What is your state of vulnerability to climate change? Biosecurity and weed threats to New South Wales primary industries

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Summary Climate change in Australia is likely to result in increased temperatures, changes in rainfall patterns and a higher frequency of extreme climate events. An extensive review of 3280+ papers for the key terms 'climate change modelling' found that only 24 specifically examined weeds, almost all relevant to New South Wales (NSW) (Darbyshire *et al.* 2022). Based on these findings, the NSW Department of Primary Industries Vulnerability Assessment project is developing a series of Multi-Criteria Analysis (MCA) models to investigate the impact of climate change on two significant weeds, serrated tussock and parthenium weed.

Published literature and expert opinion were used to inform the development of these models. The process identified the key climatic variables (e.g. temperature, rain) for each life stage in the growth cycle. This data was then used to create the MCA hierarchical structure that underpins the climate suitability model. The model captures the extent to which the climate conditions satisfy seedling and reproductive growth requirements without considering other factors like management decisions, soil, and irrigation. The climate suitability was then mapped for NSW using historical climate data from 1970 to 2019 (50-years). The maps indicate areas of high and low climate suitability for the weeds. Data was extracted for incursion sites and established areas allowing the user to view the annual changes in climate suitability in NSW to validate the model.

Current and future state-wide climate suitability maps will be used to identify research, management and adaptation priorities that can be used strategically by industry, government and community to enhance weed risk assessment and management in NSW.

Keywords Impact Assessment, serrated tussock, *Nassella trichotoma*.

INTRODUCTION

Australian primary producers operate in some of the worlds most naturally variable climates. Climate change has increased this variability, particularly with elevated temperatures and changed rainfall patterns (BoM 2022). Assessing the vulnerability of primary industries to future biosecurity/weed threats will be critical for adaptation and management.

We assessed the impacts of these threats on primary industries through a peer-reviewed (journal-only) literature search of 3280+ papers (Darbyshire *et al.* 2022). This search identified 188 relevant papers. Of the 55 papers that examined biosecurity, 24 specifically examined weeds, and almost all were relevant to New South Wales (NSW).

A second, broader review of weed species impacts on NSW was conducted (n=230+ papers). We know that NSW has 1750+ naturalised plant species, and many other non-naturalised plants (Johnson 2013). While the current/future habitat suitability of plant species is increasingly well known (e.g. the 700+ species listed at Weed Futures 2022), the degree to which their habitat suitability coincides with primary industry areas is largely unknown. We sought to partly address this as part of a broader agency study to examine the vulnerability of NSW primary industries to changing climate conditions. Two weeds: serrated tussock (*Nassella trichotoma* (Nees) Hack. ex Arechav.). and parthenium weed (*Parthenium hysterophorus* L. among 12 other biosecurity threats), were selected for their relevance to livestock and cropping commodities in the broader study. This paper reports only on the MCA model and outcomes for serrated tussock.

PROJECT BACKGROUND

This project forms part of the NSW Primary Industries Climate Change Research Strategy (CCRS) (NSW DPI 2022), an investment of $29.2 M in projects to support the State's primary industries sector to find mitigation and adaptation strategies for primary producers to climate change. Part of this strategy is the Vulnerability Assessment (VA) project which aims to deliver a consistent and state-wide understanding of climate change risks and adaptation options for a broad range of industries and some of the biosecurity risks threatening them. The

VA project will provide strategic information for policy-makers, the government and the community.

MATERIALS AND METHODS

Climate suitability This was determined using a Multi-Criteria Analysis (MCA) modelling approach. The methodology was used across 28 primary industry commodities and 14 biosecurity threats. While further details of MCA are outlined elsewhere (Saaty 1978, Romeijn *et al.* 2016); a key component is the use of an expert panel/focus group. This group critiqued the criteria within the MCA hierarchy and set the variable weightings, reflecting the importance of the variable to the weed species. Weightings are applied to each element of the model, such that each level of the model hierarchy is calculated as the weighted sum of elements in the level below. The model weightings were determined through a standard analytic hierarchy process (Saaty 1978).

Serrated tussock Serrated tussock is a Weed of National Significance. It is an invasive perennial grass weed that invades cool-season and temperate grasslands. Often forming near monocultures it reduces pasture productivity and palatability, and hence animal carrying capacity (Weeds Australia 2022). It contaminates meat, hides and wool. It readily invades both disturbed pastoral and threatened grassland ecosystems threatening non and endangered plant and animal species (Coutts-Smith and Downey 2006), ecosystem structure and function. Further, serrated tussock and similar grasses reduce community resilience. The costs associated with managing these species and their spread result in a loss of services and facilities, and human and social capital.

Serrated tussock MCA An MCA was designed to reflect the variables that influence the climate suitability of serrated tussock in NSW. This MCA used a range of national and international literature (e.g. Kriticos *et al.* 2004, Millar *et al.* 2016, Humphries *et al.* 2018, Ruttledge *et al.* 2020) and focus group observations where data was deficient. Due to Covid-19, an online focus group (see acknowledgements for membership) was convened after the initial MCA structure was designed.

The focus group recommended structural changes to the serrated tussock MCA, climate range threshold values, and participated in the analytic hierarchy process to weight the MCA variables. The final MCA structure is illustrated and was run seasonally (i.e. 3-monthly, Figure 1). It contains only the critical seedling and reproductive growth lifecycle stage arms, with the seedling arm further broken down into sub-component Establishment and Survival stages. The impact of mean temperature and cumulative rainfall on the two seedling stages is expressed in a four (rainfall) x five (temperature) matrix for each of these stages (not illustrated). Similar temperature and rainfall categories were used in the reproductive growth stage. Hot 'bombs' were employed as biological species limits.

The MCA model outputs were iteratively checked and reviewed by the VA team and focus group participants to explore and examine the implications of the MCA structure and consider whether the MCA variables and resulting output were consistent with expert knowledge.

Interpreting model outputs The serrated tussock MCA is a *climate suitability* model. *Climate suitability* is derived from climate data as a unitless index scaled between zero and one. *Climate suitability* is defined as the extent to which climate conditions satisfy the requirements of plant or animal growth without considering other limiting factors. The MCA does not account for a range of factors, including management decisions, soil, irrigation, topography and climatic extremes (e.g. drought, bushfires, flooding, hail, and consecutive hot or cold days unless specified). *Climate suitability* allows us to determine the weather conditions that are highly unfavourable (0) through to highly favourable (1) for serrated tussock growth (Figure 2). Sub-optimal conditions do not mean that the weed cannot grow, only that these conditions are less suitable.

Climate suitability results were mapped for each season (i.e. summer, autumn, winter and spring). Climate suitability was considered spatially across NSW for the years 1970 to 2019. The invaded sites were predominantly higher rainfall (600+ mm mean annual), cool temperate pasture/grazing sites, including Armidale (Northern Tablelands); Orange (Central Tablelands); Yass (Southern Tablelands/South-Western Slopes), and Young (Central Western Slopes). Three outlier sites: Tibooburra, Alstonville, and Tumbarumba were used to check model calibration. These sites were selected because Tibooburra best represents a "hot/dry extreme" area, Alstonville a "warm/wet extreme area" and Tumbarumba a "cold extreme" area.

RESULTS AND DISCUSSION

Weightings in the serrated tussock MCA model Conditions at the seedling lifecycle stage were weighted heavily at 0.88 (out of 1) as seedling growth contributed a large amount to successful serrated tussock invasion (Figure 1). Reproductive growth was weighted far lower at 0.12. The overall seedling stage was composed of two sub-components, establishment (0.13) and survival

(0.87). The substantial differences between the seedling survival and establishment ratings reflects the relative importance of the survival lifecycle stage (and sub-component) to the serrated tussock MCA model and the invasion success (Figure 2).

Validation of the historic serrated tussock MCA outputs, and future projections The historical analysis was carefully validated by analysing climate data at previous invaded and non-invaded areas from 1970 to 2019. The accuracy of these historical analyses provide confidence in the models performance to which we are now applying climate projection data (from 2036 to 2065, centered on 2050). These projection layers will be overlaid with areas of potentially impacted primary industries, particularly high rainfall pastures, mixed cropping/grazing pasture systems, sheep and cattle production based on these systems, and select horticultural industries, to assess future interactions between the weed and production systems.

Serrated tussock MCA model outputs Historic climate suitability for serrated tussock in NSW extends throughout the Northern, Central, and Southern Tablelands (Figure 2). These areas include high-value pasture and wool production systems. Suitability extends to the South Coast (southern polygon) and to higher altitude parts of the North Western, Central Western, and South Western Slopes (west of the polygons). These areas are part of the highly productive mixed wheat-sheep zone. The area between the two polygons (the Hunter Valley to the east and west of Tamworth) are active invasion fronts (Auld and Johnson 2014, ALA 2022). In contrast, much of western NSW is of lower suitability.

There is an area of relatively high suitability to the west of Kosciuszko National Park (KNP) and Tumbarumba. The Tumbarumba area is a high-value mosaic-area of horticultural crops interspersed with forestry (pine) and high rainfall cattle grazing. There are almost no records of serrated tussock from KNP, east of Tumbarumba but west of the boundary of the southern polygon. This cannot easily be explained because of the suitability of similar invaded areas around Yass, and into the Australian Capital Territory) and that the weed has had 80+ years to spread from Yass where it was first identified in 1937 from over 20,000 ha (Blackmore 2019).

IMPLICATIONS – HISTORICAL ANALYSES

Serrated tussock has a long history in NSW, with invasions in the Southern and Central Tablelands before 1937, and the Northern Tablelands before 1955 (Blackmore 2019). Despite this, the weed's continued and inevitable spread should not be

Figure 1. High-level serrated tussock MCA structure. Values denoted by 'W=' represent model weightings.

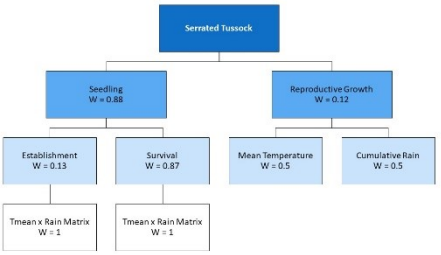
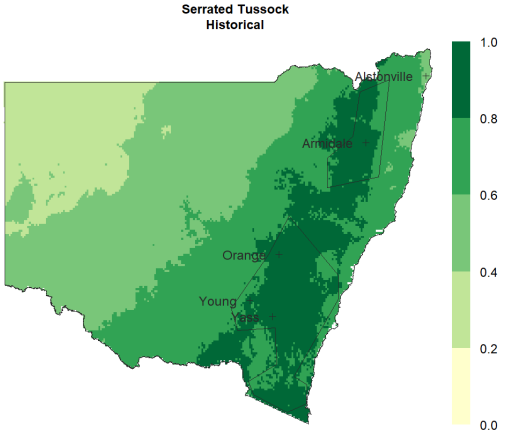


Figure 2. Average historical climate suitability for serrated tussock in NSW (1970 to 2019). The polygons enclose 95+ % of herbarium incidence data (from ALA 2022,not illustrated here). North is at the top of the map.



assumed, particularly under the combined conditions of drought, high grazing pressure, and disturbance. Various studies have indicated that the future distribution of serrated tussock will decrease within NSW and Australia (e.g. Kriticos *et al.* 2004, Watt *et al.* 2011, Gallagher *et al.* 2013, Millar *et al.* 2016, Weed Futures 2022). As such management would be best focused on eradicating outlying infestations in the Hunter, Northern Tablelands and on the North Western Slopes of NSW, and on containment further south. Opportunities also exist to revegetate both areas where serrated tussock has been managed and areas prone to invasion, particularly with more desirable and competitive native and/or exotic pasture species (while avoiding new weedy species).

More broadly, there is an opportunity to examine further weeds, and identify and examine a broader range of biosecurity threats, including possible new threats to Australian and NSW primary industries

using this method. A systematic, nation- and industry-wide analysis of impacts and adaptation activities would help prepare Australian primary industries for future biosecurity risks and management changes. Coordinated risk assessment/management and nation-building-size investment by industry, government and community will be needed.

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