlapped, and reclassified the raster to 1: hotspot, 0: not hotspot. To explore patterns in the distribution of hotspots, again used the exact_extract function to identify the hotspot area in each habitat type.

Assessing model changes from base case

To identify where habitat suitability differed between each inundation scenario and the base case within each project area, we compared the two model output rasters using the overlay function (package = raster) in R. Within the overlay, we applied a custom function which determined on a cell-by-cell basis if the habitat was; 1. unsuitable in both models, 2. suitable in the base case but unsuitable in the inundation scenario (i.e. a decrease in habitat area), 3. unsuitable in the base case but suitable in the inundation scenario (i.e. an increase in habitat area), and 4. suitable in both models.

We then calculated changes from the base case in the areas of suitable and highly suitable habitat predicted for each weed taxa, as well as weed hotspots, under each scenario, both at an overall level and with respect to each land use, vegetation type and wetland class.

Expert elicitation

A range of expert elicitation activities were undertaken during this project to support and validate the findings of the species distribution modelling. These activities included consultation with the project steering committee and other relevant stakeholders (see Capon et al. 2021) as well as two expert elicitation workshops. Because of project constraints related to COVID-19, our main expert elicitation activity was an online survey regarding weed risks and benefits in relation to the current situation as well as possible increases in inundation in the project area. This survey was designed in consultation with the steering committee and participants in the first expert workshop and co-prepared with DPI staff. The survey was conducted under Griffith University's human ethics protocols.

The survey entailed a suite of questions regarding expert perspectives on the distribution, impacts and management of weeds in the project area in general and with respect to priority taxa, including taxa used in our SDMs as well as other priority weed taxa identified in Capon et al. (2021) that did not have sufficient species presence data for modelling.

A summary of survey results is presented in this report.

Risk assessment framework

We developed a risk assessment framework to evaluate significant differences in the predicted outcomes for weeds of each RRC flow scenario in relation to the base case. Our framework comprised criteria, and associated scoring, to evaluate the risk or benefit of changes to the extent of modelled weed taxa (Table 5) as well as the consequence / severity of such changes (Table 6) based on the outputs of the species distribution modelling.

Different weightings were assigned to criteria via allocated scores to reflect the assumed contribution of each criterion to the overall likelihood or consequence. For example, a change in highly suitable habitat was deemed to be the most important risk criterion and was thus allocated higher scores than suitable habitat criteria. Changes in land use, vegetation types and wetland classes were also included as risk criteria because these reflect the diversity of spatial units that may be affected by a change in weed extents. We assumed, for instance, that the risk of a week that expands into multiple land uses or vegetation types is greater than that posed by a weed expanding with the same proportion in terms of area but in only one land use or vegetation type.

Scoring was then completed for each weed taxa as well as weed hotspots, with consequence scores only calculated for the specific weed species examined. Likelihood scores were then summed for each taxon for each flow scenario to indicate the likelihood of risks or each weed taxa under each scenario. Consequence scores were also summed for each weed species for each catchment. For each weed species, an index of overall risk under each flow scenario was then calculated by multiplying the relevant likelihood and consequence values. Finally, an overall risk score was calculated by summing these values in addition to the summed likelihood values for water plant functional groups and weed hotspots. Resulting values were then standardised by dividing by the maximum possible score and multiplying by 100 to give a final score from +/- 0 – 100, whereby a large positive result indicates a high proportionate risk and a negative value indicates a potential benefit.

Table 5. Criteria and scores to rank the likelihood of an increased distribution of a weed taxon.

Criteria	**Large proportional decrease (> 10% from base case)**	**Slight proportional decrease (<10% from base case)**	**No change**	**Slight proportional increase (< 10% from base case)**	**Large proportional increase (> 10% from base case)**
Change in total habitat					
Change in suitable habitat	-8	-2	0	+2	+8
Change in highly suitable habitat	-16	-4	0	+4	+16
Change in dominant land uses occupied					
Conservation and natural environments	-4	-1	0	+1	+4
Dryland agriculture and plantations	-4	-1	0	+1	+4
Intensive uses	-4	-1	0	+1	+4
Irrigated agriculture and plantations	-4	-1	0	+1	+4
Production from natural environments	-4	-1	0	+1	+4
Water and wetlands	-4	-1	0	+1	+4
Change in dominant vegetation types occupied					
BB woodland	-4	-1	0	+1	+4
Lignum shrubland	-4	-1	0	+1	+4
Perennial wetland GRS	-4	-1	0	+1	+4
RRG forest	-4	-1	0	+1	+4
RRG woodland	-4	-1	0	+1	+4
Terrestrial grasslands	-4	-1	0	+1	+4

Terrestrial shrublands	-4	-1	0	+1	+4
Terrestrial woodlands	-4	-1	0	+1	+4
Wetland herblands	-4	-1	0	+1	+4
Changes in dominant wetland classes occupied					
Claypan	-4	-1	0	+1	+4
Floodplain woodland	-4	-1	0	+1	+4
Freshwater herbaceous	-4	-1	0	+1	+4
Permanent herbaceous	-4	-1	0	+1	+4
Permanent waterbody	-4	-1	0	+1	+4
Temporary herbaceous	-4	-1	0	+1	+4
Temporary shrublands	-4	-1	0	+1	+4
Temporary waterbody	-4	-1	0	+1	+4
Temporary wetlands	-4	-1	0	+1	+4
Temporary woodland	-4	-1	0	+1	+4
Unspecified river	-4	-1	0	+1	+4
Waterhole	-4	-1	0	+1	+4

Table 6. Criteria and scores to rank the potential consequences/s of an increased distribution of a weed taxon. (N.B. only relevant to weed species, not water plant functional groups).

Consequence scores

Criteria				
Weed of national significance	Yes = 10	No = 0		
Regional Weed Priority	Prevention = 4	Eradication = 2	Containment = 2	Of concern = 1
Impacts to fauna	Yes = 2	No = 0		
Impacts to vegetation	Yes = 2	No = 0		
Impacts to humans	Yes = 2	No = 0		
Impacts to agriculture	Yes = 2	No = 0		
Other impacts	Yes = 2	No = 0		

Results

Species distribution models

Base case

Weed distribution and extent

Of the nine weed taxa considered, Phyla was predicted to have the greatest extent of suitable habitat in the total project area under the base case (~30 % of total project area), considerably higher than the next most widely distributed taxon - Terrestrial dry (Tdr) species (~6 % of total project area; Figure 2). Marrubium, Lycium and Xanthium also had moderately high areas of suitable habitat. Salix had the least predicted suitable habitat of the taxa considered (0.26 % of total project area).

Different patterns were evident when considering highly suitable habitat only (Figure 2). Several species (Phyla, Lycium and Sagittaria) with relatively high predicted areas of suitable habitat, for instance, had relatively low areas of highly suitable habitat and Marrubium and Tdr species had virtually no highly suitable habitat. In contrast, other taxa (Rubus and Tda species) had relatively similar areas of suitable and highly suitable habitat. The high areas of Salix highly suitable habitat suggest that most suitable habitat for this taxon is likely to be highly suitable. Xanthium had the greatest area of highly suitable habitat in the project area under the base case, representing 1.9 % of the total project area (Figure 2).

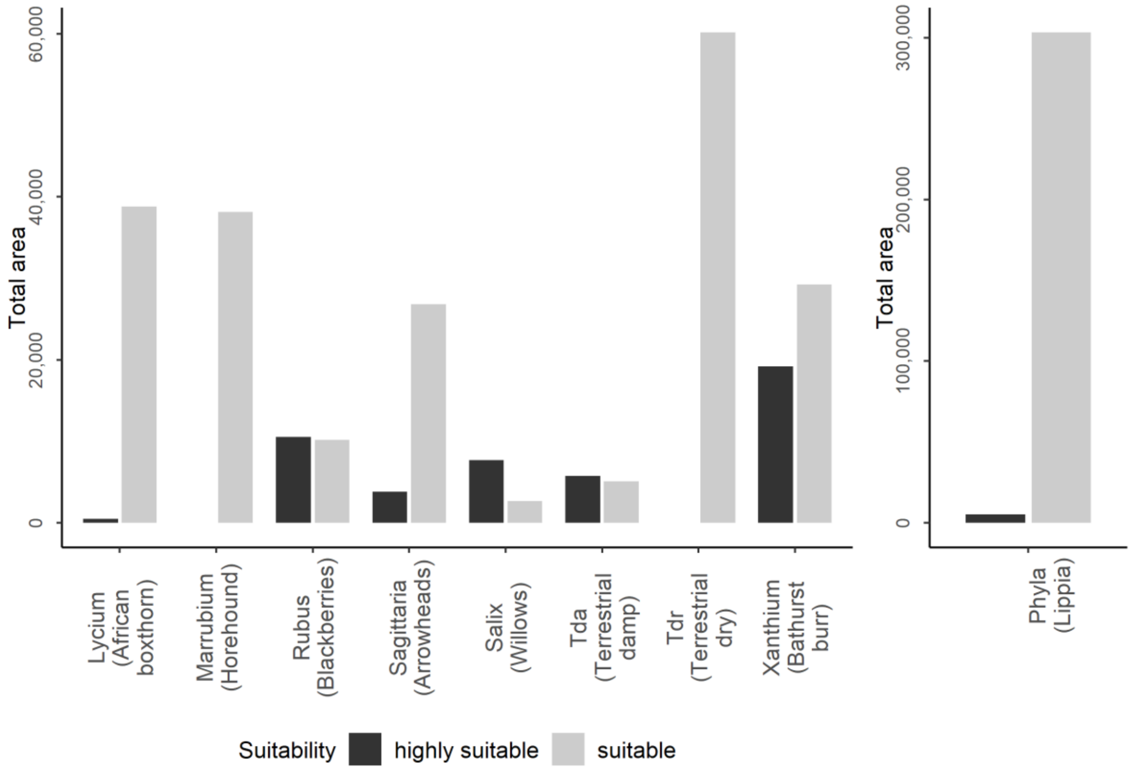

Figure 2. Total suitable habitat area (ha) and total highly suitable habitat area (ha) in the overall project area for each of the nine modelled taxa under the base case.
(N.B. Suitable habitat includes cells that were above the suitability threshold in all five model runs. Because the threshold for High Suitability was calculated as an average across these five model runs, the area classified as above this value could be greater.)

Major drivers

The most important predictor variables in each SMD across all weed taxa tended to be mainly climatic (Table 7). In particular, annual rainfall emerged as a key driver of weed distribution for five of the nine taxa. Inundation metrics were moderately important predictors in SDMs for all weed taxa considered to varying degrees, both for the amphibious and terrestrial taxa (Table 7). For most taxa, the contribution of the majority of inundation metrics to models were relatively evenly. For the Tdr (terrestrial dry species) group, and key species within this group (e.g., Lycium, Marrubrium), however, inundation metrics associated with longer dry periods (N6, N7 and N8) were particularly important predictor variables (Table 7).

Weed hotspots

Weed hotspots (i.e., areas comprising suitable habitat for four or more modelled weed taxa) occupied a total of 684 hecates in the Murray project area under the base case and 1286 hectares in the Murrumbidgee project area (Figure 3). This represents less than 0.1 % and ~ 0.4 % of the project areas in each of these catchments respectively.

Weed hotspots tended to occur in the vicinity of all the major towns in the project area (Wagga Wagga, Hay, Albury, Echuca, Denliquin and Swan Hill) as well as along the Murrumbidgee Rivers south of Griffith (Figure 3).

In both catchments, most weed hotspots under the base case occurred within the `production from relatively natural environments` and water/wetlands land uses (Table 8). With respect to vegetation types, weed hotpots had the greatest extent in both catchments in river red gum forest and then river red gum woodlands and, to a lesser degree, terrestrial grasslands. Black box woodlands in the Murray project area also comprised a significant area of weed hotspots under the base case (Table 8). Weed hotspots were most prevalent in the permanent waterbody, permanent wetland, floodplain woodland, termporary wetland and temporary woodland wetland classes in both catchments (Table 8).

Table 7. Mean contribution of each predictor variable for each weed taxa species distribution model for the overall project area. N.B. Where the Random Forest model algotirthm was selected, values represent the relative variable importance of each predictor (i.e., values do not sum to 100). Where the Maxent algorithm was used, values represent the percentage contribution of each predictor (sum to 100). Mean values represent averages across the five runs for each scenario for each weed taxa. High numbers indicate a greater relative contribution to the results, cells of the three greatest contributions for each model shaded.

	Weed taxa								
	Salix	Phyla	Tda species	Rubus	Marrubium	Sagittaria	Lycium	Tdr Species	Xanthium
SDM Model Algorithm	Random Forest	Maxent	Random Forest	Random Forest	Maxent	Random Forest	Maxent	Maxent	Random Forest
Predictor variables*									
N1 (<30 Total Inundation)	9.25	4.56	8.99	11.41	4.25	9.32	2.76	2.39	9.84
N2 (>30 Total Inundation)	8.16	0.86	9.26	12.07	0.24	9.11	3.10	0.07	10.86
N3 (>60 Total Inundation)	7.04	11.62	7.16	9.88	6.22	10.07	5.89	8.08	11.40
N4 (<30 Total NO Inundation)	8.37	4.38	8.38	10.38	0.75	9.49	2.23	0.46	12.26
N5 (>30 Total NO Inundation)	8.79	7.78	8.93	10.50	0.43	10.66	1.01	0.21	8.35
N6 (>60 Total NO Inundation)	9.58	14.53	10.49	11.89	13.33	17.93	3.43	9.15	8.21
N7 (Max Inter Flood <30)	8.89	1.70	13.03	11.06	29.08	8.56	5.52	25.37	6.51
N8 (Max Inter Flood >30)	10.12	12.16	10.20	10.07	17.34	7.99	17.18	17.32	7.81
N9 (Max Inter Flood >60)	8.77	1.02	9.41	9.92	4.57	9.69	7.43	1.98	10.44
Wetland categories	3.39	2.27	2.84	4.70	0.61	9.42	3.96	0.28	-0.37
Land use (primary categories)	2.67	2.79	4.95	8.60	9.38	7.14	9.48	24.47	5.62
Land use (secondary categories)	2.80	7.94	5.31	10.72	1.65	7.81	0.85	1.19	5.81
Vegetation (broad categories)	3.91	0.87	2.95	8.24	2.57	5.42	2.10	4.70	8.53
Vegetation (sub categories)	3.22	0.91	1.73	8.58	0.39	4.41	1.11	0.20	7.41
Average mean temperature	14.45	2.66	15.94	19.01	0.26	32.11	1.70	0.86	20.97
Maximum temp warmest month	11.60	0.39	10.38	22.54	0.36	20.87	1.89	0.32	23.42
Temperature range	9.38	3.88	8.68	18.89	0.85	20.40	1.08	0.18	19.74
Rainfall seasonality	13.19	2.54	17.40	15.11	4.23	13.88	2.88	1.43	14.51
Minimum temp coldest month	12.94	10.72	13.13	18.70	1.29	27.58	24.54	0.47	23.52
Annual rainfall	31.97	6.43	27.33	49.54	2.21	40.57	1.86	0.88	21.20

* See Tables 1 and 2 for explanation of predictor variables

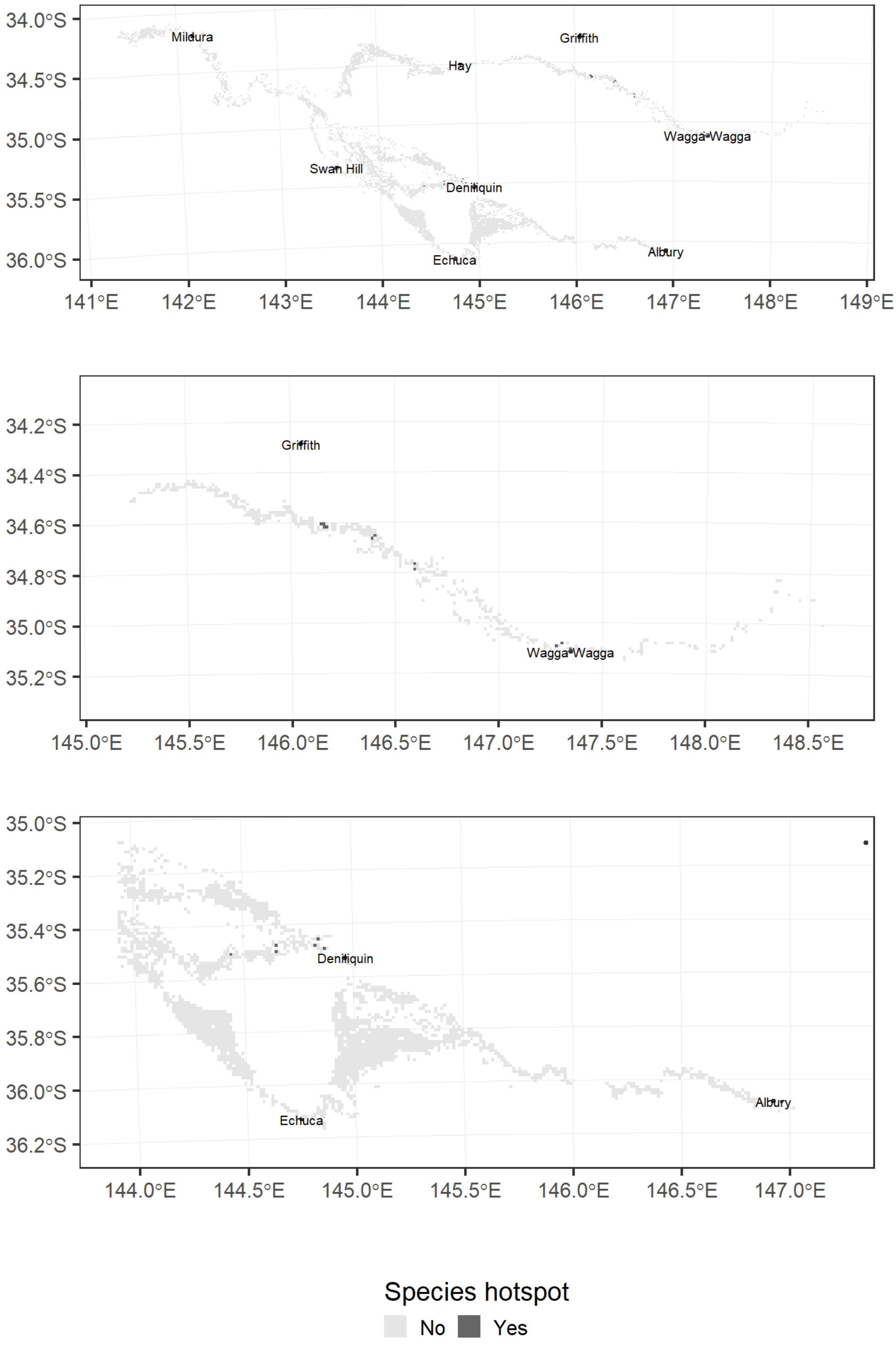

Figure 3. Distribution of modelled weed hotspots in the overall project area (top), the Murrumbidgee project area (middle) and the upper Murray project area (bottom).

Table 8. Area (ha) and proportion (%) of each Land use / Vegetation type, and Wetland class occupied by modelled weed hotspots under the base case for the Murray and Murrumbidgee project areas.

	Murray		**Murrumbidgee**	
	Suitable habitat (ha)	% of Land use / Vegetation type / Wetland class occupied by suitable habitat	Suitable habitat (ha)	% of Land use / Vegetation type / Wetland class occupied by suitable habitat
Land use				
Conservation and Natural Environments	64	0.04	145	0.08
Dryland Agriculture and Plantations	91	0.08	304	0.27
Intensive Uses	27	0.20	79	0.58
Irrigated Agriculture and Plantations	49	0.04	36	0.03
Production from Relatively Natural Environments	634	0.29	1039	0.47
Water/Wetlands	326	0.55	456	0.77
Vegetation type				
Black box woodland	145	0.11	22	0.02
Lignum shrublands	7	0.07	17	0.17
No vegetation	278	0.13	605	0.29
Perennial wetland grass, sedge and rush lands	6	0.29	2	0.10
River red gum forest	432	0.24	1176	0.65
River red gum woodland	319	0.40	297	0.37
Terrestrial grasslands	235	0.53	134	0.30
Terrestrial shrublands	14	0.11	0	0.00
Terrestrial woodlands	3	0.04	7	0.09
Wetland herblands	1	0.00	5	0.02
Wetland class				
Clay pan	1	0.00	63	0.03
Floodplain shrubland	0	0.00		0.00
Floodplain woodland	221	0.27		0.00
Freshwater herbaceous	1	0.02		0.00
Permanent herbaceous	1	0.08		0.00
Permanent waterbody	129	0.56	300	1.30
Permanent wetland	90	1.25	131	1.82
Saline herbaceous	0	0.00		0.00
Temporary herbaceous	4	0.15	4	0.15
Temporary shrubland	0	0.00		0.00
Temporary waterbody	182	1.37	6	0.05
Temporary wetland	0	0.00	1	0.05

Temporary woodland	44	0.10	85	0.19
Unspecified river	0	0.00		0.00
Waterhole	1	6.08		0.00

RRC inundation scenarios

Weed distribution and extent

Maps and plots showing absolute changes in the distribution and extent of each weed taxa in each catchment under each inundation scenario are provided in Appenidx 1.

Both positive and negative changes in the distribution of suitable and highly suitable habitat for the modelled weed taxa were predicted by the SDMs generated for each of the inundation scenarios (Figures 4-7). Overall, the direction and magnitude of change from the base case was comparable within each modelled taxon across all of the inundation scenarios for each catchment, with only a few instances where overall changes in suitable, or highly suitable, habitat were substantially greater in a particular inundation scenario (Figures 4-7).

In the Murray, suitable habitat increased under the RRC scenarios compared to the base case for Tdr species as a group and for the Tdr species considered individually (i.e. Lycium, Marrubium, Rubus and Xanthium) while significant declines in suitable habitat were apparaent for the amphibious species (Phyla and Sagittaria) and, to a lesser degree, the Tda species, both as a group and the member species (i.e. Salix; Figure 4).

Similar trends were apparent for highly suitable habitat in the Murray, although no highly suitable habitat for Tdr species as a group was predicted (Figure 5). As per suitable habitat, however, increases in highly suitable habitat were predicted under all RRC scenarios for the individual Tdr species (i.e., Lycium, Marrubium, Rubus and Xanthium) with declines in highly suitable habitat predicted for the amphibious (Phyla and Sagittaria) and Tda species as a group (Figure 5). The exception was for Salix, the individual Tda species modelled, for which highly suitable habitat increased slightly from the base case. Predicted changes from base case in highly suitable habitat tended to vary more between scenarios than that for suitable habitat, particularly for Phyla and Xanthium (Figure 5).

In the Murrumbidgee, suitable habitat also increased under inundation scenarios for three of the Tdr species considered (Lycium, Marrubium and Rubus) but declined slighty for Xanthium and completely disappeared for Tdr species as a group (Figure 6). For amphibious and Terrestrial damp species (and the Tda group), slight declines were again apparent in the Murrumbidgee although suitable habitat for Sagittaria was not predicted in this catchment under any scenario (Figure 6). Increases in highly suitable habitat in the Murrumbidgee were predicted for Phyla and Sagittaria (Figure 7).

In general, suitable habitat for Tdr species increased in both study areas with similar magnitudes of change between inundation scenarios. Conversely, suitable habitat for Tda and amphibious species decreased under inundation scenarios in both study areas. Potential drivers for these modelled responses are included in the discussion.

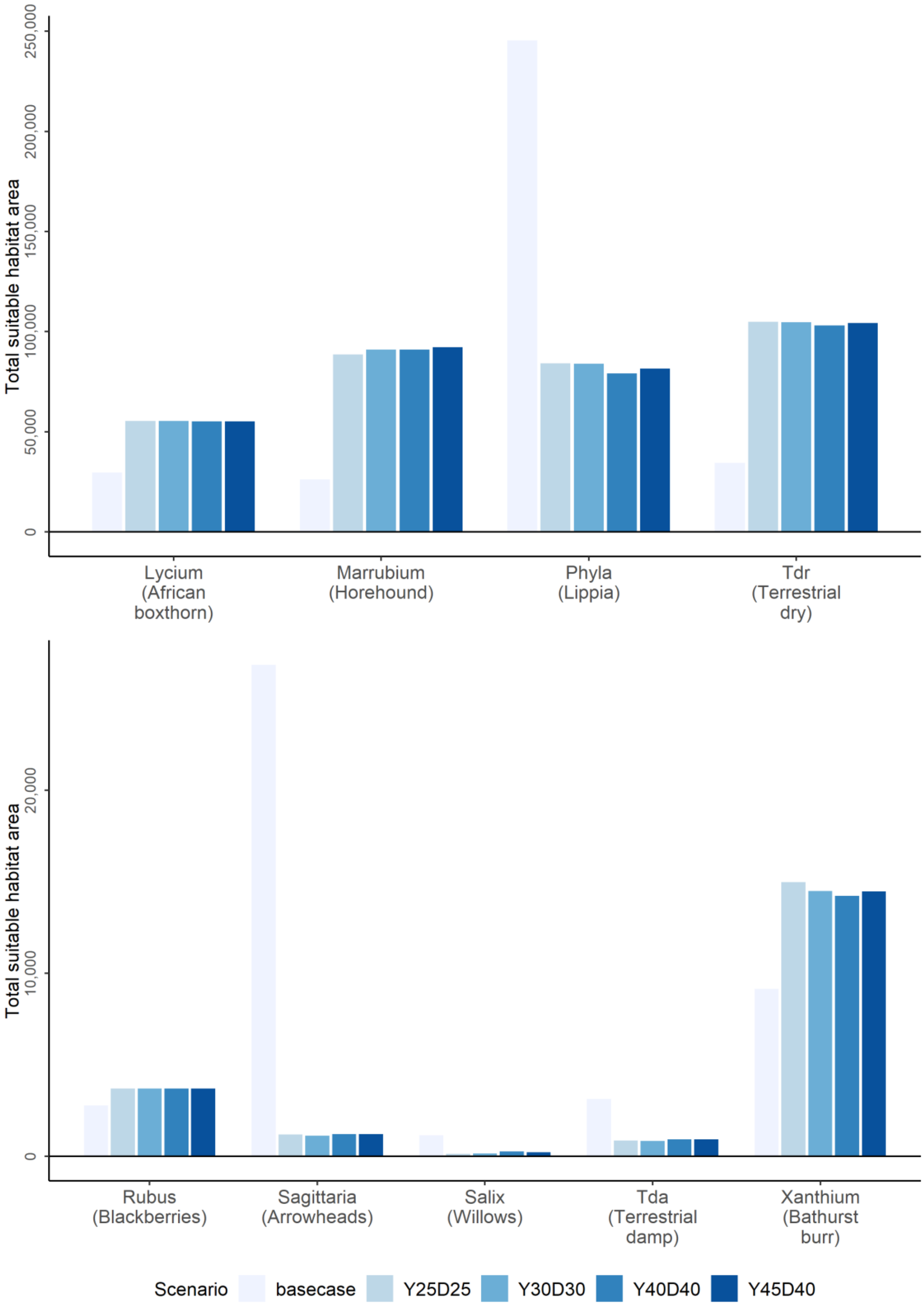

Figure 4. Total area (ha) of suitable habitat predicted by SDMs for all modelled taxa the Murray under the base case and each RRC inundation scenario.

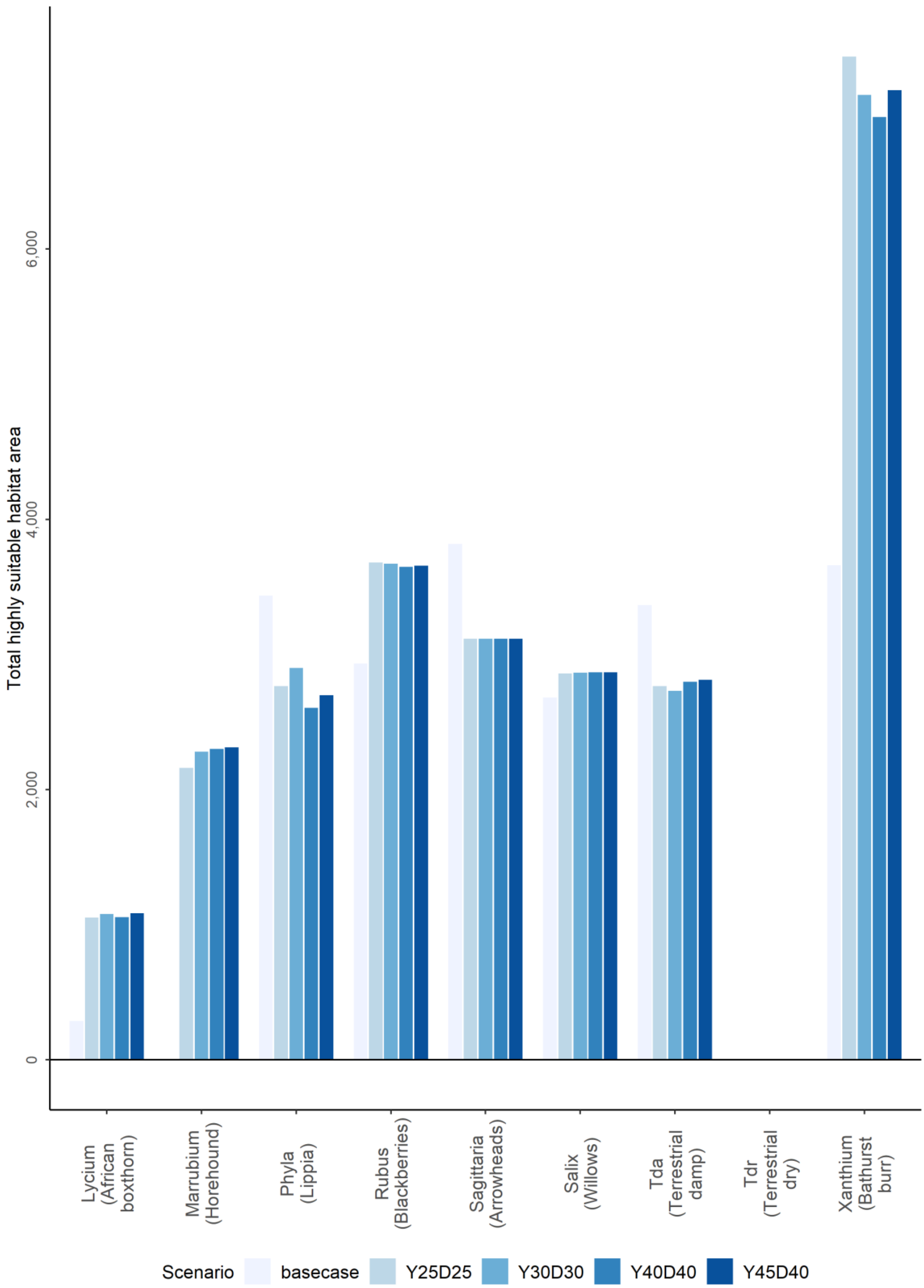

Figure 5. Total area (ha) of highly suitable habitat predicted by SDMs for all modelled taxa the Murray under the base case and each RRC inundation scenario.

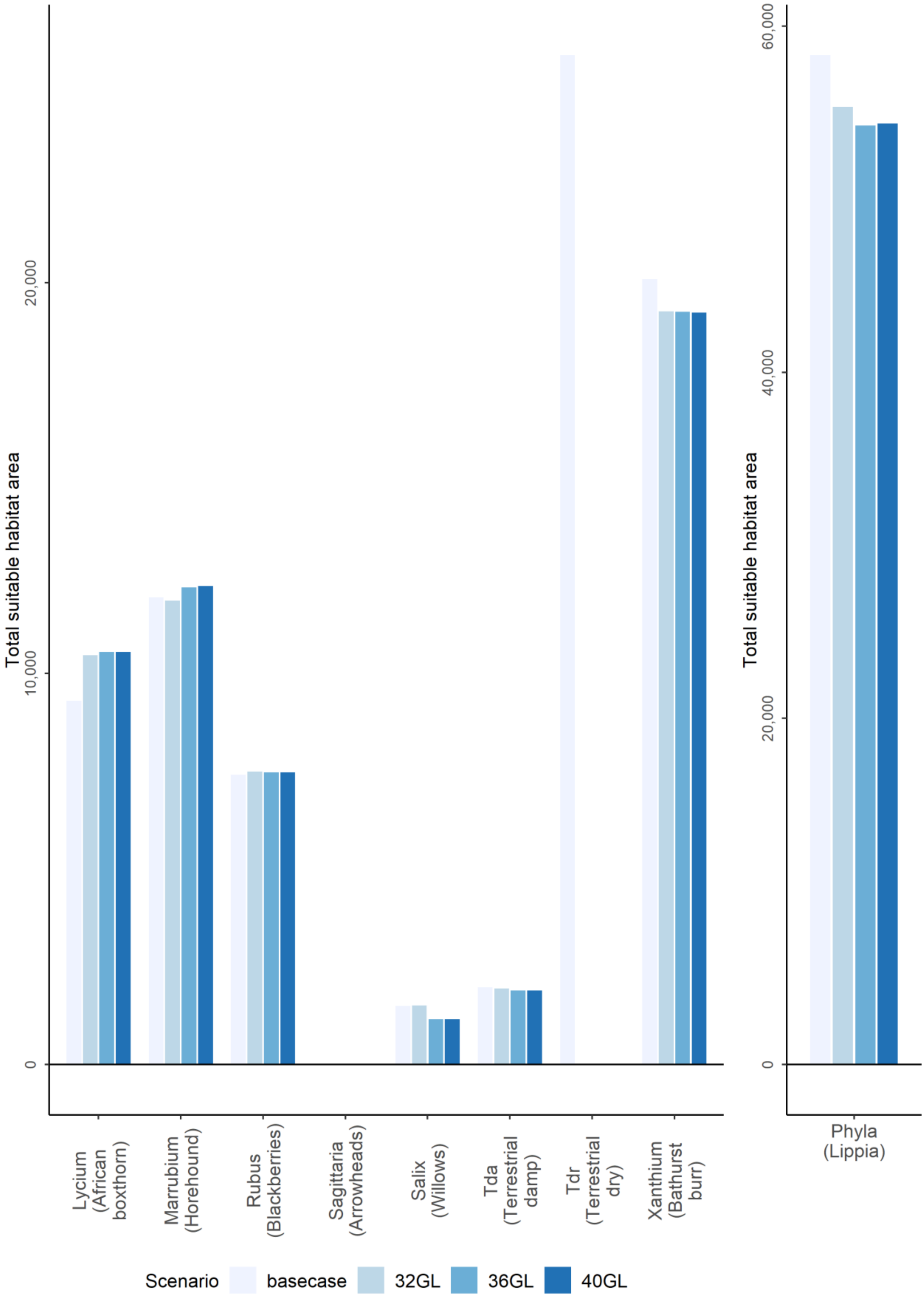

Figure 6. Total area (ha) of suitable habitat predicted by SDMs for all modelled taxa for the Murrumbidgee under the base case and each RRC inundation scenario.

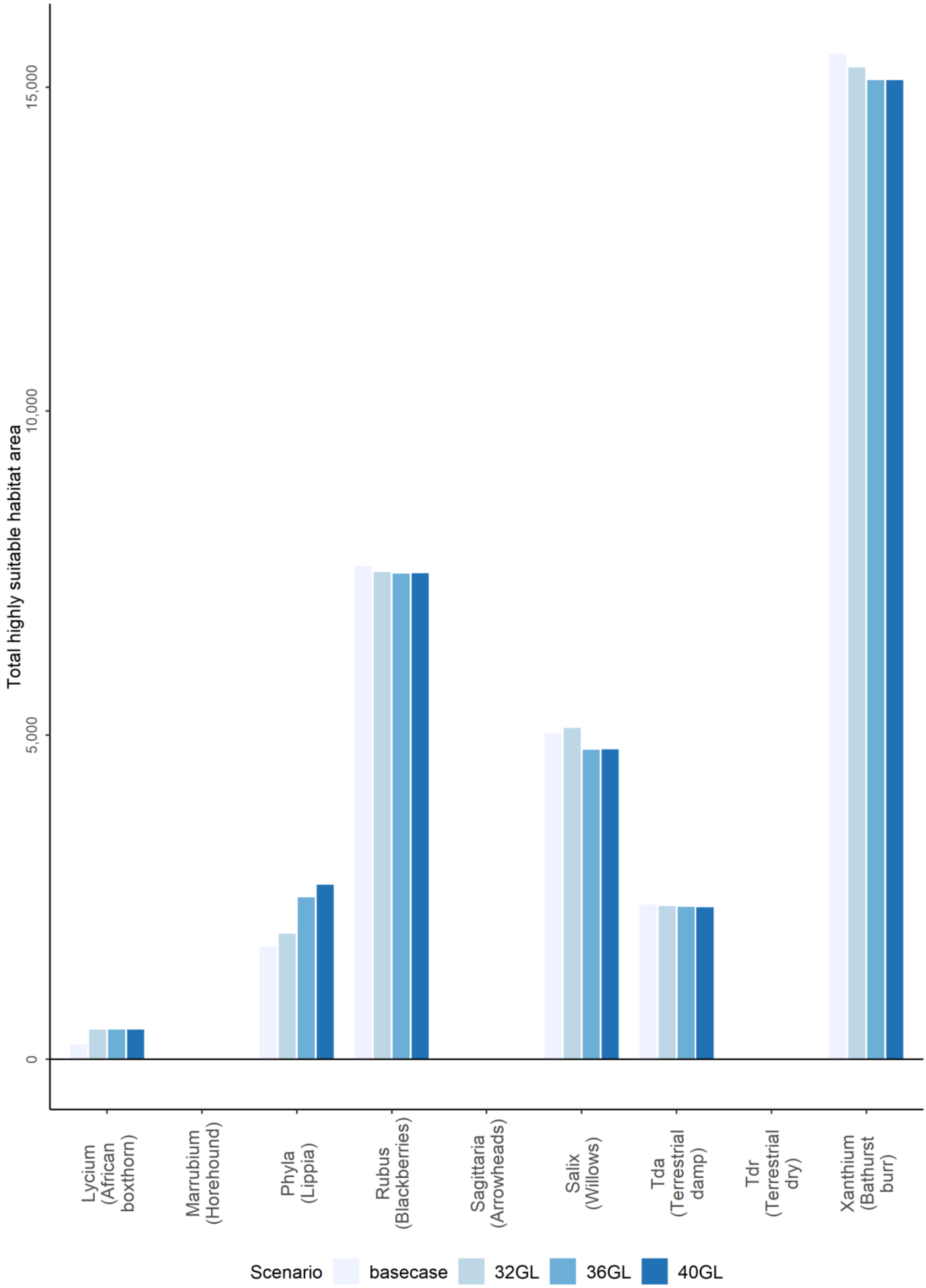

Figure 7. Total area (ha) of highly suitable habitat predicted by SDMs for all modelled taxa the Murrumbidgee under the base case and each RRC inundation scenario.

Distribution according to land use

As per total areas of suitable habitat, there was relatively little variation in the proportion of change occurring in land uses across all scenarios within each taxon for the Murray (Figures 8 and 10). Areas of highly suitable habitat exhibited greater variation across scenarios in terms of the magnitude, and in a few cases the direction, of changes predicted (Figures 9 and 12). The greatest changes in the proportion of suitable habitat for Tda species, for example, were all declines in the Murray (Figure 8) while increases in highly suitable habitat were predicted, especially in the Irrigated agriculture and plantations land use (+581 ha Y45D40 HS; Figure 9).

Conservation and natural environments emerged as the land use with the greatest change in the proportion occupied by suitable habitat in the Murray under all scenarios, especially for Marrubium (+897 ha Y45D40) and Tdr species (+26232 ha Y45D40; Figure 8), but with all taxa, except for Phyla (-56079 ha Y45D40), exhibiting increased suitable habitat in this land use. Marrubium and Tdr suitable habitat also increased in the Dryland agriculture and plantations and Water/wetlands land uses across all scenarios in the Murray (Figure 8, see appendix 1 for absolute values). Suitable habitat also increased in the Production from relatively natural environments land use for Lycium (+25441 ha Y45D40) and Xanthium (+3774 ha Y45D40; Figure 8). Suitable habitat for Rubus mainly increased in the Irrigated agriculture land use (+532 ha Y45D40; Figure 8). The greatest changes in the proportion of land uses with suitable habitat for Phyla, Sagittaria, Salix and Tda species were all declines, largely in the Intensive uses, Irrigated agriculture and plantations, Dryland agriculture and plantations and Water/wetlands land uses (Figure 8, see appendix 1 for absolute values).

For the Murrumbidgee, the greatest changes in the proportion of land use occupied by suitable habitat were all declines (Figure 9). However, Lycium was the exception where increases in area were predicted in Dryland agriculture and plantations (+145 ha 40GL) and Water/wetlands (+501 ha 40GL) land uses in all scenarios, Conservation and natural environments in the 32GL and 40GL (+1334 ha) scenarios and Production from natural environments for the 36GL scenario (+747 ha; Figure 9). For other taxa, the declines predicted were comparable amongst the 36GL and 40GL scenarios and greater than those predicted under the 32GL scenario, especially for Phyla and Salix (Figure 9; see appendix 1 for absolute values).

When considering highly suitable habitat only, Lycium exhibited similar changes amongst land uses while Phyla displayed signficant increases in highly suitable habitat in the Conservation and natural environments (+894 ha 40GL), Dryland agriculture and plantations (+39 ha 40GL) and Water/wetlands (+235 ha 40GL) land uses, mainly in the 36GL and 40GL scenarios (Figure 10). Notably, Tda species also displayed some increases in the proportions of highly suitable habitat predicted, although with overall declines in just suitable habitat (Figures 9 and 10). This was particularly apparent in the Production from natural environments land use under the 36GL scenario (-50 ha S, +538 ha HS; Figure 10).

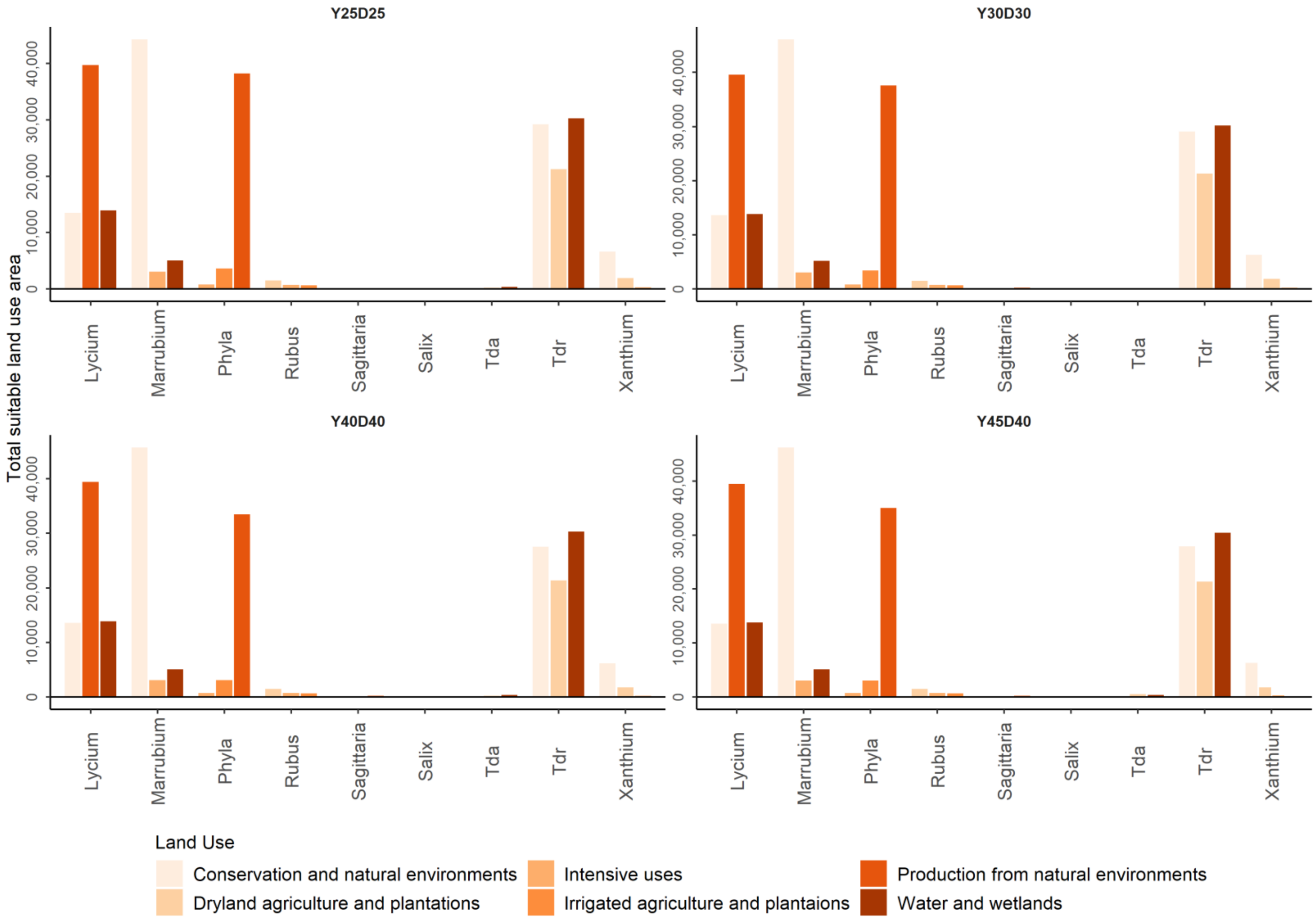

Figure 8. Land uses with top 3 changes in their proportion of suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murray across each RRC inundation scenario.

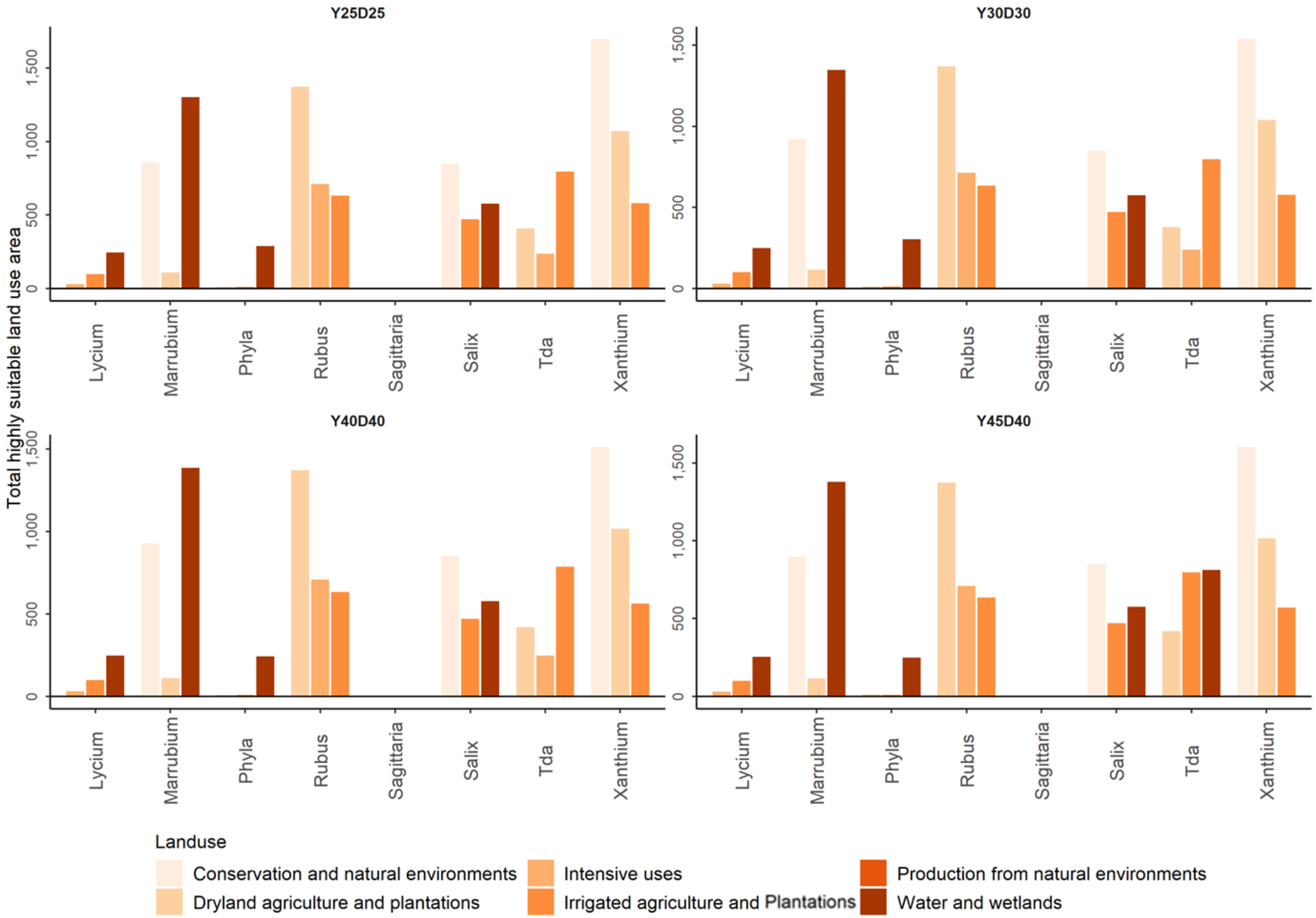

Figure 9. Land uses with top 3 changes in their proportion of highly suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murray across each RRC inundation scenario.

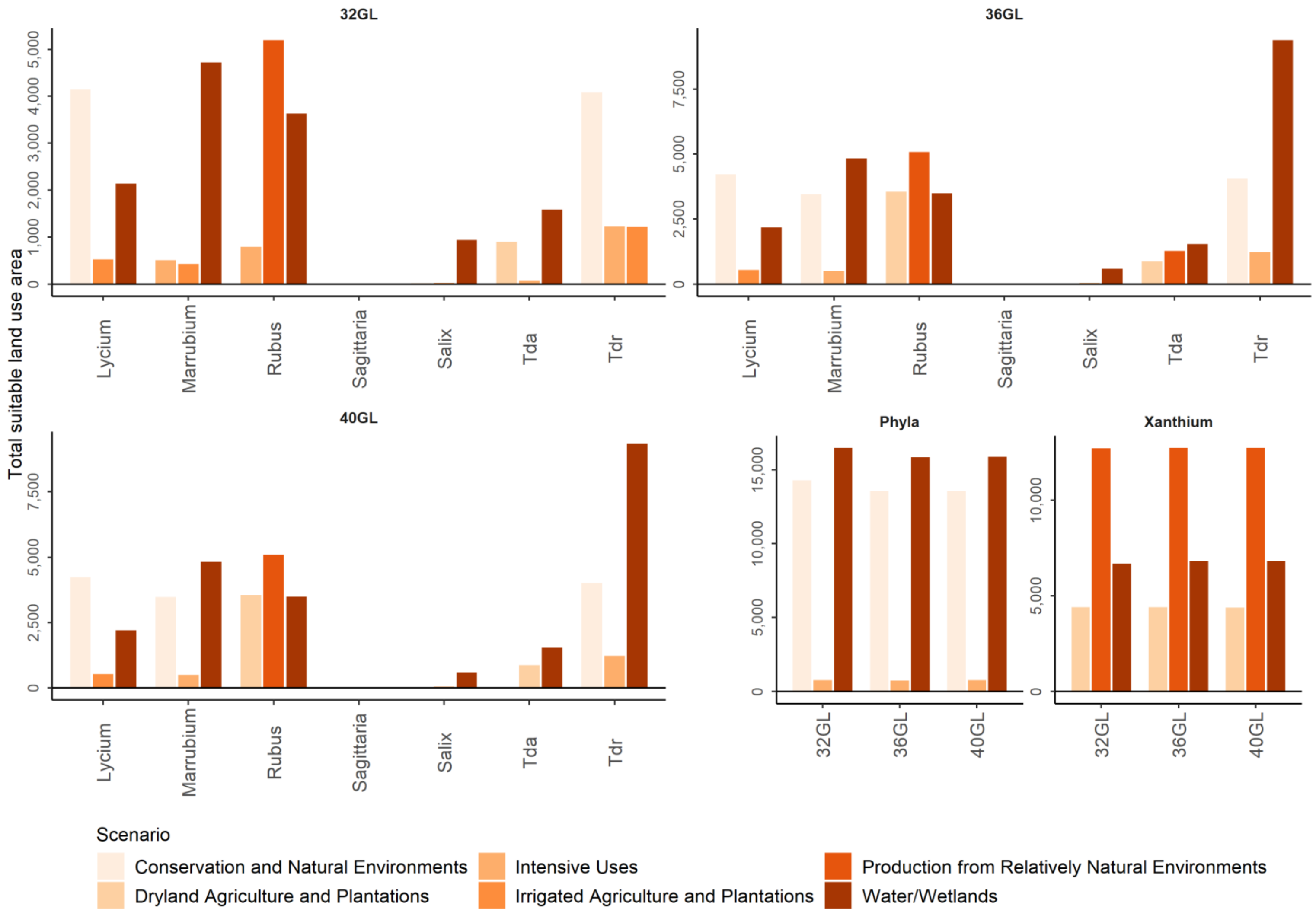

Figure 10. Land uses with top 3 changes in their proportion of suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murrumbidgee across each RRC inundation scenario.

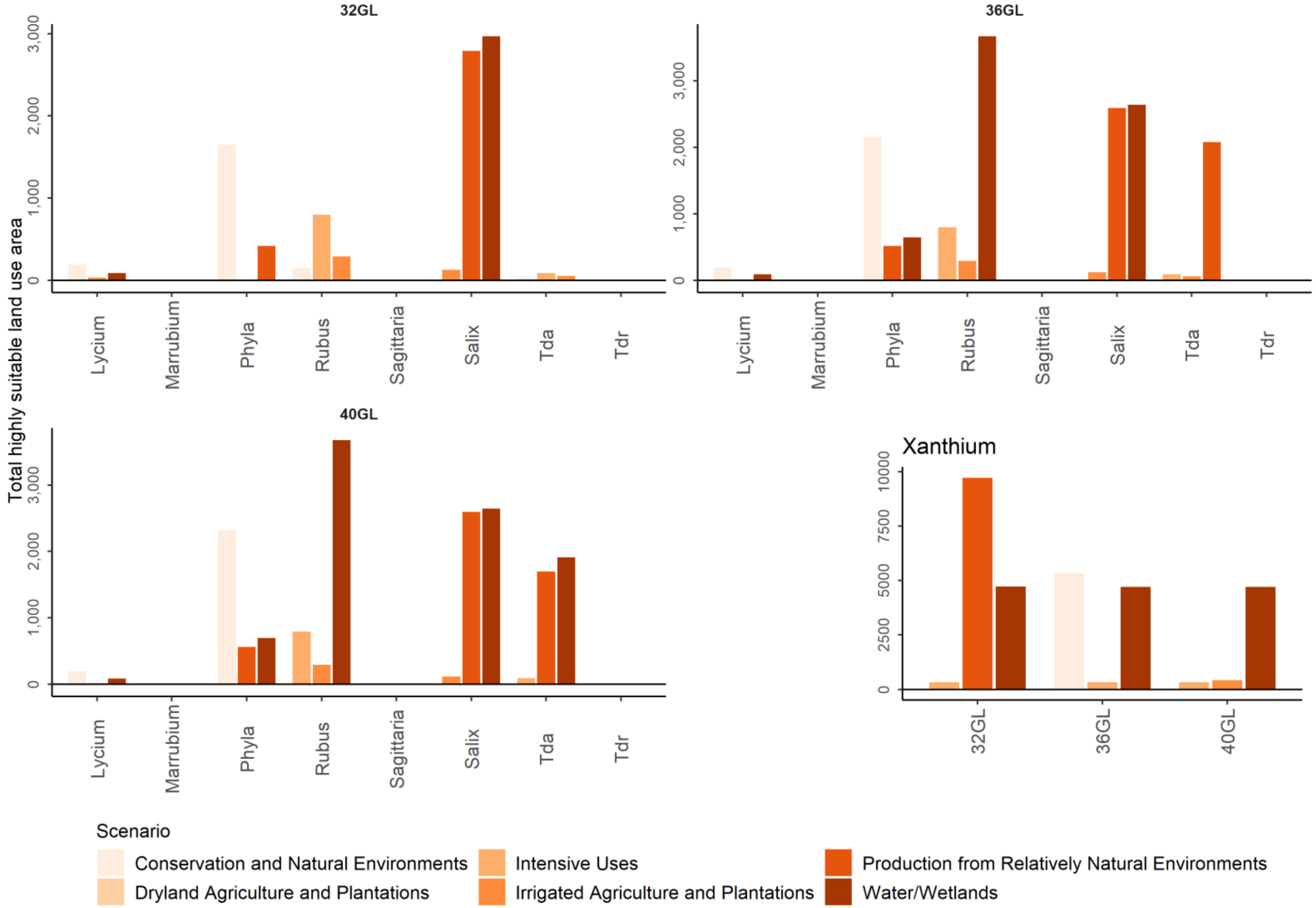

Figure 11. Land uses with top 3 changes in their proportion of highly suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murrumbidgee across each RRC inundation scenario.

Distribution according to vegetation type

Changes in the proportion of vegetation types occupied by suitable habitat in the Murray across the modelled scenarios exhibited similar patterns to overall changes and changes in land use proportions occupied, with relatively few differences in the direction or magnitude of changes predicted (Figure 12 and 13).

For the Murray, the biggest changes across all scenarios included the proportion of Perennial wetland grass, sedge and rush lands (+1446 ha Y45D40), River red gum forests (+65,669 ha Y45D40) and Wetland herblands (+6925 ha Y45D40) occupied by suitable habitat for Marrubium (Figure 12). In contrast, the greatest change in highly suitable habitat for Marrubium in the Murray occurred in River red gum woodlands (+575 ha Y45D40) and Terrestrial woodlands (+134 ha Y45D40) under all scenarios (Figure 13).

In addition to Marrubium, Wetland herblands in the Murray also had a significant increase in the proportion occupied by suitable habitat for Tdr (+5469 ha Y45D40) and Xanthium (+75 ha Y45D40), which also both increased in Lignum shrublands (Figure 12).

The taxa exhibiting overall declines in suitable habitat area in the Murray under the modelled scenarios (Figures 4-7), mostly declined in different vegetation classes as well with a few exceptions (Figures 12 and 14). Notably, the greatest changes in the proportion of suitable habitat in the Murray for Phyla were declines under all scenarios (Figure 12), but when highly suitable habitat only was considered (Figure 13), significant increases were predicted in Terrestrial woodlands (+509 ha Y45D40), Perennial wetland grass, sedge and rush lands (+328 ha Y45D40), and Terrestrial grasslands (+25 ha Y45D40; Figure 13).

In the Murrumbidgee, the significant increases predicted in suitable habitat for Lycium occurred mainly in the Black box woodland (+1431 ha 40GL), Terrestrial shrubland (+212 ha 40GL), and Wetland herbland (+365 ha 40GL) vegetation types across all three scenarios, with Wetland herbland exhibiting greater proportional change in the 36GL and 40GL scenarios (Figure 14). Notably, the greatest changes in highly suitable habitat for this taxon, however, were quite different from overall suitable habitat predictions and also differed between scenarios with large increases projected in Terrestrial grasslands (+90 ha 40GL) and Terrestrial woodlands (+18 ha 40GL) under the 36GL and 40GL scenarios but not the 32GL scenario (Figure 15).

Marrubium in the Murrumbidgee exhibited relatively variable responses across scenarios in predicted areas of suitable habitat with increases apparent in all scenarios in the Wetland herblands (+47 ha 40GL) vegetation type but the remaining vegetation types having higher and lower proportions in each scenario (Figure 14). In terms of highly suitable habitat, however, the greatest changes for Marrubium were declines in area, particularly within River red gum forest (-1 of 4 basecase ha 40GL; Figure 15). Phyla also exhibited an increase in suitable habitat in Lignum shrublands but only under the 40GL scenario (+1239 ha 40GL; Figure 14). Highly suitable habitat for Phyla in the Murrumbidgee, however, increased in all scenarios, mainly in Black box woodland (+95 ha 40GL), Terrestrial shrubland (+14 ha 40GL), and Wetland herbland vegetation types (+119 ha 40GL; Figure 15).

Other taxa exhibited declines across a range of vegetation types in the Murrumbidgee with most declining particularly in Terrestrial woodlands (Figure 14). Smaller declines in highly suitable habitat were apparent for these taxa with the vegetation types where this occurred varying between taxa and scenarios (Figure 15).

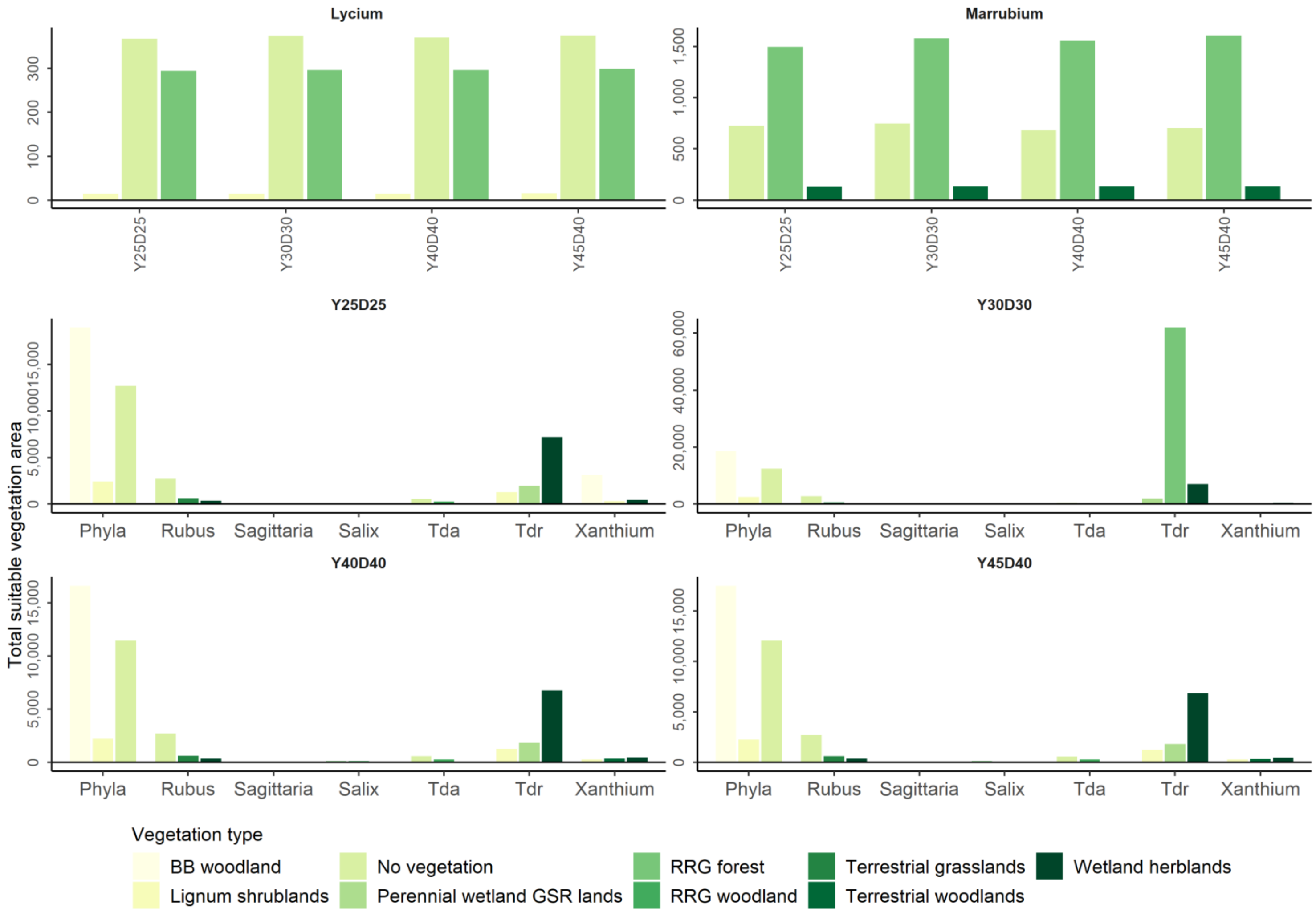

Figure 12. Vegetation types with top 3 changes in their proportion of suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murray across each RRC inundation scenario.

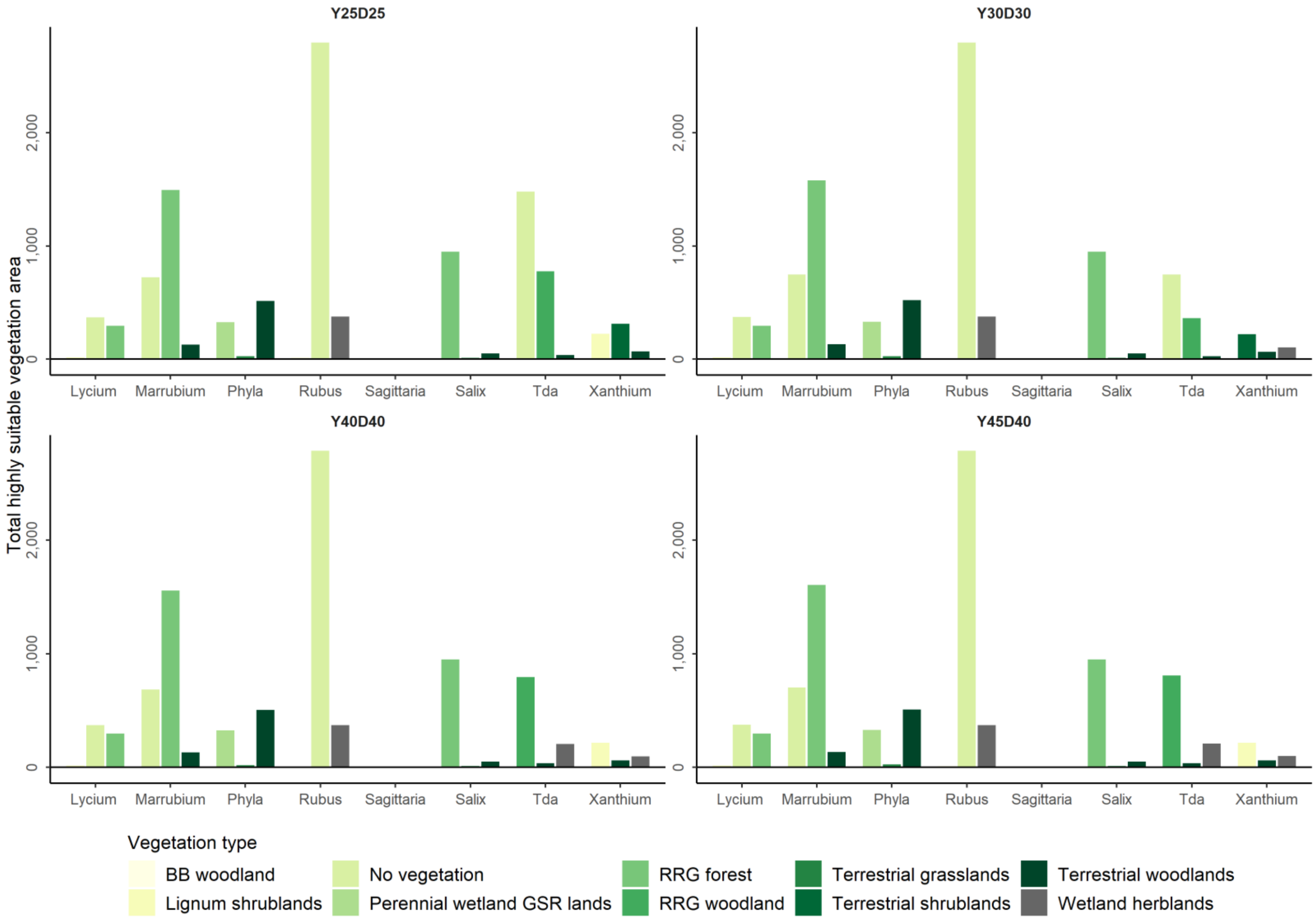

Figure 13. Vegetation types with top 3 changes in their proportion of highly suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murray across each RRC inundation scenario.

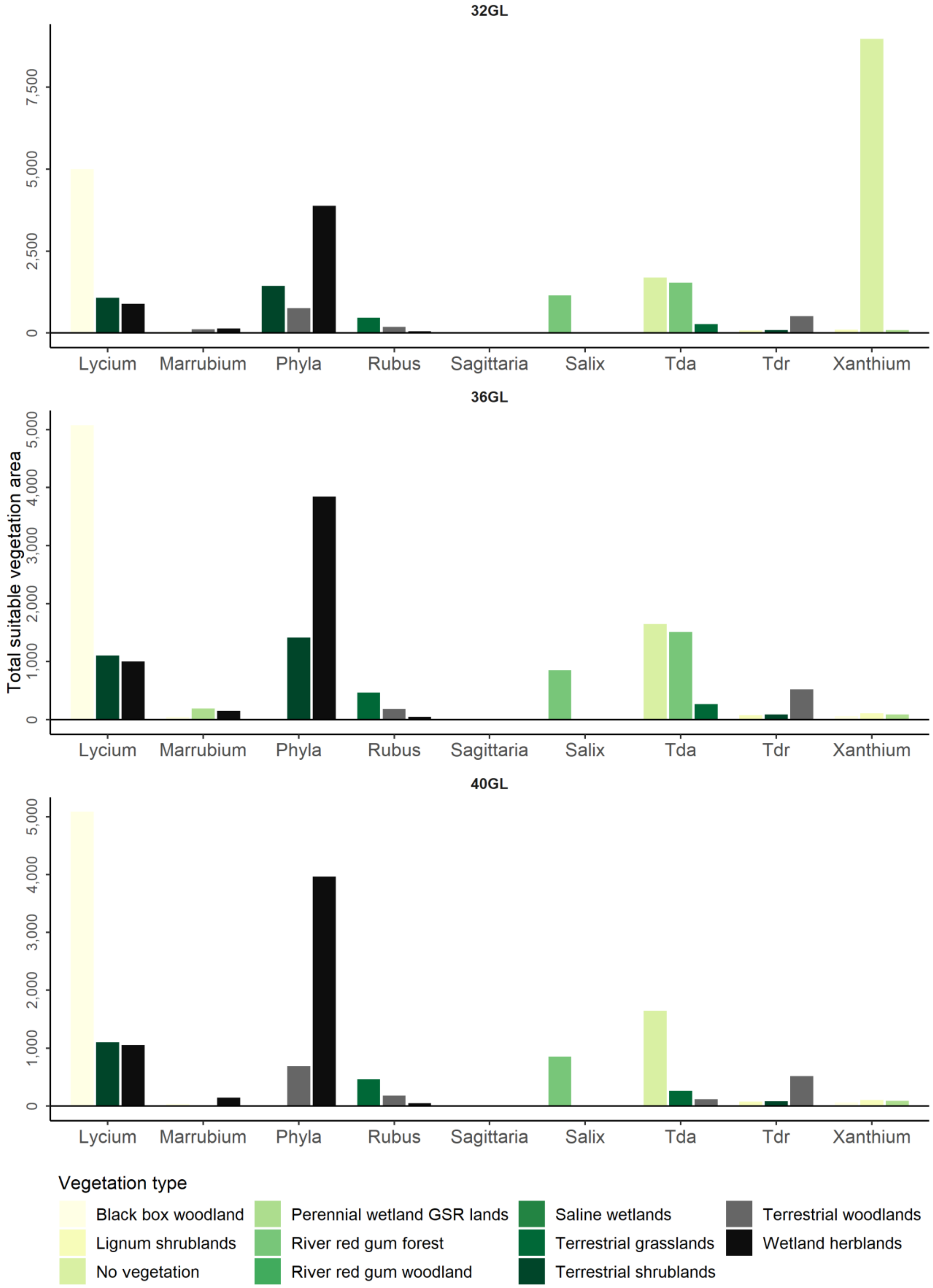

Figure 14. Vegetation types with top 3 changes in their proportion of suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murrumbidgee across each RRC inundation scenario.

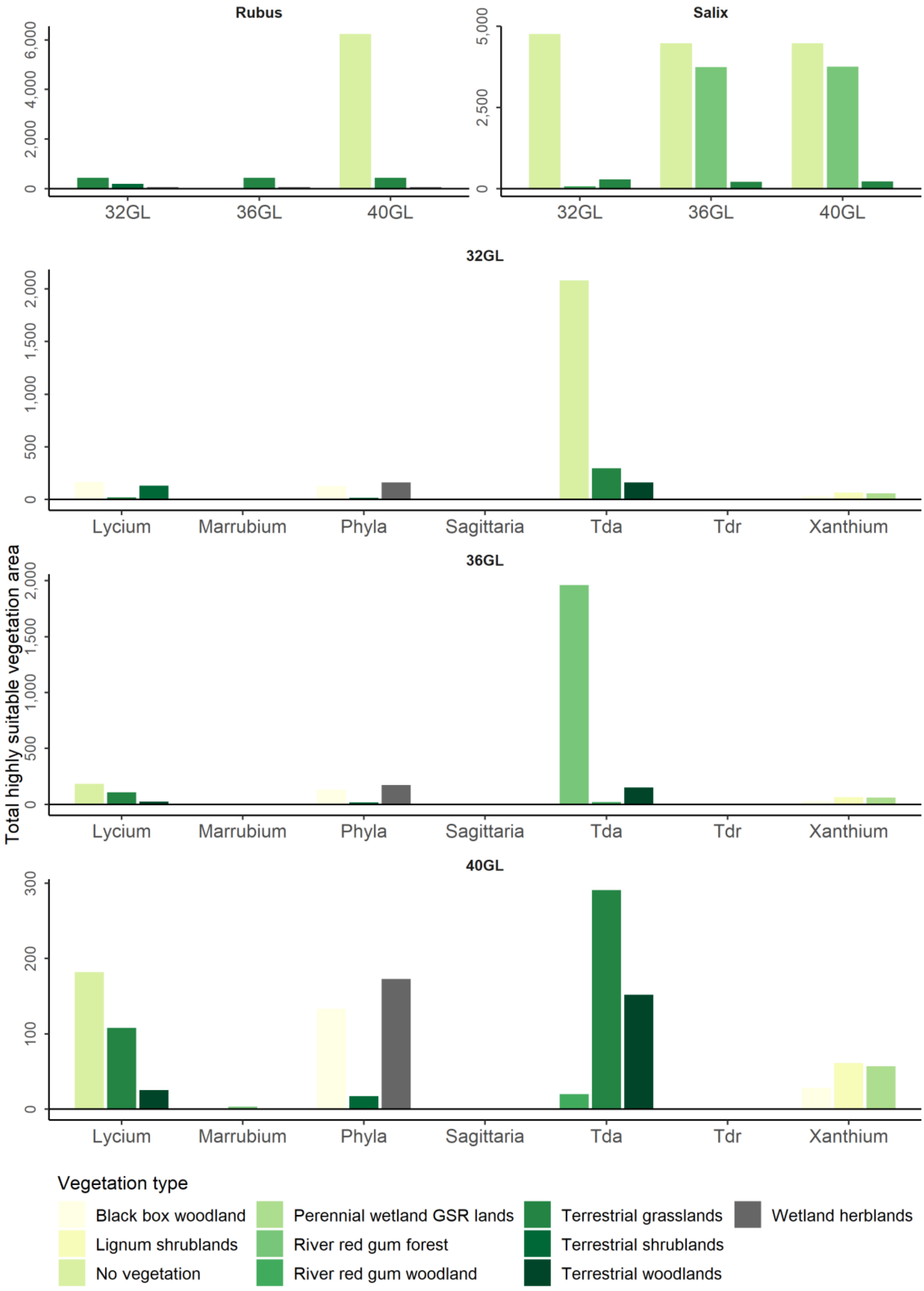

Figure 15. Vegetation types with top 3 changes in their proportion of highly suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murrumbidgee across each RRC inundation scenario.

Distribution according to wetland class

With respect to wetland classes, the greatest changes in proportion of suitable habitat in the Murray under all scenarios included Tdr species in Temporary wetlands (+783 ha Y45D40), Unspecified rivers (+7 ha Y45D40), and Waterholes (+67 ha Y45D40); Lycium around Waterholes (+29 ha Y45D40); and Marrubium in Permanent herbaceous wetlands (+1120 ha Y45D40; Figure 16). With respect to highly suitable habitat (Figure 17), Marrubium exhibited large increases in Temporary waterbodies (+970 ha Y45D40) and Temporary wetlands (+83 ha Y45D40). Highly suitable Xanthium habitat in the Murray also increased considerably in Temporary shrublands in all scenarios (+33 ha Y45D40; Figure 17). Large increases in the proportion of Temporary wetlands in the Murray providing highly suitable habitat for Phyla (+21 ha Y45D40) also increased in all scenarios except Y30D30 for which Temporary wetlands exhibited greater change (+112 ha; Figure 17). Notably, a significant increase in the proportion of highly suitable Rubus habitat in the Murray was only detected under the Y25D25 scenario but no other scenarios (Figure 17).

The wetland classes subject to the greatest changes in the proportion of suitable habitat in the Murrumbidgee included Floodplain woodlands and Temporary wetlands across all scenarios and Temporary shrublands in the 32GL and 36GL scenarios, particularly for Lycium, Marrubium and Tdr species (Figure 18; See appendix 1 for absolute values). Predicted increases in the extent of suitable habitat for Lycium were also reflected by predicted increases in the extent of highly suitable habitat, mainly in Permanent wetlands (+22 ha 40GL), Floodplain woodlands (+55 ha 40GL), and Temporary woodlands (+144 ha 40GL; Figure 19). Highly suitable habitat in the Murrumbidgee mostly declined in specific wetland habitats for most modelled taxa with the notable exception of Tda species for which an increase in the proportion of Temporary waterbody area (+4 ha) providing highly suitable habitat was predicted solely under the 36GL scenario (Figure 19).

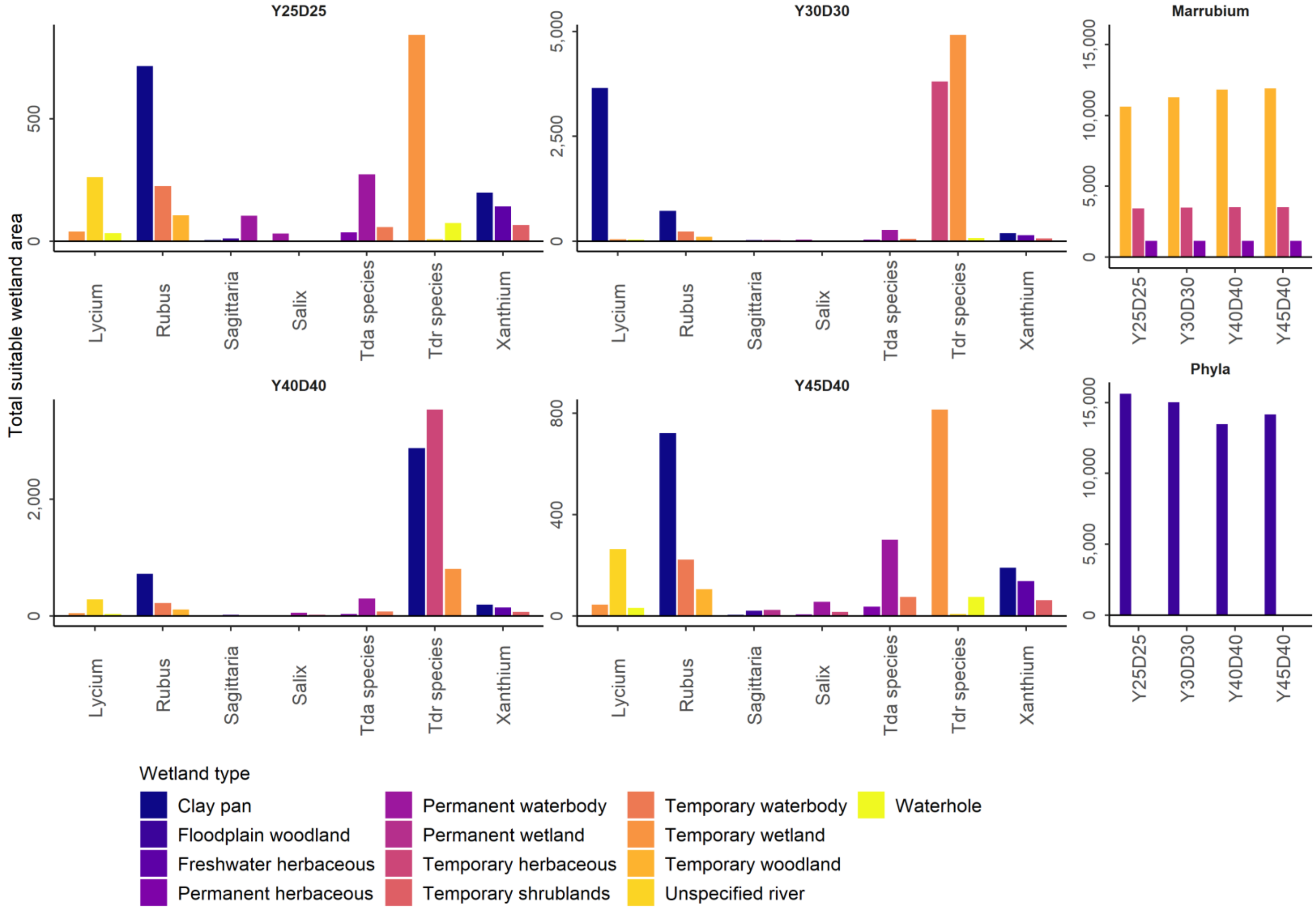

Figure 16. Wetland classes with top 3 changes in their proportion of suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murray across each RRC inundation scenario.

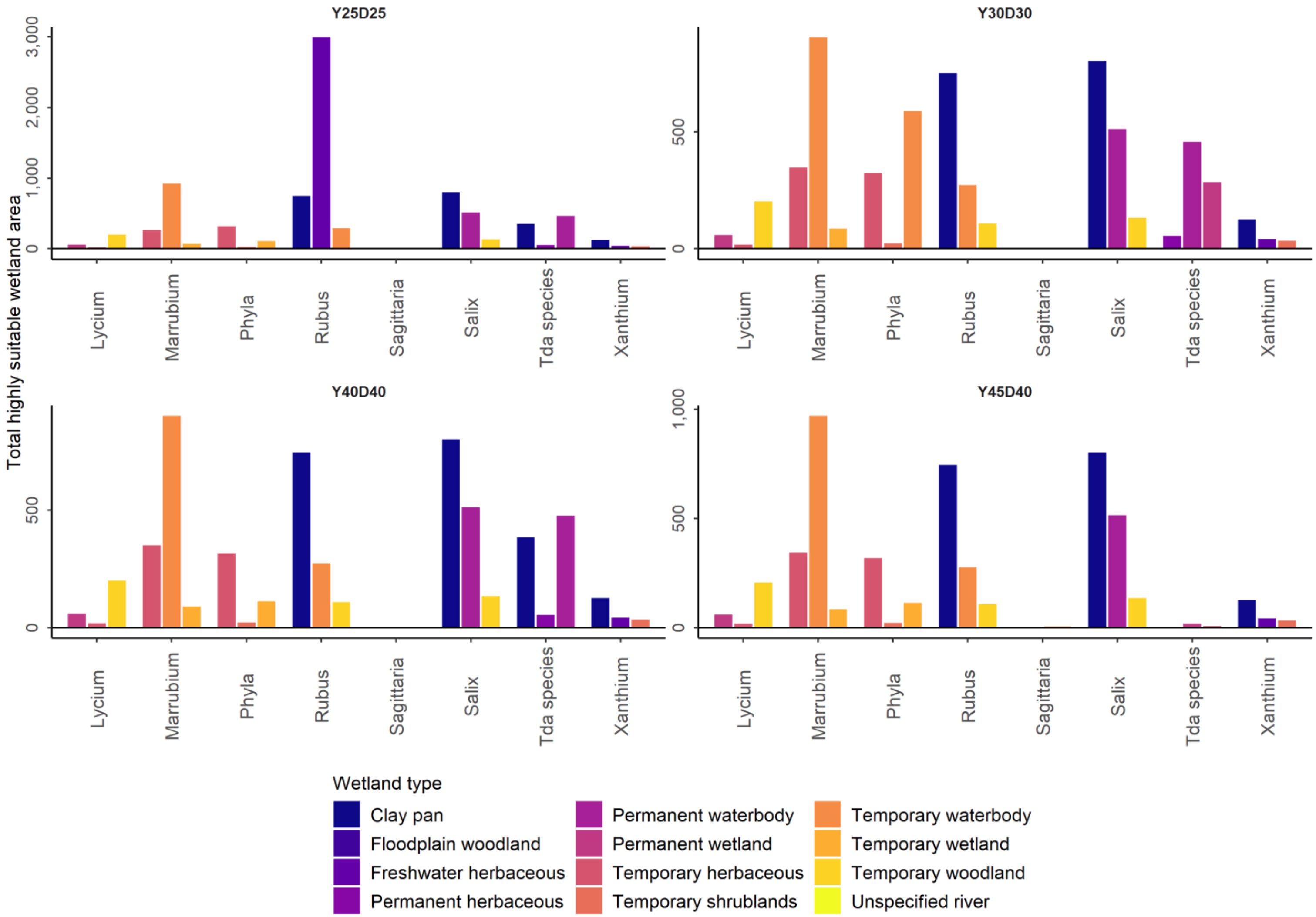

Figure 17. Wetland classes with top 3 changes in their proportion of highly suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murray across each RRC inundation scenario.

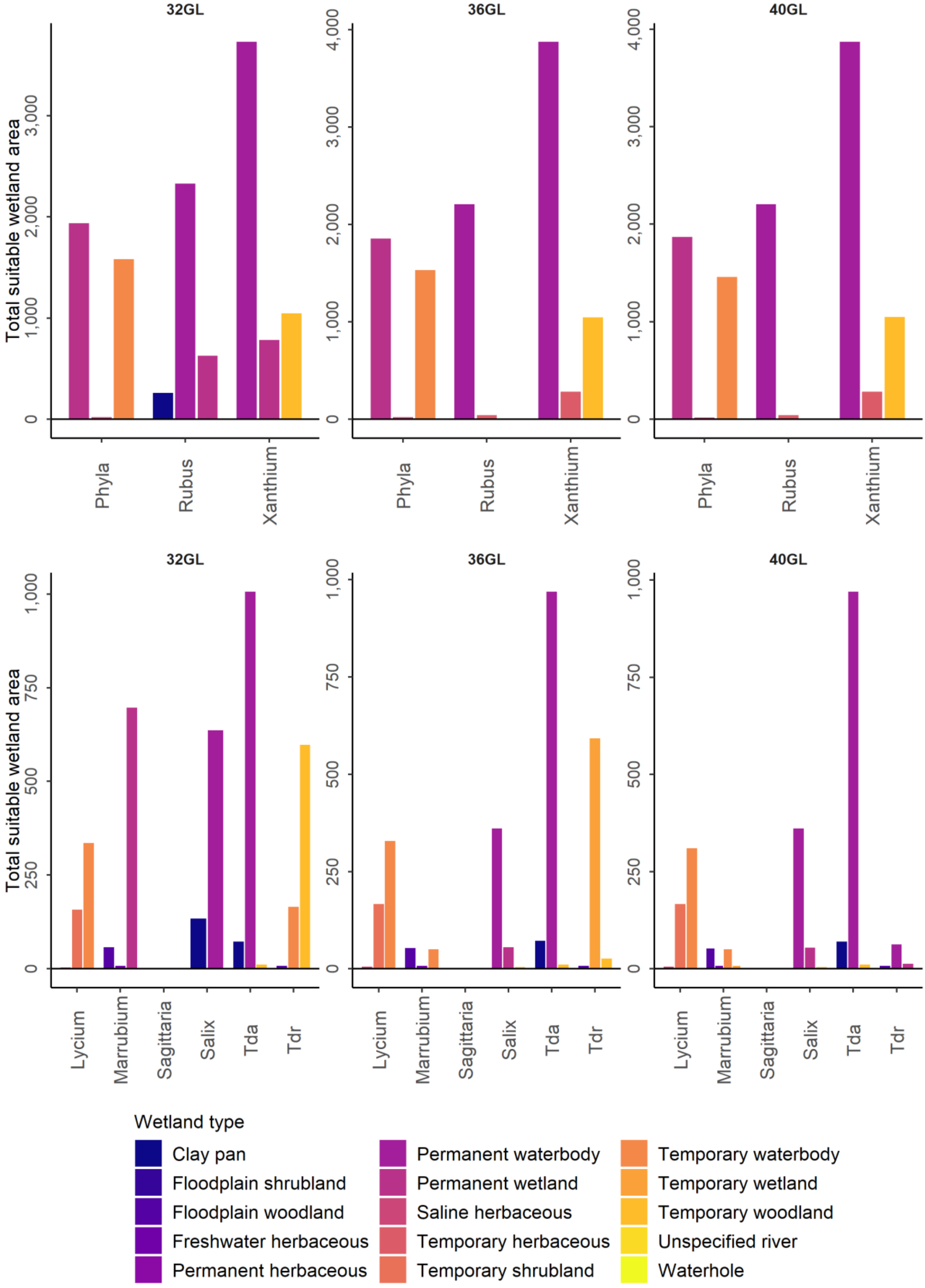

Figure 18. Wetland classes with top 3 changes in their proportion of suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murrumbidgee across each RRC inundation scenario.

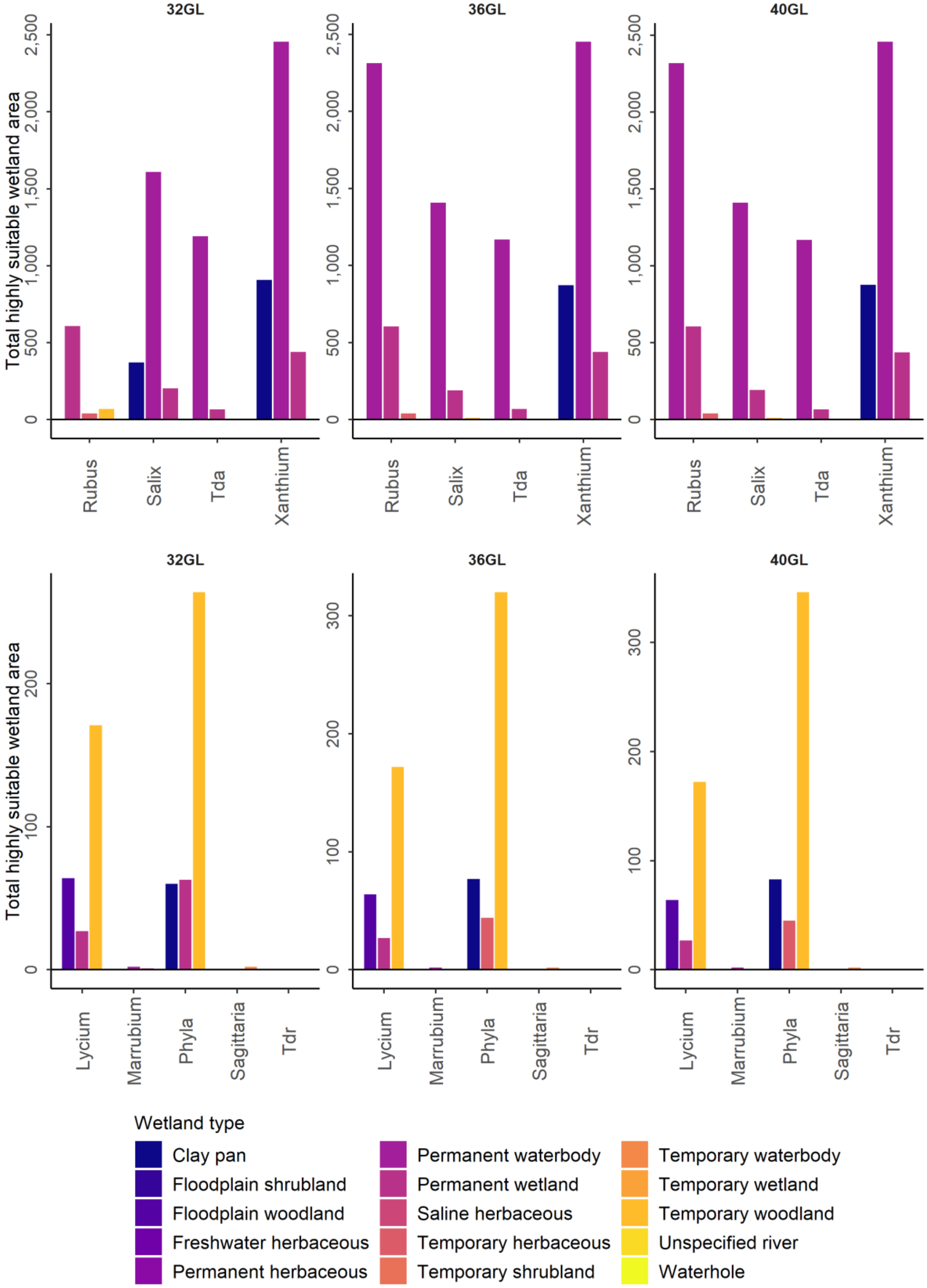

Figure 19. Wetland classes with top 3 changes in their proportion of highly suitable habitat (ha) predicted by SDMs for all modelled taxa in the Murrumbidgee across each RRC inundation scenario.

Weed hotspots

Significant declines in the total area of weed hotpots (i.e., areas with suitable habitat for four or more modelled taxa) were apparent in the Murray project area across all RRC inundation scenarios in relation to the base case (Table 9). The net decline in weed hotspot area in the Murray was greatest in the inundation scenario with the lowest level of constraint relaxation and decreased with increasing constraint relaxation (Table 9). In the Murrumbidgee, declines in the overall area of weed hotspots were also apparent under all inundation scenarios but were relatively small (Table 9). Overall, greater declines in the area of weed hotspots in the Murrumbidgee was modelled for the higher degree of constraint relaxation scenarios (Table 9). These declines in weed hotspots reflect the general decline in suitable habitat area for each taxa, particularly for amphibious species, in both the Murray and Murrumbidgee for all inundation scenarios (see Figure 4 and 6).

Table 9. Proportional (net) change in area (%) of modelled weed hotposts and the total area of weed hotpots within each Land use / Vegetation type and Wetland class from the base case under each inundation scenario for the Murray and Murrumbidgee project areas.

	Murray				Murrumbidgee		
	Y25D25	Y30D30	Y40D40	Y45D40	32GL	36GL	40GL
Total change	-66.81 (227 ha)	-59.36 (278 ha)	-58.66 (283 ha)	-49.71 (344 ha)	-0.78 (1276 ha)	-3.50 (1241 ha)	-7.70 (1187 ha)
Land use							
Conservation and Natural Environments	204.68 (195 ha)	-73.43 (17 ha)	-71.87 (18 ha)	-54.68 (29 ha)	2.07 (148 ha)	20.68 (175 ha)	7.58 (156 ha)
Dryland Agriculture and Plantations	-80.22 (18 ha)	-54.94 (41 ha)	-49.45 (46 ha)	-40.66 (54 ha)	0.98 (307 ha)	-1.64 (299 ha)	-1.31 (300 ha)
Intensive Uses	-55.5 (12 ha)	-62.96 (10 ha)	-55.55 (12 ha)	-59.26 (11 ha)	7.59 (85 ha)	8.86 (86 ha)	8.86 (86 ha)
Irrigated Agriculture and Plantations	-28.57 (35 ha)	-65.31 (17 ha)	-65.31 (17 ha)	-55.10 (22 ha)	5.55 (38 ha)	-11.11 (32 ha)	-8.33 (33 ha)
Production from Relatively Natural Environments	-58.52 (263 ha)	-57.25 (271 ha)	-56.78 (274 ha)	-47.48 (333 ha)	-1.15 (1027 ha)	-7.22 (964 ha)	-10.77 (927 ha)
Water/Wetland s	-72.7 (89 ha)	-32.21 (221 ha)	-32.51 (220 ha)	-26.38 (240 ha)	0.22 (457 ha)	-4.38 (436 ha)	-6.36 (427 ha)
Vegetation types							
Black box woodland	-64.14 (52 ha)	-56.55 (63 ha)	-53.79 (67 ha)	-48.96 (74 ha)	0 (22 ha)	0 (22 ha)	0 (22 ha)
Lignum shrublands	-100 (0 ha)	-100	-100	-100	-11.76 (15 ha)	-11.76 (15 ha)	-11.76 (15 ha)
No vegetation	-71.22 (80 ha)	-73.38 (73 ha)	-71.22 (80 ha)	-64.75 (98 ha)	2.47 (620 ha)	-2.81 (588 ha)	-3.14 (586 ha)
Perennial wetland grass, sedge and rush lands	-83.33 (1 ha)	-83.33 (1 ha)	-66.66 (2 ha)	-83.33 (1 ha)	-50 (1 ha)	-50 (1 ha)	-50 (1 ha)
River red gum forest	-52.08 (207 ha)	-40.51 (257 ha)	-39.12 (263 ha)	-27.78 (312 ha)	-1.1 (1165 ha)	-3.57 (1134 ha)	-8.33 (1078 ha)
River red gum woodland	-79.93 (64 ha)	-77.74 (71 ha)	-78.06 (70 ha)	-70.22 (95 ha)	-4.04 (285 ha)	-10.77 (265 ha)	-11.45 (263 ha)
Terrestrial grasslands	-83.83 38 ha)	-77.02 (54 ha)	-78.29 (51 ha)	-74.04 (61 ha)	-1.49 (132 ha)	-5.22 (127 ha)	-9.7 (121 ha)
Terrestrial shrublands	-64.28 (5 ha)	-64.28 (5 ha)	-57.14 (6 ha)	-71.43 (4 ha)	0	0	0
Terrestrial woodlands	0 (3 ha)	-66.6 (1 ha)	-33.33 (2 ha)	0 (3 ha)	28.57 (9 ha)	0 (7 ha)	0 (7 ha)
Wetland herblands	600 (7 ha)	400 (5 ha)	500 (6 ha)	600 (7 ha)	0 (5 ha)	80 (9 ha)	80 (9 ha)

Saline wetlands	0	0	0	0	0	0	0
Wetland classes							
Clay pan	100 (2 ha)	100 (2 ha)	100 (2 ha)	0	1.59 (64 ha)	1.58 (64 ha)	4.76 (66 ha)
Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	-71.49 (63 ha)	-66.96 (73 ha)	-65.16 (77 ha)	-59.73 (89 ha)	0	0	0
Freshwater herbaceous	200 (3 ha)	500 (6 ha)	600 (7 ha)	600 (7 ha)	0	0	0
Permanent herbaceous	100 (2 ha)	100 (2 ha)	100 (2 ha)	100 (2 ha)	0	0	0
Permanent waterbody	-42.63 (74 ha)	-43.41 (73 ha)	-41.08 (76 ha)	-37.98 (80 ha)	4.66 (314 ha)	0.33 (301 ha)	-0.66 (298 ha)
Permanent wetland	-78.88 (19 ha)	-81.11 (17 ha)	-78.88 (19 ha)	-61.11 (35 ha)	2.29 (134 ha)	0 (131 ha)	3.05 (135 ha)
Saline herbaceous	0	0	0	0	0	0	0
Temporary herbaceous	-75 (1 ha)	-75 (1 ha)	-50 (2 ha)	-100	-25 (3 ha)	75 (7 ha)	50 (6 ha)
Temporary shrubland	0	0	0	0	0	0	0
Temporary waterbody	-3.29 (176 ha)	30.77 (238 ha)	25.27 (228 ha)	40.66 (256 ha)	33.33 (8 ha)	33.33 (8 ha)	33.33 (8 ha)
Temporary wetland	0	0	0	0	0 (1 ha)	0 (1 ha)	0 (1 ha)
Temporary woodland	-86.36 (6 ha)	-75 (11 ha)	-77.27 (10 ha)	-81.82 (8 ha)	-30.58 (59 ha)	-27.05 (62 ha)	-30.58 (59 ha)
Unspecified river	0	0	0	0	0	0	0
Waterhole	-100	-100	-100	-100	0	0	0

Expert elicitation

The survey was completed by nine respondents representing a range of organisations including state and federal government agencies, universities, and the private sector. Respondents had specific expertise in both the Murray and Murrumbidgee catchments and the Murray-Darling Basin more broadly with a range of relevant experience including monitoring evaluation of weeds, on-ground weed interventions, weed policy and planning and research.

Results from the survey and input during the expert elicitation workshops generally concurred with the model outputs. Survey respondents indicated a low to moderate level of confidence in weed species distributions and suggested minimal changes to these distributions under proposed inundation changes. Although model outputs show varying directions and magnitudes of changes, there tends to be little variation between inundation scenarios for each taxa.

Base case

Most respondents considered weeds to be currently somewhat to moderately prevalent in the project area. Only two respondents considered them to be very prevalent. Half of the respondents considered the overall prevalence and extent of weeds in the project area to be maintaining while the other half perceive weed prevalence and extent to be expanding. None of the respondents considered weed prevalence and extent to be shrinking currently in the project area.

Respondents considered weeds to be most prevalent (medium to high) in the intensive land use category followed by production from dryland agriculture and plantations, and production from irrigated agriculture and plantations. However, modelling revealed that production from natural environments contained the largest suitable habitat area as well as areas of production from irrigated agriculture. The vegetation types expected to be most affected by weeds currently, as expected by survey respondents, included terrestrial grasslands, wetland herblands and no vegetation categories with the least expected in lignum shrubland and saline wetlands. Again, modelling revealed that black box woodland, lignum shrublands, and no vegetation categories contained the most suitable habitat area for the basecase. Permanent wetlands were identified as the wetland class most likely to have a medium to high prevalence of weeds currently with little difference expected by respondents in weed prevalence amongst other wetland classes. However, basecase modelling suggests that temporary waterbodies, floodplain woodlands, and permanent waterbodies contained the largest areas of suitable weed habitat.

Effects of constraints relaxation

Most respondents (4) expected no change in the overall prevalence of weeds in the project area would occur in response to increased inundation while three anticipated a slight increase and one a moderate increase. One respondent indicated that they would expect a slight decrease in weed prevalence in response to proposed inundation changes. Similar responses were evident with regards to anticipated effects of inundation scenarios on weed impacts and management in the project area. The expectation of minimal change in response to inundation scenarios differed compared to the modelling outputs where all species saw a change (+ve or -ve) from the basecase under inundation scenarios.

At a taxa level, all taxa except two (Rubus and Senecio) received at least one survey response, although very few respondents indicated high confidence in their answers regarding expected change under inundation scenarios.

Alligator weed – Alternanthera philoxeroides

Respondents expected no change to a slight to moderate increase in the extent and corresponding impacts of Alligator weed in the project area under proposed inundation changes. Respondents also noted that proposed inundation changes would result in a slight increase in the need for management of Alligator weed.

Water hyacinth - Eichhornia crassipes

Respondents expected a slight increase in the extent of Water hyacinth under proposed inundation changes, however, suggested that there would be no changes to impacts other than a slight increase in the impacts to vegetation. Respondents also noted that proposed inundation changes could see a slight increase in management of this species.

African boxthorn – Lycium ferocissimum

Respondents suggest that proposed inundation changes could result in a slight decline, no change, to a slight increase in extend of African boxthorn. This change in extent also aligns with the respondents perceived changes in impacts and management under proposed inundation changes, both which received responses of slight decrease to slight increase. One respondent noted that proposed inundation changes could result in a moderate increase in the impacts of African boxthorn on vegetation.

Horehounds - Marrubium vulgare

Respondents expected a slight to strong decrease in extent of Marrubium under proposed inundation changes which is currently perceived to have a somewhat to moderately prevalent distribution. A slight decrease in impacts and management of this species was also noted under proposed inundation changes. Our modelling results indicate a large increase in the suitable habitat area for Marrubium under all inundation scenarios. This contrast in findings suggests that risk associated with this species requires further investigation.

Lippia – Phyla canescens

Respondents expected Lippia (*Phyla canescens*) to have a slight increase in extent under proposed inundation changes but expected changes in impacts and management were varied. Respondents expected a slight decrease to moderate increase in the impacts to agriculture and vegetation while the impacts to humans and fauna expect no change to slight increases. Respondents suggest that there will be no change to a moderate increase in management of Lippia under proposed inundation changes. Our modelling suggests that proposed inundation changes will slightly reduce the suitable habitat area for Lippia, potentially due to increased depth and permanence of inundated conditions. Specific responses of Lippia to different flood regimes requires further investigation.

Arrowheads – Sagittaria platyphyla

Respondents expect a slight to moderate increase in extent of Sagittaria under proposed inundation changes where the current distribution is perceived to be maintaining to growing. This change in distribution under proposed inundation changes is expected to have no change to moderate increase in the impacts of Sagittaria to agriculture, vegetation, and fauna, while only a slight increase could be expected for impacts to humans. No change to a slight increase in the management of Sagittaria could be expected under proposed inundation changes.

Willows – Salix spp.

Respondents expected Willows to have a slight increase in extent under proposed inundation changes where their current distribution is perceived to be maintaining to shrinking. Similarly, respondents expected no change to a

slight increase in the impacts of willows under proposed inundation changes, particularly for the impacts to vegetation. Respondents also expected and slight increase in the management of willows under proposed inundation changes. Our modelling suggests that the distribution of Willows is constrained to the uppermost reaches of the Murray and Murrumbidgee rivers and that proposed inundation changes will have a negligible impact on this species.

Salvinia – Salvinia molesta

No changes to a slight increase in extent is expected by respondents for Salvinia under proposed inundation changes, where the current distribution is perceived to be maintaining to shrinking. Respondents expect no change to a slight increase to the impacts of Salvinia, specifically a slight increase in the impacts of Salvinia to vegetation and fauna. No change to a slight increase in management is expected.

Burrs - Xanthium spp.

Respondents expected varied changes in extent of Xanthium spp. Burrs under proposed inundation changes from moderate decreases to no change to slight and moderate increases in extent, although increases were the most common answer. Most respondents expected no change to a slight increase in the impacts of Xanthium under proposed inundation changes, particularly increases in the impacts to vegetation. A slight increase in management is expected by most respondents for Xanthium under proposed inundation changes, however responses also included no change and moderate increase.

Several species were noted as having no change under proposed inundation changes. These included, Serrated tussock grass, Asparagus spp., Cats claw creeper, Equisetum spp., Lantana camara, Parkinsonia, and Tamarix. Respondents also noted that no change in impacts or management could be expected under proposed inundation changes, except for Lantana where inundation changes could slightly decrease its impacts on vegetation.

Risk assessment

Risk scores for each likelihood and consequence criterion under each scenario are provided for all weed taxa, and weed hotspots, in Appendix 2.

Little variation in assigned risk likelihood scroes was apparent within each taxon between inundation scenarios within each project area (Table 10). For the most part, likelihood scores were equivalent for each taxon across the inundation scenarios, especially for the Murray. Exceptions included a slightly greater total likelihood score for an increased extent of Rubus under the Y45D40 scenario and gradually increasing likelihood of greater extents of Marrubium with greater relaxation of constraints in the Murray (Table 10). In contrast, Lycium and Xanthium exhibited higher likelihood scores for greater extents under the inundation scenarios with the least relaxation of constraints in the Murray. For the Murrumbidgee, greater reductions in the likelihood scores were apparent for Rubus and Salix with increasing relaxation of constraints while reductions in likelihood scores exhibited the opposite trend for Xanthium (Table 10). Both Marrubium and Lycium in the Murrumbidgee had higher scores for the likelihood of increasing in extent in the intermediate inundation scenario (i.e., 36 GL).

Total risk likelihood scores for the two water plant functional groups, Tda and Tdr species, were equivalent across inundation scenarios in the Murray but differed between scenarios for the Murrumbidgee (Table 10). Likelihood scores for Tda species indicated a greater reduction in the extent of this weed taxon under the two extreme scenarios (32 GL and 40 GL) while the greatest reduction for Tdr species was apparent with the greatest relaxation of constraints (i.e., 40 GL; Table 10).

Total risk likelihood scores for weed hotspots were equivalent across scenarios for the Murrumbidgee but greater declines in the extent of weed hotpots were indicated by scores for the Murray under scenarios with greater constraint relaxation (i.e. Y30D30, Y40D40 and Y45D40).

Table 10. Total risk likelihood scores (see table 5 for scoring method) for each modelled weed taxa as well as weed hotpots under each RRC inundation scenario.

	Murray				**Murrumbidgee**		
Taxa	**Y25D25**	**Y30D30**	**Y40D40**	**Y45D40**	**32GL**	**36GL**	**40GL**
Sagittaria (Arp)	-128	-128	-128	-128	0	0	0
Phyla (Atl)	-136	-136	-136	-136	-46	-45	-46
Salix (Tda)	-84	-84	-84	-84	18	-32	-32
Rubus (Tdr)	63	63	63	66	-19	-22	-22
Marrubium (Tdr)	92	98	100	106	9	29	26
Lycium (Tdr)	101	101	98	98	60	70	63
Xanthium (Tdr)	89	83	83	83	-36	-30	-30
Tda species	-104	-104	-104	-104	-21	-2	-11
Tdr species	128	128	128	128	-44	-45	-71
Weed hotspots	-61	-68	-68	-68	-2	-2	-2

Calculated risk consequence scores were highest for Salix, Rubus, Lycium and Sagittaria, which all scored relatively highly out of a possible total of 24 points (Table 11). Consequence scores were relatively low for Phyla, Marrubium, and Xanthium. Phyla was the only species which differed in score between the two catchments.

Table 11. Total risk consequence scores out of 24 (see table 6 for scoring method) for each modelled weed species over all RRC inundation scenarios.

Taxa	Murray	Murrumbidgee
Sagittaria (Arp)	16	16
Phyla (Atl)	8	9
Salix (Tda)	18	18
Rubus (Tdr)	17	17
Marrubium (Tdr)	5	5
Lycium (Tdr)	17	17
Xanthium (Tdr)	9	9

Overall risk scores

Overall risk did not vary considerably between inundation scenarios in the Murray for which a likely overall benefit of constraint relaxation on the distribution and consequence of weeds in the catchment can be expected based on our results (Table 12). This is due to predicted conservation benefits of constraint relaxation to the distribution and extent of Sagittaria, Phyla and Salix as well as Tda species and weed hotspots in this catchment (i.e. overall declines). Nevertheless, our results indicate a potential risk in the Murray associated with increased extents and distribution of Marrubium, Xanthium, Rubus, and especially Lycium as well as Tdr species. For Rubus and Marrubium, this risk appears to be greater under the greatest relaxation of constraints while the reverse is indicated for Lycium and Xanthium (i.e. greater risk under lower constraints relaxation). Risk of increasing distribution and extent of Tdr species, however, does not significantly vary across scenarios according to our scores (Table 12).

Much greater variation in overall risk across inundation scenarios is apparent from calculated risk scores for the Murrumbidgee (Table 12). Most notably, scoring indicates an overall risk associated with the 32 GL scenario in the Murrumbidgee compared with an overall benefit for the 36 GL and 40 GL scenarios (Table 12). This difference can be attributed mainly to a significantly greater risk of increase in the extent and distribution of Salix under the 32 GL scenario compared to the 36 GL and 40 GL scenarios under which there is a likely benefit of constraint relaxation in relation to this weed’s extent and distribution.

Table 12. Total risk scores for each weed taxa and weed hotspots under each inundation scenario and overall total and standardised scores (i.e. total divided by maximum possible score *100). A negative risk score relates to a reduced weed risk and a positive risk score related to an increased weed risk (represented by colours red: increased risk, green: reduced risk, white: no change).

	Murray				Murrumbidgee		
Taxa	**Y2D25**	**Y30D30**	**Y40D40**	**Y45D40**	**32GL**	**36GL**	**40GL**
Sagittaria (Arp)	-2048	-2048	-2048	-2048	0	0	0
Phyla (Atl)	-1088	-1088	-1088	-1088	-414	-405	-414
Salix (Tda)	-1512	-1512	-1512	-1512	324	-576	-576
Rubus (Tdr)	1071	1071	1071	1122	-323	-374	-374
Marrubium (Tdr)	460	490	500	530	45	145	130
Lycium (Tdr)	1717	1717	1666	1666	1020	1190	1071
Xanthium (Tdr)	801	747	747	747	-324	-270	-270
Species sub-total	***-599***	***-623***	***-664***	***-583***	***328***	***-290***	***-433***
Tda species	-104	-104	-104	-104	-21	-2	-11
Tdr species	128	128	128	128	-44	-45	-71
Weed hotspots	-61	-68	-68	-68	-2	-2	-2
Total	***-636***	***-667***	***-708***	***-627***	***261***	***-339***	***-517***
Standardised score (-100 to +100)	***-2.8***	***-3.0***	***-3.2***	***-2.8***	***1.2***	***-1.5***	***-2.3***
Overall risk	***Likely overall slight benefit***	***Likely overall slight benefit***	***Likely overall slight benefit***	***Likely overall slight benefit***	***Likely overall slight risk***	***Likely overall slight benefit***	***Likely overall slight benefit***

Discussion

Proposed flow constraints relaxation in the Murray and Murrumbidgee Rivers will likely influence the extent of target weed species in this region. Relaxation of constraints will produce conditions where water delivered to the river and floodplain environments occurs more frequently and for longer durations, with a particular target to provide inundation of low-lying wetlands, billabongs, and flood runners.

Our modelling suggests that it is very likely that there will be a reduction in the area of suitable habitat for the amphibious weed species considered, i.e. Phyla (lippia) and Sagittaria (Arrowheads) under the proposed RRC inundation scenarios. Furthermore, our modelling suggests that these reductions in suitable habitat are likely to be relatively similar across the different scenarios. This may be explained by the changes to inundation patterns that can be expected under the inundation scenarios in areas currently providing suitable habitat for these weeds. As these amphibious species are likely to be favoured by conditions of intermediate flood frequency and duration, the more frequent and longer periods of inundation that can be expected to occur under constraints management may exceed the tolerances of these weed taxa. Furthermore, it appears that all of the proposed RRC inundation scenarios deliver changes to inundation regimes in the current suitable habitat of these amphibious weeds sufficient to reduce its degree of suitability.

Lippia specifically was associated with drivers of both extended wet and dry periods and the largest areas of changes were in habitats that typically experience periodic inundation (i.e. temporary wetlands, black box woodlands). Presently, these amphibious weeds occur in areas such as permanent and temporary waterbodies and floodplain woodlands, where reduced flood duration and magnitude under flow constraints may have facilitated their invasion and dominance. Lippia typically becomes dominant in areas where water regulation and agricultural practices have altered the natural flooding regime but can be controlled through annual land cultivation (Macdonald et al. 2012). Restoring natural inundation regimes, particularly longer summer floods in the northern MDB, is also known to reduce the extent and dominance of Lippia (Price et al. 2010). Our results suggest that for the Murray and Murrumbidgee regions, the increased frequency and duration of inundation events proposed with relaxation of constraints, will also reduce the extent of Lippia.

Terrestrial species, on the other hand, showed increases in suitable habitat area under proposed inundation scenarios. This is likely a result of larger fringing areas generated by flooding under the RRC scenarios in which moisture is readily available more frequently but where inundation does not occur for longer periods of time. Terrestrial species under the water plant functional group definitions do not require flooding for completion of their lifecycle, but still require moisture for germination and establishment. These fringing areas of flood extents may provide suitable conditions for the germination for these weeds which can quickly establish and dominate a region, potentially minimising habitat for native species and reducing the productivity of agricultural land (Downey et al. 2010; Noble et al. 2013). Our modelling suggested that the distribution of terrestrial species is associated with environmental drivers of extended dry periods (e.g. maximum inter flood metrics, and days of no inundation metrics).

Constraint relaxation will also influence the dispersal of both amphibious and terrestrial weeds, increasing movement through the landscape with more frequent inundation events. Dispersal will further facilitate the expansion of terrestrial weeds where inundation can transport seeds to more elevated or off-channel areas that do not currently experience inundation. These areas where water would not persist for long periods are ideal for invasion of terrestrial weeds. Amphibious weeds would also spread through the same mechanisms, however, would require longer water permanence for establishment. This project did not specifically identify areas where water permanence differed between inundation scenarios, although this is an area for further investigation as it would likely provide further justification for the results presented here.

Substantial declines in the total extent of weed hotspots (i.e., areas with suitable habitat for four or more modelled taxa) were modelled under all constraint relaxation scenarios compared with the base case in the Murray project area and, to a lesser degree, in the Murrumbidgee. Net decline in the predicted area of weed hotspots was greatest in the inundation scenario with the lowest level of constraint relaxation and decreased with increasing constraint relaxation while the opposite trend is predicted for the Murrumbidgee. It is difficult to explore mechanisms for these results without further exploring the species composition of hotspot areas, however, visual inspection of the species distribution models (Appendix 1) suggests that hotspots are generally composed of overlapping terrestrial species (i.e. Marrubium, Lycium, Xanthium). Given the location of hotspots on the main river channel in urban areas, greater inundation with relaxed flow constraints would suggest that these species could be displaced. The minimal area of weed hotspots also suggests that the modelled species do not commonly occur together.

Differences in modelled suitable habitat area between inundation scenarios was negligible for most species. Where differences between inundation scenarios did occur it was generally apparent between the lower constraint relaxation models while the higher models tended to be more similar to each other. The distribution of Salix (willows) in the Murrumbidgee catchment is one example where an increase in suitable habitat was projected under the lowest constraint relaxation scenario (32GL) but decreases in suitable habitat predicted under the higher scenarios. Investigation into projected differences in the extent, magnitude, and duration of inundation between scenarios were beyond the scope of this project. However, it is likely that the conditions provided under the lowest constraint relaxation scenario are suitable for dispersal and establishment of Salix propagules while the higher relaxation scenarios, associated with more frequent and longer flooding, may result in dieback of new recruits under prolonged flooding (Stokes 2008). Consecutive flood events or prolonged inundation can favour native species over exotics resulting in reduced weed species richness in riparian areas (Greet et al. 2015).

The changes in weed species distribution modelled in this project are largely consistent between the two focus catchments, the Murray and Murrumbidgee Rivers, although the magnitude of change often differed. For species which showed contrasting changes between catchments (i.e. Rubus, Xanthium), the changes were generally larger in the Murray compared to the Murrumbidgee catchment where changes were relatively minimal, potentially due to more fringing habitat in the Murray floodplain.

Limitations of approach

The approach taken for this project was completed to the best of our knowledge with the available data. The outputs of this project were limited by the coarse spatial resolution of environmental predictor variables and the lack of species records for many significant weed species, resulting in models that show general distribution trends. The resolution and classifications used to delineate habitats has also limited the outputs of this project where the lack of consistency between vegetation and wetland type categories and limited category definitions raises some concern for the application of management actions in specific habitat types. This is particularly evident when comparing the model results to that of the expert elicitation survey where habitat types of expected change did not often correspond to the habitat types where change was predicted through modelling. Most survey respondents also noted a low level of confidence in the distribution and potential changes of weeds in relation to constraints relaxation highlighting the lack of knowledge regarding these species and the effects of inundation on their distribution and lifecycle, even from experts in the field.

Additionally, the results of this project seem counter intuitive in some cases (e.g. the reduction of widespread weed Lippia – *Phyla canescens* – under constraints relaxation). It is important to note that our modelling was restricted to the area of the smallest dataset, in our case the inundation modelling, which was restricted to the extent of the floodplain. This greatly reduced the number of available species occurrence data points but also reduces the range and extent of potential environmental predictors. It is likely that each species investigated occurs in many more habitat types than what is reported here and potentially skewed the results towards habitats not typical of each weed species. The modelling of species in an area greater than the floodplain was not in the scope of this project and would require inundation modelling to be conducted at a larger extent.

The water plant functional group classification of weed species used in this project also has its limitations, particularly when a large proportion of the species investigated do not rely on flooding for completion of their lifecycle or for dispersal, although it is aided by on many occasions. Classification by plant form (i.e. herbaceous, grasses, shrubs, trees) and life history (i.e. annual, perennial) would likely provide a more intuitive result, however the time required to generate models for each of these combinations and the time constraints of this project meant that more classification options could not be explored. The consideration of species as individuals and within a plant functional group potentially exacerbated the results of the group models, particularly in the case of Marrubium and Lycium which are included in the Tdr group, where a large proportion of observations used for modelling are for these two species. It is likely, however, that the general resulting trends of this group would still be found if they were removed, consistent with our hypothesis of greater area for terrestrial weeds under constraints relaxation due to greater fringing areas.

The classification of suitable habitat used in our approach is a conservative assessment as the suitability value needed to be above the threshold value for all five model runs for a cell to be classed as suitable habitat. High suitability on the otherhand was less conservative and included any cell that had a suitability value in the top twenty percent of the average suitability threshold calculated across the five model runs. In theory, high suitability would be a complete subset of suitability, calculated during the model run and would only include those cells which are highly suitable in each model run. In practice however, the high suitability threshold can show more or less habitat because the threshold value is calculated from an average. Despite this difference in methodology, we suggest that changes in highly suitable habitat under modelled inundation scenarios may be more significant than changes in suitable habitat because this likely represents a more probable outcome in terms of realised changes in weed distribution.

Management options

- Develop management plans for species and areas that do not have one.
- Develop targeted management plans for weed hotspot areas to limit spread
- Increase weed monitoring and evaluation in the study area guided by habitat distributions and hotspots modelled here
- Invest in research to better understand weed responses to specific hydrological regimes

Future directions

- Conduct on-ground surveys of vegetation communities to better assess the prevalence and distribution of weeds within the region. Surveys and management actions could be incorporated in a citizen science program, particularly for urban regions identified as weed hotspots. Including soil seed bank assessments would be preferable to gain an understanding of invasion potential.
- Develop species distribution models for other classifications of plant functional groups (i.e. life history and plant form) and for joint species groups to investigate weed hotspots.
- Extend inundation modelling past the floodplain extent to capture variation in habitat types and better predict areas of change
- Potential for modelling of individual species and plant functional groups at a basin scale to increase data availability
- Further explore areas of highly suitable habitat to provide more in-depth analysis of weed risk
- Explore how water will flow through the landscape under relaxed constraints scenarios to further understand pattern in weed distribution and differences between catchments

Conclusions

- Our results indicate that the extent and distribution of priority weeds in the project area, across a range of functional groups, are moderately associated with patterns of flooding and drying. For the Tdr (terrestrial dry species) group, and key species within this group (e.g., Lycium, Marrubrium), metrics associated with longer dry periods appear to be particularly important drivers
- Under current conditions (i.e., base case), weed hotspots (i.e., areas with suitable habitat for four or more modelled taxa) occur in less than 0.1 % and ~ 0.4 % of the Murray and Murrumbidgee project areas respectively with hotspots tending to occur in the vicinity of major towns and in Production from relatively natural environments and water/wetlands land uses. With respect to vegetation types, river red gum forests and woodlands can be expected to have more weed hotspots than most other vegetation types under current conditions.
- Both increases and decreases in suitable habitat of weed taxa can be expected under potential constraint relaxation flow options depending on the taxa. Little variation between RRC inundation scenarios within each catchment for predicted suitable habitat of each weed taxa was predicted, however. Greater variation was apparent amongst inundation scenarios in terms of highly suitable habitat for some taxa (e.g., Phyla and Xanthium in the Murray).
- In the Murray, suitable habitat is likley to increase under RRC inundation scenarios compared to the base case for both Tdr species as a group (although no highly suitable habitat for Tdr species as a group was predicted in the Murray) and for the Tdr species considered individually (i.e. Lycium, Marrubium, Rubus and Xanthium) while significant declines in suitable habitat can be expected for the amphibious species (Phyla and Sagittaria) and, to a lesser degree, the Tda species, both as a group and the member species (i.e. Salix). Slight increases in suitable habitat for Salix, however, can be expected under the inundation scenarios.
- In the Murrumbidgee, suitable habitat can be expected to increase under all inundation scenarios for three of the Tdr species considered (Lycium, Marrubium and Rubus) but decline slighty for Xanthium. Our results also indicate that highly suitable habitat for Tdr species as a group may completely disappear under constraint relaxation. Slight declines in suitable habitat can be expected for amphibious and Tda species with suitable habitat for Sagittaria not predicted in this catchment under any scenario. Increases in highly suitable habitat in the Murrumbidgee were predicted for Phyla and Sagittaria.
- Projected changes in distribution can be attributed overall to increasing duration and magnitude of inundation events ‘drowning out’ amphibious species but providing more fringing habitat for terrestrial species.
- Substantial declines in the total extent of weed hotspots (i.e., areas with suitable habitat for four or more modelled taxa) can be expected under all inundation scenarios compared with the base case in the Murray project area and, to a lesser degree, in the Murrumbidgee. Net decline in the predicted area of weed hotspots was greatest in the inundation scenario with the lowest level of constraint relaxation and decreased with increasing constraint relaxation while the opposite trend is predicted for the Murrumbidgee.
- Our expert elicitation activities indicate that most experts consulted expect slight to no increases in the prevalence and consequences of weeds in the project area in response to increased inundation. However, there is a considerable degree of uncertainty regarding outcomes of changes to

inundation and their importance relative to other drivers of weed distribution, impacts and management.

- Risk assessment scores were largely consistent with findings of expert elicitation and suggest that only slight increases or decreases in weed risk are likely under constraint relaxation.
- In the Murray, benefits are likely to accrue under all inundation scenarios in relation to reductions in the distribution and extent of Sagittaria, Phyla and Salix as well as Tda species and weed hotspots, although there are likely to be increase in the extents and distribution of Marrubium, Xanthium, Rubus and especially Lycium as well as Tdr species. For Rubus and Marrubium, this risk is likely to be greater under the greatest relaxation of constraints while the reverse is indicated for Lycium and Xanthium while the risk of increasing distribution and extent of Tdr species is unlikely to vary across scenarios according to our risk assessment.
- In the Murrumbidgee, a significant difference between inundation scenarios is associated with a greater risk of increase in the extent and distribution of Salix under the 32 GL scenario compared to the 36 GL and 40 GL scenarios under which there is a likely benefit of constraint relaxation in relation to this weed’s extent and distribution.
- Overall, our risk assessment suggests a likely overall benefit of constraint relaxation on the distribution and consequence of weeds in the Murray across all inundation scenarios, to a slightly greater degree in intermediate scenarios, and in the Murrumbidgee under the 36 GL and 40 GL scenarios. An overall risk for weeds, however, is indicated for the Murrumbidgee under the 32 GL scenario.

References

Brock, MA and Casanova, MT. 1997. Plant life at the edges of wetlands; ecological responses to wetting and drying patterns. In *In: Frontiers in Ecology; Building the links (Eds N. Klomp and I. Lunt* (pp. 181–192). Elsevier Science.

Capon, SJ, Grieger, R, Chauvenet, Al, Franklin, H and Burgoyne, H. 2021. Weed distribution and consequences: Hume to Yarrawonga (Murray), Murrumbidgee and Lower Murray. Report 1. Report prepared by Griffith University for NSW Department of Planning and Environment, December 2021.

Downey, PO, Scanlon, TJ, Hosking, JR (2010) Prioritizing weed species based on their threat and ability to impact on biodiversity: A case study from New South Wales. *Plant Protection Quarterly,* 25(3): 111-126

Greet, J, Webb, JA, Cousens, RD (2015) Floods reduce the prevalence of exotic plant species within the riparian zone: evidence from natural floods. *Applied Vegetation Science,* 18(3): 503-512

Macdonald, MJ, Whalley, WRDB, Julien, MH, Sindel, BM, Duggin, JA (2012) Flood-induced recruitment of the invasive perennial herb <i>Phyla canescens</i> (lippia). *The Rangeland Journal,* 34(3): 269-276

Noble, MR, Rose, MC, Balnaves, J (2013) *African Boxthorn National Best Practice Manual: Managing African Boxthorn (Lycium ferocissimum) in Australia*: Tasmanian Department of Primary Industries, Parks, Water and Environment

O'Donnell, J, Gallagher, RV, Wilson, PD, Downey, PO, Hughes, L, Leishman, MR (2012) Invasion hotspots for non-native plants in Australia under current and future climates. *Global Change Biology,* 18(2): 617-629

Price, J, Gross, CL, Whalley, W (2010) Prolonged summer flooding switched dominance from the invasive weed Lippia (Phyla canescens) to native species in one small, ephemeral wetland. *Ecological Management & Restoration,* 11(1): 61-63

Shabani, F, Ahmadi, M, Kumar, L, Solhjouy-fard, S, Shafapour Tehrany, M, Shabani, F, . . . Esmaeili, A (2020) Invasive weed species' threats to global biodiversity: Future scenarios of changes in the number of invasive species in a changing climate. *Ecological Indicators,* 116: 106436

Stokes, KE (2008) Exotic Invasive Black Willow (Salix nigra) in Australia: Influence of Hydrological Regimes on Population Dynamics. *Plant Ecology,* 197(1): 91-105

Appendices

Appendix 1.

Species distribution model summary results

List of figures and tables

Amphibious fluctuation responders (Arp) species

Sagittaria sp.

Amphibious fluctuation tolerators (Atl) species

Phyla sp.

scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.9. Total area of modelled highly suitable habitat for Phyla sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.10 Changes from the basecase in extent of modelled suitable habitat area for Phyla sp. In the Murrumbidgee project area under each RRC inundation scenario.

Figure A1.11. Changes from the basecase in extent of modelled highly suitable habitat area for Phyla sp. In the Murrumbidgee project area under each RRC inundation scenario.

Figure A1.12. Total area of modelled suitable habitat for Phyla sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.13. Total area of modelled highly suitable habitat for Phyla sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Terrestrial damp (Tda) species

Tda species

Figure A1.14. Changes from the basecase in extent of modelled suitable habitat area for Tda species in the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

Figure A1.15. Changes from the basecase in extent of modelled highly suitable habitat area for Tda species in the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

Figure A1.16. Total area of modelled suitable habitat for Tda species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.17. Total area of modelled highly suitable habitat for Tda species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.18. Changes from the basecase in extent of modelled suitable habitat area for Tda species in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.19. Changes from the basecase in extent of modelled highly suitable habitat area for Tda species in the Murrumbidgee project area (map constrained to upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.20. Total area of modelled suitable habitat for Tda species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.21. Total area of modelled highly suitable habitat for Tda species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Salix sp.

Figure A1.22. Changes from the basecase in extent of modelled suitable habitat area for Salix sp. in the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

Figure A1.23. Changes from the basecase in extent of highly suitable habitat area for Salix sp. In the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

Figure A1.24. Total area of modelled suitable habitat for Salix sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.25. Total area of modelled highly suitable habitat for Salix sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.26. Changes from the basecase in extent of modelled suitable habitat area for Salix sp. in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.27. Changes from the basecase in extent of modelled highly suitable habitat area for Salix sp. In the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.28. Total area of modelled suitable habitat for Salix sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.29. Total area of modelled highly suitable habitat for Salix sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Terrestrial dry (Tdr) species

Tdr species

Figure A1.30. Changes from the basecase in extent of modelled area for Tdr species in the Murray project area (map constrained to the mid- upper Murray reaches / Albury - Swan Hill) under each RRC inundation scenario.

Figure A1.32. Total area of modelled suitable habitat for Tdr species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.33. Changes from the basecase in extent of modelled area for Tdr species in the Murrumbidgee project area under each RRC inundation scenario.

Figure A1.34. Total area of modelled suitable habitat for Tdr species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Lycium sp.

Figure A1.35. Changes from the basecase in the extent of modelled suitable habitat area for Lycium sp. In the Murray project area (map constrained to lower Murray reaches) under each RRC inundation scenario.

Figure A1.36. Changes from the basecase in the extent of modelled highly suitable habitat area for Lycium sp. In the Murray project area (map constrained to lower Murray reaches) under each RRC inundation scenario.

Figure A1.37. Total area of modelled suitable habitat for Lycium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.38. Total area of modelled highly suitable habitat for Lycium sp in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.39. Changes from the basecase in extent of modelled area for Lycium species in the Murrumbidgee project area under each RRC inundation scenario.

Figure A1.40. Changes from the basecase in extent of modelled highly suitable habitat area for Lycium sp. In the Murrumbidgee project area under each RRC inundation scenario.

Figure A1.41. Total area of modelled suitable habitat for Lycium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.42. Total area of modelled highly suitable habitat for Lycium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Marrubium sp.

Figure A1.43. Changes from the basecase in extent of modelled suitable habitat area for Marrubium sp. in the Murray project area (map constrained to the mid - upper Murray reaches / Albury - Swan Hill) under each RRC inundation scenario.

Figure A1.44. Changes from the basecase in extent of modelled highly suitable habita area for Marrubium sp. In the Murray project area (map constrained to the mid – upper reaches / Albury – Swan Hill) under each RRC inundation scenario.

Figure A1.45. Total area of modelled suitable habitat for Marrubium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.46. Total area of modelled highly suitable habitat for Marrubium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.47. Changes from the basecase in extent of modelled suitable habitat area for Marrubium sp. in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.48. Total area of modelled suitable habitat for Marrubium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.49. Total area of modelled highly suitable habitat for Marrubium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Rubus sp.

Figure A1.50. Changes from the basecase in extent of modelled suitable habitat area for Rubus sp. in the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

Figure A1.51. Changes from the basecase in extent of modelled highly suitable habitat area for Rubus sp. In the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

Figure A1.52. Total area of modelled suitable habitat for Rubus sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.53. Total area of modelled highly suitable habitat for Rubus sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.54. Changes from the basecase in extent of modelled suitable habitat area for Rubus sp. in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.55. Changes from the basecase in extent of modelled highly suitable habitat for Rubus sp. In the Murrumbidgee project area (map constrained to upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.56. Total area of modelled suitable habitat for Rubus sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.57. Total area of modelled highly suitable habitat for Rubus sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Xanthium sp. (Tdr)

Figure A1.58. Changes from the basecase in extent of modelled area for Xanthium sp. in the Murray project area (map constrained to the mid - upper Murray reaches / Albury - Swan Hill) under each RRC inundation scenario.

Figure A1.59. Changes from the basecase in extent of modelled highly suitable habitat area for Xanthium sp. In the Murray project area (map constrained to the mid – upper Murray reaches / Albury – Swan Hill) under each RRC inundation scenario.

Figure A1.60. Total area of modelled suitable habitat for Xanthium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.61. Total area of modelled highly suitable habitat for Xanthium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.62. Changes from the basecase in extent of modelled suitable habitat area for Xanthium sp. in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.63. Changes from the basecase in extent of modelled highly suitable habitat area for Xanthium sp. In the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Figure A1.64. Total area of modelled suitable habitat for Xanthium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Figure A1.65. Total area of modelled highly suitable habitat for Xanthium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Amphibious fluctuation responder morphologically plastic (Arp) species

Sagittaria

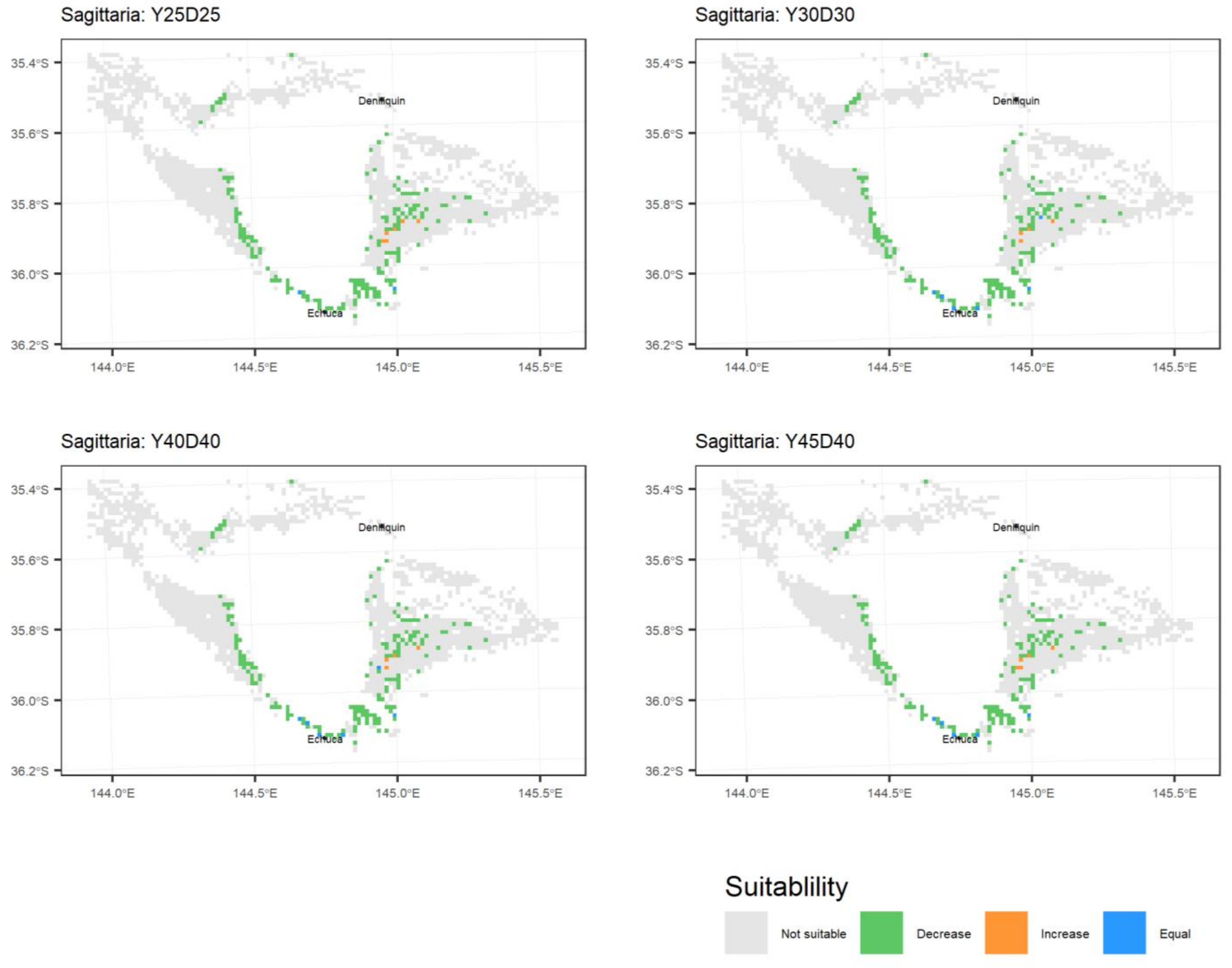

Figure A1.1. Changes from the basecase in extent of modelled suitable habitat area for Sagittaria sp. In the Murray project area (map constrained to the Barmah National Park area) under each RRC inundation scenario.

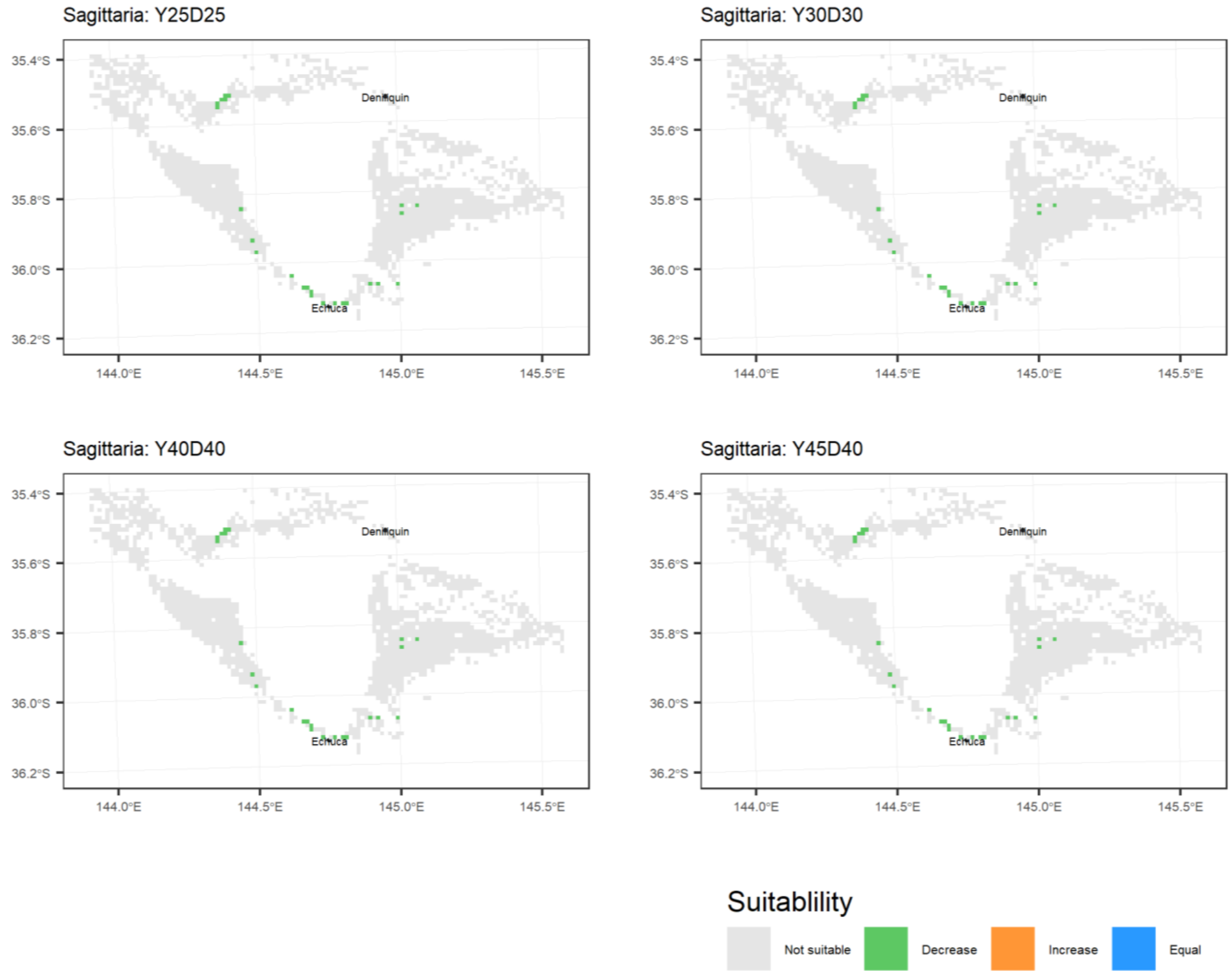

Figure A1.2. Changes from the basecase in extent of modelled highly suitable habitat area for Sagittaia sp. In the Murray project area (map constrained to the Barmah National Park area) under each RRC inundation scenario.

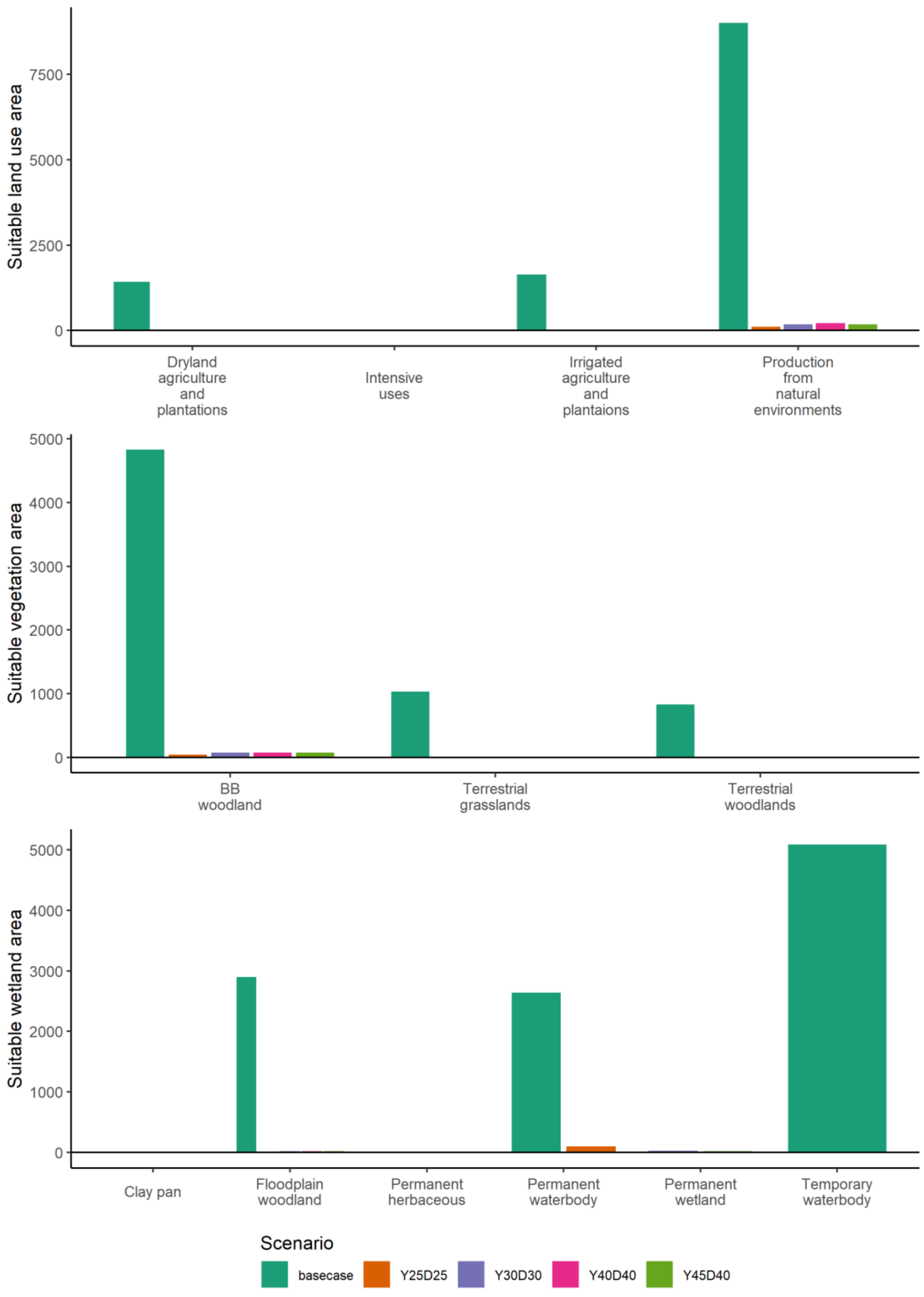

Figure A1.3. Total area of modelled suitable habitat for Sagittaria sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

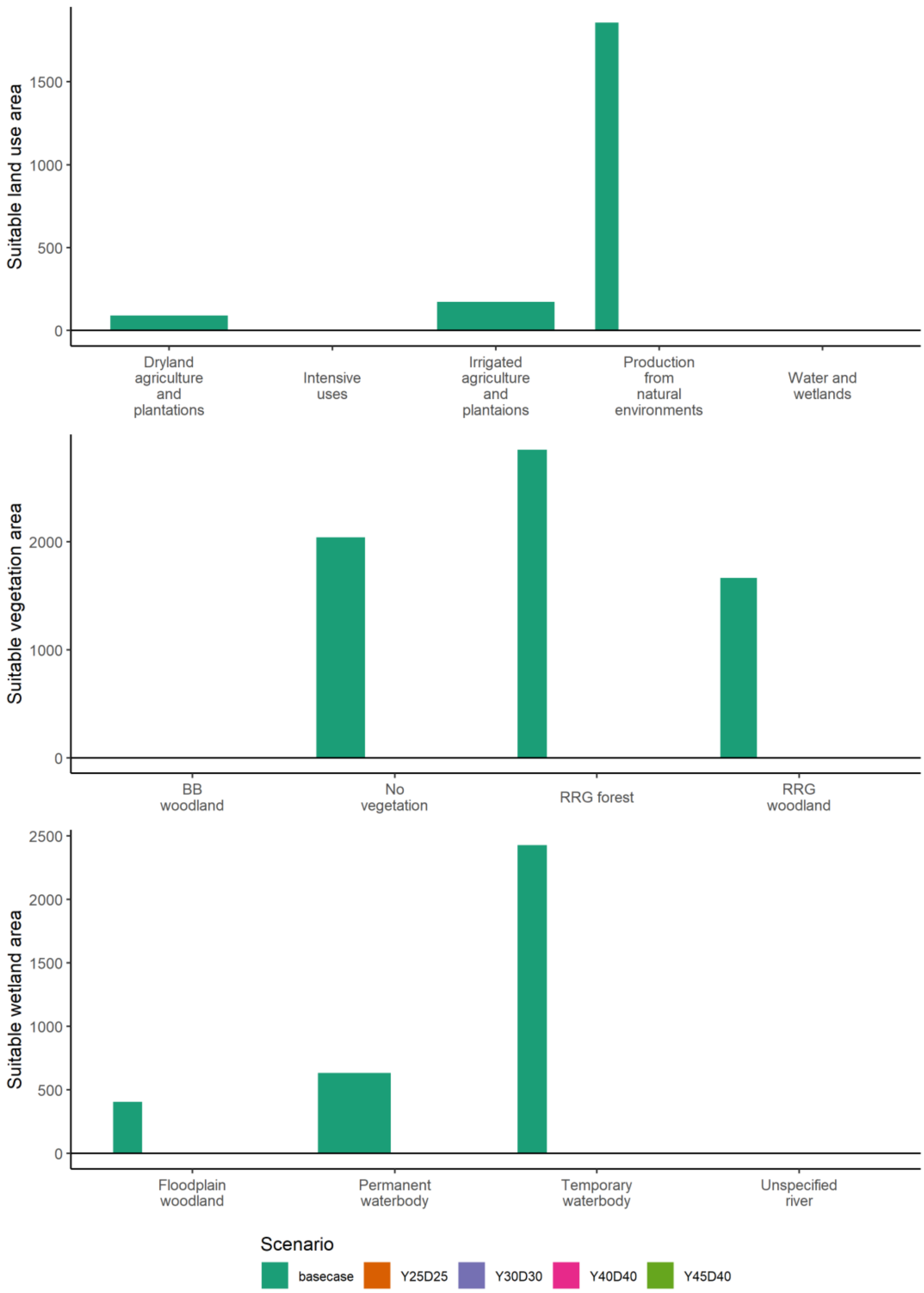

Figure A1.4. Total area of modelled highly suitable habitat for Sagittaria sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Note. Suitable habitat area for Sagittaria was minimal and could not be visualised in the Murrumbidgee under each scenario hence no graph of change is presented here and no maps of suitable and highly suitable area are presented.

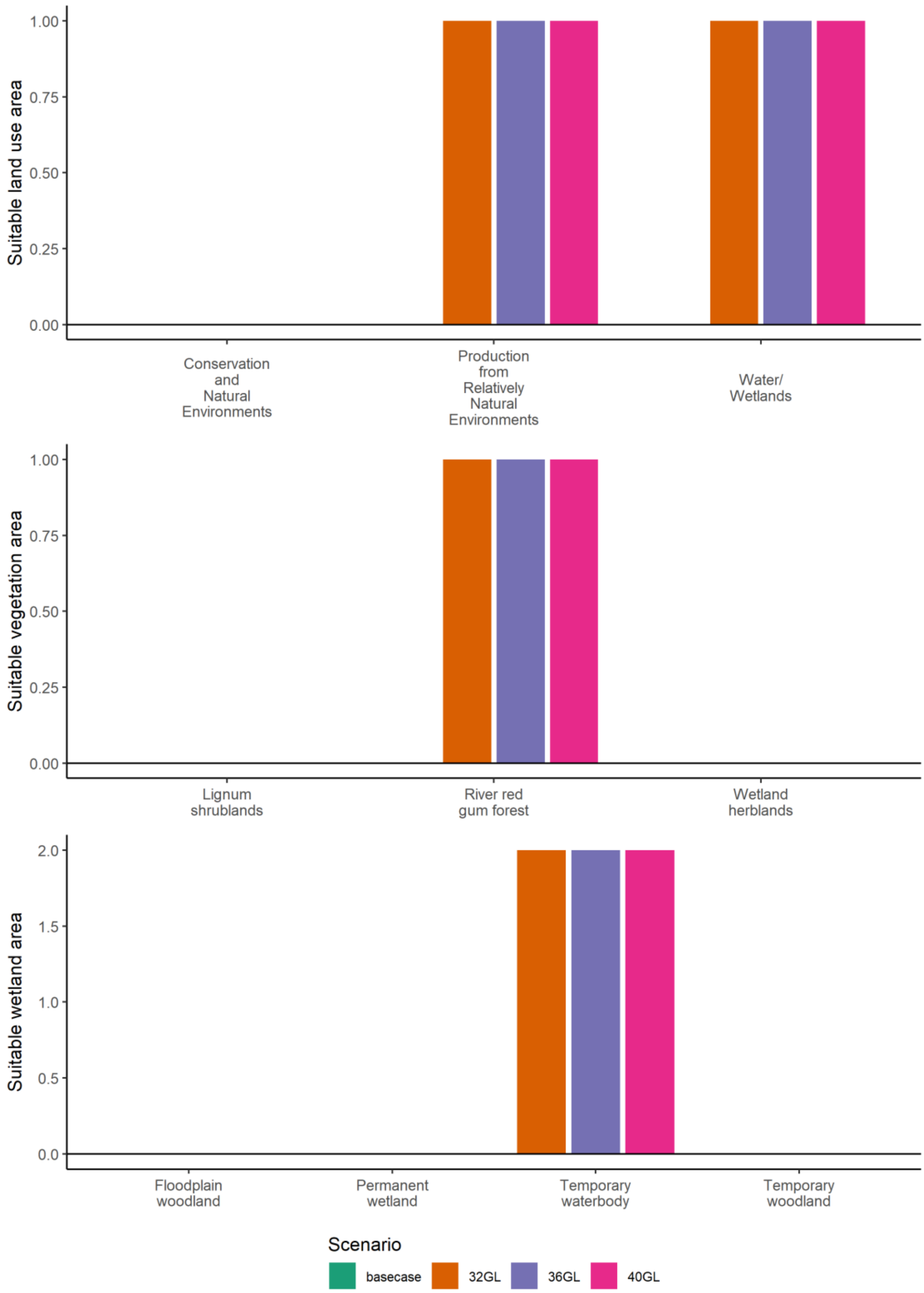

Figure A1.5. Total area of modelled highly suitable habitat for Sagittaria sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Amphibious fluctuation tolerant low-lying (Atl) species

Phyla sp

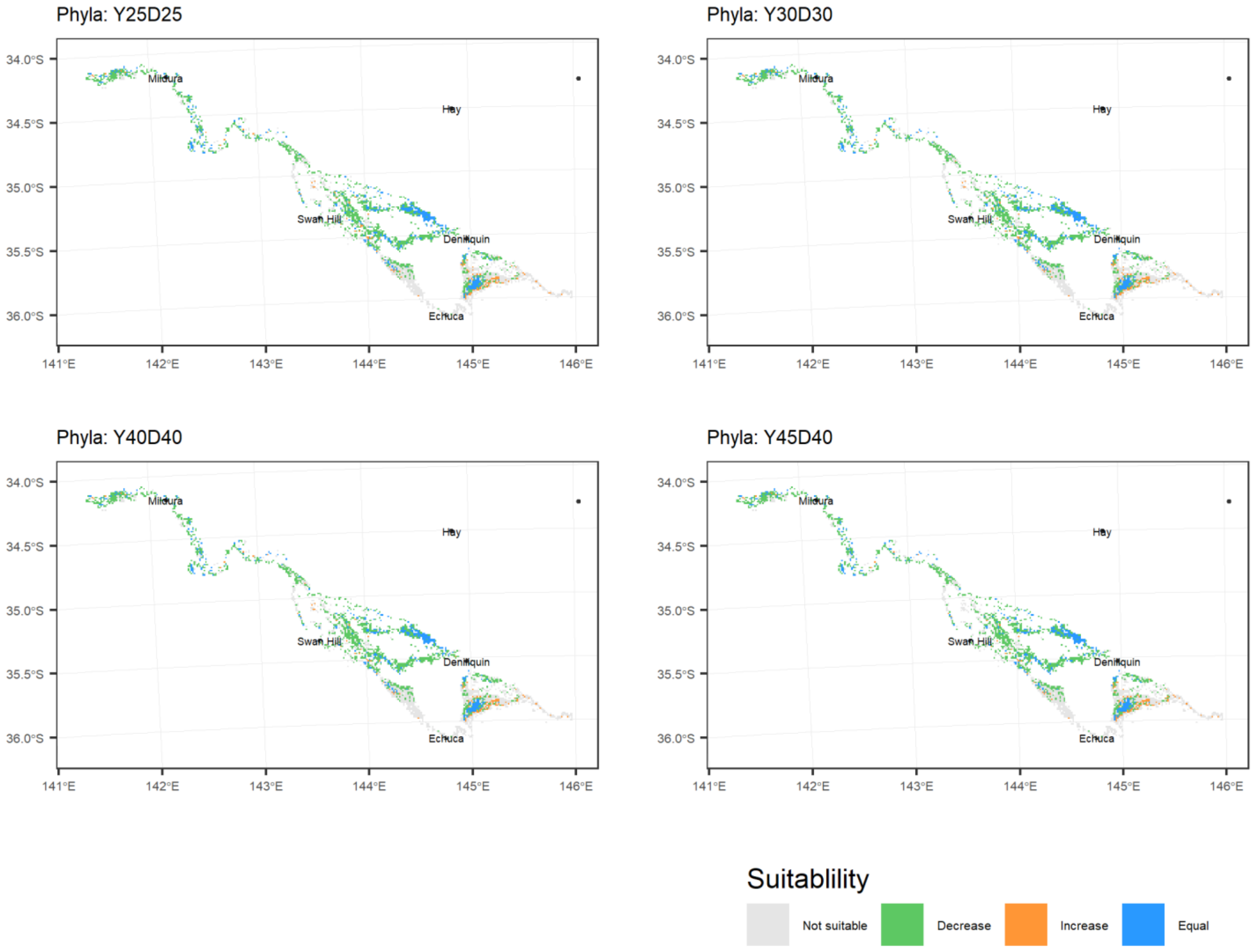

Figure A1.6. Changes from the basecase in extent of modelled suitable habitat area for Phyla sp. In the Murray project area under each RRC inundation scenario.

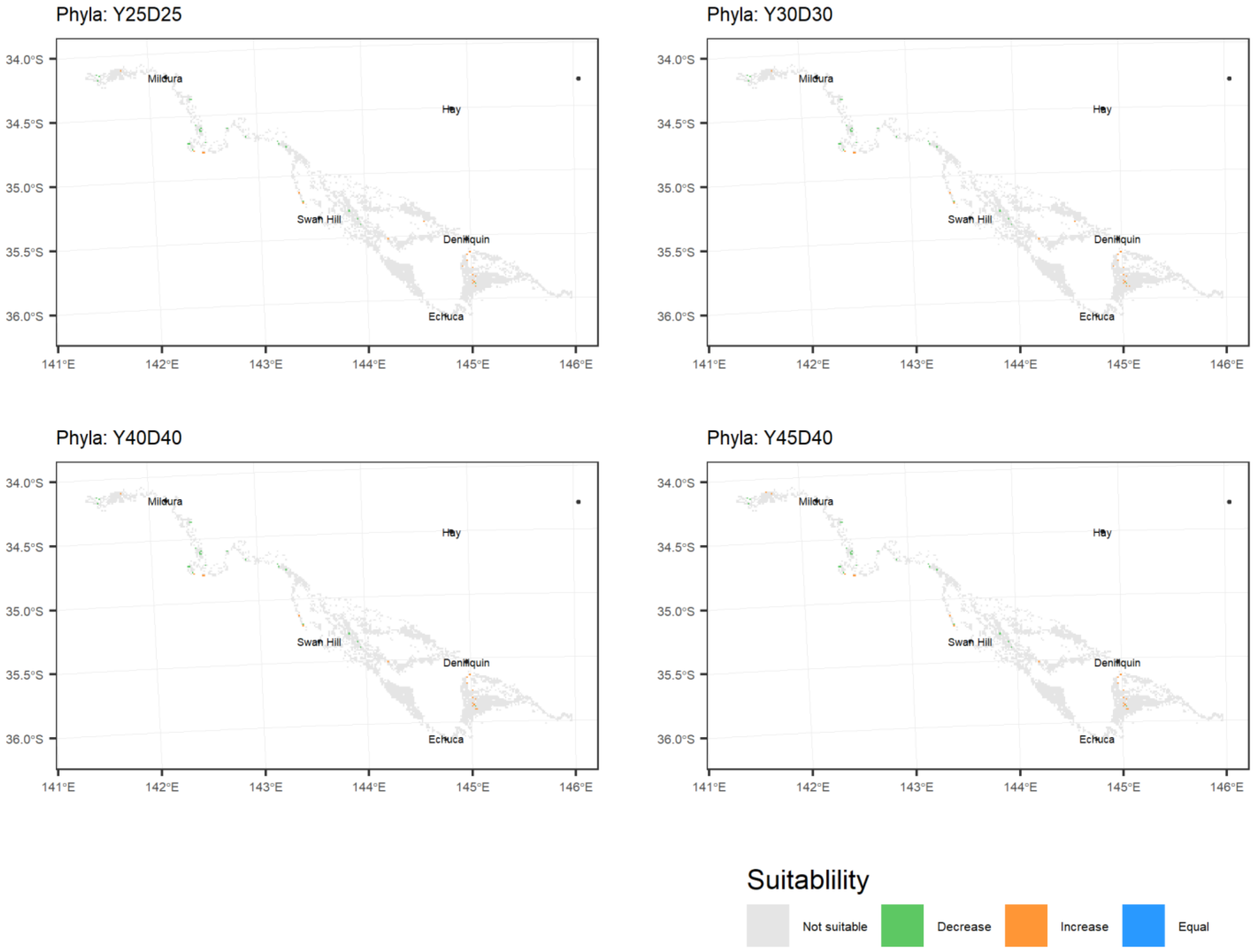

Figure A1.7. Changes from the basecase in extent of modelled highly suitable habitat area for Phyla sp. In the Murray project area (map constrained to lower Murray reaches) for each RRC inundation scenario.

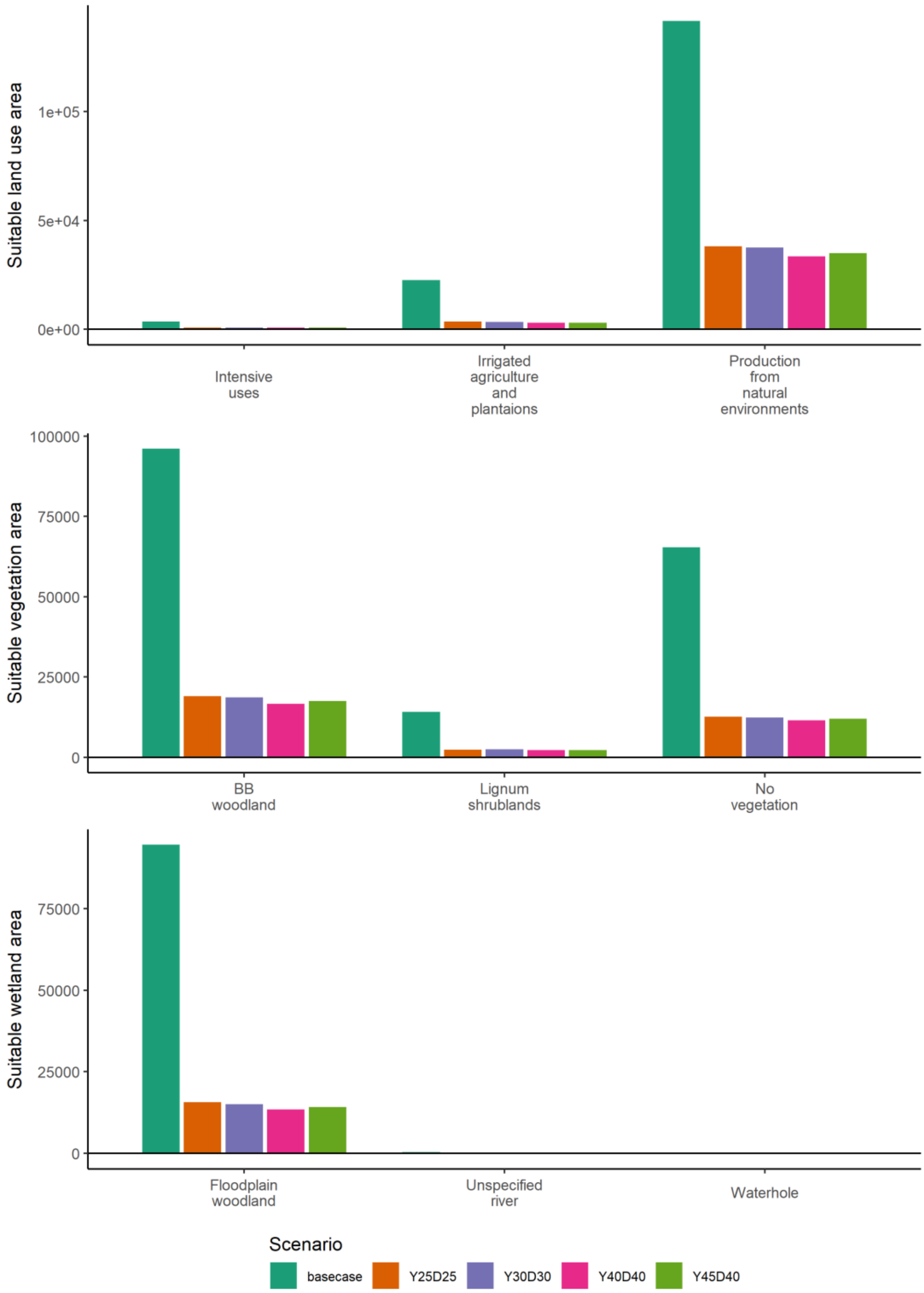

Figure A1.8. Total area of modelled suitable habitat for Phyla sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

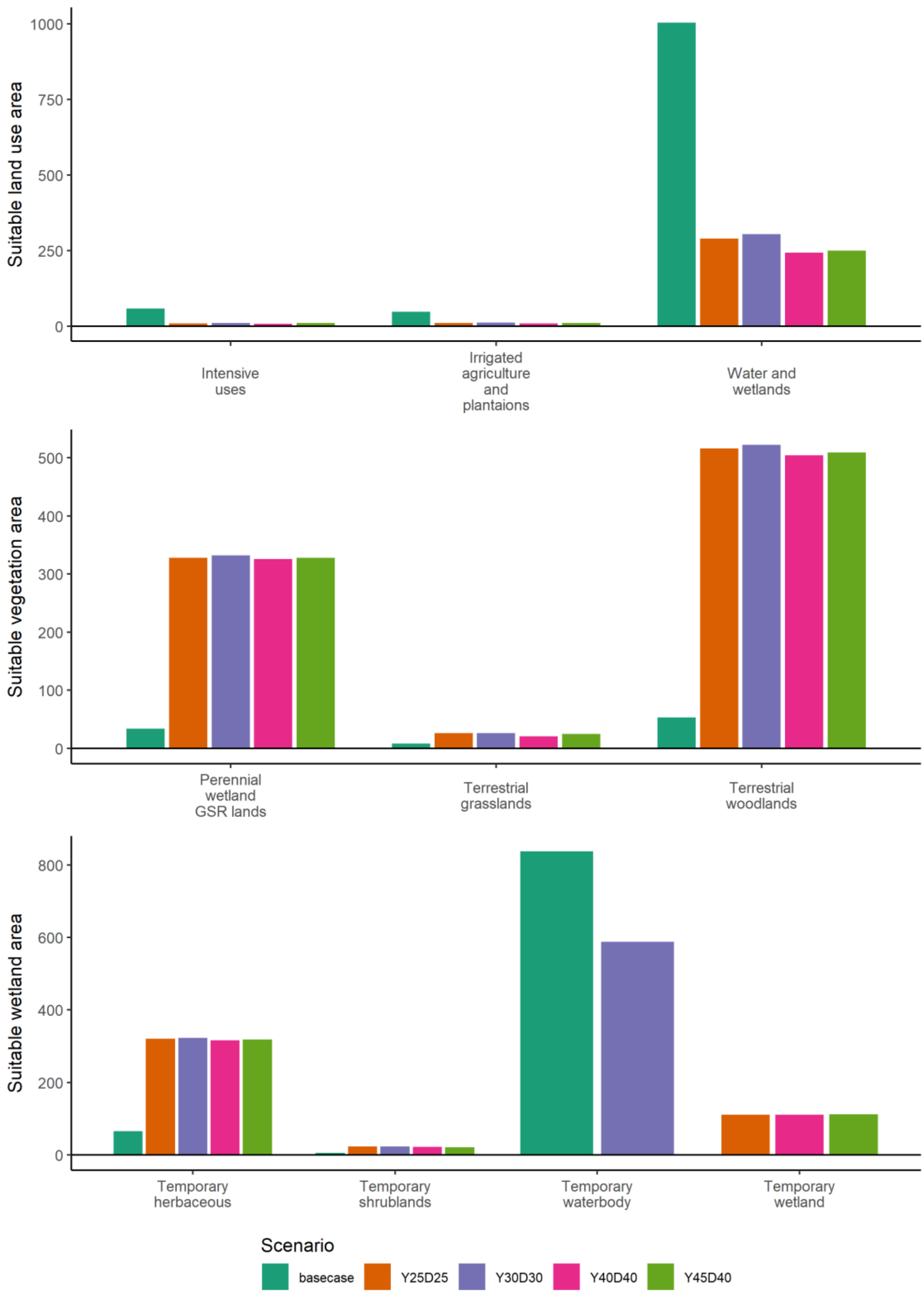

Figure A1.9. Total area of modelled highly suitable habitat for Phyla sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

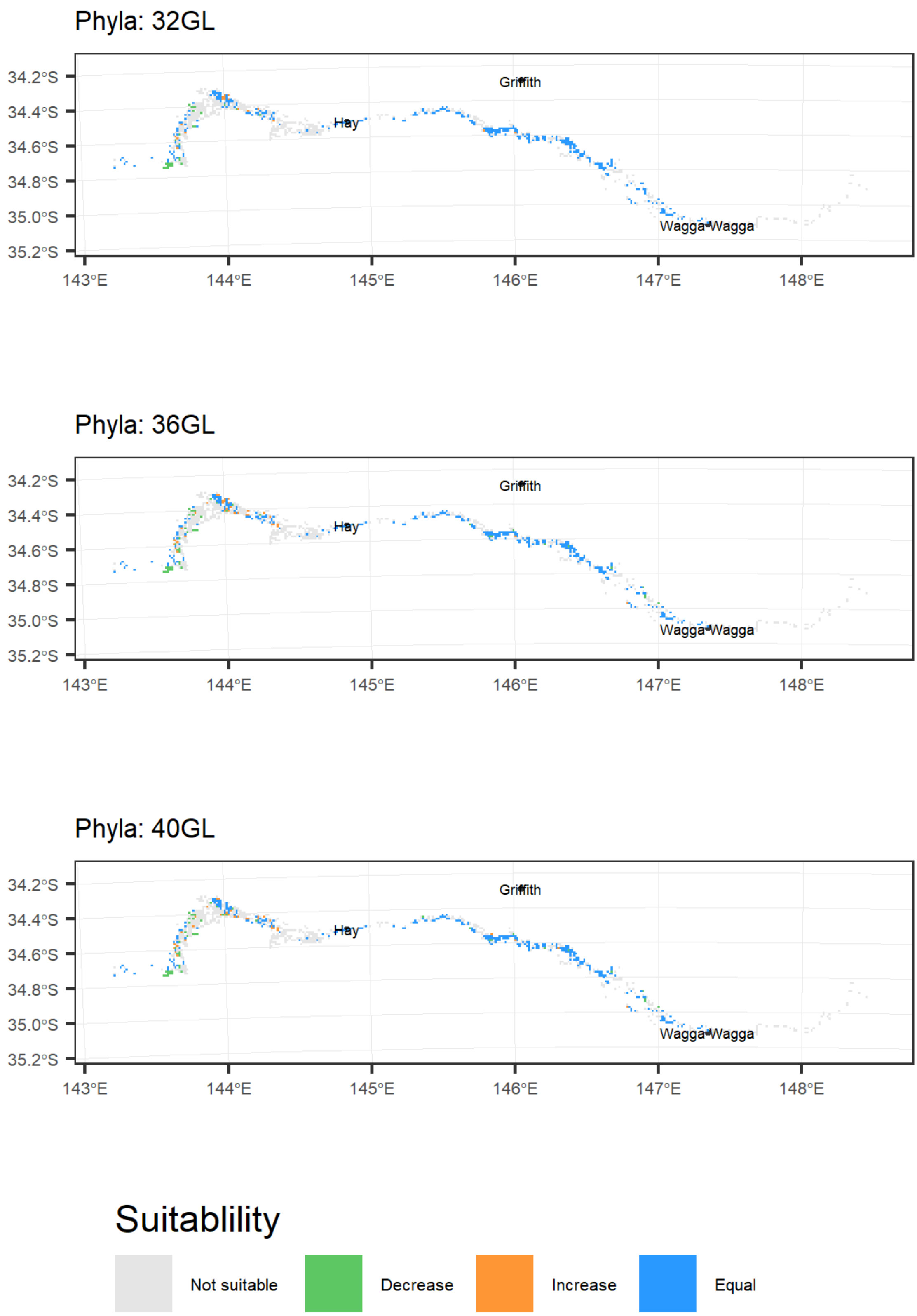

Figure A1.10. Changes from the basecase in extent of modelled suitable habitat area for Phyla sp. In the Murrumbidgee project area under each RRC inundation scenario.

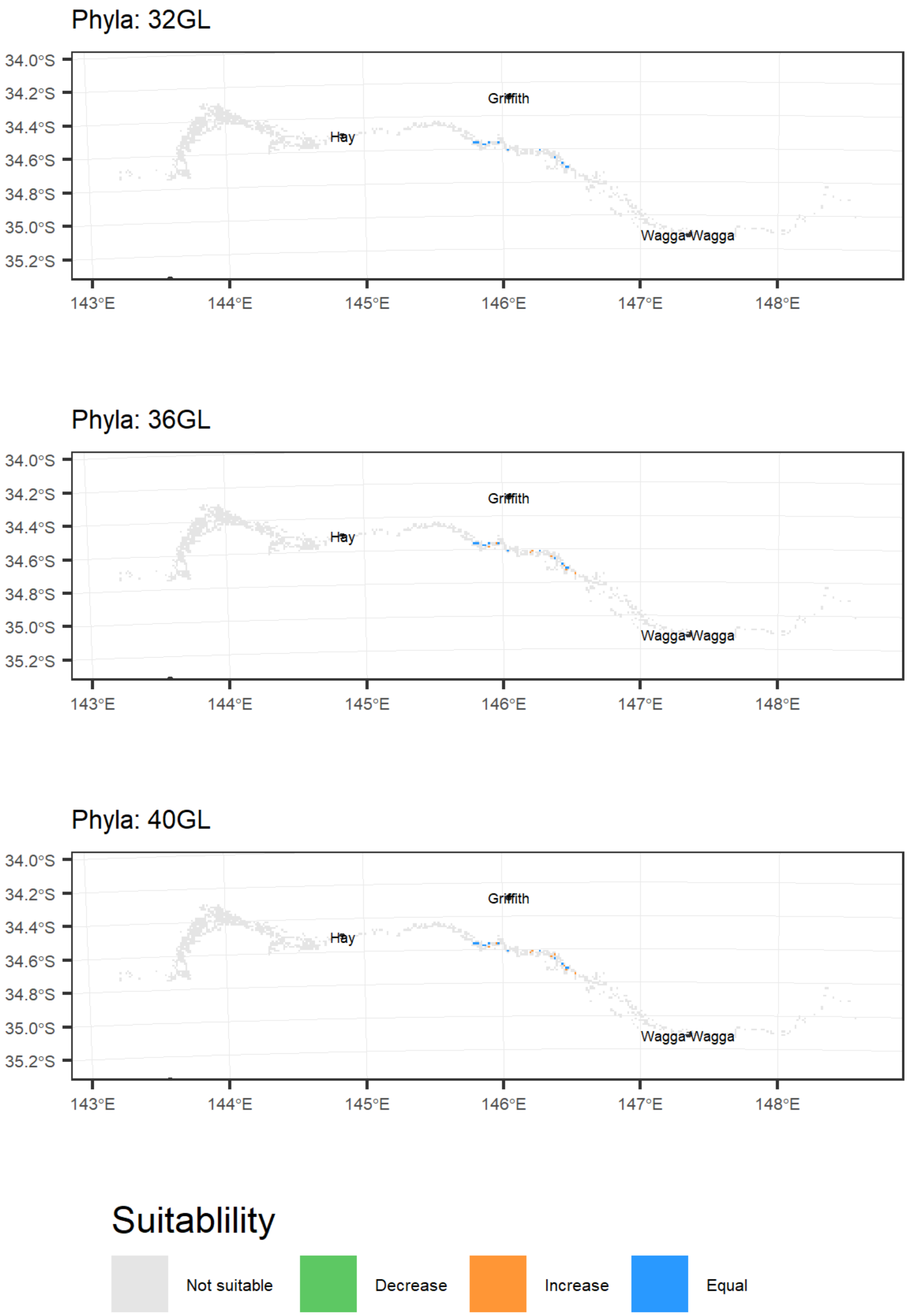

Figure A1.11. Changes from the basecase in extent of modelled highly suitable habitat area for Phyla sp. In the Murrumbidgee project area under each RRC inundation scenario.

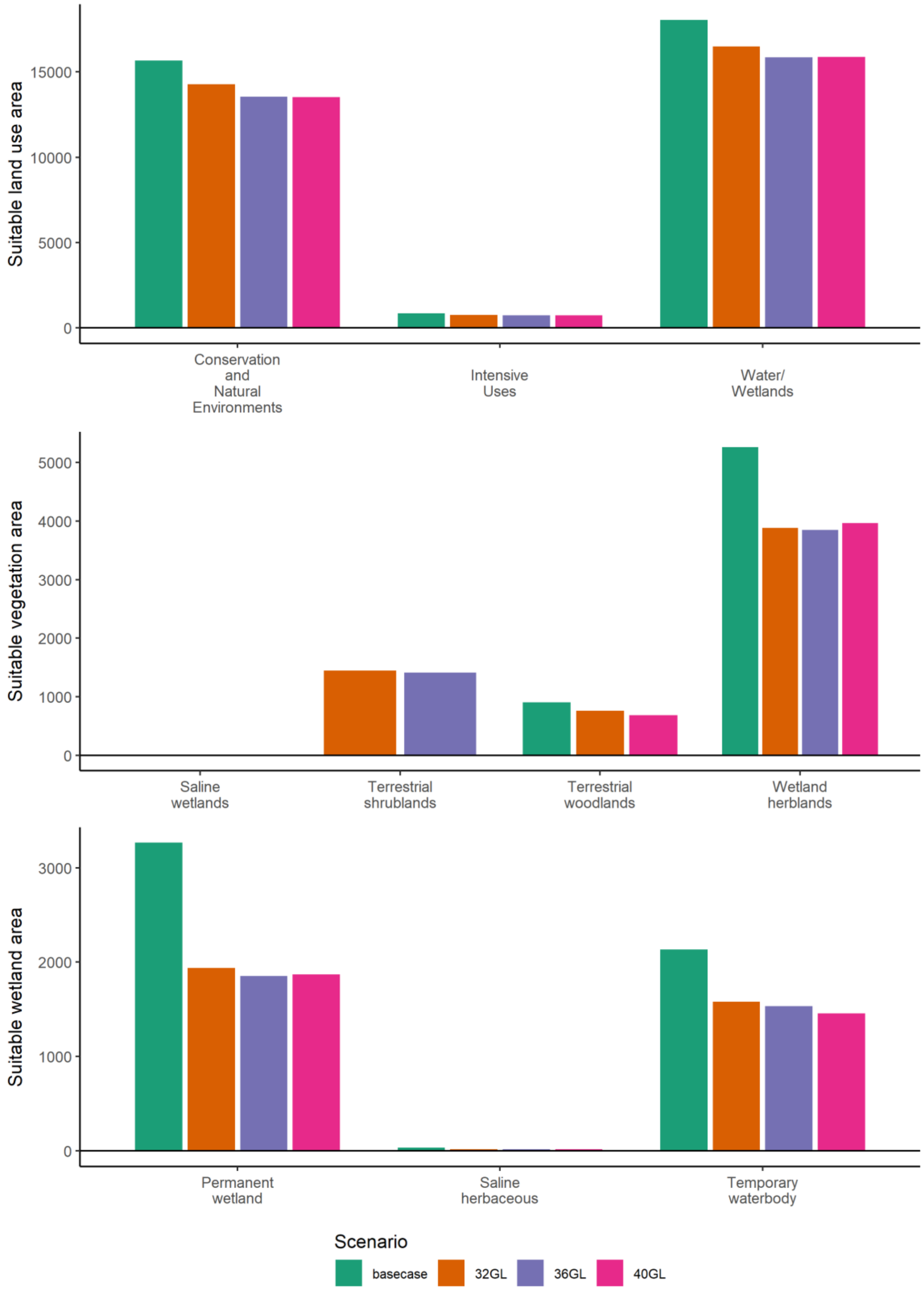

Figure A1.12. Total area of modelled suitable habitat for Phyla sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

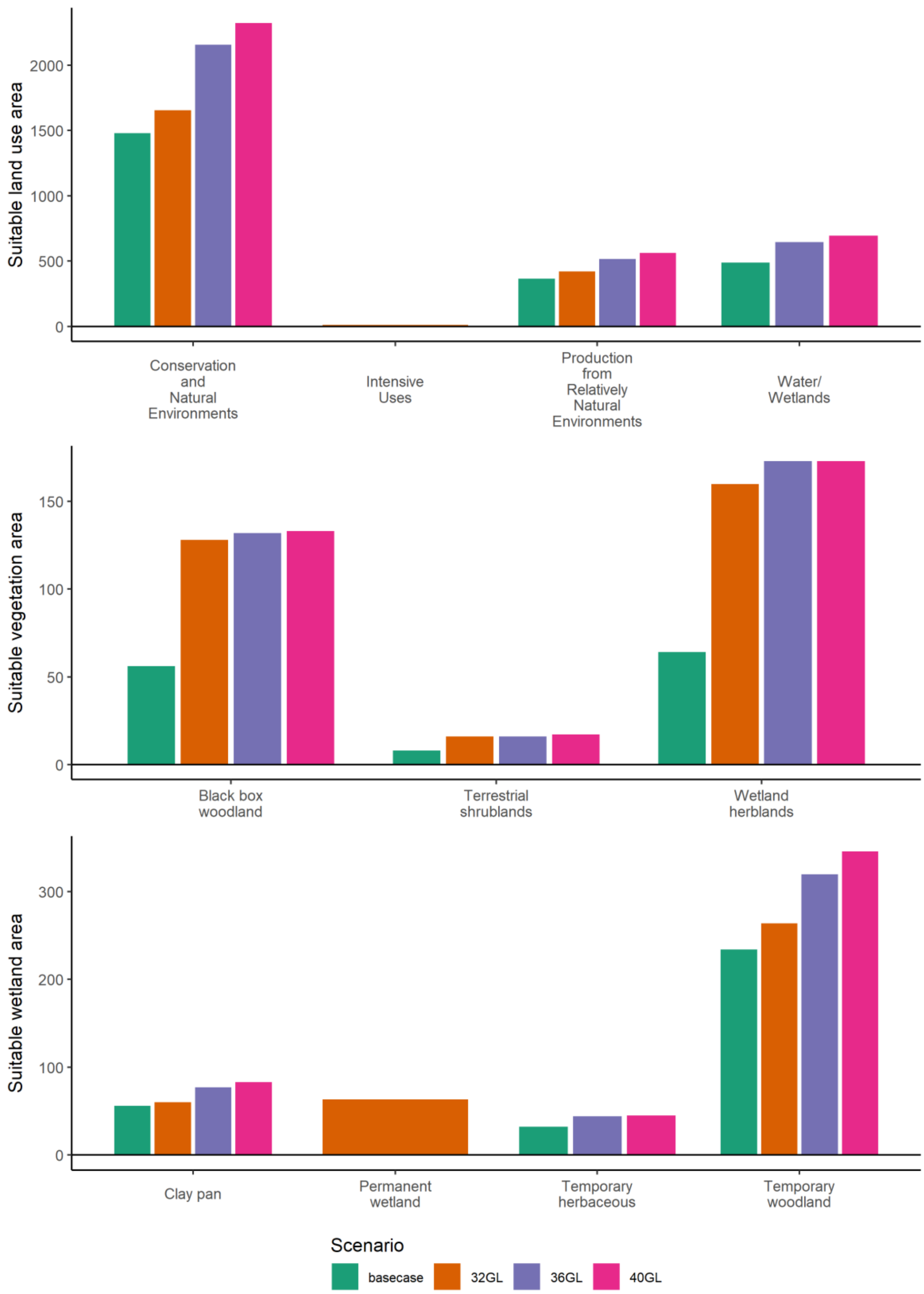

Figure A1.13. Total area of modelled highly suitable habitat for Phyla sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Terrestrial damp (Tda) species

Tda species

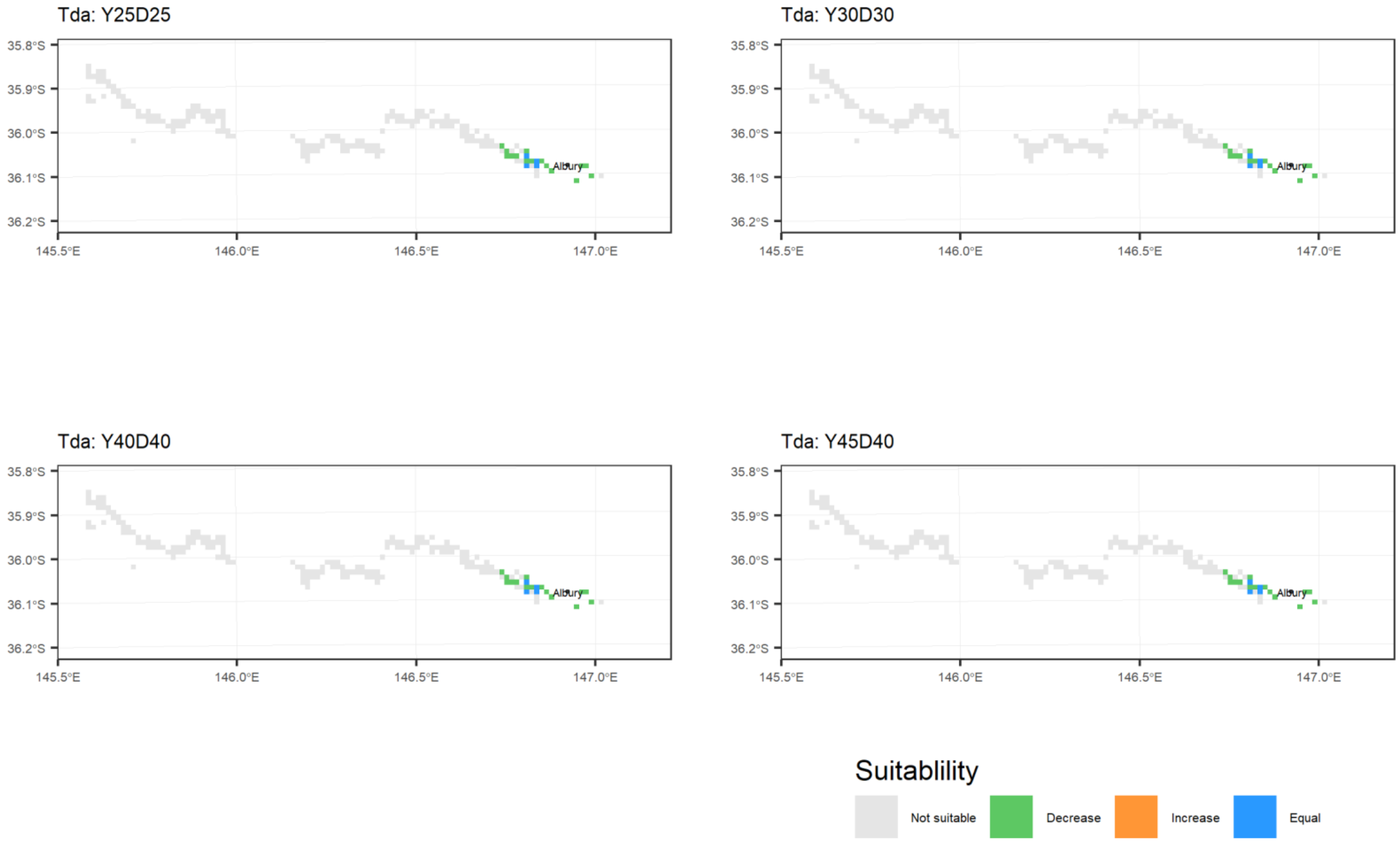

Figure A1.14. Changes from the basecase in extent of modelled suitable habitat area for Tda species in the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

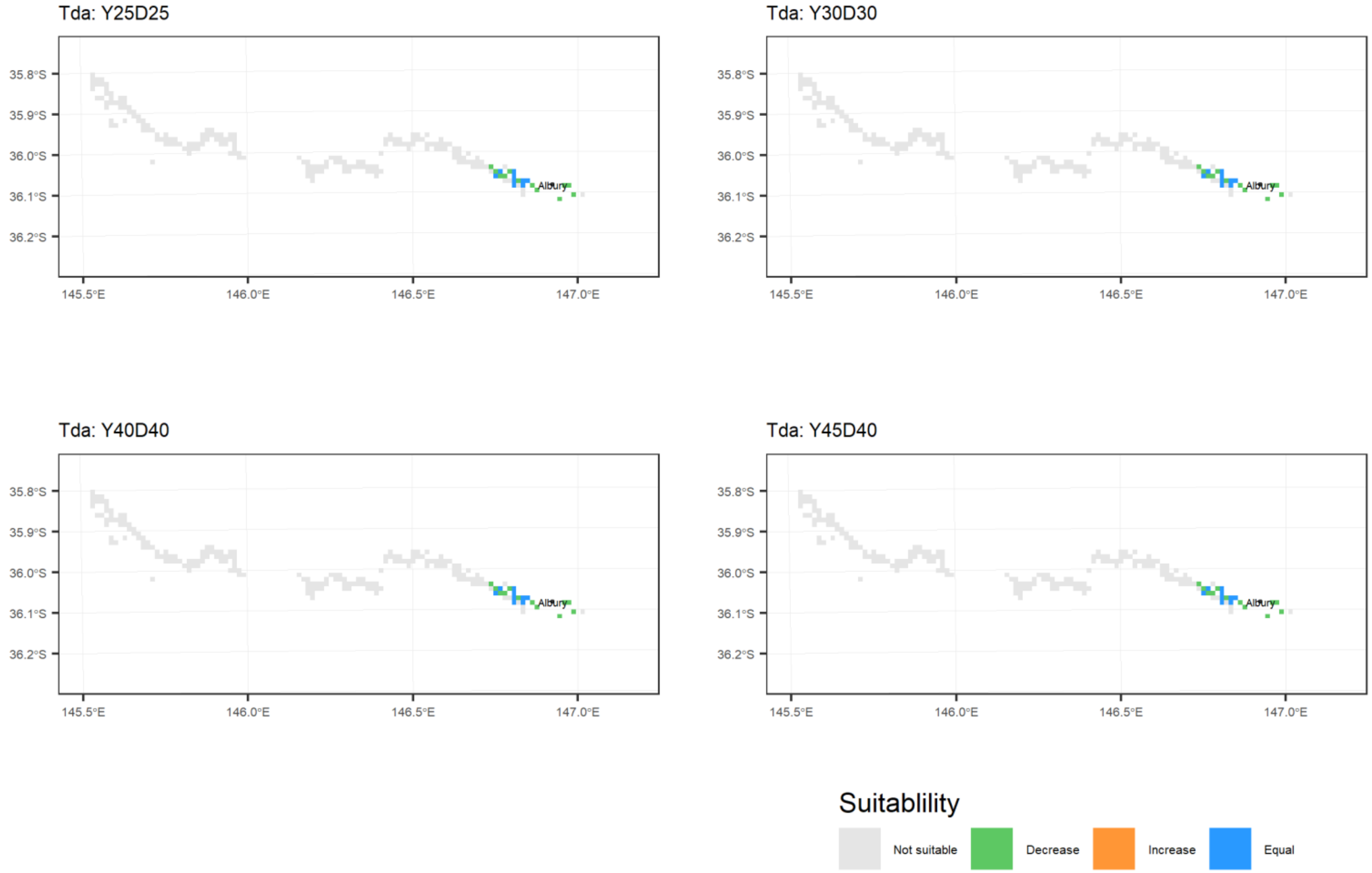

Figure A1.15. Changes from the basecase in extent of modelled highly suitable habitat area for Tda species in the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

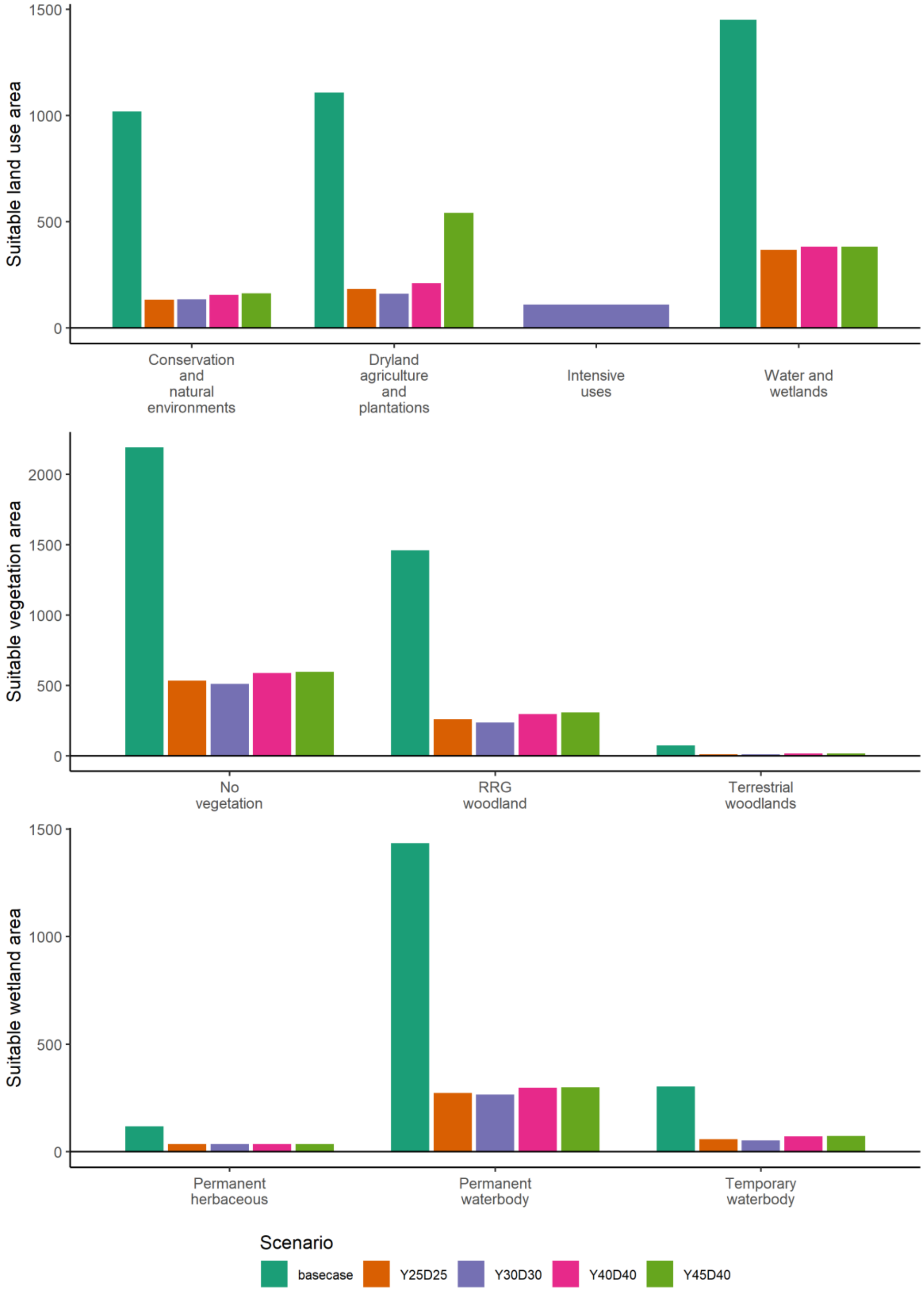

Figure A1.16. Total area of modelled suitable habitat for Tda species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RRC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

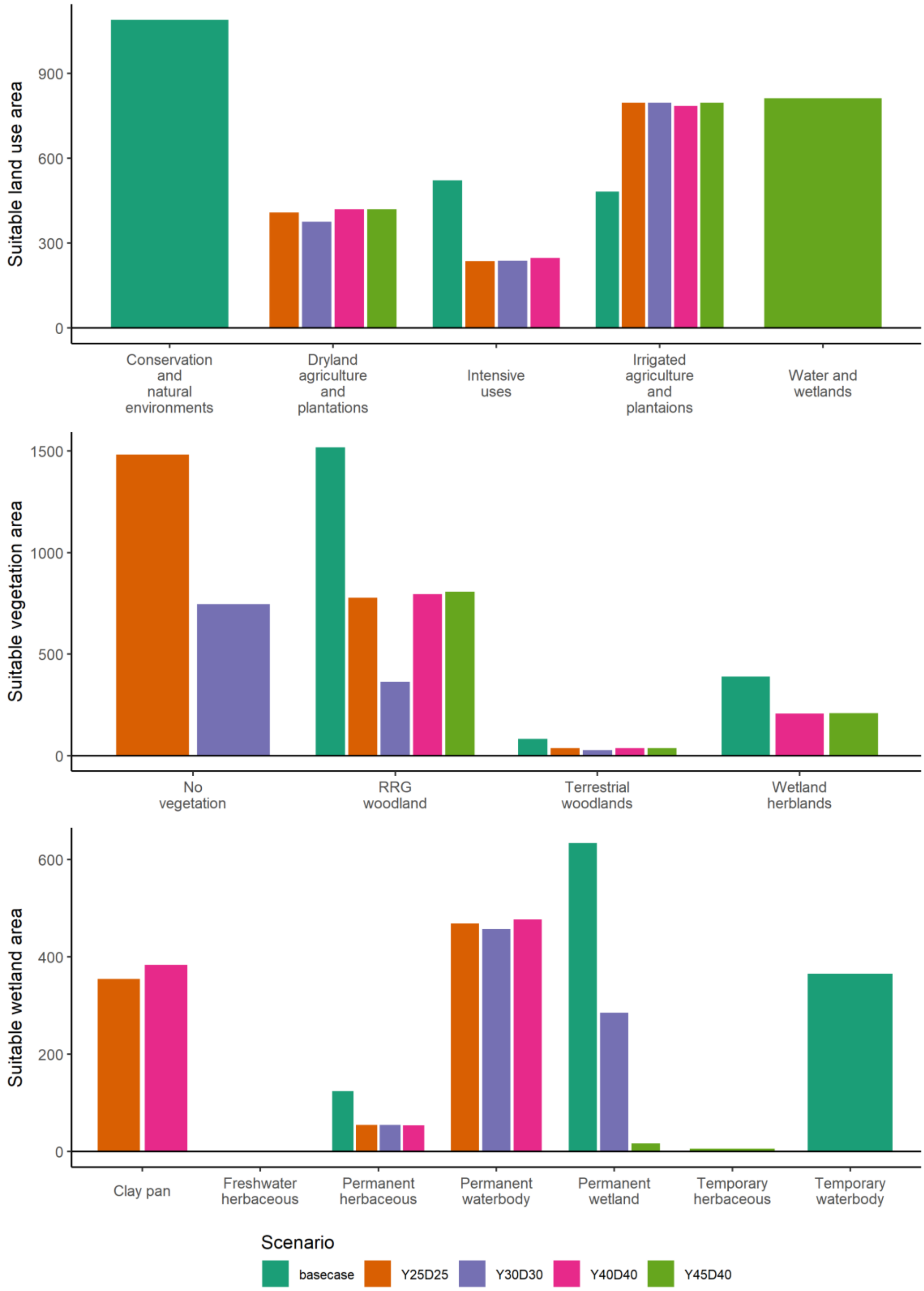

Figure A1.17. Total area of modelled highly suitable habitat for Tda species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

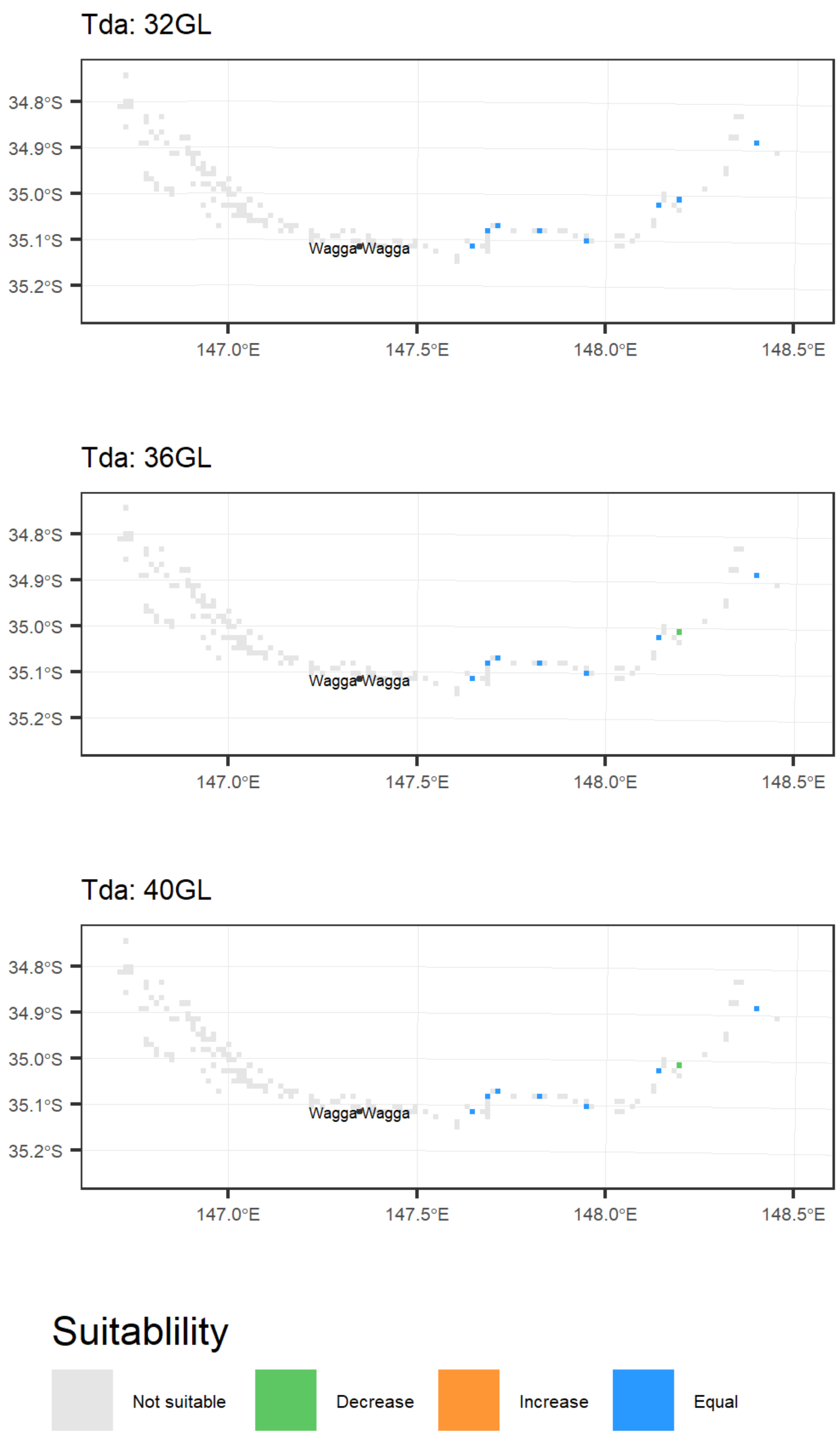

Figure A1.18. Changes from the basecase in extent of modelled suitable habitat area for Tda species in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

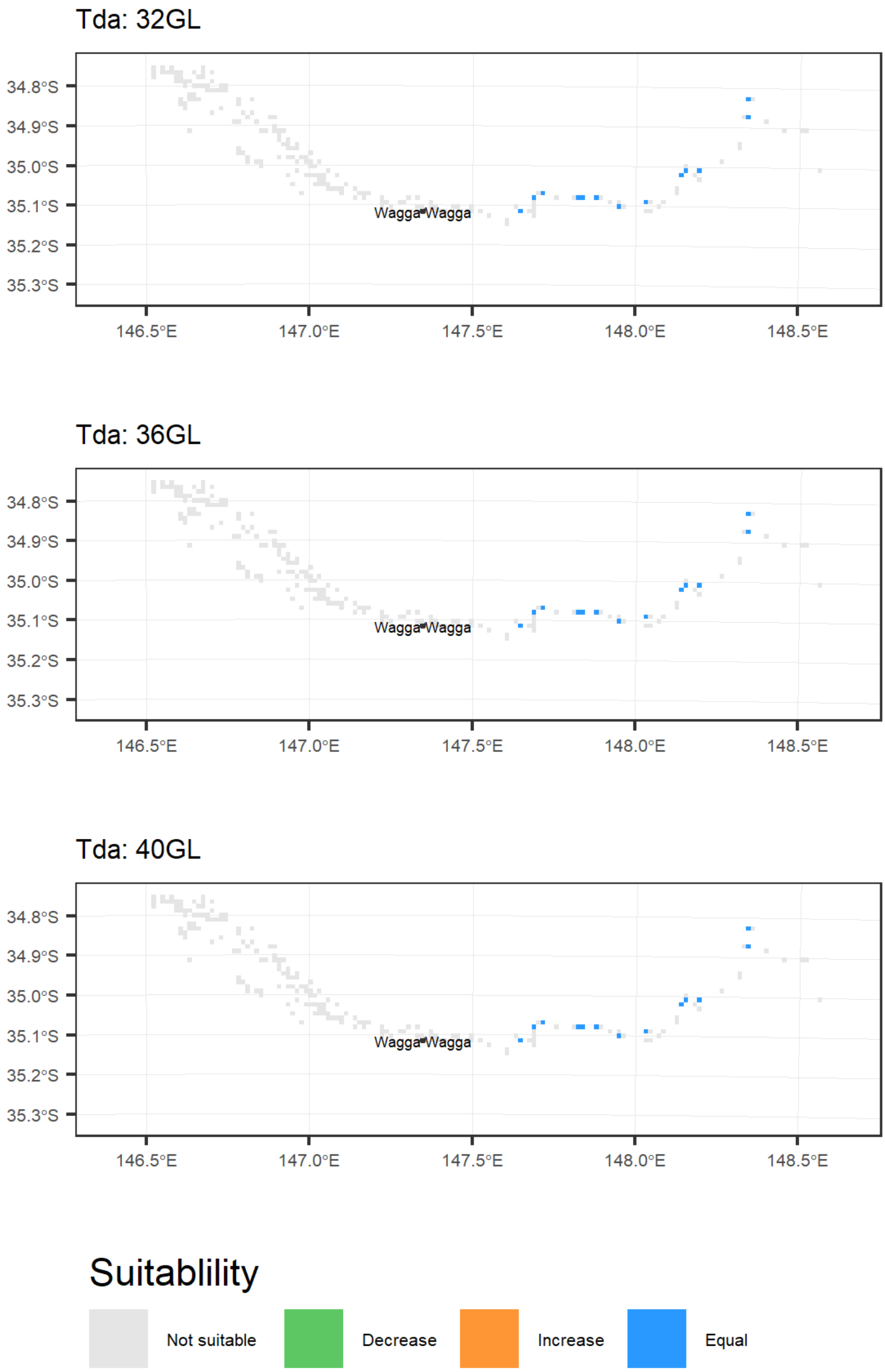

Figure A1.19. Changes from the basecase in extent of modelled highly suitable habitat area for Tda species in the Murrumbidgee project area (map constrained to upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

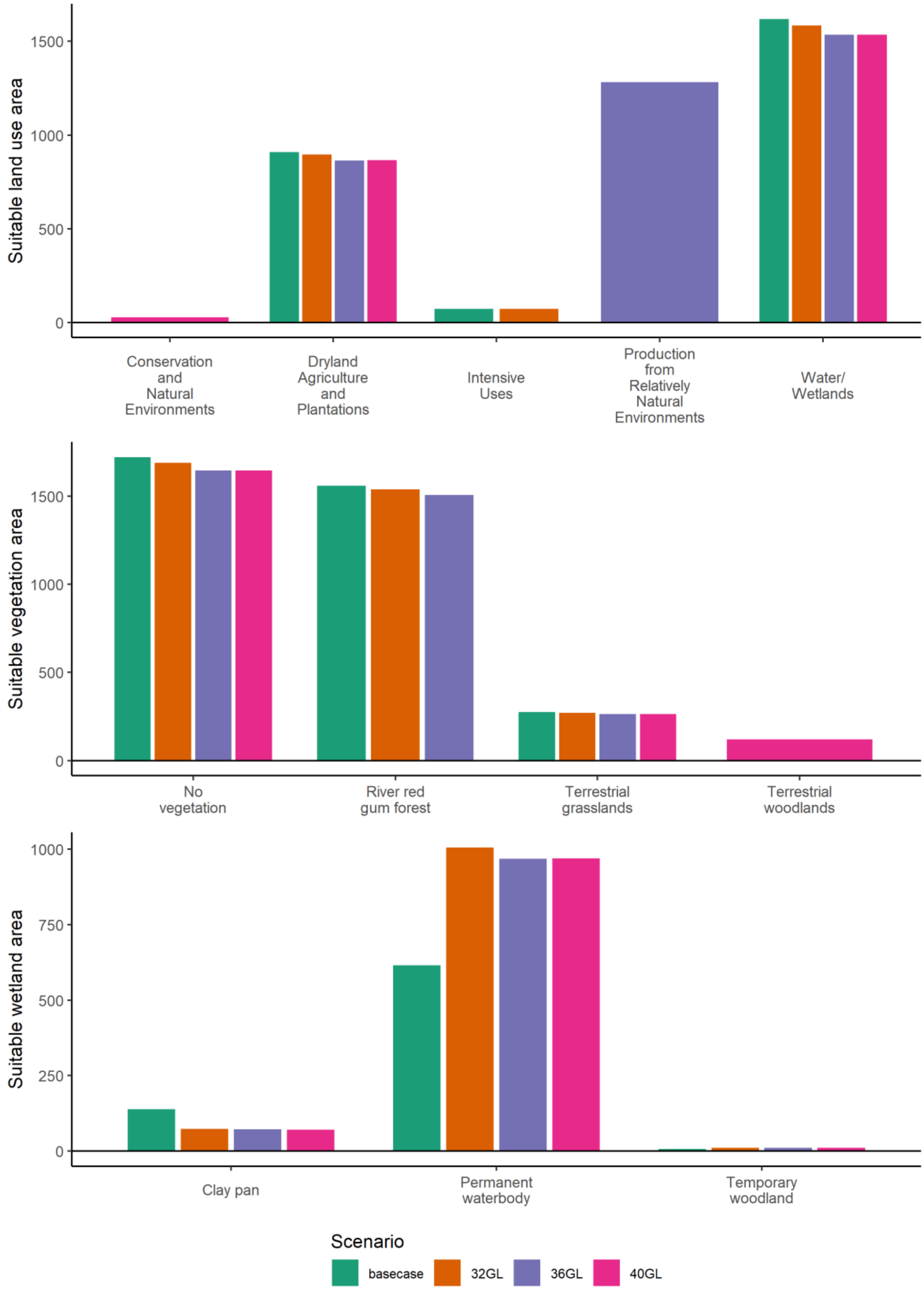

Figure A1.20. Total area of modelled suitable habitat for Tda species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

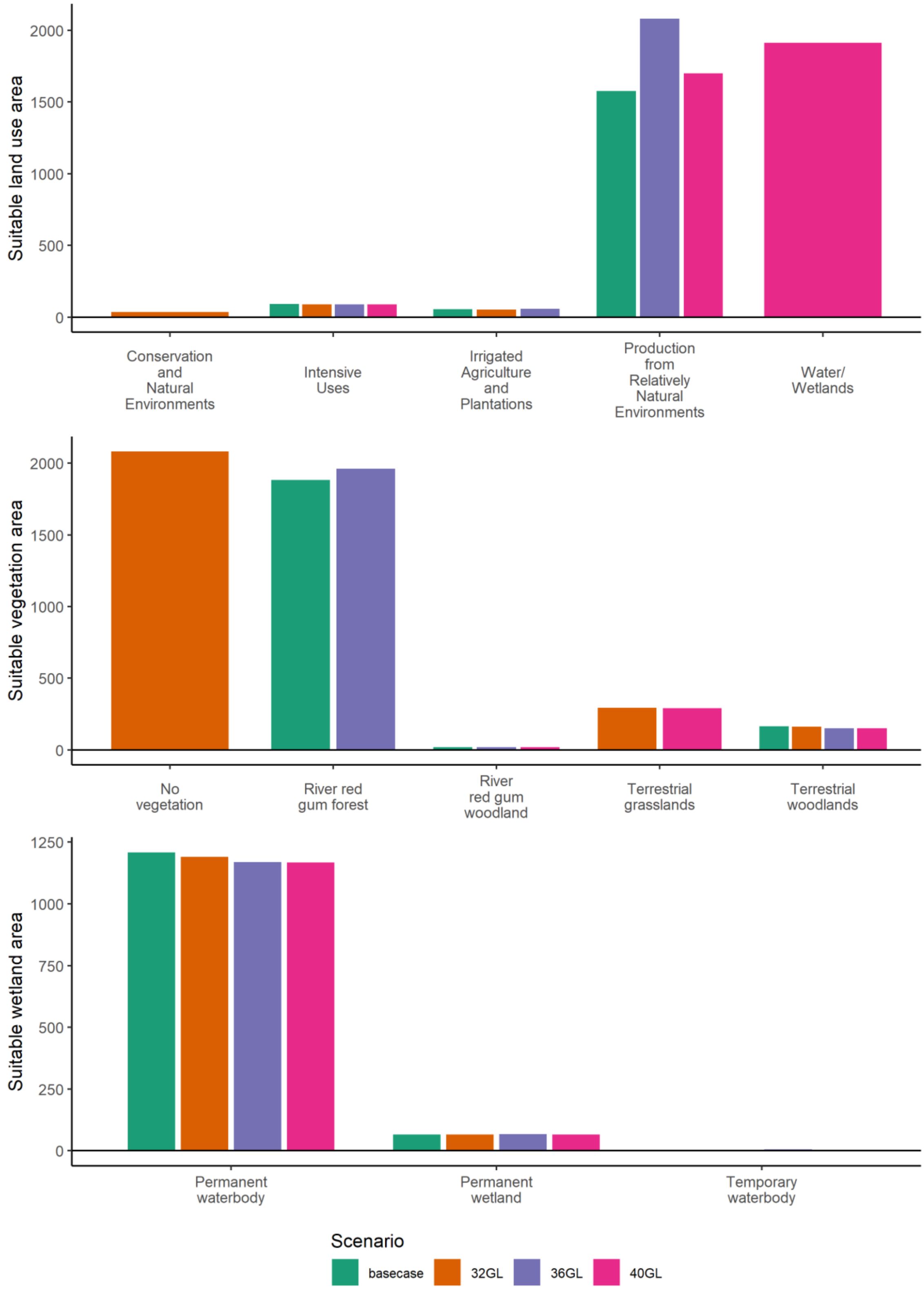

Figure A1.21. Total area of modelled highly suitable habitat for Tda species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Salix sp. (Tda)

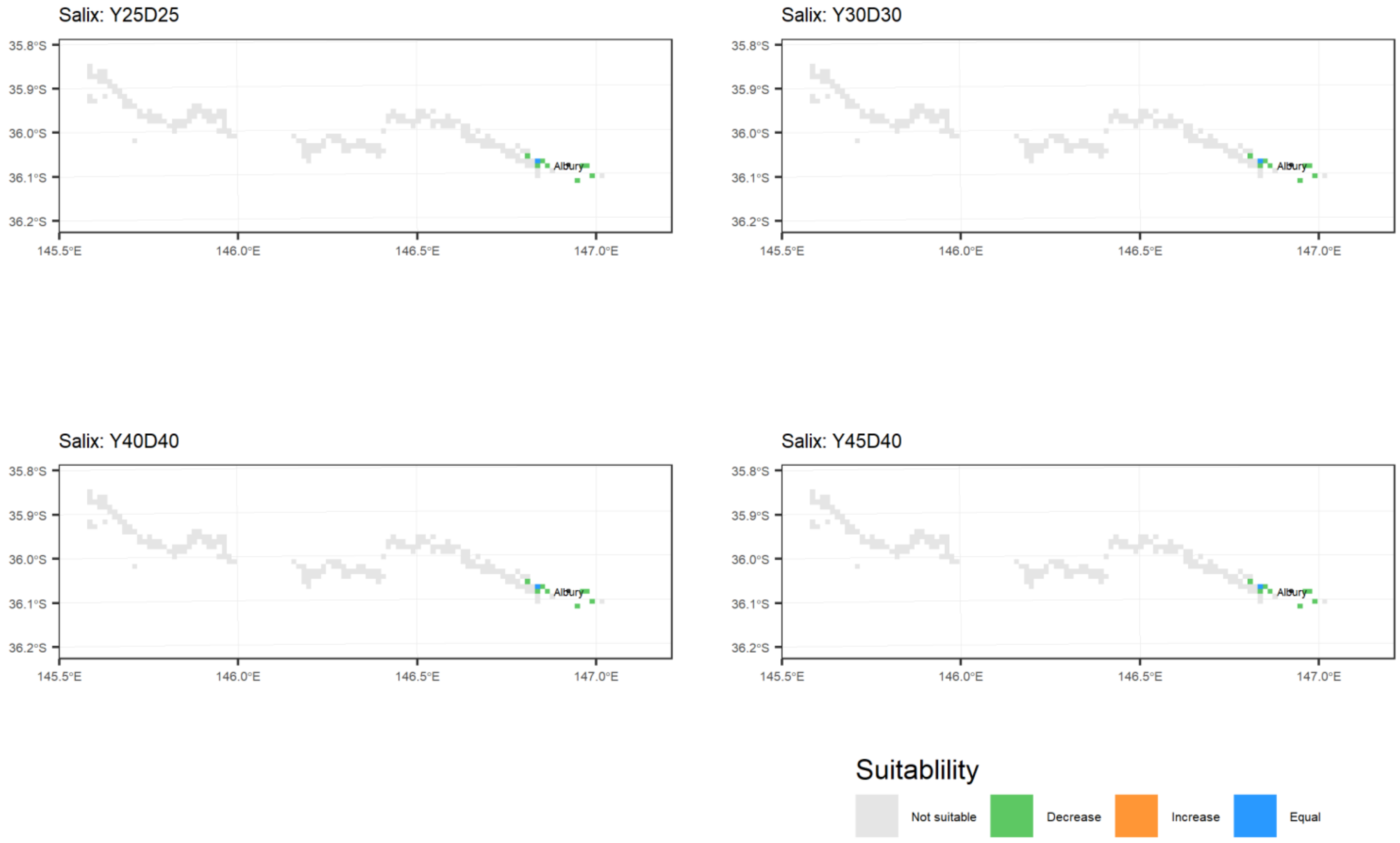

Figure A1.22. Changes from the basecase in extent of modelled suitable habitat area for Salix sp. in the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

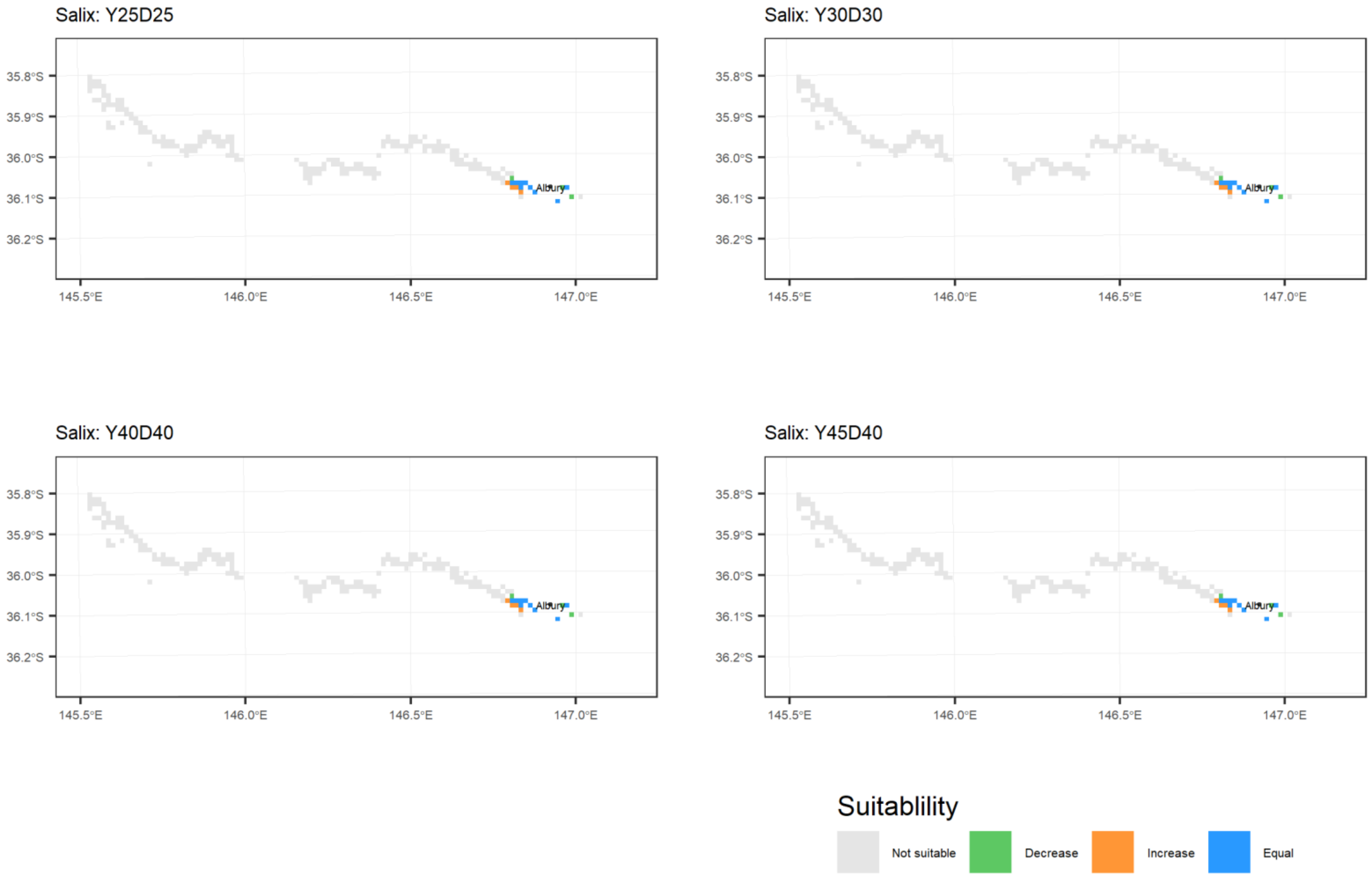

Figure A1.23. Changes from the basecase in extent of highly suitable habitat area for Salix sp. In the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

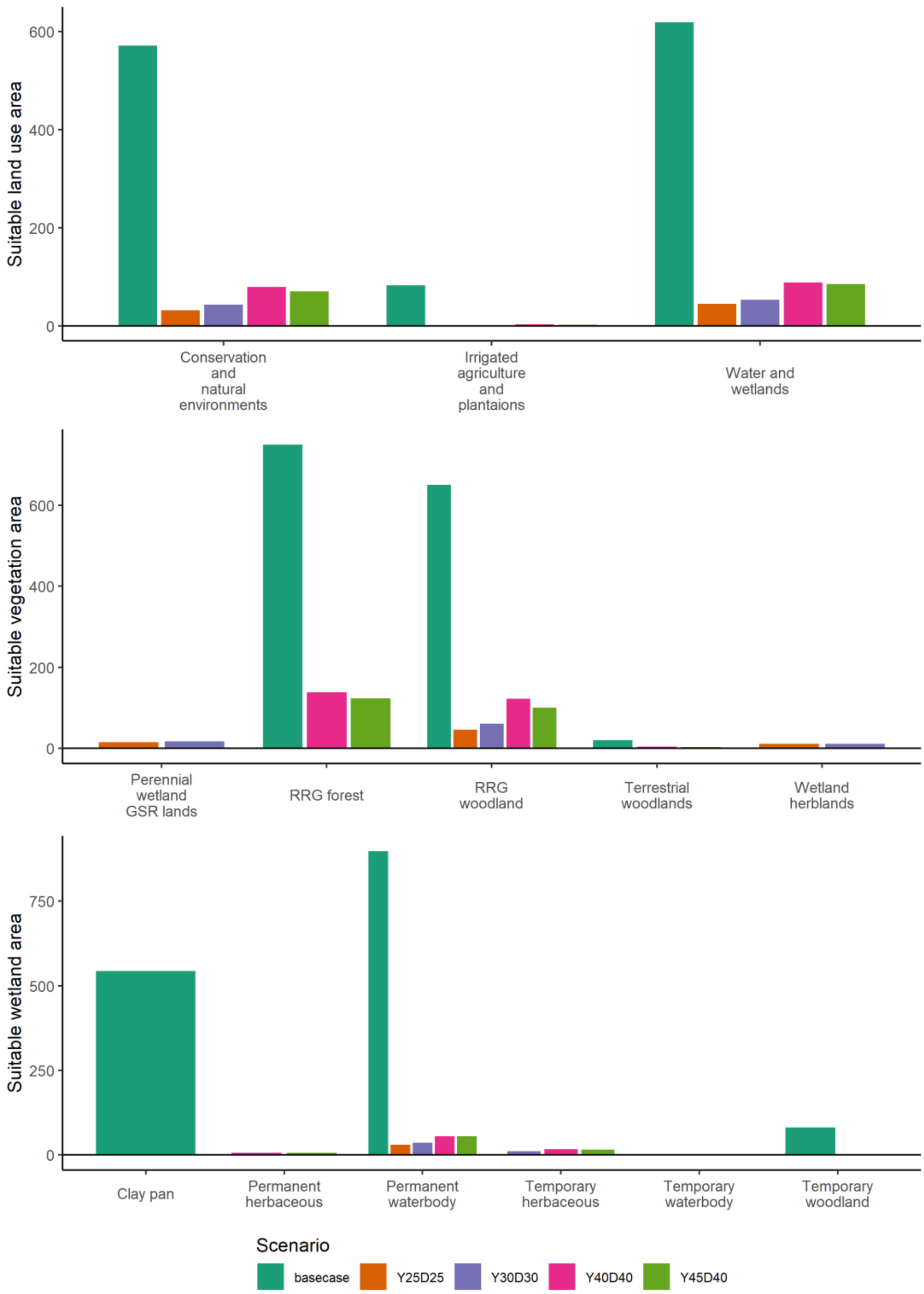

Figure A1.24. Total area of modelled suitable habitat for Salix sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

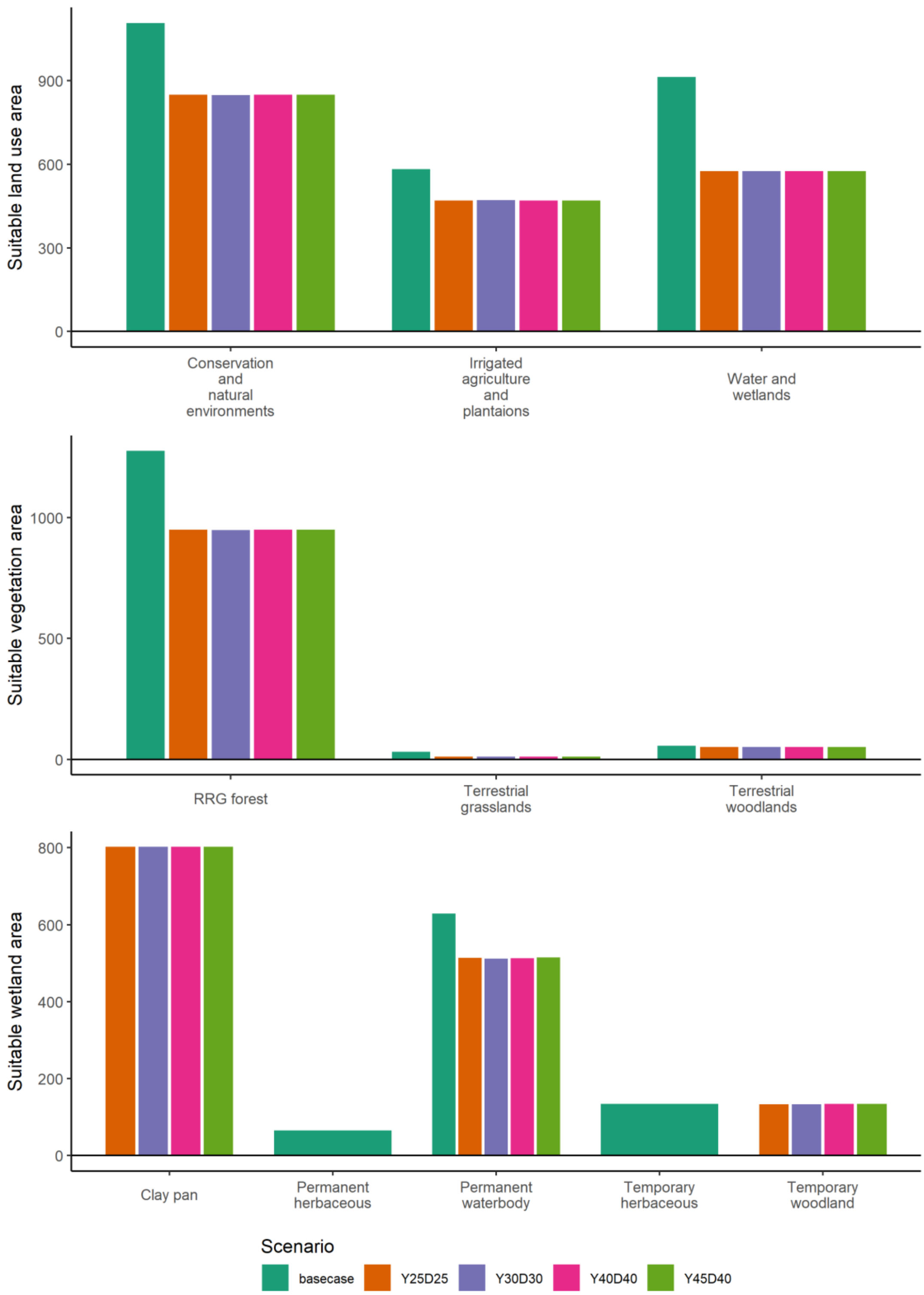

Figure A1.25. Total area of modelled highly suitable habitat for Salix sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

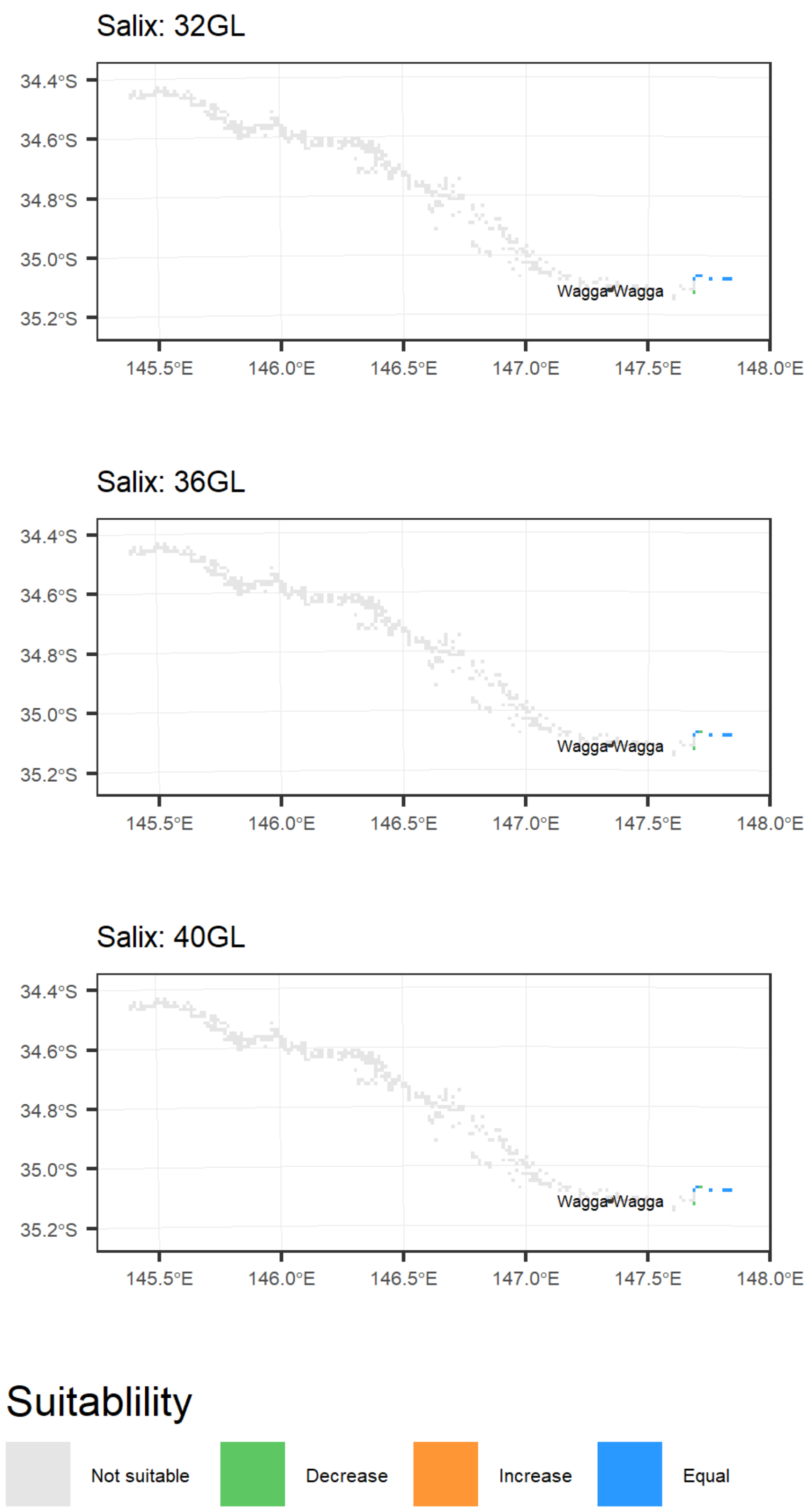

Figure A1.26. Changes from the basecase in extent of modelled suitable habitat area for Salix sp. in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

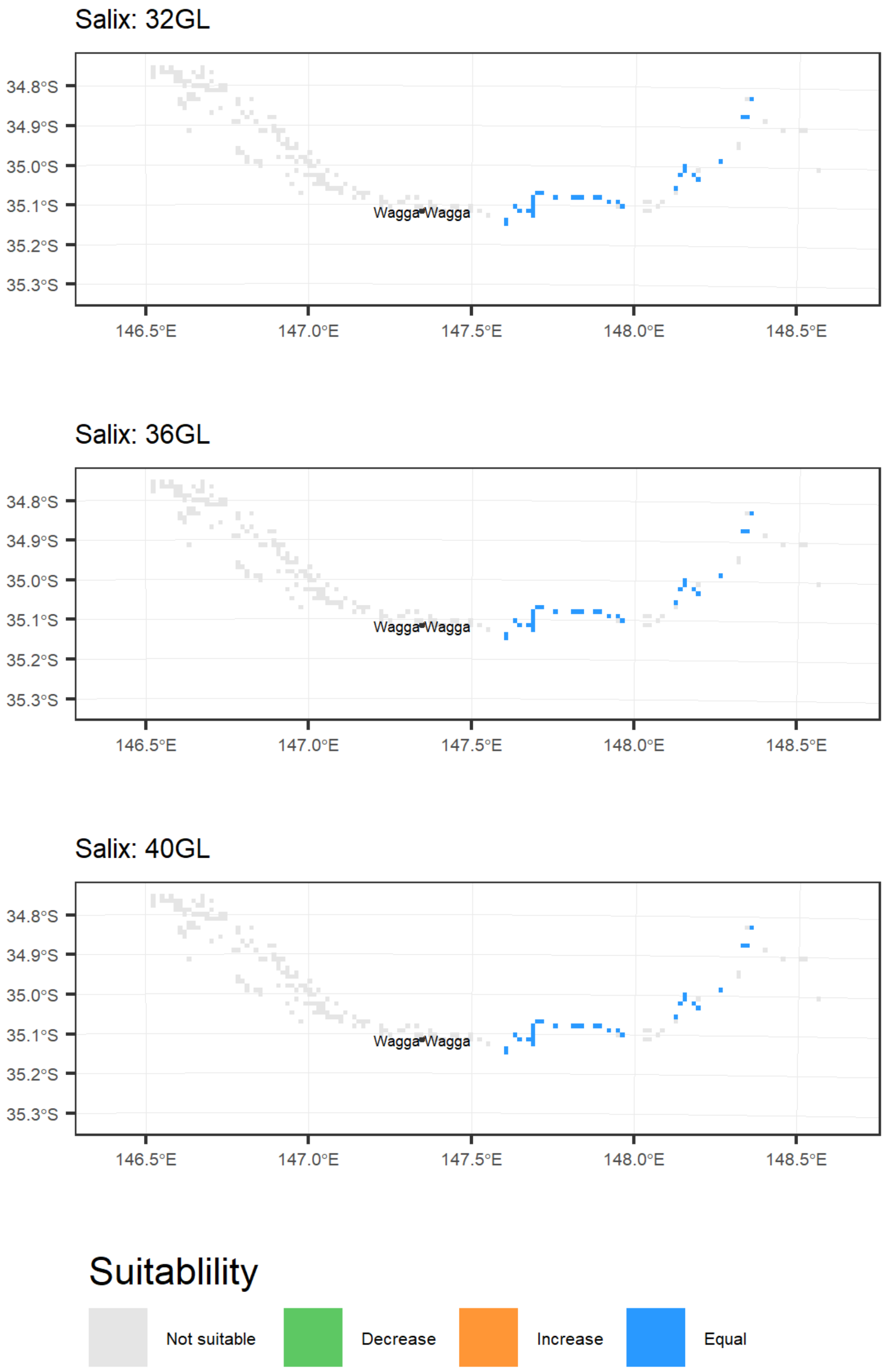

Figure A1.27. Changes from the basecase in extent of modelled highly suitable habitat area for Salix sp. In the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

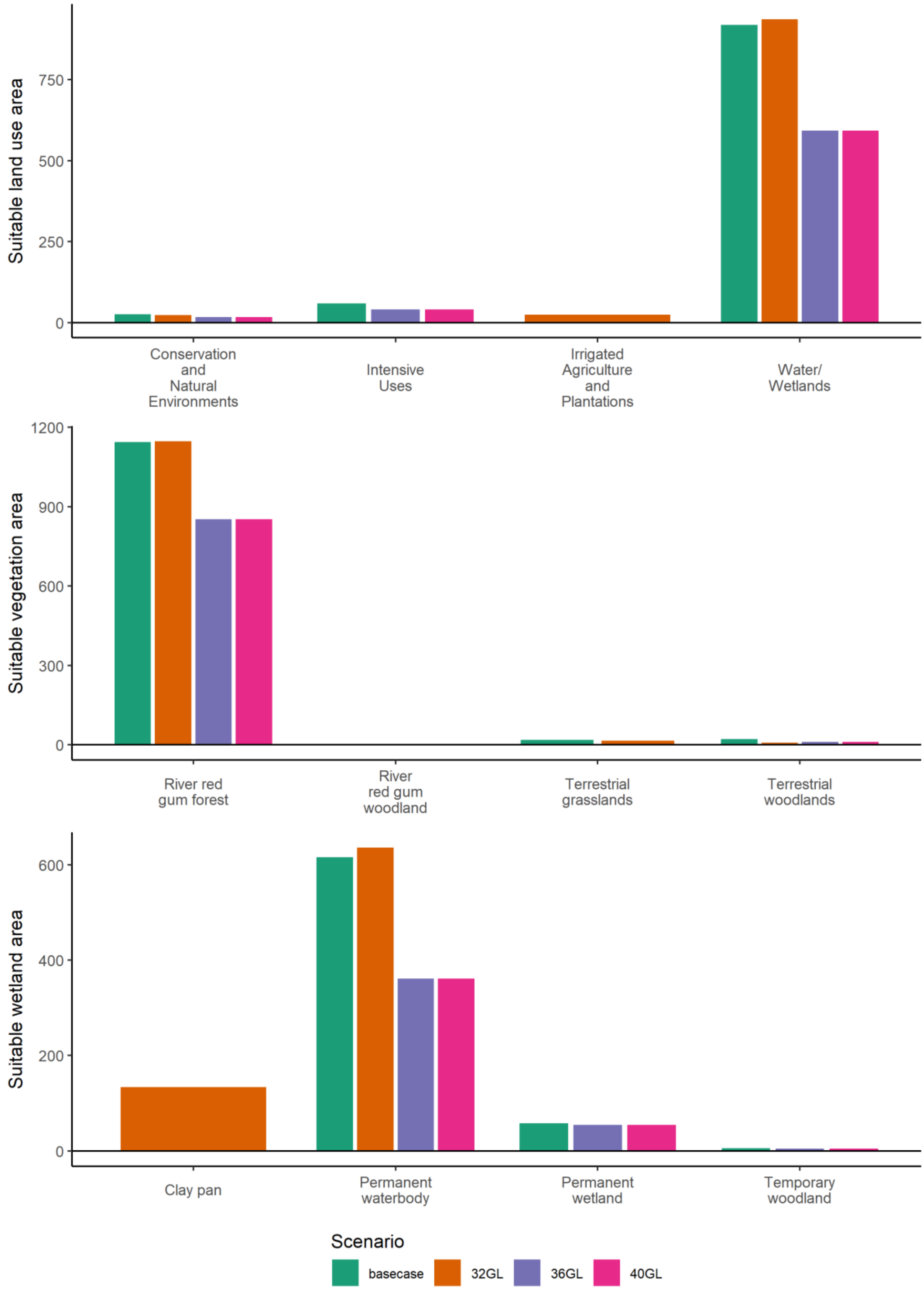

Figure A1.28. Total area of modelled suitable habitat for Salix sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

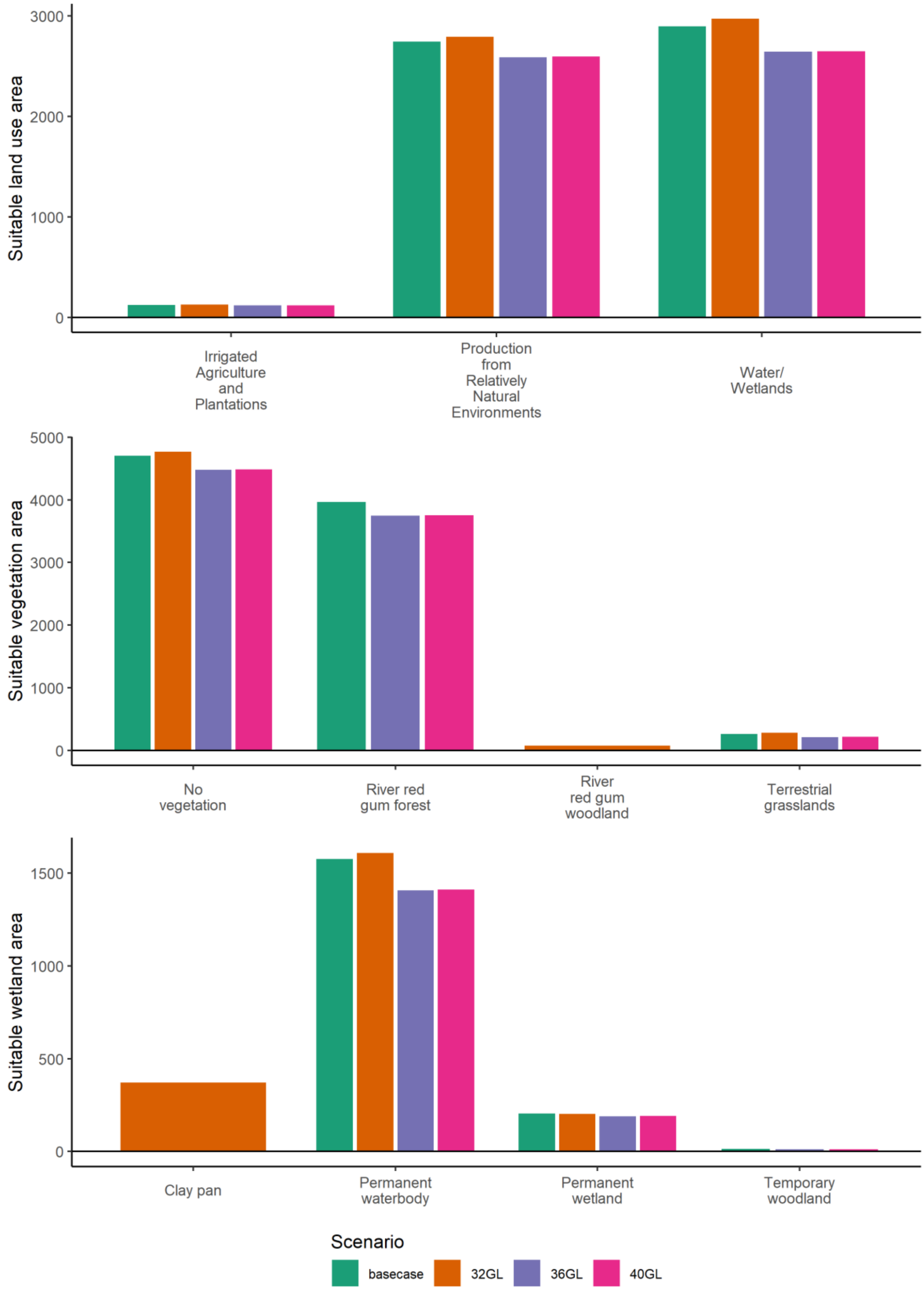

Figure A1.29. Total area of modelled highly suitable habitat for Salix sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Terrestrial dry (Tdr) species

Tdr species

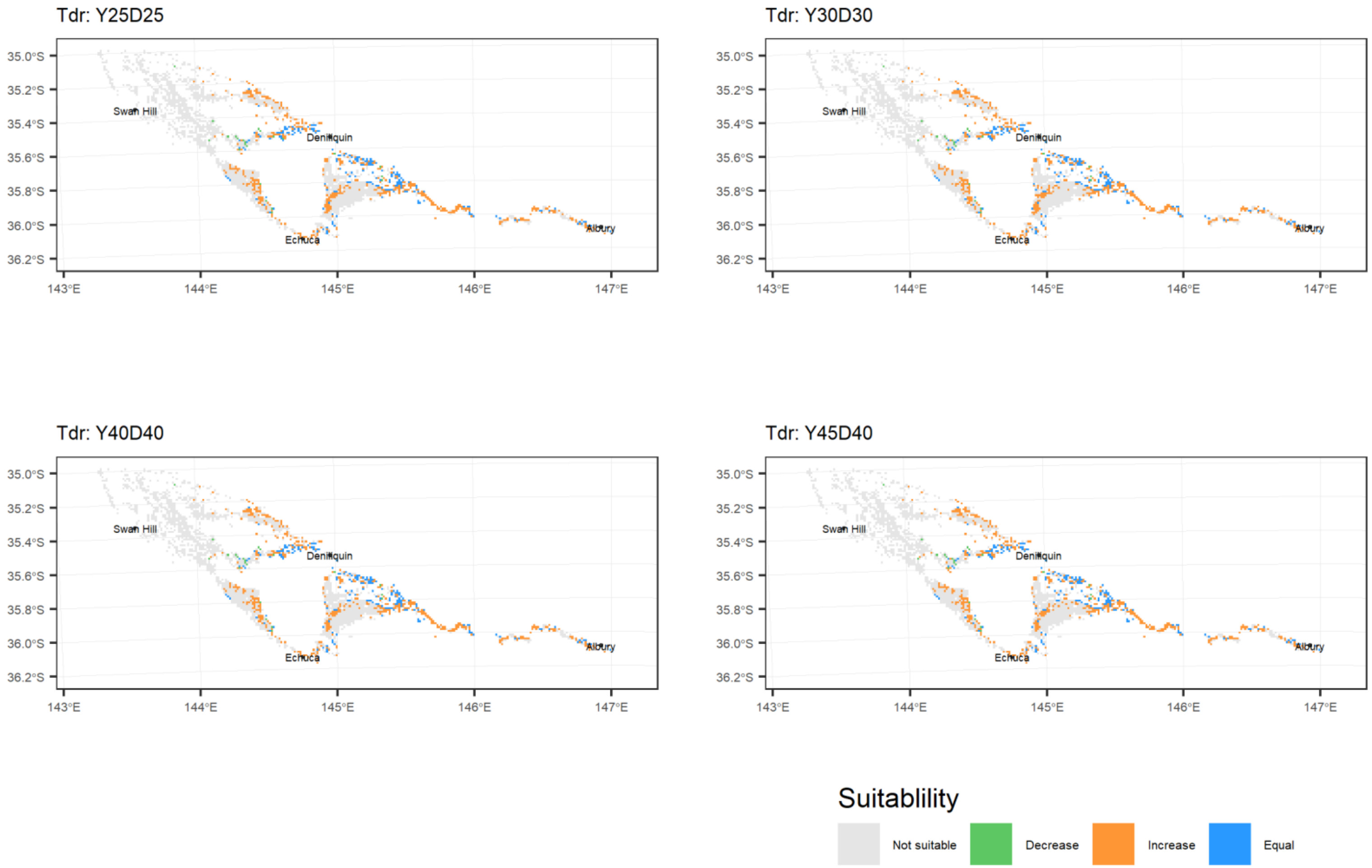

Figure A1.30. Changes from the basecase in extent of modelled area for Tdr species in the Murray project area (map constrained to the mid- upper Murray reaches / Albury - Swan Hill) under each RRC inundation scenario.

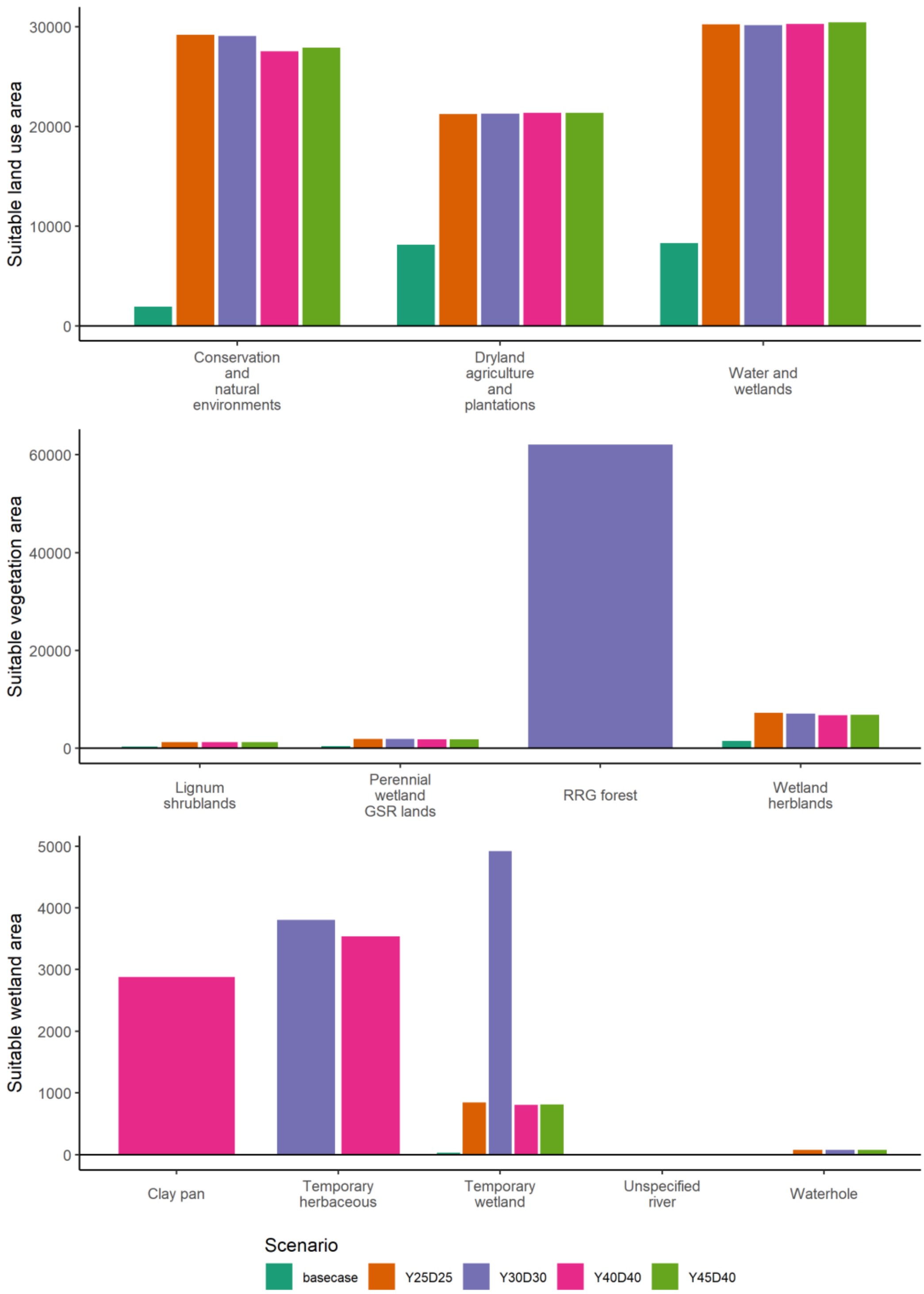

Figure A1.32. Total area of modelled suitable habitat for Tdr species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Note. No highly suitable habitat area is modelled for Tdr species in the Murray under any scenario, hence no map or graph shown here.

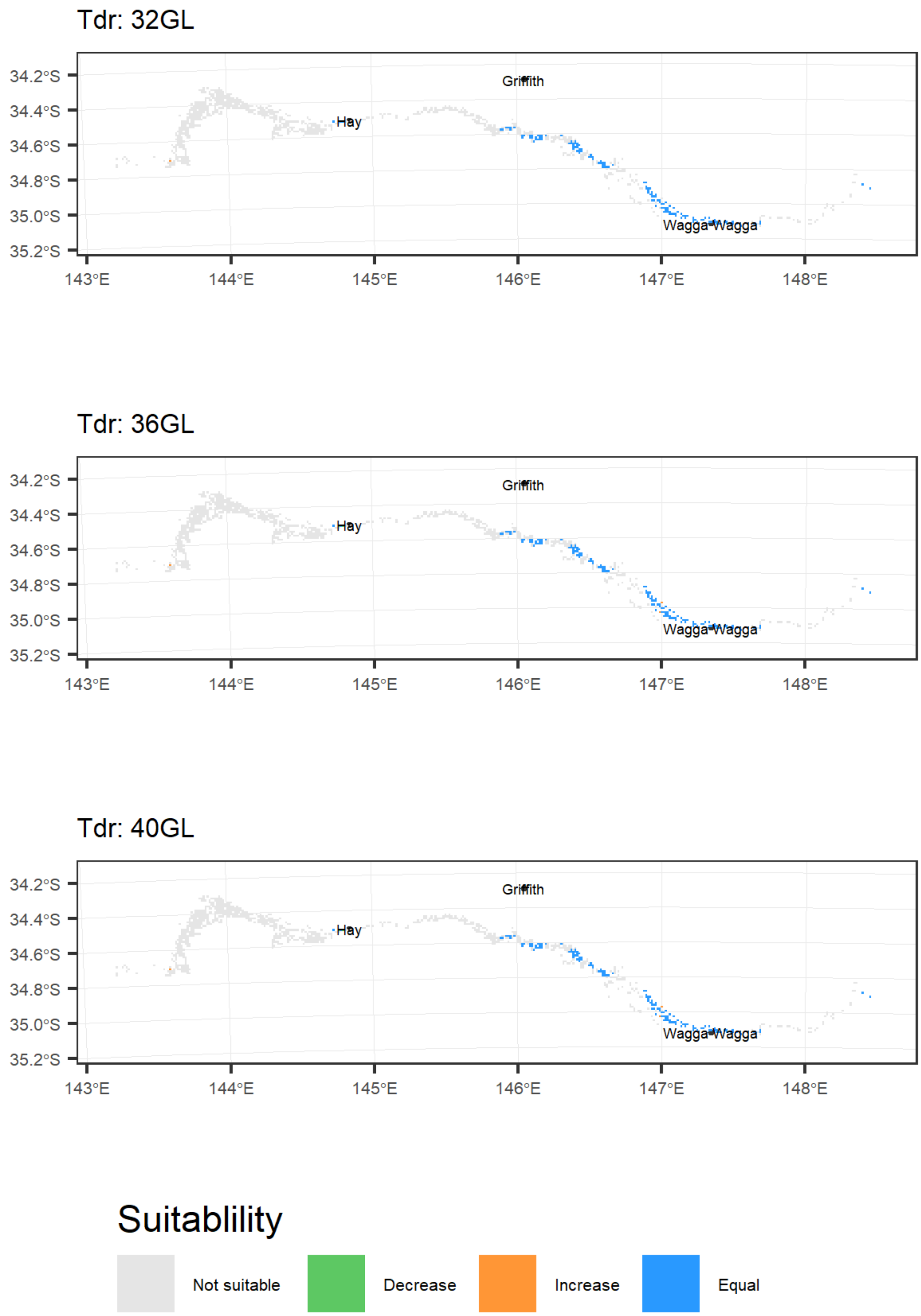

Figure A1.33. Changes from the basecase in extent of modelled area for Tdr species in the Murrumbidgee project area under each RRC inundation scenario.

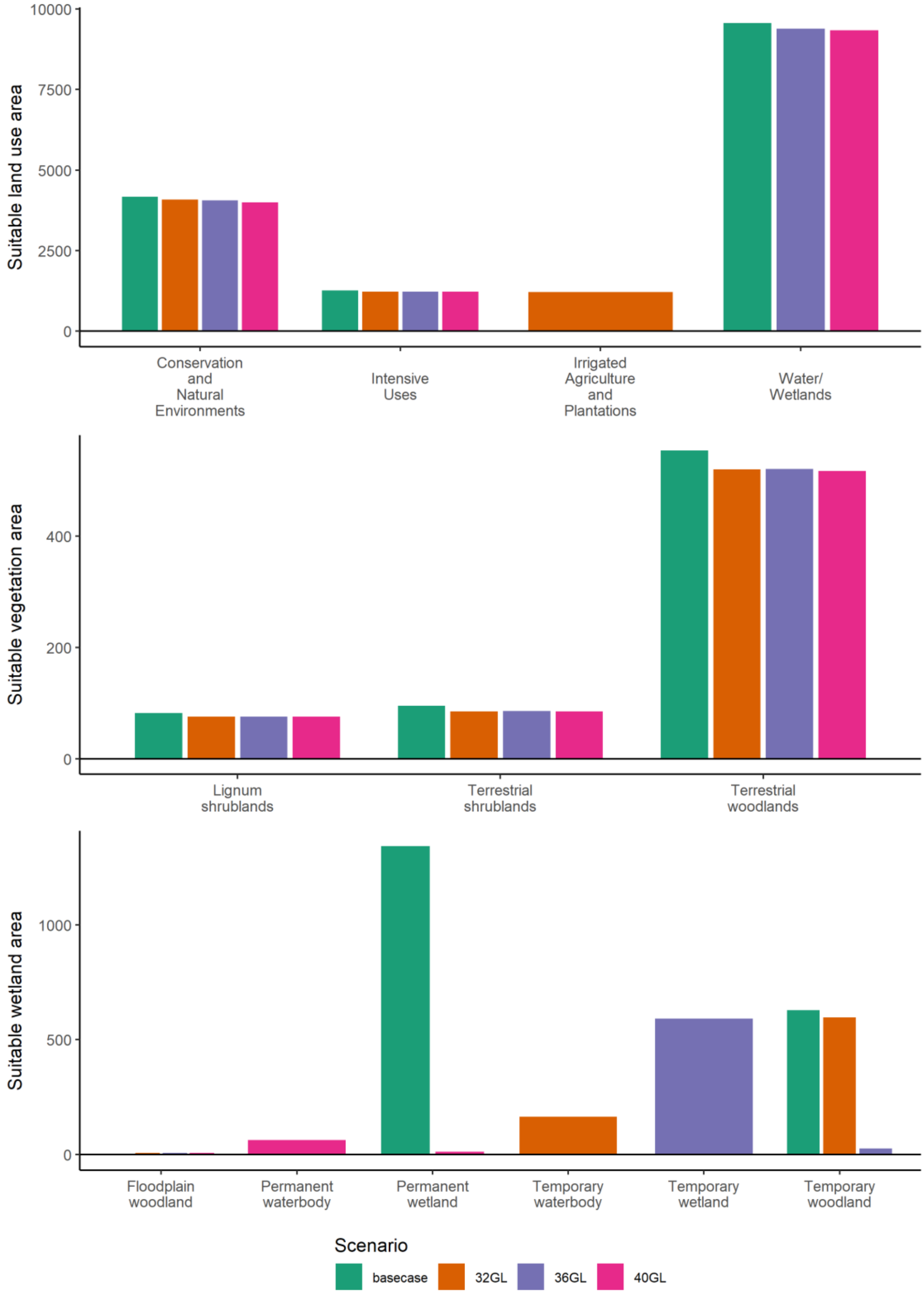

Figure A1.34. Total area of modelled suitable habitat for Tdr species in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Note. No highly suitable habitat area is modelled for Tdr species in the Murrumbidgee under any scenario, hence no map or graph shown here.

Lycium sp. (Tdr)

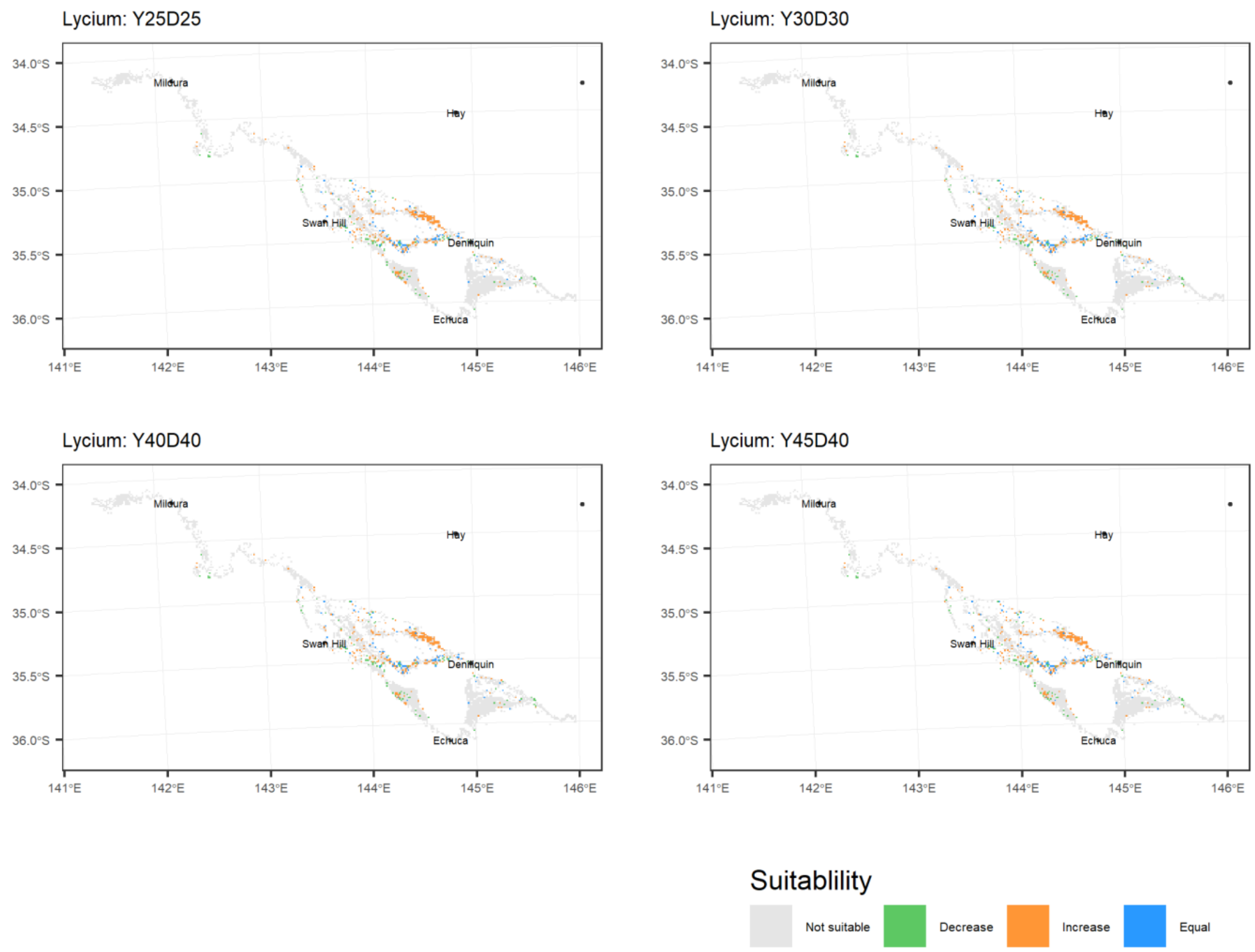

Figure A1.35. Changes from the basecase in the extent of modelled suitable habitat area for Lycium sp. In the Murray project area (map constrained to lower Murray reaches) under each RRC inundation scenario.

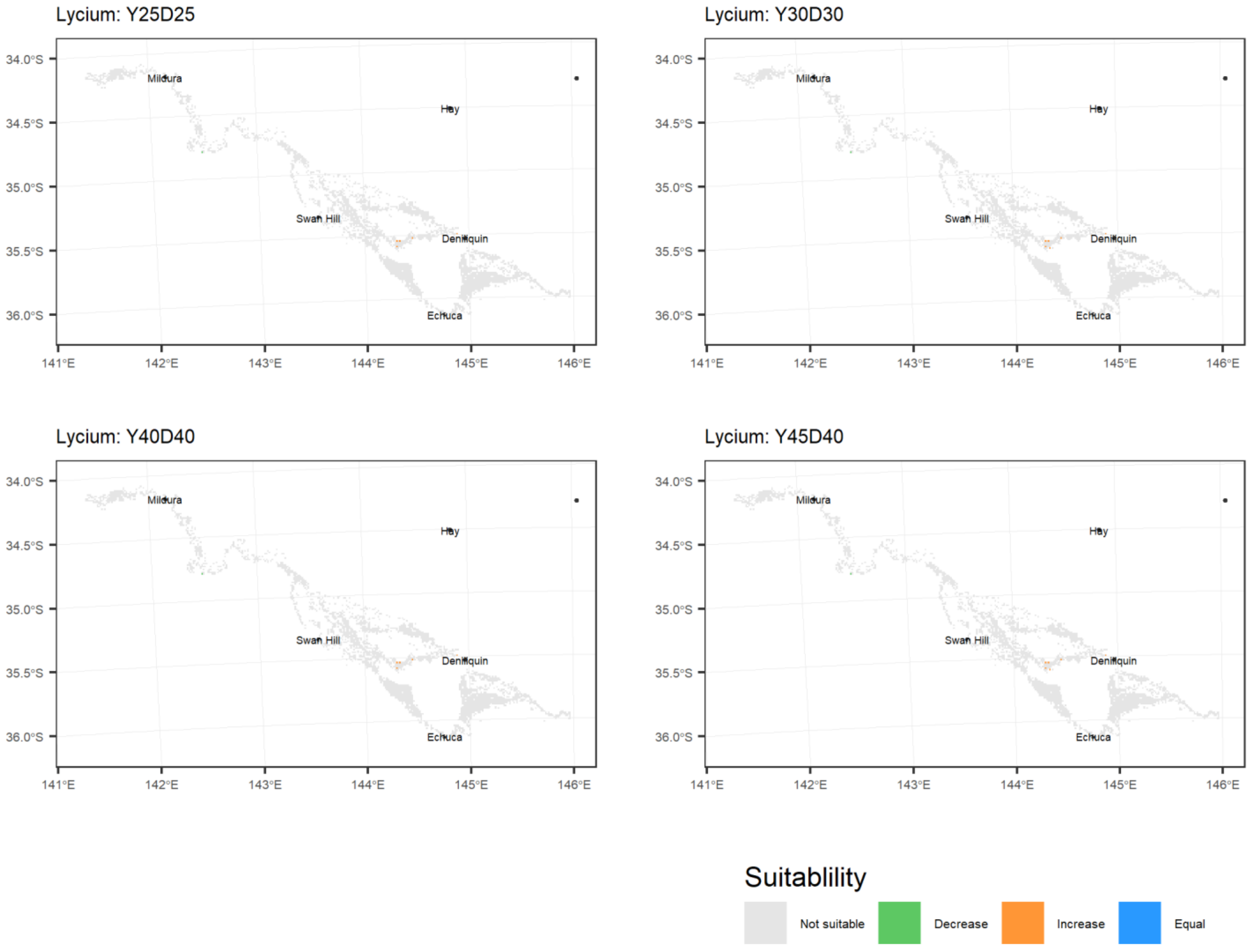

Figure A1.36. Changes from the basecase in the extent of modelled highly suitable habitat area for Lycium sp. In the Murray project area (map constrained to lower Murray reaches) under each RRC inundation scenario.

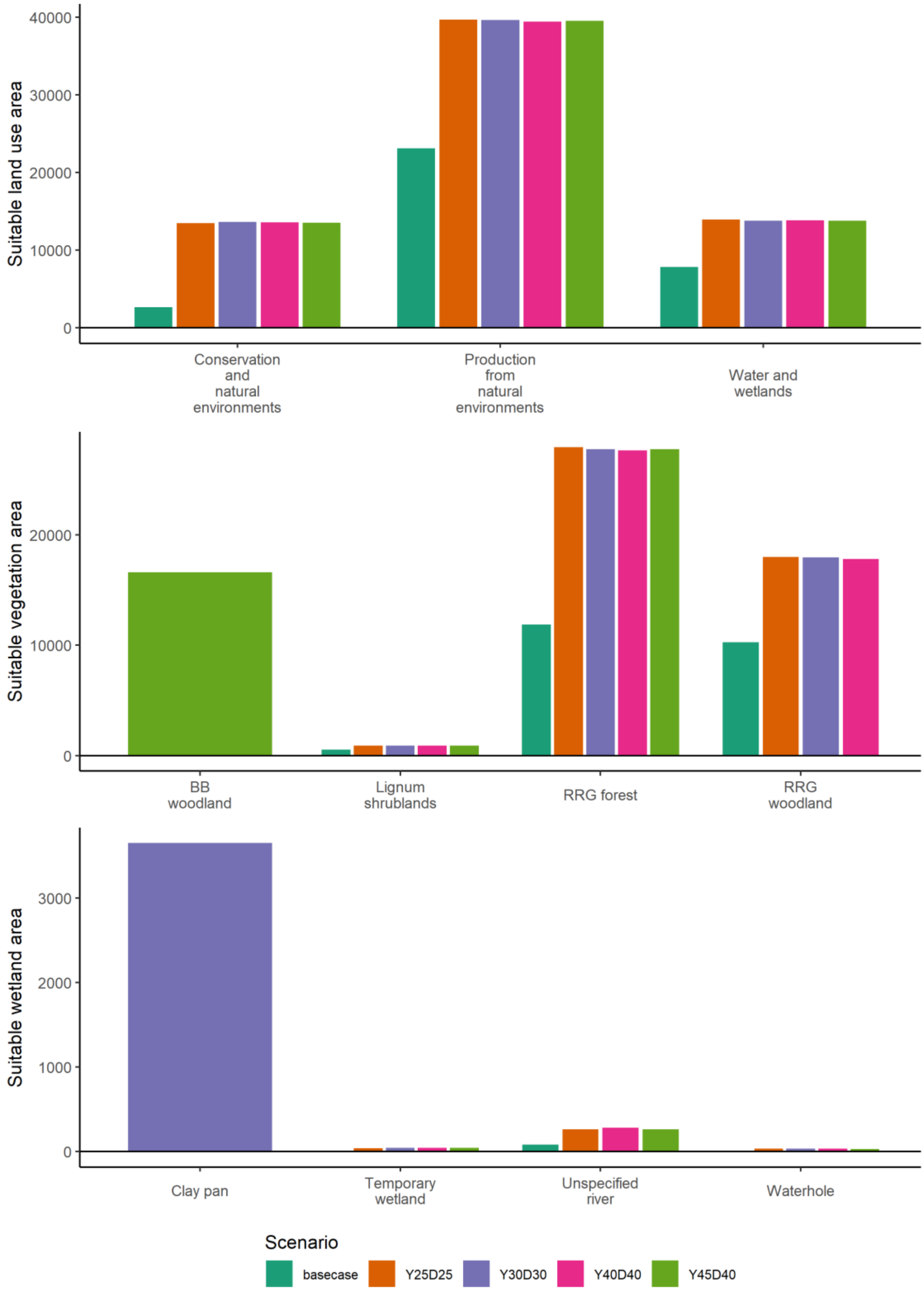

Figure A1.37. Total area of modelled suitable habitat for Lycium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

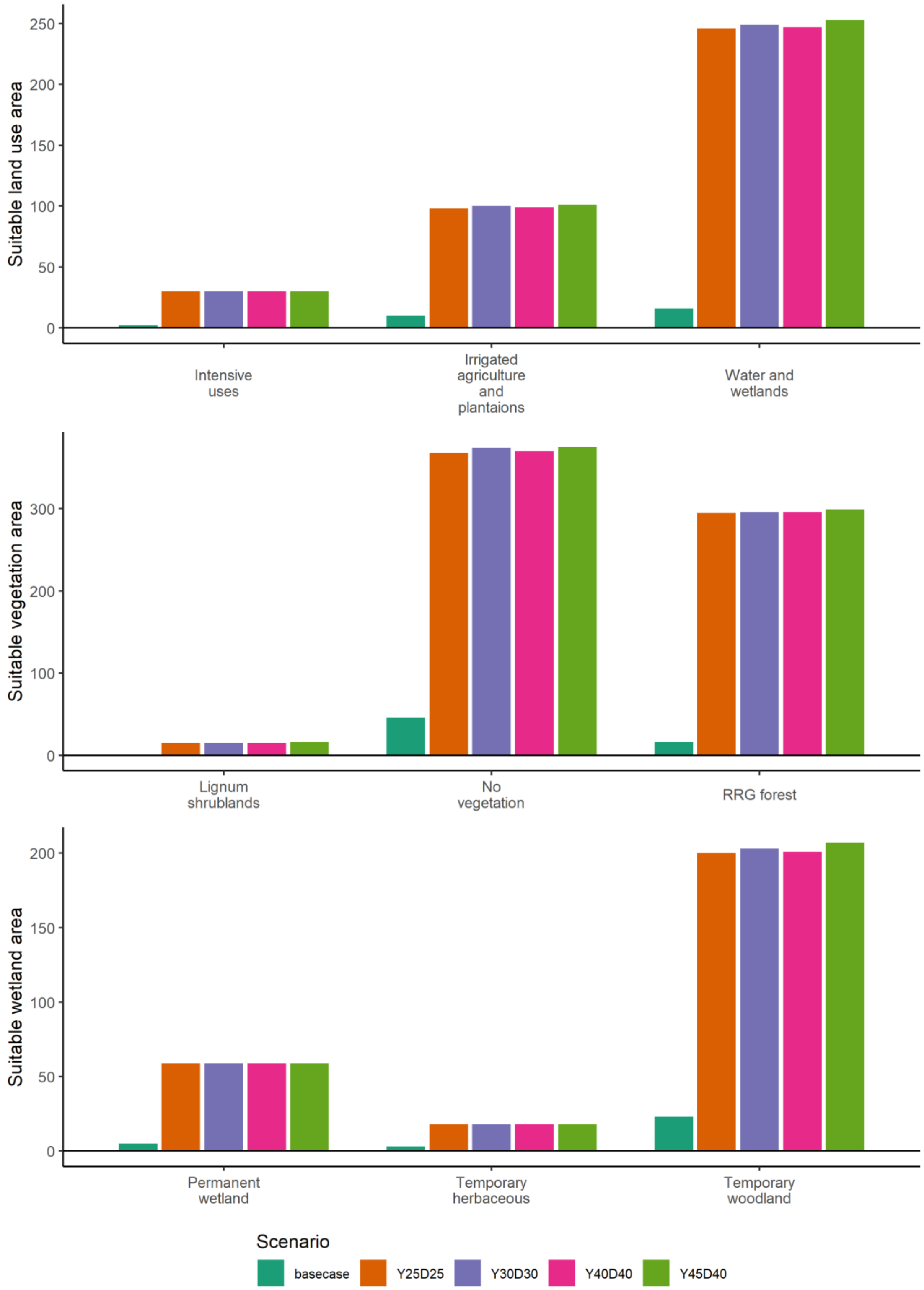

Figure A1.38. Total area of modelled highly suitable habitat for Lycium sp in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

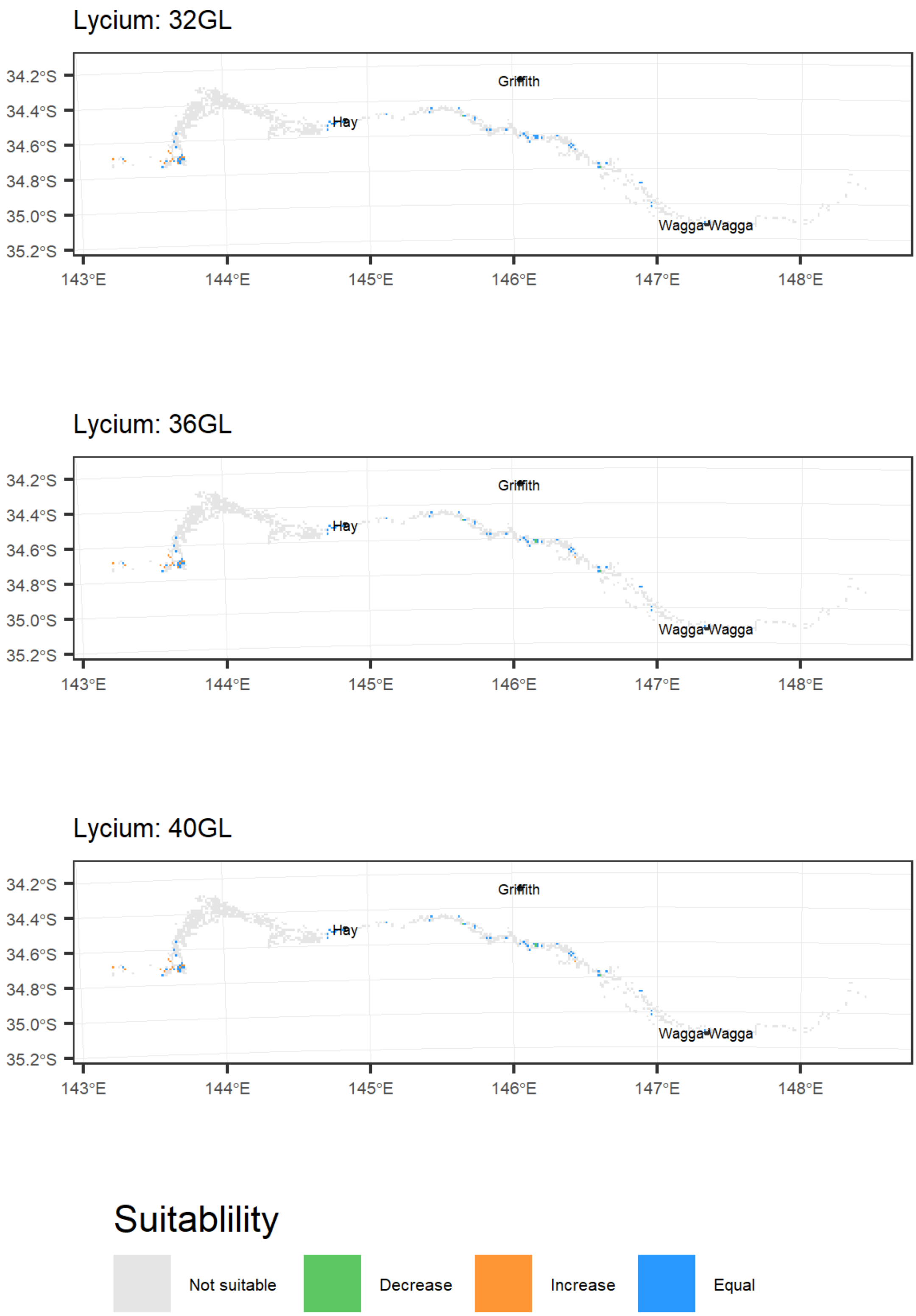

Figure A1.39. Changes from the basecase in extent of modelled area for Lycium species in the Murrumbidgee project area under each RRC inundation scenario.

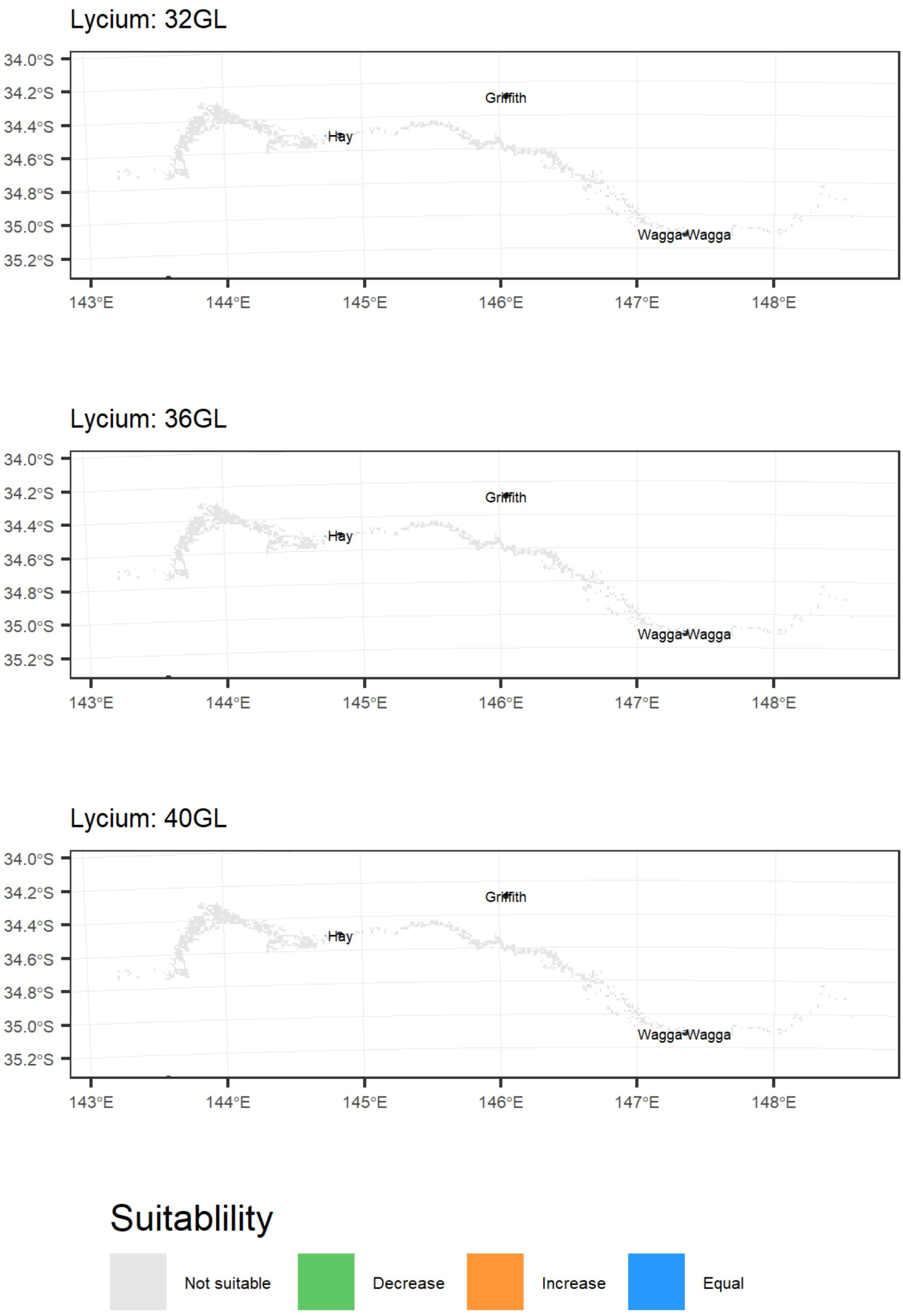

Figure A1.40. Changes from the basecase in extent of modelled highly suitable habitat area for Lycium sp. In the Murrumbidgee project area under each RRC inundation scenario.

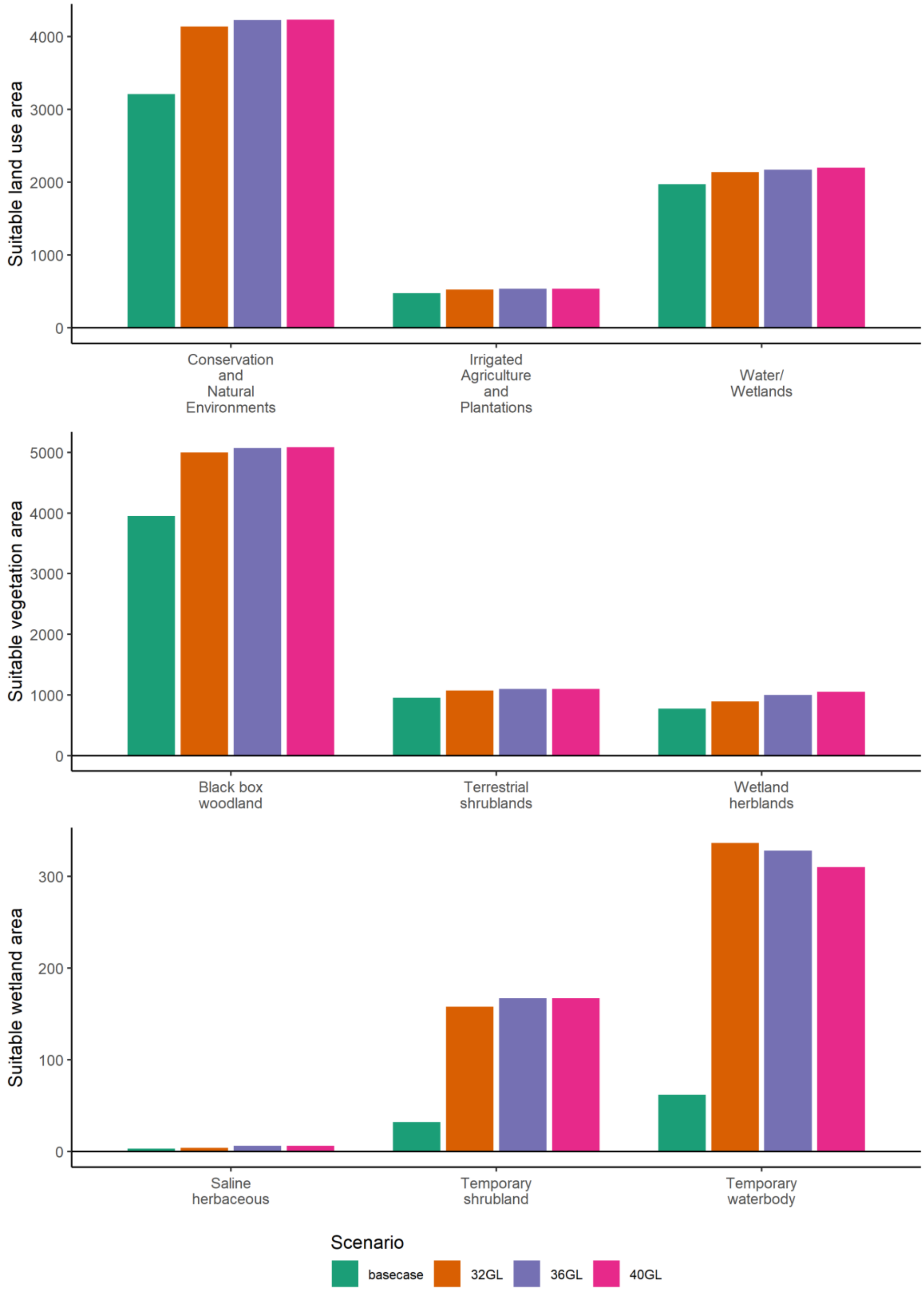

Figure A1.41. Total area of modelled suitable habitat for Lycium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

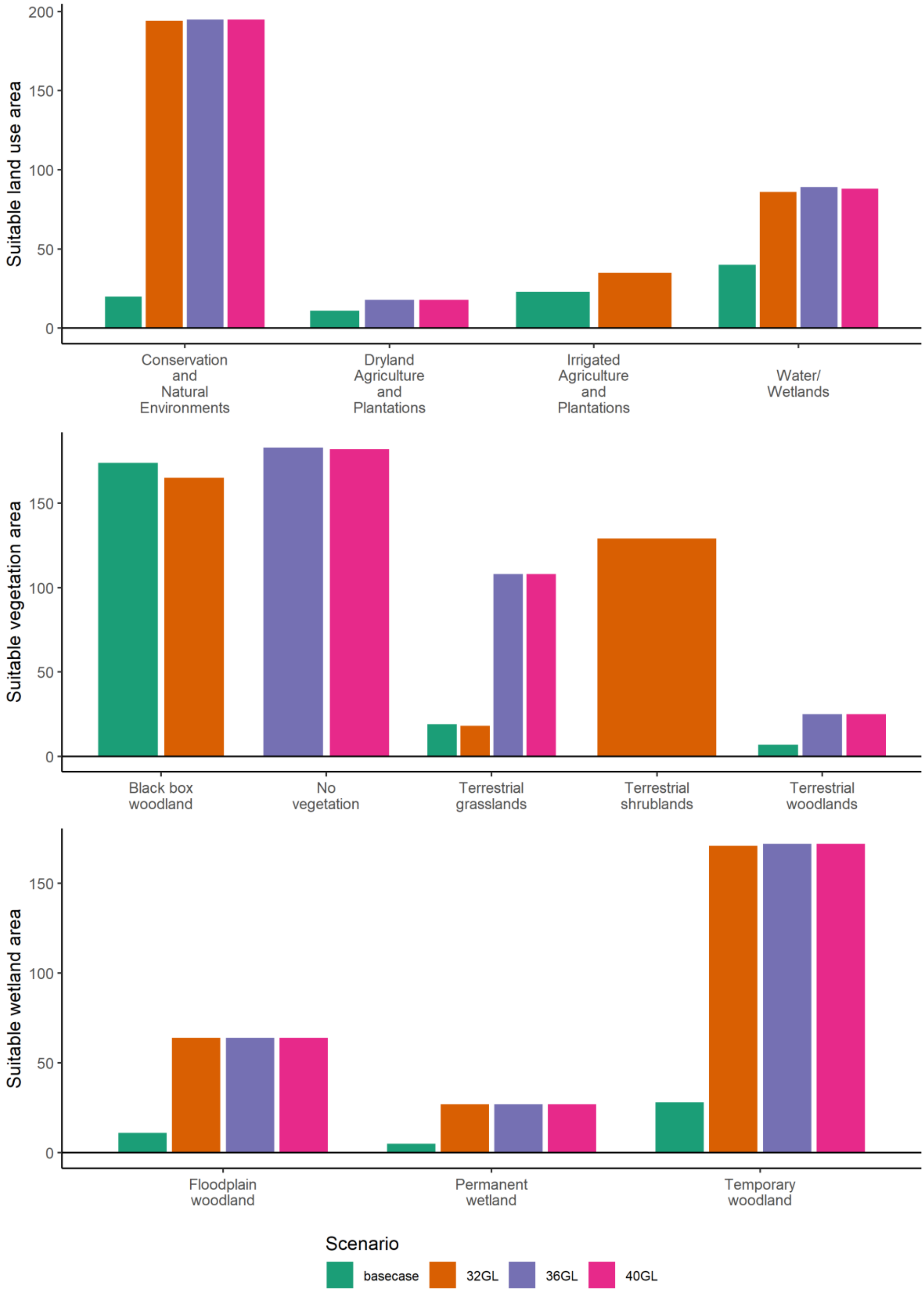

Figure A1.42. Total area of modelled highly suitable habitat for Lycium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Marrubium sp. (Tdr)

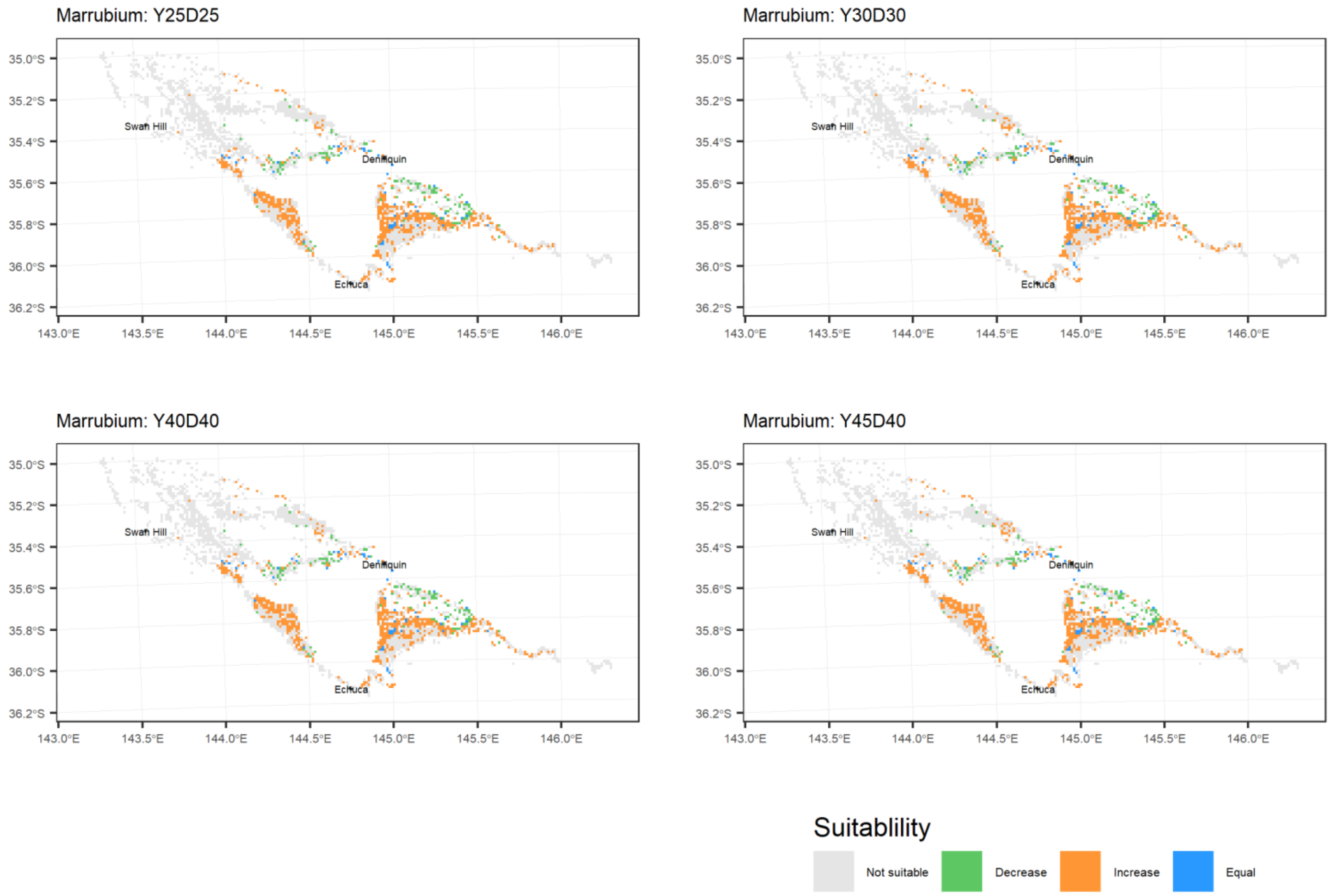

Figure A1.43. Changes from the basecase in extent of modelled suitable habitat area for Marrubium sp. in the Murray project area (map constrained to the mid - upper Murray reaches / Albury - Swan Hill) under each RRC inundation scenario.

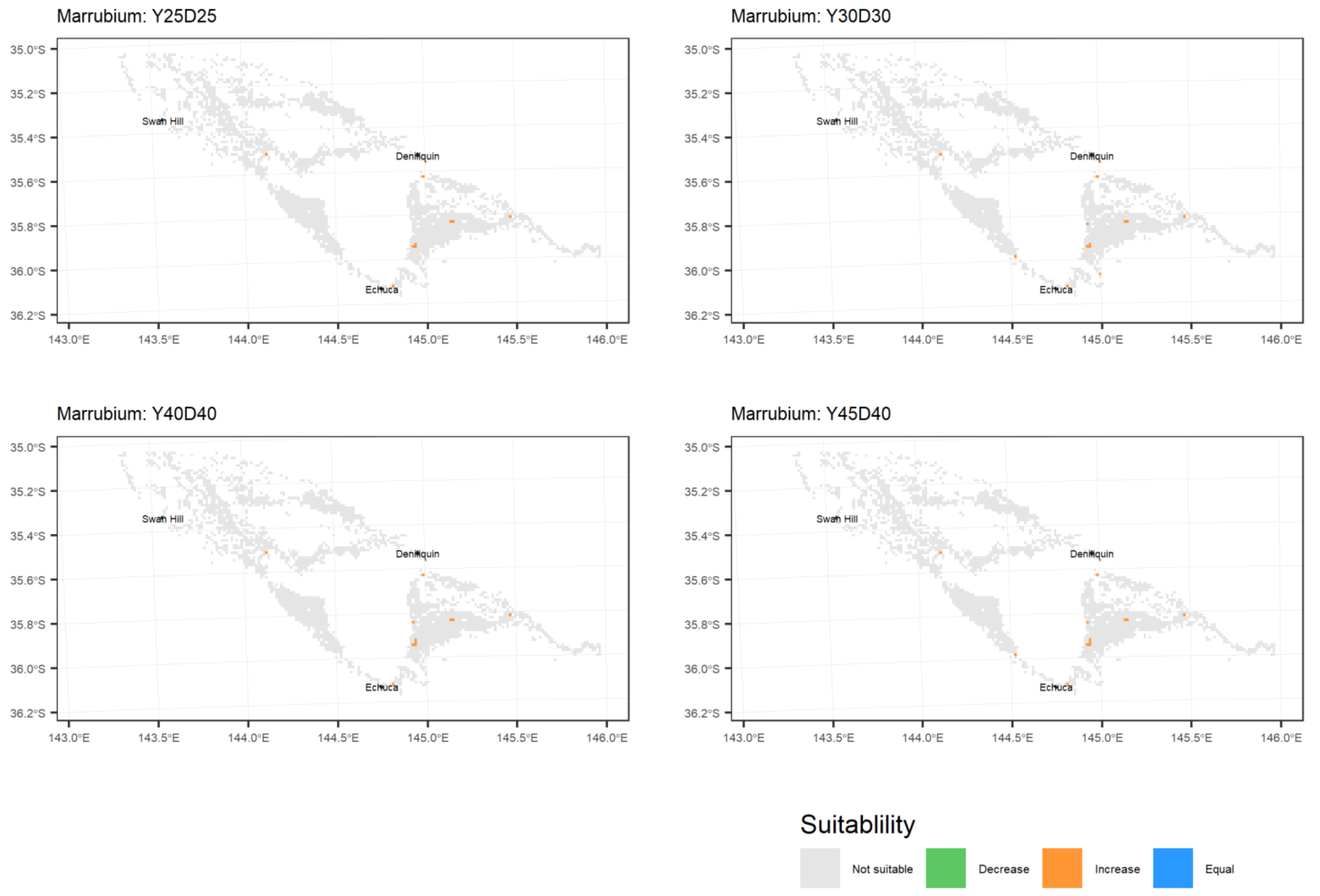

Figure A1.44. Changes from the basecase in extent of modelled highly suitable habita area for Marrubium sp. In the Murray project area (map constrained to the mid – upper reaches / Albury – Swan Hill) under each RRC inundation scenario.

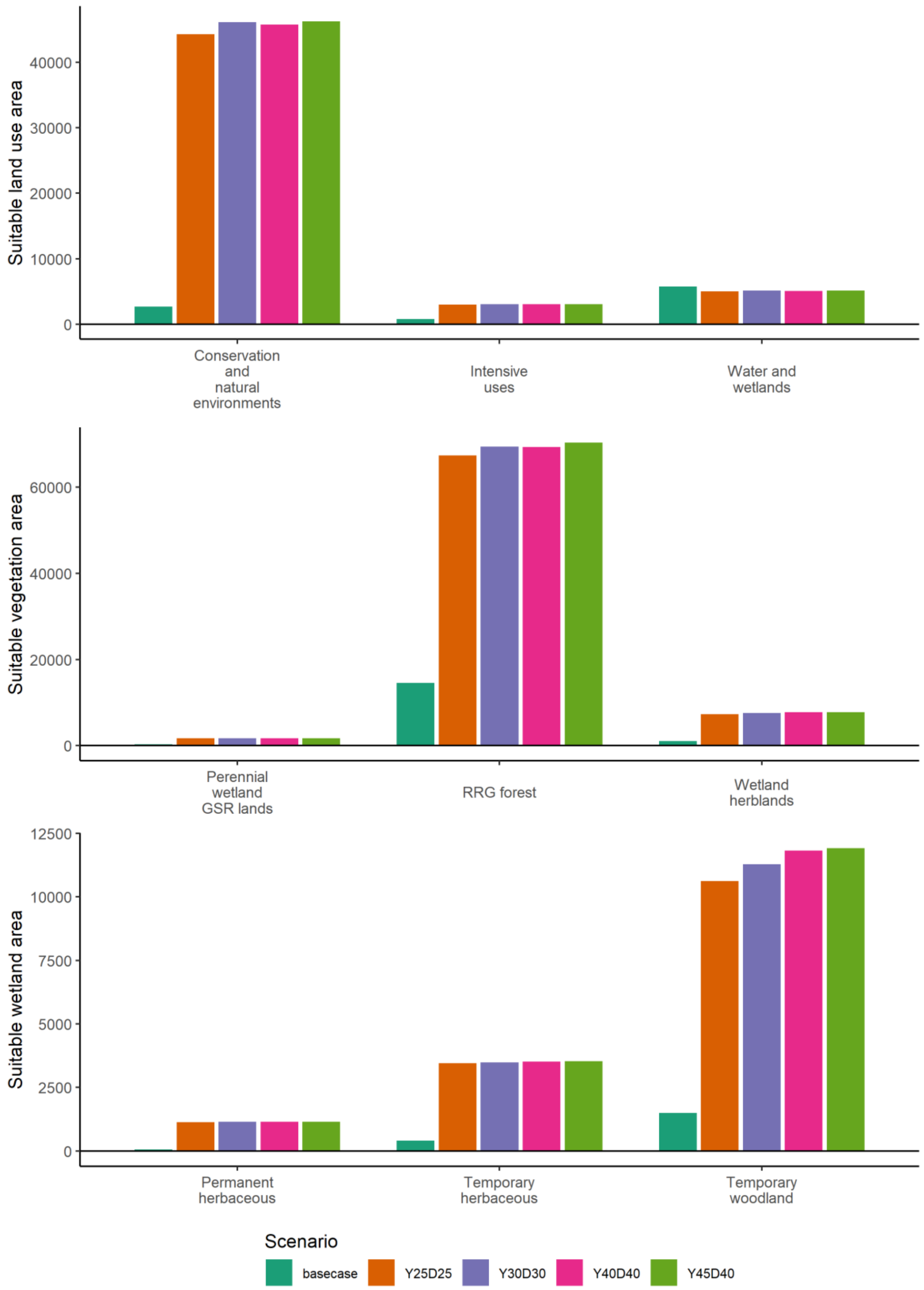

Figure A1.45. Total area of modelled suitable habitat for Marrubium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

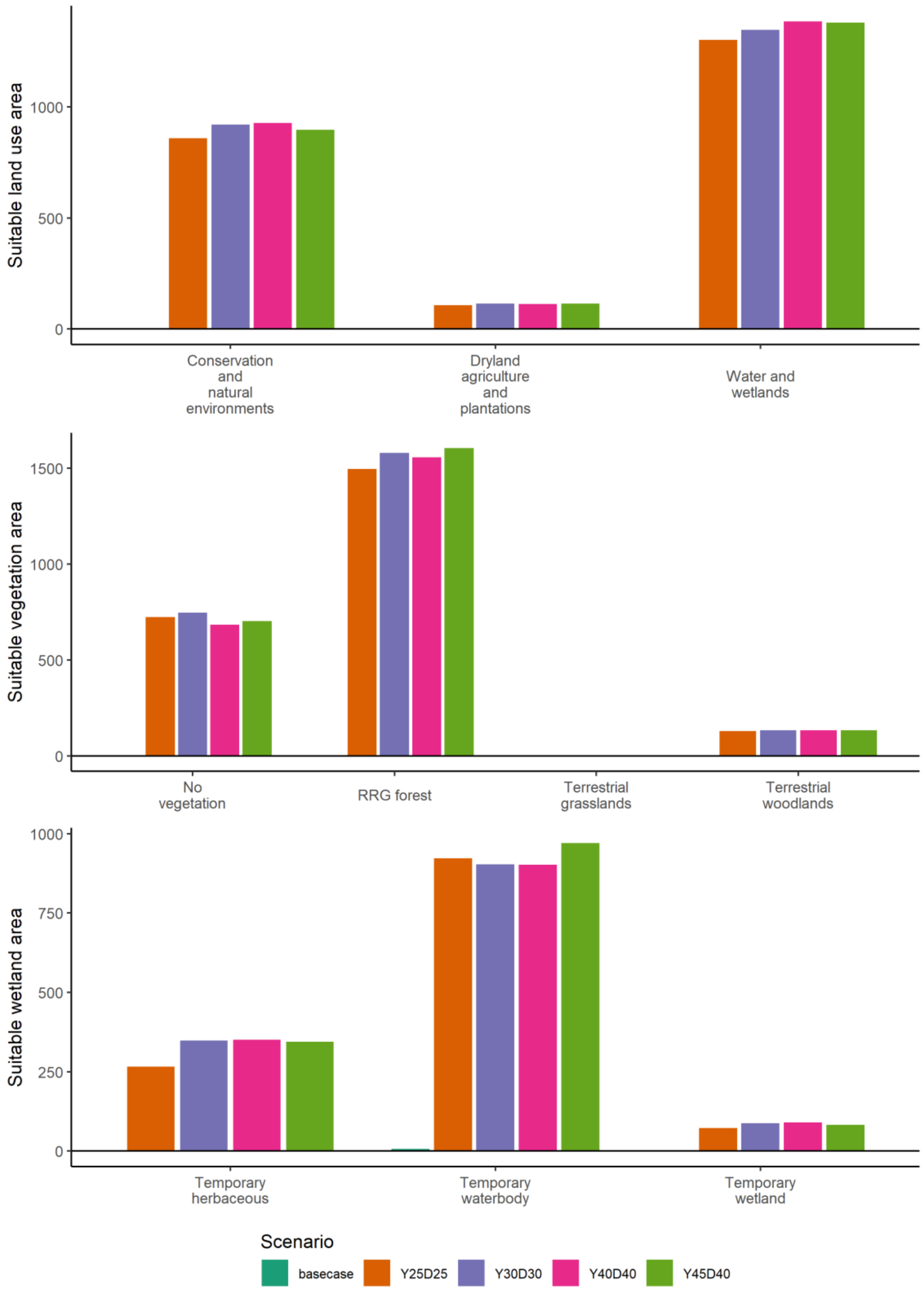

Figure A1.46. Total area of modelled highly suitable habitat for Marrubium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

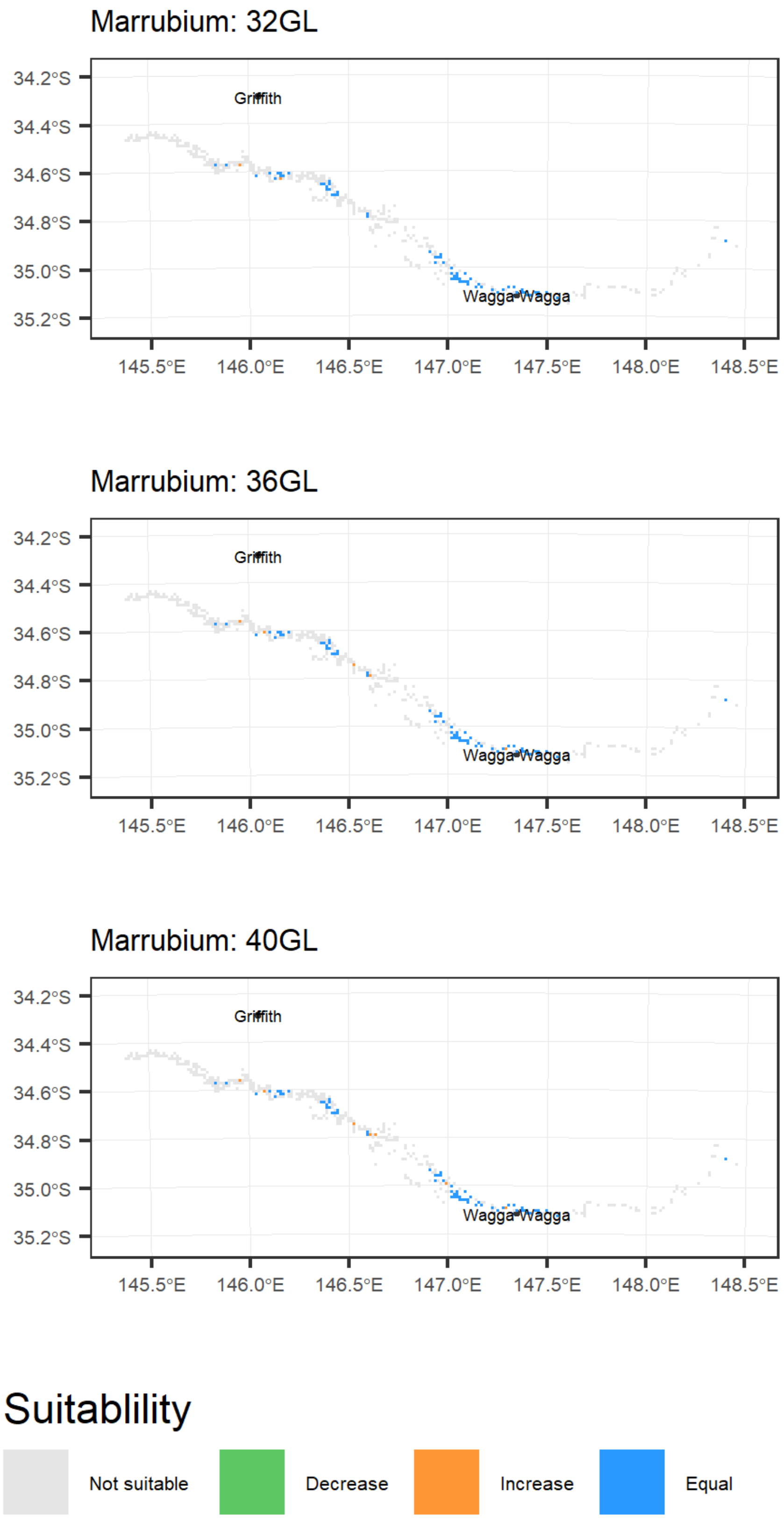

Figure A1.47. Changes from the basecase in extent of modelled suitable habitat area for Marrubium sp. in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

Note. Changes from basecase too small to visualise in map for high suitability in the Murrumbidgee

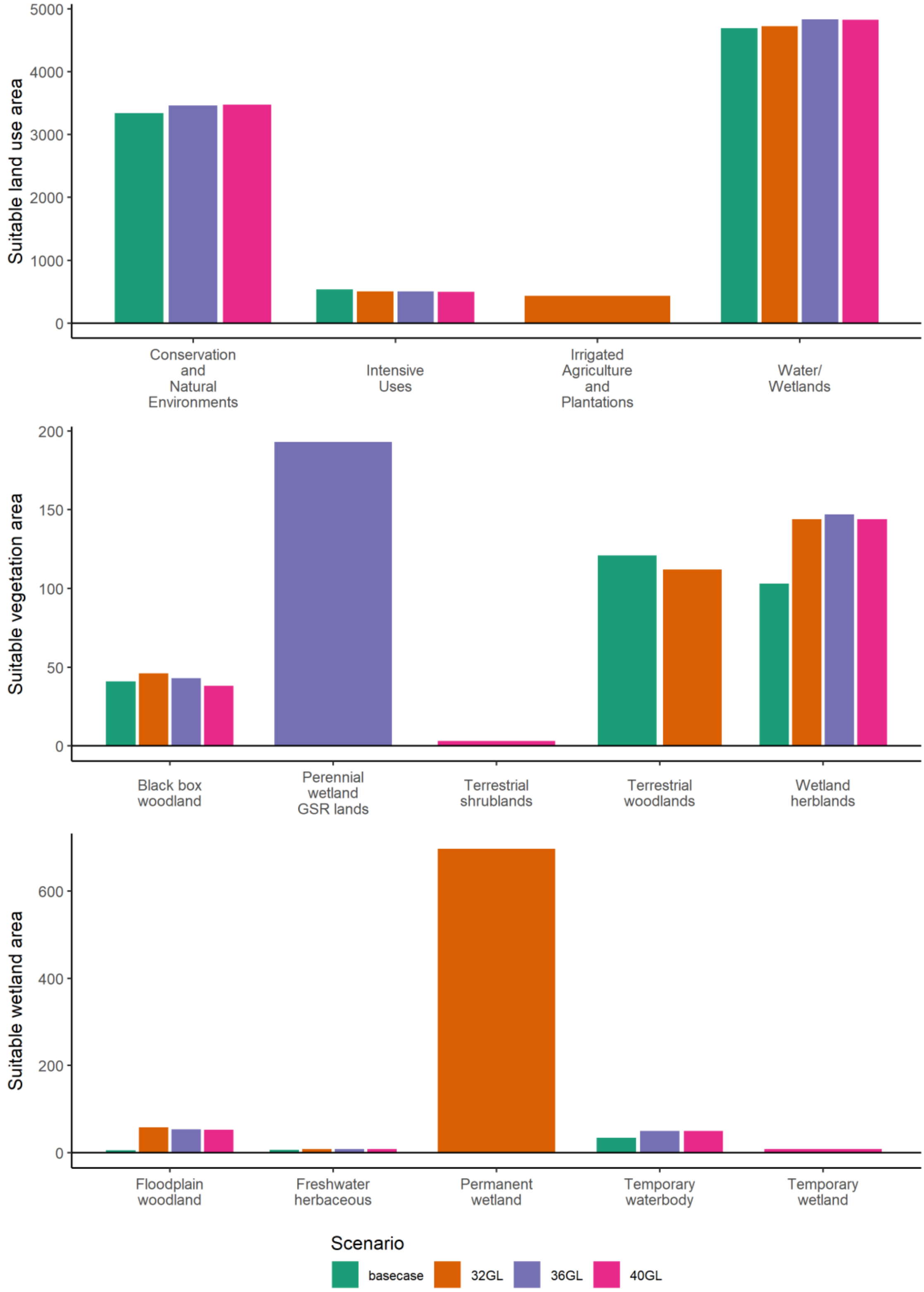

Figure A1.48. Total area of modelled suitable habitat for Marrubium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

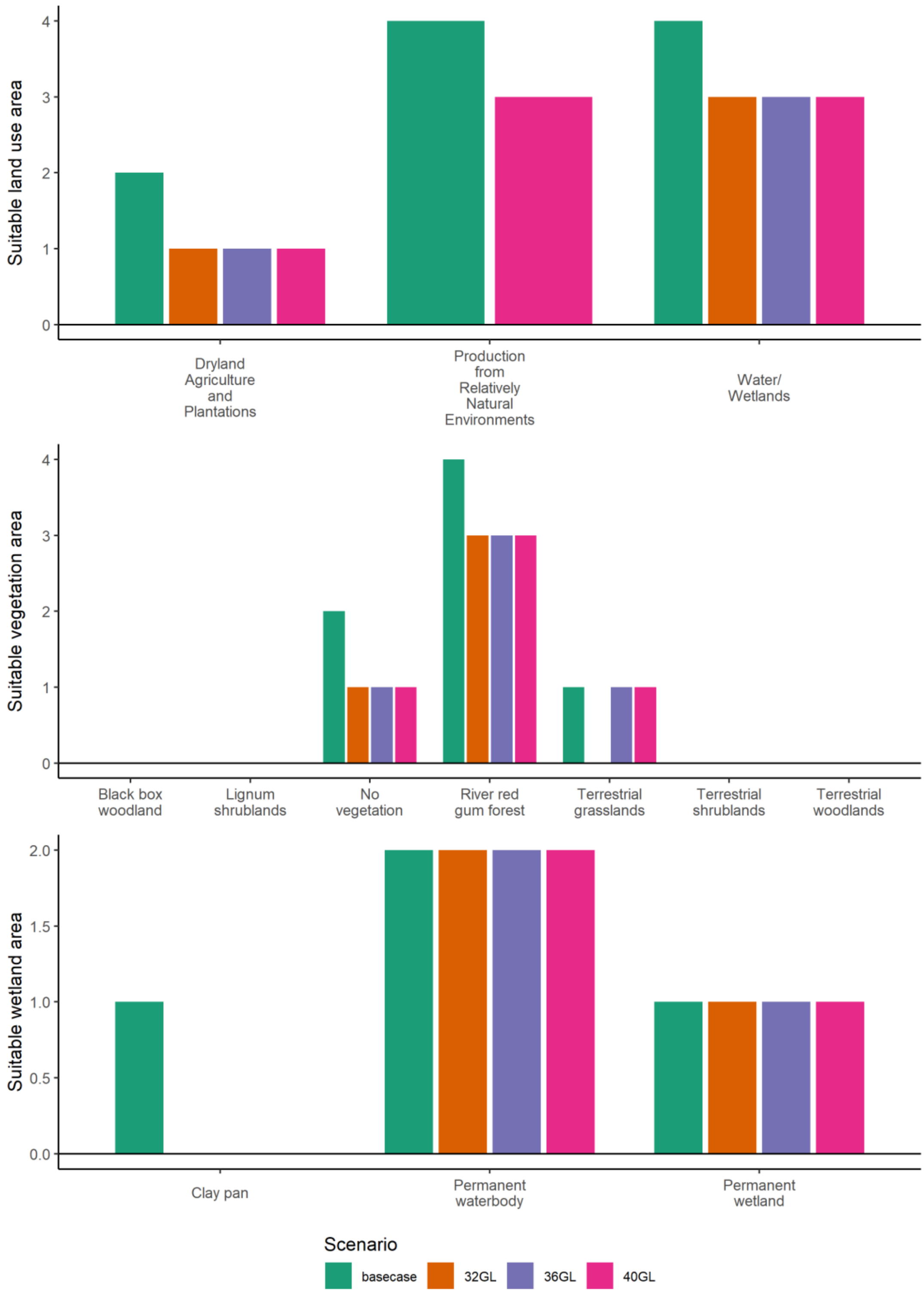

Figure A1.49. Total area of modelled highly suitable habitat for Marrubium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Rubus sp. (Tdr)

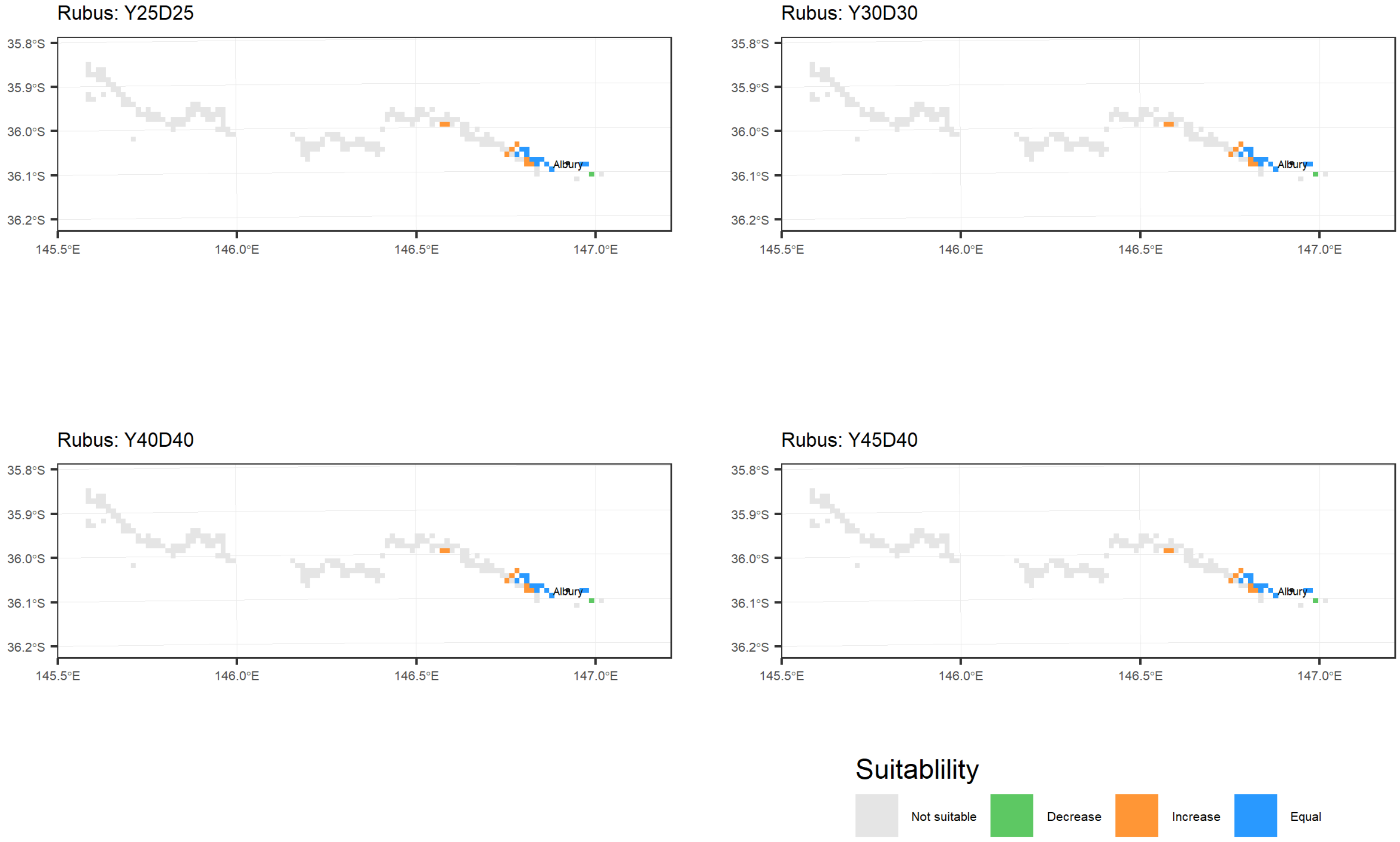

Figure A1.50. Changes from the basecase in extent of modelled suitable habitat area for Rubus sp. in the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

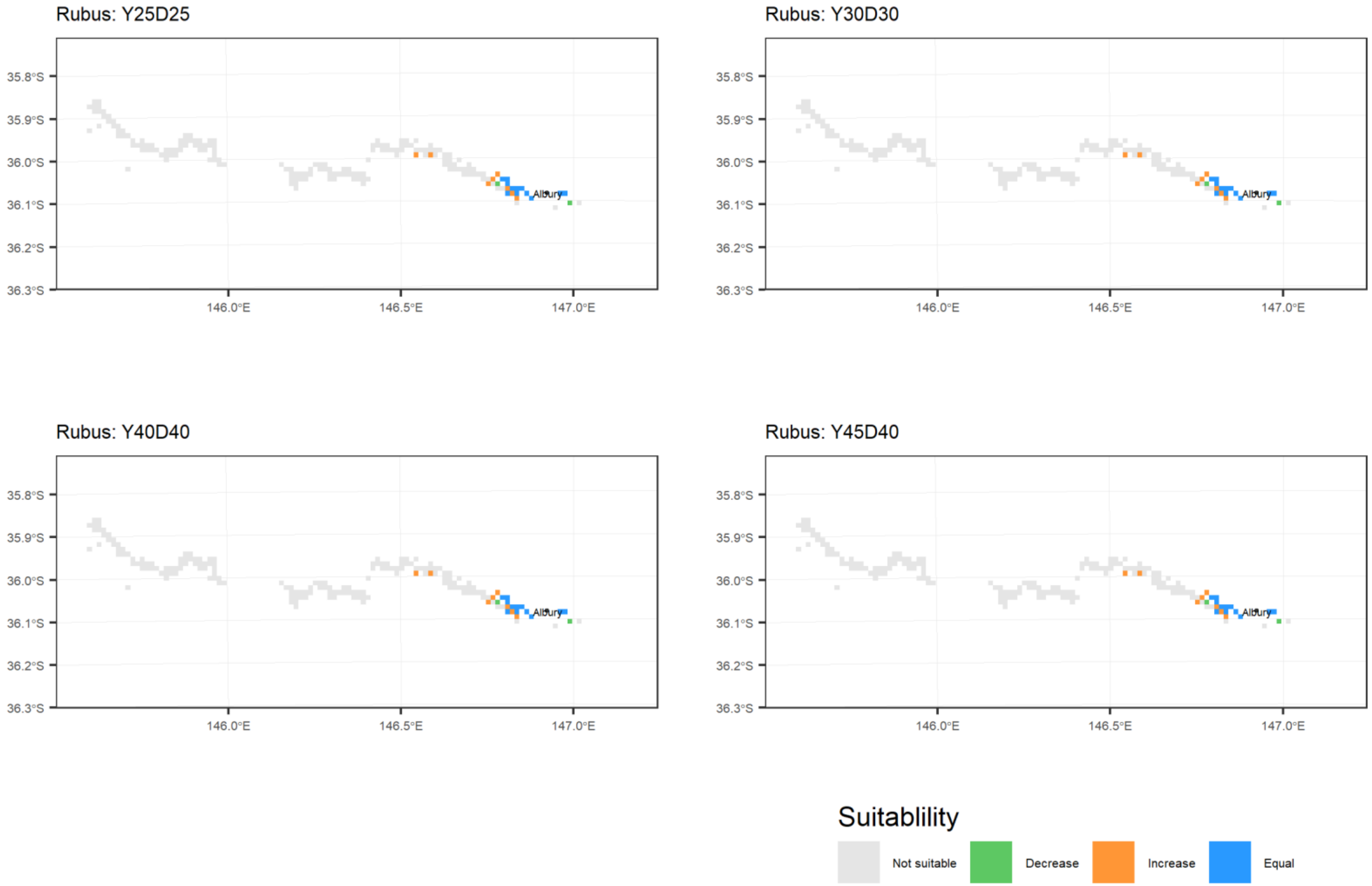

Figure A1.51. Changes from the basecase in extent of modelled highly suitable habitat area for Rubus sp. In the Murray project area (map constrained to the upper Murray reaches / Albury) under each RRC inundation scenario.

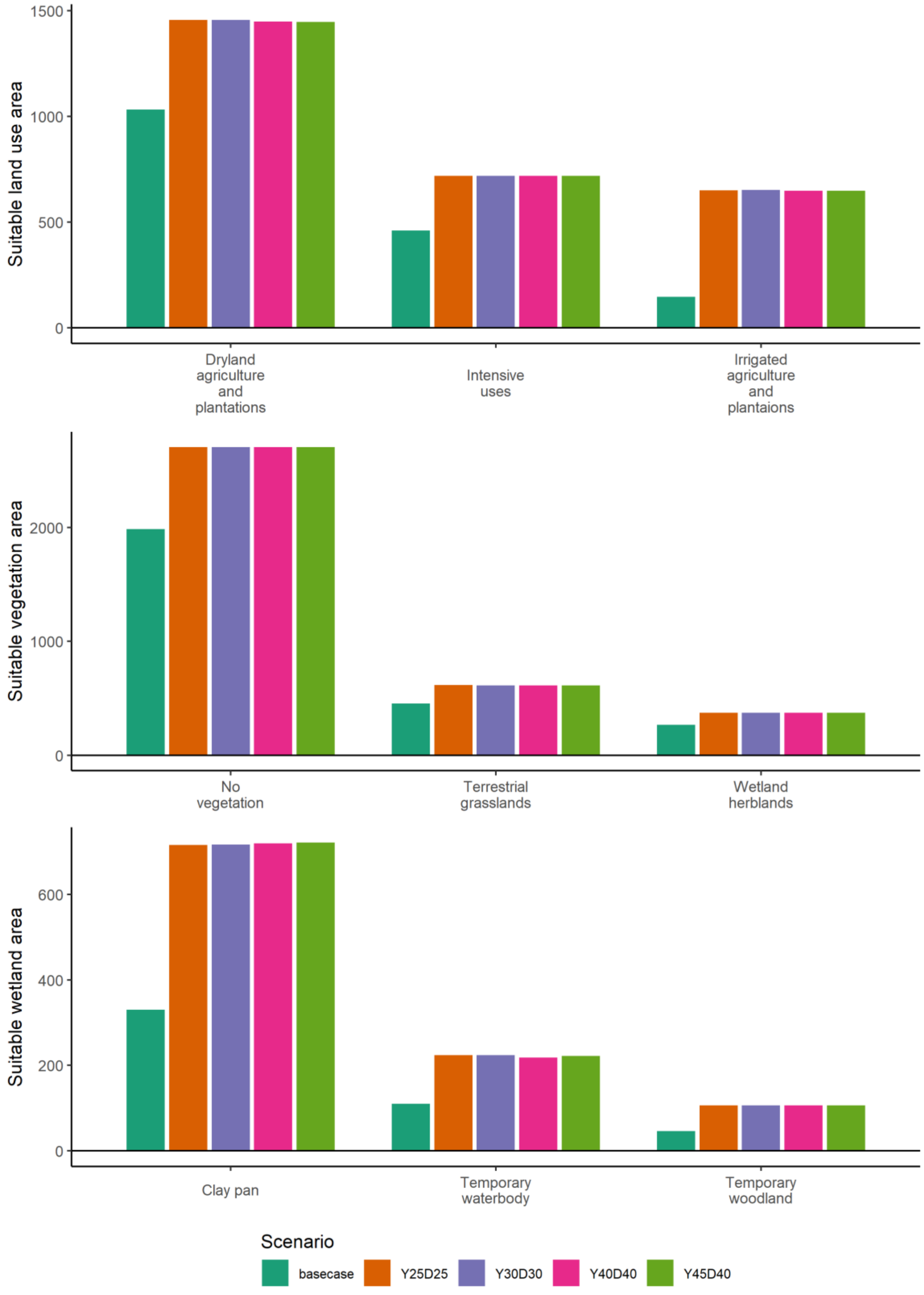

Figure A1.52. Total area of modelled suitable habitat for Rubus sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

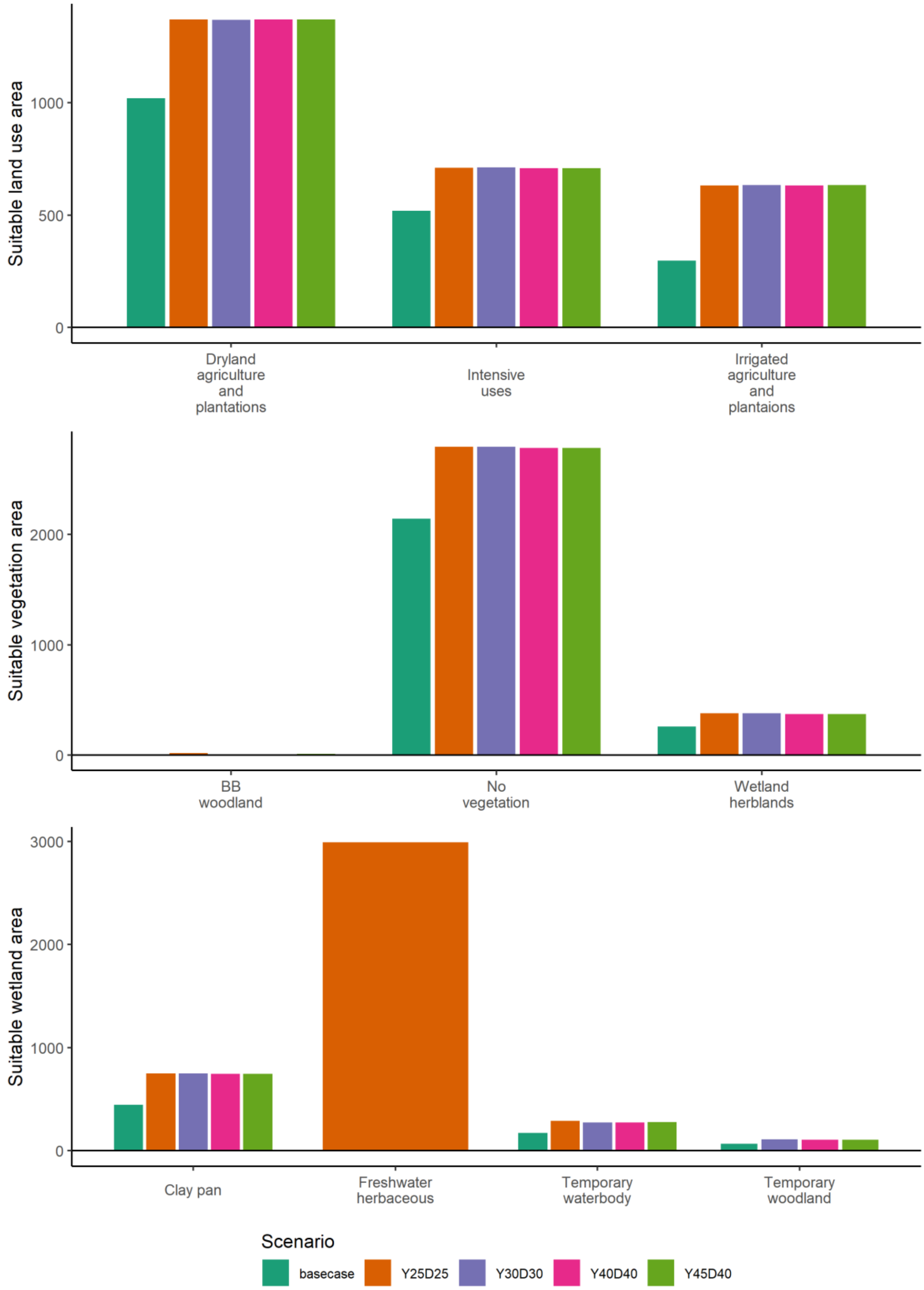

Figure A1.53. Total area of modelled highly suitable habitat for Rubus sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

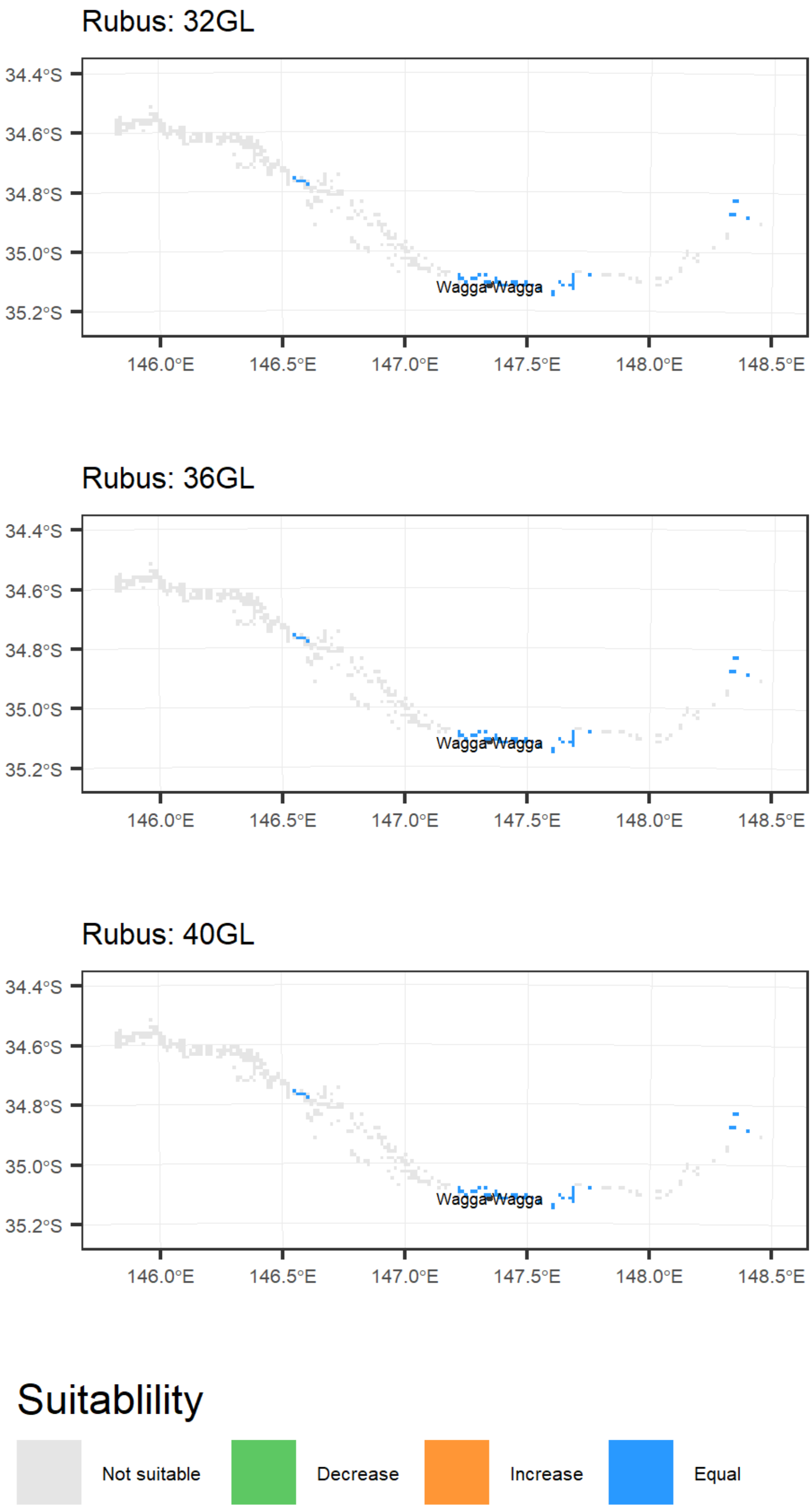

Figure A1.54. Changes from the basecase in extent of modelled suitable habitat area for Rubus sp. in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

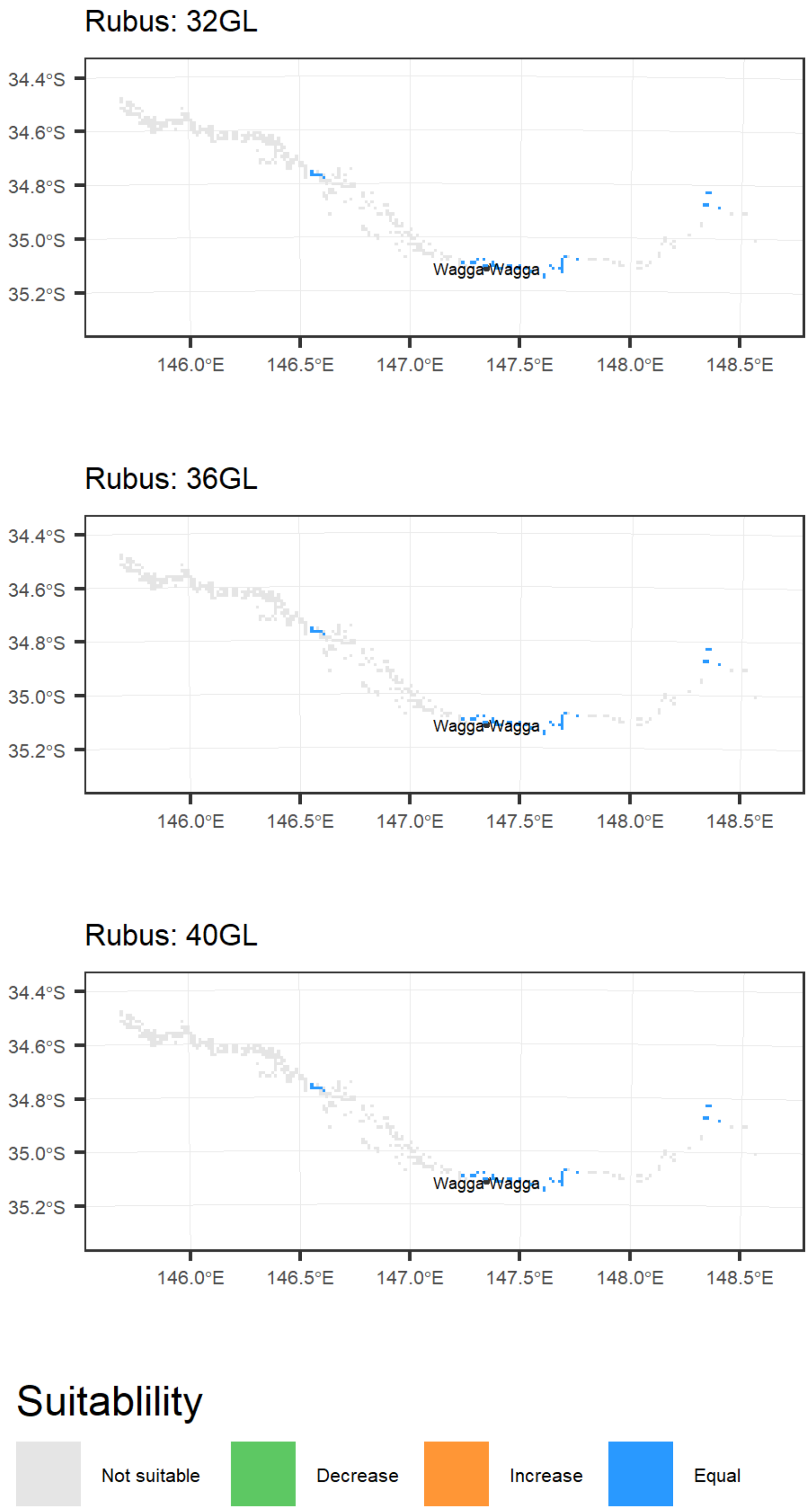

Figure A1.55. Changes from the basecase in extent of modelled highly suitable habitat for Rubus sp. In the Murrumbidgee project area (map constrained to upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

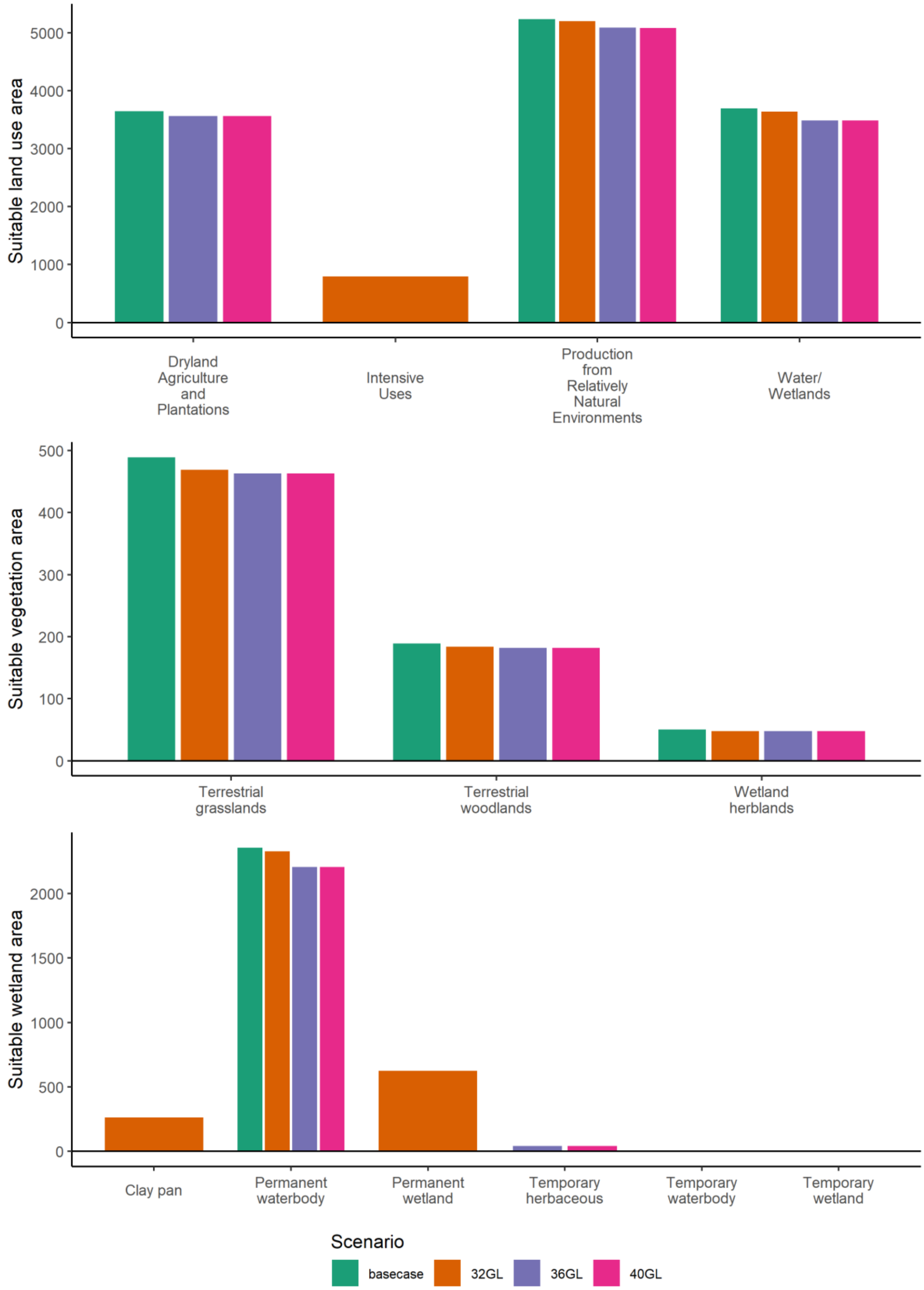

Figure A1.56. Total area of modelled suitable habitat for Rubus sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

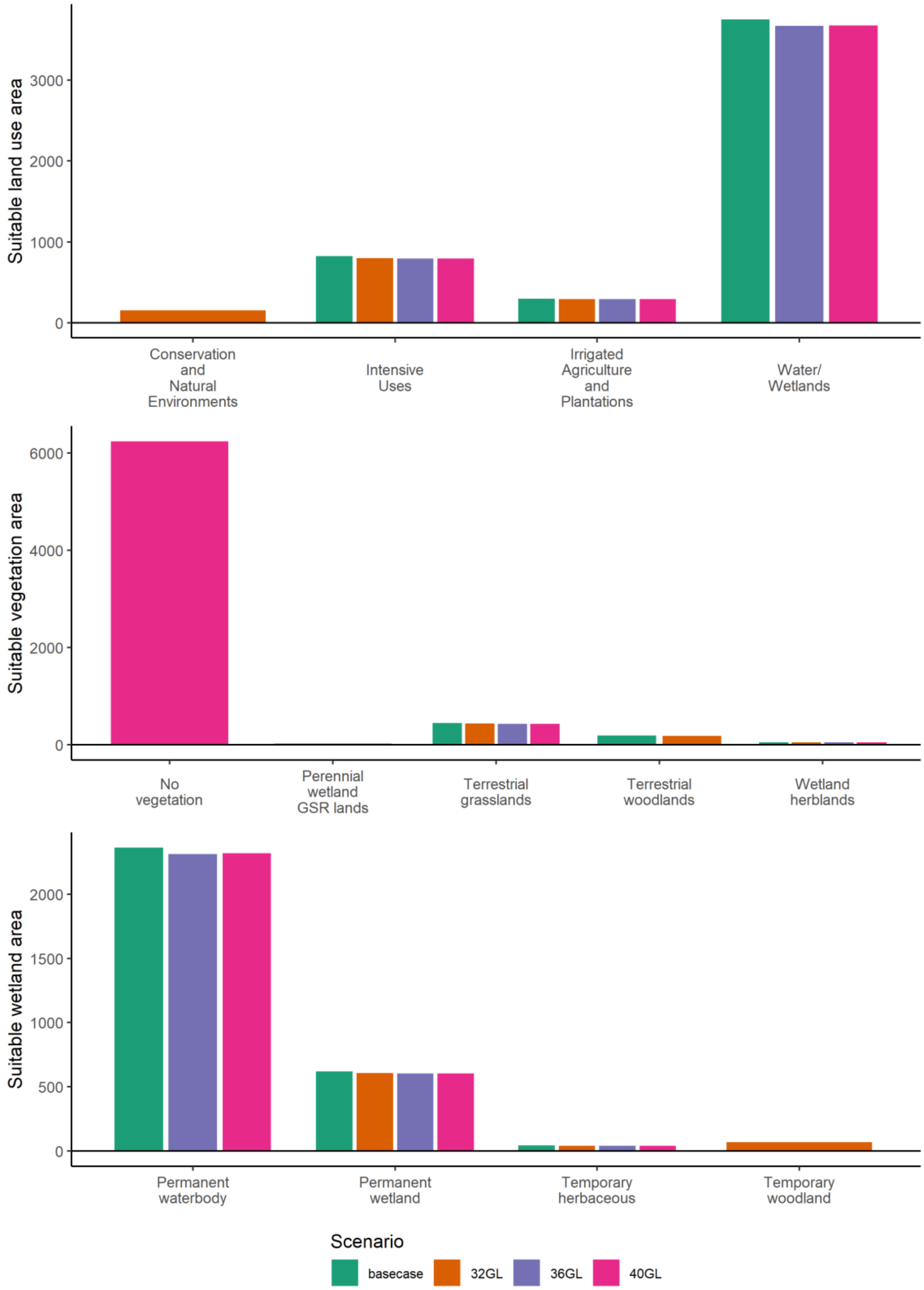

Figure A1.57. Total area of modelled highly suitable habitat for Rubus sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Xanthium sp. (Tdr)

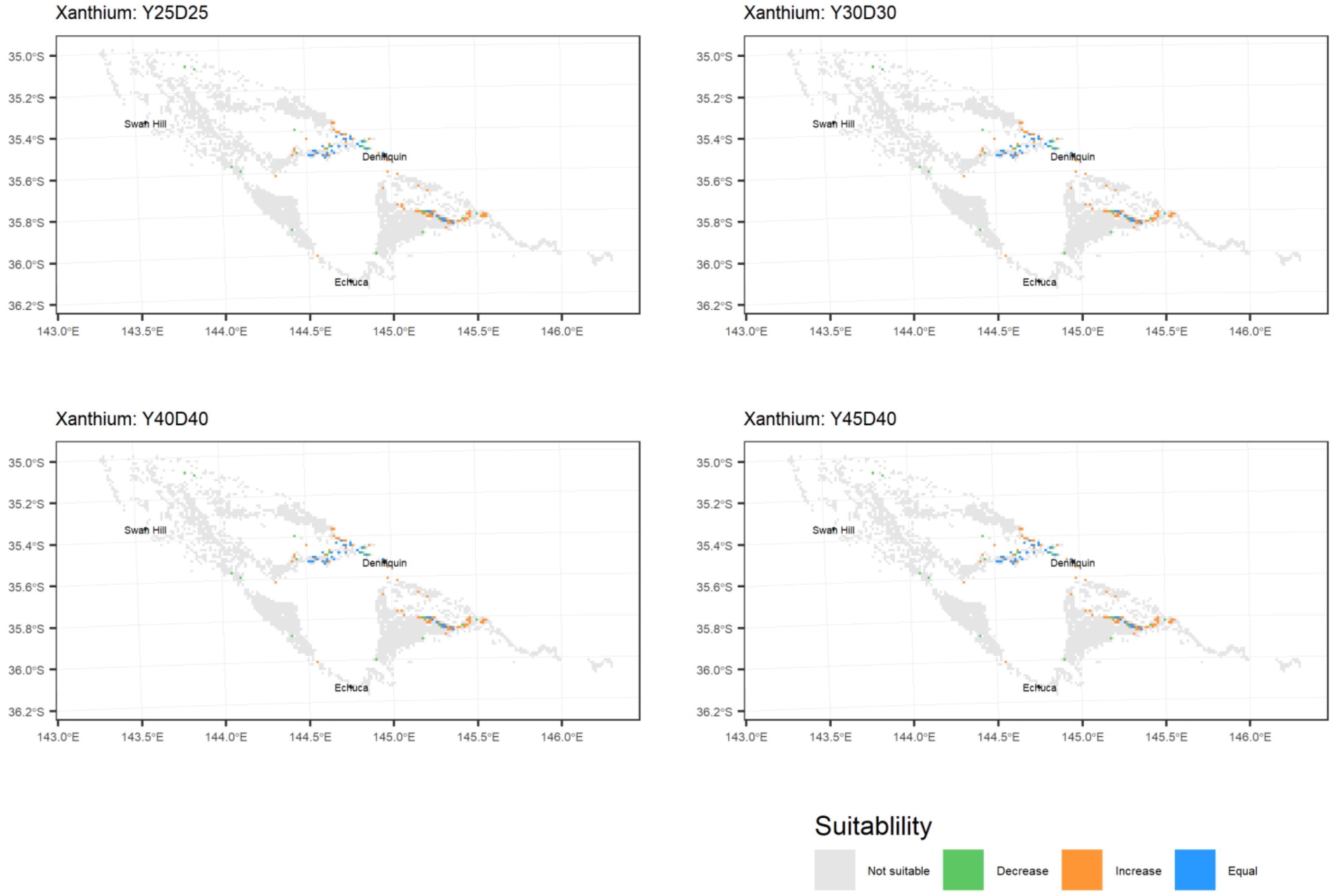

Figure A1.58. Changes from the basecase in extent of modelled area for Xanthium sp. in the Murray project area (map constrained to the mid - upper Murray reaches / Albury - Swan Hill) under each RRC inundation scenario.

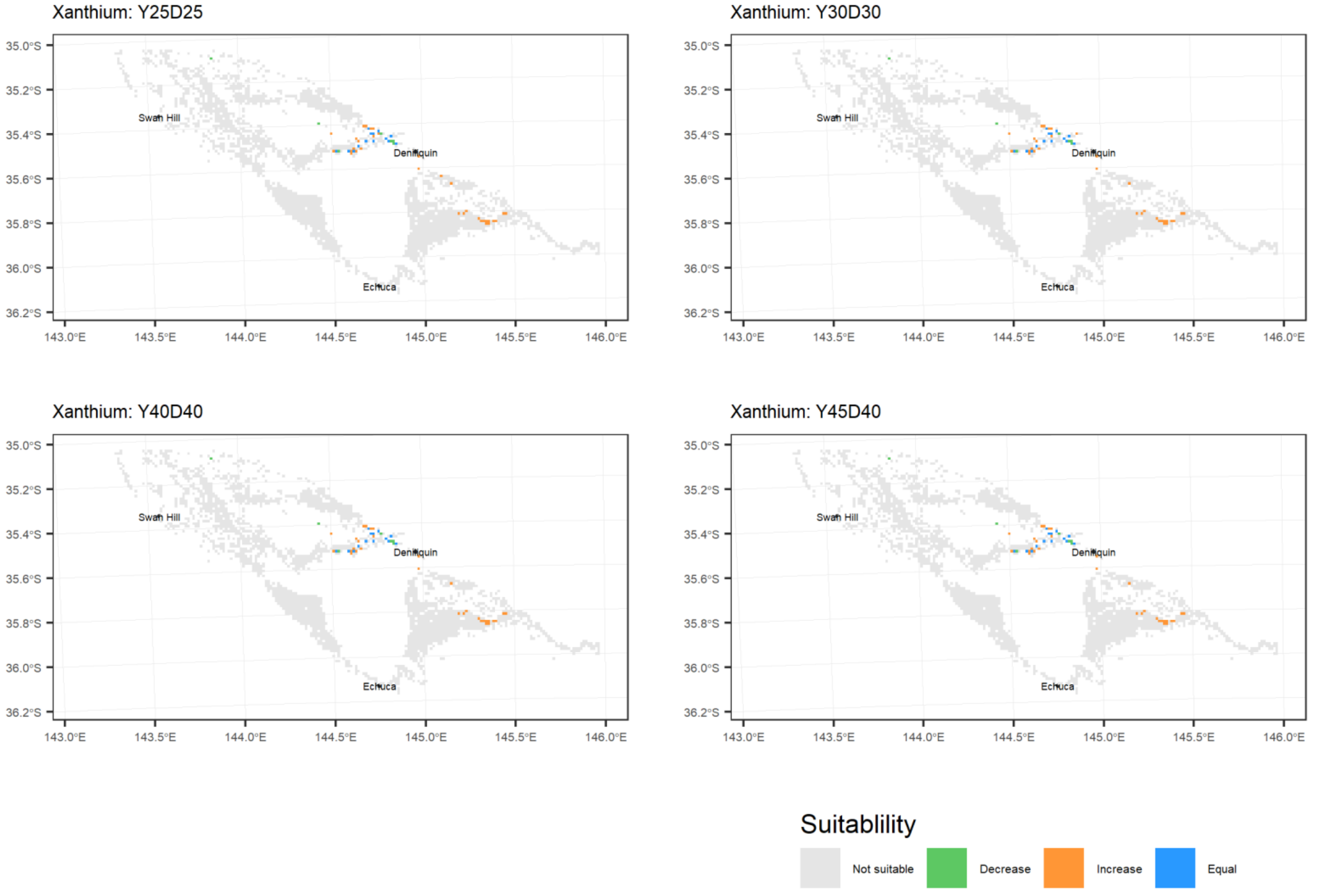

Figure A1.59. Changes from the basecase in extent of modelled highly suitable habitat area for Xanthium sp. In the Murray project area (map constrained to the mid – upper Murray reaches / Albury – Swan Hill) under each RRC inundation scenario.

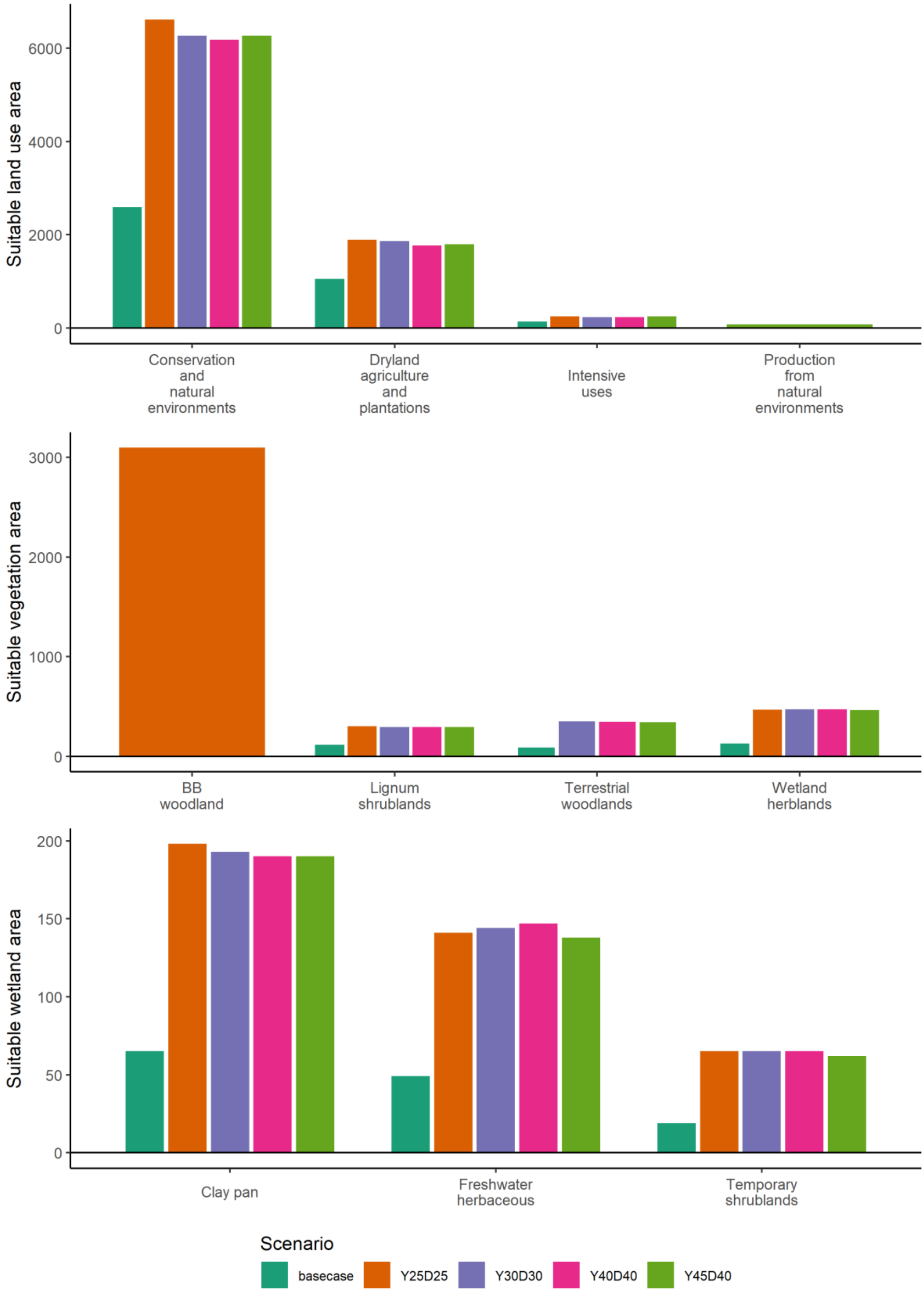

Figure A1.60. Total area of modelled suitable habitat for Xanthium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

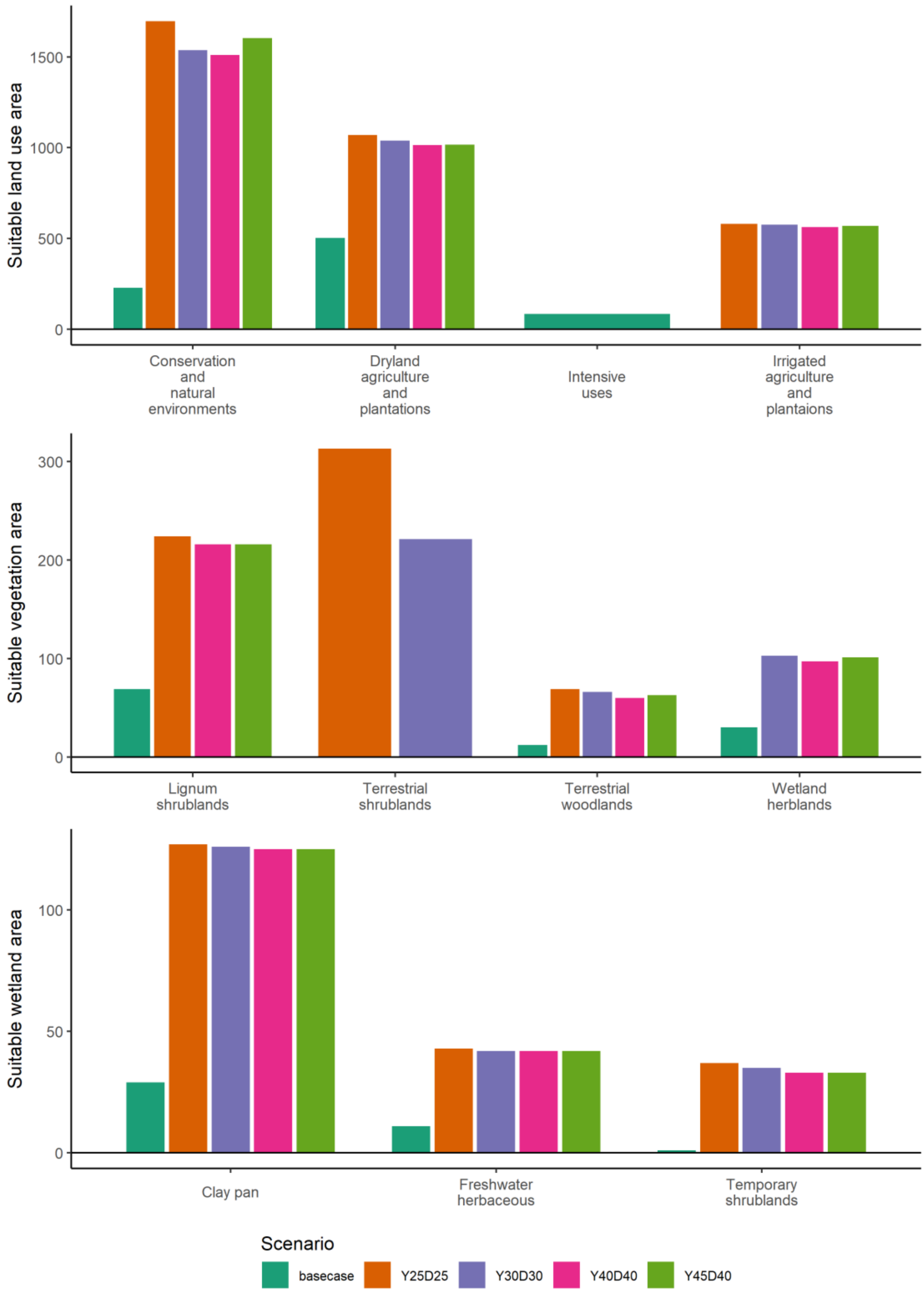

Figure A1.61. Total area of modelled highly suitable habitat for Xanthium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murray project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

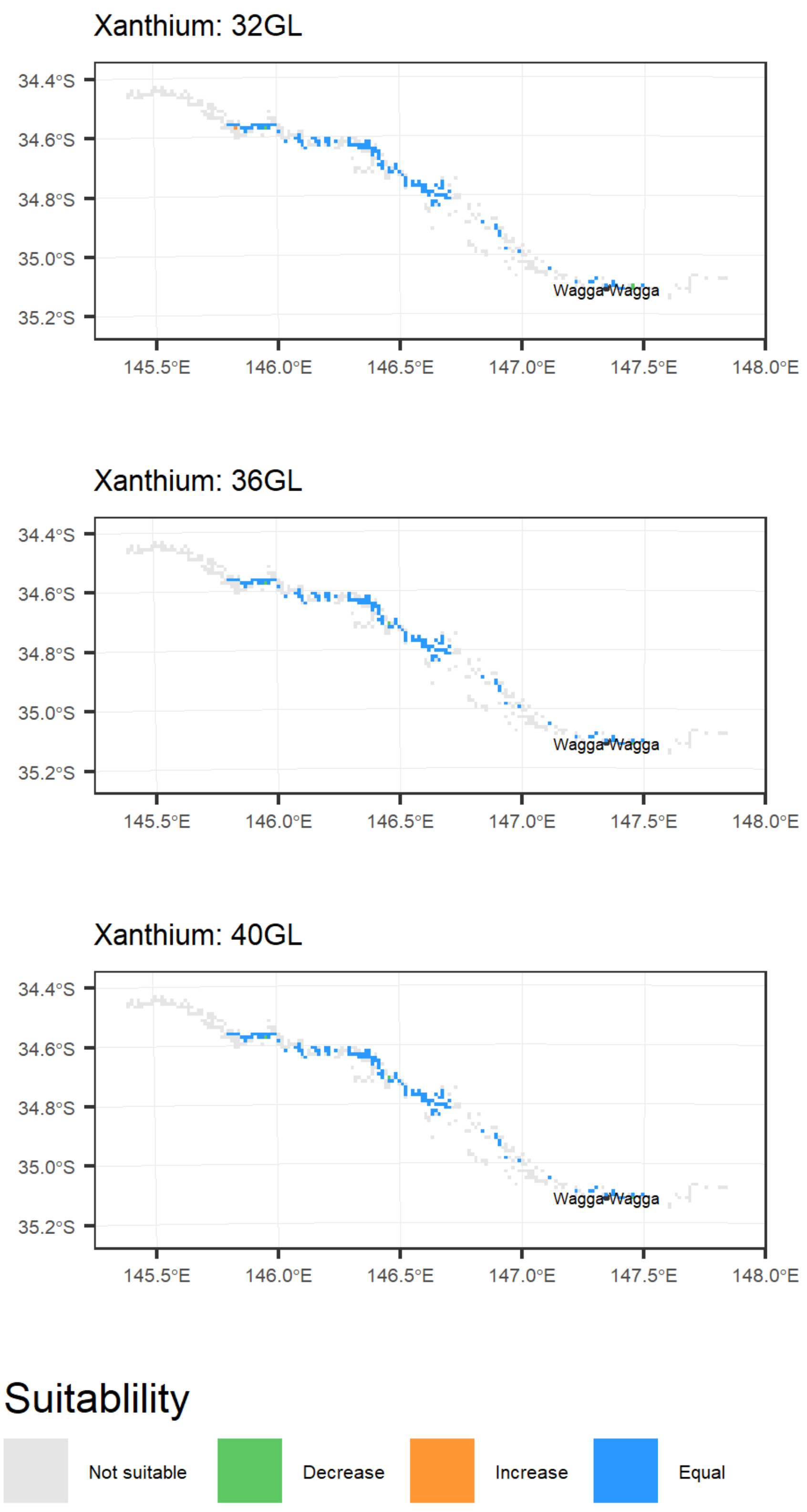

Figure A1.62. Changes from the basecase in extent of modelled suitable habitat area for Xanthium sp. in the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

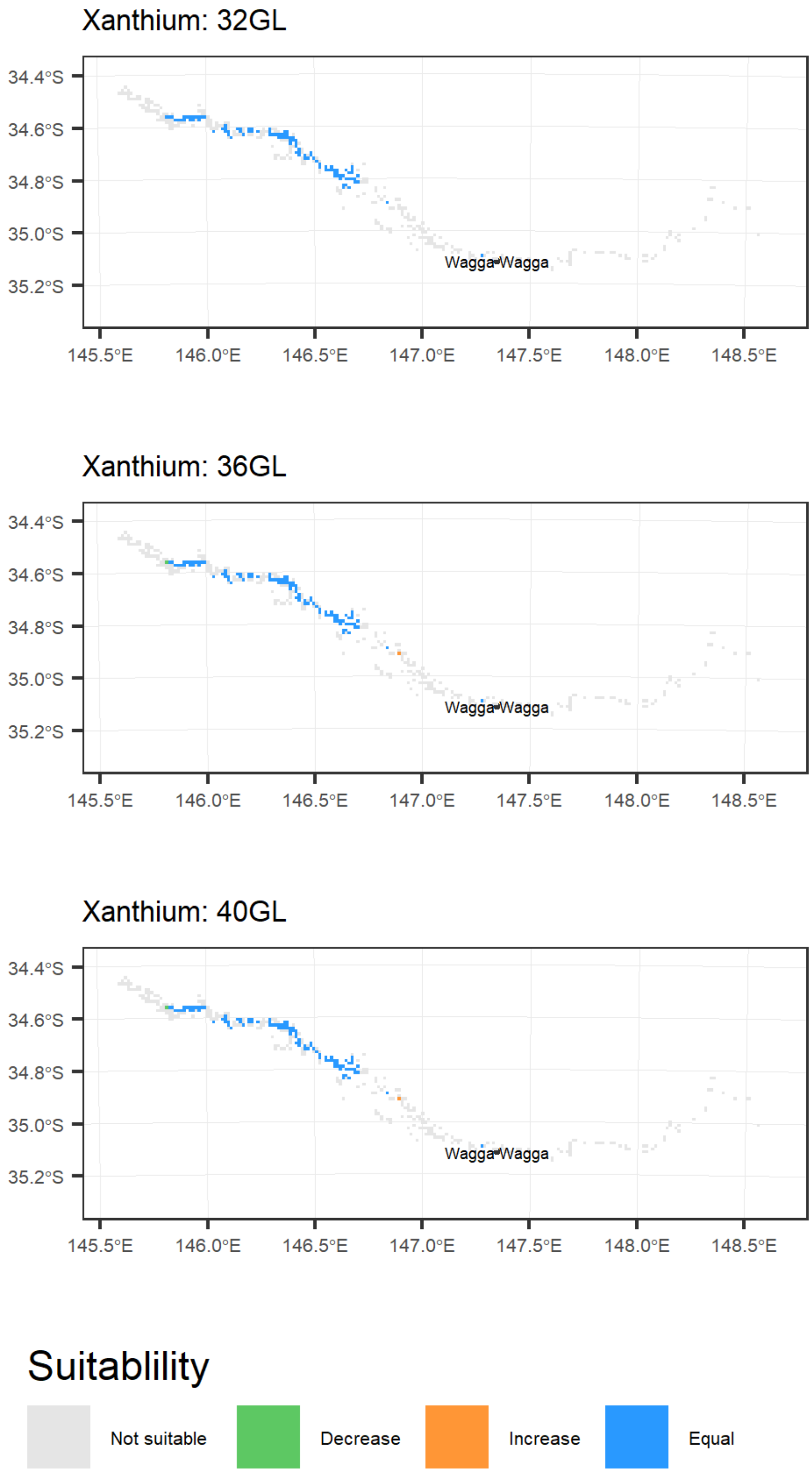

Figure A1.63. Changes from the basecase in extent of modelled highly suitable habitat area for Xanthium sp. In the Murrumbidgee project area (map constrained to the upper Murrumbidgee reaches / Wagga Wagga) under each RRC inundation scenario.

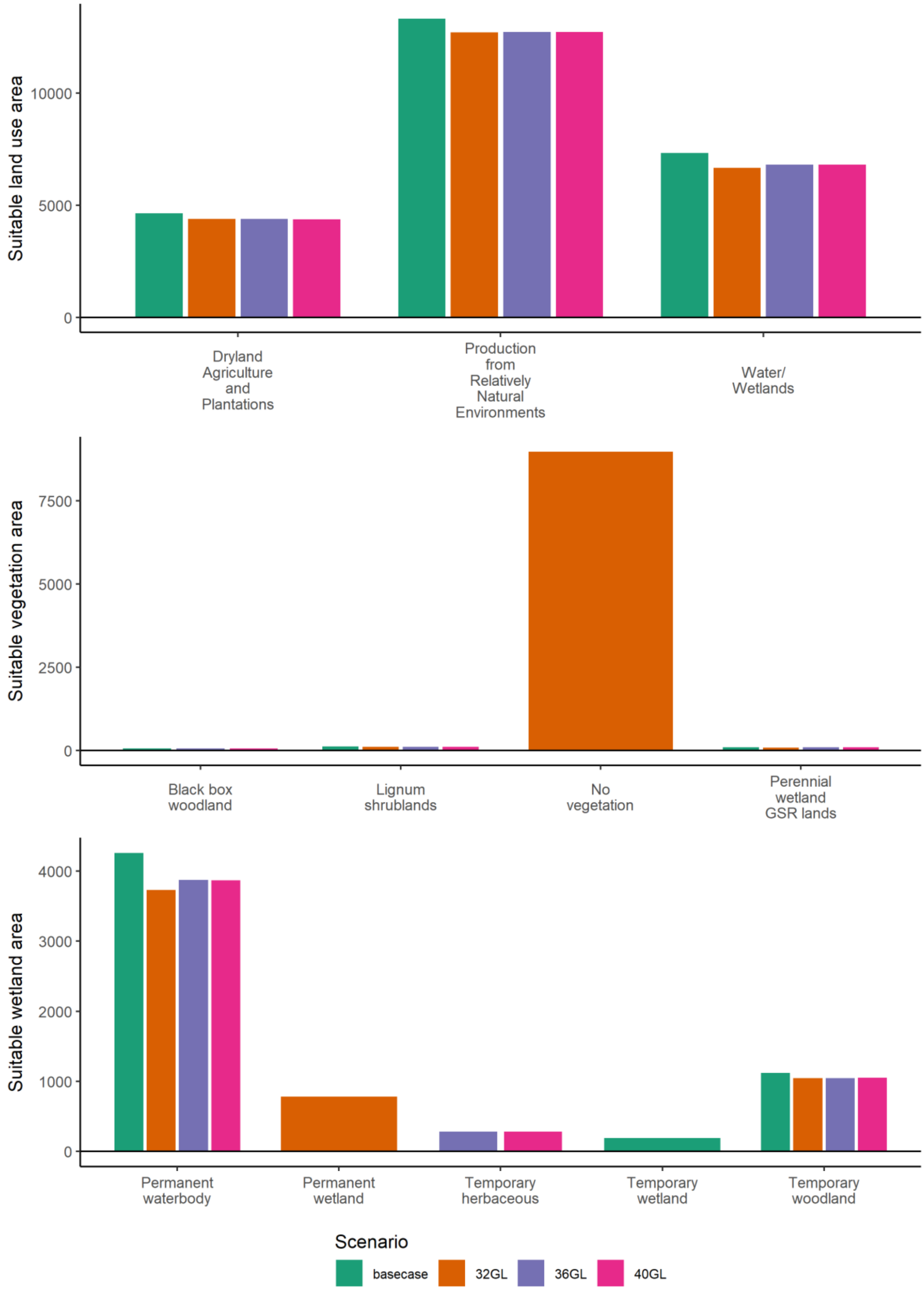

Figure A1.64. Total area of modelled suitable habitat for Xanthium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

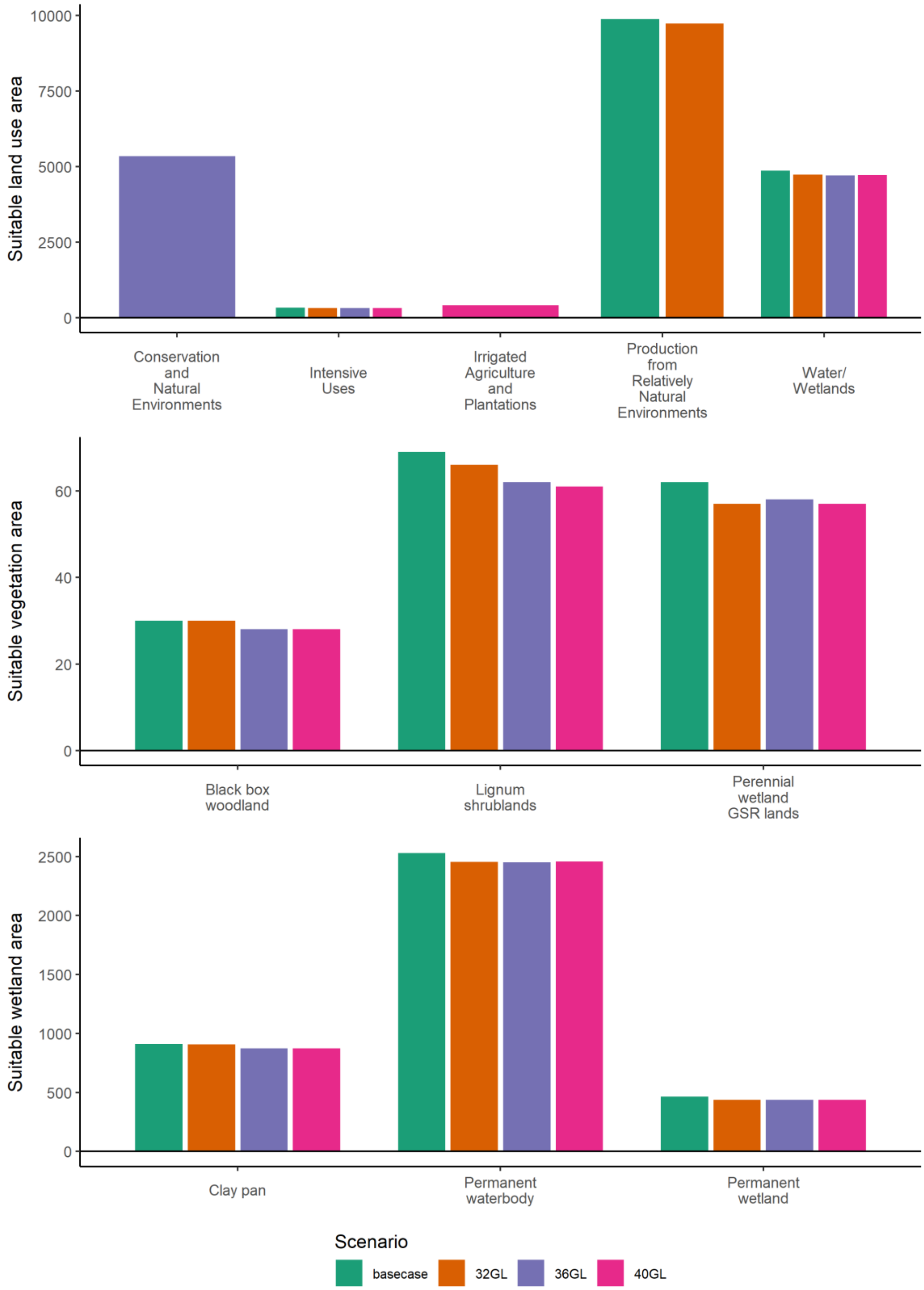

Figure A1.65. Total area of modelled highly suitable habitat for Xanthium sp. in land use (top), vegetation (middle), and wetland (bottom) classes in the Murrumbidgee project area under each RCC inundation scenario. Figure shows total area of three classes with the greatest (+ve or –ve) proportional change from the basecase in each scenario.

Appendix 2.

Risk assessment scores

Sagittaria (Arp)

Table A2.1. Likelihood scores for each criterion under each scenario for Sagittaria.

Criteria	Murray				Murrumbidgee		
	Y2D25	Y30D30	Y40D40	Y45D40	32GL	36GL	40GL
Change in total habitat							
Change in suitable habitat	-8	-8	-8	-8	0	0	0
Change in highly suitable habitat	-16	-16	-16	-16	0	0	0
Change in dominant land uses occupied							
Conservation and natural environments	-4	-4	-4	-4	0	0	0
Dryland agriculture and plantations	-4	-4	-4	-4	0	0	0
Intensive uses	-4	-4	-4	-4	0	0	0
Irrigated agriculture and plantations	-4	-4	-4	-4	0	0	0
Production from natural environments	-4	-4	-4	-4	0	0	0
Water and wetlands	-4	-4	-4	-4	0	0	0
Change in dominant vegetation types occupied							
Black box woodland	-4	-4	-4	-4	0	0	0
Lignum shrubland	-4	-4	-4	-4	0	0	0
Perennial wetland GRS	-4	-4	-4	-4	0	0	0
RRG forest	-4	-4	-4	-4	0	0	0
RRG woodland	-4	-4	-4	-4	0	0	0
Terrestrial grasslands	-4	-4	-4	-4	0	0	0
Terrestrial shrublands	-4	-4	-4	-4	0	0	0
Terrestrial woodlands	-4	-4	-4	-4	0	0	0
Wetland herblands	-4	-4	-4	-4	0	0	0
Saline wetlands	0	0	0	0	0	0	0
Changes in dominant wetland classes occupied							
Claypan	-4	-4	-4	-4	0	0	0

Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	-4	-4	-4	-4	0	0	0
Freshwater herbaceous	-4	-4	-4	-4	0	0	0
Permanent herbaceous	-4	-4	-4	-4	0	0	0
Permanent waterbody	-4	-4	-4	-4	0	0	0
Permanent wetland	-4	-4	-4	-4	0	0	0
Saline herbaceous	0	0	0	0	0	0	0
Temporary herbaceous	-4	-4	-4	-4	0	0	0
Temporary shrubland	-4	-4	-4	-4	0	0	0
Temporary waterbody	-4	-4	-4	-4	0	0	0
Temporary wetland	-4	-4	-4	-4	0	0	0
Temporary woodland	-4	-4	-4	-4	0	0	0
Unspecified river	0	0	0	0	0	0	0
Waterhole	0	0	0	0	0	0	0
Overall	**-128**	**-128**	**-128**	**-128**	**0**	**0**	**0**

Table A2.2. Consequence scores for each criterion for each project area catchment for Sagittaria.

Criteria	**Murray**	**Murrumbidgee**
Weed of national significance	10	10
Regional Weed Priority	2	2
Impacts to fauna		
Impacts to vegetation		
Impacts to humans/infrastructure	2	2
Impacts to agriculture		
Other impacts	2	2
Overall	***16***	***16***

Phyla (Atl)

Table A2.3. Likelihood scores for each criterion under each scenario for Phyla.

	Murray				Murrumbidgee		
Criteria	**Y2D25**	**Y30D30**	**Y40D40**	**Y45D40**	**32GL**	**36GL**	**40GL**
Change in total habitat							
Change in suitable habitat	-8	-8	-8	-8	-2	-2	-2
Change in highly suitable habitat	-16	-16	-16	-16	16	16	16
Change in dominant land uses occupied							
Conservation and natural environments	-4	-4	-4	-4	-1	-4	-4
Dryland agriculture and plantations	-4	-4	-4	-4	-1	-1	-1
Intensive uses	-4	-4	-4	-4	-4	-4	-4
Irrigated agriculture and plantations	-4	-4	-4	-4	-1	-1	-1
Production from natural environments	-4	-4	-4	-4	-1	-1	-1
Water and wetlands	-4	-4	-4	-4	-1	-4	-4
Change in dominant vegetation types occupied							
Black box woodland	-4	-4	-4	-4	-1	-1	-4
Lignum shrubland	-4	-4	-4	-4	1	1	4
Perennial wetland GRS	-4	-4	-4	-4	-1	-1	-1
RRG forest	-4	-4	-4	-4	-1	-1	-1
RRG woodland	-4	-4	-4	-4	-1	-1	-1
Terrestrial grasslands	-4	-4	-4	-4	-4	-4	-4
Terrestrial shrublands	-4	-4	-4	-4	-4	-4	-4
Terrestrial woodlands	-4	-4	-4	-4	-4	-4	-4
Wetland herblands	-4	-4	-4	-4	-4	-4	-4
Saline wetlands	0	0	0	0	-4	-4	-4
Changes in dominant wetland classes occupied							
Claypan	-4	-4	-4	-4	-1	-1	-1

Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	-4	-4	-4	-4	-4	-4	-4
Freshwater herbaceous	-4	-4	-4	-4	-1	-1	-1
Permanent herbaceous	-4	-4	-4	-4	1	0	1
Permanent waterbody	-4	-4	-4	-4	-1	-1	-1
Permanent wetland	-4	-4	-4	-4	-4	-4	-4
Saline herbaceous	0	0	0	0	-4	-4	-4
Temporary herbaceous	-4	-4	-4	-4	-1	-1	-1
Temporary shrubland	-4	-4	-4	-4	1	1	1
Temporary waterbody	-4	-4	-4	-4	-4	-4	-4
Temporary wetland	-4	-4	-4	-4	1	1	1
Temporary woodland	-4	-4	-4	-4	-1	-4	-4
Unspecified river	-4	-4	-4	-4	0	0	0
Waterhole	-4	-4	-4	-4	0	0	0
Overall	**-136**	**-136**	**-136**	**-136**	**-46**	**-45**	**-46**

Table A2.4. Consequence scores for each criterion for each project area catchment for Phyla.

Criteria	**Murray**	**Murrumbidgee**
Weed of national significance		
Regional Weed Priority		1
Impacts to fauna		
Impacts to vegetation	2	2
Impacts to humans/infrastructure	2	2
Impacts to agriculture	2	2
Other impacts	2	2
Overall	***8***	***9***

Tda species

Table A2.5. Likelihood scores for each criterion under each scenario for Tda species

Criteria	Murray				Murrumbidgee		
	Y2D25	Y30D30	Y40D40	Y45D40	32GL	36GL	40GL
Change in total habitat							
Change in suitable habitat	-8	-8	-8	-8	-8	-8	-8
Change in highly suitable habitat	-16	-16	-16	-16	-4	-4	-4
Change in dominant land uses occupied							
Conservation and natural environments	-4	-4	-4	-4	-1	0	0
Dryland agriculture and plantations	-4	-4	-4	-4	-1	-1	-1
Intensive uses	-4	-4	-4	-4	-1	-1	-1
Irrigated agriculture and plantations	-4	-4	-4	-4	-1	1	-1
Production from natural environments	-4	-4	-4	-4	-1	4	1
Water and wetlands	-4	-4	-4	-4	-1	-1	-1
Change in dominant vegetation types occupied							
Black box woodland	0	0	0	0	0	0	0
Lignum shrubland	0	0	0	0	0	0	0
Perennial wetland GRS	-4	-4	-4	-4	0	0	0
RRG forest	-4	-4	-4	-4	-1	1	1
RRG woodland	-4	-4	-4	-4	0	4	4
Terrestrial grasslands	-4	-4	-4	-4	-1	0	-1
Terrestrial shrublands	0	0	0	0	0	0	0
Terrestrial woodlands	-4	-4	-4	-4	-1	-1	-1
Wetland herblands	-4	-4	-4	-4	0	0	0
Saline wetlands	0	0	0	0	0	0	0

Changes in dominant wetland classes occupied							
Claypan	-4	-4	-4	-4	0	0	1
Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	0	0	0	0	0	0	0
Freshwater herbaceous	-4	-4	-4	-4	0	0	0
Permanent herbaceous	-4	-4	-4	-4	0	0	0
Permanent waterbody	-4	-4	-4	-4	0	-1	-1
Permanent wetland	-4	-4	-4	-4	0	1	1
Saline herbaceous	0	0	0	0	0	0	0
Temporary herbaceous	-4	-4	-4	-4	0	0	0
Temporary shrubland	0	0	0	0	0	0	0
Temporary waterbody	-4	-4	-4	-4	0	4	0
Temporary wetland	0	0	0	0	0	0	0
Temporary woodland	-4	-4	-4	-4	0	0	0
Unspecified river	0	0	0	0	0	0	0
Waterhole	0	0	0	0	0	0	0
Overall	**-104**	**-104**	**-104**	**-104**	**-21**	**-2**	**-11**

Salix (Tda)

Table A2.6. Likelihood scores for each criterion under each scenario for Salix.

	Murray				**Murrumbidgee**		
Criteria	**Y2D25**	**Y30D30**	**Y40D40**	**Y45D40**	**32GL**	**36GL**	**40GL**
Change in total habitat							
Change in suitable habitat	-8	-8	-8	-8	4	-8	-8
Change in highly suitable habitat	4	4	4	4	4	-4	-4
Change in dominant land uses occupied							
Conservation and natural environments	-4	-4	-4	-4	0	-1	-1
Dryland agriculture	-4	-4	-4	-4	1	-1	-1

and plantations							
Intensive uses	-4	-4	-4	-4	1	0	0
Irrigated agriculture and plantations	-4	-4	-4	-4	1	-1	-1
Production from natural environments	-4	-4	-4	-4	1	-1	-1
Water and wetlands	-4	-4	-4	-4	1	-1	-1
Change in dominant vegetation types occupied							
Black box woodland	0	0	0	0	0	0	0
Lignum shrubland	0	0	0	0	0	0	0
Perennial wetland GRS	-4	-4	-4	-4	0	0	0
RRG forest	-4	-4	-4	-4	1	-1	-1
RRG woodland	-4	-4	-4	-4	1	-1	-1
Terrestrial grasslands	-4	-4	-4	-4	1	-4	-4
Terrestrial shrublands	0	0	0	0	0	0	0
Terrestrial woodlands	-4	-4	-4	-4	1	1	1
Wetland herblands	-4	-4	-4	-4	0	0	0
Saline wetlands	0	0	0	0	0	0	0
Changes in dominant wetland classes occupied							
Claypan	-4	-4	-4	-4	1	-1	-1
Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	0	0	0	0	0	0	0
Freshwater herbaceous	-4	-4	-4	-4	0	0	0
Permanent herbaceous	-4	-4	-4	-4	0	0	0
Permanent waterbody	-4	-4	-4	-4	1	-4	-4
Permanent wetland	-4	-4	-4	-4	-1	-1	-1
Saline herbaceous	0	0	0	0	0	0	0
Temporary herbaceous	-4	-4	-4	-4	0	0	0
Temporary shrubland	0	0	0	0	0	0	0
Temporary waterbody	-4	-4	-4	-4	0	0	0
Temporary wetland	0	0	0	0	0	0	0

Temporary woodland	-4	-4	-4	-4	0	-4	-4
Unspecified river	0	0	0	0	0	0	0
Waterhole	0	0	0	0	0	0	0
Overall	**-84**	**-84**	**-84**	**-84**	**18**	**-32**	**-32**

Table A2.7. Consequence scores for each criterion for each project area catchment for Salix.

Criteria	**Murray**	**Murrumbidgee**
Weed of national significance	10	10
Regional Weed Priority	2	2
Impacts to fauna	2	2
Impacts to vegetation	2	2
Impacts to humans/infrastructure		
Impacts to agriculture		
Other impacts	2	2
Overall	***18***	***18***

Tdr species

Table A2.8. Likelihood scores for each criterion under each scenario for Tdr species.

	Murray				**Murrumbidgee**		
Criteria	**Y2D25**	**Y30D30**	**Y40D40**	**Y45D40**	**32GL**	**36GL**	**40GL**
Change in total habitat							
Change in suitable habitat	8	8	8	8	-8	-8	-8
Change in highly suitable habitat	0	0	0	0	-16	-16	-16
Change in dominant land uses occupied							
Conservation and natural environments	4	4	4	4	-1	-1	-1
Dryland agriculture and plantations	4	4	4	4	-1	-1	-1
Intensive uses	4	4	4	4	-1	-1	-1
Irrigated agriculture	4	4	4	4	-1	-1	-1

and plantations							
Production from natural environments	4	4	4	4	-1	-1	-1
Water and wetlands	4	4	4	4	-1	-1	-1
Change in dominant vegetation types occupied							
Black box woodland	4	4	4	4	-1	-1	-1
Lignum shrubland	4	4	4	4	-1	-1	-1
Perennial wetland GRS	4	4	4	4	-1	-1	-1
RRG forest	4	4	4	4	-1	-1	-1
RRG woodland	4	4	4	4	-1	-1	-1
Terrestrial grasslands	4	4	4	4	-1	-1	-1
Terrestrial shrublands	4	4	4	4	-4	-1	-4
Terrestrial woodlands	4	4	4	4	-1	-1	-1
Wetland herblands	4	4	4	4	0	-1	0
Saline wetlands	4	4	4	4	-1	-1	-1
Changes in dominant wetland classes occupied							
Claypan	4	4	4	4	-1	-1	-1
Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	4	4	4	4	4	4	4
Freshwater herbaceous	4	4	4	4	-1	-1	-4
Permanent herbaceous	4	4	4	4	0	0	-4
Permanent waterbody	4	4	4	4	-1	-1	-4
Permanent wetland	4	4	4	4	-1	-1	-4
Saline herbaceous	4	4	4	4	0	0	0
Temporary herbaceous	4	4	4	4	-1	-1	-4
Temporary shrubland	4	4	4	4	0	0	0
Temporary waterbody	4	4	4	4	1	-4	-4
Temporary wetland	4	4	4	4	-1	4	-4
Temporary woodland	4	4	4	4	-1	-4	-4
Unspecified river	4	4	4	4	0	0	0
Waterhole	4	4	4	4	0	0	0
Overall	**128**	**128**	**128**	**128**	**-44**	**-45**	**-71**

Rubus (Tdr)

Table A2.9. Likelihood scores for each criterion under each scenario for Rubus.

	Murray				Murrumbidgee		
Criteria	Y2D25	Y30D30	Y40D40	Y45D40	32GL	36GL	40GL
Change in total habitat							
Change in suitable habitat	8	8	8	8	2	2	2
Change in highly suitable habitat	16	16	16	16	-4	-4	-4
Change in dominant land uses occupied							
Conservation and natural environments	-4	-4	-4	-4	0	-1	-1
Dryland agriculture and plantations	4	4	4	4	-1	-1	-1
Intensive uses	4	4	4	4	-1	-1	-1
Irrigated agriculture and plantations	4	4	4	4	-1	-1	-1
Production from natural environments	4	4	4	4	-1	-1	-1
Water and wetlands	-4	-4	-4	-4	-1	-1	-1
Change in dominant vegetation types occupied							
Black box woodland	0	0	0	0	0	0	0
Lignum shrubland	0	0	0	0	0	0	0
Perennial wetland GRS	1	1	1	4	0	0	0
RRG forest	1	1	1	1	-1	-1	-1
RRG woodland	4	4	4	4	-1	-1	-1
Terrestrial grasslands	4	4	4	4	-1	-1	-1
Terrestrial shrublands	-4	-4	-4	-4	0	0	0
Terrestrial woodlands	0	0	0	0	-1	-1	-1
Wetland herblands	4	4	4	4	-1	-1	-1
Saline wetlands	0	0	0	0	0	0	0
Changes in dominant wetland classes occupied							
Claypan	4	4	4	4	-1	-1	-1

Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	0	0	0	0	0	0	0
Freshwater herbaceous	1	1	1	1	0	0	0
Permanent herbaceous	4	4	4	4	0	0	0
Permanent waterbody	-4	-4	-4	-4	-1	-1	-1
Permanent wetland	4	4	4	4	-1	-1	-1
Saline herbaceous	0	0	0	0	0	0	0
Temporary herbaceous	4	4	4	4	-4	-1	-1
Temporary shrubland	0	0	0	0	0	0	0
Temporary waterbody	4	4	4	4	0	0	0
Temporary wetland	0	0	0	0	0	-4	-4
Temporary woodland	4	4	4	4	0	-1	-1
Unspecified river	0	0	0	0	0	0	0
Waterhole	0	0	0	0	0	0	0
Overall	**63**	**63**	**63**	**66**	**-19**	**-22**	**-22**

Table A2.10. Consequence scores for each criterion for each project area catchment for Rubus.

Criteria	**Murray**	**Murrumbidgee**
Weed of national significance	10	10
Regional Weed Priority	1	1
Impacts to fauna	2	2
Impacts to vegetation	2	2
Impacts to humans/infrastructure		
Impacts to agriculture	2	2
Other impacts		
Overall	***17***	***17***

Marrubium (Tdr)

Table A2.11. Likelihood scores for each criterion under each scenario for Marrubium.

Criteria	Murray				Murrumbidgee		
	Y2D25	Y30D30	Y40D40	Y45D40	32GL	36GL	40GL
Change in total habitat							
Change in suitable habitat	8	8	8	8	-2	2	2
Change in highly suitable habitat	16	16	16	16	0	0	0
Change in dominant land uses occupied							
Conservation and natural environments	4	-4	-4	-4	1	1	1
Dryland agriculture and plantations	-4	-4	-4	-4	-1	1	1
Intensive uses	-4	-4	-4	-4	-1	-1	-1
Irrigated agriculture and plantations	-4	-4	-4	-4	-1	1	0
Production from natural environments	-4	-4	-4	-4	-1	1	1
Water and wetlands	-4	-4	-4	-4	1	1	1
Change in dominant vegetation types occupied							
Black box woodland	-4	-4	-4	-4	4	1	-1
Lignum shrubland	-4	-4	-4	-4	0	0	0
Perennial wetland GRS	-4	-4	-4	-4	1	1	1
RRG forest	-4	-4	-4	-4	-1	1	1
RRG woodland	-4	-4	-4	-4	-1	-1	-1
Terrestrial grasslands	-4	-4	-4	-4	0	1	1
Terrestrial shrublands	-4	-4	-4	-4	0	0	-4
Terrestrial woodlands	-4	-4	-4	-4	-1	-1	-1
Wetland herblands	4	4	4	4	4	4	4
Saline wetlands	0	0	0	0	0	0	0
Changes in dominant wetland classes occupied							
Claypan	4	4	4	4	-1	1	1

Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	-4	-4	-4	-4	4	4	4
Freshwater herbaceous	4	4	4	4	4	4	4
Permanent herbaceous	4	4	4	4	0	0	0
Permanent waterbody	-4	-4	-4	-4	1	1	1
Permanent wetland	-4	-4	-4	-4	1	1	1
Saline herbaceous	0	0	0	0	0	0	0
Temporary herbaceous	-4	-4	-4	-4	-1	1	1
Temporary shrubland	0	0	0	0	0	0	0
Temporary waterbody	-1	4	4	4	0	4	4
Temporary wetland	0	0	0	0	0	0	4
Temporary woodland	-4	-4	-4	-4	-1	1	1
Unspecified river	0	0	0	0	0	0	0
Waterhole	-4	-4	-4	-4	0	0	0
Overall	**92**	**98**	**100**	**106**	**9**	**29**	**26**

Lycium (Tdr)

Table A2.12. Likelihood scores for each criterion under each scenario for Lycium.

	Murray				**Murrumbidgee**		
Criteria	**Y2D25**	**Y30D30**	**Y40D40**	**Y45D40**	**32GL**	**36GL**	**40GL**
Change in total habitat							
Change in suitable habitat	8	8	8	8	8	8	8
Change in highly suitable habitat	16	16	16	16	16	16	16
Change in dominant land uses occupied							
Conservation and natural environments	4	4	4	4	4	4	4
Dryland agriculture	4	4	4	4	1	1	1

and plantations							
Intensive uses	-4	-4	-4	-4	-1	-1	-1
Irrigated agriculture and plantations	1	1	1	1	4	4	4
Production from natural environments	4	4	4	4	1	1	1
Water and wetlands	4	4	4	4	1	4	4
Change in dominant vegetation types occupied							
Black box woodland	4	4	4	4	4	4	4
Lignum shrubland	4	4	4	4	1	-1	-1
Perennial wetland GRS	-4	-4	-4	-4	-1	-1	-4
RRG forest	4	4	4	4	1	1	1
RRG woodland	4	4	4	4	-1	-1	-1
Terrestrial grasslands	4	4	4	4	1	1	1
Terrestrial shrublands	4	4	4	4	4	4	4
Terrestrial woodlands	-4	-4	-4	-4	-1	1	1
Wetland herblands	4	4	4	4	4	4	4
Saline wetlands	0	0	0	0	0	0	0
Changes in dominant wetland classes occupied							
Claypan	4	4	4	4	1	1	1
Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	4	4	4	4	4	4	4
Freshwater herbaceous	4	4	4	4	-4	-4	-4
Permanent herbaceous	-1	-1	-4	-4	0	4	0
Permanent waterbody	4	4	4	4	-1	-1	-1
Permanent wetland	4	4	4	4	-1	1	4
Saline herbaceous	0	0	0	0	4	4	4
Temporary herbaceous	1	1	1	1	-1	4	1
Temporary shrubland	4	4	4	4	4	4	4
Temporary waterbody	4	4	4	4	4	4	4
Temporary wetland	4	4	4	4	0	-4	-4

Temporary woodland	4	4	4	4	4	4	4
Unspecified river	4	4	4	4	0	0	0
Waterhole	4	4	4	4	0	0	0
Overall	**101**	**101**	**98**	**98**	**60**	**70**	**63**

Table A2.13. Consequence scores for each criterion for each project area catchment for Lycium.

Criteria	**Murray**	**Murrumbidgee**
Weed of national significance	10	10
Regional Weed Priority	1	1
Impacts to fauna	2	2
Impacts to vegetation	2	2
Impacts to humans/infrastructure		
Impacts to agriculture	2	2
Other impacts		
Overall	***17***	***17***

Xanthium (Tdr)

Table A2.14. Likelihood scores for each criterion under each scenario for Xanthium.

	Murray				**Murrumbidgee**		
Criteria	**Y2D25**	**Y30D30**	**Y40D40**	**Y45D40**	**32GL**	**36GL**	**40GL**
Change in total habitat							
Change in suitable habitat	8	8	8	8	-2	-2	-2
Change in highly suitable habitat	16	16	16	16	-4	-4	-4
Change in dominant land uses occupied							
Conservation and natural environments	4	4	4	4	-1	-1	-1
Dryland agriculture and plantations	4	4	4	4	-1	-1	-1
Intensive uses	4	4	4	4	-1	-1	-1
Irrigated agriculture and plantations	4	4	4	4	-1	-1	-1
Production from natural environments	4	4	4	4	-1	-1	-1

Water and wetlands	1	1	1	1	-1	-1	-1
Change in dominant vegetation types occupied							
Black box woodland	4	4	4	4	-1	-1	-1
Lignum shrubland	4	4	4	4	-4	-4	-4
Perennial wetland GRS	-4	-4	-4	-4	-4	-1	-1
RRG forest	4	4	4	4	-1	-1	-1
RRG woodland	4	4	4	4	-1	-1	-1
Terrestrial grasslands	4	4	4	4	-1	-1	-1
Terrestrial shrublands	4	4	4	4	0	0	0
Terrestrial woodlands	4	4	4	4	-1	-1	-1
Wetland herblands	4	4	4	4	-1	-1	-1
Saline wetlands	0	0	0	0	0	0	0
Changes in dominant wetland classes occupied							
Claypan	4	4	4	4	-1	-1	-1
Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	4	4	4	4	0	0	0
Freshwater herbaceous	4	4	4	4	0	0	0
Permanent herbaceous	4	4	4	4	0	0	0
Permanent waterbody	-1	-1	-1	-1	-4	-1	-1
Permanent wetland	4	4	4	4	-1	-1	-1
Saline herbaceous	0	0	0	0	0	0	0
Temporary herbaceous	-4	-4	-4	-4	-1	-1	-1
Temporary shrubland	4	4	4	4	0	0	0
Temporary waterbody	1	-1	-1	-1	-1	-1	-1
Temporary wetland	-4	-4	-4	-4	-1	-1	-1
Temporary woodland	4	4	4	4	-1	-1	-1
Unspecified river	0	-4	-4	-4	0	0	0
Waterhole	-4	-4	-4	-4	0	0	0
Overall	**89**	**83**	**83**	**83**	**-36**	**-30**	**-30**

Table A2.15. Consequence scores for each criterion for each project area catchment for Xanthium

Criteria	Murray	Murrumbidgee
Weed of national significance		
Regional Weed Priority	1	1
Impacts to fauna	2	2
Impacts to vegetation	2	2
Impacts to humans/infrastructure	2	2
Impacts to agriculture	2	2
Other impacts		
Overall	***9***	***9***

Weed hotspots

Table A2.16. Likelihood scores for each criterion under each scenario for weed hotspots.

	Murray				Murrumbidgee		
Criteria	**Y2D25**	**Y30D30**	**Y40D40**	**Y45D40**	**32GL**	**36GL**	**40GL**
Change in total habitat							
Change in suitable habitat	-8	-8	-8	-8	-2	-2	-2
Change in dominant land uses occupied							
Conservation and natural environments	4	-4	-4	-4	0	0	0
Dryland agriculture and plantations	-4	-4	-4	-4	0	0	0
Intensive uses	-4	-4	-4	-4	0	0	0
Irrigated agriculture and plantations	-4	-4	-4	-4	0	0	0
Production from natural environments	-4	-4	-4	-4	0	0	0
Water and wetlands	-4	-4	-4	-4	0	0	0
Change in dominant vegetation types occupied							
Black box woodland	-4	-4	-4	-4	0	0	0
Lignum shrubland	-4	-4	-4	-4	0	0	0
Perennial wetland GRS	-4	-4	-4	-4	0	0	0
RRG forest	-4	-4	-4	-4	0	0	0
RRG woodland	-4	-4	-4	-4	0	0	0

Terrestrial grasslands	-4	-4	-4	-4	0	0	0
Terrestrial shrublands	-4	-4	-4	-4	0	0	0
Terrestrial woodlands	0	-4	-4	0	0	0	0
Wetland herblands	4	4	4	4	0	0	0
Saline wetlands	0	0	0	0	0	0	0
Changes in dominant wetland classes occupied							
Claypan	4	4	4	0	0	0	0
Floodplain shrubland	0	0	0	0	0	0	0
Floodplain woodland	-4	-4	-4	-4	0	0	0
Freshwater herbaceous	4	4	4	4	0	0	0
Permanent herbaceous	4	4	4	4	0	0	0
Permanent waterbody	-4	-4	-4	-4	0	0	0
Permanent wetland	-4	-4	-4	-4	0	0	0
Saline herbaceous	0	0	0	0	0	0	0
Temporary herbaceous	-4	-4	-4	-4	0	0	0
Temporary shrubland	0	0	0	0	0	0	0
Temporary waterbody	-1	4	4	4	0	0	0
Temporary wetland	0	0	0	0	0	0	0
Temporary woodland	-4	-4	-4	-4	0	0	0
Unspecified river	0	0	0	0	0	0	0
Waterhole	-4	-4	-4	-4	0	0	0
Overall	**-61**	**-68**	**-68**	**-68**	**-2**	**-2**	**-2**