Could tropical species have potential in southern Australia? Defining the potential geographical distribution of Rhodes grass in current and future climates

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Abstract: *Grazing systems in southern Australia are currently based on temperate species. Increasing climate variability and changing spatial distribution of rainfall and temperatures are impacting on these grazing systems. Climate change predictions vary, but in general they indicate that in southern Australia temperatures will increase, annual rainfall will either remain the same or decline, and the rainfall distribution will shift from winter to summer dominance. This is predicted to result in a more pronounced summer-autumn feed gap. The integration of tropical pastures into grazing systems could contribute to filling this feed gap. As part of an ongoing study, the potential distributions of a range of tropical pasture species have been modelled under current and future climate scenarios. In this paper we present our preliminary results for Rhodes grass (*Chloris gayana *Kunth). These results suggest that the potential geographical extent of Rhodes grass is large. In the current climate Rhodes grass potentially extends along the eastern side of Australia, with distribution likely to extend into higher altitude environments under future climate projections.*

Key words: CLIMEX, global climate models, CSIRO-MK 3.0, MIROC-H

Introduction

Australia's climate has warmed since 1910 and particularly since 1950 (Climate Change in Australia 2018). Average temperatures are projected to further increase by 2050 potentially ranging from 0.8–1.8°C under a low emissions scenario and from 1.5–2.8°C under a high emissions scenario (Whetton 2011). Long-term average annual rainfall across Australia has increased slightly since 1900. A decline in winter rainfall has been observed for the south-west of Australia since the 1960s, and more recently, in the south-east of Australia, autumn and winter rainfall has been below average since 1990 (Climate Change in Australia 2018). Summer rainfall during the last three decades has increased in some parts of the Northern Grains Region of Australia (Simpson *et al.* 2018). Projections for annual rainfall are that for some regions there will be little change or a decline and that the rainfall distribution will shift from winter to summer dominance (Cullen *et al.* 2009). Therefore, the integration of summer-growing perennials into farming systems could aid in overcoming the summer-autumn feed gap (Descheemaeker *et al.* 2014). Northern inland NSW was once considered to be a marginal environment for tropical species, but over recent years their persistence, productivity and ability to respond to summer rainfall has made them an important component of the feedbase (Harris *et al.* 2014; Boschma *et al.* 2017).

In 2018 a study commenced to define the potential geographical boundaries of a range of key tropical pasture species and show the extent where these species could persist in Australia in current and under future climate projections. In this paper we report preliminary results for the potential geographical boundary for Rhodes grass (*Chloris gayana* Kunth) in current and future climates as part of this ongoing study.

Methods

The CLIMEX software version 4.0.2 (Hearne Scientific Software Pty Ltd) was used to model the geographical distribution of tropical pasture species (Kriticos *et al.* 2015). This software has been used previously for modelling the distribution for a range of plant species including serrated tussock (*Nassella trichotoma*; Kriticos *et al*. 2004), buffel grass (*Cenchrus ciliaris*; Lawson *et al*. 2004) and several bioenergy crops (Barney and DiTomaso 2011). CLIMEX is a species distribution model that uses parameters to define a species potential distribution. A series of temperature, moisture and light parameters describe the species growth response. Outside these settings growth does not occur and negative growth accumulates, which is described by four stress indices and their interactions. The stress indices are set to limit a species' survival in adverse seasonal climatic conditions. Together these growth and stress parameters are used to determine the geographical distribution.

The climatic data set, CliMond CM10_1975H_V1.2 (Kriticos *et al*. 2012), was used to model the climate. This raster dataset at an approximately 18 km^2 resolution, included the variables required for the CLIMEX software including monthly averages for minimum and maximum temperatures, rainfall and relative humidity. The current climate was based on monthly averages for 1961–1990. Climate projections for 2030 (2016–2045) were generated using the A1B emission scenario, also referred to as SRES scenarios, and two global climate models (GCMs), CSIRO-MK 3.0 and MIROC-H (Kriticos *et al*. 2012).

ArcGIS™ software Version 10.6.1 was used to generate the maps. Occurrence records for each species from Atlas of Living Australia (https://www.ala.org.au/) were also mapped to support the parameter fitting. The Ecoclimatic Index (EI) presented on each map integrates the annual growth and the stress indices into a single number between one and 100. This value describes the climatic suitability of a given location to support a permanent population of the species. Values of EI close to zero indicate that the location is not favourable for the long-term survival of the species. Ecoclimatic Index values of 100 are only achievable under constant and ideal conditions comparable to those in a growth cabinet (Kriticos *et al*. 2015). In this paper an EI<10 was considered unfavourable for a species while an EI>25 represented a highly favourable climate.

Rhodes grass is native to south and east Africa in areas from 660–2160 m elevation. It has become widely naturalised across a large area of Africa, the tropics and subtropics, and many other continents including Australia (Cook *et al*. 2005). The reported broad adaptation of the species is related to the range in intra-specific variation that exists within the species. Rhodes grasses can be both diploid (2n = 20) and tetraploid (2n = 40). In general the tetraploids are more 'tropical' and originated from lower latitudes (≤20°) while the diploids are from more subtropical latitudes (≥20°) (Loch 1983; Loch *et al*. 2004). The modelled distribution in this study is for diploid rather than tetraploid-types.

In the natural range of Rhodes grass, rainfall varies from 500–1500 mm/yr. It is generally sown in areas with annual rainfall ranging 700–1200 mm, but has been successful in areas with lower rainfall (Cook *et al*. 2005). It is considered to be relatively drought tolerant and able to survive dry periods (six months) (Loch and Harvey 1999; Cook *et al*. 2005). Rhodes grass grows on a wide range of soils from sand to heavy clay, alkaline and saline soils. Soil pH commonly ranges pH 5.5–7.5, but it can grow on soils as low as pH 4.5 and as high as pH 10 (Cook *et al*. 2005). Annual average temperatures for growth range 16.5–>26°C (Cook *et al*. 2005) and 17–22°C (Russell and Webb 1976). Optimal growth has been reported to occur at 30/26–40/29°C and 34/29°C day/night temperatures (Ivory 1976; Ivory and Whiteman 1978). Extreme temperatures for growth are 5 and 50°C. Some cultivars are can survive sub-zero temperatures, but are killed by -10°C (Loch and Harvey 1999; Cook *et al*. 2005).

Results

Maps for the potential distribution of Rhodes grass in the current and future climates are presented in Figures 1 and 2. The species distribution in the current climate shows a wide adaption from northern Australia, along the length of eastern Australia, around to South Australia. Rhodes grass is also suitable for areas from the Northern Agricultural Region in Western Australia to the south coast and east of Esperance to Cape Arid National Park (Fig. 1). In southern inland NSW, Rhodes grass has potential west in longitude ranges 145–147°E, for example to Condobolin and Wagga Wagga (Fig. 1).

The potential distribution under two GCMs was modelled with results from one model presented here (Fig. 2). Using the MIROC-H map, the area suitable for Rhodes grass across northern Australia is predicted to decline. The area in southern Australia is predicted to increase, especially in the cooler, higher altitude areas such as the NSW Northern Tablelands, and from the Central Tablelands in NSW south to the southern end of the Dividing Range in Victoria, also Tasmania (Fig. 2).

Discussion

Initial results from this study show that the potential distribution of Rhodes grass extends across south eastern Australia and south Western Australia. This wide adaptation supports reported literature. Distribution is currently restricted in higher elevation areas due to cold stress. Previous field evaluation and modelling studies conducted in a range of different locations across south eastern Australia have demonstrated the potential of tropical pastures as an alternative feed source (Bell *et al.* 2013; Descheemaeker *et al.* 2014). Our preliminary results are in agreement with those locations in terms of potential suitability. This map, and those of other key species modelled in this project including digit grass (*Digitaria eriantha* Steud.) were used to identify areas in marginal environments, such as southern NSW and tablelands regions, where widely adapted species could potentially be grown. Tropical grass evaluation experiments have commenced at a number of locations, including two sites in marginal areas. As part of this ongoing project relevant field data will be collected from these species evaluations and other experiments.

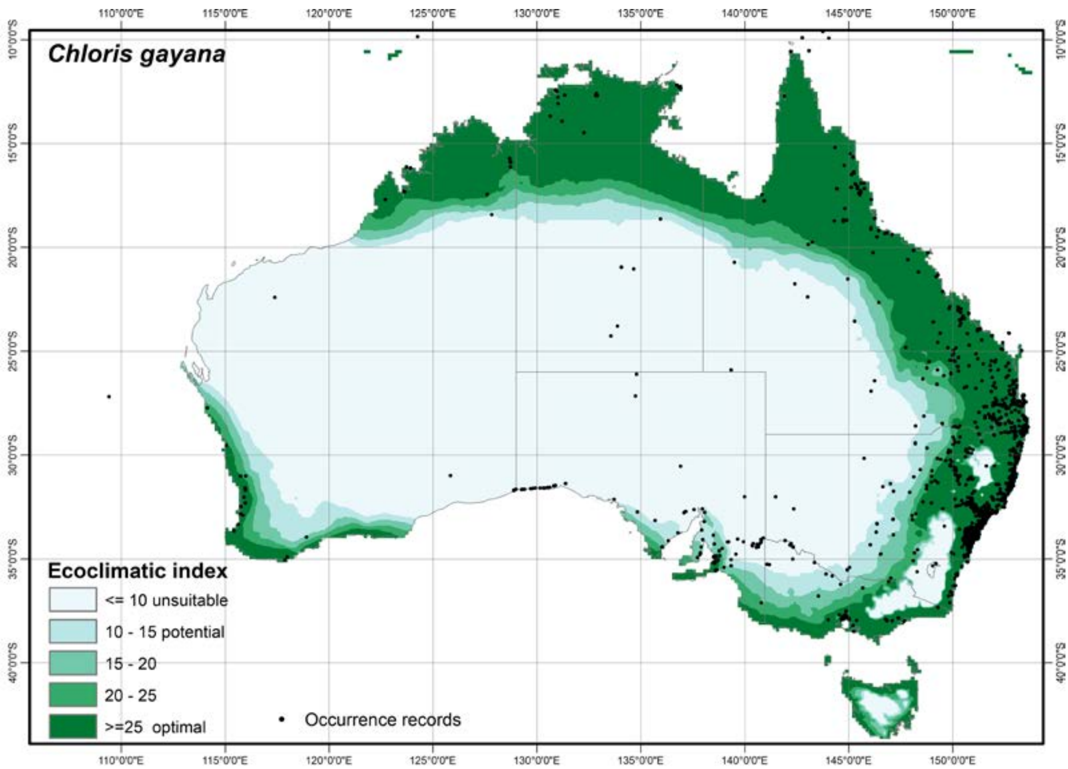

Figure 1. Potential distribution of Rhodes grass under the current climate. Dots represent *C. gayana* occurrence records from Atlas of Living Australia.

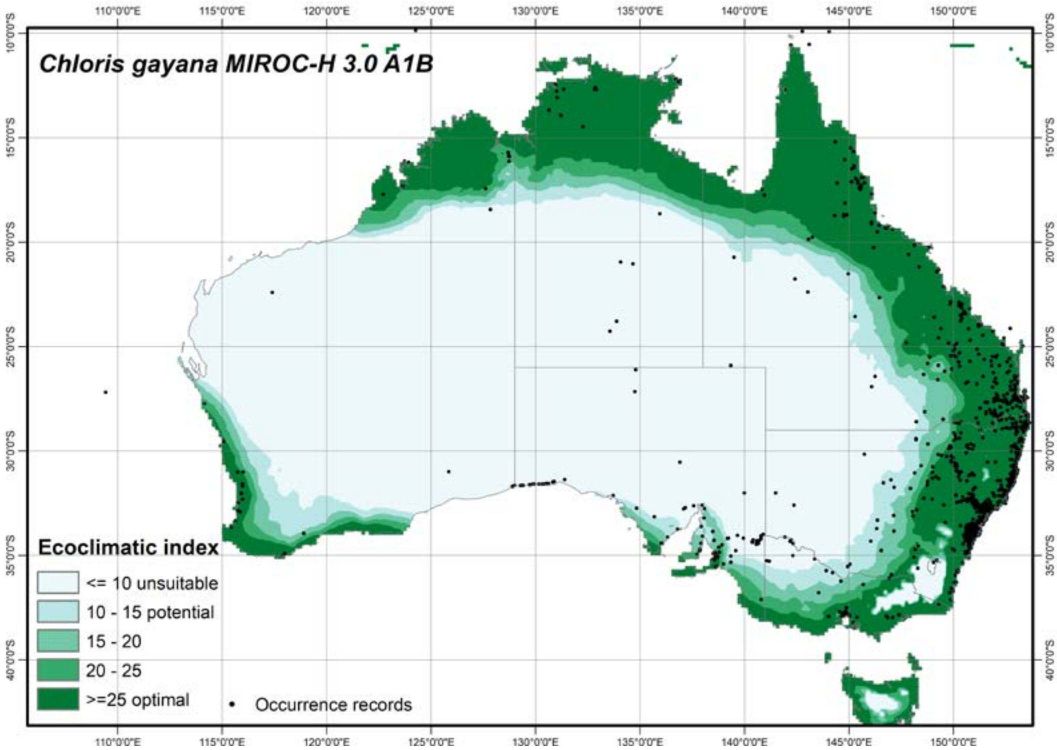

Figure 2. Projected potential distribution of Rhodes for 2030 using the MIROC-H 3.0 A1B climate projection. Dots represent *C. gayana* occurrence records from Atlas of Living Australia.

These data will be used to refine the model parameters and validate the distribution maps.

The preliminary species distributions modelled under a future climate suggest that the area suitable for Rhodes grass will increase especially in the higher elevation areas (Fig. 2). A comprehensive comparison of current and future distribution of each species will be conducted when the maps are finalised in the final year of the project.

Conclusions

Rhodes grass has potential to be a valuable pasture species in southern Australia – in both our current and projected climate. While this paper focussed on Rhodes grass, this is just one of a range of tropical pasture species that have been modelled. This is the first study to model the potential distribution under the current and a future climate for these key tropical pasture species for Australia. Spatial mapping using models such as CLIMEX can be effective to enable predictions for locations and regions where experimental data are sparse.

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