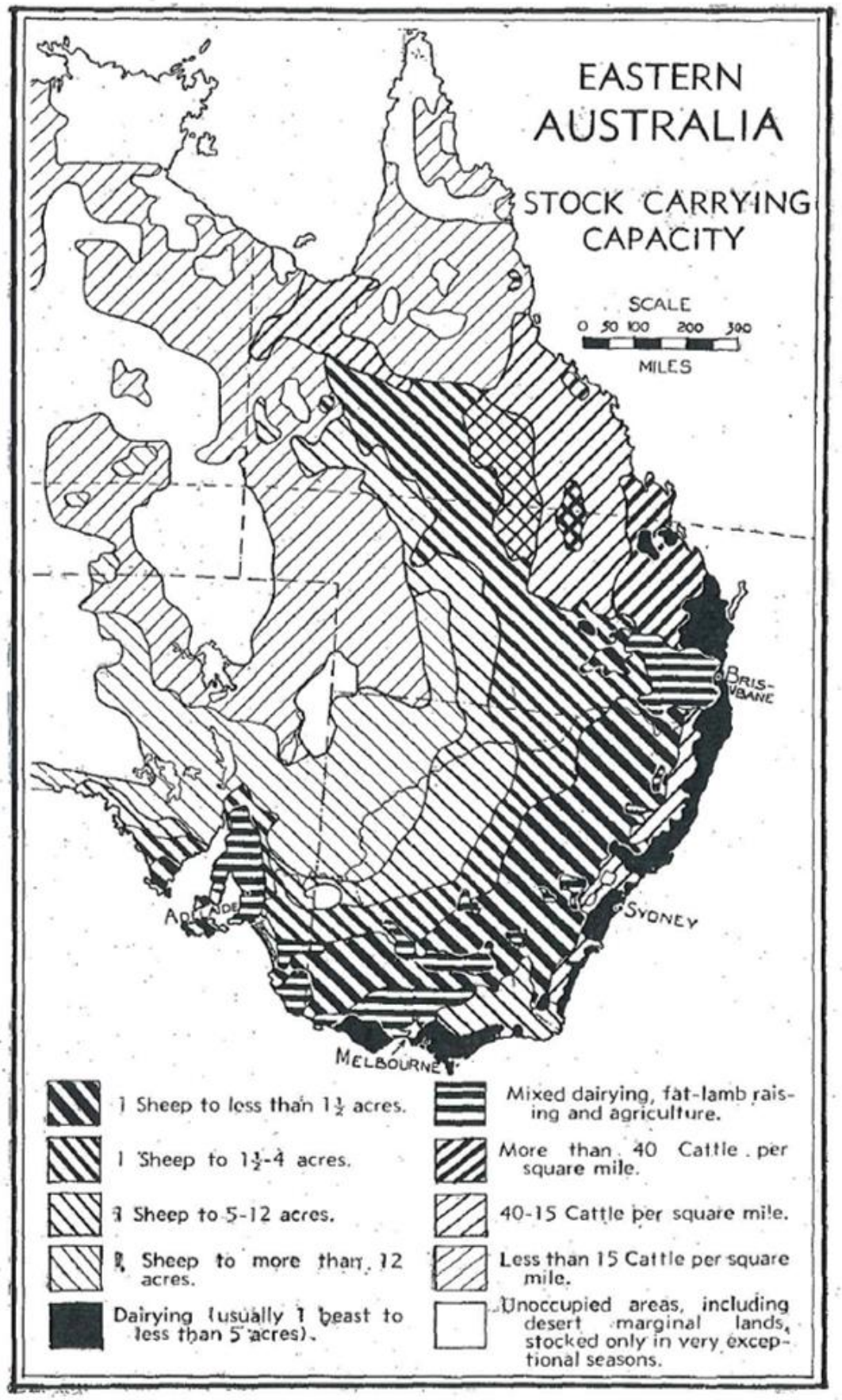
Estimating Historical Domestic Grazing Density for Australia, 1788-1980

Scott Irvine, John Carter and Grant Stone 2024

Technical Paper

Queensland Government



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Livestock density in eastern Australia as published in 1940 (Queensland, 1860-1974; 1940 p120).

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Contents

Summary

Domestic livestock statistics across all Australian jurisdictions have been collected since 1788. Cattle, sheep and horse numbers from 1788 to 1980 were digitised from paper sources. Statistical District boundaries were also digitised from mapping sources for each year and coded to link to the digitised livestock records. Estimation of pre-European vegetation, natural waters, the development of stock water areas (bores, small dams), irrigation (fodder crops and pastures) and protected areas were used to distribute livestock within each Statistical District for each year. This dataset produced at a continental scale, can be intersected with modern boundaries to produce a time-series of domestic grazing pressure, to help understand the impacts of grazing on the landscape.

Introduction

Providing an estimate to historical livestock grazing distribution within Australia will provide better understanding and background to current environmental impacts. Climate variability and grazing pressure are well documented in (McKeon *et al.* 2004a p 19), along with impacts on the Great Barrier Reef (Lewis *et al.* 2021), changes in native pasture composition (Dixon 1892; Harrington *et al.* 1979; Rolls 1981 pp 111,129), scrub and/or woody regrowth (Rolls 1981 p 185, Wilson 1990) and soil degradation (Carr and Turner 1959; Rolls 1981 pp 129, 246). This dataset will facilitate exploration of issues such as land clearing, woodland thickening and methane emissions (Hempson *et al.* 2017).

Historical geography studies of the Australian environment are often hampered due to issues of scale and the availability or consistency of information. Previous studies of past livestock grazing have focussed on individual businesses (McKeon *et al.* 2004b), or as a part of a geographical study using regional livestock numbers (Heathcote 1962a; Quinn 1995). To some extent these studies have shown the environmental and economic impacts of livestock grazing within the confines of the locale but were not able to be extended to other areas.

Information about past domestic grazing is necessary for natural resource conservation and management, contributing to improved assessment of impacts on soil and ecosystems processes, historical exposure of ecosystems to grazing, and grazing productivity (Lunt *et al.* 2007). Within Australia, information about grazing history is frequently insufficient, as it does not adequately distinguish between the impacts of past and current grazing (Lunt et al. 2007).

'Domestic livestock' within this paper refers to only horses, cattle and sheep, with feral livestock numbers not being included. The paper will use livestock as an overall term for domestic horses, cattle and sheep. Similarly the term 'Statistical District' is used for any spatial entity where livestock numbers were reported, with many such areas, especially in the 19th century, doubling as administration or juridical boundaries.

To address the gap in knowledge about Australia's grazing history, annual livestock population data that were available for all Statistical Districts were acquired and digitised. Mapping sources that showed the Statistical Districts (or similar entities) were collected and used to estimate likely spatial boundaries at the time of collection. Later, a disaggregation method was used, that apportioned the livestock population in each Statistical District in each year to likely grazing densities that would be experienced and shown as an animal equivalent estimate per square kilometre (AE km^2). This work extends the methodology used by Irvine (2016) to map livestock density for Queensland between 1860 to 1950.

This work focuses on the collection of a historical dataset published prior to 1980 and the subsequent construction of a basic grazing distribution model. This is part of an undertaking to produce a

comprehensive Australian high-resolution time series map of livestock from 1788 to 1980 for use in grazing system models such as AussieGRASS (Carter *et al.* 2000). The results document the expansion of domestic livestock, and the probable distribution since their introduction to Australia to 1980. The information will aide any investigation to past grazing distribution within any Australian study area.

Information Sources

Animal numbers for each jurisdiction were digitised from historical records (Table 1). The earliest livestock records from 1788 to 1820 were obtained from irregular dispatches from the Governors of the original settlements (Watson and Chapman 1914). From 1821 to the 1850s records were provided by the Colonial Office (see Great Britain references in Table 1), where each established jurisdiction provided a yearly report. From the 1860s all jurisdictions published annual statistics via individual periodicals.

The statistics do not indicate livestock numbers prior to the proclamation of Statistical Districts, despite evidence of pastoral activity outside these areas (Campbell 1922 p 228; King 1957 pp 45-46) and escaped cattle (Oxley 1820). However, more livestock was unaccounted for due to squatters as they later became known. As a collective, they commenced pastoral activity outside established districts without legal title, which became common after 1826 until the 1850s.

The livestock statistics accessed were not continuous and gaps at the Statistical District level were common (Figures 1,2). In these years, livestock totals for the jurisdiction were provided and used to estimate numbers for the Statistical Districts based on a percentage breakdown from the years where recorded data were present. The statistics also have differing reference dates over the time of the study (Figure 3), and for the records prior to the 1850s no reference date could be found.

Statistical District records for Tasmania (1812-1827), New South Wales (1830-1842) and Victoria (1856-1865) were either absent or unavailable. The New South Wales and Victorian dataset gaps appear to be influenced by the uncertainty around livestock numbers involved with squatter activity from 1826.

The use of a ‘dash’ or ‘ellipsis’ (i.e. …) is common within the historical published statistics, and there is some uncertainty if these symbols refer to a low number, no data collected or a level of doubt to exclude a zero being shown. In these records a zero has been substituted or inserted as these records were generally for areas of minimal livestock or were in areas that normally were not suitable for the type of livestock (i.e. sheep in tropical areas).

Mapping the Statistical Districts

Mapping was based on likely spatial boundaries that used at the time of collection and was based on the information shown in Table 2 and Appendix 1. The spatial boundaries were subsequently captured using ArcGIS (ESRI 2024) software and current administrative or cadastral boundaries as a reference where possible. While records exist at the land parcel scale (which would show exact boundaries at any given time), collating and creating such a spatial dataset on a continental scale was beyond the resources of this study, thus the study focussed on the likely statistical districts used at the time.

Much of the statistical record contained either no mapping of the Statistical Districts that were referenced or the maps that were provided were generalised. Therefore, it was necessary to acquire digital copies of maps which were then georeferenced with current GIS-based mapping in order to re-create the likely boundaries of the Statistical Districts for each year.

Table 1. Sources of the Livestock Statistics to 1788 to 1980.

Jurisdiction*	Source	Year Range	Years with no Statistical District Records^
Australian Capital Territory[1]	Australian Yearbooks (Australian Bureau of Statistics 1911-1980[4])	1927-1980	*None*
New South Wales[2]	Historical Records of Australia (Watson and Chapman 1914); Perry 1957).	1788-1820	1789-1791, 1793, 1809, 1818-1819
	Returns of the Colony New South Wales (Great Britain 1822-1855)	1821-1855	1822-1824, 1826-1827, 1830-1842
	Statistical Register of New South Wales (New South Wales 1856-1888)	1856-1888	1856, 1876-1880, 1885-1886
	New South Wales Statistical Register (New South Wales 1889-1954)	1889-1954	1927-1944[3], 1948, 1950, 1953
	New South Wales Yearbook[3] (New South Wales 1955-1970)	1955-1970	1962-1963, 1970
	New South Wales statistics (Australia Bureau of Statistics 1971-1979[4])	1971-1978	1973-1974, 1976, 1978, 1980
Northern Territory	Statistical Register of South Australia (South Australia 1877-1915)	1880-1910	1880-1883, 1886-1889,1898-1899
	Australian Yearbooks (Australian Bureau of Statistics 1911-1980)	1911-1927	*None*
	The Northern Territory Annual Report (Australian Government 1911-1957)	1928-1957	*None*
	Australian Yearbooks (Australian Bureau of Statistics 1911-1980[4])	1958-1980	*None*

** Horse records were withdrawn from the statistical record between 1965-1972 within all jurisdictions.*

^ Australian Bureau of Statistics and Colony/State references have published yearly livestock totals for each jurisdiction and estimates based on district percentages have been used in lieu of incomplete data.

1 Livestock numbers were rounded to the nearest thousand (cattle) and million (sheep) after 1950.

2 Includes statistics for the present-day jurisdictions of Tasmania (1800-1820), Victoria (1836-1849) and Queensland (1843-1859).

3 Division totals only.

4 Formerly Commonwealth Bureau of Census and Statistics prior to 1975

Table 1. *continued*

Jurisdiction*	Source	Year Range	Years with no District Records^
Queensland	Statistics of the Colony of Queensland (Queensland 1860-1974)	1860-1974	1940, 1942, 1944
	Queensland statistics of livestock and wool production (Australian Bureau of Statistics (1975-1980)	1975-1980	*None*
South Australia	First Report from the Select Committee on South Australia (South Australia 1841)	1838-1840	*Estimates only (1838-1839)*
	Returns of the Colony South Australia (Great Britain 1841-1855) and Vamplew *et al.* (1984)	1841-1855	1843-1845, 1848-1849, 1851-1855
	Statistics of South Australia (South Australia 1856-1858)	1856-1858	1859[5]
	South Australia Agricultural and Livestock Statistics (South Australia 1860-1876)	1860-1876	1861
	Statistical Register of South Australia (South Australia 1877-1975)	1877-1975	1885-1889, 1893-1896, 1915[2], 1958-1962, 1973, 1975
	South Australia statistics (Australian Bureau of Statistics (1976-1980)	1976-1980	*None*
Tasmania	Historical Records of Australia (Watson and Chapman 1914)	1804-1819	1805-1809, 1811-1816
	Returns of the Colony of Van Diemen's Land / Tasmania (Great Britain 1822-1858)	1820-1858	1821-1827, 1855
	Statistical Returns of the colony of Tasmania (Tasmania 1859-1874)	1859-1874	*None*
	Statistics of Tasmania (Tasmania 1875-1968)	1875-1968	1941[6]
	Tasmania statistics (Australian Bureau of Statistics (1969-1980)[7]	1969-1980	*None*
** Horse records were withdrawn from the statistical record between 1965-1972 within all jurisdictions.*			
^ Australian Bureau of Statistics and Colony/State references have published yearly livestock totals for each jurisdiction and estimates based on district percentages have been used in lieu of incomplete data.			
5 Statistical record collection date change from 1st December 1858 to 31st March 1860 (see Figure 3)			
6 Sheep numbers only			
7 Formerly Commonwealth Bureau of Census and Statistics prior to 1975			

Table 1. *continued*

Jurisdiction*	Source	Year Range	Years with no District Records^
Victoria	Statistics of the Port Phillip District (Victoria 1850)	1850	*None*
	Statistics of the Colony of Victoria, Agricultural and Livestock (Victoria 1857-1867) and Statistics of Victoria (Victoria 1851-1875)	1851-1875	1853,1856
	Statistical Register of the Colony/State of Victoria (Victoria 1876-1917)	1876-1917	1894, 1896-1899, 1901-1903, 1911
	Victorian Yearbook[8,9] (Victoria 1918-1973) and (Australian Bureau of Statistics 1974-1980[11])	1918-1980	1965, 1969-1970
Western Australia	Returns of the Colony Western Australia (Great Britain 1829-1869) and Burrows (2014).	1829-1899	1831-1833, 1865
	Statistical Register of Western Australia (Western Australia 1900-1960)	1900-1960	1917[10]
	Western Australia Statistics (Australian Bureau of Statistics 1961-1978[11])	1961-1978	1979-1980
** Horse records were withdrawn from the statistical record between 1965-1972 within all jurisdictions.*			
^ Australian Bureau of Statistics and Colony/State references have published yearly livestock totals for each jurisdiction and estimates based on district percentages have been used in lieu of incomplete data.			
8 Division totals only.			
9 County totals published for 1918-1939 and 1955-1959			
10 Statistics commenced from 1917 as biannual seasons			
11 Formerly Commonwealth Bureau of Census and Statistics prior to 1975			

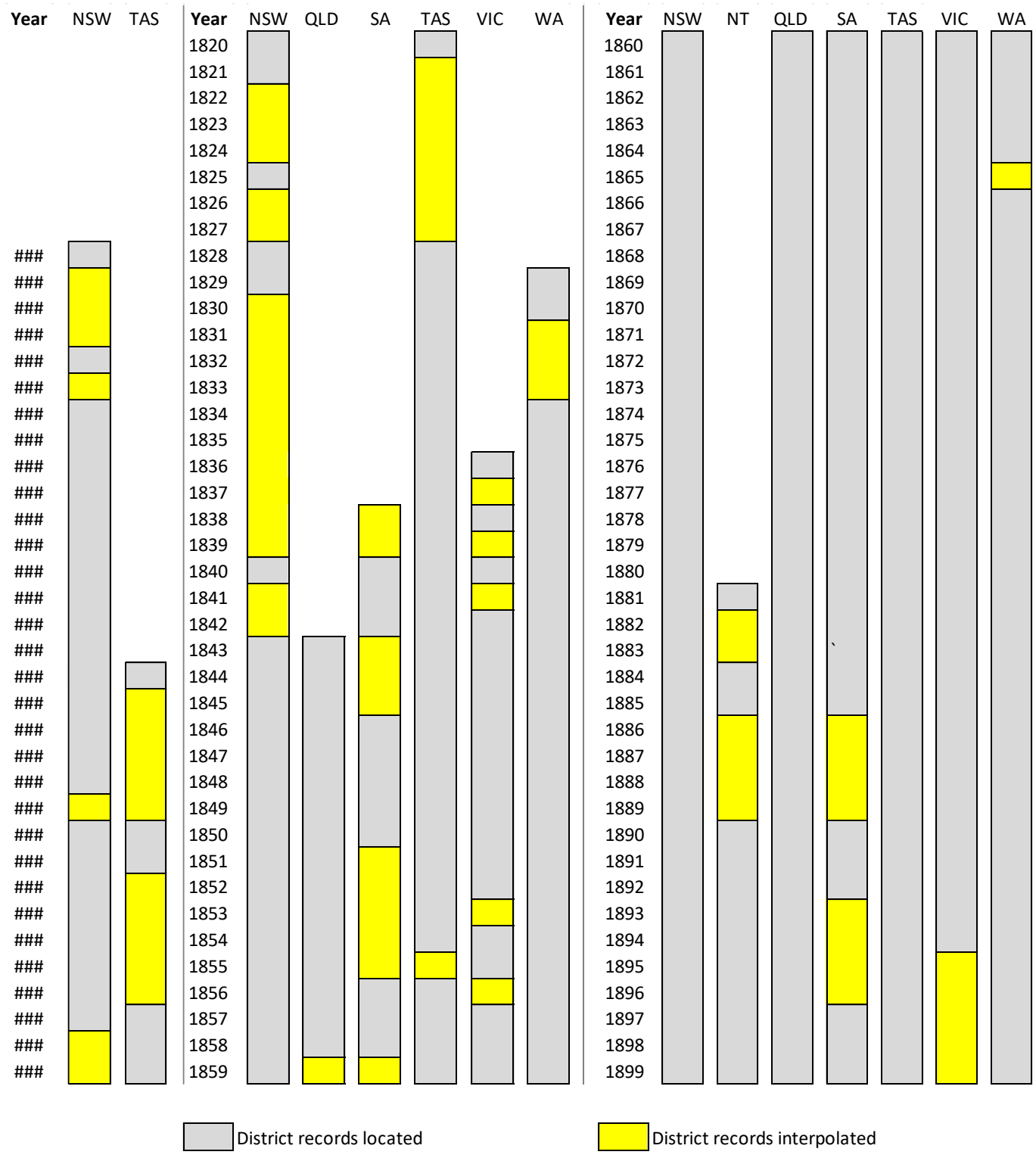


Figure 1. Graphical representation of the availability of the livestock statistics for 1788-1899, showing the years that were available or interpolated for individual jurisdictions.

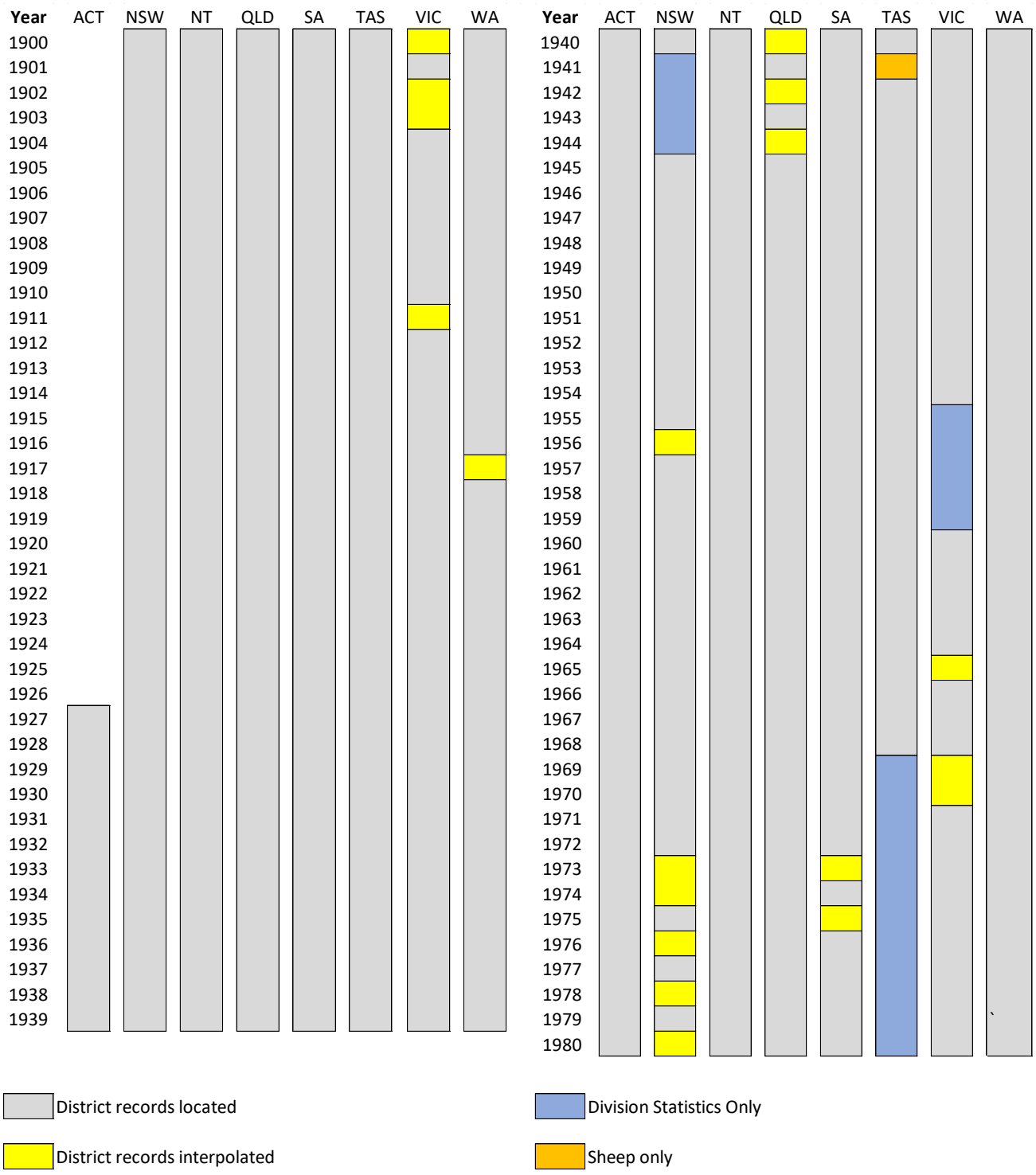


Figure 2. Graphical representation of the availability of the livestock statistics for 1900 to 1980, showing the years that were interpolated for individual jurisdictions.

The early mapping could only be estimated via official proclamations that contained coordinates and directions or river boundaries and mountain peaks. Likewise some boundaries could only be determined by cadastral features that are still present, particular in the jurisdictions of South Australia and Tasmania. However, by the 1850s most jurisdictions had developed similar land cadastral hierarchies that had ~~have~~ not changed since inception, which allowed subsequent Statistical Districts to be determined. An example of the early mapping is provided in Figure 4. Appendix 1 is a series of maps demonstrating the location and mapping sources of the statistical districts that were determined for the study.

Table 2. The statistical district boundaries and mapping sources.

Jurisdiction	Statistical Boundary Used	Years	Mapping Source
Australian Capital Territory	Statistical Districts	1927-1980	Australian Bureau of Statistics (2018)
New South Wales	Settlement or Muster Districts[1]	1788-1813	Burr and Ballisat (1814); Perry (1957)
	Counties and Pastoral Districts[2]	1814-1879	Baker (1841); Arrowsmith (1845); Betts (1846); News South Wales (1847); Tayler *et al.* (1879)
	Police Districts[3]	1875-1880	New South Wales (1899)
	Electorate Areas	1881-1892	Higinbotham and Robinson (1892)
	Counties	1893-1922	New South Wales (2021)
	City Council[4], Municipalities[4] and Shires[4]	1923-1926	New South Wales (1915); Robertson (1929)
	Police Districts[3]	1927-1940	New South Wales (1933)
	Statistical Divisions	1941-1944	Robertson (1943); Australian Bureau of Statistics (2018)
	City Council, Municipalities and Shires	1945-1980	
Northern Territory	Pastoral District	1880-1883	Carroll (1876)
	Statistical Areas	1884-1980	Australian Bureau of Statistics (2018)

1 Settlement Districts were used by Great Britain et al. (1821-1859) and reflected areas of European population.

2 Pastoral Districts represented the initial land administration process for the European distribution of land outside of county areas. Counties were surveyed areas of designated closer settlement.

3 Police or Magisterial Districts and Shires are akin to Local Government Areas.

4 Municipalities and City Councils are akin to Local Government Areas.

Table 2. *continued*

Jurisdiction	Statistical Boundary Used	Years	Mapping Source
Queensland	Police Districts[5]	1860-1891	Ham (1871)
	Court of Petty Sessions Districts[5]	1892-1939	Queensland (1892, 1896-1924, 1902, 1935); Queensland Commissioner for Railways (1913-1917); Robertson (c1940).
	City Council[6] and Shires[6]	1940-1980	Queensland (1928, 1947); Australian Bureau of Statistics (2018).
South Australia	Settlement Districts[7]	1841-1859	*No sources (Hundred boundaries used)*
	Hundreds[8], Counties and Pastoral Districts[9]	1860-1980	Harris (1862); Presgrave and Edmonds (1870); Carroll (1876); South Australia (2020a, 2020b)
	Corporations[6], Corporate Towns[6], District Councils[6], Suburban Councils[6], Towns[6] (Adelaide County)	1860-1935	South Australia (1925,1935)
	District Councils (Adelaide County)	1936-1980	Australian Bureau of Statistics (2018)
Tasmania	Settlement Areas[7]	1804-1819	Scott (1824); Hall (1828)
	Land Districts (hundred based)[8]	1820-1827	Scott (1830); Arrowsmith (1834); Tasmania (2021)
	Land, Municipal and or Police Districts (county based)	1828-1919	
	Municipalities[6]	1920-1969	Tasmania (1907); Australian Bureau of Statistics (2018)
	Statistical Divisions	1970-1980	Australian Bureau of Statistics (2018)

5 Police Districts were used as the division of a Pastoral District and later renamed as Court of Petty Sessions Districts.5

6 Akin to Local Government Areas.

7 Settlement Districts were used by Great Britain et al. (1821-1859) and reflected areas of European population.

8 Hundreds were terms used for cadastral sub-divisions within a County.

9 Pastoral Districts represented the initial land administration process for the European distribution of land outside of county areas. Counties were surveyed areas of designated closer settlement.

Table 2. *continued*

Jurisdiction	Statistical Boundary Used	Years	Mapping Source
Victoria	Settlement Districts[10]	1836-1842	Kenyon *et al.* (1932)
	Parish[11], Counties and Pastoral Districts[11]	1843-1855	Arrowsmith (1848); Stephens (1864); Victoria (2021)
	Commissioners Districts (based on Counties)	1856-1878	Ham (1854)
	Counties	1879-1880; 1902-1916; 1940-1954; 1960-1970	Victoria (2021)
	Ridings[12], Boroughs[12] and Shires[13]	1880-1901	Victoria (1891); Arnall and Jackson (1895)
	Statistical Districts	1917-1939; 1971-1980	Victoria (1920-1960), Australian Bureau of Statistics (2018).
	Statistical Divisions	1955-1959	
Western Australia	Settlement Districts[10]	1829-1879	Arrowsmith (1839); Battye (1924)
	Magisterial Districts[14]	1880-1897 1903-1906	Western Australia (1880, 1891,1896)
	Electoral Districts	1898-1902	Western Australia (1896-1960)[15]
	Statistical Districts (grid based)	1907-1929	
	Municipalities and Road Districts[13]	1930-1961	
	Towns and Shires[13]	1962-1980	Australian Bureau of Statistics (1962-1971, 2018).

10 Settlement Districts were used by Great Britain et al. (1821-1859) and continued by Western Australia until 1879.

11 Pastoral Districts represented the initial land administration process for the European distribution of land outside of county areas. Counties were surveyed areas of designated closer settlement. Parish is a term used for cadastral sub-divisions within a County.

12 Ridings is a term used for cadastral sub-divisions within a Borough. Borough is term used for cadastral sub-divisions within a Shire.

13 Municipalities, Road Districts, Shires and Towns are akin to Local Government Areas.

14 Magisterial Districts are akin to the present Local Government Areas.

15 The Western Australian Statistical Register included maps for the majority of years.

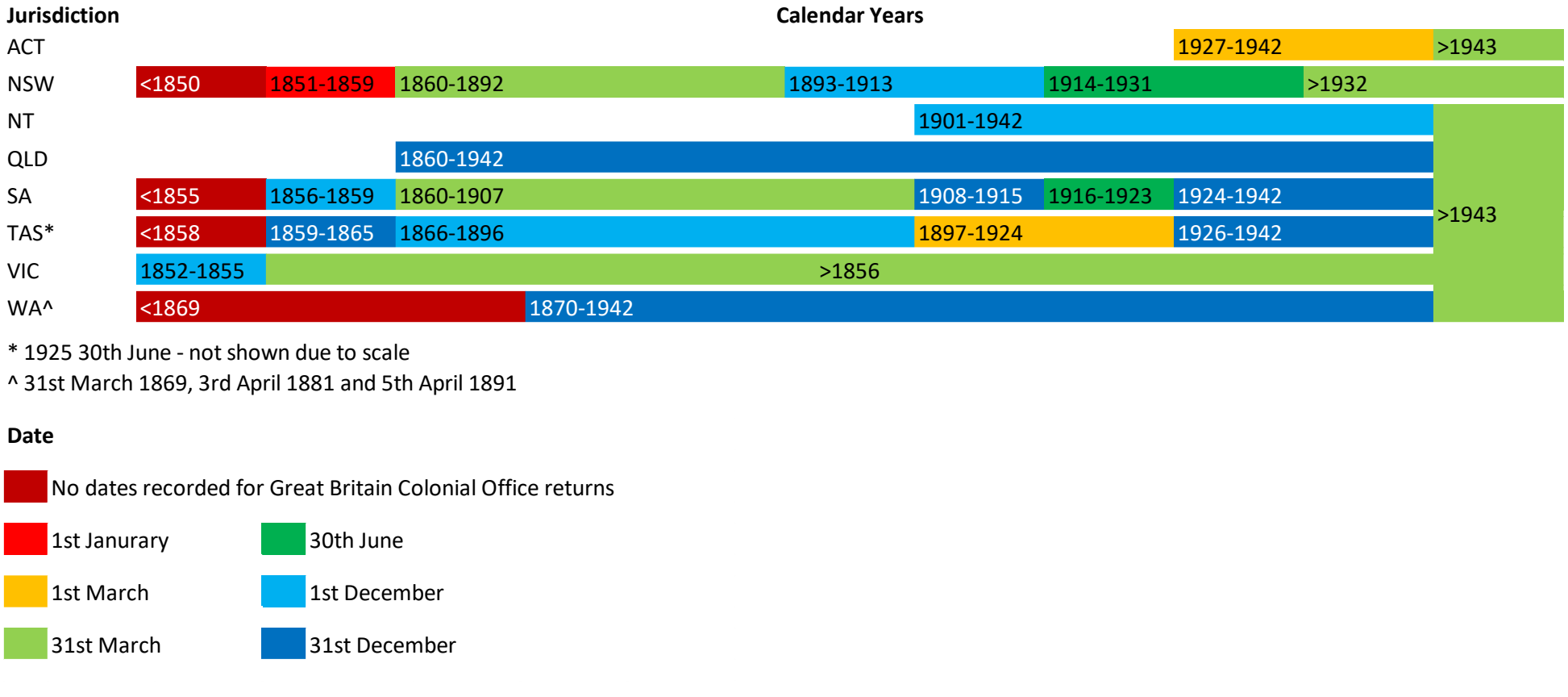


Figure 3. The livestock statistics reference dates.

Figure 4. Livestock numbers for New South Wales Pastoral Districts as at 1841 (Baker 1841).

Australian Capital Territory

Livestock statistics were described in the 1911-1926 New South Wales statistical series as an administrative division between Cowley and Murray counties. From 1927, the territory has recorded livestock statistics as a single entity.

New South Wales

Livestock were introduced in 1788 with the arrival of the first fleet from Great Britain. The initial cattle escaped and were later found as an expanded herd in an area subsequently named the 'Cow Pastures' located within a northern portion of the future Camden County. During 1806, the town area was divided into 22 Muster Districts (Perry ,1957) and were located within the future Cumberland County. By 1814, land grants that were issued by the Governor were predominately located within or adjacent to the future Cumberland County (Burr and Bathsat, 1814).

After 1820, land grants (then known as a ticket of occupation) were made available outside of the Cumberland County (Perry 1957 p86-87, 88). The ticket was issued to a grazier and allowed exclusive grazing rights to an area surrounding the stockyard; usually 2 miles in distance or to a declared area. As land was being surveyed and redistributed, a grantee was given notice to leave and if requested, was issued with a new grant to be used in another unsurveyed area. Two hundred grants were issued from 1822-26 (Perry, 1957 p88-89) with the area comprising the 'Cow Pastures' and Cumberland County gradually changing to private landholders, with further land grants being awarded (see Figure 5).

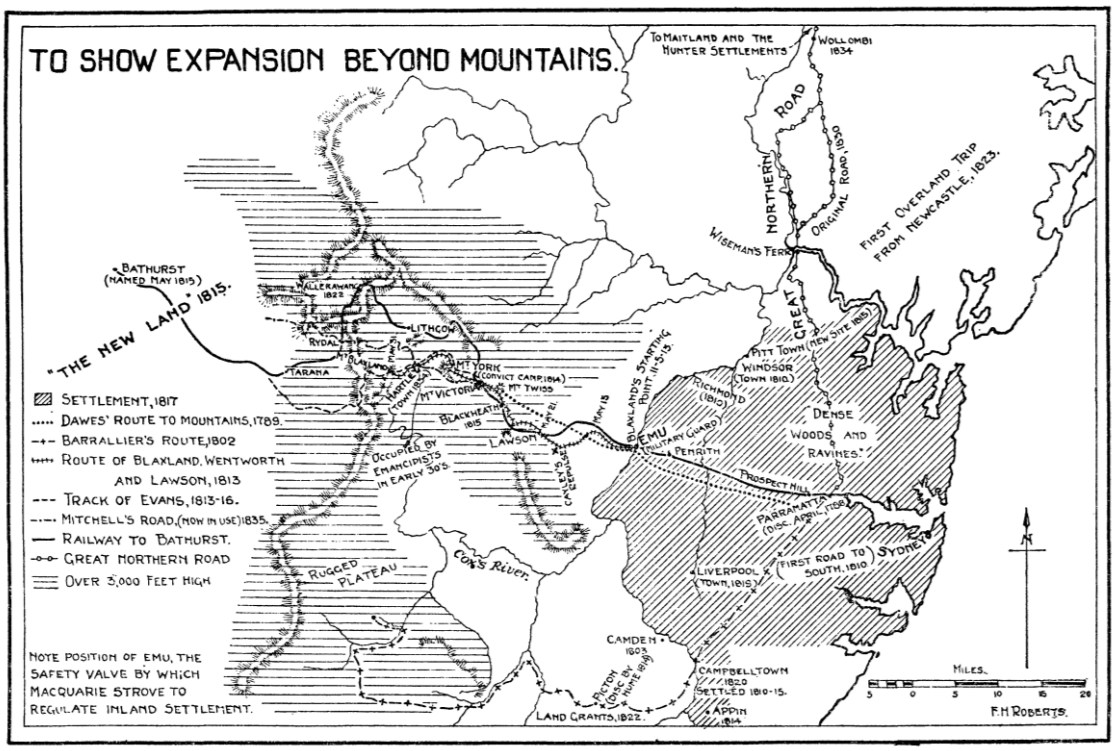


Figure 5. The Sydney environs *c*1817 showing the initial town areas and early land grants prior to 1822 (Roberts 1969 p11).

Livestock statistics outside the Cumberland County commenced from 1814 and by 1828, 15 Settlement Districts were referenced and subsequently assigned within the County boundaries (that were later proclaimed in 1829-1834). Livestock records prior to 1825 were referenced from Watson and Chapman (1914).

In 1825 the United Kingdom authorities ordered the New South Wales governor to commence a land survey to enable land to be divided into a cadastral hierarchy (Counties, Hundreds and Parishes) (Perry, 1957 p112 and 137-138). As there was no suitable mapping at the time, it was decided to limit the area available for land grants (Perry, 1957 p112). These areas outside of the survey become known as the 'limits of location', with restrictions in place on land grants and other tenure rights. However, squatter activity became common and was largely uncontrolled.

Unfortunately, no published livestock numbers for New South Wales from 1826-1842 could be found. Estimates were therefore calculated for the Counties for this period. More problematic was the livestock statistics for the pastoral districts not being publicly reported, although Baker (1841); Thomson (1846); Campbell (1922) provided livestock populations pertaining to the Pastoral Districts. Therefore, estimates were calculated separately for the Counties and Pastoral Districts.

By 1829, with the completion of the initial survey, the 'limits of location' were declared to the boundaries of the 19 Counties, later extended with the proclamation of County of Macquarie (Betts 1846; Figure 6).

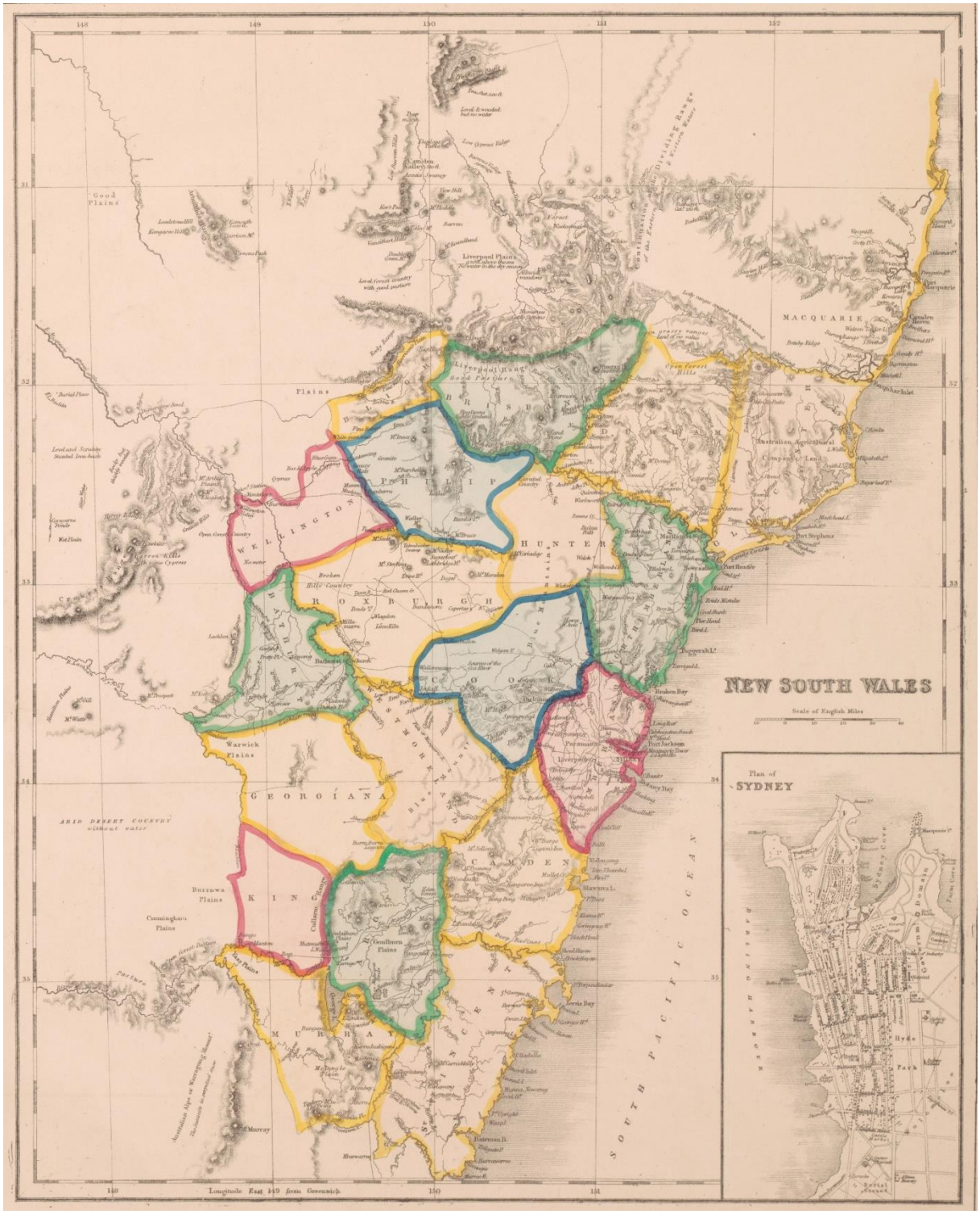


Figure 6. The 'Limits of Location' as shown in Betts (1846). Note the initial Australian Agricultural Country land grant (granted in 1824) is shown within Gloucester County (approximate location only). Macquarie County was incorporated within the limits of location in 1834.

Evidence of significant pastoral activity by squatters was observed (Campbell, 1931 p43; King ,1957 pp 45-46). Lack of pastures via drought was seen as a motivation for the movement of livestock herds to new lands (Heathcote, 1962a pp23,41,130; Gale and Haworth (2002). However, it was probably economic interests that drove squatters across the landscape seeking new pastures for their livestock, despite the frontier risk.

In 1828 the New South Wales authorities attempted to control squatter activity by allowing leasing of unsurveyed land that was adjoining existing alienated lands (i.e. lands that passed from crown to private use) for an annual fee (Perry, 1957 p119). This was administered administrated by the *Crown Lands Encroachment Act 1833* (NSW), which led to the appointment of Commissioners of Crown Lands to prevent unauthorised occupation of crown land. Although 13 Commissioners were appointed, none were appointed in a full-time capacity and had little impact on the expansion of pastoral lands (New South Wales State Archives and Records, 2021).

County boundaries were permanently fixed in 1834, with minor changes to the northern and western boundaries being declared (i.e. Brisbane County and additions to Macquarie County (Perry, 1957 pp114-115, 394-395) see Figure 6). Campbell (1931 p43) described 23 squatters (along with 11,800 cattle and 2,900 sheep) that were displaced in the future Liverpool Plains Pastoral District due to a land grant awarded to the Australian Agricultural Company (State Library of New South Wales, 2023) (Figure 7). This grant replaced the initial land grant made in 1824 (Figure 6).

Figure 7 shows the extent of alienated lands prior to 1835. However, significant livestock numbers were located outside the 'limits of location'. According to Gale and Haworth (2002), by 1836 the government had realised restrictions to settlement and continuing population dispersal were difficult to control. Pastoral expansion commenced with the provision of legislation permitting grazing licenses.

The *Crown Lands Unauthorised Occupation Act 1836* (NSW) lead to the new appointment of seven Commissioners of Crown Land who were responsible for managing unalienated lands outside of the 'limits of location' and allowed the provision of grazing licenses within newly created Pastoral Districts: i.e., Monaroo, Murrumbidgee, Lachlan, Wellington, Blight, Liverpool Plains and Port Macquarie. During 1839-1840 New England and Port Phillip Bay were proclaimed (Baker 1841).

The pastoral extent between 1830-1838 was estimated by Jeans (1972) and this boundary was intersected within the newly proclaimed pastoral districts as the area where livestock were located. For 1839, the southern boundary of the Murrumbidgee Pastoral District was adjusted to Port Phillip Pastoral District as described by New South Wales (1839) and Barker (1841).

Campbell (1922) provided a base livestock population for the Liverpool Plains for 1827 and this number provided a base percentage for subsequent estimates from 1829 to 1837. Thomson (1846); (Baker (1841) provided total livestock numbers for 1839 and 1841 respectively. The statistics for the Counties and Wentworth (1837); Thomson (1846) provided totals for the Pastoral Districts (as a whole), which allowed for the livestock statistics to be presented for New South Wales for 1843.

Mapping for additional Pastoral Districts (Clarence River, Darling Downs, Gippsland, McLeay River, Moreton Bay, Murray Portland Bay and Western Port) was provided by Baker (1841) and New South Wales (1842, 1843). Newly proclaimed Counties (Bourke, Grant, Normanby and Stanley) were added in 1843 with mapping showing an approximate northern boundary of Stanley (within Moreton Bay Pastoral District) being sourced from Arrowsmith (1845).

An 1847 map showed the northern boundary to Moreton Bay and the division of Lower Darling and Wellington Pastoral Districts (New South Wales, 1847). The western boundary of Maranoa Pastoral District was estimated as shown by Heathcote (1962b, p120).

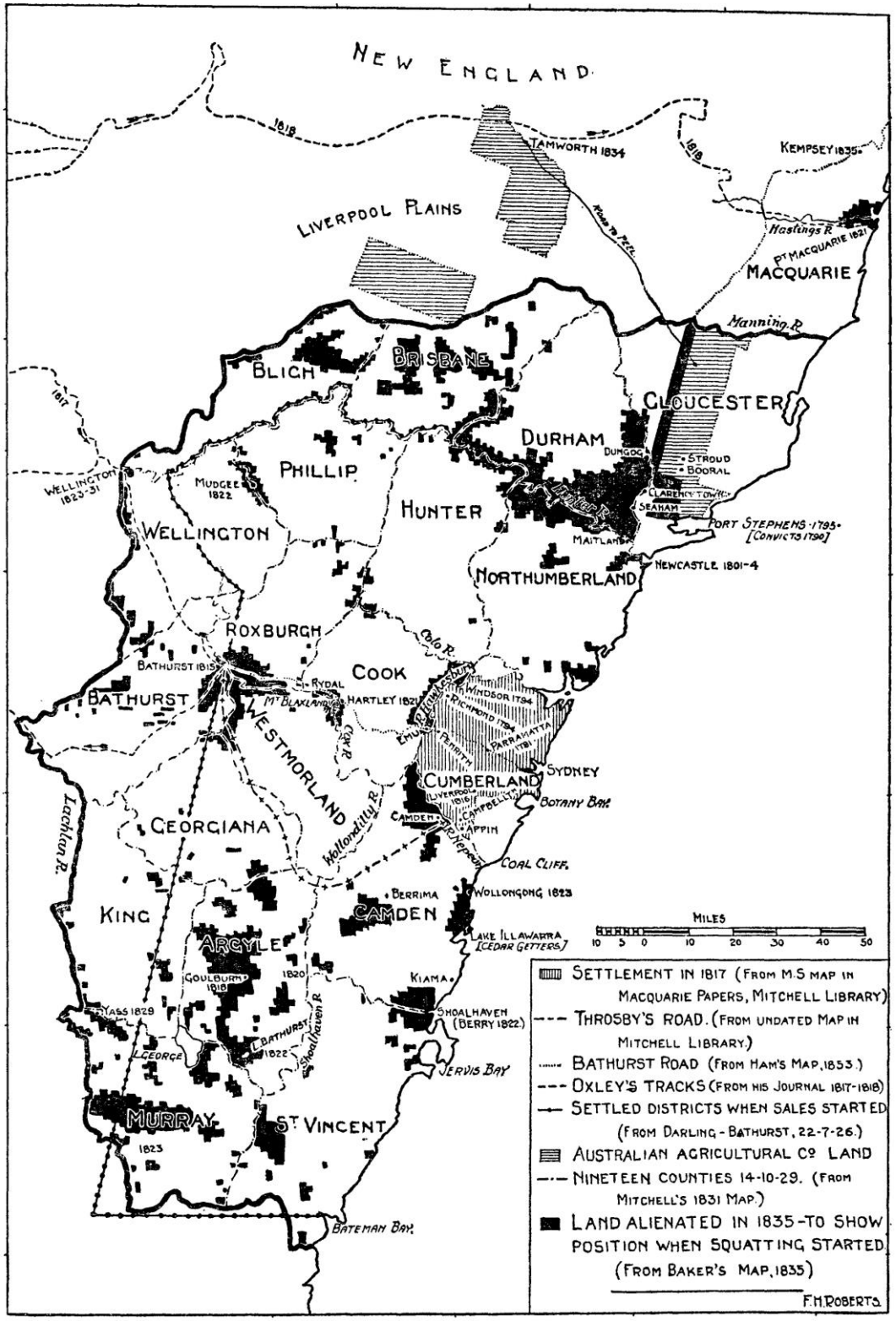


Figure 7. Alienated lands within the limits of location c1835 (Roberts 1969 p29).

New Pastoral Districts (Burnett, Gwydir, Lower Daring River, Maranoa and Wide Bay) were added in 1848-1849 (New South Wales, 1848). The northern boundary was set at the 26th parallel latitude which was based on the creation of the colony of North Australia, located at Curtis Bay (now Gladstone) during February 1846 (and abandoned in May 1847) (Queensland, 2023). There was confusion about the northern river boundaries of Burnett Pastoral District, as the Dawson River was described as joining the Burnett River. It was later determined that the current Auburn River was first described as the Dawson River hence the mapping was adjusted to these river boundaries.

This showed leased lands located adjacent to the Barwon and Narran Rivers in 1850. New South Wales (1851) and Reuss and Browne (c1865), provided boundaries for the Albert Pastoral District and the northern Pastoral Districts (in future Queensland) from 1851. Additional pastoral districts (Leichhardt and Port Curtis) were proclaimed in 1854 (New South Wales, 1854).

From 1875 to 1880, the Statistical Districts were changed to Police Districts and mapping was based on New South Wales (1899). Several Police Districts shown in 1899 mapping were not established during 1875-1880 and were merged to reflect the livestock statistics (Table 3).

Table 3. New South Wales Police Districts for 1875-1880 created from the 1899 boundaries.

Police District (1875-1880)	Mapping Boundaries (1899 Districts)
Bourke	Bourke, Brewarrina (1875- 1878), Cobar, Nyngan, Warren
Coonamble	Coonabarrabran, Coonamble
Tamworth	Gunnedah (1875-1878), Tamworth
Moree	Moree, Narrabri
Oxley	Hay, Hillston, Narrandera (southern portion), Wyalong
Wagga Wagga	Cootamundra, Narrandera (northern portion), Temora, Wagga Wagga

From 1881 to 1892, parliamentary Electorates were used as Statistical Districts and mapping was based on Higinbotham and Robinson (1892). From 1893 to 1922, Counties returned as Statistical Districts.

From 1923 to 1926, Local Government Areas were used as Statistical Districts with mapping provided by New South Wales (1915); Robertson (1929).

Between 1927-1940, livestock records were described via individual Police Stations (listed as Police Patrol Districts). During this period an average of 520 locations were reported (excluding 6 being listed as federal territory in 1927). The geographic coordinates for each station were obtained by either by:

- Geoscience Australia (2023a) for current stations;
- New South Wales (1933, 1951) for closed stations; or
- A geographical estimate based on the locality if not found within the previous sources.

The locations were then grouped into the 447 Police Patrol Districts shown by New South Wales (1933). The difference between the locations and mapping was due to large scale mapping and several locations particularly in metropolitan areas were unable to be mapped and the number of stations being closed or relocated at the time. Table 4 shows the allocation of police districts not shown in the 1933 mapping and the subsequent allocation to a relevant district. From 1941, Local Government Areas were returned as Statistical Districts with mapping provided by Robertson (1943) and Australian Bureau of Statistics (2018). The statistics between 1941-1944 were amalgamated into statistical divisions. Many of the Municipality (i.e. town and city council) boundaries were estimated due to mapping scale, with most being amalgamated with the surrounding Local Government Areas during the second half of the 20th century.

Table 4. Police Stations listed in the 1927-1940 Statistical Records not shown in Mapping Sources and subsequent Police District allocation.

Station	Years	District Allocation	Station	Years	District Allocation
Adamstown	1927-1940	Wellsend	Circular Quay	All	Metropolitan
Alectown	1927-1930	Parkes	City	All	Metropolitan
Appin	1927-1933	Cambelltown	Cobborah	1927-1933	Multiple[6]
Auburn	1927-1932	Metropolitan	Comborah	1927-1934	Multiple[7]
Austinmer	1934-1940	Scarborough	Come By Chance	1927-1933	Multiple[8]
Balgownie	1927-1940	Bulli	Coolac	1927-1932	Gundagai
Balmain	1927-1940	Metropolitan	Copeland	1927-1934	Gloucester
Bankstown	1927	Metropolitan	Corrimal	All	Bulli
Barringun	1927-1935	Enngonia	Cronulla	1929	Metropolitan
Beecroft	1930-1932	Epping	Cudgen	1927-1937	Tweed Heads
Bellambi	1927-1933	Bulli	Cullen Bullen	1928-1940	Lithgow
Bellbird	1927-1935	Cessnock	Cundletonw	1927-1936	Taree
Berridale	1927-1934	Multiple[1]	Darcyville	All	Metropolitan
Berrima	1927-1934	Moss Vale	Dandaloo	1927-1933	Albert
Bobadah	1927-1933	Multiple[2]	Dapto	1927-1933	Albion Park
Bodangora	1927-1931	Multiple[3]	Darlinghurst	All	Metropolitan
Bowna	1927-1932	Jindera	Dundas	1927-1936	Metropolitan
Bowning	1927-1935	Yass	Eastwood	1927-1936	Metropolitan
Broke	1927-1934	Singleton	Fairfield	1927-1934	Metropolitan
Bullarah	1927-1935	Multiple[4]	Fifield	1927-1930	Trundle
Bungwahl Flat	1927-1931	Bulahdelah	Fig Tree	1927-1933	Wollongong
Buronga	1927-1931	Wentworth	Galston	1927-1933	Castle Hill
Burwood	All	Metropolitan	Gerringong	1927-1933	Kiama
Campsie	1933-1940	Metropolitan	Glebe	1927-1932	Metropolitan
Carrington	1933-1940	Newcastle	Glenbrook	1931-1933	Springwood
Carroll	1927-1933	Multiple[5]	Greenrock	1927-1931	Moonan Flat
Chatswood	1927-1929	Metropolitan	Gongolgon	1927-1935	Brewarrin
Divided into police districts: 1 Cooma, Dalgety and Jindabyne; 2 Nymagee and Tottenham; 3 Geurie and Wellington; 4 Moree and Rowena; 5 Gunnedah and Somerton; 6 Dundedoo and Mendooran; 7 Lightning Ridge and Walgett; 8 Coonamble, Pilliga and Walgett.					

Table 4. *continued.*

Station	Years	District Allocation	Station	Years	District Allocation
Granville	1927-1934	Metropolitan	Manly	All	Metropolitan
Guildford	All	Metropolitan	Marengo	1927-1933	Nymboida
Gunbar	1927-1932	Multiple[1]	Marrickville	1927-1932	Metropolitan
Gundaroo	1927-1935	Multiple[2]	Marsden	1927-1930	Multiple[4]
Hamilton	All	Wallsend	Matong	1927-1932	Ganmain
Harris Park	1927-1933	Metropolitan	Maude	1938-1939	Multiple[5]
Hillgrove	1927-1938	Armidale	Mayfield	All	Tighes Hill
Hornsby	All	Metropolitan	Merrylands	All	Metropolitan
Howell	1927-1934	Tingha	Milparinka	1927-1930	Tibooburra
Howes Valley	1927-1934	Bulga	Minmi	1927-1933	Wallsend
Huskisson	1927-1933	Nowra	Miranda	1929	Metropolitan
Illabo	1927-1933	Bethungra	Morangarell	1927-1928	Bribaree
Iluka	1928-1932	Harwood Island	Morpeth	All	Maitland East
Islington	1927-1936	Wallsend	Mount McDonald	1927-1928	Woodstock
Jamberoo	1927-1933	Kiama	Mulbring	1927-1934	Kurri Kurri
Kearsley	1927-1935	Cessnock	Mulgoa	1927-1933	Penrith
Kelso	1930-1932	Bathurst	Narrabri West	1927-1931	Narrabri
Kendall	1927-1937	Kew	Newcastle West	1934-1935	Newcastle
Kiandra	1927-1936	Adaminaby	Newtown	All	Metropolitan
Kingstown	1927-1936	Multiple[3]	North Sydney	All	Metropolitan
Kogarah	1933-1940	Metropolitan	Oranmeir	1927-1930	Braidwood
Kurrajong	1931-1933	Richmond	Oxley	1927-1933	Maude
Lambton	1927-1936	Wallsend	Paddington	All	Metropolitan
Lambton New	1927-1936	Wallsend	Palmers Island	1927-1930	Mclean
Leadville	1927-1938	Dunedoo	Paxton	1927-1934	Cessnock
Lidcombe	1927-1932	Metropolitan	Pennant Hills	1930-1932	Metropolitan
Liverpool	All	Metropolitan	Petersham	All	Metropolitan
Lower Acacia Creek	1927-1933	Wilsons Downfall	Prospect	1928-1934	Blacktown

Divided into police districts: 1 Booligal, Carrathool and Merriwagga; 2 Collector, Gunning and Yass; 3 Bundarra and Uralla; 4 Riverstone and St Marys; 5 Booligal and Hay.

Table 4. *continued.*

Station	Years	District Allocation	Station	Years	District Allocation
Redfern	All	Metropolitan	Tinonee	1927-1936	Taree
Regent Street	1933-1940	Metropolitan	Tomingley	1927-1937	Peak Hill
Reids Flat	1929-1936	Multiple[1]	Torrowangie	1927-1931	Broken Hill
Richmond North	1927-1933	Richmond	Towamba	1927-1936	Wyndham
Rooty Hill	1927-1933	St Marys	Waratah	1927-1936	Wallsend
Ryde	1927-1932	Metropolitan	Warroo	1927-1932	Multiple[4]
Shellharbour	1927-1933	Albion Park	Wattle Flat	1927-1929	Multiple[5]
Smithfield	All	Metropolitan	Wee Jasper	1927-1937	Yass
St Albans	1927-1934	Wisemans Ferry	Wentworth Falls	All	Parramatta
Sutherland	1929	Metropolitan	White Cliffs	1927-1938	Wilcannia
Terry Hie Hie	1927-1934	Multiple[2]	Wickham	1927-1936	Newcastle
The Oaks	1927-1933	Multiple[3]	Wilberforce	1927-1933	Windsor
Thirroul	All	Scarborough	Wombat	1927-1933	Multiple[6]
Thornleigh	1927-1929	Metropolitan			

Divided into police districts: 1. Bigga and Rugby; 2 Gravesend, Moree and Pallanallawa; 3 Camden and Picton; 4 Bogan Gate, Condoublin and Forbes; 5 Bathurst and Sofala; 6 Murrumburrah, Wallendbeen and Young;

Northern Territory

The Northern Territory was originally part of New South Wales until ceded to South Australia in 1863. The area was then subsequently administrated by the Australian government from 1911, followed by self-government in 1978. Livestock statistics for the Northern Territory have been obtained from 1880. The occurrence of livestock prior was minimal with Carroll (1876) suggesting the later 1880s for introduction of livestock.

In the southern portion, pastoral leases were granted from 1872 by the South Australia authorities with 42 leases being granted by the mid-1870s (Carroll 1876). The lease boundaries were digitised. Administratively, the Northern Territory pastoral leases were divided into two, being Central Australia and North Australia, delineated by the 20-degree latitude line by 1884.

In 1882 the South Australian statistics contained livestock records for 31 pastoral stations, divided into Northern, Eastern and Southern pastoral station lists (South Australia 1882). The records note the omission of travelling stock and the use of 'unofficial' sources. The records were later summarised into North (North and East station lists combined) and Central region (South station list). Newcastle Waters Station was listed as South but was added to the North region as it is located above the 20-degree latitude line.

The Northern Territory returned to a single Statistical District from 1885 to 1926. After 1927, four Pastoral Districts were created. During 1927-28 Alice Springs pastoral district was omitted and the livestock was calculated by the difference between the Northern Territory total and the sum of the other three pastoral districts recorded. The 1929 statistics did not include Central (Southern) Australia division and was calculated by a similar method. Statistical reporting reverted to the totals to the four pastoral districts from 1931 (Australian Government 1929-1931). An examination of a series of maps showing the Northern Territory showed there were no changes to the Pastoral Districts to 1980.

Queensland

The area was initially considered as a northern extension of New South Wales (1840-1859), until separation in 1860. The mapping of the Statistical Districts is detailed in Irvine (2016) and covered 1860 to 1949. These data were fully incorporated into this study. However, further examination of the mapping from the New South Wales records prior to 1860, provided improvement to the designation of the western boundaries of the Pastoral Districts to the river catchments, that were shown by Ham (1871).

Additional mapping (Queensland 1902; Southern Sales Ltd 1909; Queensland (1928), allowed the following mapping revisions:

- Division of the Maranoa Pastoral District (East and West) leading to the designations of the Police Districts of Charleville and St George (1865-1873);
- Central and North-western Police and Petty Sessions Districts between 1873-1928 particularly the mapping changes associated with the redesignation of Hughenden and surrounding districts; and
- Determining the former Statistical Districts, particularly in the southeast and southwest of Queensland.

South Australia

The Province of South Australia was established in 1834 and estimates to livestock numbers were first made from 1838. Prior to the first land legislation being passed in late 1842, free squatting by the pastoralists had been tolerated (South Australia 2023a). The *Protecting the Waste Lands of the Crown in South Australia Act 1842* (SA) prevented persons from encroachment, intrusion and trespass. Annual licenses for pastoral purposes were issued outside of surveyed areas but were able to be resumed and any improvements were to be sold at auction, with no compensation to the license holder (State Library of South Australia 2023).

The first Counties were proclaimed in 1842 and were used for general administrative purposes and later subdivided into Hundreds. Both County and Hundreds formed the boundaries of statistical districts, whilst the remote areas were formed as Pastoral Districts. Hundreds were proclaimed after land survey and a series of land regulations from 1850 provided for pastoral leases up to 14 years instead of the annual licence (South Australia 2023a). These were issued outside of the Hundreds (or surveyed areas) at the time.

No mapping for the early Statistical Districts could be found, therefore future Hundred boundaries were used based on the locality. The McLarens Vale District (1838-49) was based on the southern portion of the Willinga Hundred. The survey boundaries established for each Hundred have not been altered since their proclamation except to the Hundred of the Murray or Murray District (1856-1859) which was later absorbed by surrounding Hundreds (see Table 5 notes).

The South Australian 1856 livestock statistics described 7 districts, and the mapping was based on Counties and Hundreds proclaimed prior to 1855 (Table 5). The statistics were also described for District Councils and Corporations (e.g. built-up areas). The Corporations and District Councils at the time were mainly contained within the Counties of Adelaide, Gawler, Hindmarsh, Light and Sturt. The livestock numbers for an individual Corporation or District Council were combined based on the town centre and assigned to the local Hundred. It must be noted that District Councils were based on property boundaries and often contained portions of surrounding Hundreds. Hence the areas assigned in Table 5 are estimates.

From 1860 to 1935, the Statistical Districts were a combination of Corporations or District Council boundaries divided by Hundreds and Pastoral Districts. District Council mapping was possible via the following references (Robbins and Robbins 1987, South Australia 1925,1935 and Marsden, 2012), although several District Councils could not be determined (Table 5).

Yorkes Peninsula was divided into North and South portions in the 1861 statistics and this division was estimated. In addition there were four areas outside of the then survey area being designated as Pastoral lease areas. The statistical districts, North of the County of Flinders, North of the County of MacDonnell County and North of the County of Victoria and were based on actual leases shown by Harris (1862) for the years 1860 to 1879.

Kangaroo Island and Yorkes Peninsula Statistical Districts used the lease mapping for the years 1861-1874 and 1861-1868. Williams (1870) showed agreement to the location and an increase to pastoral leases to that of Harris (1862). Carroll (1876) provided boundaries to the Northern and North-Eastern Pastoral districts.

Several counties were divided into portions between 1873-1875 and included Eyre, Fergusson, Grey, MacDonnell and Robe, with these boundaries being estimated.

Table 5. Mapping sources used for South Australia statistical districts 1856-1859.

District 1856-1859	Mapping Boundary Used*
North of Adelaide	Counties of Gawler and Light, Hundreds of Apoinga, Clare, Dutton (after 1858), Gregory (after 1858), Kooringa, North Rhine (now Jellicoe) Pirie, Stanley, Upper Wakefield and Wongyarra*
South-East District	Hundreds of Blanche, Gambier, Grey, Hindmarsh and Young
Port Lincoln District	Hundreds of Louth and Lincoln
Yorkes Peninsula	Hundreds of Melville, Moorowie, Parawurlie
Hundred of the Murray	Gazetted 1853-1860[#]
Kangaroo Island	County of Carnarvon
Other Hundreds and District Councils^	Counties of Adelaide, Hindmarsh and Stuart

** County and Hundred boundaries have remained unaltered since designation and current sources have been used (South Australia 2020a, 2020b). The exception is the Hundred of the Murray which was superseded by new boundaries (2 counties and 24 hundreds).*

[#] Adelaide Observer (1853)

^ In 1859 the statistical area was divided into 'District Councils' and 'Hundreds not including District Councils'. The north-east portion of Adelaide and Hindmarsh County was designed as areas without district councils.

Pastoral Districts were mapped from 1877 into broad areas across the jurisdiction.

From 1890 the Statistical Districts were a combination of Corporations or District Council boundaries divided by Hundreds, Hundred boundaries and Pastoral Districts. District Council mapping was possible via the following references (Robbins and Robbins 1987; South Australia 1925; Marsden, 2012), although several District Councils could not be determined (Table 6).

Several District Councils were named as Corporations 1890-1906, Corporate Towns 1907-1916 and Suburban Councils or Towns 1917-1923. In 1890, Electoral Districts were used as portions within several District Councils within Adelaide and Light Counties. These portions were merged into the pre-existing District Council mapping.

Within Hamley County, Statistical Districts were described from 1890 to 1976 for the Renmark irrigation area and later irrigation area extensions. Boundaries based on the irrigation area gazettal boundaries were substituted within the County (Australian Government 2013 and South Australia 2022b). Additional irrigation districts or settlements were progressively added between 1922 to 1930.

The 19 Pastoral Districts were merged into 5 Divisional entities from 1906 to 1914. From 1936 to 1980, Adelaide County statistics showed 21 District Councils, which aligned with the information available from South Australia (1877-1975) for the years of 1935, 1946 and 1955 and later reduced to 16 District Councils in 1961 and 15 by 1969 (Australia Bureau of Statistics 2018). Outside of Adelaide county, Hundred boundaries were used as Statistical Districts except for the irrigation areas within Hamley County.

Table 6. Allocation of Corporations and District Councils (1862-1935) where mapping was not able to be determined.

Start Year	Corporation or District Council	Mapping Boundary Used
1860	Barossa East and West	Barossa District Council
	Portland Estate	Adelaide City or Corporation
	Alberton and Queenstown	Port Adelaide District Council
	Yankalilla	Myponga District Council
1862	Echunga Portion within Hindmarch County	Echunga District Council
1865	Granville	Hindmarsh later Campbelltown District Council
	Bremer Portion within Sturt County	Bremer District Council
1866	Flaxman's Valley	Angaston District Council
	Hindmarsh Townships	Hindmarsh later Campbelltown District Council
1868	Stepney	Payneham District Council
1874	Le Fevre's Peninsula	Port Adelaide District Council
1877	Birkenhead	Port Adelaide District Council
	Rosewater	Port Adelaide District Council
1890	Semaphore	Port Adelaide District Council
1899	Gawler South	Gawler Corporation
1929	Weigall Irrigation Settlement, Irrigation and Dry Areas	Katarapko Hundred
1935	Cobdolga Dry Area	Cobdolga Irrigation Settlement

From 1961 several Hundreds with low livestock numbers were amalgamated as "Other Districts" within respective County boundaries, with some merging with portions of the areas previously listed as a Statistical District with no Hundred subdivisions.

From 1970, a single Statistical District replaced the 16 Pastoral Districts located outside the County boundaries. Livestock statistics were not recorded for 1973 and 1975.

Tasmania

Tasmania (known as Van Diemen's Land until 1856) was initially divided at 42-degrees latitude into two counties (Buckingham and Cornwall), with Hobart Town and Launceston (formerly Port Dalrymple and George Town) as their administration centres, in 1804. Two Lieutenant-Governors, who represented each county, commenced to issue land grants to settlers and free convicts until 1813 when a single Governor was appointed. The livestock statistics for Hobart Town and Port Dalrymple were reported during 1804, 1810 and 1819 (Watson and Chapman 1914). By the mid-1820s, 19 land or police districts (assumably based on Hundreds) were established across the colony (Scott 1824; Hall 1828).

For this study the boundaries of the Land Districts were combined and separated at the 42-degree parallel and named as Hobart Town and Launceston statistical districts prior to 1828. The 1828 livestock statistics

used newly defined Land Districts (assumably based on the Counties), with nine being mapped by Scott (1830); Arrowsmith (1834). Additional Counties were added throughout the 19th century, accumulating to 49 Counties by 1919 (Tasmania 2021). At times these boundaries were known as Land, Municipal and or Police Districts but retained the county boundaries. The county boundaries remained unchanged from their initial proclamation.

The 1895 statistics combined 17 districts which included much of the south-eastern area and the Bass Strait Islands into one entity.

From 1920 Municipality Boundaries (Local Government Areas) were used (Tasmania 1907). Later, Statistical divisions based on Local Government Areas were established in 1969 (Australian Bureau of Statistics 2018).

Victoria

The area was initially considered as a southern extension of New South Wales, where the Port Phillip Settlement was listed as a Statistical District in 1836 (New South Wales 1836). The Port Phillip District was later defined by further proclamations (New South Wales 1839) and by 1843, and the Counties of Bourke, Grant and Normanby were established and declared as part of the 'limits of location'. The remainder of the lands were designated as Pastoral Districts. The Pastoral Districts of Portland Bay, Gippsland, Murray and Western Port were proclaimed in 1844 (Arrowsmith 1845), with the Wimmera in 1847 (Arrowsmith 1848; Ham 1854; Kenyon 1932). Annual grazing licenses were issued within the Pastoral Districts due to the large influx of squatters.

During 1841-1848, there was an adjustment to the Pastoral Districts adjoining the future boundary between New South Wales and Victoria. Initially the Murrumbidgee Pastoral District extended southwards beyond the Murray River from 1839 (see Figure 4) before the Murray Pastoral District established the northern boundary on the Murray River in 1844 (Arrowsmith 1845). This northern boundary subsequently served as the boundary between New South Wales and Victoria.

There was considerable delay from 1847 in the re-granting of pastoral leases under the *Waste Lands, Australia Act 1846* (UK) due to the survey demands being managed from Sydney and then later by the separation from New South Wales in 1851, followed by the granting of self-government in 1855 (Quick, 1883 pp 9,15). The map of pastoral holdings of the Port Phillip District 1835-55 (Kenyon 1932) was used as a reference and current parish boundaries (Victoria 2021) were used to designate the Settled and Pastoral Districts in 1849. The Settled Districts were based on a circular distance buffer from the following towns:

- Bourke (30 miles from Melbourne)
- Grant (18 miles from Geelong)
- Normanby (12 miles from Portland)
- Belfast (9 miles from Port Fairy)
- Alberton (12 miles from Port Albert)

County and Parish boundaries (Victoria 2021) were used as Statistical Districts in the settled districts in 1855 and the Pastoral Districts were referenced from Ham (1854).

The statistics from 1856 to 1877 included livestock managed on crown lands (i.e. pastoral licenses being converted into title).

The 1859-1862 livestock statistics on crown and unalienated lands only showed a jurisdiction total, these were distributed within the Land Commissioner Districts based on the yearly percentage difference between 1858 and 1863 district totals. Alienated lands livestock totals based on Counties were later added.

Until 1863, the livestock numbers on unalienated lands were reported within the original Pastoral Districts then known as Crown Land Commissioner Districts and livestock freehold reported via Counties and Land Districts. Unlike other jurisdictions at the time Commissioner and County boundaries were not separate spatial entities but were incorporated.

Due to the large livestock numbers reported for Portland Bay and Western Port Pastoral Districts, it was necessary to combine County and or District boundaries into these original Pastoral Districts and to include the alienated lands livestock totals listed for the Counties and Districts (Table 7). It was assumed that Bouke, Grant, Gippsland, Murray and Wimmera Commissioners Districts were identical to the similar named Pastoral District boundaries

Table 7. Selected Victorian Pastoral Districts and County and District Allocation for 1856-1858

Commissioner District	**County and or Districts**
Portland Bay	Dundas, Follett, Grenville, Hampden, Heytesbury, Normanby, Polwarth, Ripon and Villiers Counties
Western Port	Anglesey, Dalhousie, Evelyn, Mornington and Talbot Counties Avoca, Bendigo and Rodney Districts.
Settled Districts (1858 only)	Mutiple[1]

1 Livestock numbers for Settled Districts within Crown Lands were distributed on a 1858 percentage basis

In 1863 new Crown Land Commissioners districts were formed and no mapping could be found to ascertain the boundaries. Therefore, each Crown Land Commissioner District was allocated a County (Table 8) and added to the freehold County totals. Most of the Districts (Gippsland, Loddon, Murray and Wimmera) were unable to be divided into their respective Commissioner Districts and were combined to reflect the County/District mapping, until 1872 when new Counties were created within the former districts. Livestock numbers for Settled Districts within Crown Lands were continued to be distributed on an annual percentage basis.

From 1877 the statistics included an entity “grazing rights”, these were distributed in a similar method as for the settled districts. The *Land Act 1878* (Vic) provided land selection for grazing on any unsurveyed lands.

Between 1879 and 1880, the livestock numbers were reported via Counties. The 1879 livestock statistics estimated 20,000 cattle and 750,000 sheep as being ‘unenumerated’ livestock due to a new system used for calculation of livestock on squattering stations. This number represents approximately 8% of the sheep herd within Victoria. In addition, there were no livestock recorded for Millewa and Karkarooc Counties (formerly a part of the Wimmera District) and therefore were estimated based on the 1880 records. The unenumerated livestock totals were re-distributed to the County totals based on total livestock numbers for 1880.

Table 8. The allocation of livestock statistics to Victorian Counties or Pastoral Districts from Crown Land Commissioner Districts for 1863-1878. The Crown Land Commissioner Districts represent areas of squatter-owned livestock.

Crown Land Commissioner District	County/District Boundaries
Ararat	Ripon
Ballarat	Grenville
Beechworth	Murray District (Benambra[2])
Benalla	Murray District (Delatite, Moira and Part Wonnangatta[2,3])
Castlemaine	Rodney District (Bendigo[1] and Rodney[1])
Echuna	Loddon District (Gladstone[1], Gunbower[2] and Part Tatchera[2,3])
Gippsland North	Gippsland District (Croajingolong[4], Dargo and Tambo[2])
Gippsland South	Gippsland (Buln Buln, Tanji and Part Woonangatta[2,3])
Gisborne	Anglesey, Dalhousie and Talbot
Grant	Grant
Melbourne	Bourke, Evelyn and Mornington
Omeo	Murray District (Bogong[2])
Portland	Dundas, Follett and Normanby
Swan Hill	Wimmera (Part Tatcher[2,3])
Warrnambool	Hampden, Heytesbury, Polwarth and Villers
Wimmera East	Wimmera District (Borung[2], Kara Kara[2] and Karkarooc[5])
Wimmera West	Wimmera District (Lowan[2], Milewa[2] and Weeah[5])

1 After 1870; 2 After 1872; 3 Livestock numbers allocated 50% to the Commissioner District; 4 After 1878

5 After 1877

The livestock statistics from 1880 to 1900 were based on Local Government Boundaries (city, town, borough, shire and ridings) (Arnall and Jackson 1895; Victoria 1891). The immediate environs of Melbourne were combined as a metropolitan entity. In 1882 a portion of Tambo Shire was included into the Bairnsdale Shire livestock statistics, and it was assumed that the westernmost portions (Bruthen, Bumberran and Snowy River ridings) were these portions, leaving the remainder of Tambo shire outside of the local jurisdiction.

From 1883, there were areas that were assumed or shown as outside of jurisdiction:

- Tambo Shire (until 1883);
- Shires of Healesville, Upper Yarra and Walhalla (until 1890);
- French Island shown as no municipality; and
- Eastern portion of Wonnangatta was shown as uninhabited and, allocated no municipality on the 1891 map.

Between 1895 and 1900 only jurisdiction totals were based on Australian estimates and based on the 1894 Local Government Boundaries and its percentage distribution.

The Statistical Districts reverted to Counties from 1904-1916 (County estimates for 1902-1903 were used), 1940-1954 and 1960-1968. Eight Divisions (comprising an amalgamation of County boundaries) were used during the period of 1917-1939, 1955-1959 and 1969 to 1975. County estimates were calculated for the period of 1969-1970 based on the livestock statistics of 1968. Since 1976, twelve Statistical Divisions have been used for the livestock statistics.

Western Australia

The Swan River Settlement was first proclaimed in 1828 and renamed as Western Australia in 1832. The livestock statistics were based on settlement districts, which were presumably based on County boundaries (Arrowsmith 1839). Like South Australia, grazing was regulated and controlled first by grants (ceasing in 1832) followed by licensing of grazing rights on adjoining Crown land, which continued with the provisions under the *Waste Lands, Australia Act 1846* (UK), followed by amendments in 1865, 1872 and 1878 (Western Australia, 1940 p42). In 1863, two Statistical Districts were proclaimed, being East and North and described by Battye (1924, p 260). A more regulated system commenced with the *Land Regulations 1887* (WA).

It was assumed that from 1842 the Magisterial District boundaries were used for the livestock statistics. The mapping from (Western Australia 1880) to the central-division boundary was used. The Statistical Districts were then expanded to the whole jurisdiction by 1882, with the boundaries sourced from the census map (Western Australia 1891). Magisterial District mapping (Western Australia 1897) was used during this time, except for the years 1898-1902 where Electoral Districts were used.

From 1907 to 1929, the livestock statistics were based on a grid survey (Western Australia 1896-1960). After 1917, the livestock statistics reverted to a biannual record (hence 1917 was estimated). After 1939, the boundaries of Road Board Districts and Municipalities were adopted as Statistical Districts. The statistical district mapping, where possible, was based on Local Government boundaries (Australia Bureau of Statistics 2018), adjusted to the maps from 1929. As there were limited livestock statistics for the Municipality entities, they were merged into the surrounding Road District. Also the various Road Districts and Municipalities associated with the Metropolitan Statistical Division were merged into a single entity. After 1962, Road Districts and Municipalities were renamed shires and towns.

Determining Livestock Density

The livestock numbers were converted to a common unit representing dry adult equivalents (AE) (450kg cow or horse). Sheep numbers used a conversion of 7 sheep to 1 adult equivalent, with horse and cattle numbers being assumed as the same adult equivalents (Stone 2004 p194). AE is a measure of pastoral grazing in northern Australia and was developed by McLean and Blakely (2014).

Using the ArcGIS (ESRI 2024) software, a map code was added to the livestock (tabular) and to the Statistical District dataset (spatial), which allowed a spatial join to be performed, creating a dataset showing the relevant livestock information within a spatial boundary for each year. The spatial dataset was later dissolved via the map code.

A heuristic Livestock Distribution was generated via the ArcGIS (ESRI 2024) software to downscale the livestock record for each Statistical District for any given year. The distribution was based on a grazing land class (GL) which is an estimate of grazing distribution that is likely to occur in the Statistical District, based on the grazing land class and the availability of water.

The GL was determined via a combination of:

- An estimation of pre-European vegetation density;
- The natural presence of water;
- Water improvements over time;
- Subsequent woodland clearing;
- Wire fencing; and
- Protected lands.

The following criteria were used to designate lands that were able to be grazed with:

- Little or no restriction such as natural grassland (GL1);
- Minor restrictions such as open forest (GL2);
- Restrictions such as closed forest (GL3); and
- Major restrictions such as steep lands (GL4).

GL4 is based on steep areas and were generated from a digital elevation surface layer (Gallant *et al.* 2009) where sloping lands greater than 30 precent were assigned zero stock distribution. Each GL was assigned a weighting (Table 8) which determined the likelihood of livestock being present within the Statistical District. Water areas are denoted by the suffix *w* and were determined by a spatial analysis to determine where riparian lands were likely to occur prior to 1850. The primary sources of water for livestock in the initial grazing phase was natural water sources located on riparian lands (i.e. creeks, rivers and water holes).

A summary to the methodology is presented in Figures 8 and 9.

Each record of the yearly dataset (GL per statistical district) underwent a series of calculations within ArcGIS to determine the GL area, district capacity and carrying capacity. This was followed by calculating a redistributed stock number and stock density within each statistical district (see Figure 8b).

Later, as land development occurred, annual changes were added to the base Vegetation Density and Water Areas and intersected to create the Grazing Land Classes for each year (Figure 9).

Table 8. The Grazing Land Classes and the weighting that was used for the Livestock Distribution.

Grazing Land Class	Vegetation Growth Form Tall and Lower Stratum*	Water Availability[#]	Weighting (%)
Grassland, Irrigated Pastures (after 1900) (GL1)	F3^, F4^, G3, G4, L1G3, M1G3, S1G3, Z1G3	GL1*w*	85
		GL1	15
Open Woodlands (GL2)	G2, L2G2, M2G2, S2G2, Z2G2	GL2*w*	50
		GL2	10
Woodlands and Forest (GL3)	All others	GL3*w*	30
		GL3	5
Steep Lands, Protected, Irrigated Cropping (after 1900) (GL4)	Not Applicable	GL4*w*	5
		GL4	0

** Lower stratums densities not provided but have been assumed to equal the remaining balance from the density of the tall stratum (Geoscience Australia 2001).*

^ Post European vegetation (Geoscience Australia 1988)

[#] w refers to the presence of water

Determining Base Distribution Features 1788 to1849

Vegetation Density

The base Grazing Land Class (GL) was based on an estimate to vegetation density provided by the tall and lower stratum vegetation growth forms attributed to the mapping of pre-European vegetation (Geoscience Australia, 2001) (see Table 8). As the lower stratum datum was not provided in the dataset an estimate was allocated based on the remaining balance to the vegetation coverage.

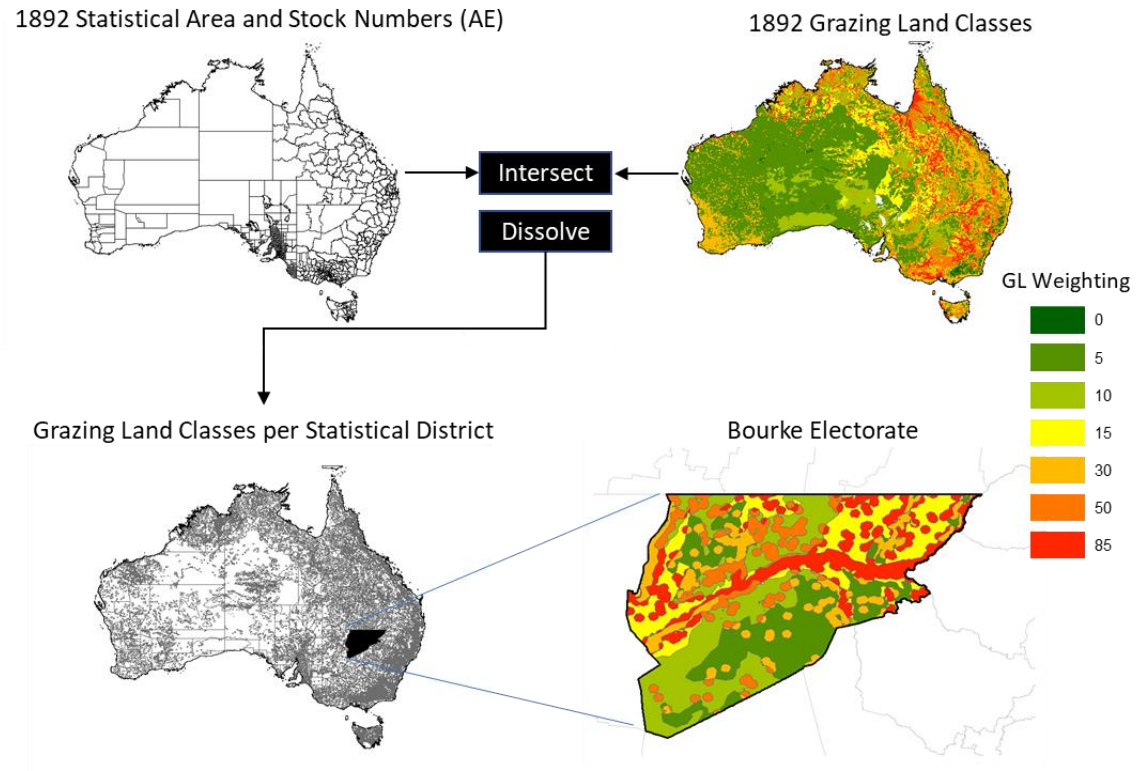
Mapping riparian lands

The primary sources of water for livestock in the initial grazing phase (prior to 1850) was natural water sources located from riparian lands (i.e. creeks, river and water holes). Here the riparian lands were identified by the distance from streamlines (Crossman and Li 2015a). and valley flatness (Gallant *et al.* 2012). Within riparian areas, individual water sources were identified by Geoscience Australia (2015), which were later intersected by the Prescott Index (PI) (Gallant and Austin 2012) which is an estimate calculated from water availability and evaporation balance, that was used to remove saline water areas.

Identification of valley flatness was necessary to cater for the stream characteristics within the Australian landscape, where multiple channel developments occur within internal drainage basins and the episodic or seasonal nature of water flows, leading to waterhole development (as opposed to river flow). The Multi-resolution Valley Bottom Flatness (MrVBF) (Gallant *et al.* 2012) is a topographic index designed to identify riparian areas. By multiplying the MrVBF to the streamline, riparian areas were able to be identified ranging from distances of 100m to 900m. Most Australian streamlines are multiple channels, with a continuous spatial area along major rivers decreasing in width in undulating landscapes (Figure 10a).

Given the large riparian area that was created, individual water sources were then required to be identified. By using the riparian lands mask, water sources identified by the Water Observation from Space (WOFS) (Geoscience Australia 2015) were selected. For each cell, the WOFS provided a percentage number to the occasions where water was detected across the imagery history (1987-2015), hence a higher percentage would be an indicator of persistent waters that would likely be a water source.

(a) Spatial Information



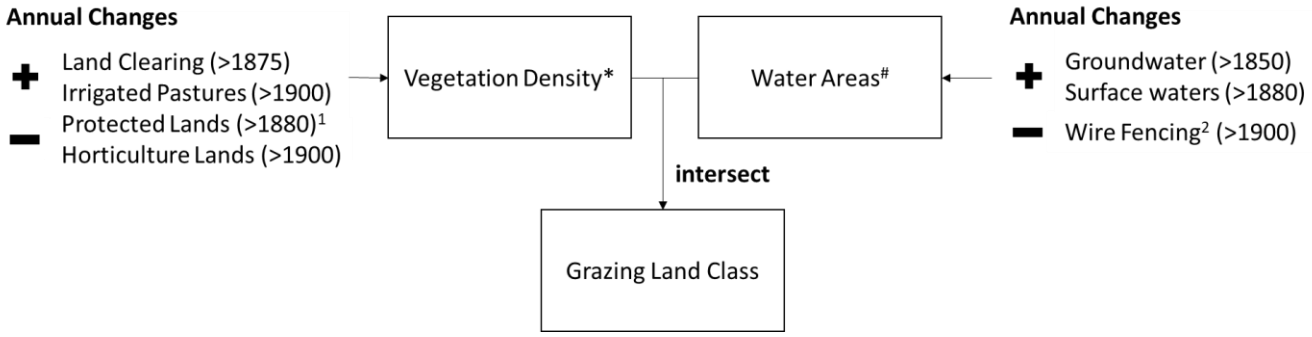
(b) Example Calculation for the Bourke Electorate 1892

Year	Code	Statistical District Name	Adult Equivalents	Statistical District Area (sqkm)	Grazing Land Class (GL) Weight	GL Area (sqkm)	GL Area x (Weight/100)	District Capacity (DC)	Carrying Capacity (CC)	Stock Number (SN)	Stocking Density (SD) (AE sqkm^{-1})
					0	22	-		-	-	-
					5	24,414	1,221		0.034	39,224	1.61
					10	26,994	2,699		0.075	86,739	3.21
1892	2016	Bourke Electorate	1,149,123	118,766	15	18,341	2,751	35,762	0.077	88,401	4.82
					30	14,753	4,426		0.124	142,215	9.64
					50	12,690	6,345		0.177	203,881	16.07
					85	21,553	18,320		0.512	588,669	27.31
					Totals	*118,767*	*35,762*		*1.000*	*1,149,129*	

Calculations	*Method*
Statistical District Area (sqkm) Grazing Land Density Area (sqkm)	ArcGIS Area Calculation: GDA 2020 Australia Albers (EPSG: 9457)
Adult Equivalents (AE)	Cattle number + Horse number + (Sheep Number / 7) (per Statistical District)
Grazing Land Class	Spatial Dataset Value
District Capacity (DC)	Sum GL Area x Weight (per Statistical District)*
Carrying Capacity (CC)	GL Area x Weigh % / DC
Stock Number (SN)	AE x CC
Stocking Density (SD)	SN / GL Area

* ArcGIS calculation : (1) GL Area Features to Point (2) GL Area Points to Raster (3) Zone statistics: Sum of GL Area per Statistical District (4) Join to Table

Figure 8. The Livestock Distribution is based on the GIS intersect and dissolve functions which enable polygons to be generated for GL within statistical districts for each year. The example (a) (Bourke Electorate as at 1892) shows the spatial information; and (b) the calculations that were performed to determine GL Area, District Capacity (DC), Carrying Capacity (CC), Stock Number (SN) and Stocking Density (SD).



** Base vegetation based on Geoscience (2001)*
 # Base water Areas based on Riparian Lands
1 Changes occurred for 1880,1900,1910,1920, 1930, 1955, 1965 and 1970 (Australian Government 2023)
2 Water area boundary at 7km (1788-1989) later reduced to 5km for >1900

Figure 9. Grazing Land Class was determined on an annual basis based on the land development factors that commenced from 1850 on the initial Vegetation Density and Riparian Lands.

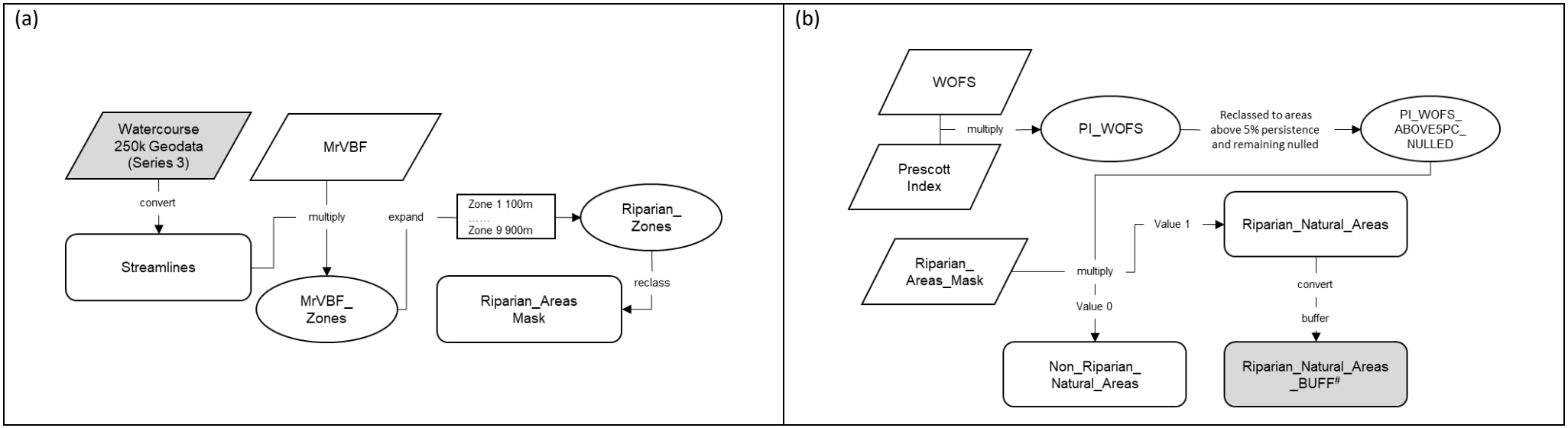
As some areas identified in WOFS would have contained saline water sources, it was necessary to remove possible saline water areas as they may have been 'non-potable' for livestock. The PI was used because it is a coarse estimate of water availability based partly on evaporation, where low values would indicate evaporation is more dominate than precipitation. High evaporation in episodic waterflows is likely an indicator of saline water. The PI was multiplied to WOFS to determine areas where fresh permanent water is more likely to occur, referred to as PI_WOFS.

The resultant raster PI_WOFS was reclassed to show water areas during 5% of time during 1987-2015. Areas within 1km of the coastline were removed to remove potential saline areas. The next step was to multiply the riparian areas mask to the reclassed PI_WOFS, creating a raster that shows natural water sources within the riparian area. These areas were vectorised and buffered by 7km pre1900 (Figure 10b) and buffered by 5km post 1900 to cater for fencing improvements.

Water areas

Grazing Lands Class weights were based on their distance to water sources. Most livestock grazing occurs within 3km of a water source provided there is adequate forage and access, with the maximum distance being 5km (Cowley *et al.* 2015). However, in areas of poor pasture availability distances travelled by livestock can be greater at 7km a day (Pringle and Landsberg 2008; Cowley *et al.* 2015).

Thus, for this study, an initial distance of 7km was applied to all water layers given the probable status of grazing. Prior to 1900 grazing was more likely to be unfenced or managed as grazing circles restricted by natural features. This distance was reduced to 5km after 1900 when wide-scale use of fencing was employed. Fencing was in development during the 19th century along with traditional herding practises (i.e. sheep camps Taylor *et al.* 1984) and not common until after 1900 (McKeon et al. 2004b p 75). Wire fencing for sheep herds was becoming standard within south-eastern Australia from the mid-1880s although the more labour-intensive brush fencing which consisted of lines of felled timber, paling and slab fencing was also common during this time (Pickard 2007; 2022). Wire fencing in Central Queensland was in use by 1878 (Cooper 2005 p7).



 # buffer area of 7km are vector based.

Non coloured data entities are raster based.

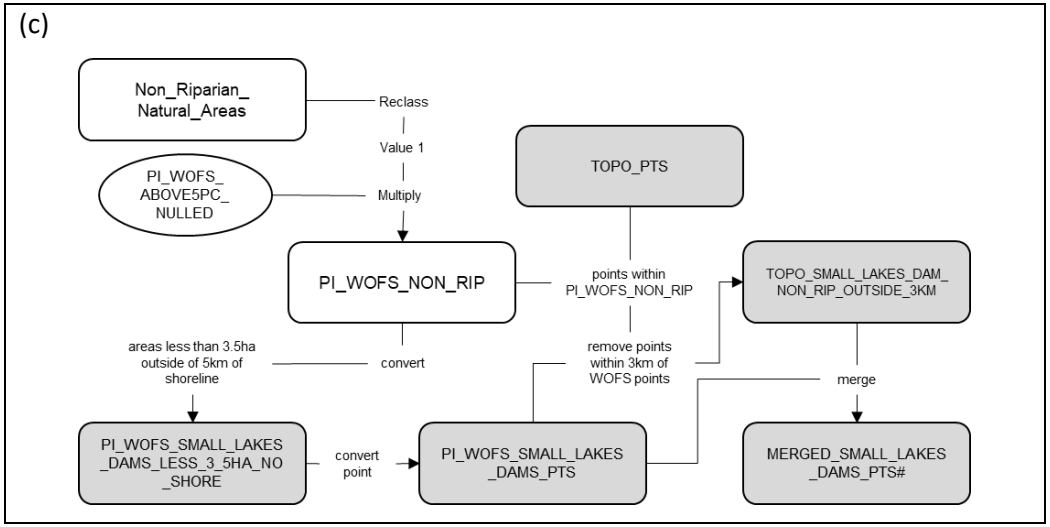


Figure 10. Flowcharts showing the creation of the: (a) riparian lands raster; (b) water areas; and (c) surface water development point layers.

Determining Land Development Features 1850 onwards

Groundwater Development

The earliest ground water bore was recorded as early as 1828. Buxton (1969) describes how in the Riverina district of New South Wales during the 1850s, wells were occasionally dug by manual labour but were expensive due to labour and equipment transport costs. As steam technology became more available and cheaper, permanent use of groundwater occurred in all pastoral industries (Condon *et al.* 2002 p 88).

Groundwater use increased when the Great Artesian Basin was discovered in 1878. After its discovery, the pastoral industry was able to expand within non-riparian lands (Williamson 2012 p 10). The map of Queensland described in Queensland (1896) shows the extent of bores that were operating within Queensland, the numbers of which are consistent with the records described by Powell (2012). The windmill and water trough had become widespread by the end of the 19th century, by which water was pumped from shallow bores (Condon *et al.* 2002 p 87).

Location information for groundwater bores used for pastoral purposes (Bureau of Meteorology 2018) were used to define areas where stock water was available. Each bore location had a commencement (drilled) date, and this was used to create groundwater areas by year. Likewise, an end date (where provided) indicated an abandoned bore and hence the location was removed from the year end date and subsequent years. Only three bores were recorded as abandoned for the study period (Figure 11). However, many records appeared to have a default drill date, and it was assumed that these records were a default for bore registrations prior to 1900. Therefore, a new drill date was inserted based on the jurisdiction and year range (see Table 9).

Within the Western Australian dataset there was a high number of records with a null drill date (see Table 9. It was recognised that due to urban settlement, wells were used in the agriculture areas (Powell 1998 p 14) as early as the 1840's. Based on information provided in Payne *et al.* (1987 p 35) and Powell (1998), an alternative year range was used for the agricultural areas and rangelands of Western Australia (Table 9).

A buffer distance of 7km for each groundwater bore was created for each year from 1850 to 1899 and decreased to 5 km after 1900. Figure 11 shows the ground water locations used in this study to 1900, along with the abandoned bores that were excluded for the years after decommissioning. Post 1900, the water area as determined by groundwater expanded considerably, with an estimated 1,290,806 km^2 (65% increase) added from 1900 to 1980 (Figure 11). However, as groundwater bores are not required to be licensed in many areas, the total number of bores can only be estimated (Boughton 1999 p6).

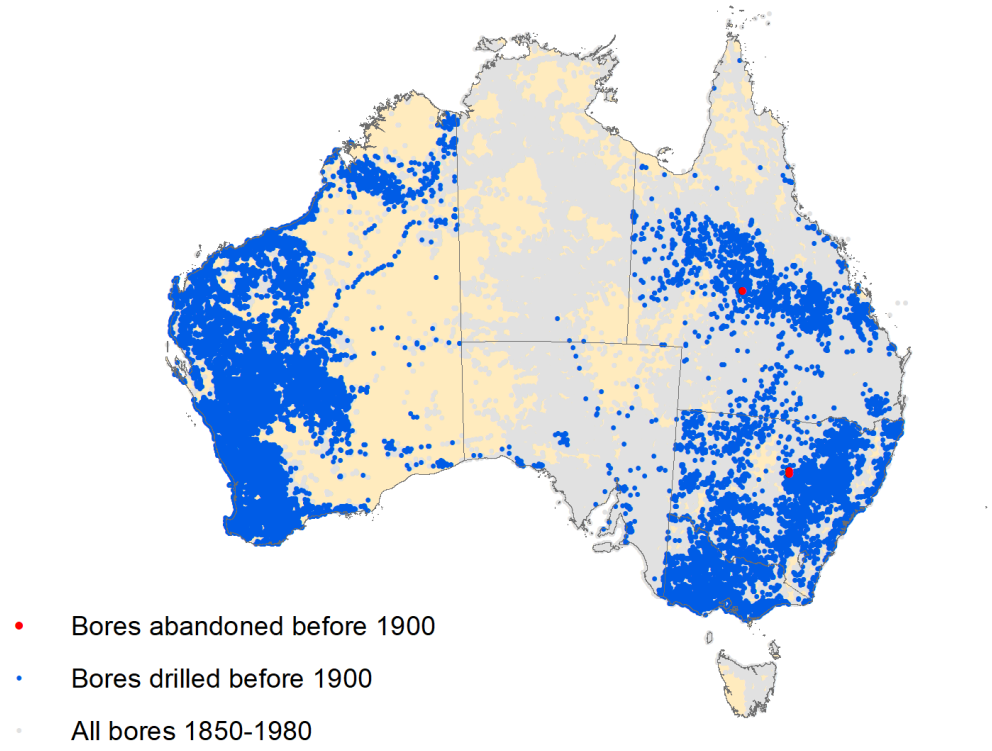


Figure 11. Groundwater locations with an estimated drill date between 1850 and 1900 superimposed over all groundwater locations up to 2020.

Table 9. The allocation of a random year to locations with a default drill date to the groundwater dataset.

Default drill date	Jurisdictions	Number of locations	Random year range
1/1/1800	New South Wales	8,169	1850-1900
	Queensland	34	1890-1900
1/12/1800, 12/12/1800	New South Wales	2	1850-1900
1/1/1900	Victoria	10,709	1850-1900
	Queensland	2,021	1890-1900
	Western Australia	29,102	1850-1900*,1880-1910

** Defined as the 1901 East, Metropolitan, South-East and West Provinces (Agricultural Region)*

Surface Water Development

As more capital and earth-moving equipment become available during the latter 1880s, farm dams became a feature to capture surface water. Condon *et al.* (2002 p 82) describes the use of excavated tanks using tools from shovels, drays with ploughs and simple scoops. Later, horse-drawn 'delvers' and graders were used. Godwin and L'Oste-Brown (2012) documented the methods of surface-water capture used in central-west Queensland during the 1880s, in conjunction with the use of wind-powered pumps and troughs.

Dams were dug using horse-drawn scoops and were further developed as mechanised steam tractor technology became commonplace.

The early construction methods were quickly superseded by the discovery of ground water and the use of steam power was increasingly used for drilling ground water bores, and associated channels and storages structures (Hoch 1990; James *et al.* 1999). For this study it was assumed that surface water improvements occurred in non-riparian lands, however it is known that existing water sources within riparian land would have been continuously improved.

The point layer for surface-water improvement (Figure 10c) was sourced from:

(1) Water points in the surface hydrology dataset (Crossman and Li 2015b); and
(2) Analysis of the non-riparian lands with the Prescott Index and WOFS datasets described above.

All water points within the non-riparian area were selected and any points within 3km of any WOFS points. The resultant raster was converted to a polygon layer and large water sources representing salt lakes and man-made reservoirs were removed by an area calculation along with all polygons greater than 3.5 ha (approximately a square of 4 pixels) and within 7km of the coast. The polygons were reconverted to a centroid point.

A 7km buffer was created around each point, based on the random year, and converted to a raster for 1880 to 1899 (Figure 12). Areas overlapping with the riparian and groundwater areas were assigned zero. The buffer distance was decreased to 5km after 1900.

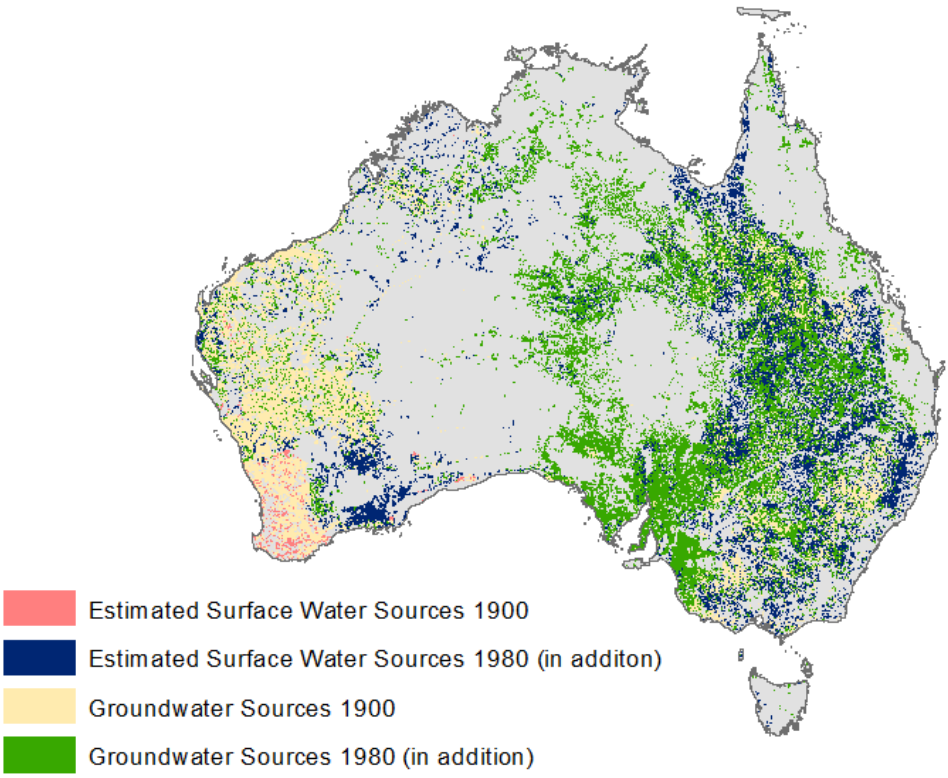


Figure 12. Map of non-riparian water sources from 1900 to 1980 showing an increase in area available for pastoral use. These water areas are dated either from the groundwater drill date or to an estimate to the construction year of the surface water source ranging from 1900 to 1980.

Surface water development was only considered in locations outside the riparian lands and groundwater areas. For this dataset there was no known source of construction date. Hence a mean livestock density (AE km^2) for Statistical Districts (grazing land classes were not used) was calculated annually from 1880 to1980 and was used as an estimate of construction date. For every km^2 cell, the year where density was highest (maximum) and a median year were calculated. Both maximum and median year were extracted for all surface water points and the following was calculated:

Estimated Construction Date = Random number (between 0 to 1) x ((Median Year – Maximum Year) + Maximum Year).

The surface water source was allocated the estimated year of construction. As shown in Figure 13 approximately 31,156 km^2 was estimated to have non-riparian surface water in 1900, which increased to 805,944 km^2 by 1980.

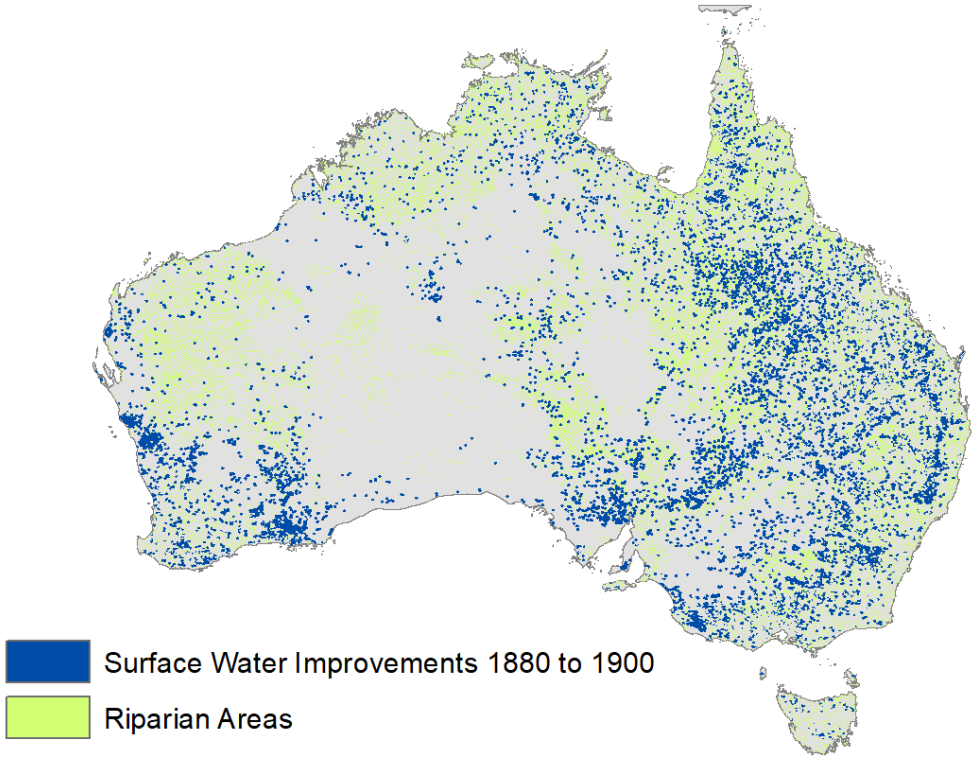


Figure 13. Map of developed surface water areas (blue) and riparian areas (natural waters; green) between 1880-1900.

Vegetation Clearing

With the introduction of livestock across Australia there were changes to vegetation either by direct grazing impact and/or land clearing. Vegetation clearing for livestock was initially limited to the outskirts of towns and cities. According to Stubbs (1998) and Neldner *et al.* (2017), clearing was probably not widely practised due to the labour requirements and the availability of grassland and open timbered areas allowed pastoral use prior to the 1860s. Forestry practices are not covered in this study.

As land access for grazing became more restrictive from the 1860s onwards, ringbarking (the removal of bark from the trunk to disrupt water and nutrient uptake resulting in tree death) was practised by landholders in open forest areas, as it was assumed that this promoted further grass production as trees reduced grass growth (Powell 1998). Stubbs (1998) prescribed 1859-1862 as the probable date range when ringbarking commenced (within the Hunter area of New South Wales).

An increase in carbon flux (an indicator of woodland clearing) was estimated to commence from *c*1870 for the Australian region (Houghton and Hackler 2002) which was determined by the annual cropping area estimates from the New South Wales statistics (Houghton 1999). From 1875, specific controls over ringbarking within Crown land leases were legislated (*Crown Lands Regulation Act 1881* NSW; *Crown Lands Act 1884* Qld; *Land Act 1884* Vic). Within New South Wales, ringbarking was considered as an improvement and was calculated within lease payments. Hence ringbarking became a common mechanism across the pastoral lands within New South Wales by the 1880s (Stubbs 1998). Statistics in New South Wales on land clearing (mainly ringbarking) were recorded from 1891 to 1902 showing the percentage of the statistical district as cleared either for agriculture and or grazing.

From the information presented in Figure 14, the vegetation mapping from 1875 was changed to grasslands (GL1) in areas where:

(1) Clearing rates of >45% in the 1891-1902 occurred (New South Wales 1889-1902); and
(2) Where vegetation density differences have been observed between the 1750 and 1988 vegetation mapping (Geoscience Australia 1988, 2001).

No comparable statistics could be found for the remainder of Australia, although in Queensland it has been estimated that clearing represented less than 10% of the area (Neldner *et al.* 2017), whilst in Victoria pastoral land clearing appears to be of a small scale during the study period (Victoria 1869).

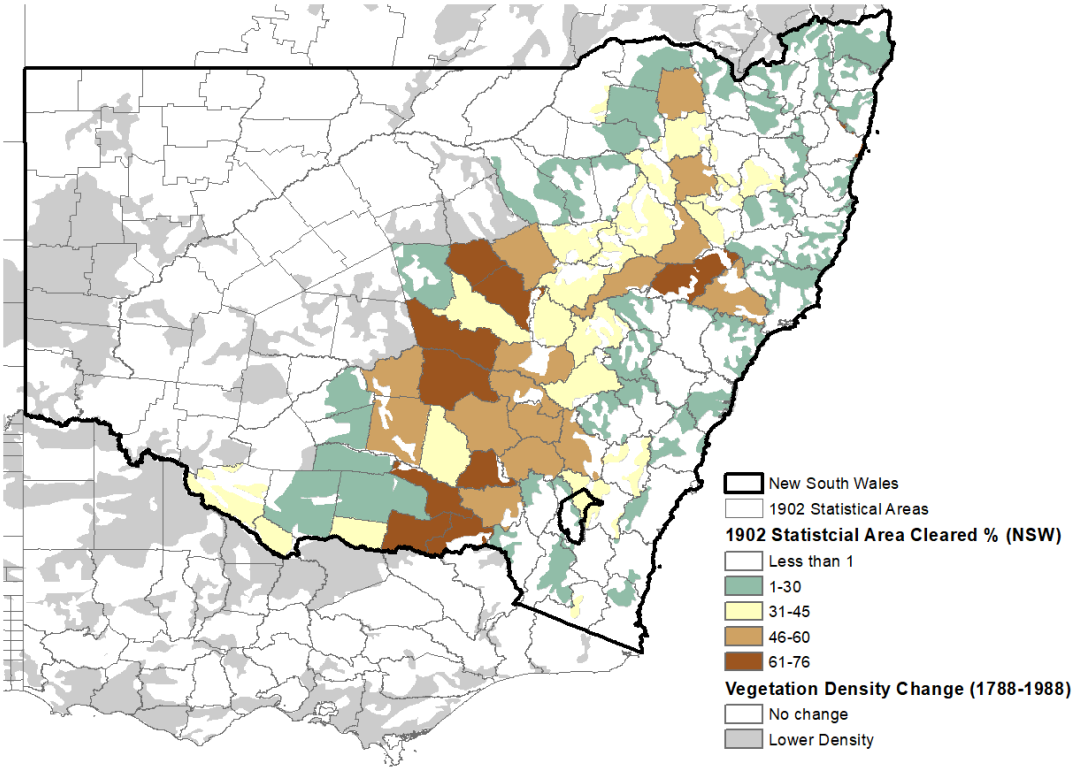


Figure 14. Significant areas of New South Wales have been cleared, resulting in lower natural vegetation densities by 1902.

Changes to vegetation density intensified due to mechanisation throughout the 20th century. Whilst the main areas of vegetation change have been identified (Geoscience Australia 1988; 2001), the temporal aspect of vegetation change prior to 1980 for many areas is largely unknown due to the low coverage of aerial photography from 1928 onwards (Geoscience Australia 2023b).

The percentage area of vegetation clearing within statistical districts was recorded between 1900 and 1920 for New South Wales and between 1900 and 1960 for Western Australia) but was not mapped. The purpose of clearing was also not defined accurately (either ringbarked and/or agricultural) refer Bedward *et al.* (2007). Many of these areas are considered as mixed farming (combination of cropping and grazing) and it has been assumed that these areas were utilised for livestock grazing.

To establish a timeline of vegetation density change, the extent of change was observed by the difference between the 1788 and 1988 vector mapping (Geoscience Australia 1998; 2001), which was converted to a 1km grid and then intersected with areas with less than 30% Foliage Projective Coverage (Armston *et al.* 2002). This area was then intersected by the Interim Biogeographic Regionalisation for Australia (IBRA) bioregions (Australian Government 2000). A year was assigned where 50% of the area was believed to be modified for agricultural or pastoral purposes and assigned as grasslands (GL1) (Figure 15). In all, vegetation within 37 bioregions were found to have been modified from 1788 to 1980. Of these, 25 were combined, as the time of modification was prior to 1900 (Lamb *et al.* 2001; Duncan and Dorrough 2009, Bradshaw 2012). The remainder were assigned a modification date as listed in Table 10.

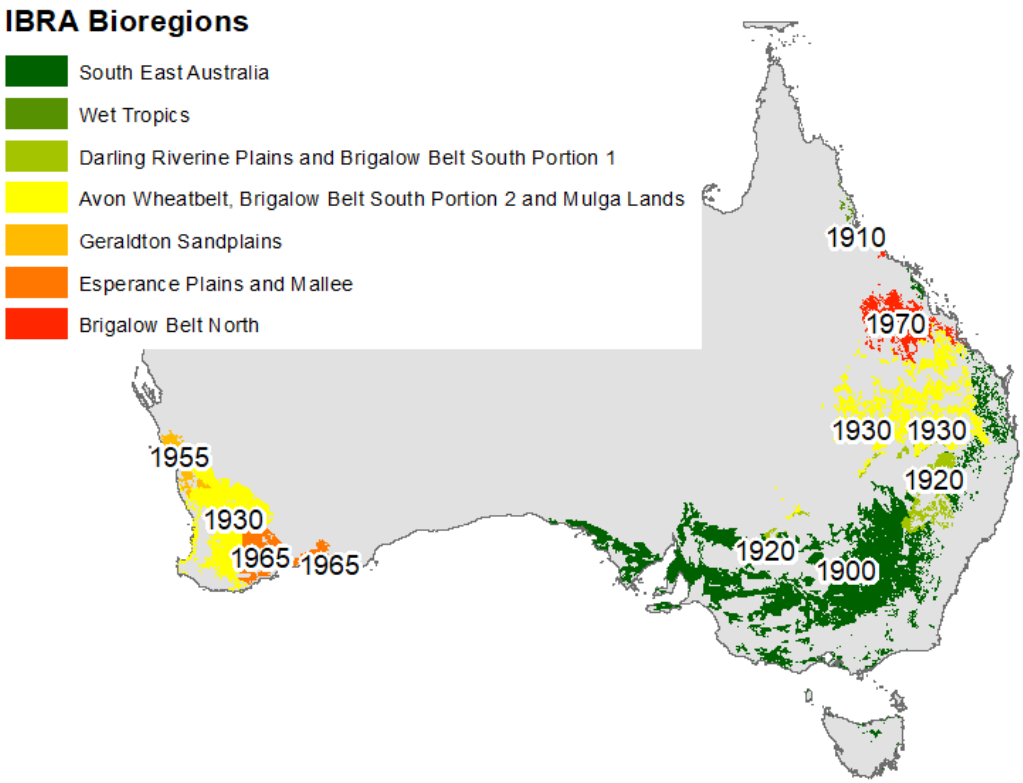


Figure 15. Map of Vegetation Density Change from 1788 to 1980 showing a generalised year where 50% clearing has occurred within the IBRA region. These areas are considered grassland (GL1) for consecutive years after the year indicated where vegetation density changes have occurred.

The bioregions Darling Riverine Plains and Brigalow Belt South were each divided (Bedward *et al.* 2007) and denoted Portion 1 and 2 respectively for this study. The Western Australian agricultural areas comprising four IBRA bioregions were also combined due to vegetation clearing for mixed farming from 1900 to 1930. The 1930 date for the Brigalow Belt South Portion 2 was based on the observations by Dodd (1940 pp 11-12, and Seabrook et al. 2006) where prickly-pear (*Opuntia spp.*) removal via biological control allowed agricultural and or pastoral land use to proceed with clearing of emergent vegetation. The mapping by Skerman (1958) showed widespread clearing of Brigalow (*Acacia harpophylla*) in the southern portions of Queensland.

The Mulga Lands (IBRA) bioregion is characterised by the presence of Mulga (*Acacia aneura*) which has been used as a fodder species since the mid to late 19th century during times of drought (Anon. 1877). Land clearing has been limited to eucalyptus and other acacia species such as Brigalow and Gidgee (*Acacia cambagei*) within the eastern portion of the bioregion (Fensham *et al.* 2011). The natural death of Mulga has been observed, particularly after drought (Heathcote 1962a, p263, Fensham *et al.* 2011) and fire (Silcock *et al.* 2016) and consequently from over-grazing (Heathcote 1962a: p264-65). However, the return of sufficient rainfall (Anon. 1947, Fensham *et al.* 2011) and the use of Mulga as a fodder species (Everist 1949) has seen Mulga regeneration.

Western Australia reported agricultural/pastoral clearing and ringbarking for statistical districts from 1900 with some areas reporting 16% cleared for agriculture and/or livestock. By 1930, cleared areas within statistical districts were approaching 40% within the south-western agricultural area and some statistical districts within the northern agricultural area were 40% cleared by 1955. Bradshaw (2012) commented that most clearing within Western Australia commenced after 1945. According to Andrich and Imberger (2013) land clearing was slow within the agricultural areas of Western Australia, but accelerated between 1950 and 1980, during which a further 40% of the land was cleared by 1980.

Further land clearing continued in Queensland in the Brigalow Belt North (IBRA) bioregion, with the commencement of the Brigalow Land Development Scheme from 1962. It has been estimated that over 40% of the Brigalow Belt North bioregion was cleared by 1970 for pastoral land uses (Seabrook *et al.* 2006).

Protected Areas

There are instances where lands were excluded from livestock for environmental protection, mainly from the gradual introduction of National Parks from 1880. The protected lands were determined from the Collaborative Australia Protected Area Database (CAPAD) (Australian Government 2021). The CAPAD generally over represents protected areas during the study period, as the areas that are shown represent the first digital cadastral records and do not show the initial protected areas that have, over time, expanded (particularly after 1966) (Figure 16

The earliest National Parks were often proclaimed due to the natural appearance, or appreciation of the locality, or (more often) that the land was considered useless for pastoral activities. For example, steep lands as delineated in the study would have been considered non-pastoral lands in this regard. Land uses such as timber reserves, forestry and First Nation interests have been excluded from this study, due in part to the unavailability of records in some jurisdictions and the unlikeliness of livestock grazing within such areas. Many of these areas have subsequently been converted to protected areas and this date has been captured by CAPAD where possible. Protected areas were added annually from 1880 and assigned as GL4.

Table 10. Generalised Year of Vegetation Clearing within IBRA Bioregions.

Year[1]	IBRA Bioregion	Comments	Reference
1900	South-eastern Australia[2]	Areas considered to be modified prior to 1900	Bradshaw (2012)
1910	Coastal Queensland[2] Wet Tropics	Clearing for agriculture, pastoral and or forestry	Lamb *et al.* (2001 p11); Thorpe (1996 p85) Birtles (1997 p182); Payne (1959 p25)
1920	Brigalow Belt South Portion 1 Daring Riverine Plains Portion 2	Cleared areas of >40% of individual statistical districts	Bedward *et al.* 2007
1930	Brigalow Belt South Portion 2	Areas of Prickly Pear infestation returned to sown or naturalised pastures	Dodd (1940) pp 11-12, Payne (1959 p20)
	Mulga Lands	Eastern areas only	Fensham *et al.* (2011); Heathcote (1962a p263); Oxley (1987)
	Western Australia Agriculture Areas[2]	Cleared areas of >40% of individual statistical districts	Bradshaw (2012); Western Australia (1896-1960)
1955	Geraldton Sandplains	Cleared areas of >40% of individual statistical districts	Western Australia (1900-1960)
1965	Esperance Plains and Mallee	Clearing for agriculture	Andrich and Imberger (2013)
1970	Brigalow Belt North	Clearing for pastoral use	Australian Government (2001 p11), Bradshaw (2012); Saha *et al.* (2019); Seabrook *et al.* (2006)

1 Estimate based on 40% vegetation density modification

2 IBRA bioregions combined

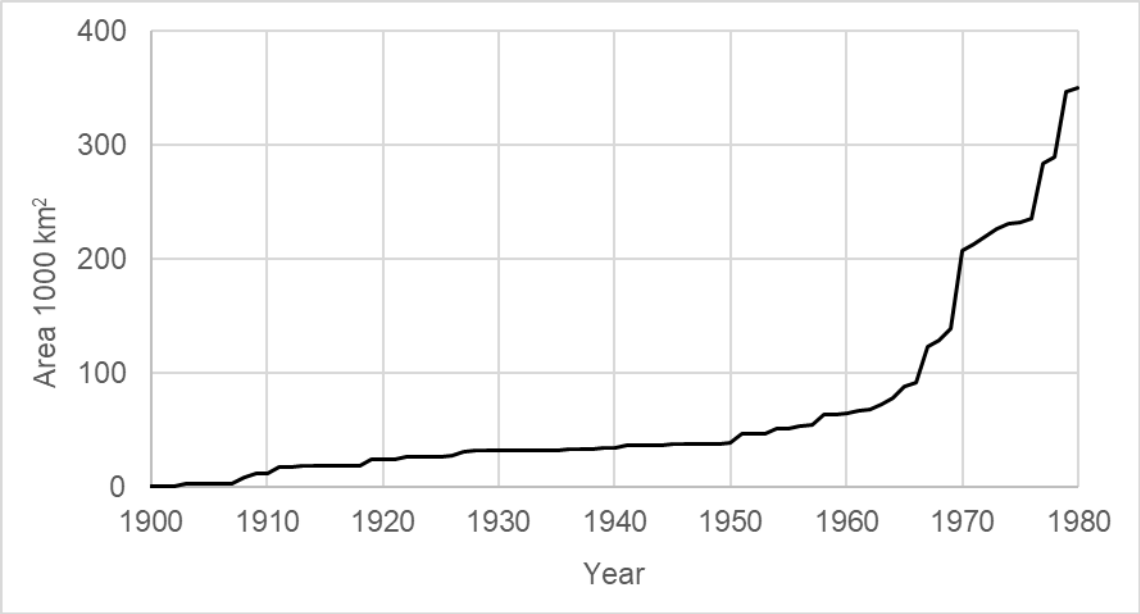


Figure 16. The estimated area of protected lands from 1900 to 1980. Note the large increase after 1966.

Irrigated Cropping Areas

The differentiation of cropping areas to that of naturalised or improved pastures is seasonal and represents the economic decisions of individual businesses in any given period. Due to the lack of annual consistent imagery prior to the mid-1970s, the task to separate pasture areas on an annual basis was challenging especially in areas of mixed farming. Water allocations that were separated to land (water trading) commenced after 1983 (Australian Government 2023), therefore the use of irrigation areas/districts to restrict livestock was used for this study.

Although declared irrigation areas or districts were used throughout the 20th century, the land use was often dominated by fodder and sown pastures, particularly in southern Australia. Where possible, permanent crops such as cotton, rice, sugarcane, tobacco and horticulture were excluded from the Livestock Distribution within the irrigation areas/districts. In 1980 it was estimated that 3,726 km^2 was covered by these crops, using cropping areas for 1976 and 1984 (Australia Bureau of Statistics (1911-1984) (Table 11).

Table 11. Land Use within Irrigation Areas 1992/1993 and Grazing Land (GL) weighting applied to the Livestock Distribution.

Australian Land Use and Management Classification (1992/93)*	**GL Weighting (%)**	**Estimated Area (km^2) 1980^**
Apples, Citrus, Cotton, Grapes, Legumes, Nuts, Oilseeds, Other non-cereal, Other vegetables, Pears, Planation fruit, Potatoes, Rice, Stone fruit, Sugarcane, Unallocated	0	3,726
Sown Pastures	85	8,262

* Version 3 Knapp *et al.* 2006

^ Australia Bureau of Statistics (1911-1984)

Permanent cropping within irrigated areas were selected from the earliest Australian land use mapping was 1992/93 (Knapp *et al.* 2006). These areas were converted to a 1km^2 grid and assigned a random value. The 1km^2 pixels were sorted and any values higher than the first 3,726 count were removed.

This left a random area that represents permanent irrigated cropping. Crop irrigation area statistics were available for selected years (Australia Bureau of Statistics 1909-1930 and 1948-1969) for most of the major irrigation areas. The irrigation areas (Australian Government 2022; Victoria 2018;Western Australia 2023) used in the study along with the estimated permanent irrigated cropping area is shown in Table 12.

An area representing 3,726 km^2 (see Table 12) were allocated a random year based on the irrigated crop statistics (Australia Bureau of Statistics 1909-1984) and a GL weighting of zero was assigned for the initial and subsequent years to exclude livestock from these areas. The allocation continued for every year until 1980 with all pixels being assigned a year. Whilst the actual spatial areas are not known, the overall distribution shows a gradual increase in irrigated permanent cropping.

Limited irrigated area statistics were available prior to 1946 with more information collected for irrigation areas being available between 1947 to 1970.

Victoria operated various irrigation schemes that changed over time with waters diverted to all systems. The statistical record (Australian Bureau of Statistics 1911-1984) showed that between 1948-1969 there were six irrigation entities, and these areas were used for the study. Mildura was included with the Murray River scheme (see Figure 17).

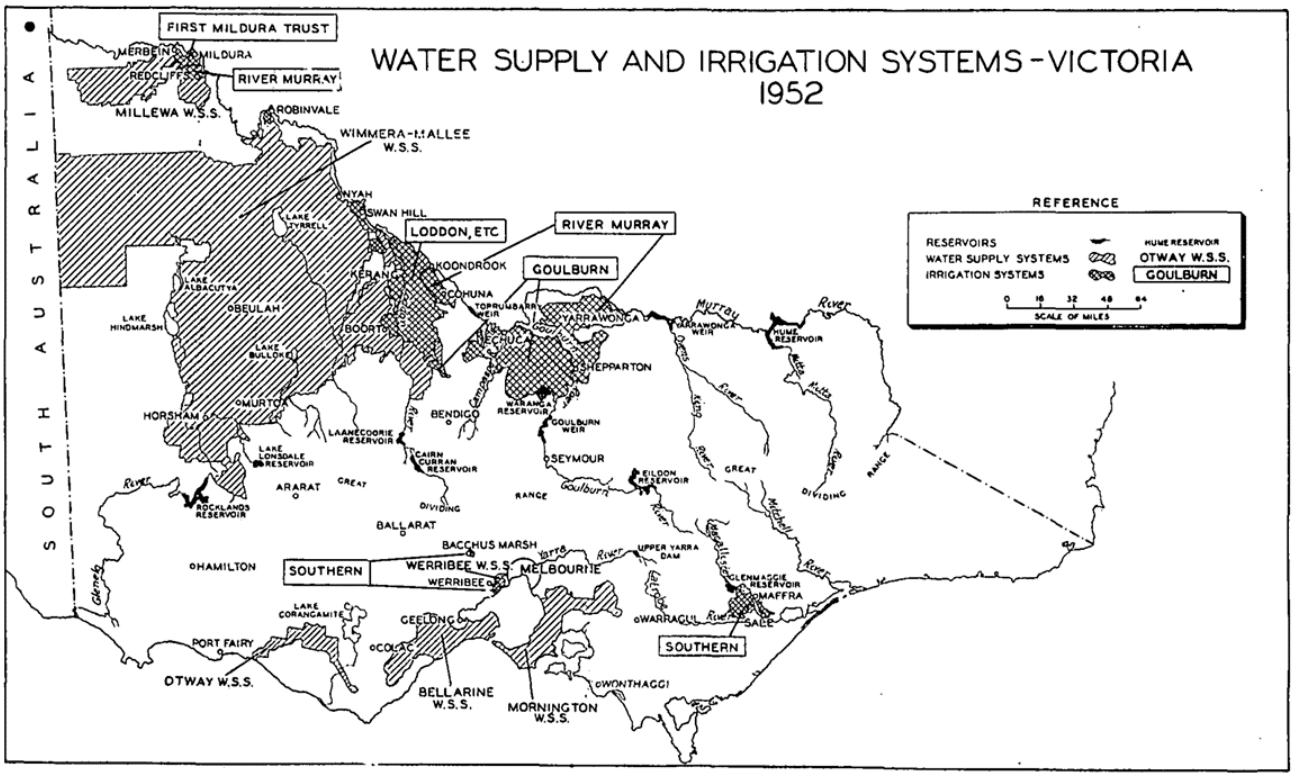


Figure 17. Victorian Irrigated areas as used in the study (Australian Bureau of Statistics 1911-1984; 1955 p963).

Table 12. Start dates and estimated areas of cropping and pastures within the irrigated areas used in the study.

Start Year	Location	Permanent Cropping Area (km^2) 1980^	Pasture and Fodder Area (km^2) 1980^
New South Wales			
1912	Yancoo[1]	95	89
1926	Mirrol[1]	111	54
1928	Coomella	21	1
1946	Lowbidgee[1]	17	77
	Wah Wah[1]	123	211
1947	Hay	-	5
	Tullakool	6	28
1949	Benerembah	53	38
	Tabbita	13	19
	Wakool	176	364
1951	Berriquin	257	666
	Bungunyah	6	-
	Pomona	3	-
1955	Denimein	69	67
1957	Deniboota	70	237
1963	Coleambally	184	130
	Namoi River catchment[2]	199	29
1964	Buronga	6	-
1967	Macquarie River catchment[2]	249	140
1969	Border River catchments[2]	147	5
1970	Jemalong and Wyles Plains[3]	68	209
1972	Gwydir River catchment	198	12
Victoria			
1900	Goulburn[4]	141	1796
	Mildura and Lower Murray River[5]	135	459
	Wimmera[6]	45	372
1923	Torrumbarry[7]	50	721
1927	Loddon River catchment[8]	74	650
1947	Yarrawonga Weir and Upper Murray River	24	658

^ Estimated 1900-1914, 1931-1947 and 1970-1980.

1 Calculated as part of the former Murrumbidgee Irrigation Area (New South Wales 2003).

2 Cotton areas, data from Namoi River (Porter 1966 p5) where 60% of land area was irrigated within 4 years.

3 No horticulture reported (Australia Bureau of Statistics 1911-1984; 1962), expansion occurred in 1970.

4 Estimates used for 1900-1947.

5 Established in 1887 and reformed in 1895.

6 Wimmera Irrigation Area was closed in 2013 (Australian Government 2013 p10). Southern System Irrigation systems included.

7 Estimated 1923-1948.

8 Estimated 1927-1948

Table 12. *continued*

Start Year	Location	Permanent Cropping Area (km^2) 1980^	Pasture and Fodder Area (km^2) 1980^
Queensland[9]			
1900	Burdekin River catchment[10]	258	3
1927	Theodore	20	49
1937	Bundaberg	429	51
1947	Lockyer Valley	63	10
	Mareeba	43	105
	Mary River	33	12
1953	St George	48	21
1972	Emerald	77	66
South Australia[11]			
1900	Lyrup	3	2
	Renmark	53	-
1905	Mobilong	-	2
	Monteith	-	6
	Mypolonga	3	9
1911	Berri	39	
	Moorook	4	2
	Waikerie	16	1
1913	Kingston	2	-
1920	Cadell	1	-
1921	Cobdolga and Loveday	28	-
1922	Chaffey and Cooltong	13	-
1940	Burdett	-	2
	Cowirra	-	3
	Jervois	-	24
	Long Flat	-	2
	Neeta	-	2
	Pompoota	-	5
	Wall	-	1
1949	Loxton	28	3
Western Australi[12]			
1916	Harvey	3	175
1932	Waroona	-	54
1933	Collie[5]	9	494
1964	Ord River Catchment[13]	13	0
Tasmania			
1900	No declared areas	-	127
	Grand Total	3726	8256

^ Estimated 1900-1914, 1931-1947 and 1970-1980.

9 Eton irrigation area not included.

10 Included records form Griggs (1989 pp205-206, 280, 348) (average cropping area between 1900-1930).

11 South Australia (2023b).

12 Anon (1955); Gibsone (1960); Gauntlett (1966)

13 Maximum area of cotton reached 32km^2 prior to 1970

Irrigated Natural and Sown Pastures

A similar method that was used to estimate permanent cropping was also applied to irrigated natural and sown pastures. The calculations also include lucerne and fodder crops, where present. It was estimated that 8,256 km^2 was used as irrigated sown pasture for 1980 (Australia Bureau of Statistics 1911-1984) and this number of random pixels were designated across the irrigation areas.

A GL weighting of 85% (GL1*w*) was assigned for the initial and subsequent years to these areas.

Results

From the natural state of grazing lands, approximately 992,905 km^2 of Australia was estimated to have been modified by 1980, allowing an increased livestock density across the continent.

A mean Livestock Distribution is shown in Figure 18. Biannual maps of the Livestock Distribution are presented in Appendix 2. Decadal means are shown in Appendix 3.

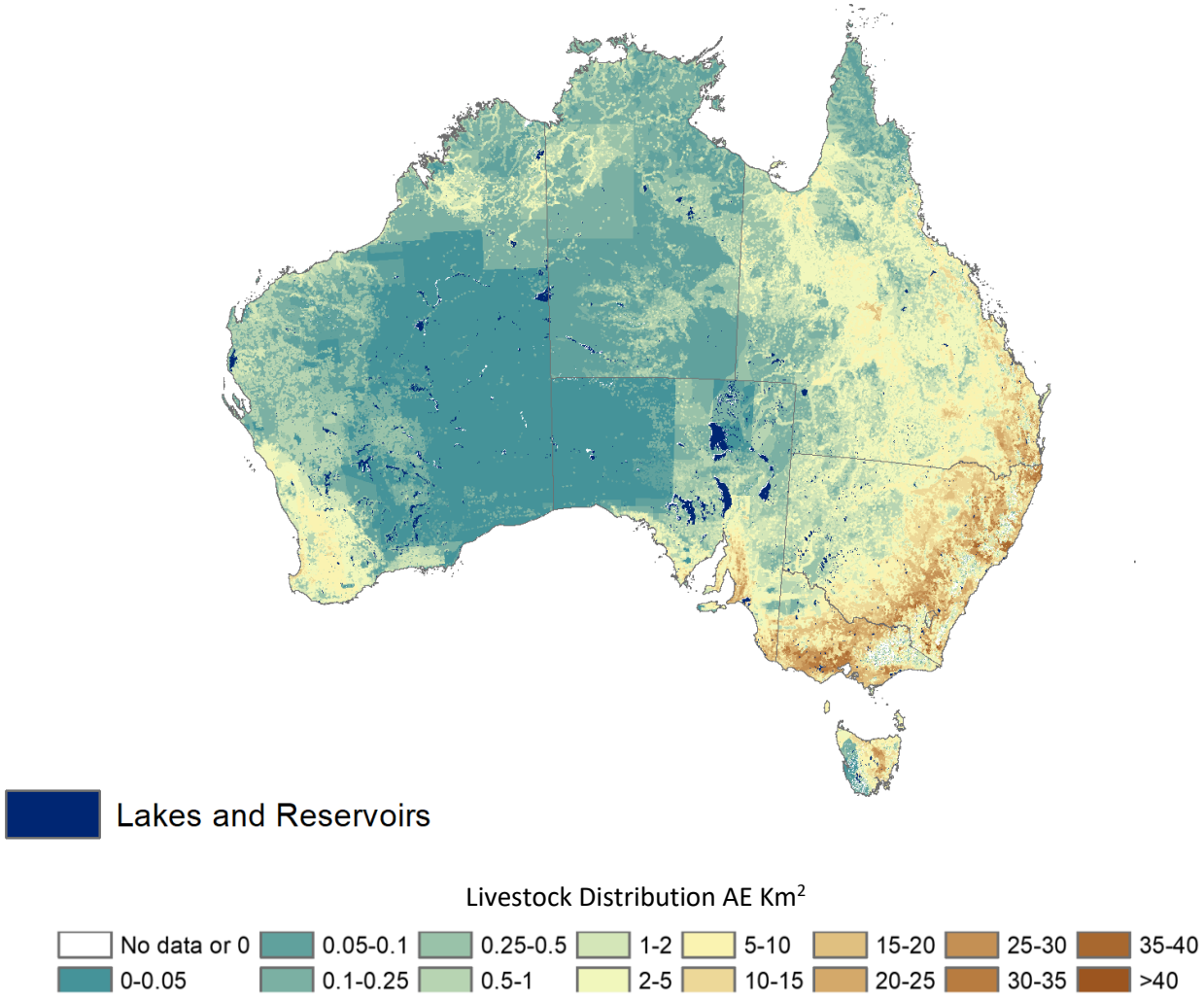


Figure 18. Mean Livestock Distribution calculated for the years 1788 to 1980.

Local Validation Southwest Queensland 1939-1949

A livestock dataset for 208 properties from 1939-1949 centred on Murweh Shire, Queensland (Bird 1953) were used as a comparison to the Livestock Distribution calculated in this study. Many of the properties (*n* =192) could be identified by comparing current cadastral information with mapping by Robertson (c1940), albeit with minor boundary changes identified from topographic mapping (Queensland 1944-45) (see Figure 19).

During the 1940s vegetation density, particularly Mulga (*Acacia aneura*), was likely at its lowest levels with Fensham *et al.* (2011) discussing the likelihood of mulga contraction before 1952, followed by subsequent regrowth. This was supported by Oxley (1987) that also suggested a decreased grazing pressure due to falling rabbit numbers. Drought declarations were made in November 1940 to January 1941, and from May 1944 to June 1947 (Irvine, 2021; Bird, 1953). Despite the change of collection date of the livestock statistics that occurred in Queensland from 1943 (see Figure 3), the property dataset from Bird (1953) was reported as 1st January throughout the property study.

The Livestock Distribution was calculated by a similar method as described in this study but using a clip of the grazing land classes from 1939 to 1949 based on the 192 properties and livestock numbers. The property results are consistent with the broader scaled annual Livestock Distributions (see Figure 20 and Appendix 4).

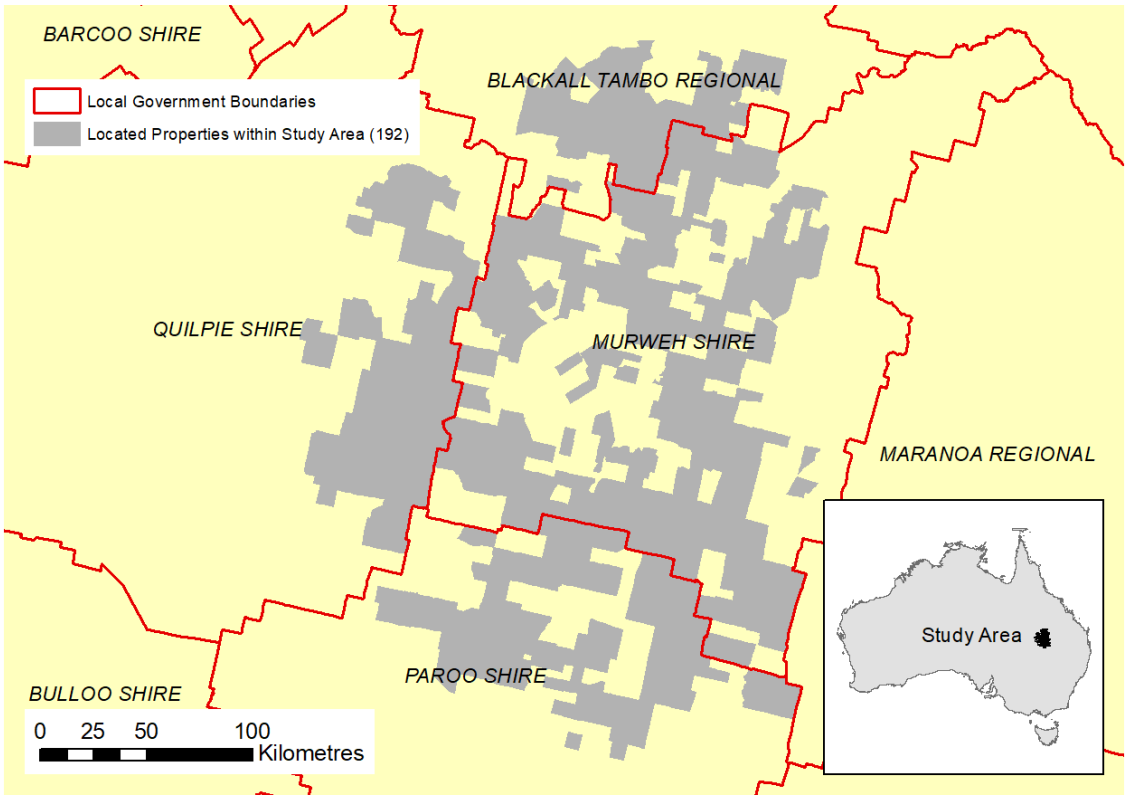


Figure 19. Location of the Queensland properties where livestock information from 1939-1949 was available for comparison.

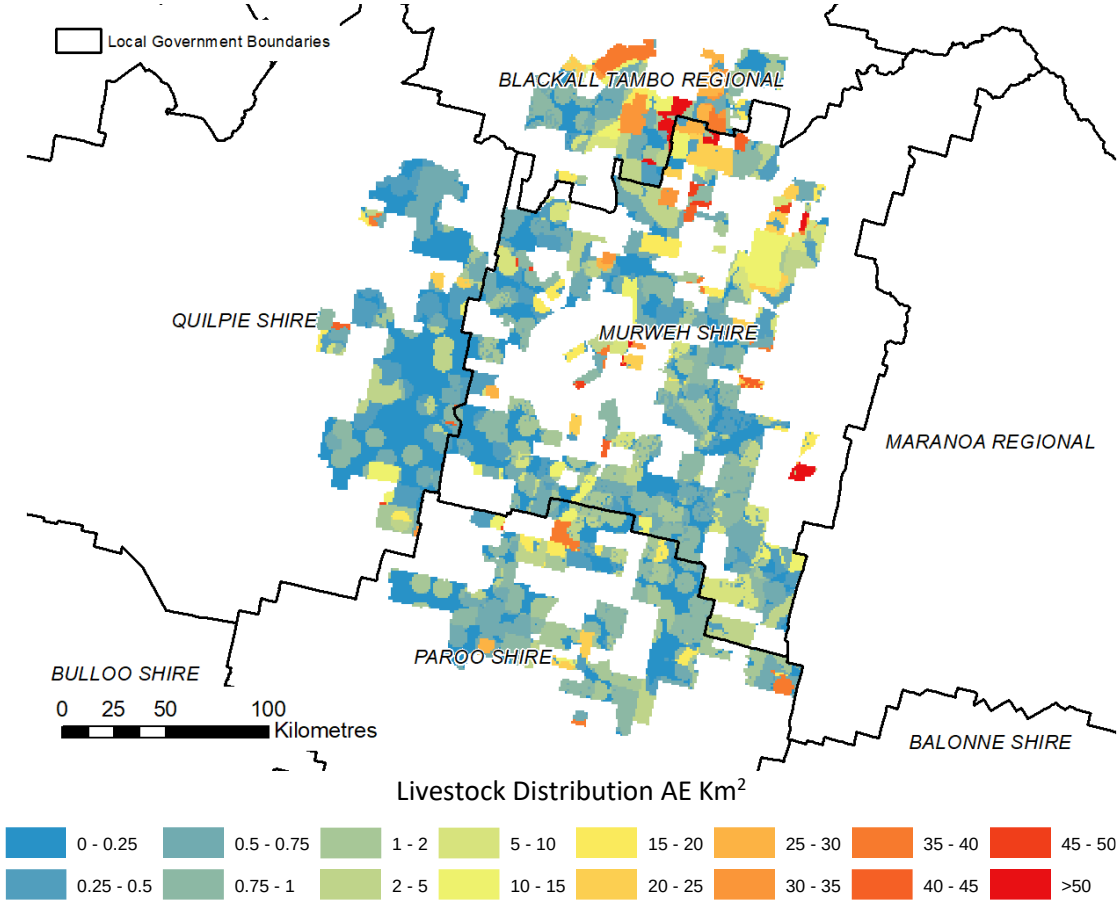


Figure 20. Mean Livestock Distribution calculated for the property used in the validation study for the years 1939 to 1949.

The livestock density calculated for the property is consistent with the broader scale Australian coverage (correlation coefficient 0.53 mean mapping). Higher distributions were observed within smaller properties, which was also observed by Bird (1953). As the Livestock Distribution was calculated by Statistical Districts, individual property differences would have been cancelled out, especially for smaller properties, hence the largest and smallest values would be smoothed within the Australia coverage.

Likewise, boundary effects, in this case for the property dataset with Quilpie Shire and Blackall Tambo Regional Council were higher than the broader Livestock Density. This is probably due to a lower representation of the property dataset within the Statistical Districts involved.

Limitations to the Livestock Distribution Model

Barrier Fences

During the late 19th century, the advance of the European Rabbit (*Oryctolagus cuniculus*) led authorities to the construction of barrier fences in New South Wales (Pickard 2022), Queensland (Biosecurity Queensland 2007), Victoria (Pickard 2022) and Western Australia (Crawford 1969). These were normally of extended distances. In addition, property barrier fencing was common within New South Wales Proclaimed Rabbit Infested Districts (New South Wales 1902) and Queensland Rabbit Board Districts (Queensland 1899) until the 1930s. In later decades, much of the barrier fencing was repurposed for wild dog control (Biosecurity Queensland 2007; Crawford 1969; Queensland 1957).

Examination of the available mapping shows substantial portions of the barrier fencing comprise property boundaries inside statistical districts. As the estimated Livestock Distribution uses statistical district

boundaries, no differences regarding Livestock Distribution to that of grazing pressures of feral animals or to unrestricted wild dogs would be seen.

Distribution Methodology

The methodology used in this study can be compared to the modelling of the Gridded Livestock of the World (GLW) (Robinson *et al.* 2014; Gilbert *et al.* 2018), albeit with temporal differences. There are some similarities, particularly the use of vegetation indicators, protected lands and topographic information. The GLW model used a topographic limit of 40% slope and made use of climatic and seasonal vegetation indices in order to estimate stock movements due to seasons. The map of Livestock Distribution presented above is simpler due to the lack of remote sensed information and is dependent on a vegetation density estimate. Seasonal effects were not considered.

Groundwater Information

The Interstate Conference on Artesian Water (1914) contained a map showing artesian bores and the drill date as provided by Bureau of Meteorology (2018) was checked for any matches. Unfortunately, the locations could not be matched to the current bore locations and the recorded drill dates on the 1914 map was unable to be used. Groundwater information used for the validation was also observed within the topographic mapping (Queensland 1944-45). More than double the number of bores were recorded within the property dataset compared with the groundwater dataset (Bureau of Meteorology 2018) used for the Livestock Distribution. This may be due to the occurrence of unregistered bores in the property information which the groundwater dataset would have not included. However, the topographical mapping is not consistent and not available as a digital form to enable further use within the map of Livestock Distribution.

Livestock herd and weight size

There is uncertainty about the composition of the cattle livestock herd in the historical statistical records. The conversion to 'adult equivalents' is based on a population count. More accurate conversion from a livestock number would be achieved by applying a herd adjustment value, if data were available. Stone (2004 p 94-95) discussed the weight changes of sheep over time, noting that a conversion of 10 sheep for an adult equivalent was common at the start of the 20th century, likely due to the ease of calculation.

Permanent Cultivation Areas

Permanent cultivation has intensified at the expense of grazing areas since the 1980s (Duncan and Dorrough 2009; Bell and Moore 2012). However, determining a spatial history of permanent cultivation is problematic as many agricultural areas are mixed farming systems and incorporate livestock, particularly in the sheep-wheat belt of Southern Australia (Puckridge and French 1983; Hacker *et al.* 2009).

As mentioned previously, the clearing statistics (where available) are vague about the purpose for clearing, being either cultivation or sown/naturalised pastures (Bedward *et al.* 2007). In addition, cultivation and pasture areas are not static and are linked to climatic/economic drivers (Bell and Moore 2012). As an example, Puckridge and French (1983) discussed the introduction of ley pastures within cereal growing farming systems that had occurred since the mid-1930s and allowed greater sheep and cattle stocking rates.

Land use studies using aerial photograph mosaics (i.e. Skerman 1958; Fensham 2003; Duncan and Dorrough 2009) demonstrated that many areas in southeast Australia were cultivated prior to 1945 and correspond with the vegetation clearing presented in Figure 15.

Protected Areas

The CAPAD generally over-represents protected areas that are shown prior to the use of digital cadastral records. To accurately represent the areas of protected areas over the course of time, the acquisition of survey plan records and subsequent digital capture would be required for individual parcels, a process beyond the scope of the study.

Despite this historical difference, there is general agreement between the CAPAD and the historical estimation (Sattler 2017 p156). The earliest national parks were often proclaimed due to the natural appearance, or appreciation of the locality, or (more often) that the land was considered useless for pastoral activities. Steep lands as delineated in the study would have been considered non-pastoral lands in this regard.

Land uses such as timber reserves, forestry and First Nation interests have been excluded from this study, due, in part, to the unavailability of records in some jurisdictions, and the status of livestock grazing within such areas. Many of these areas have subsequently been converted to protected areas and are thus captured by CAPAD.

Surface Water Structures

There is uncertainty with the estimated date of construction of dams or small reservoirs that has been used for the Livestock Distribution. This method is only one possible indicator of economic development and may not be a comprehensive or definitive measure. Other factors such as population growth, industrialization, and agricultural development should also be considered when assessing the economic development of an area.

The construction of surface water structures was continuous throughout the 20th century but not at a constant rate. Construction date appears to be related to economic activity and the availability of land (Malerba *et al.* 2021; Roohi and Webb 2012).

As the annual surface water points were used as an extension to the existing riparian and groundwater areas and then as a modifier to the grazing land (GL) proportion, the effects on the Livestock Distribution would be a time-lagged difference to the actual distribution.

Use of Interpolated Data

As shown in Figure 1, there are gaps within the statistical record that required an estimate to be made within some statistical districts. This in turn may have caused the Livestock Distribution to be distorted due to Statistical Districts changes, particularly in Victoria between 1856 and 1865.

Vegetation Density Change

Assigning a year to the change in vegetation density should be viewed with caution as the data were limited and generalised. It is expected that these areas would have seen incremental change over several years and may have exhibited no spatial relationship except to individual property boundaries.

The Mulga Lands bioregion is particularly problematic, as thinning and selective clearing was practiced, as opposed to broadscale clearing that was common in other bioregions. Hence the heuristic Livestock Distribution is directly limited by this feature. According to Lunt (2002) there has been little published literature that attempts to reconstruct vegetation change over the past century.

Recommendations

Further livestock data is required forNew South Wales 1830-1842 and Victoria 1856-1865, which may be located within the respective state archives.

Spatial datasets comprising the Statistical Districts and Adult Equivalents numbers, along with the Livestock Distribution results, should be made available to public. The data and modelling limitations should be included with any transfer of the available information.

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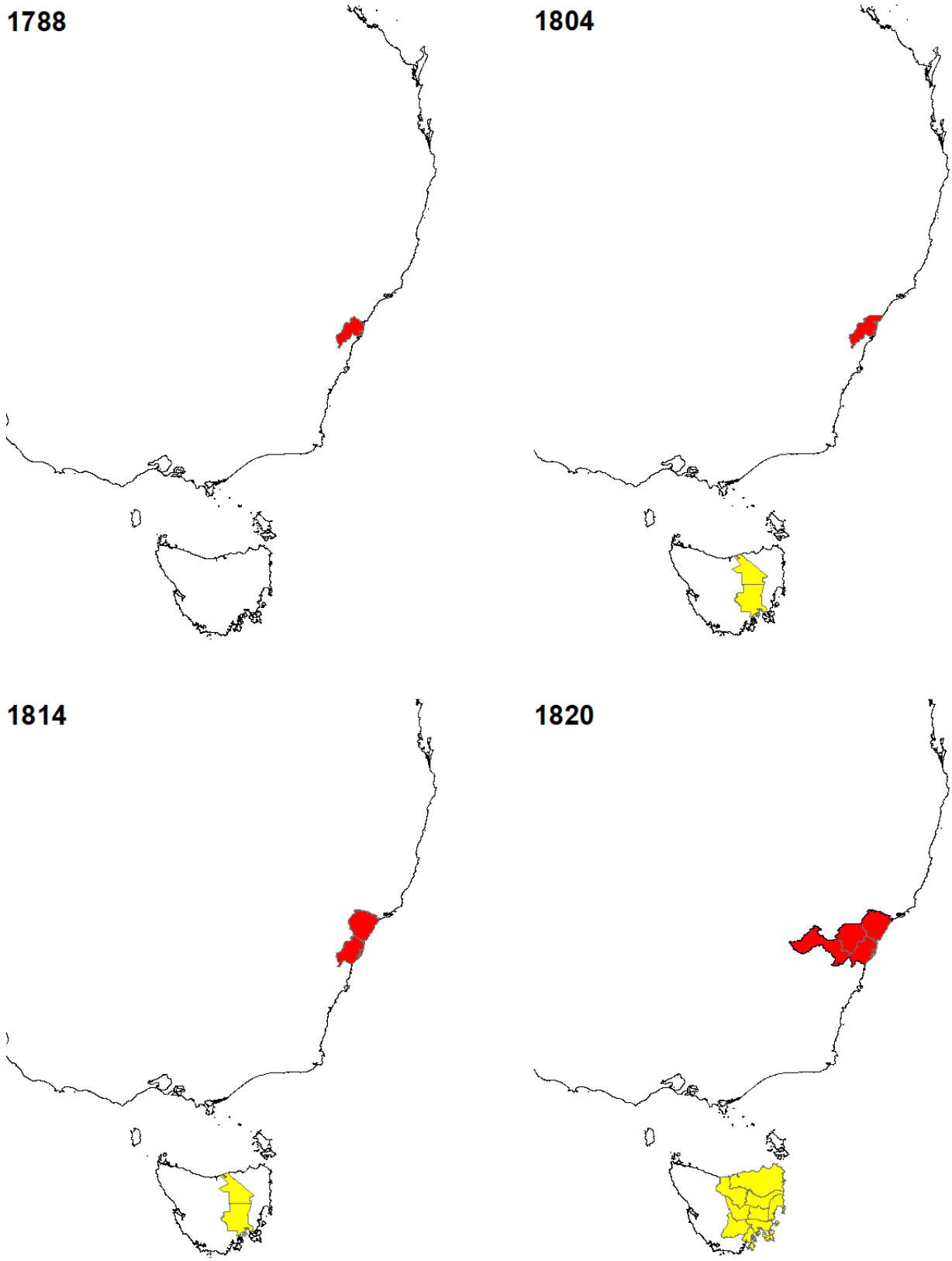
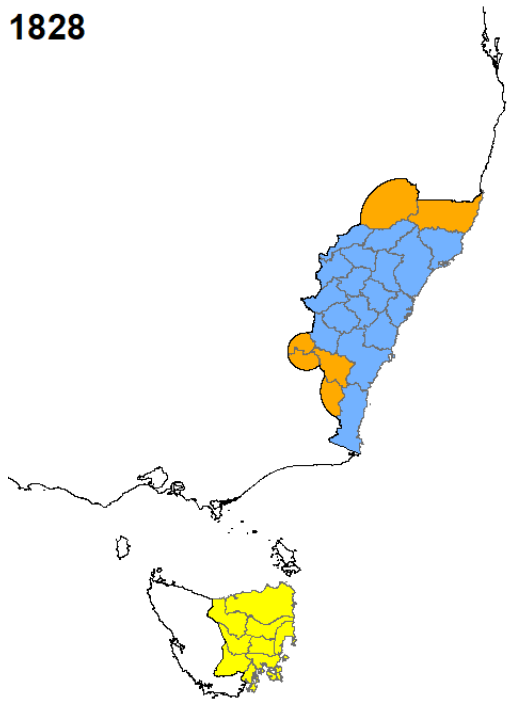
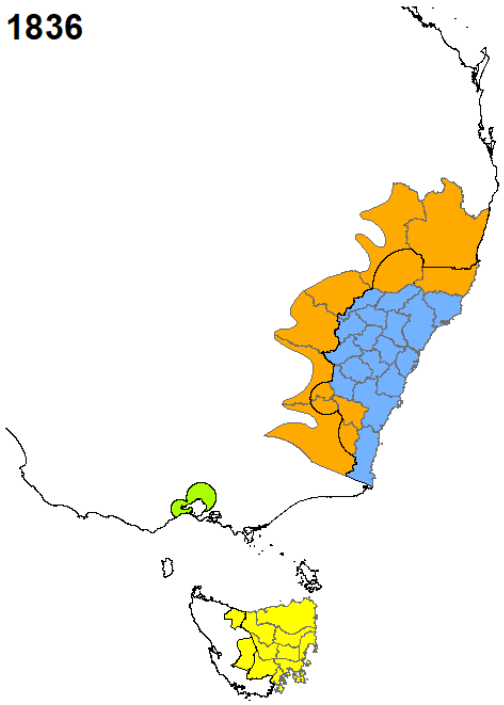
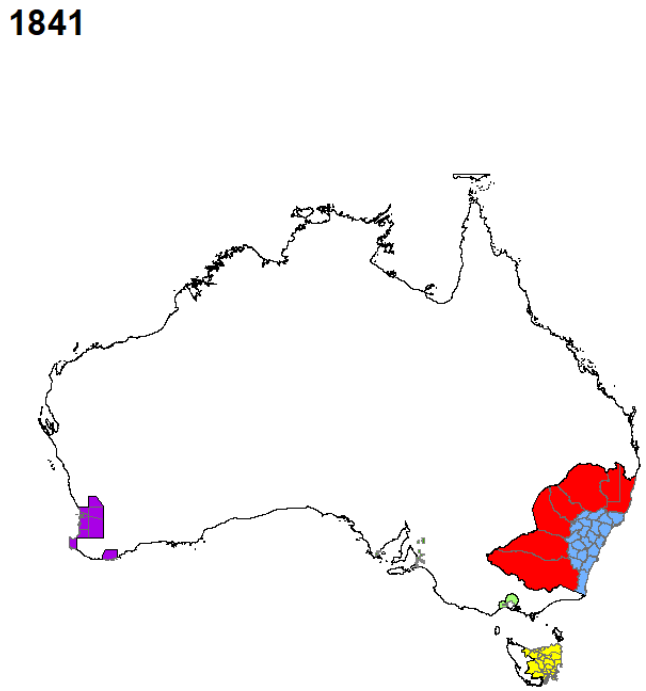
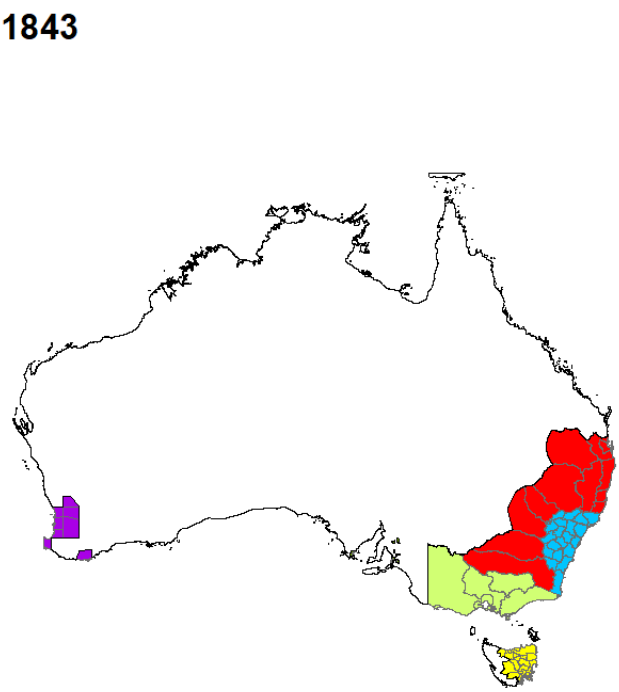
Appendix 1 Statistical Districts Mapping Sources







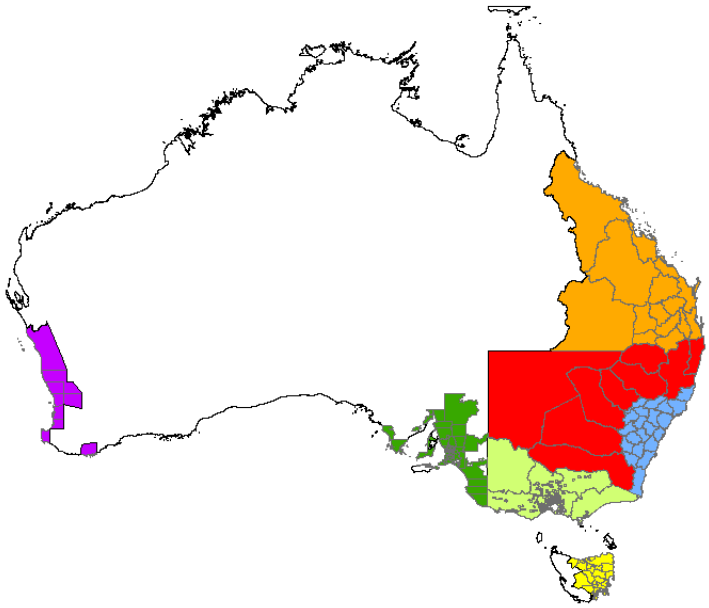




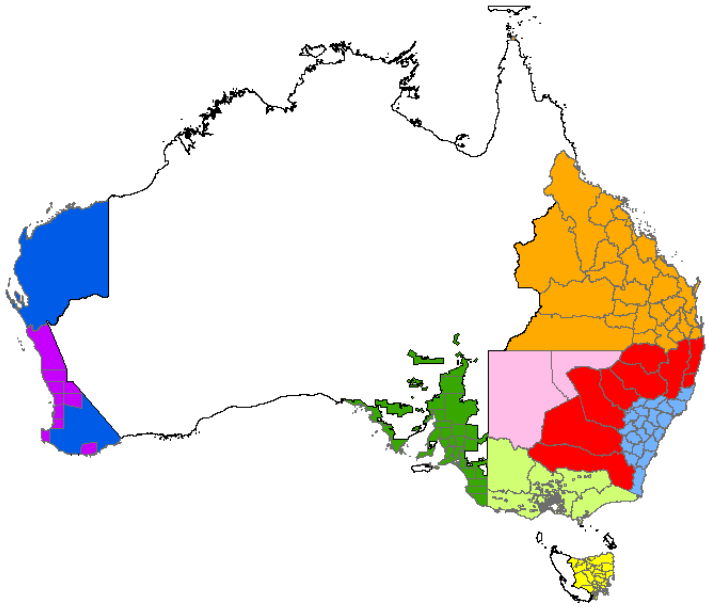
References (1828-1843)

Not designated	Baker (1841)	Harris (1862	Kenyon et al. (1932)
Arrowsmith (1839)	Betts (1846)	Jeans (1972)	Scott (1830); Arrowsmith (1834)

1860



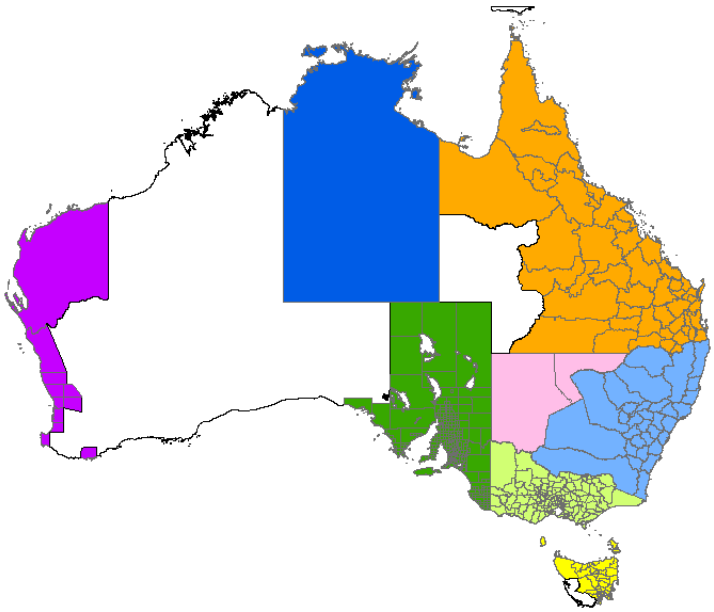
1865



References (1860 and 1865)

Not designated	Battye (1924)	Harris (1862)	New South Wales (1847)	Tayler et al. (1879)
Arrowsmith (1839)	Ham (1871)	New South Wales (2021)	Tasmania (2021)	Victoria (2021)

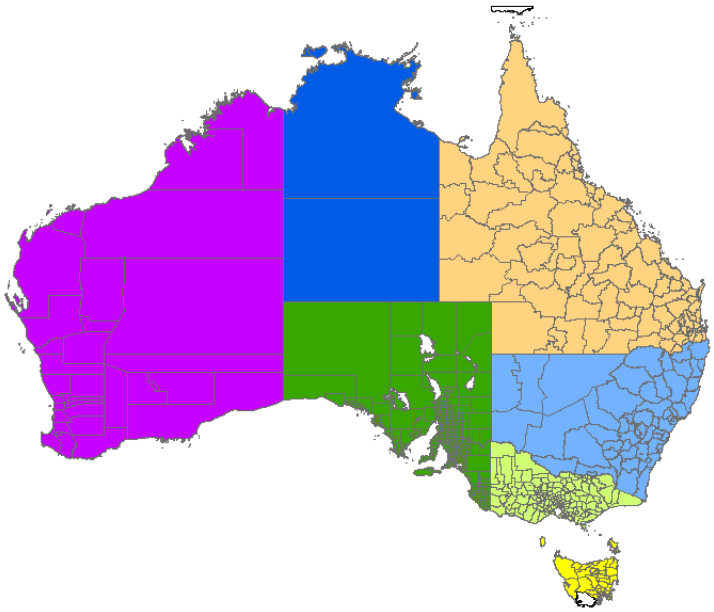
1880



Reference 1880

Not designated	New South Wales (2021)	Tayler et al. (1879)
Australian Bureau of Statistics (2018)	South Australia (2020a, 2020b)	Victoria (1891); Arnall and Jackson (1895)
Ham (1871)	Tasmania (2021)	Western Australia (1880)

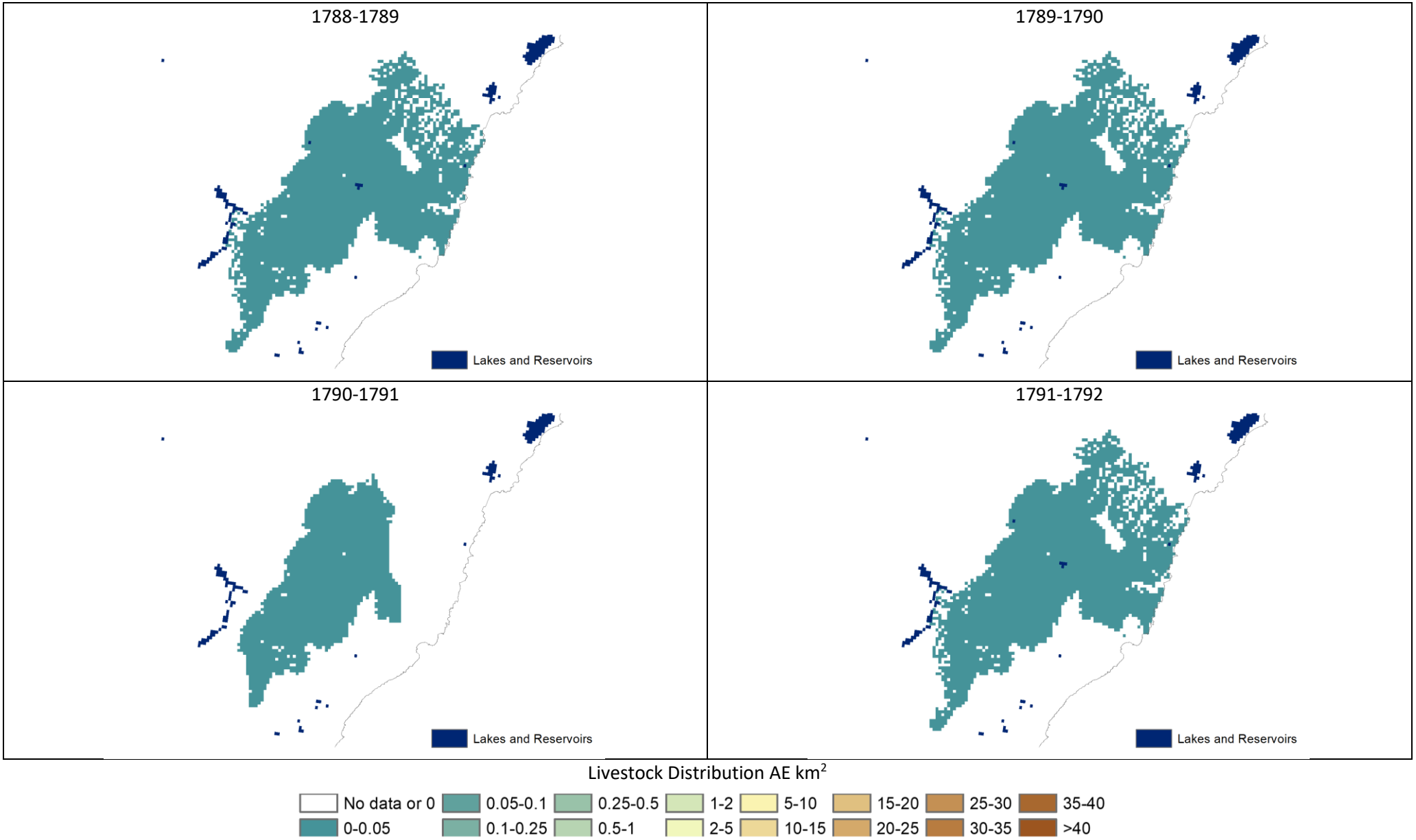
1892



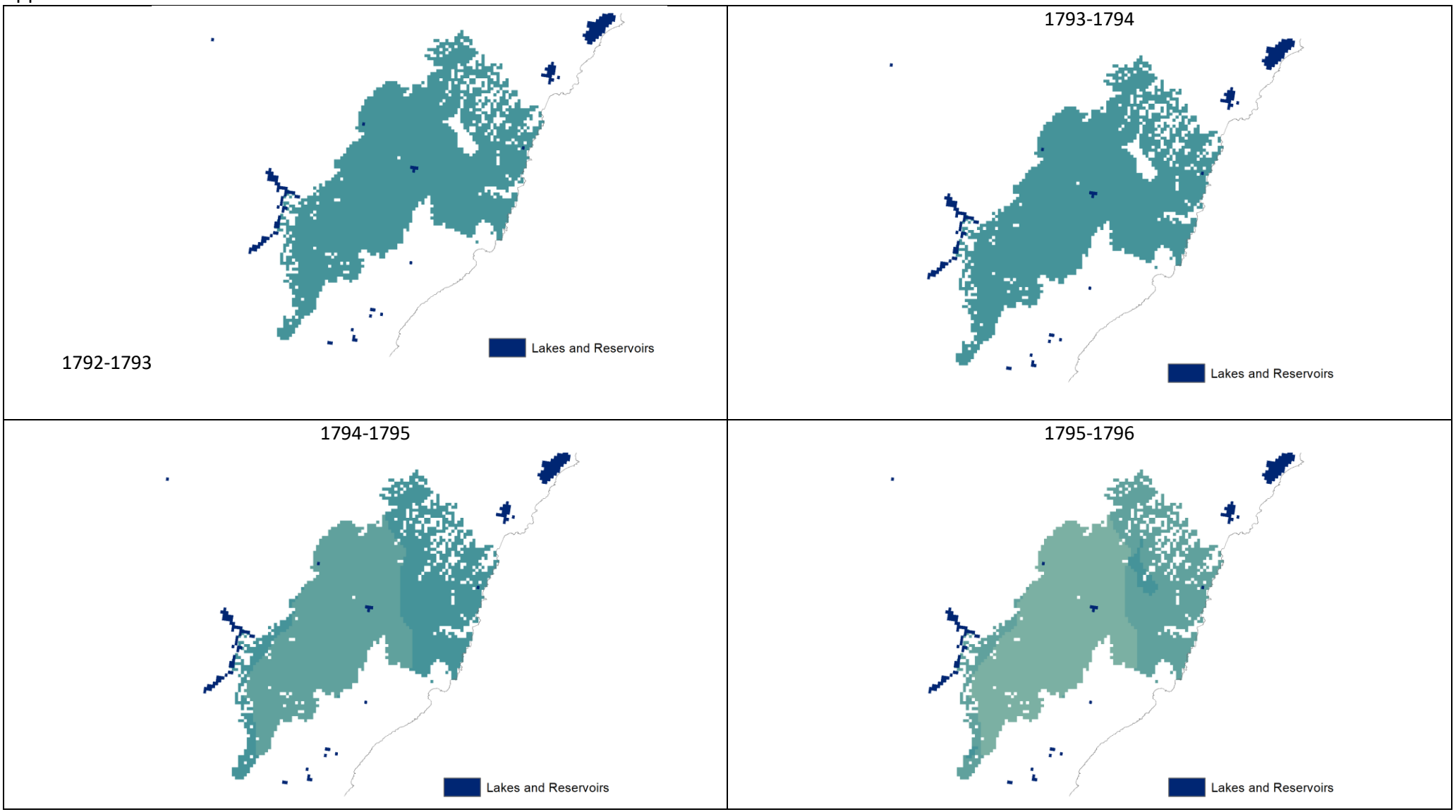
Reference 1892

Not designated	Queensland (1892)	Victoria (1891); Arnall and Jackson (1895)
Australian Bureau of Statistics (2018)	South Australia (2020a, 2020b)	Western Australia (1896)
Higinbotham and Robinson (1892)	Tasmania (2021)	

Appendix 2 Livestock Biannual Mean Distribution 1788-1980



Appendix 2 *continued*



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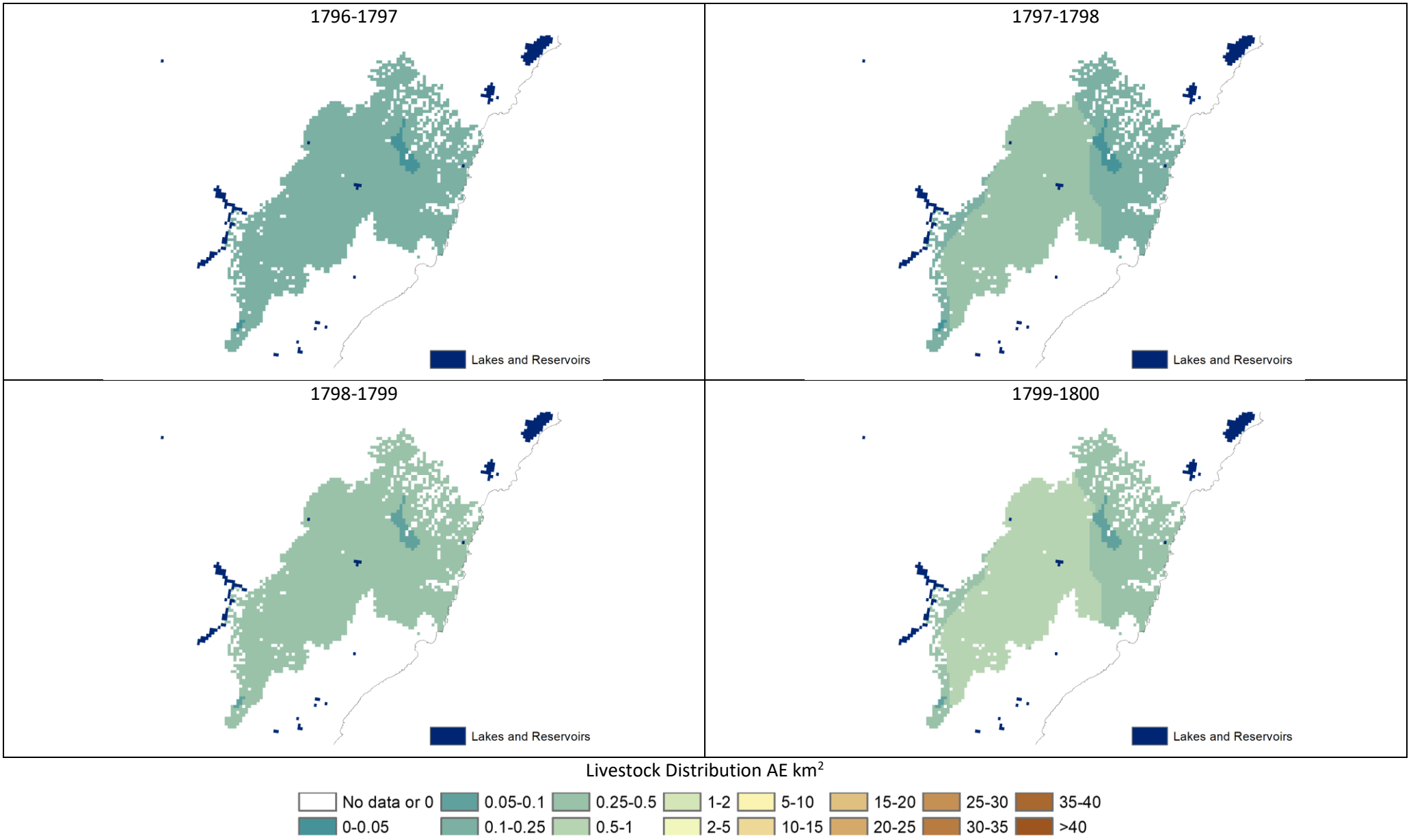

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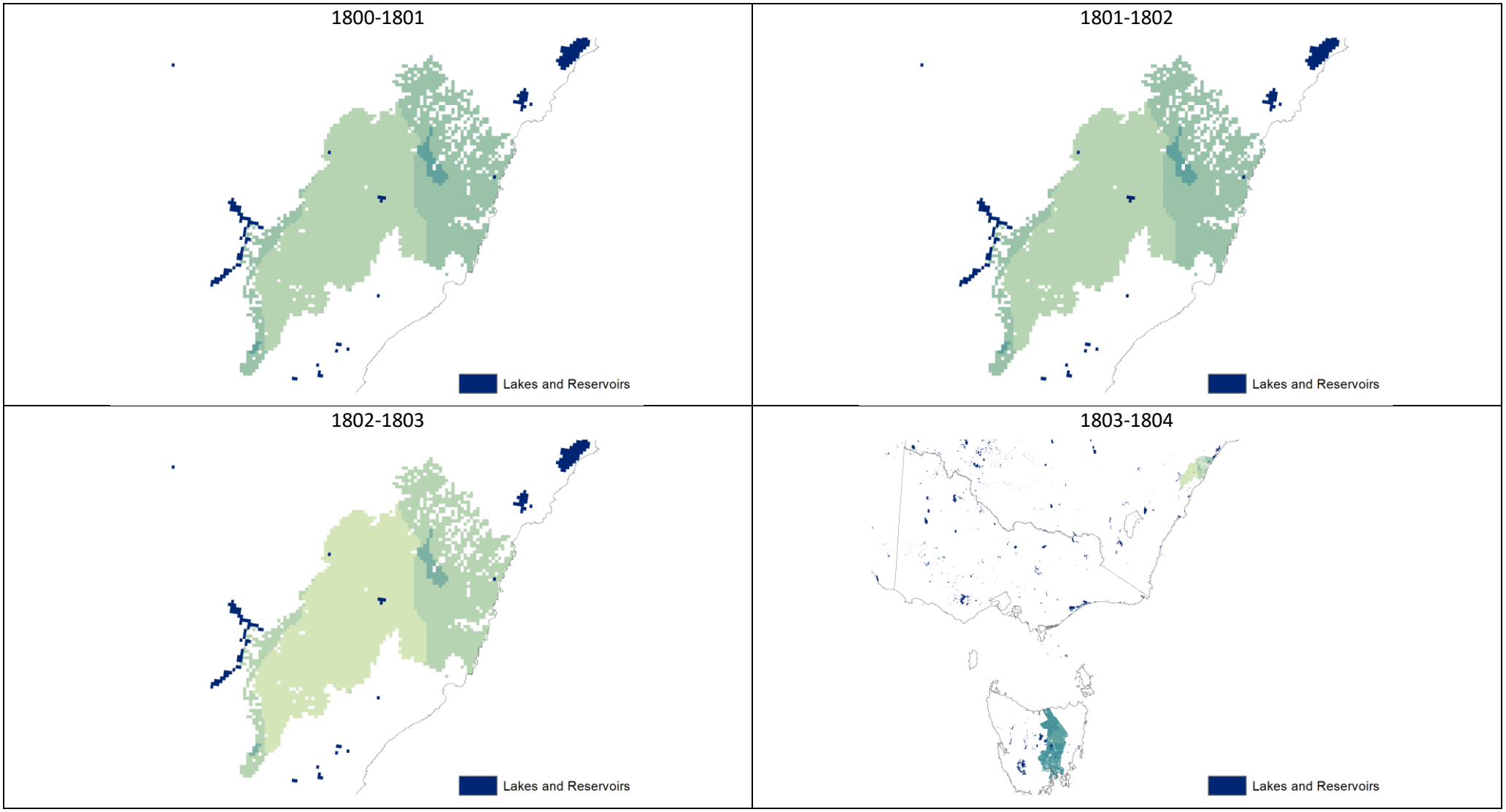

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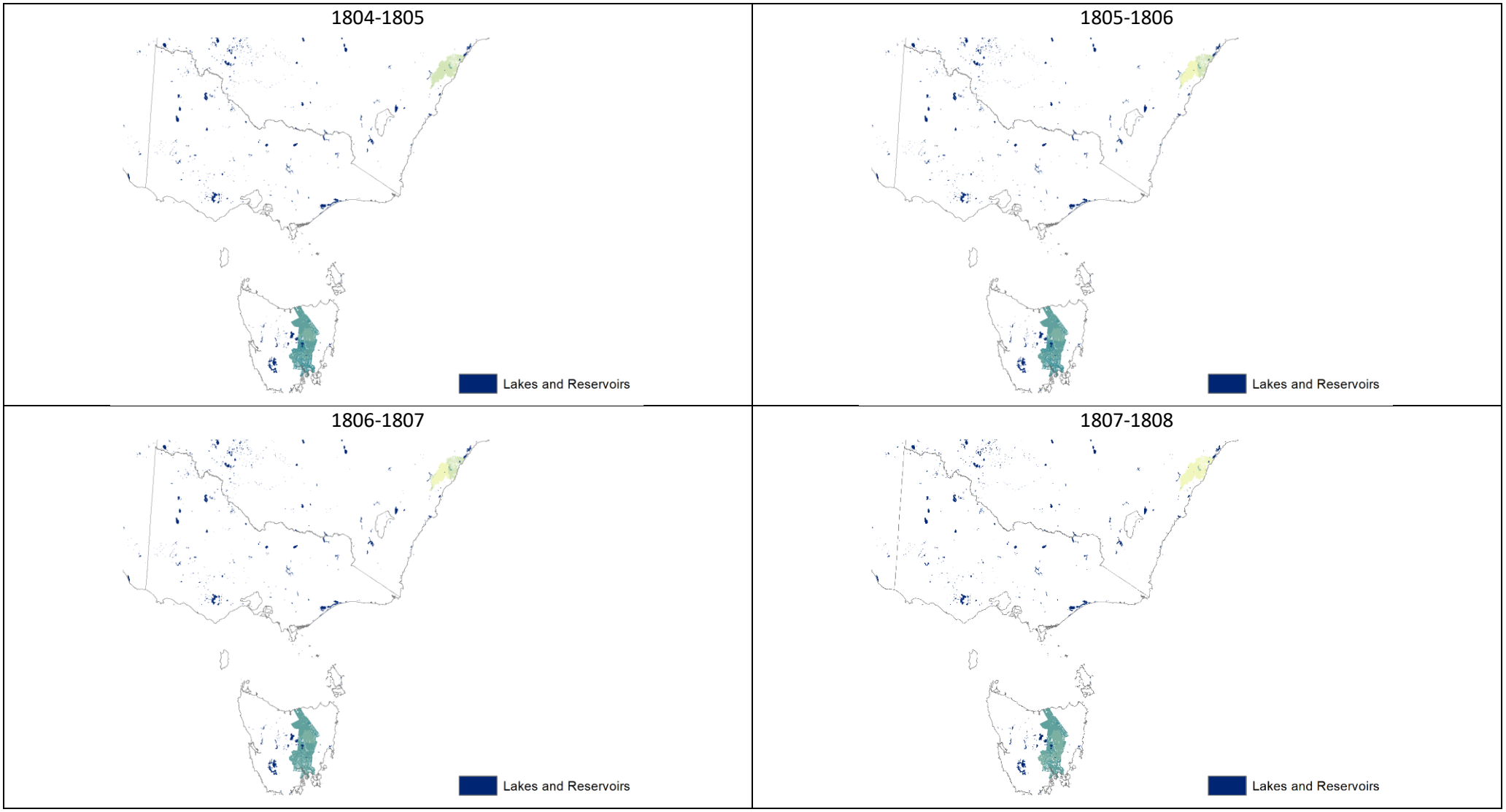
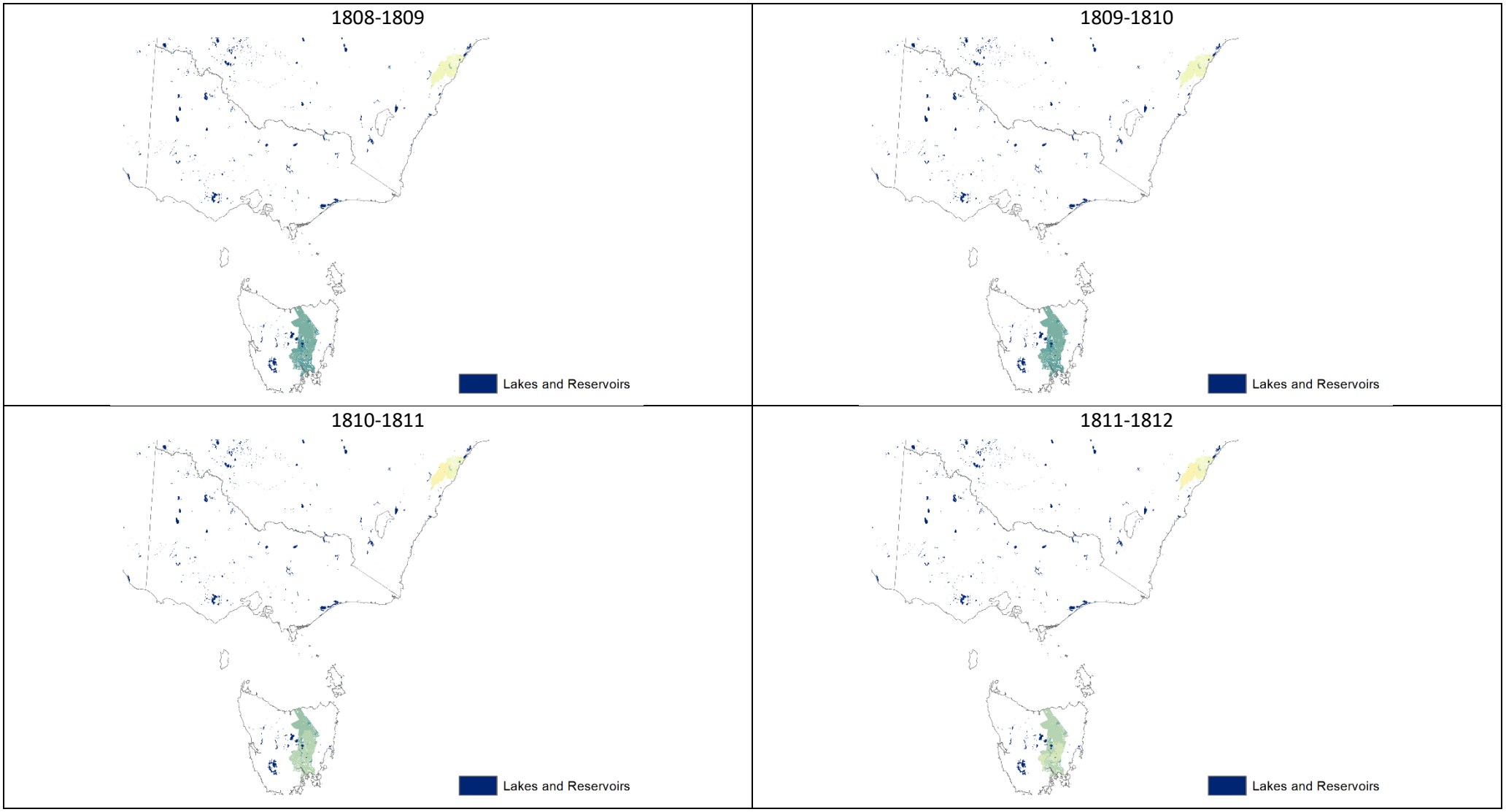
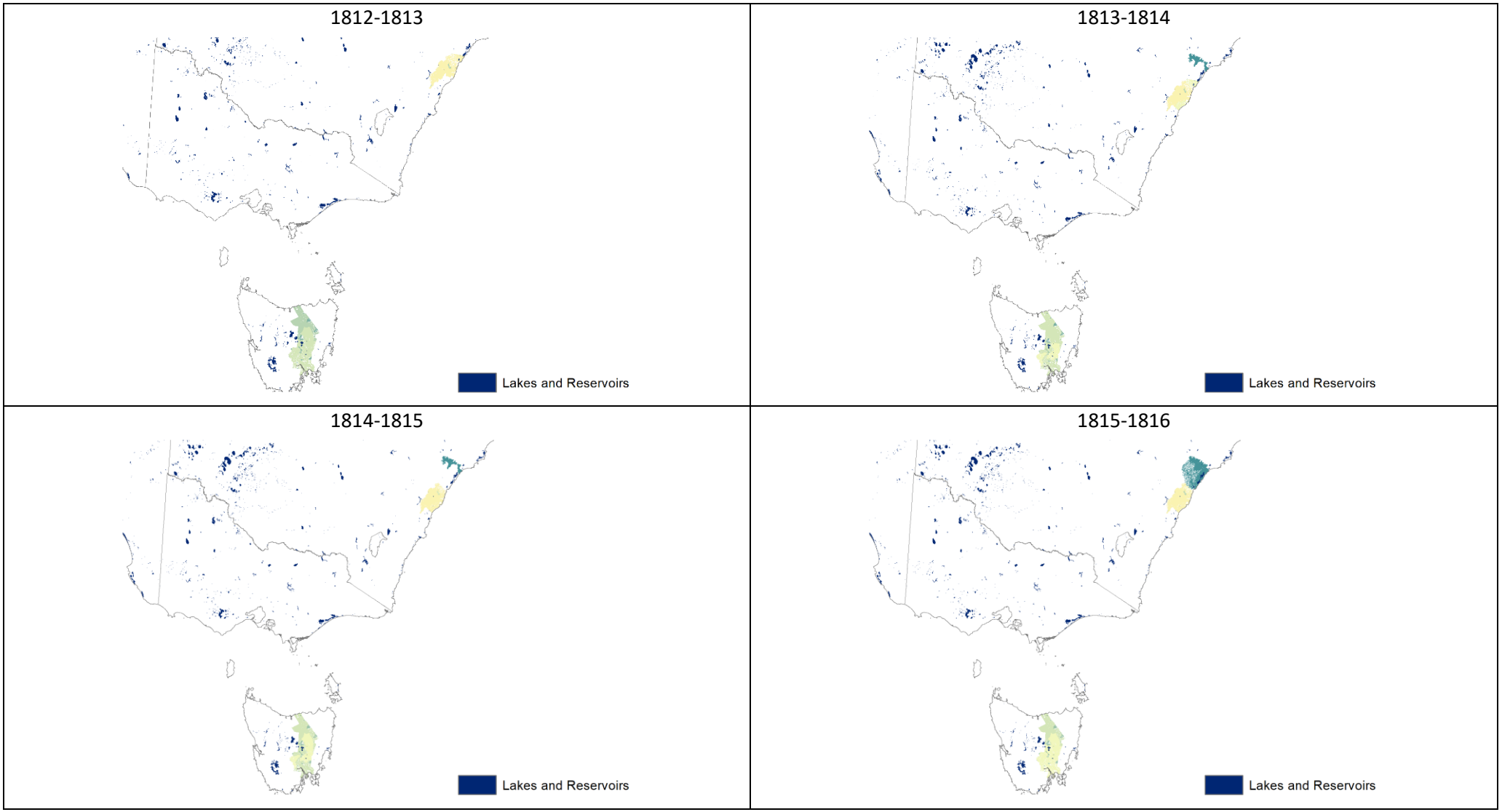
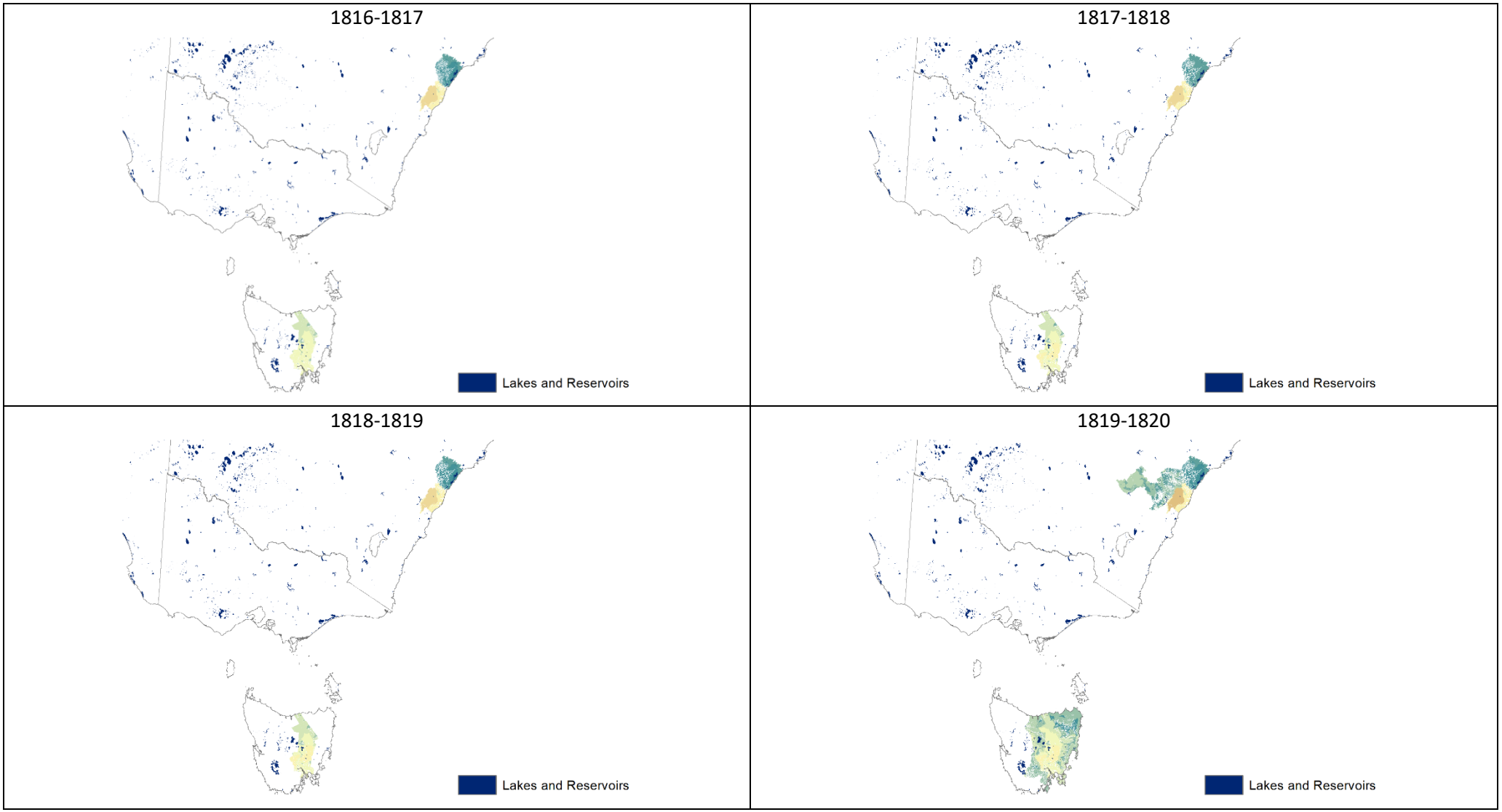



1808-1809
Lakes and Reservoirs
1809-1810
Lakes and Reservoirs
1810-1811
Lakes and Reservoirs
1811-1812
Lakes and Reservoirs
Livestock Distribution AE km2
No data or 0
0-0.05
0.05-0.1
0.1-0.25
0.25-0.5
0.5-1
1-2
2-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
>40

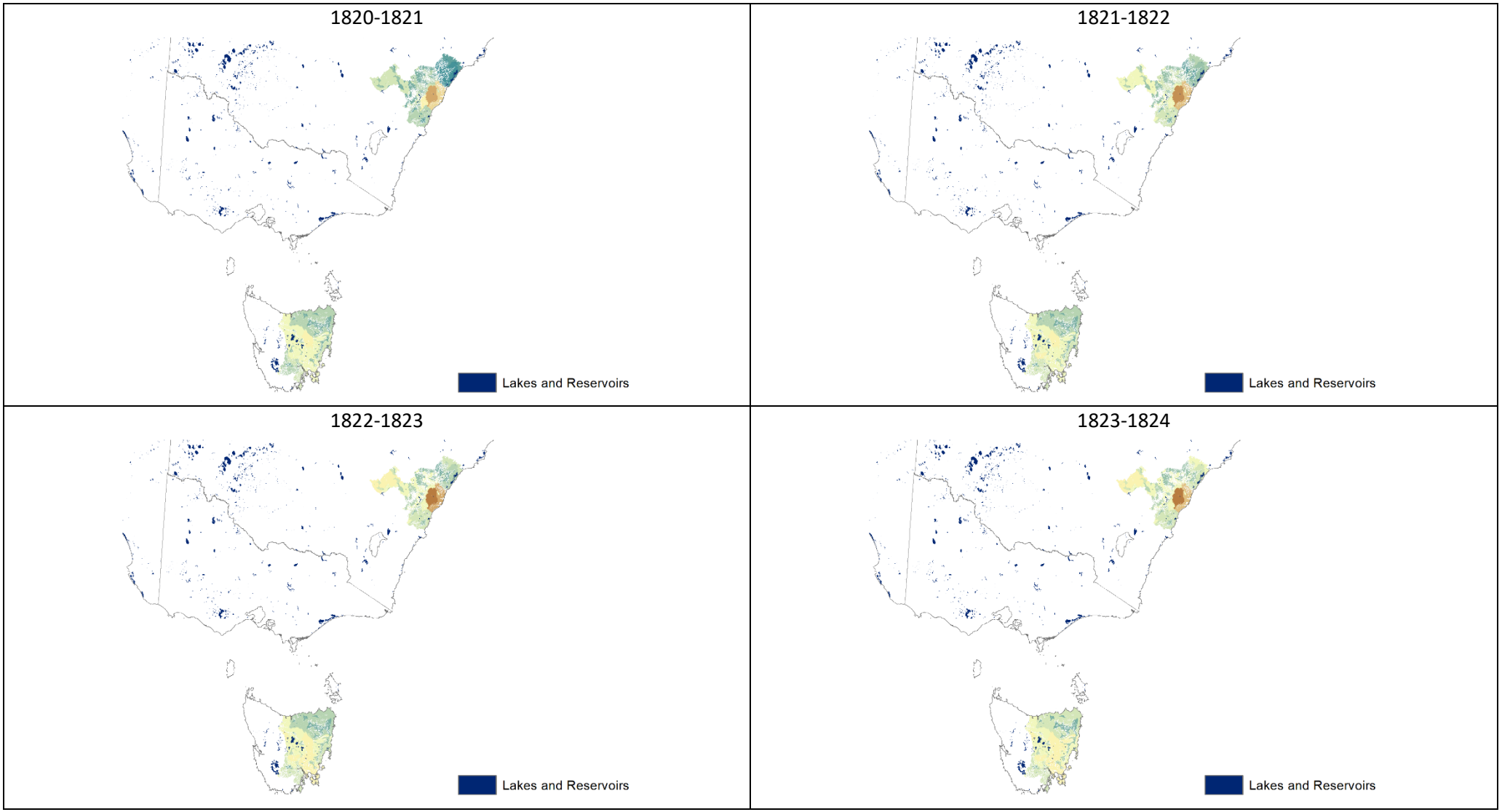
Appendix 2 *continued*

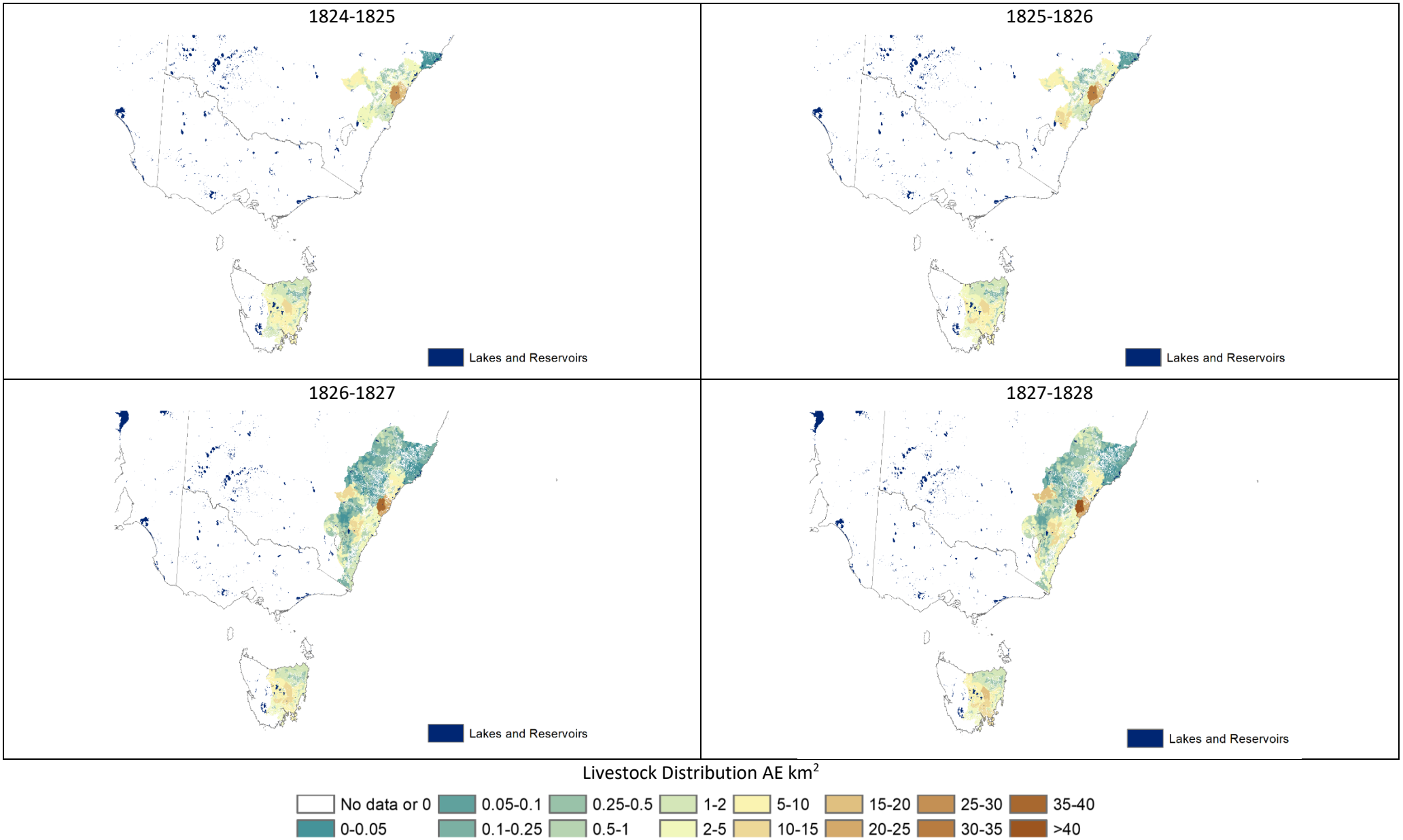


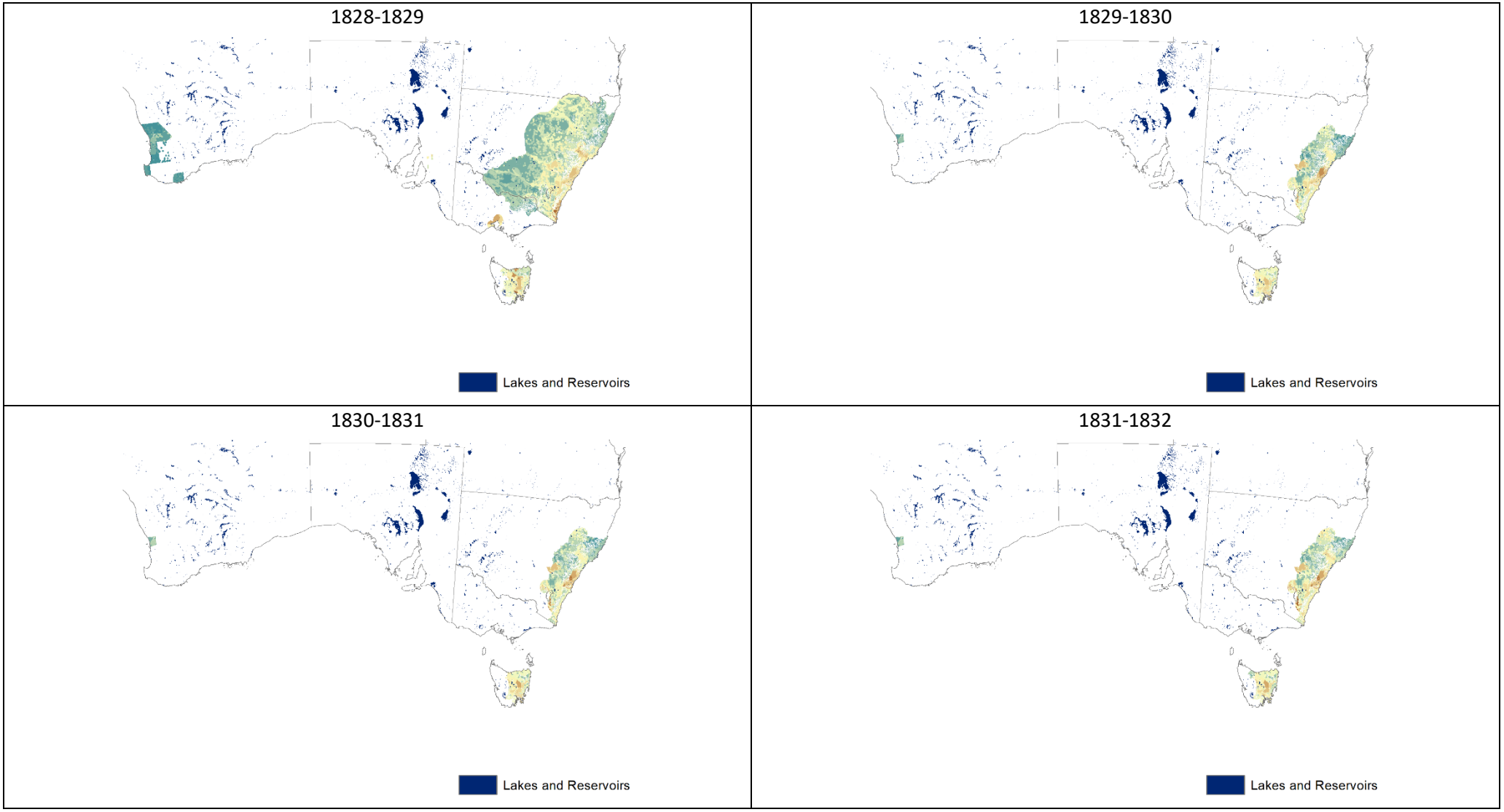
Appendix 2 *continued*



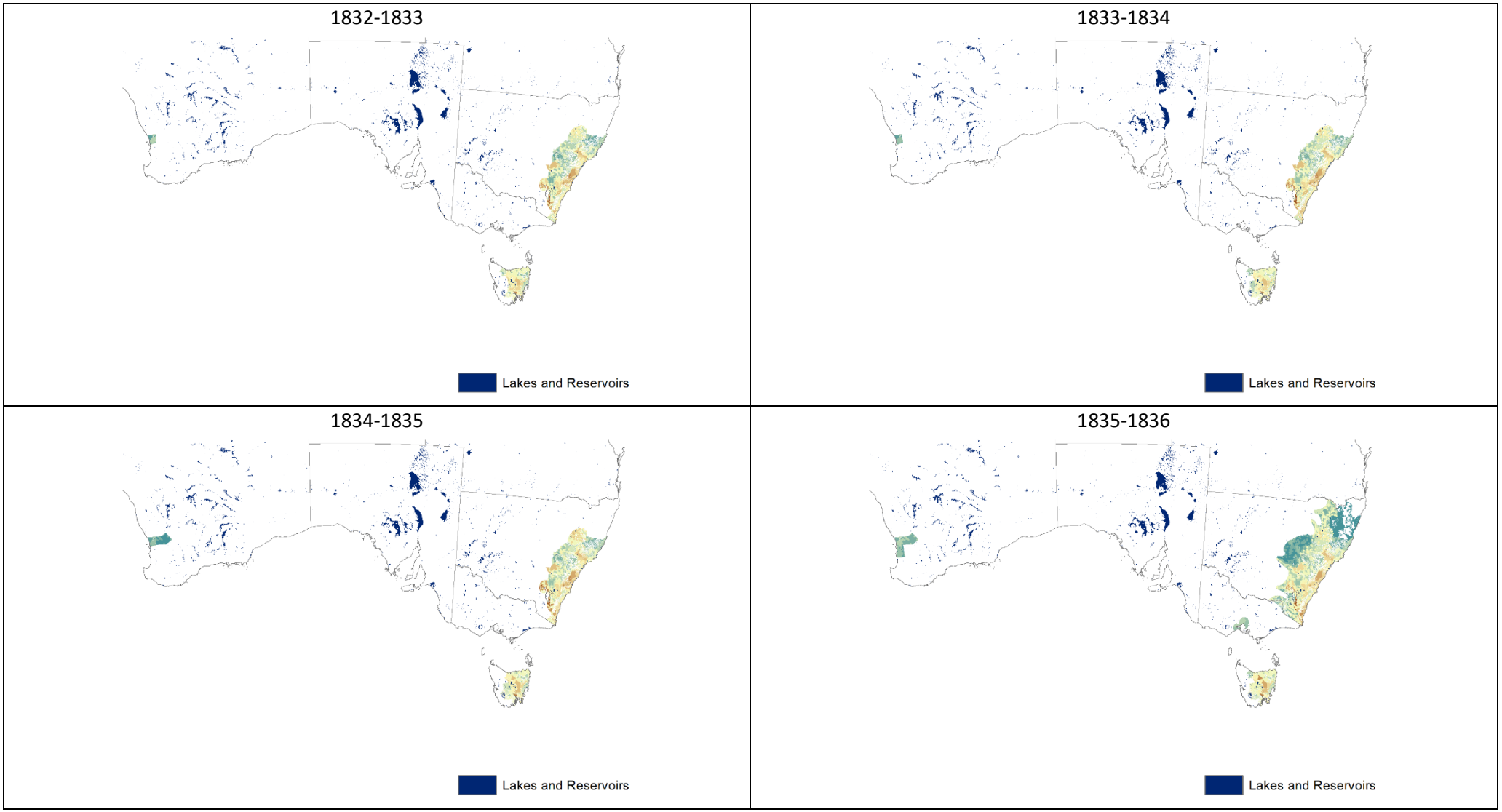
Appendix 2 *continued*




1824-1825
Lakes and Reservoirs
1825-1826
Lakes and Reservoirs
1826-1827
Lakes and Reservoirs
1827-1828
Lakes and Reservoirs
Livestock Distribution AE km2
No data or 0
0-0.05
0.05-0.1
0.1-0.25
0.25-0.5
0.5-1
1-2
2-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
>40


1828-1829
Lakes and Reservoirs
1829-1830
Lakes and Reservoirs
1830-1831
Lakes and Reservoirs
1831-1832
Lakes and Reservoirs
Livestock Distribution AE km2
No data or 0
0-0.05
0.05-0.1
0.1-0.25
0.25-0.5
0.5-1
1-2
2-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
>40

Appendix 2 *continued*



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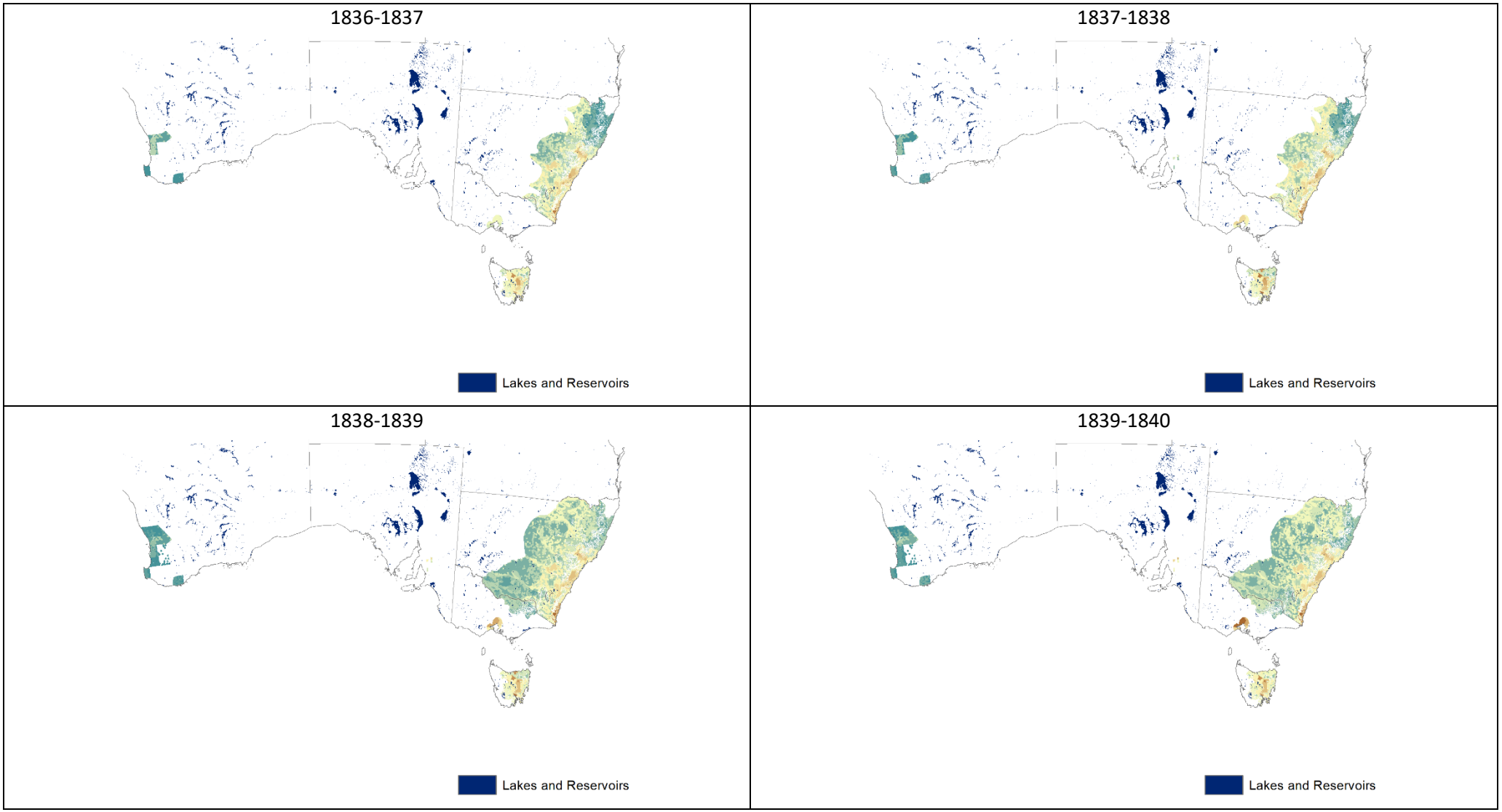

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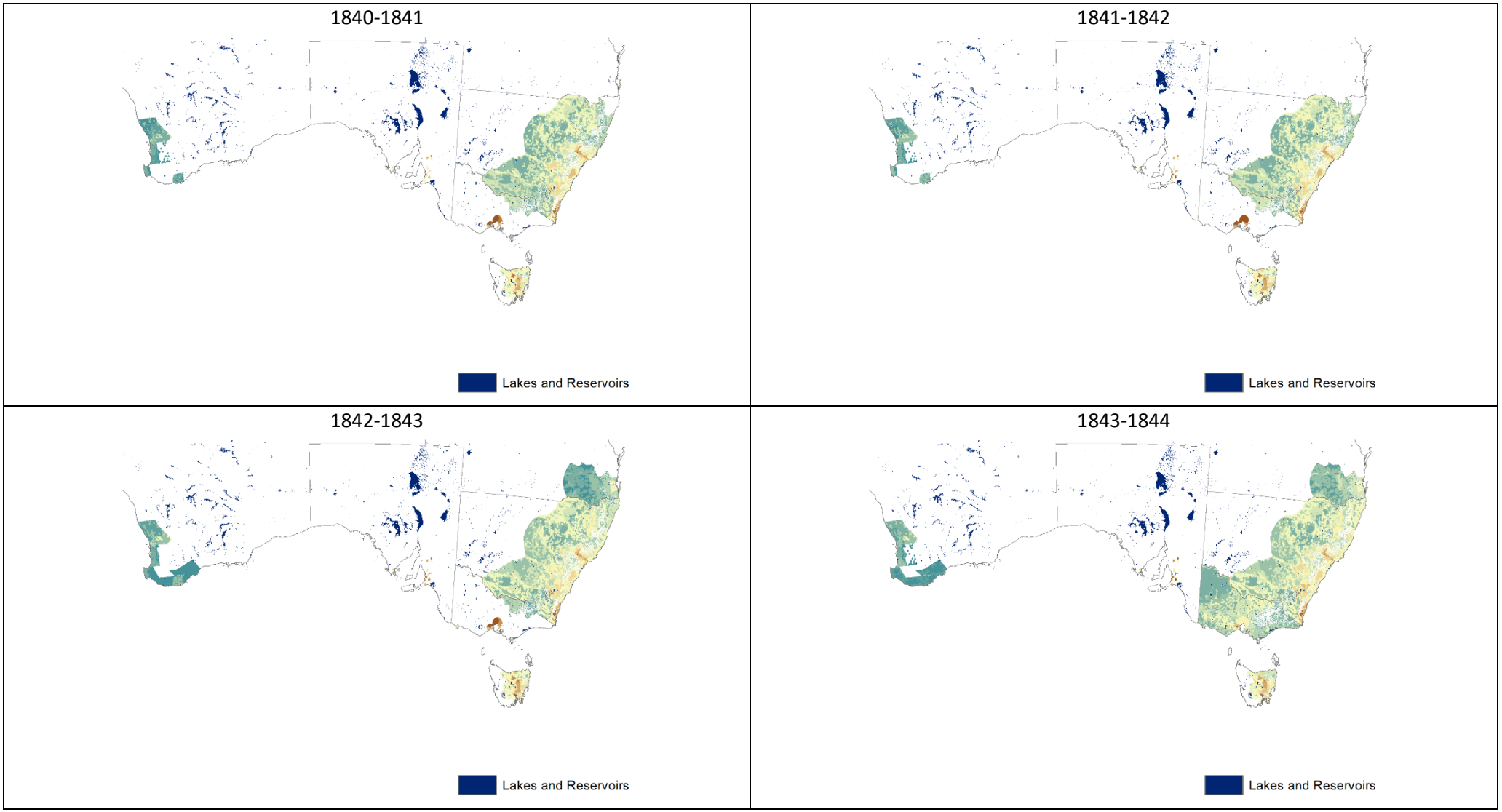

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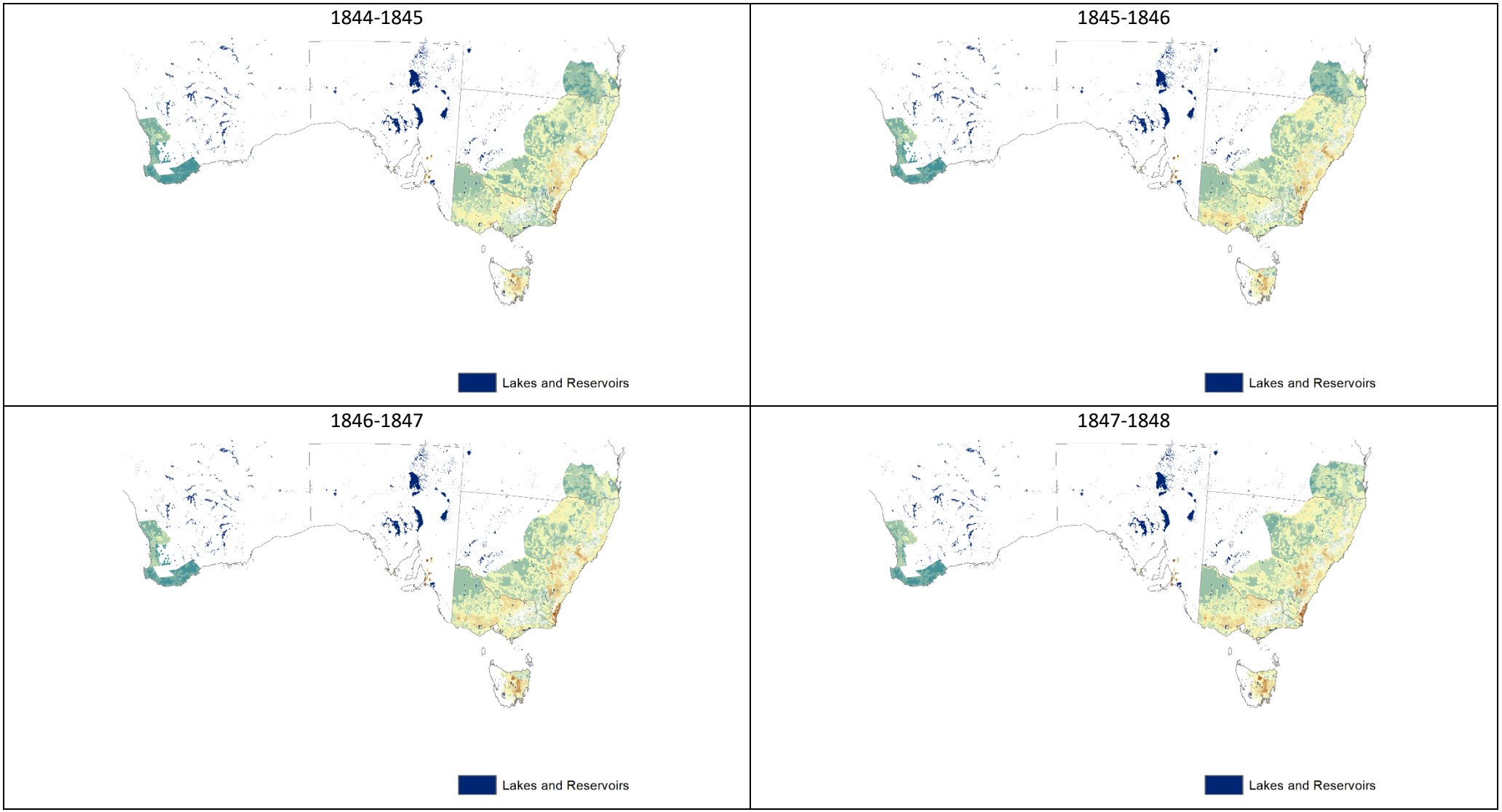

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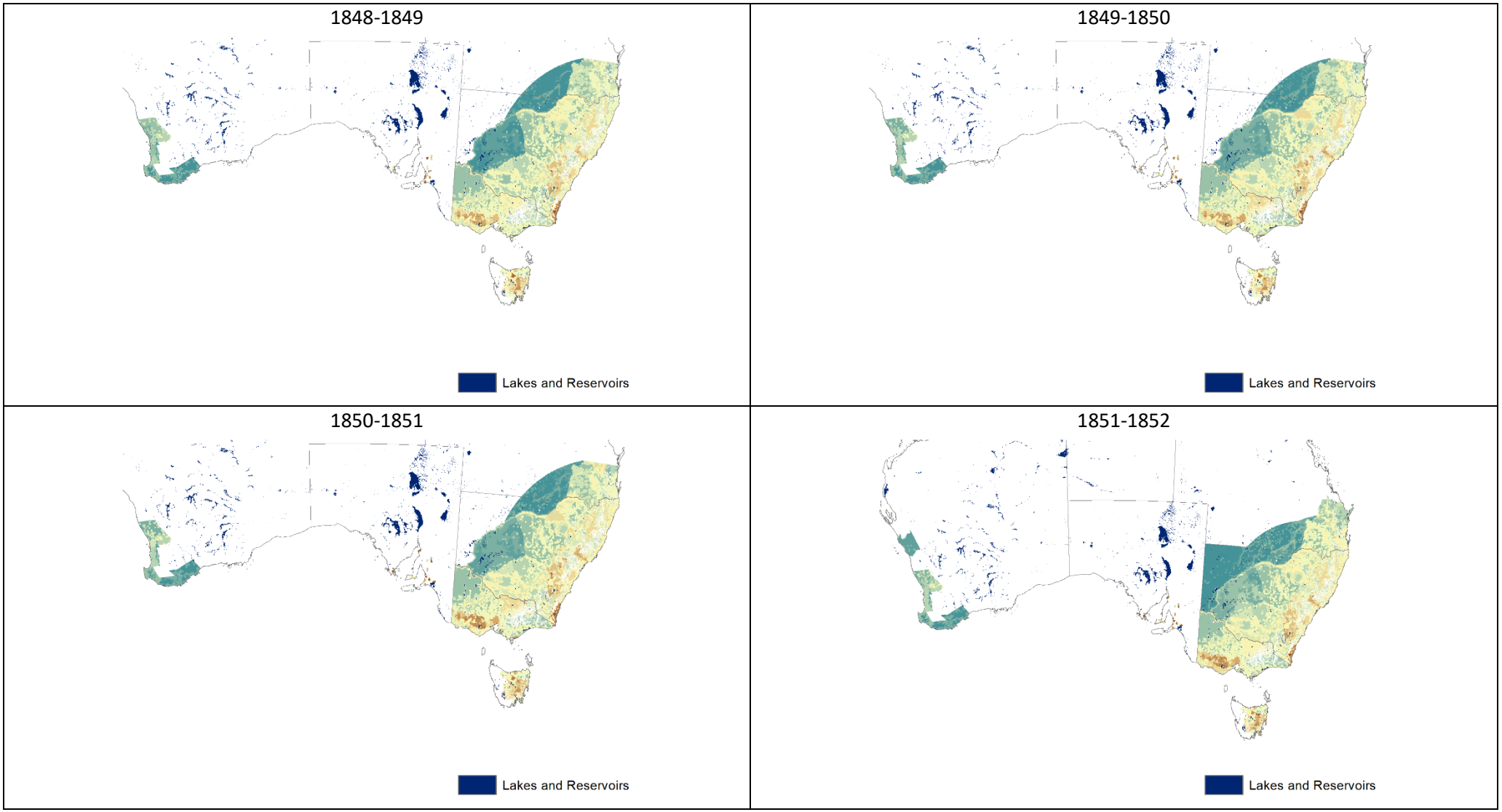

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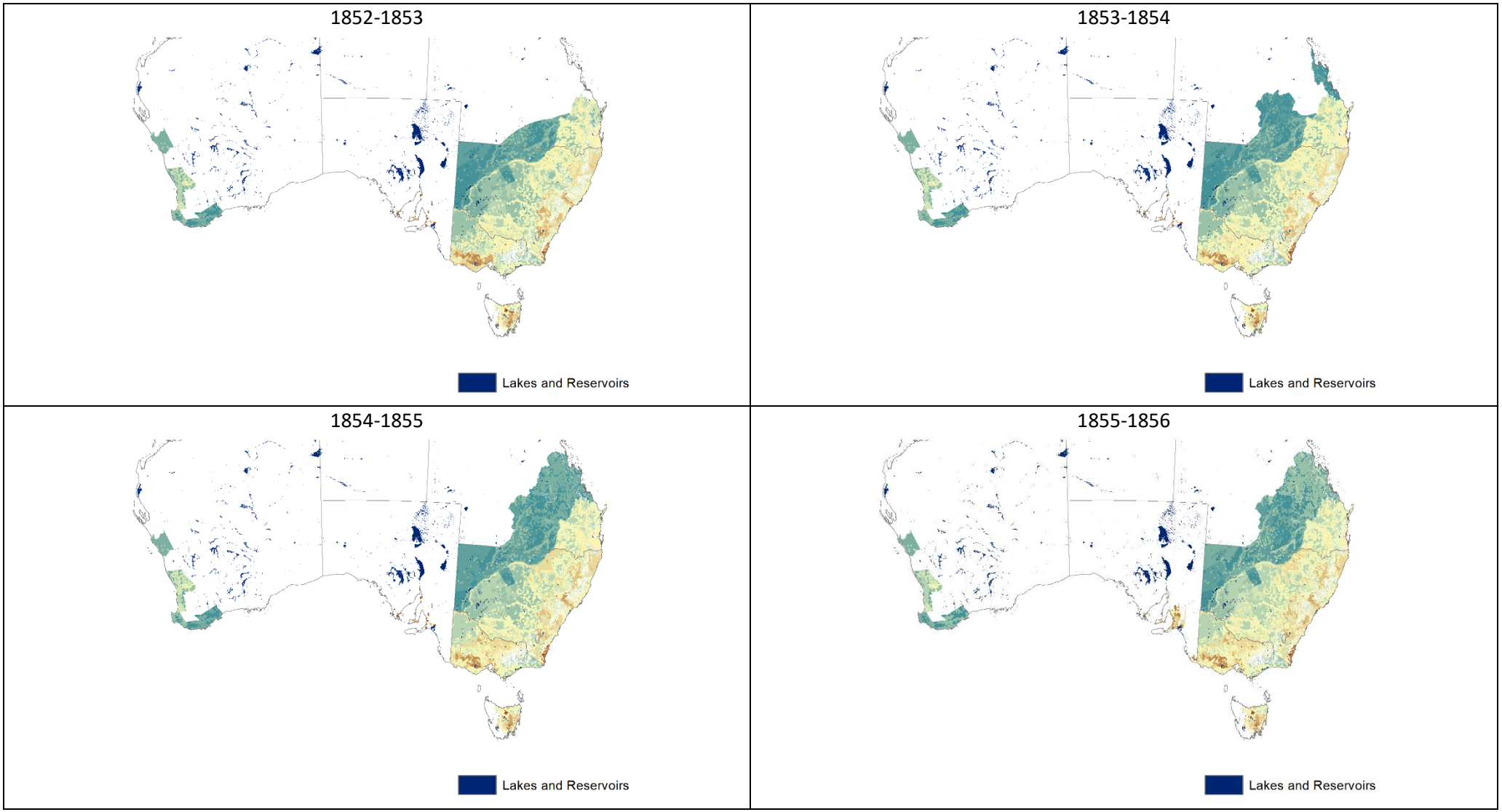

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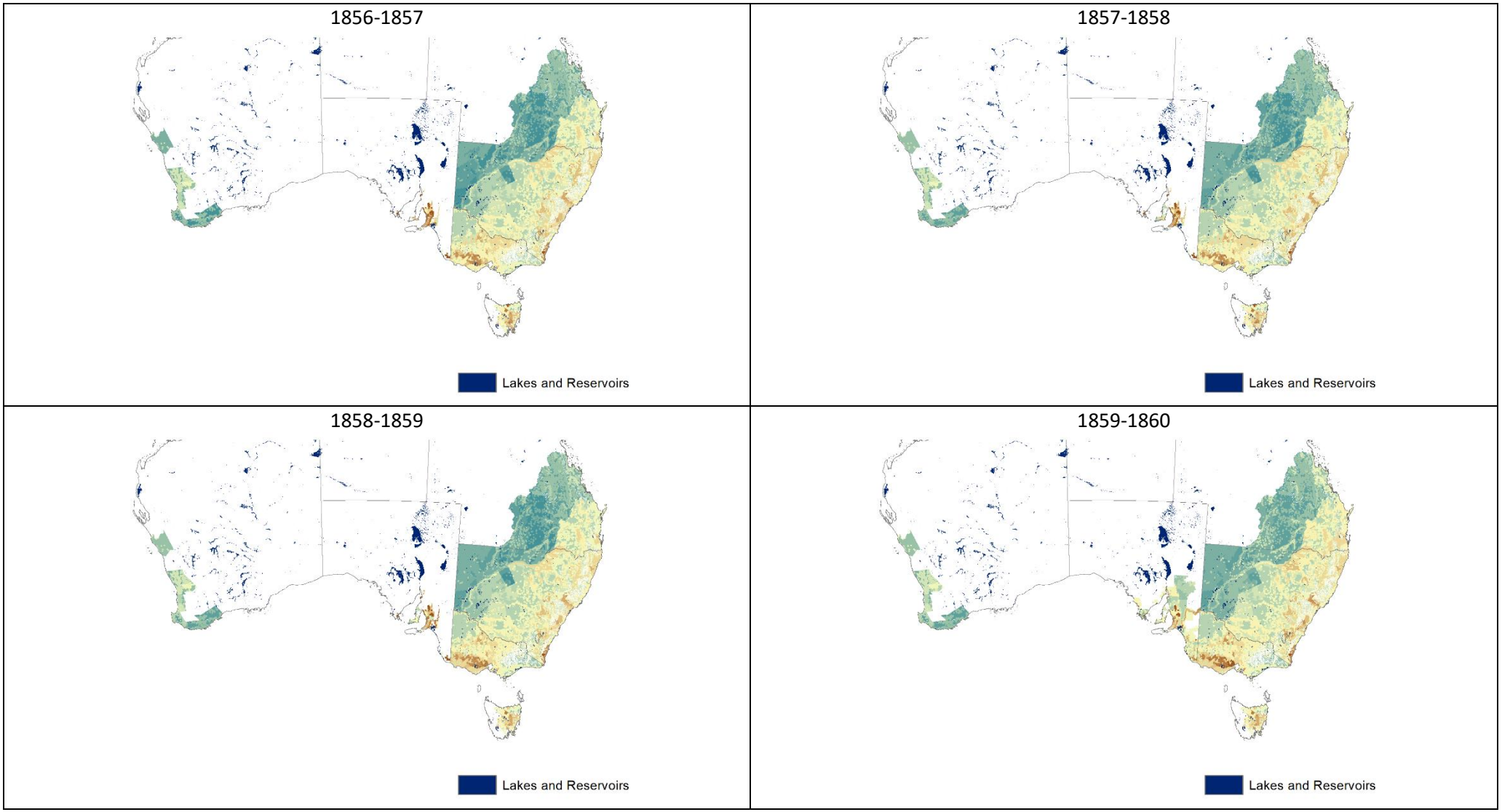

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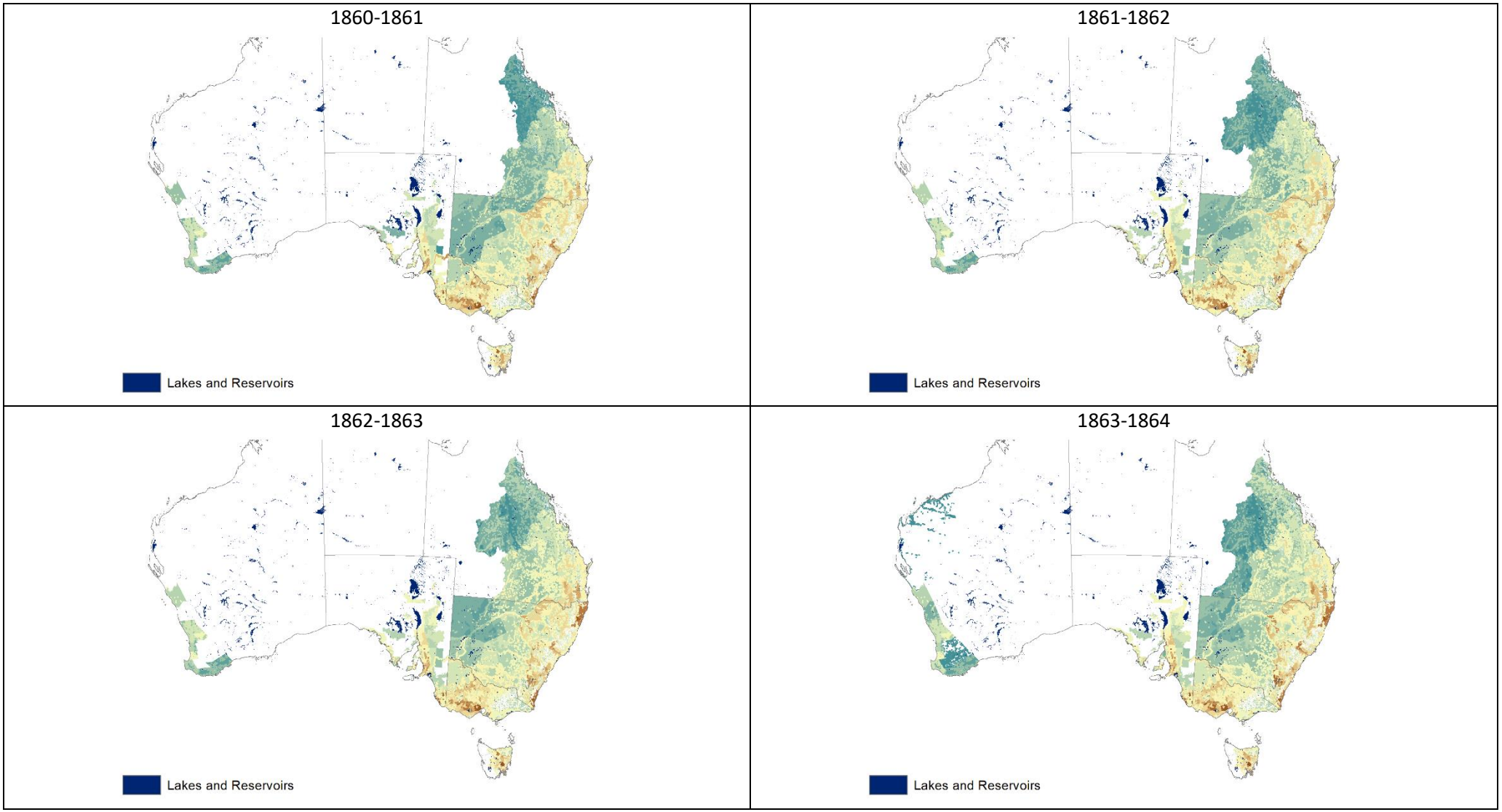

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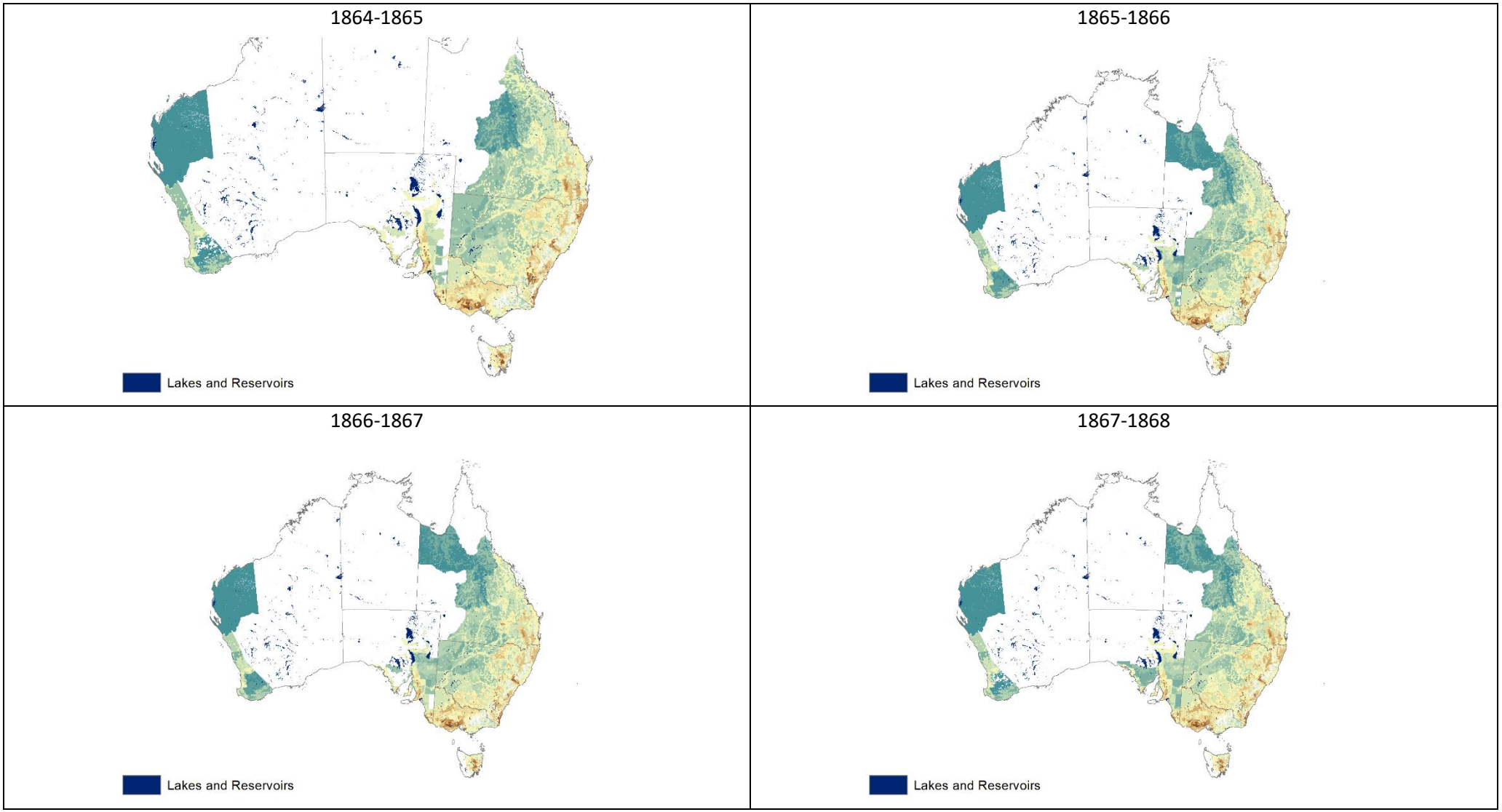

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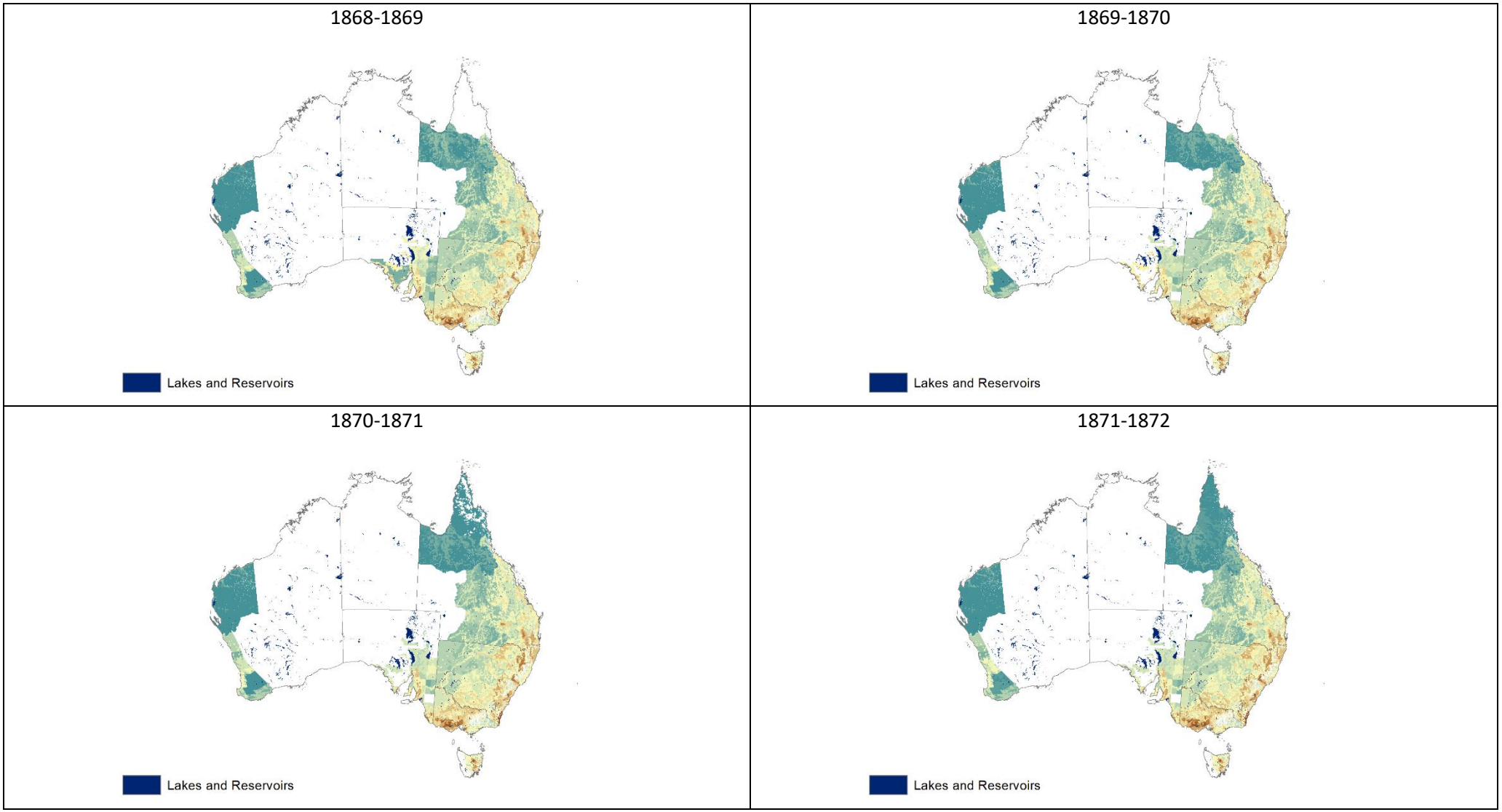

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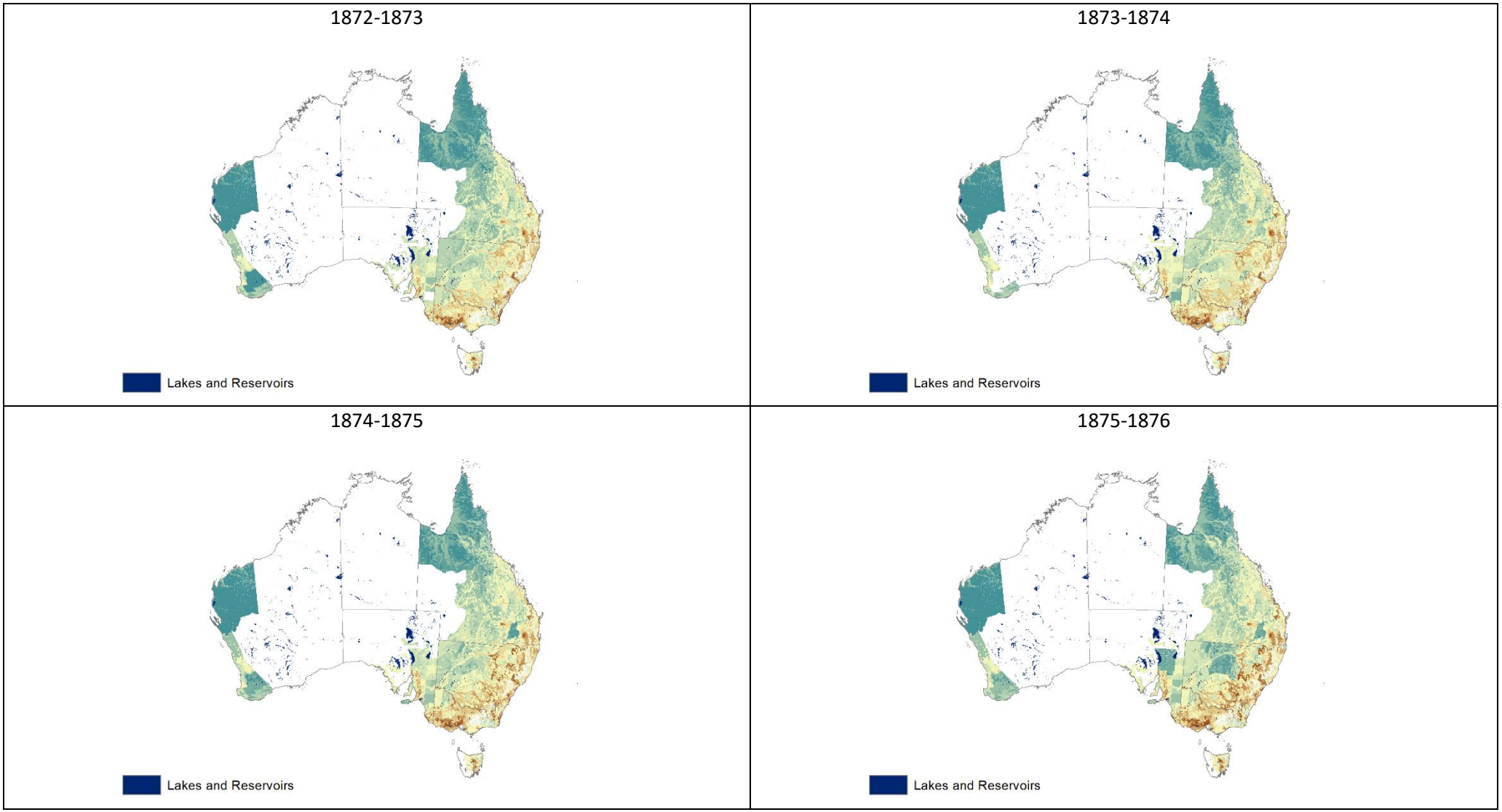

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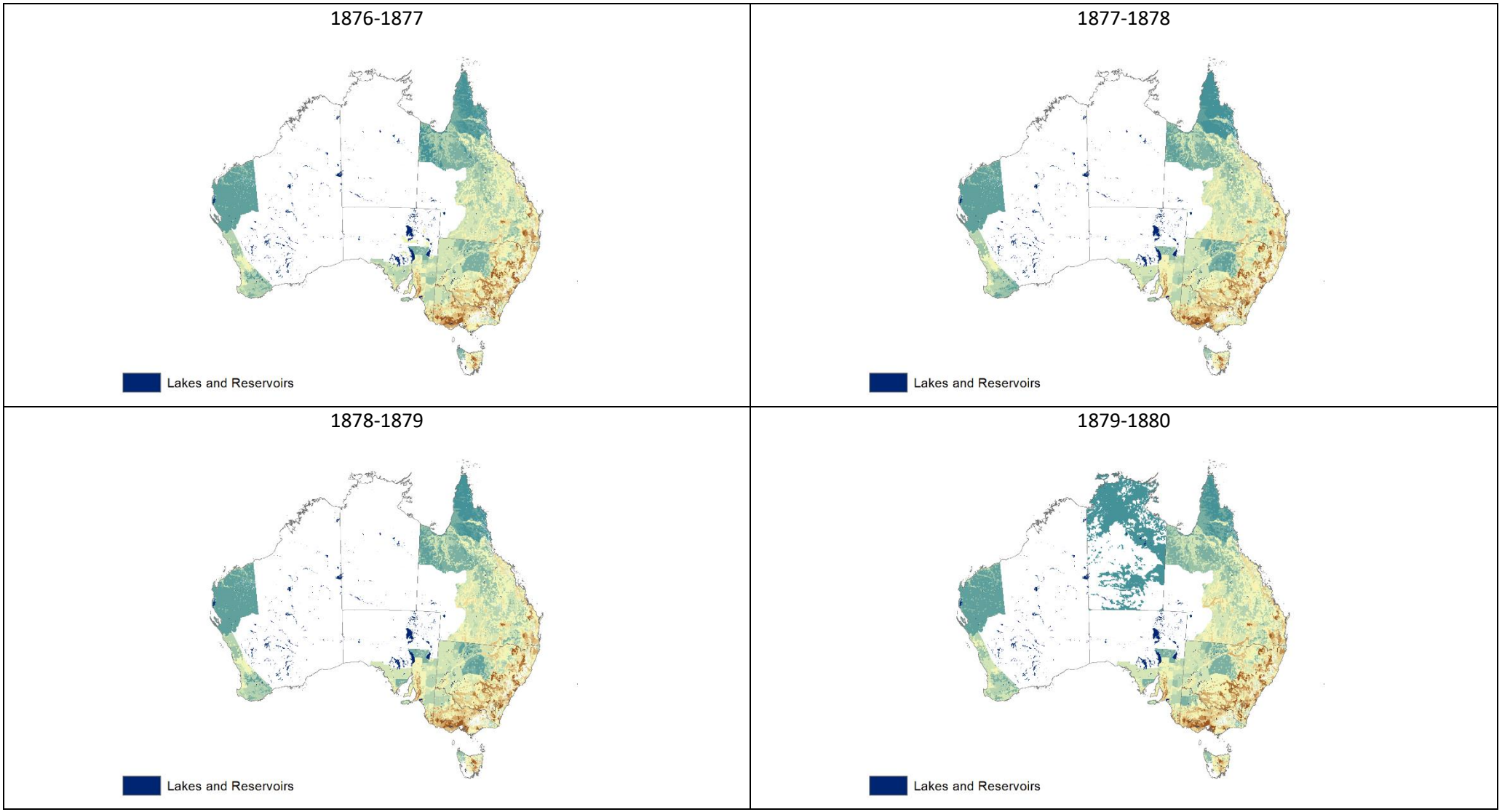

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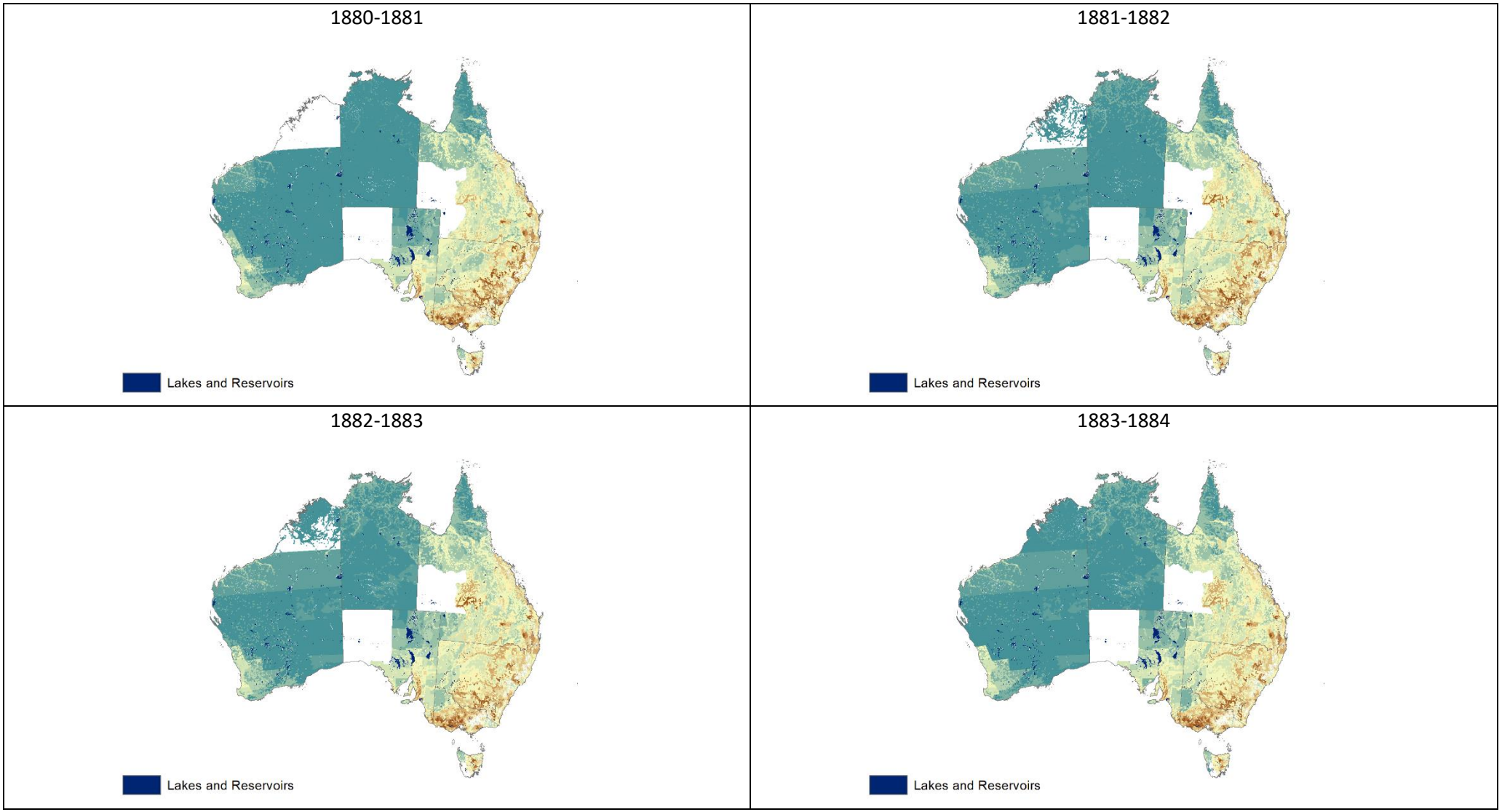

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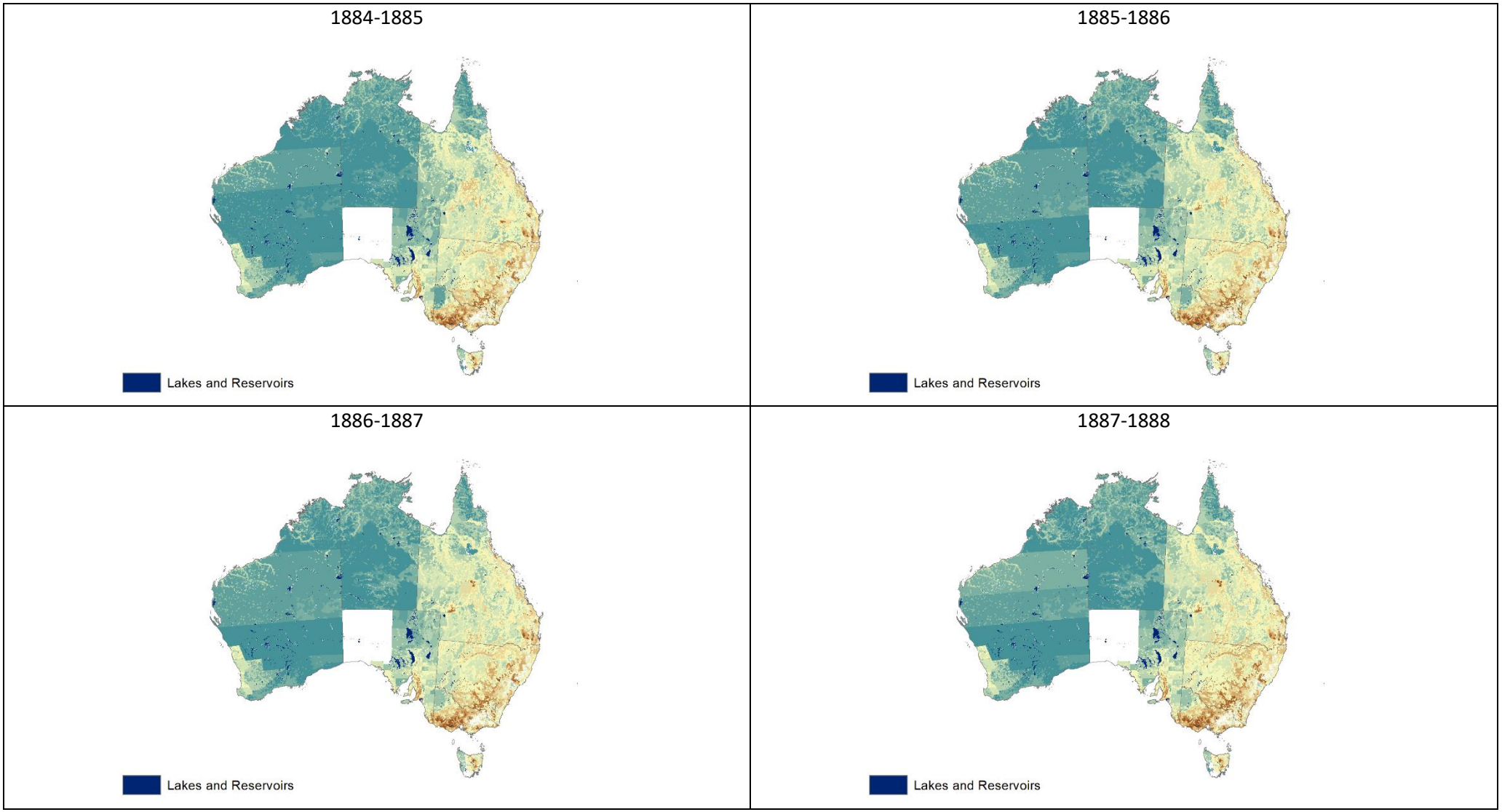

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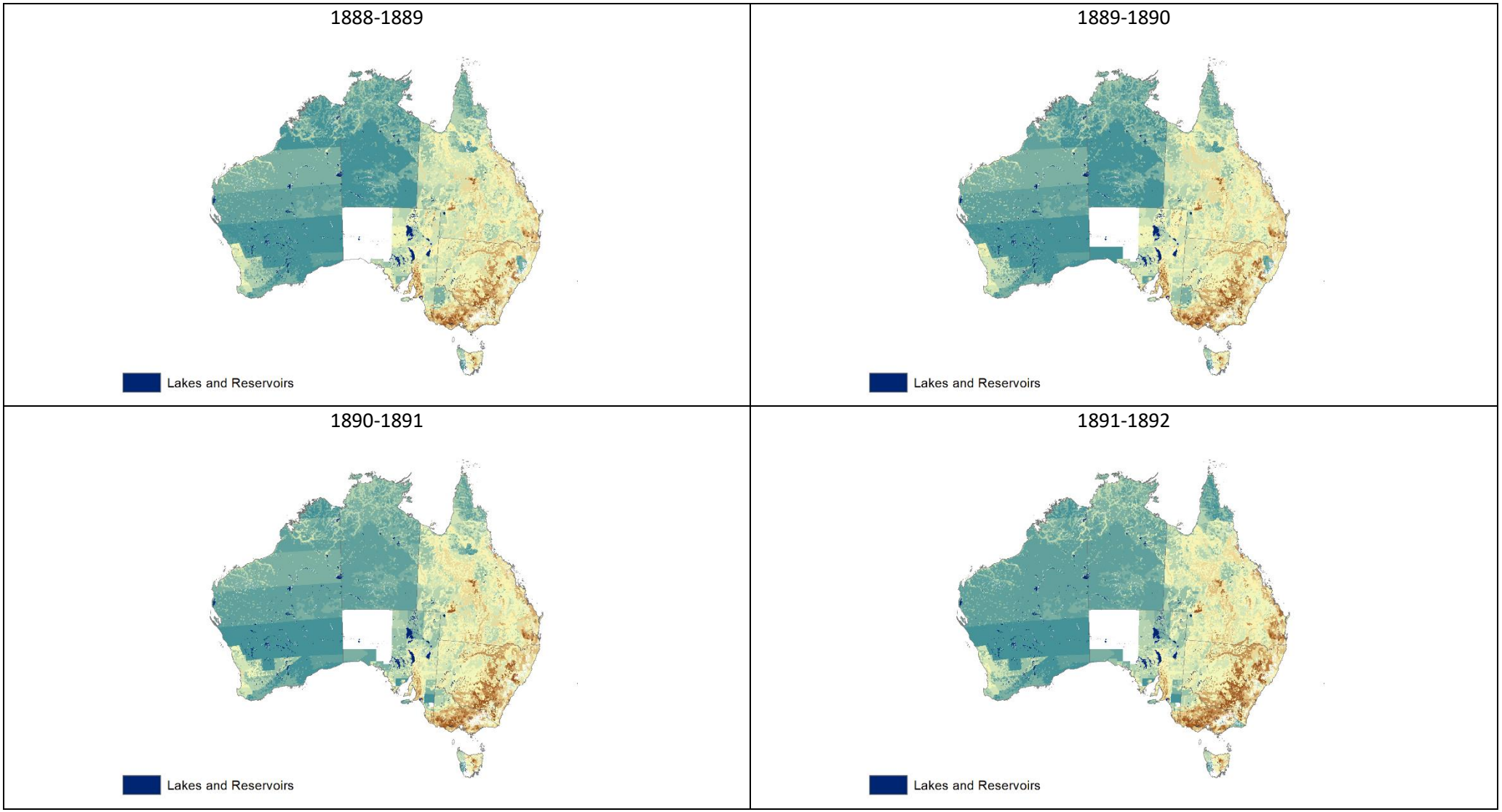

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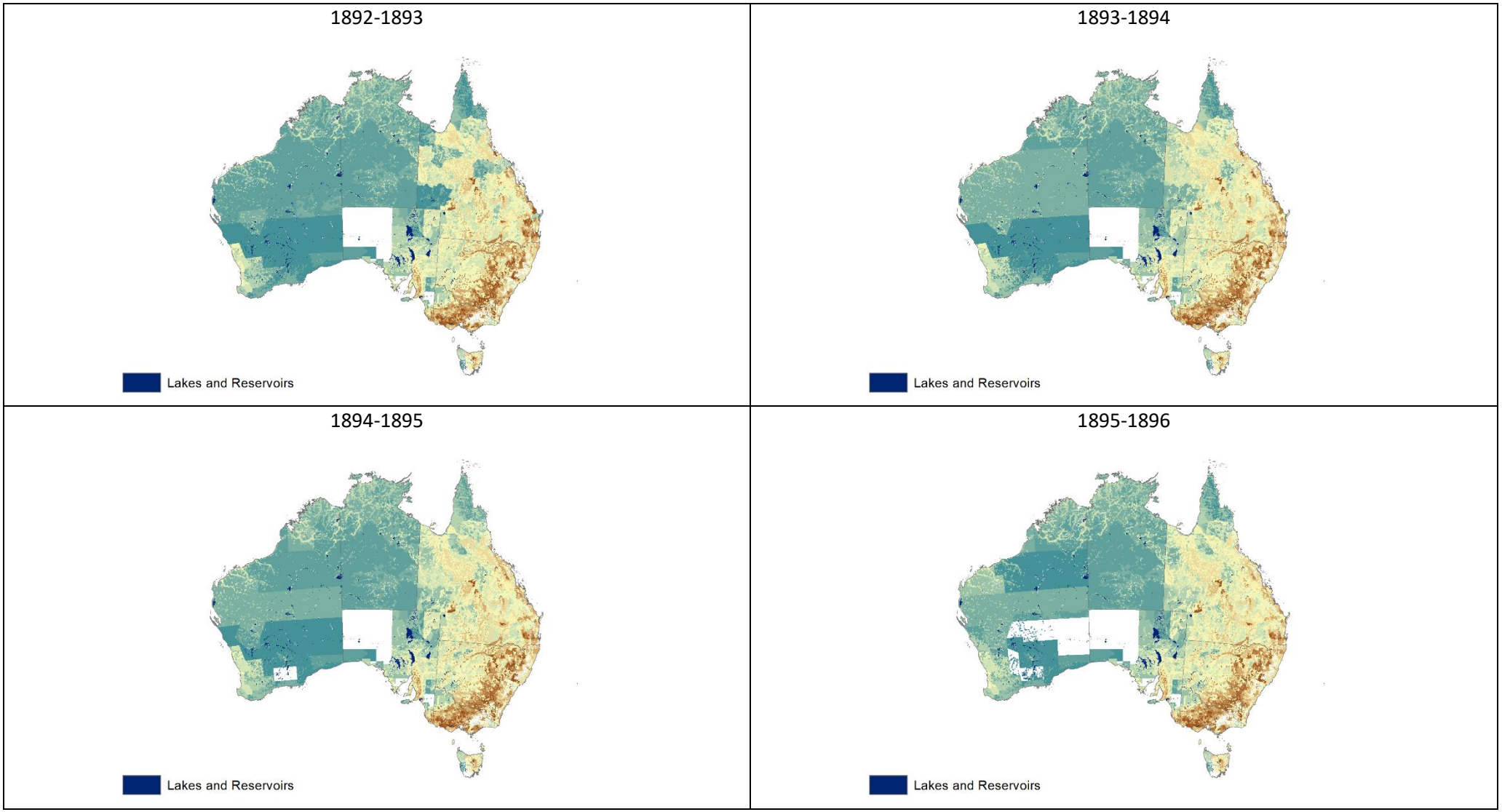

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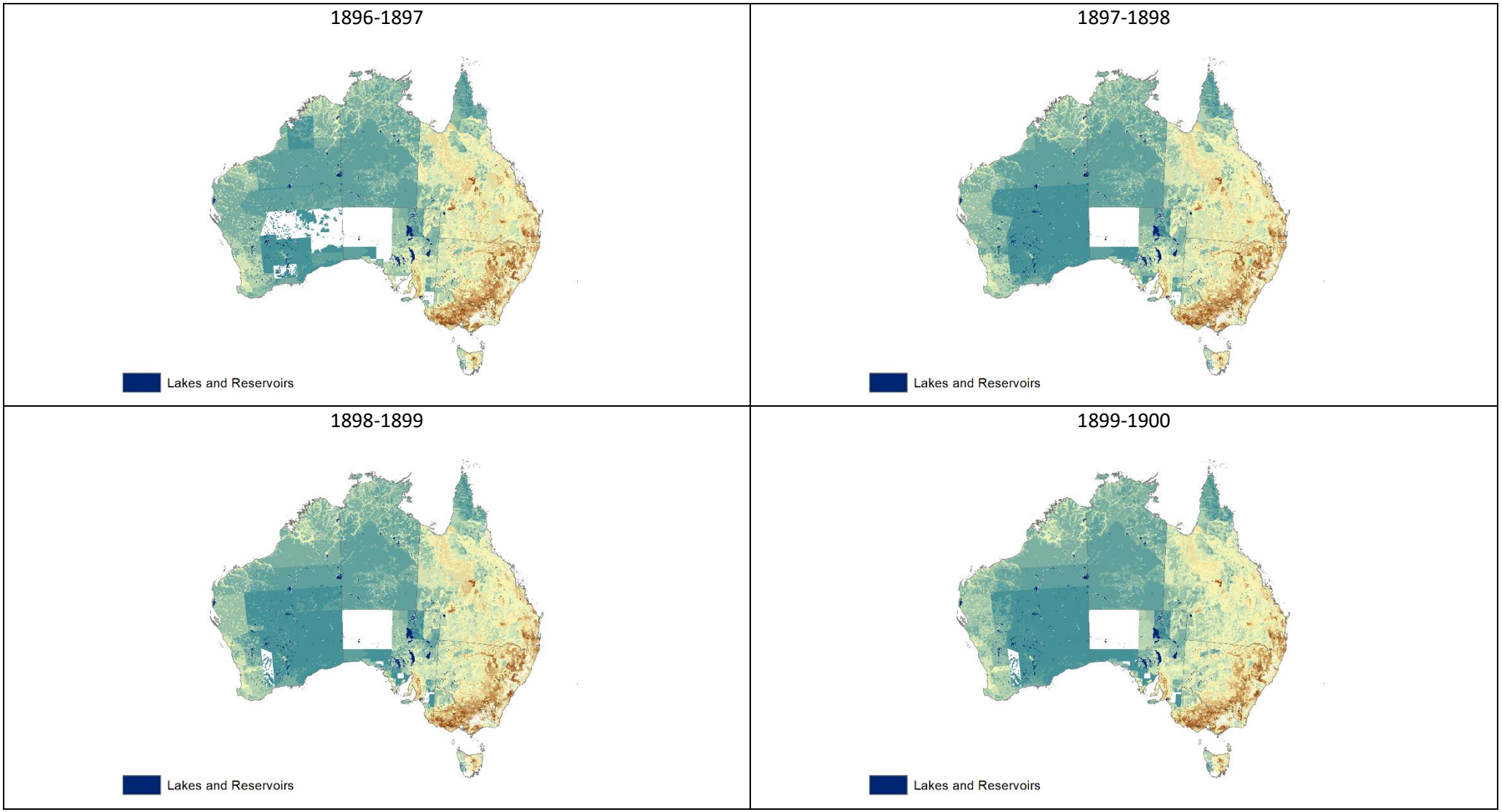

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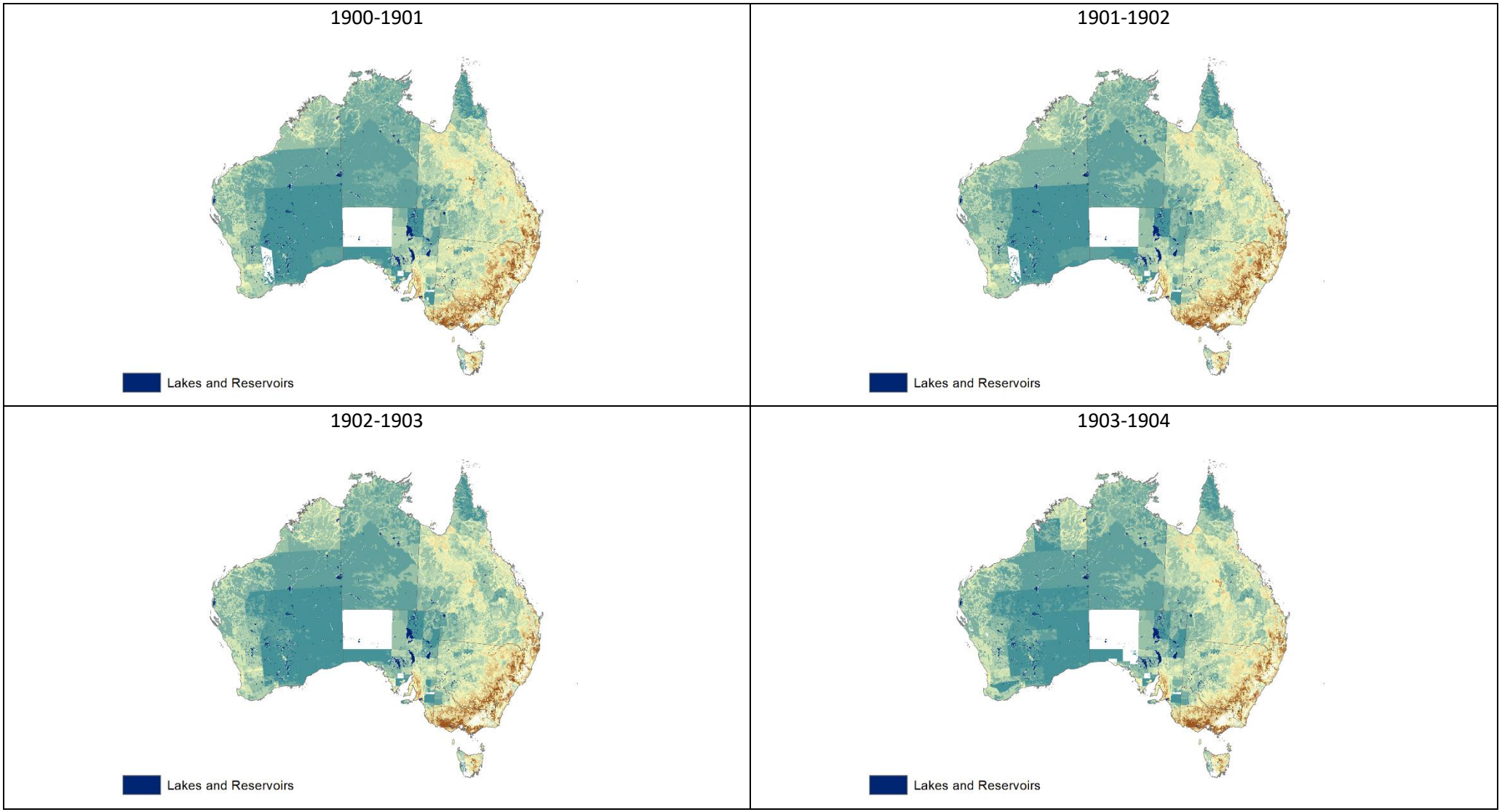

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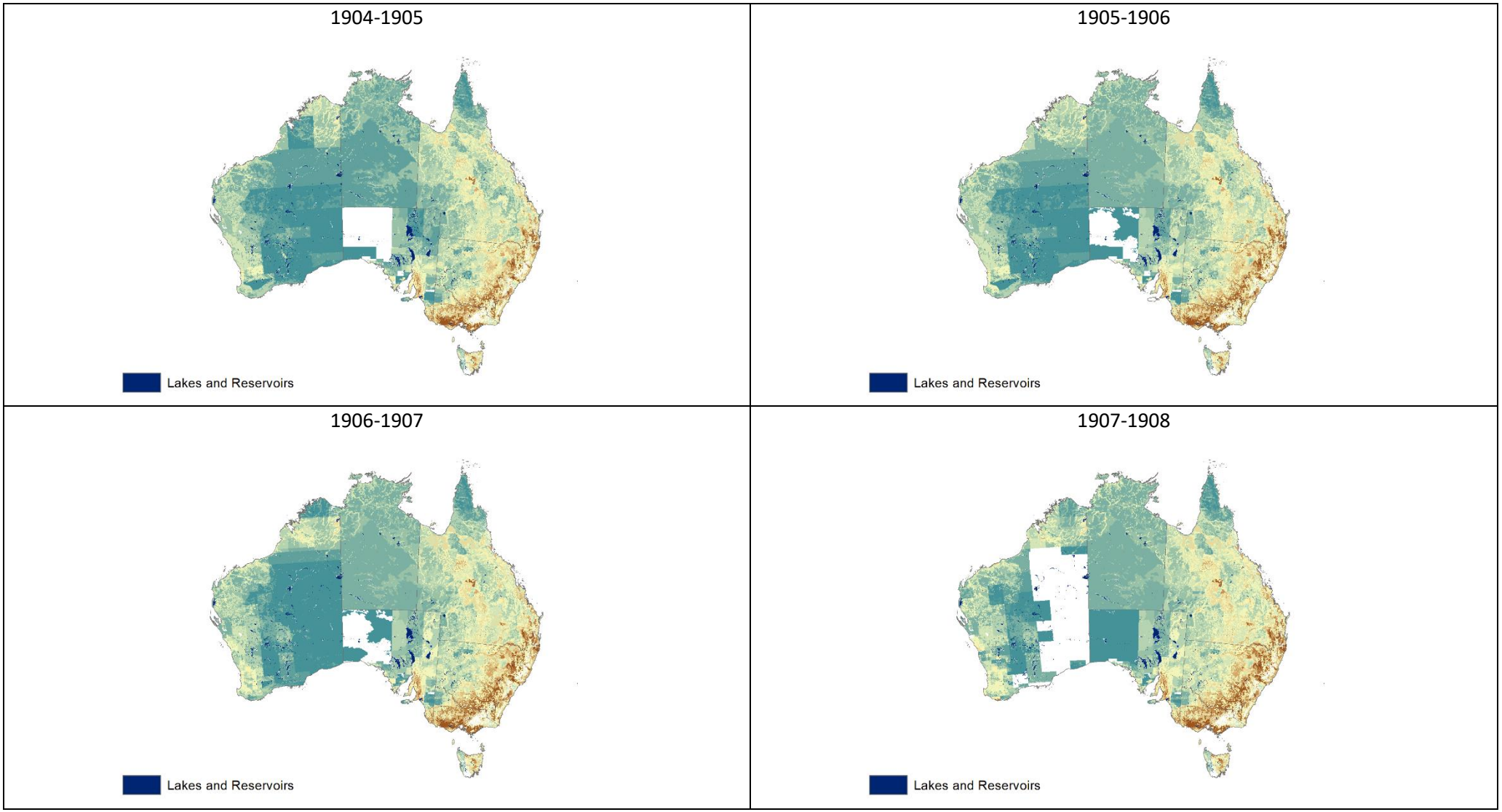

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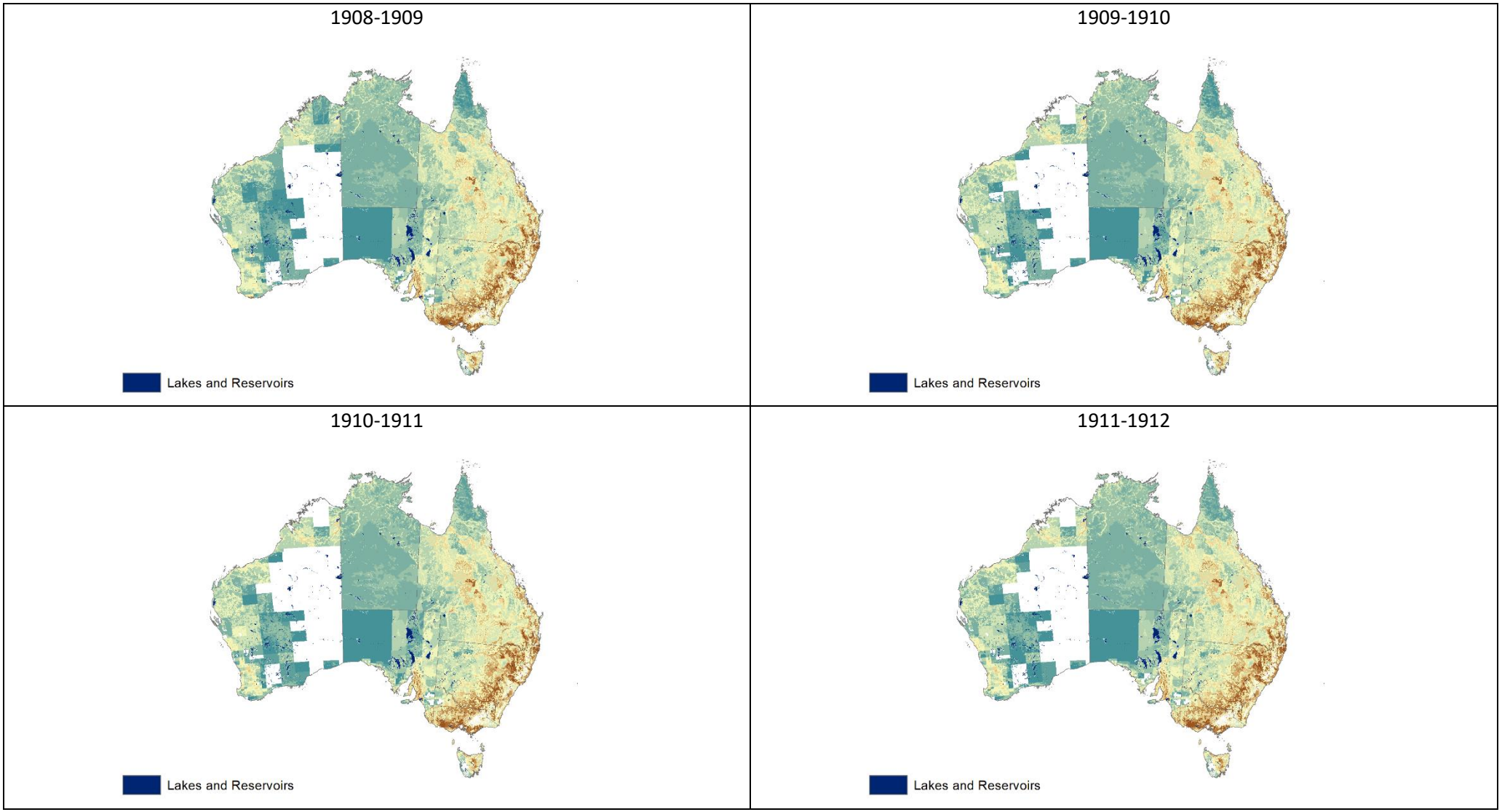

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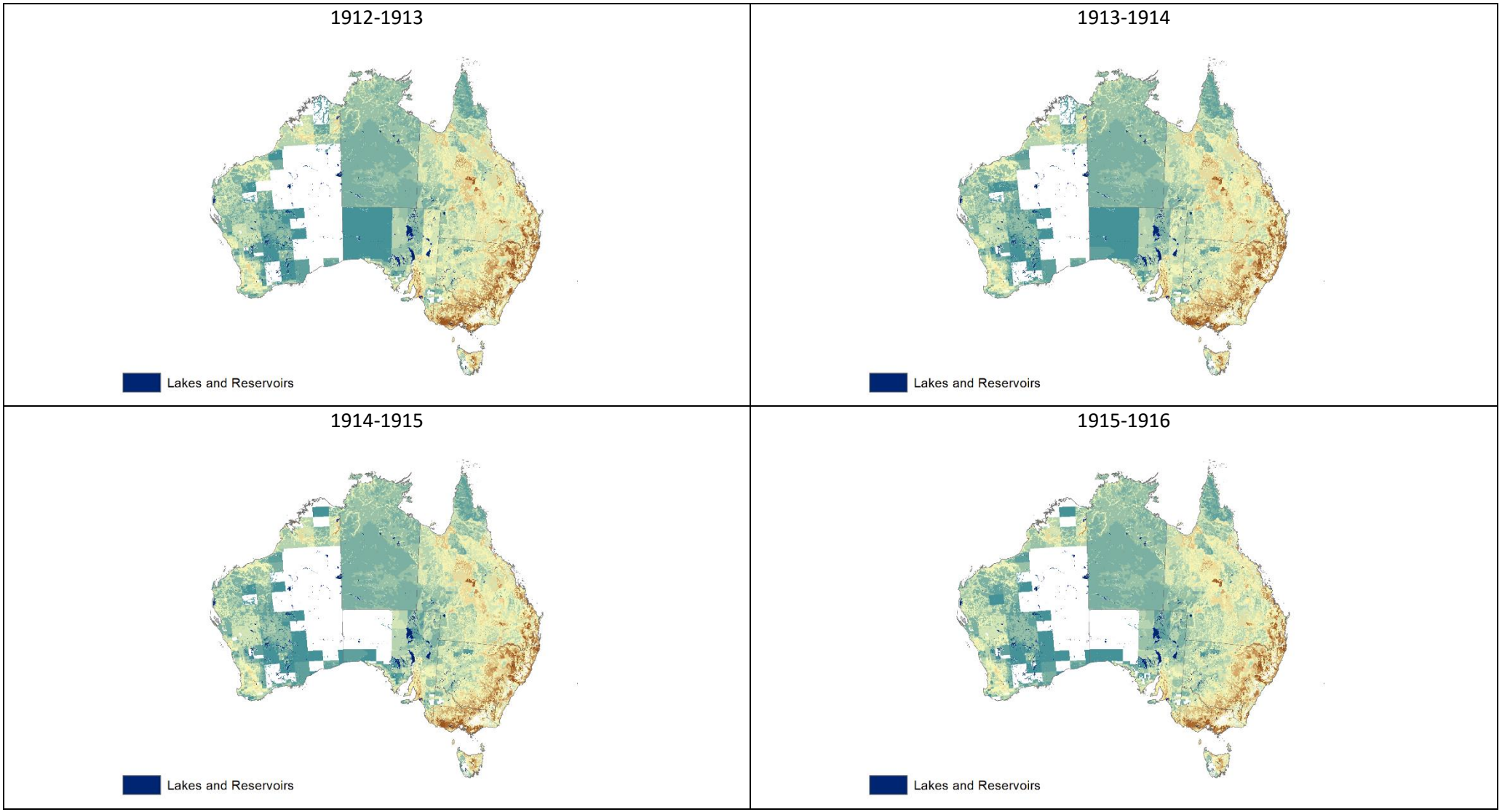

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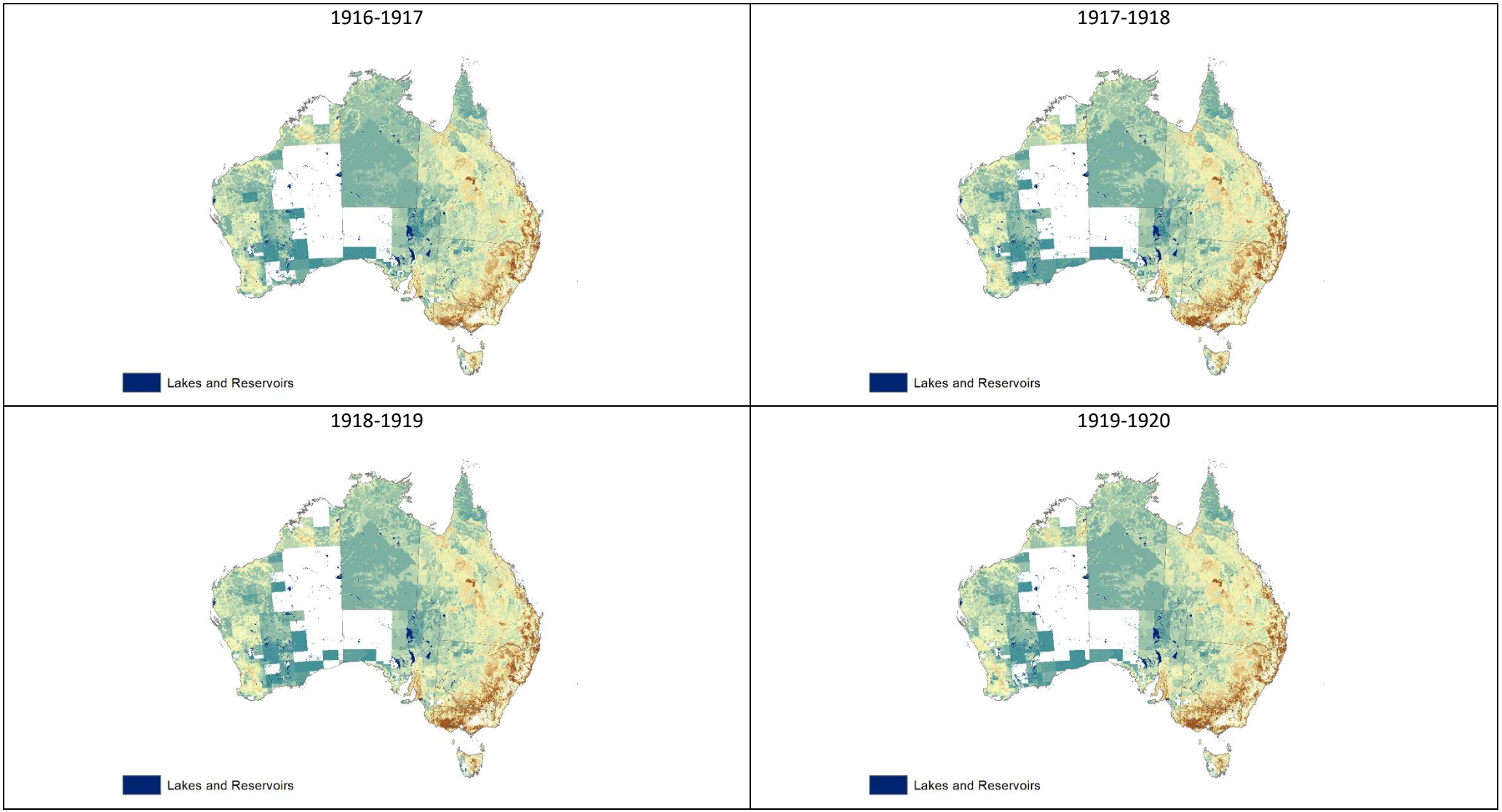

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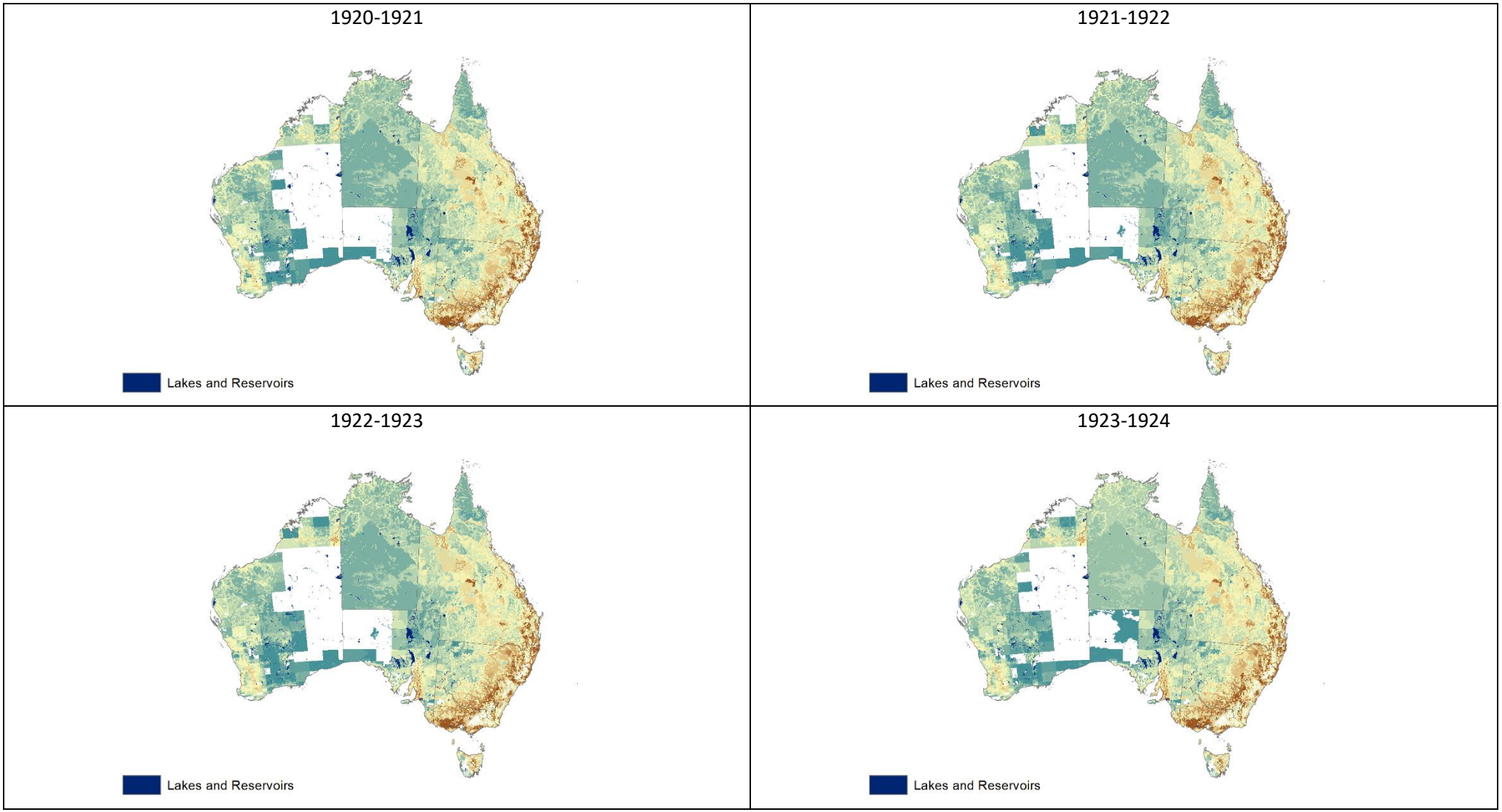

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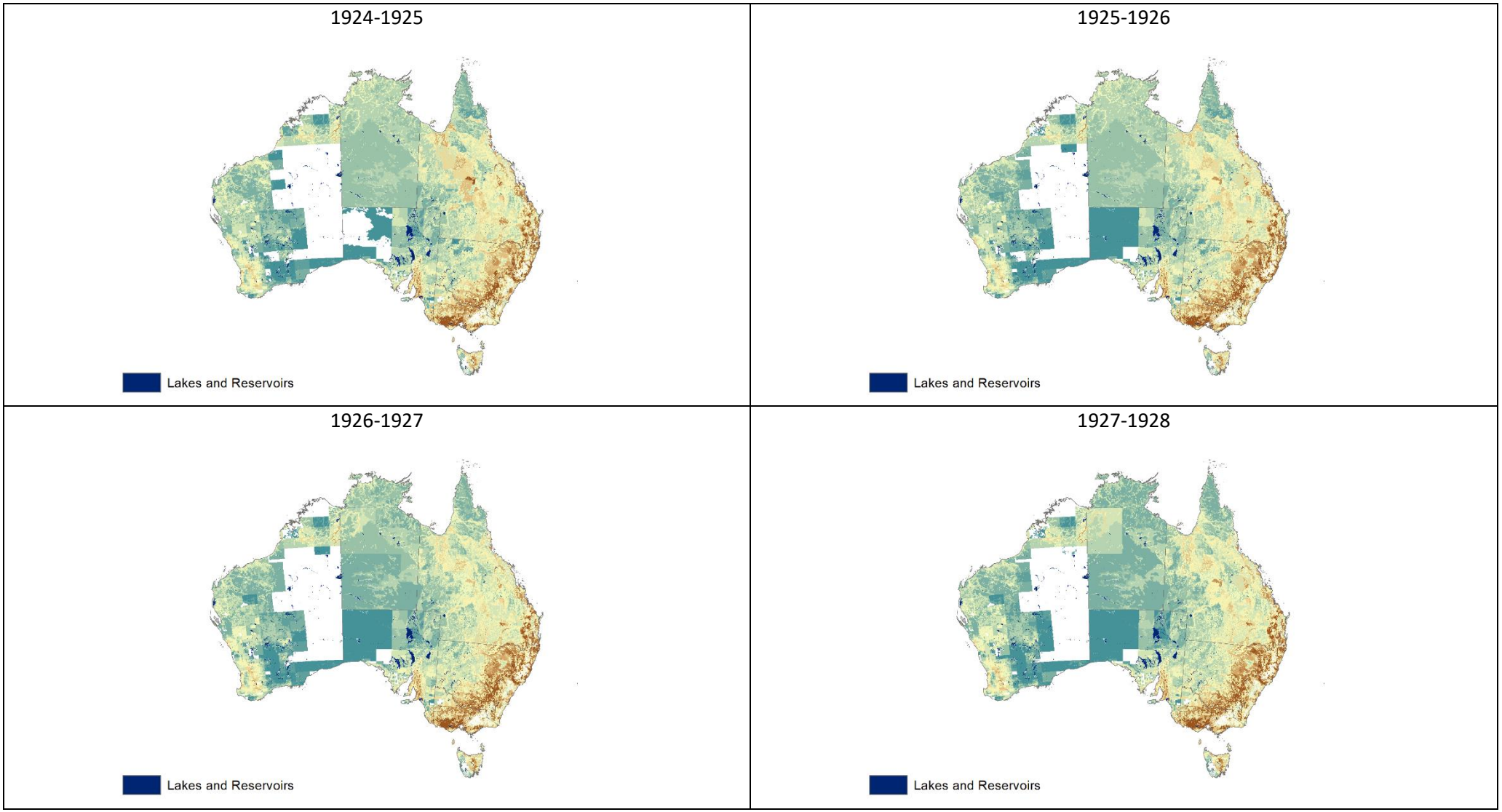

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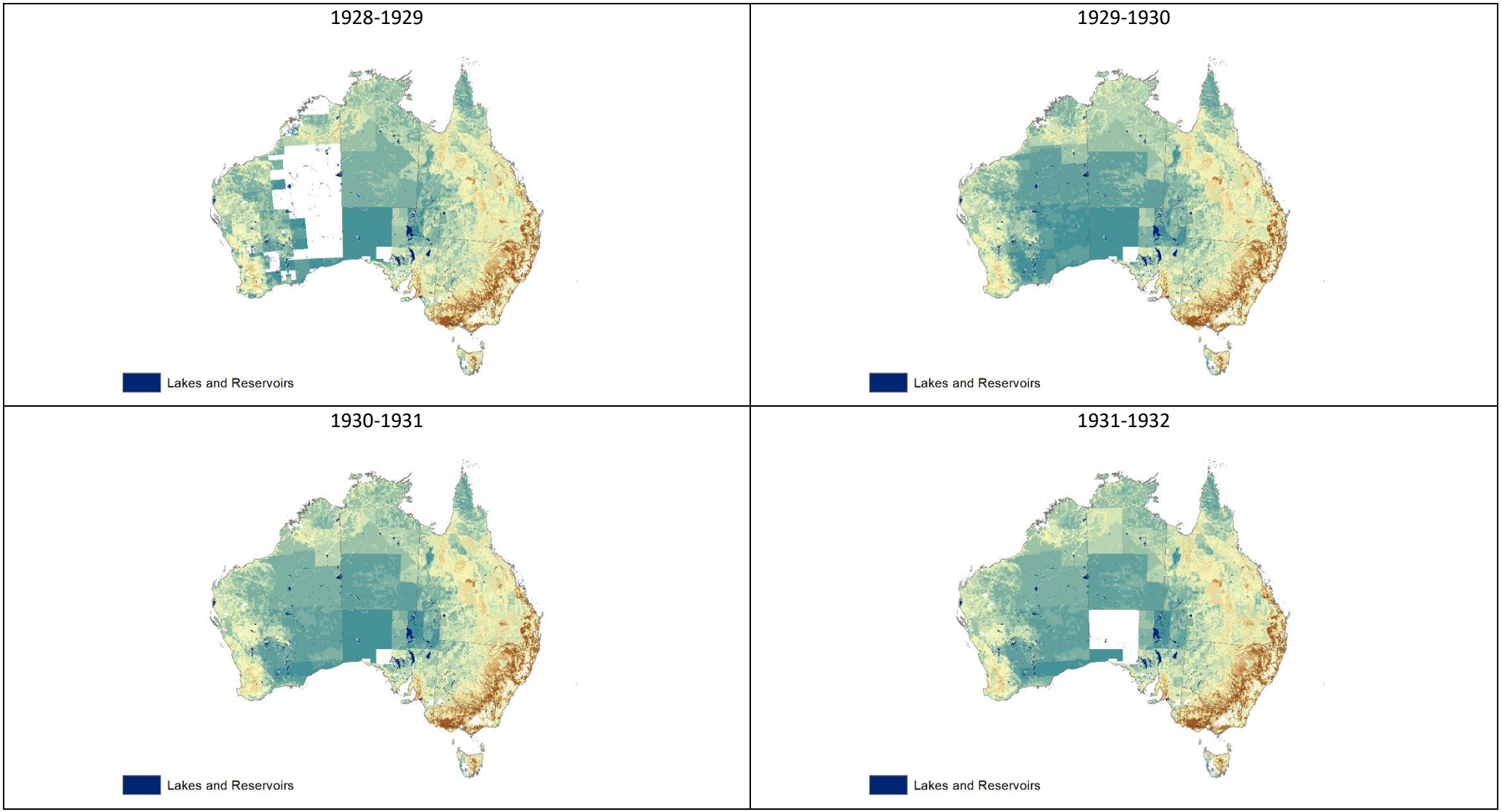

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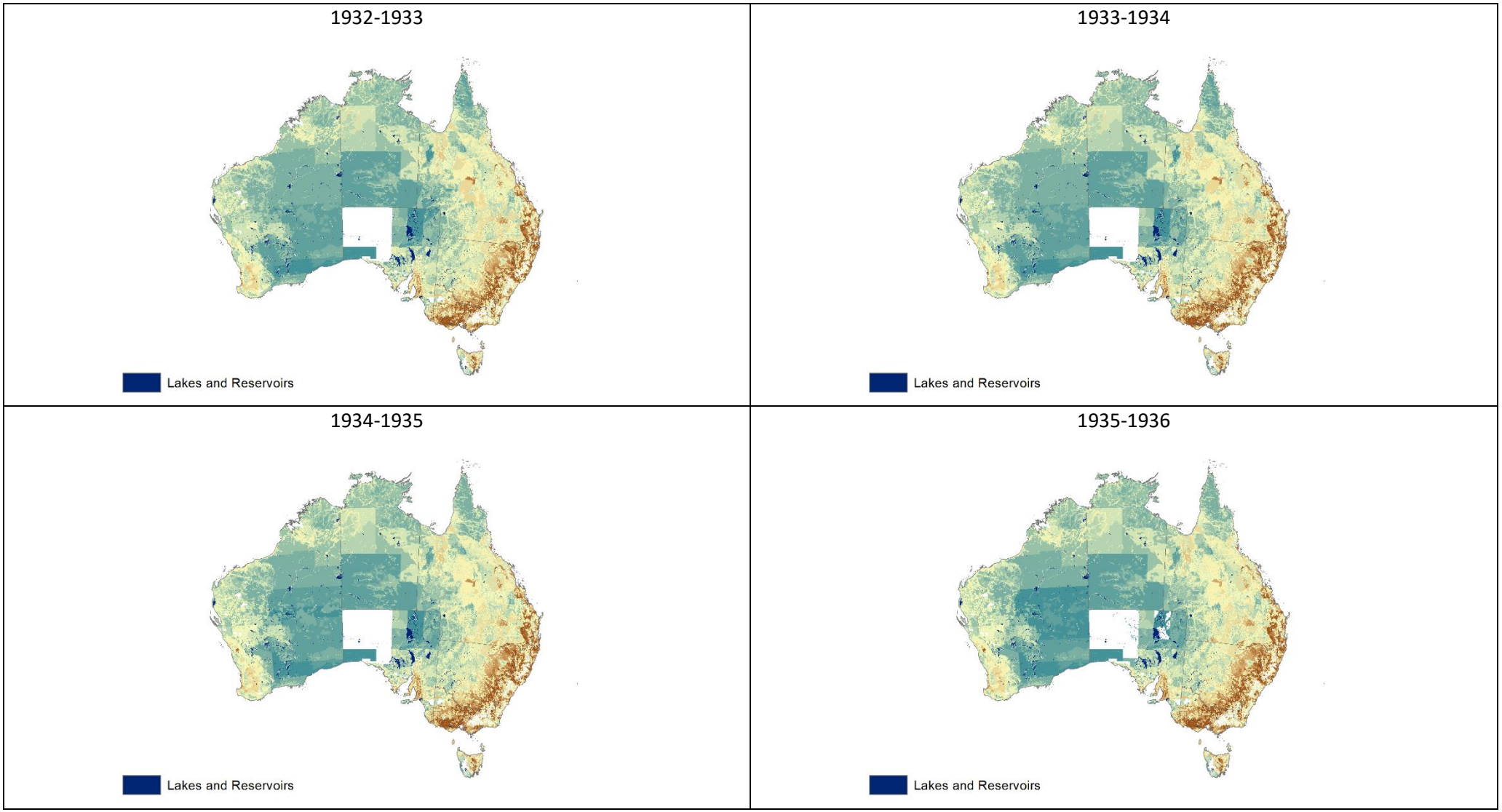

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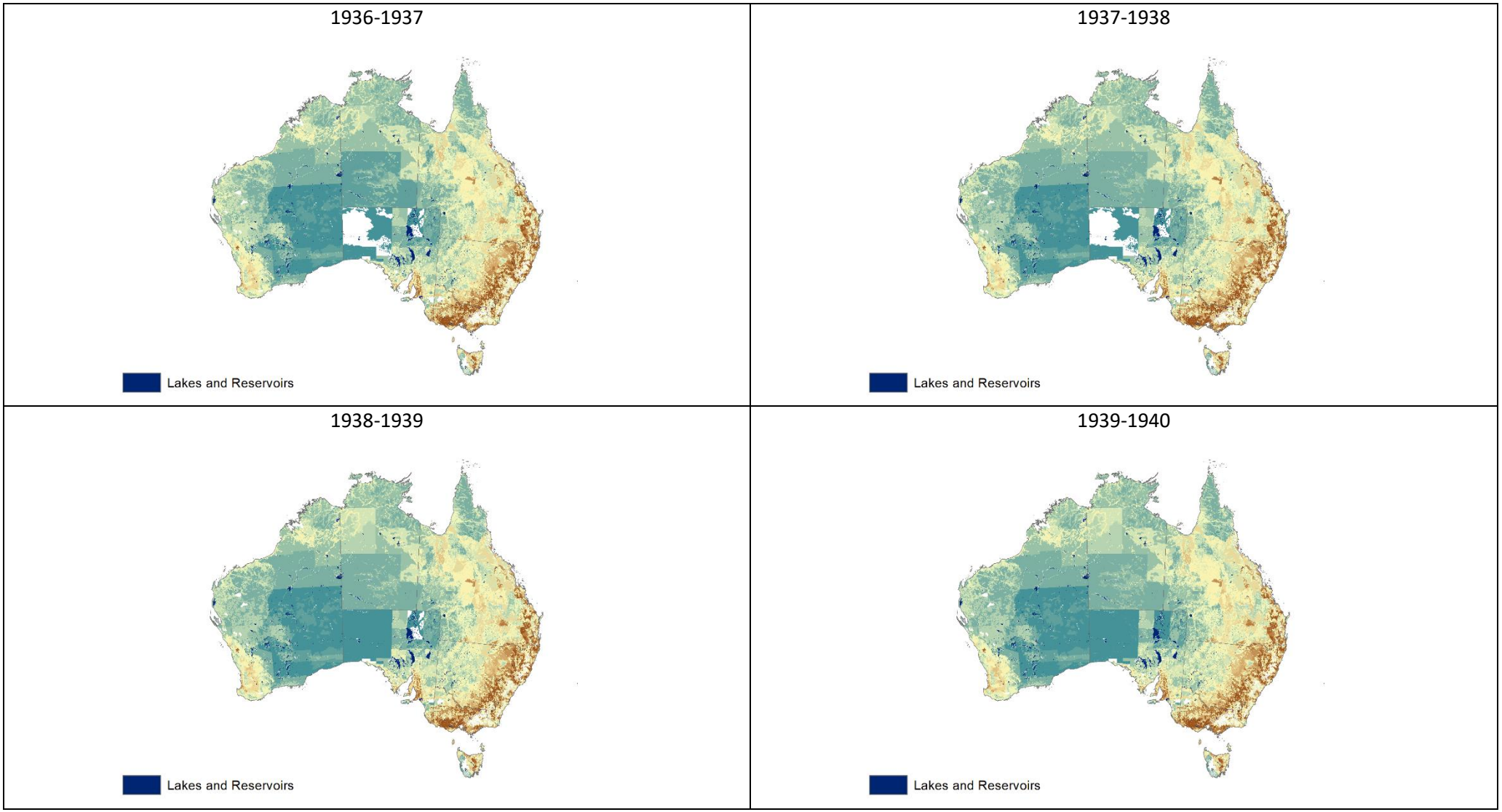

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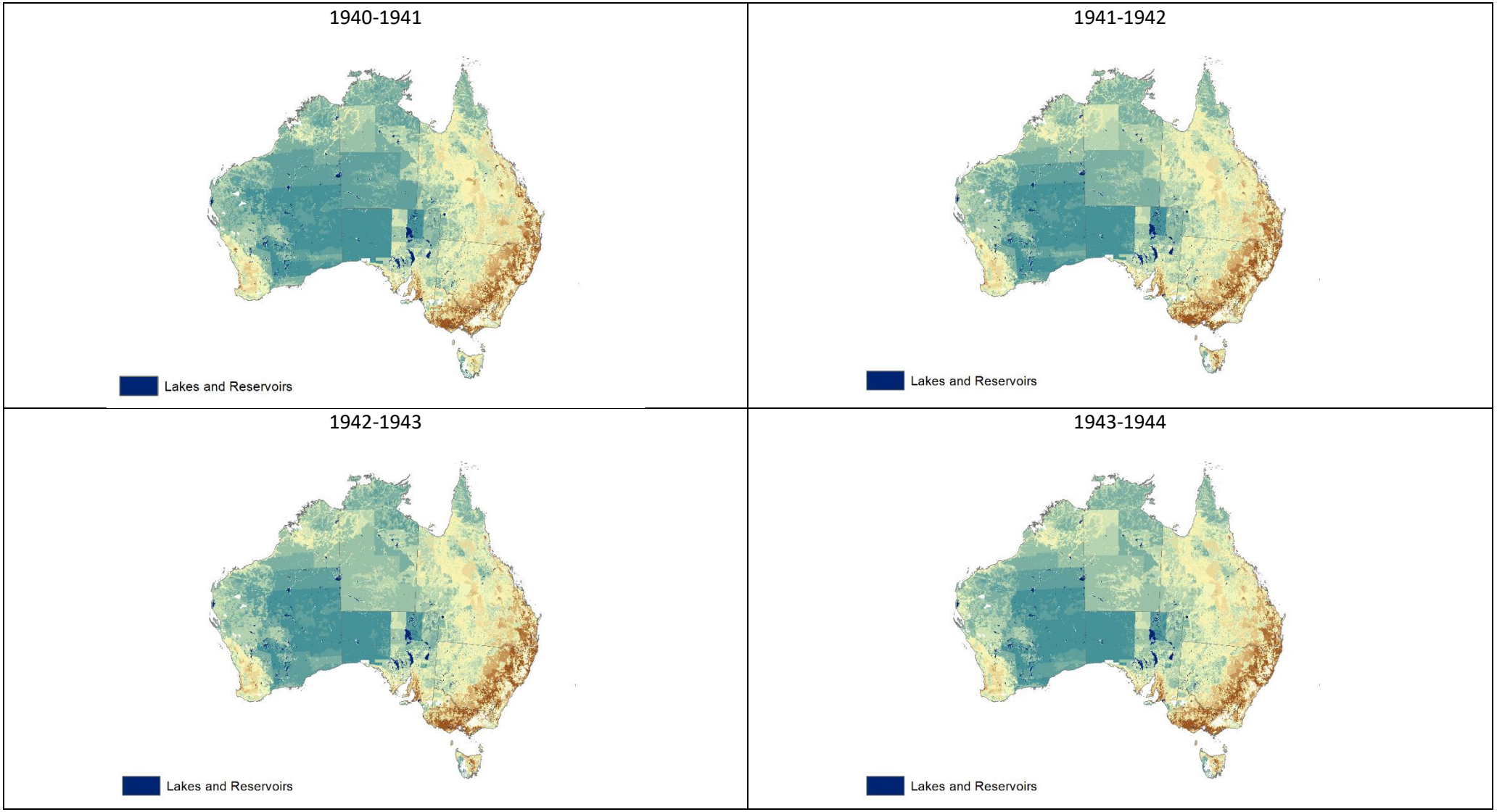

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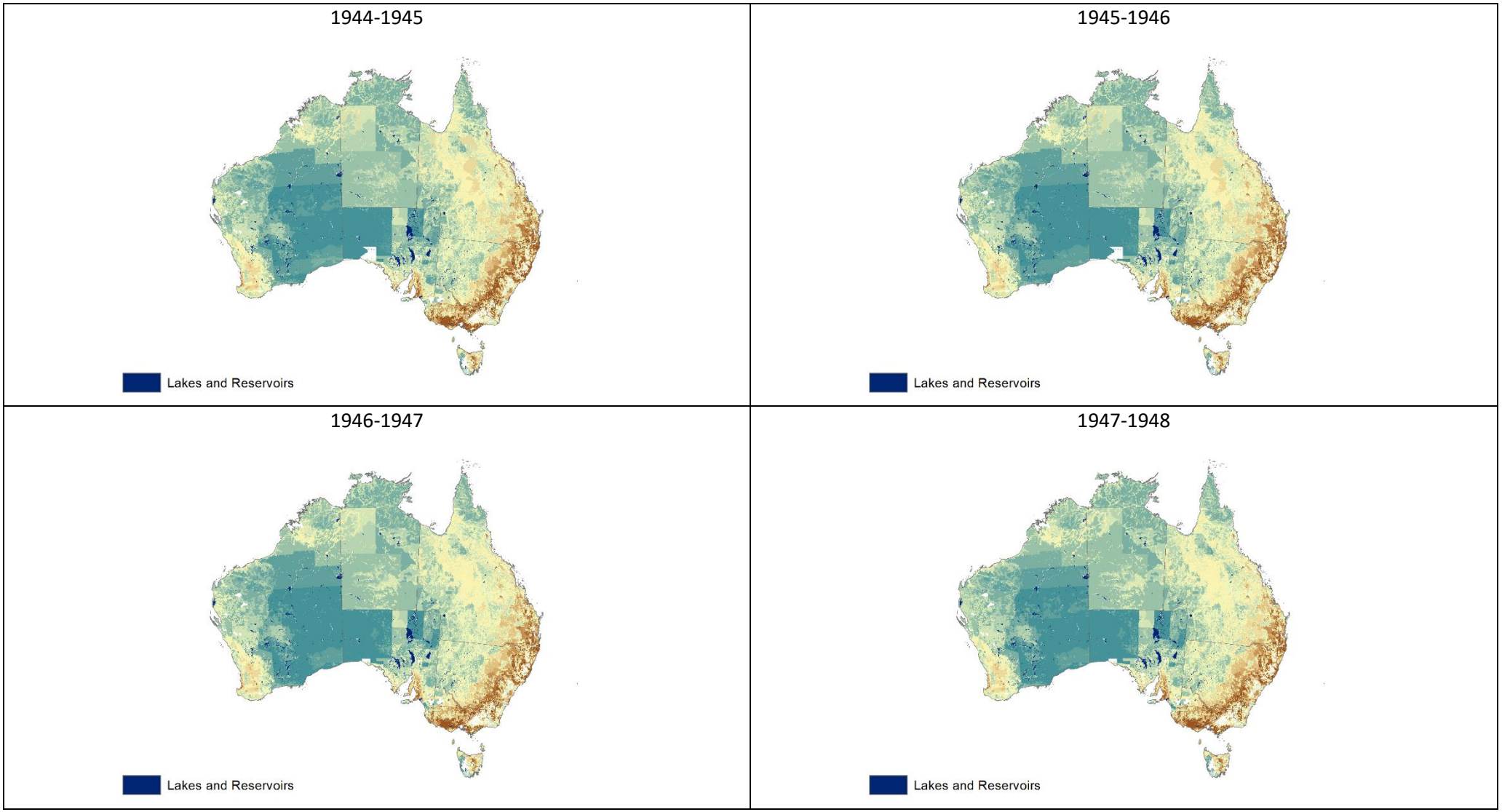

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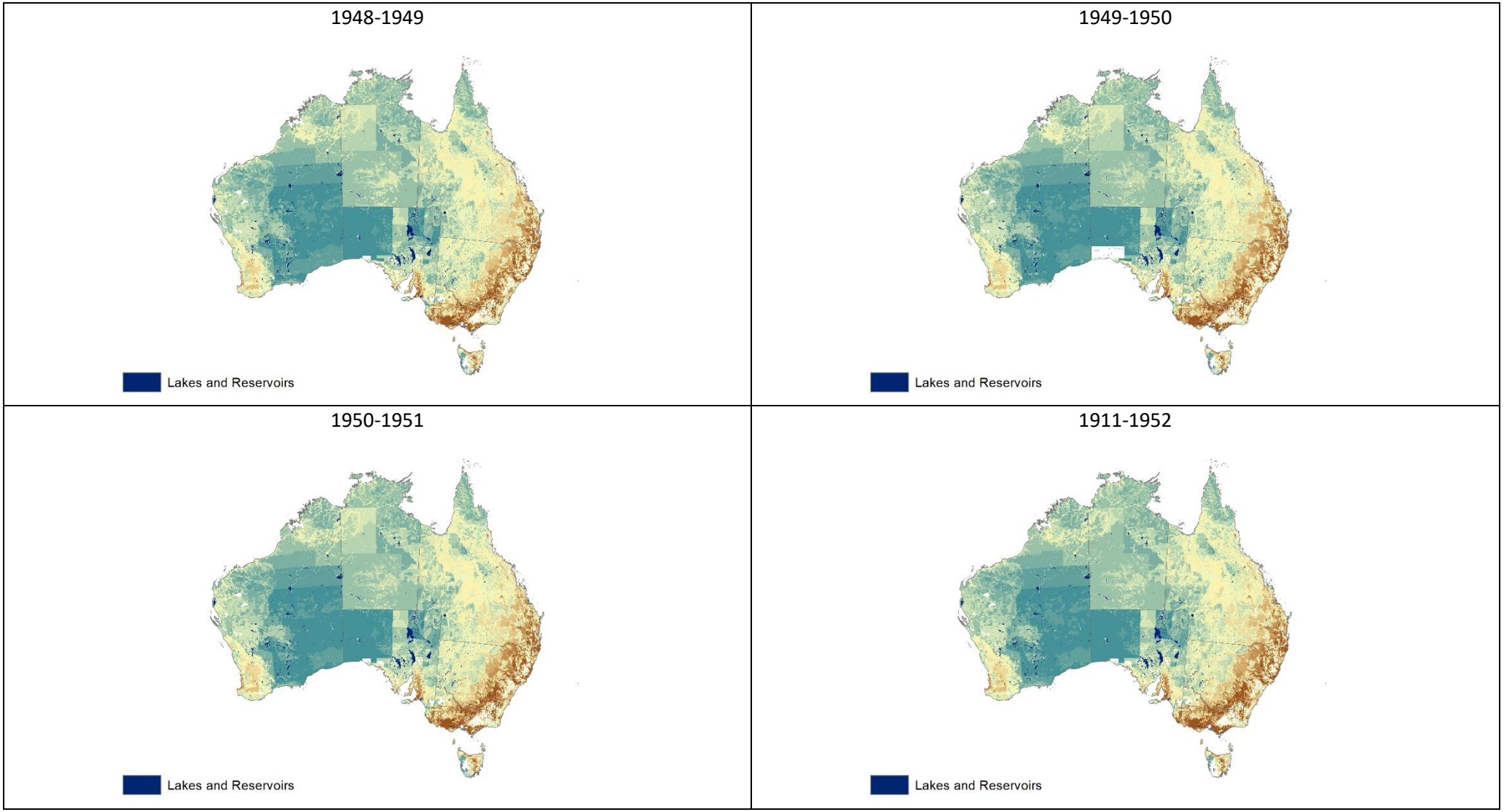
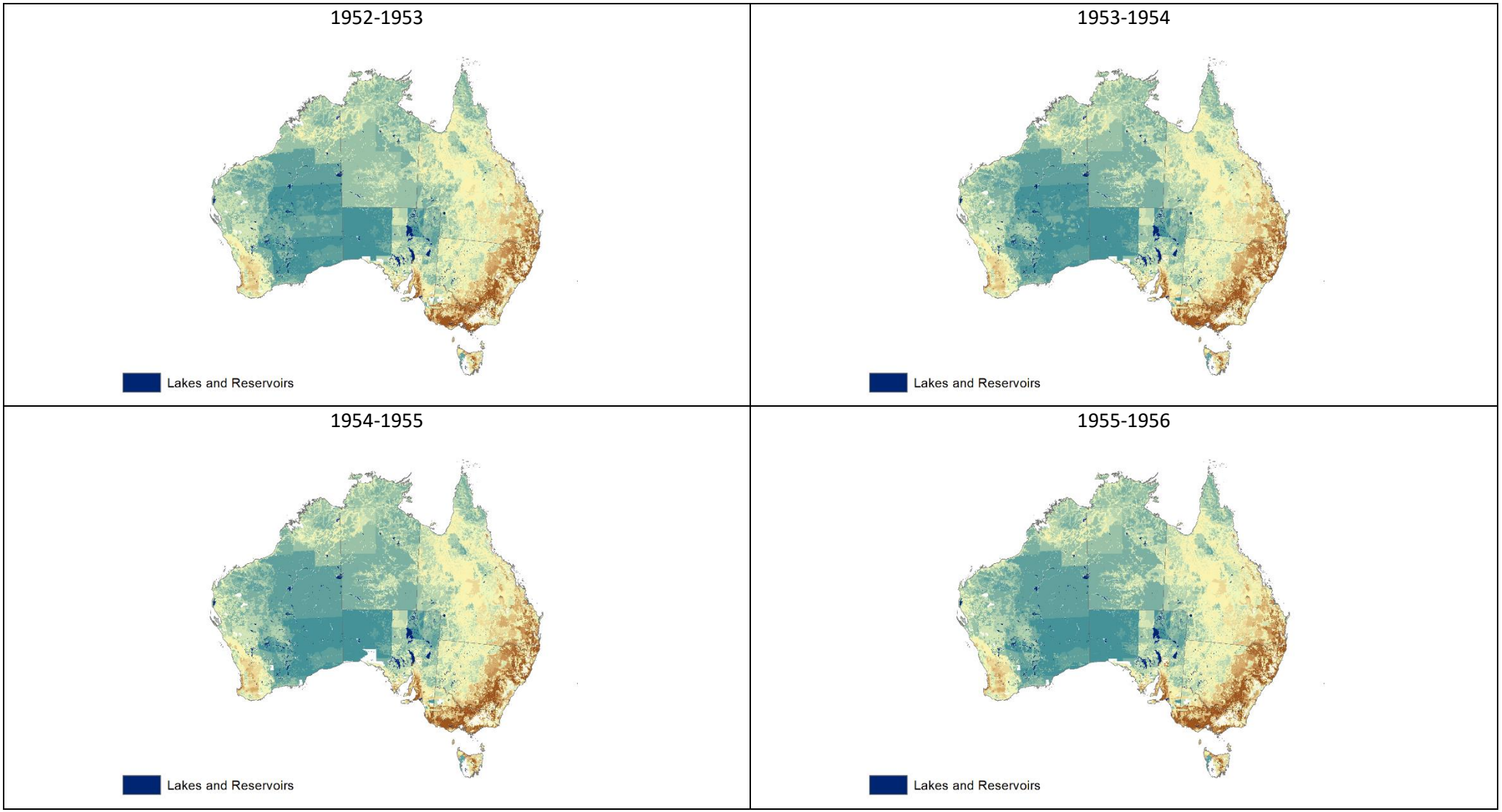
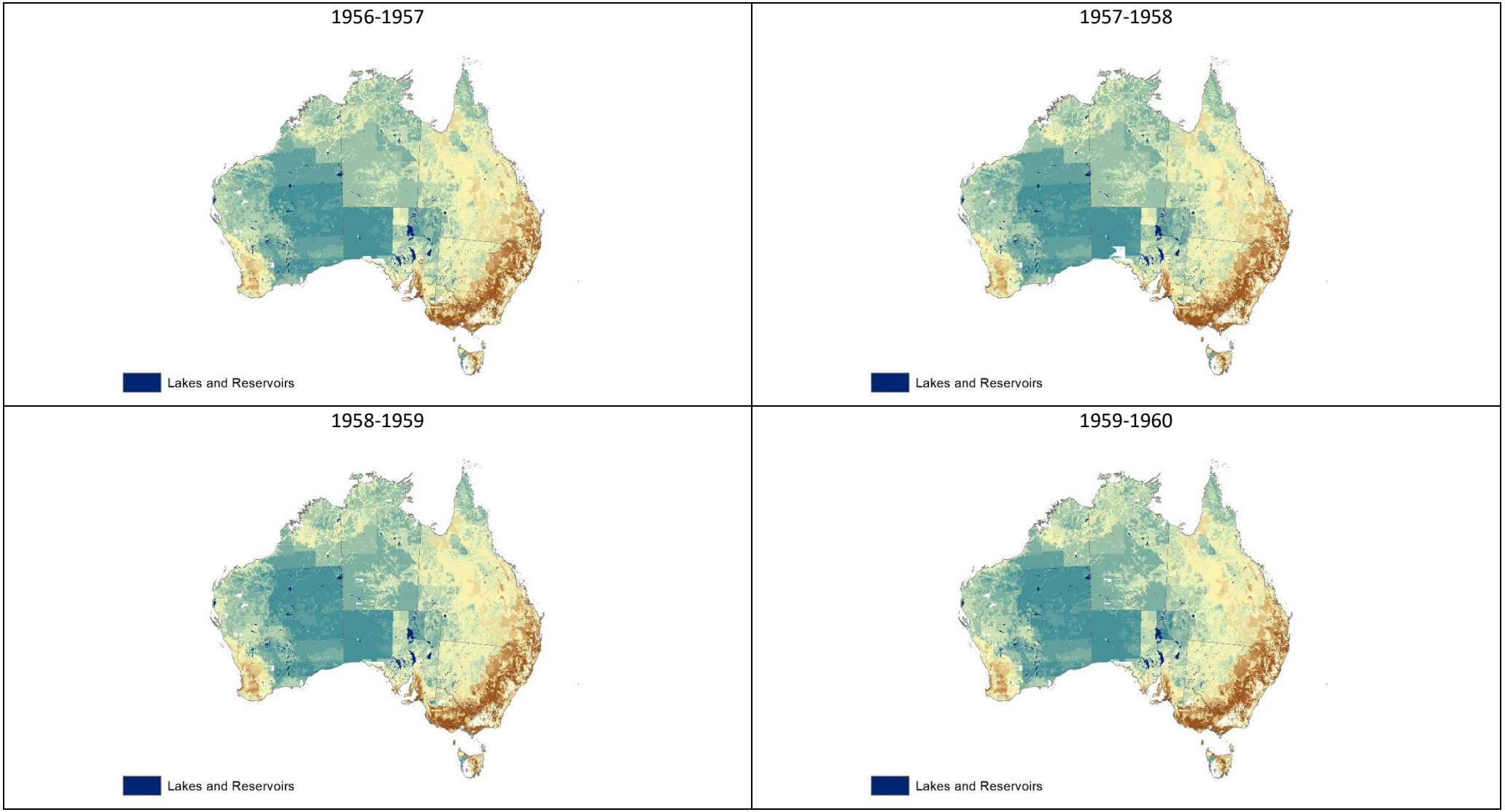
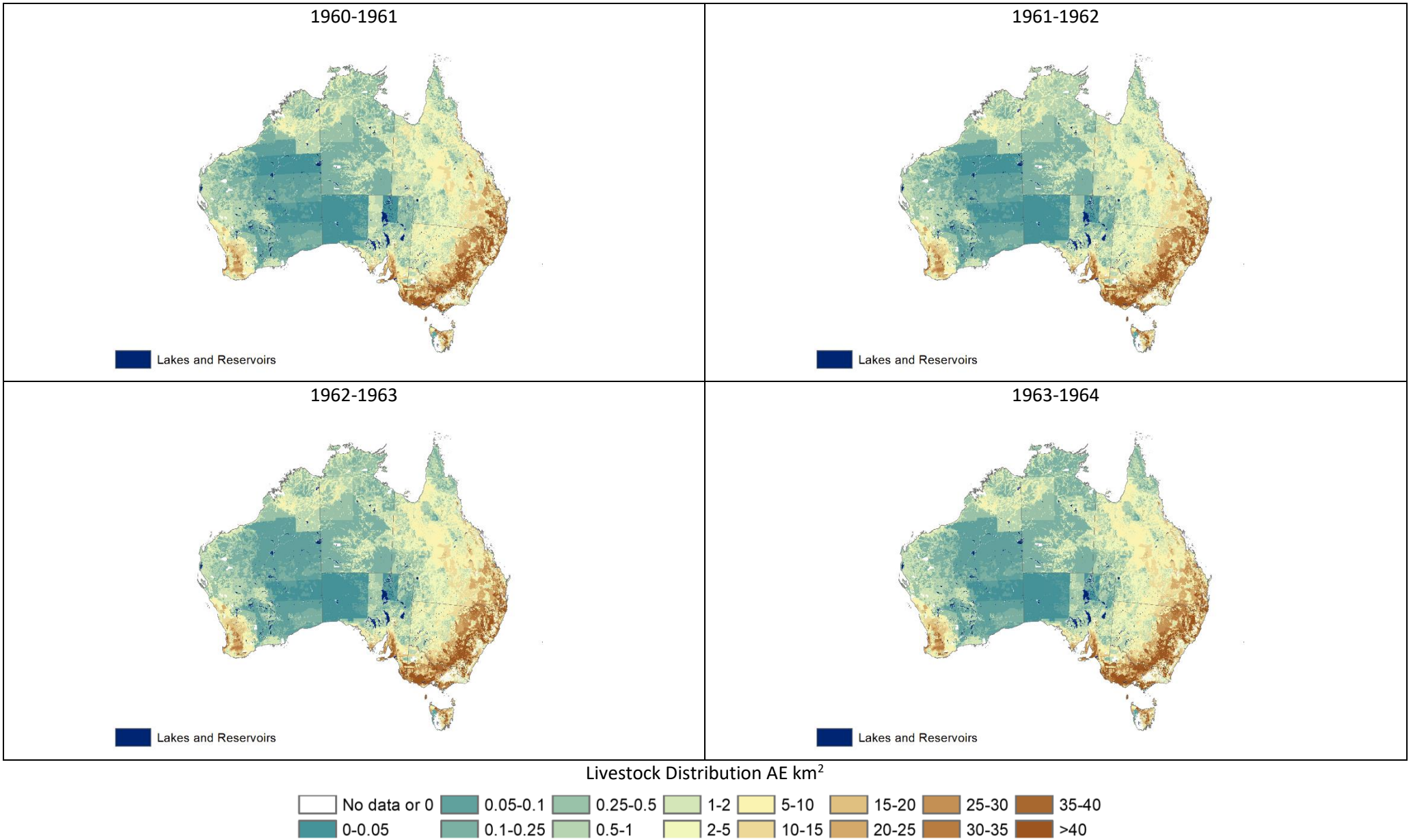


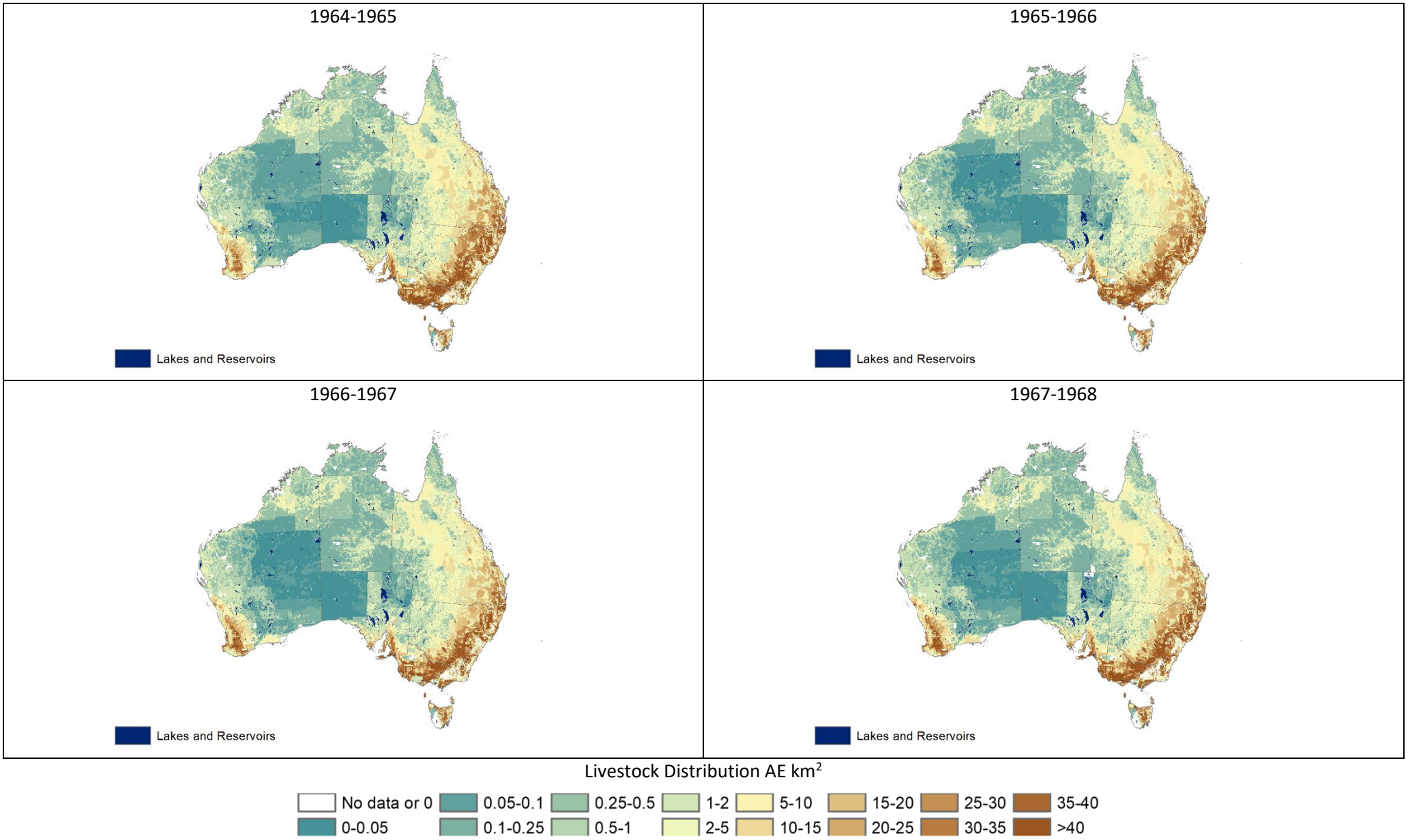

1952-1953
Lakes and Reservoirs
1953-1954
Lakes and Reservoirs
1954-1955
Lakes and Reservoirs
1955-1956
Lakes and Reservoirs
Livestock Distribution AE km2
No data or 0
0-0.05
0.05-0.1
0.1-0.25
0.25-0.5
0.5-1
1-2
2-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
>40


1956-1957
Lakes and Reservoirs
1957-1958
Lakes and Reservoirs
1958-1959
Lakes and Reservoirs
1959-1960
Lakes and Reservoirs
Livestock Distribution AE km2
No data or 0
0-0.05
0.05-0.1
0.1-0.25
0.25-0.5
0.5-1
1-2
2-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
>40

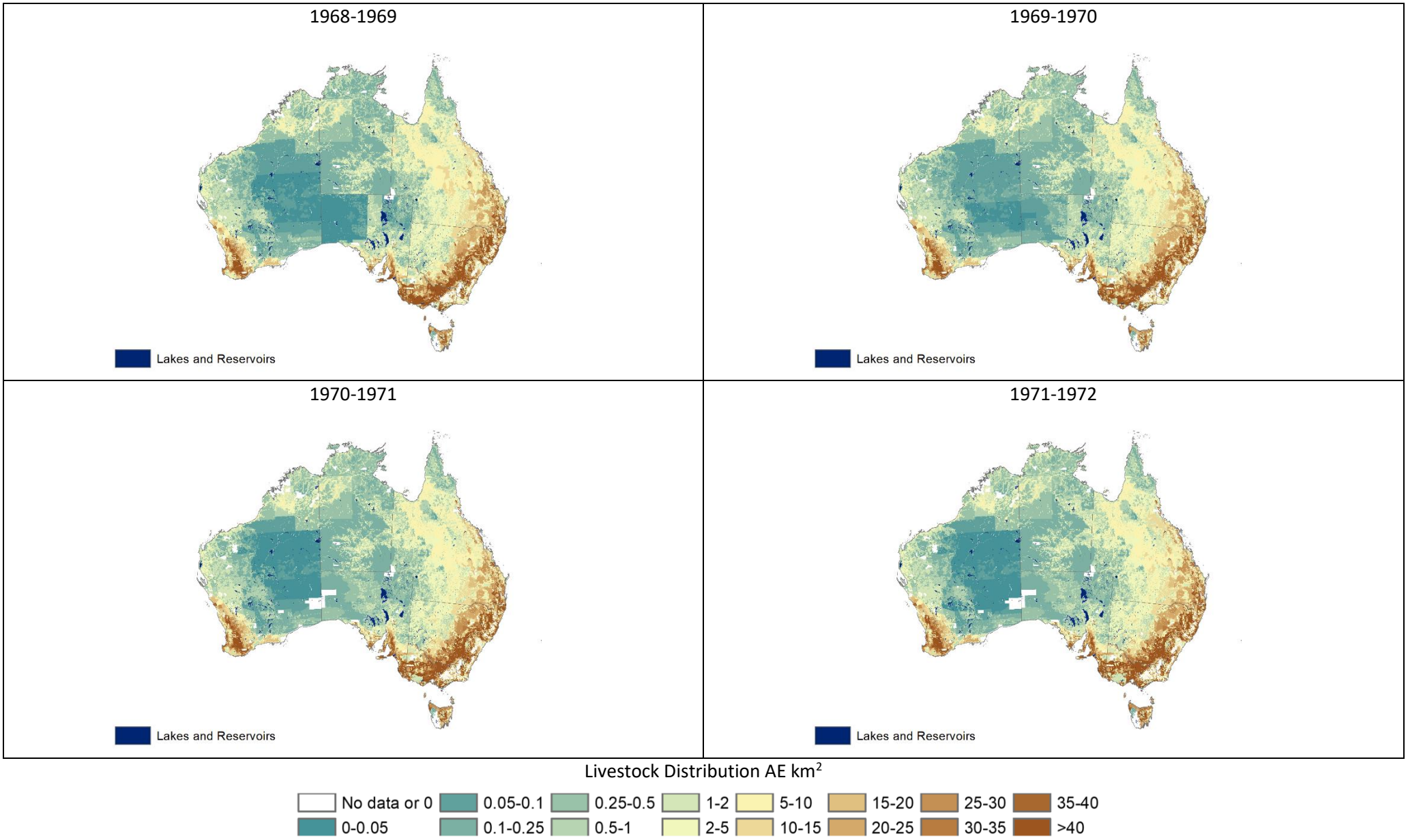
Appendix 2 *continued*



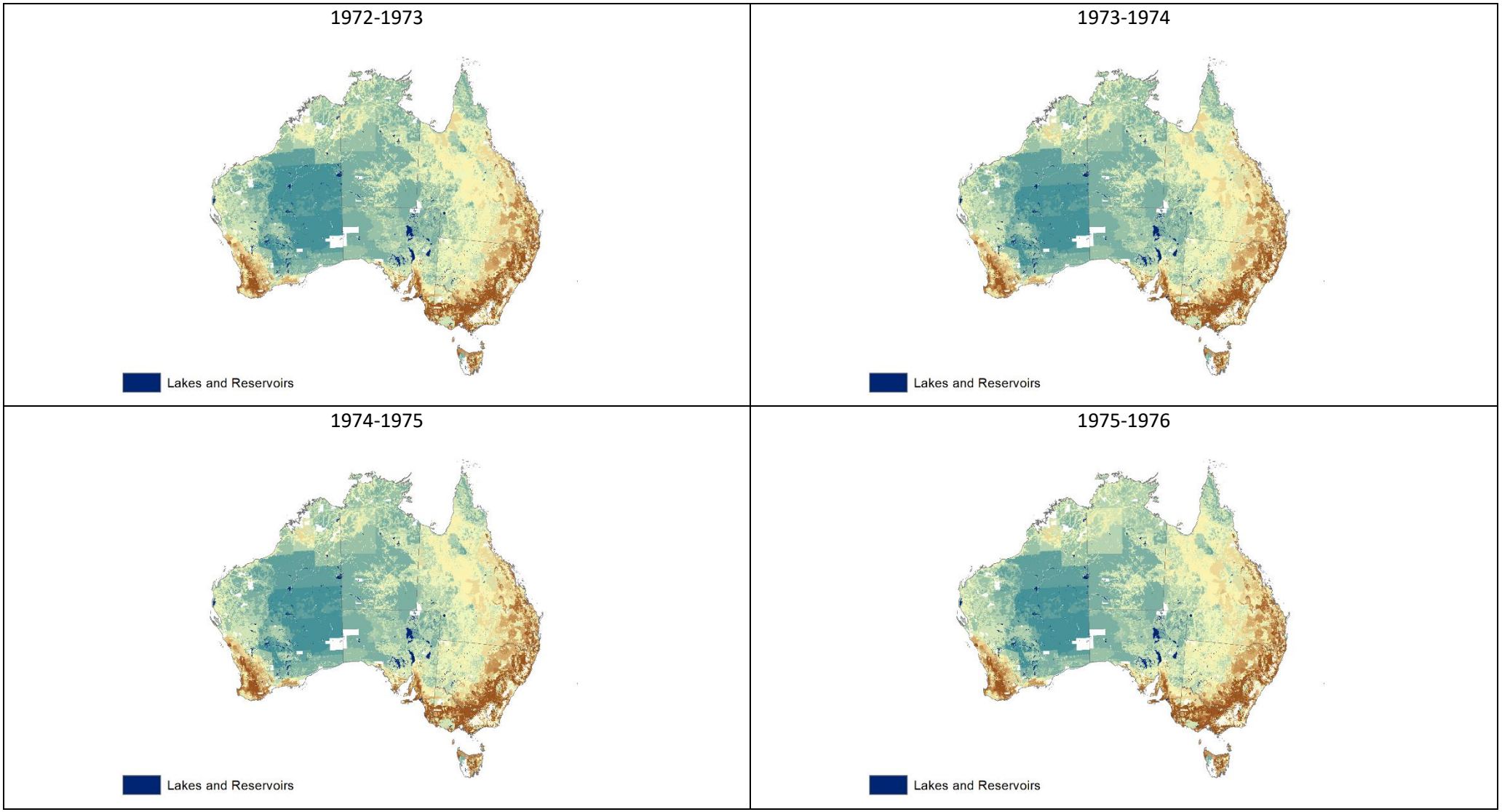
Appendix 2 *continued*



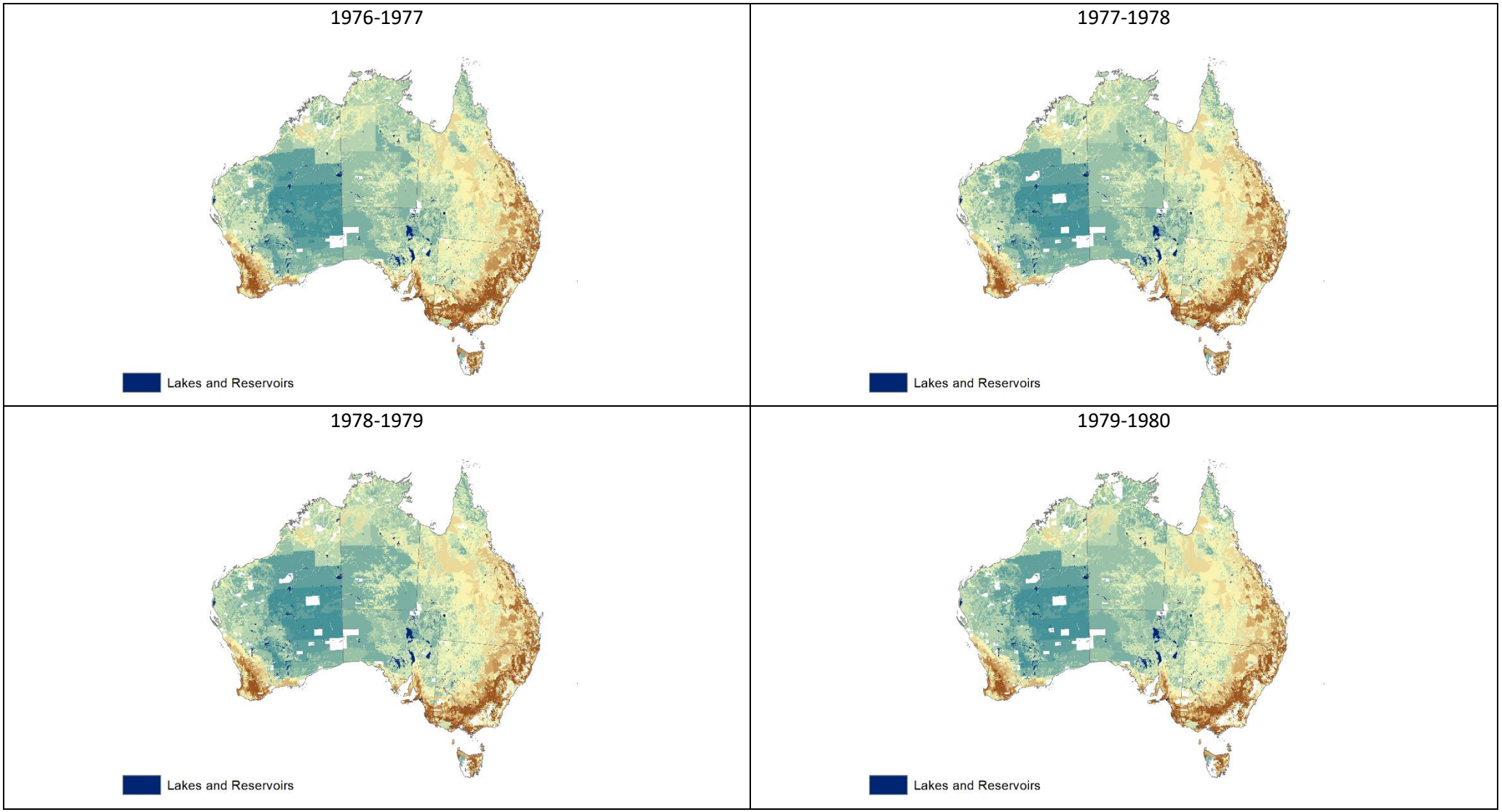
Appendix 2 *continued*



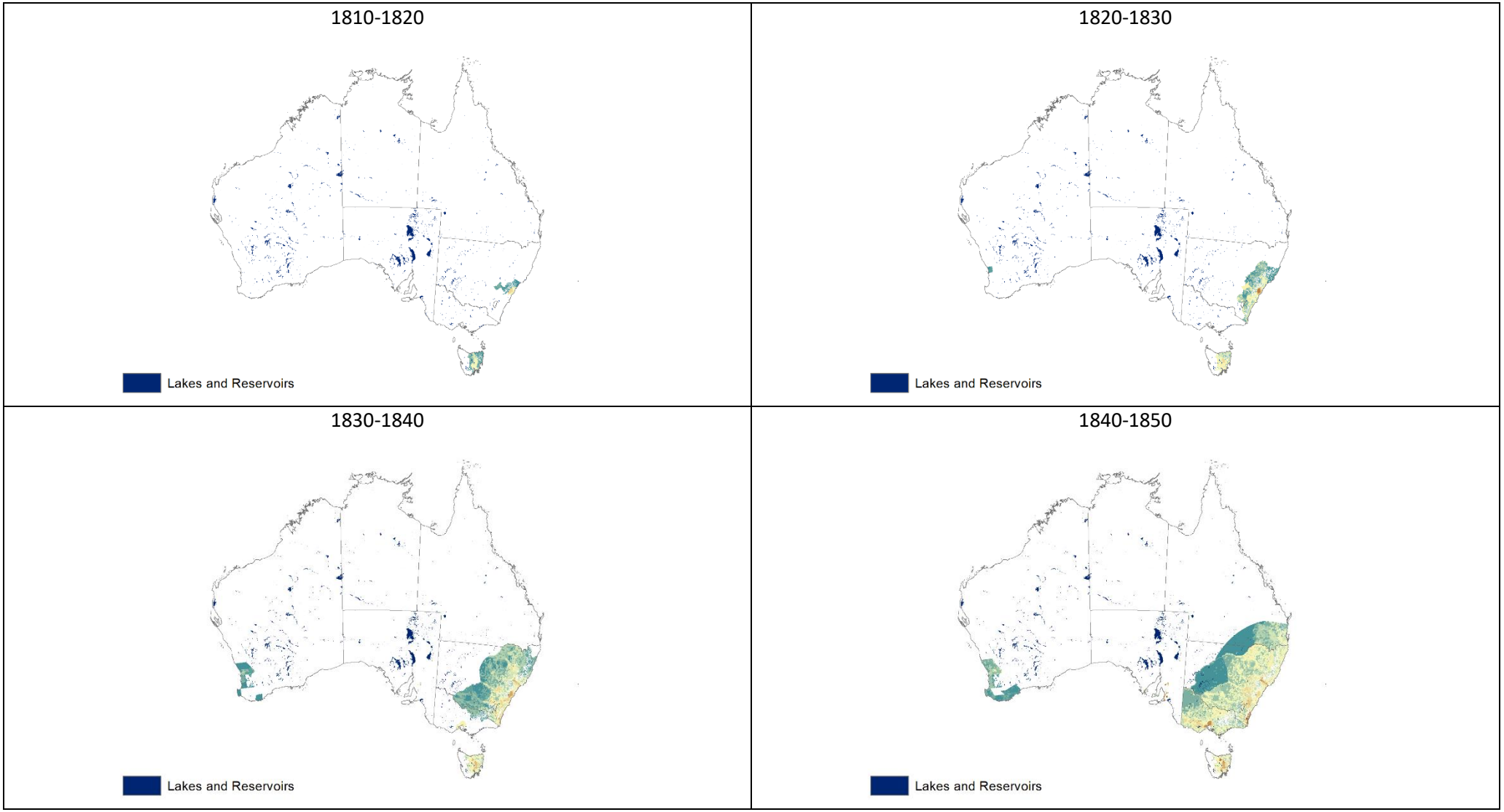
Appendix 2 *continued*



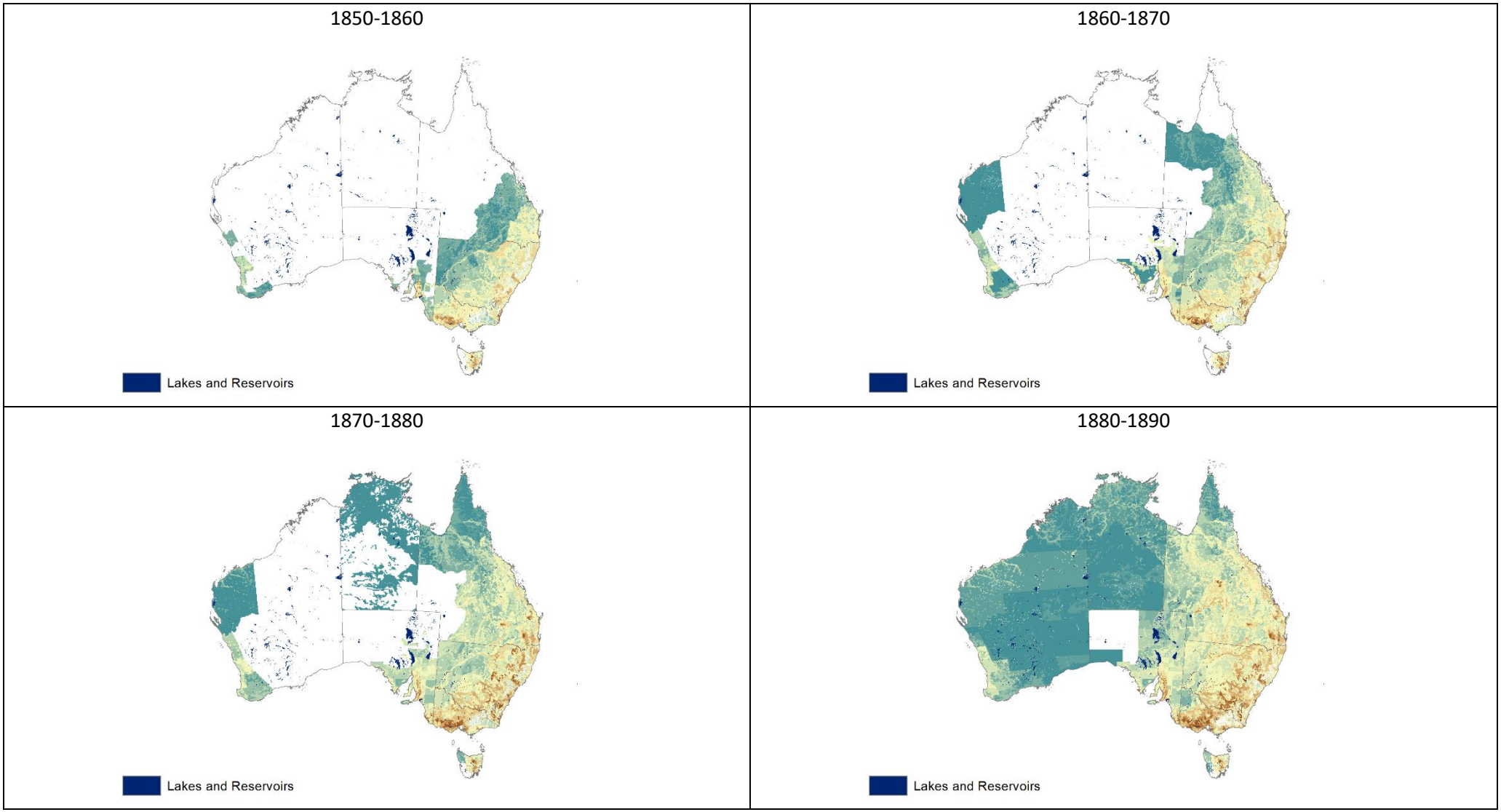
Appendix 2 *continued*



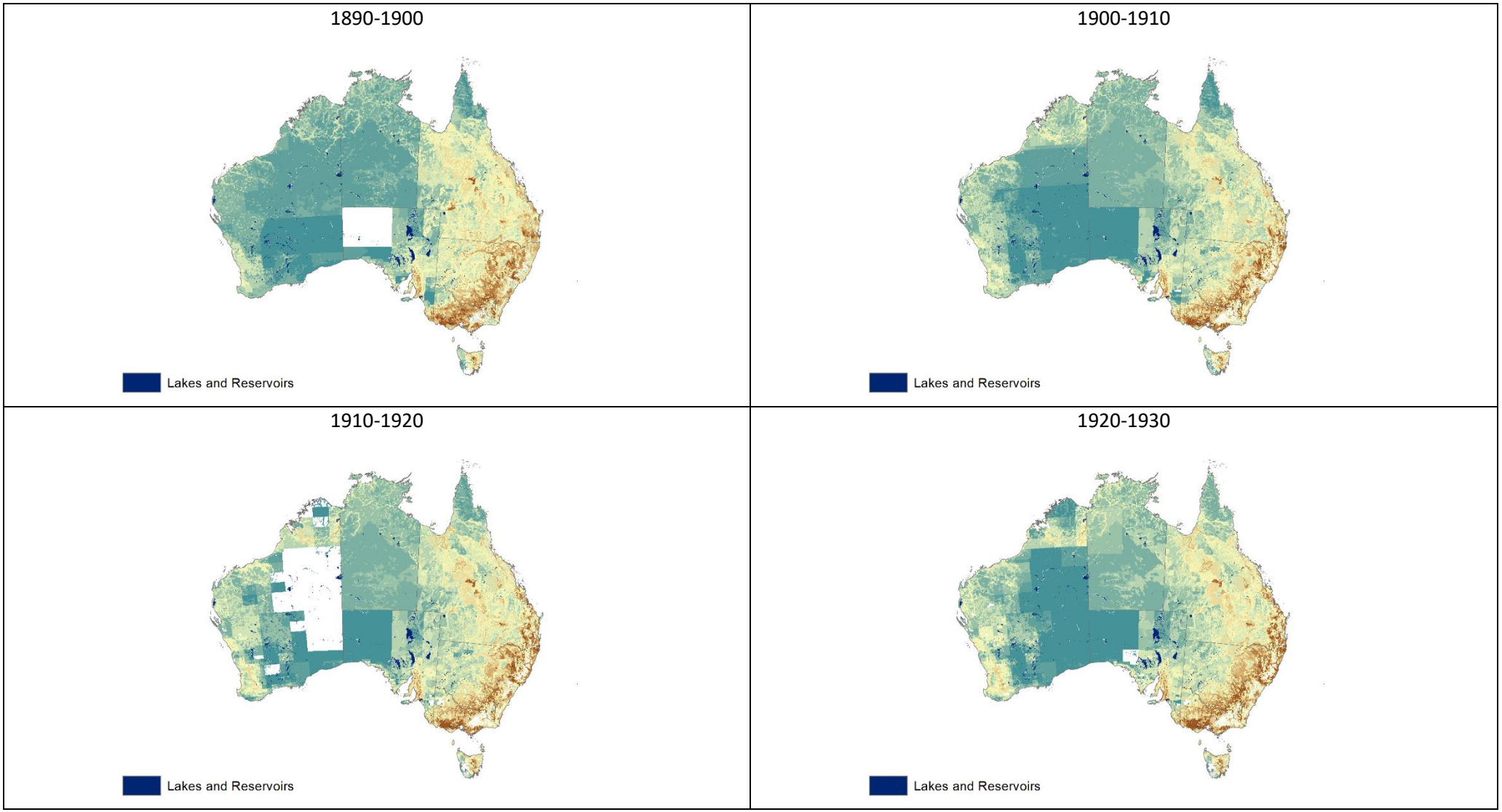
Appendix 3 Livestock Distribution Decadal Means 1810-1980



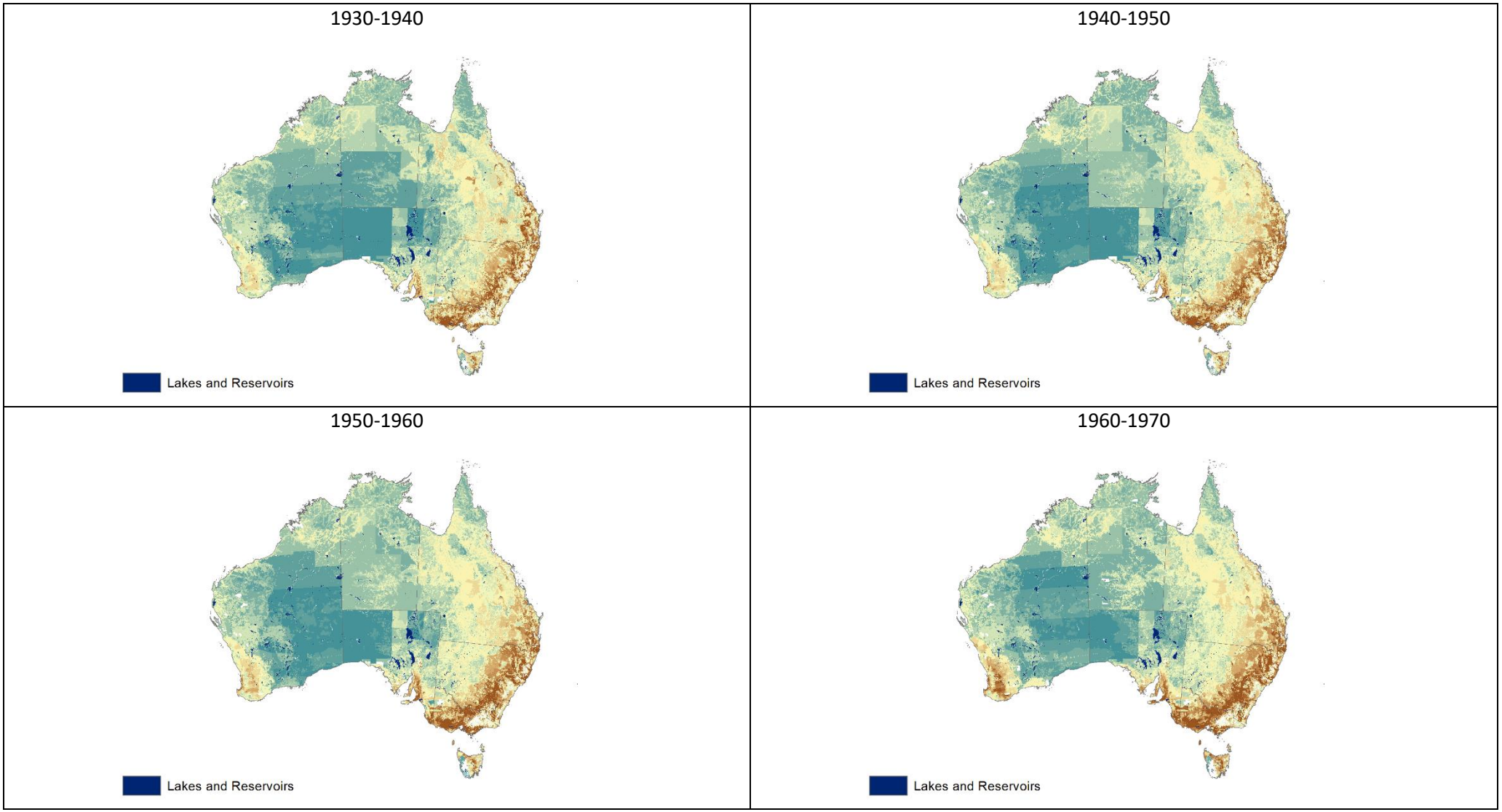
Appendix 3 *continued*



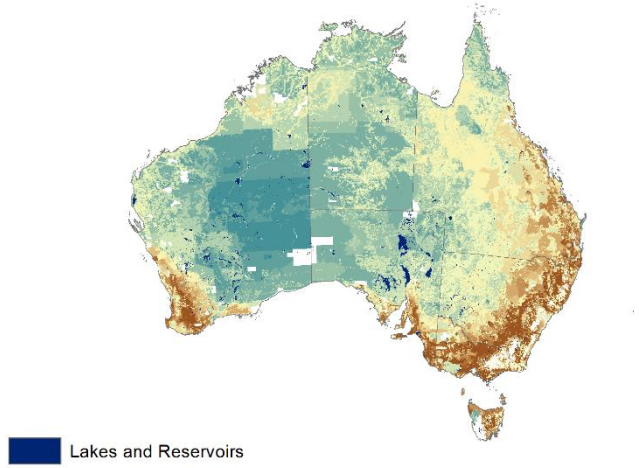
Appendix 3 *continued*



Appendix 3 *continued*

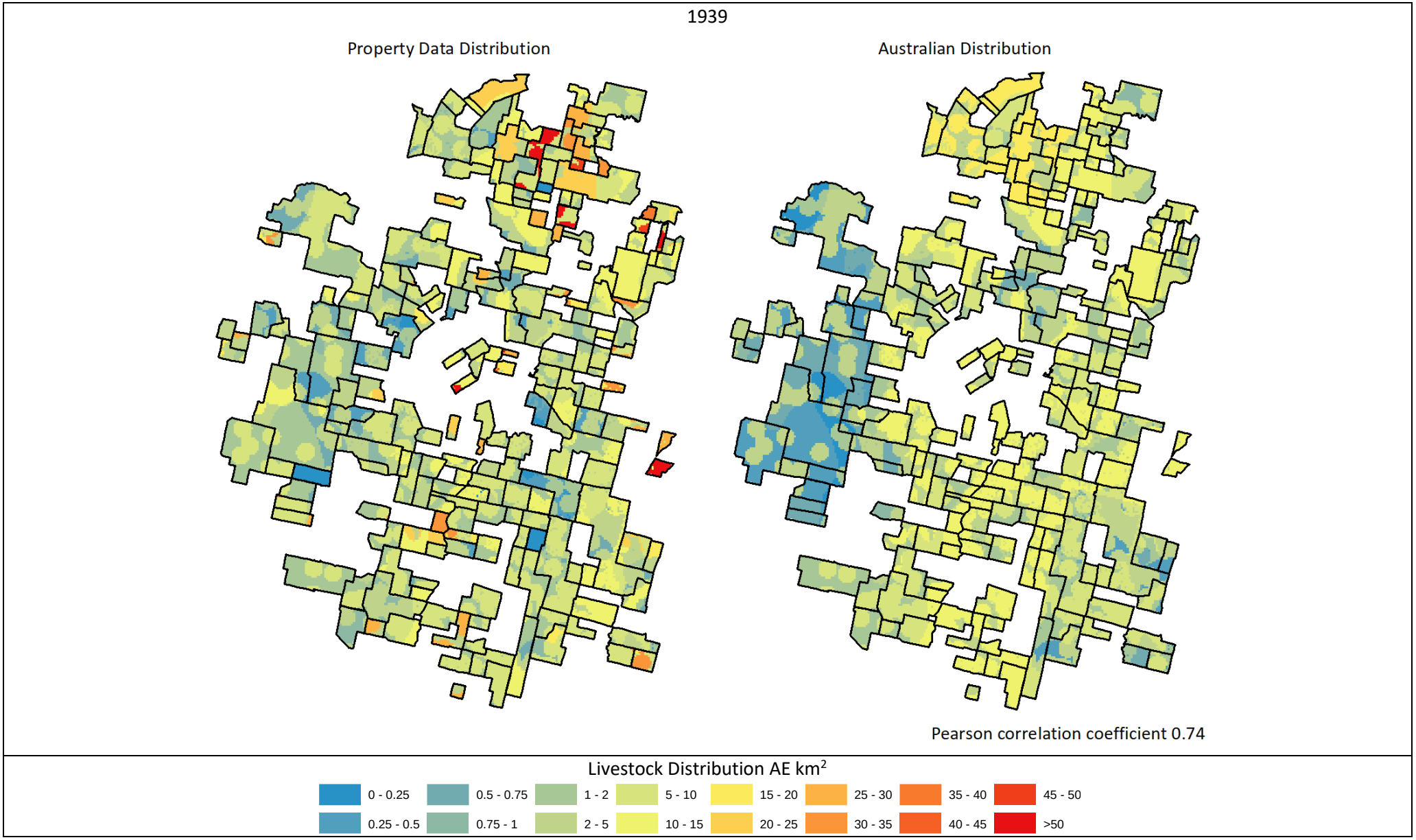


1970-1980



Livestock Distribution AE km^2

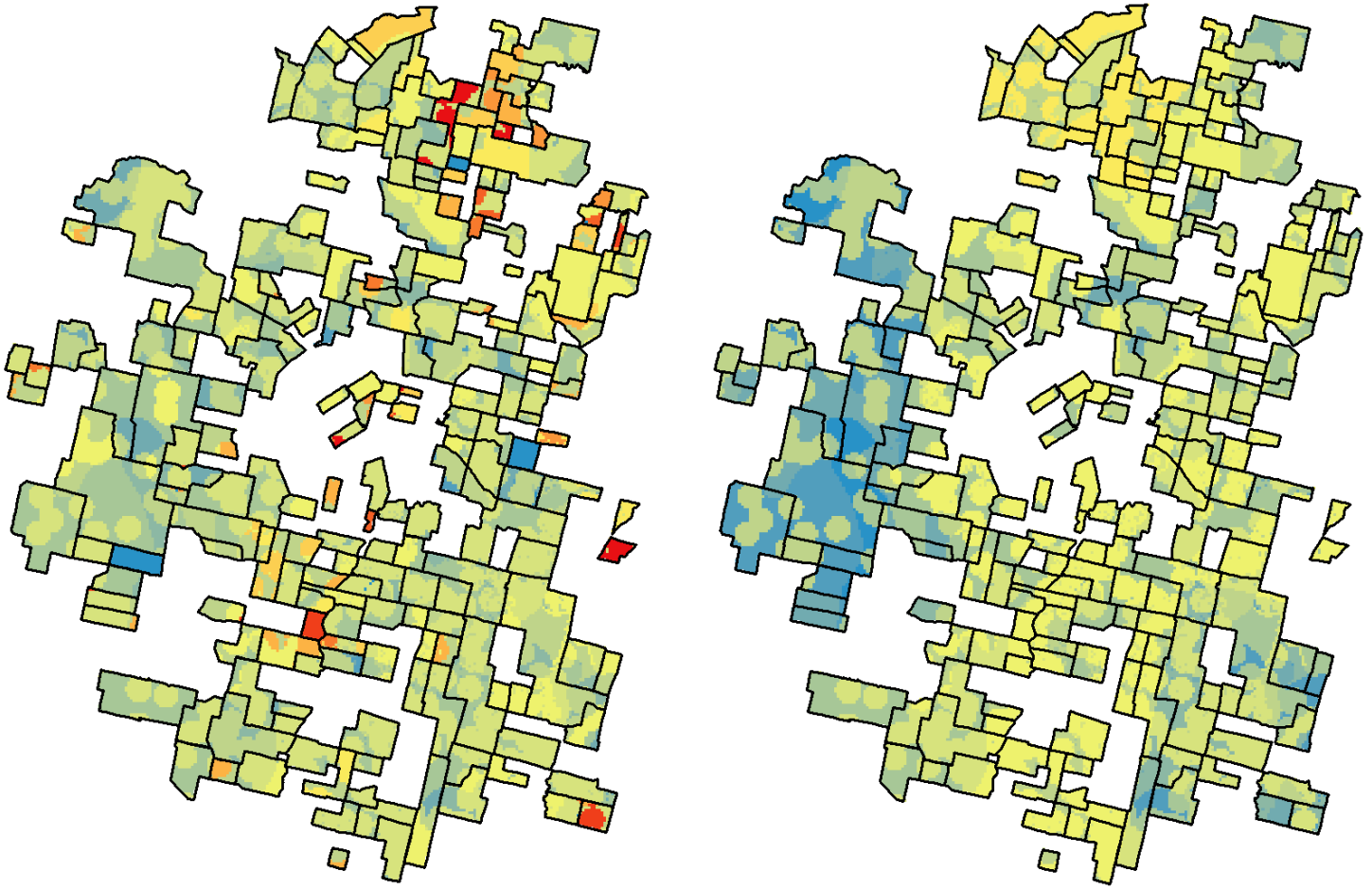
No data or 0 | 0-0.05 | 0.05-0.1 | 0.1-0.25 | 0.25-0.5 | 0.5-1 | 1-2 | 2-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | >40


1939
Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.74
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50

1940

Property Data Distribution

Australian Distribution

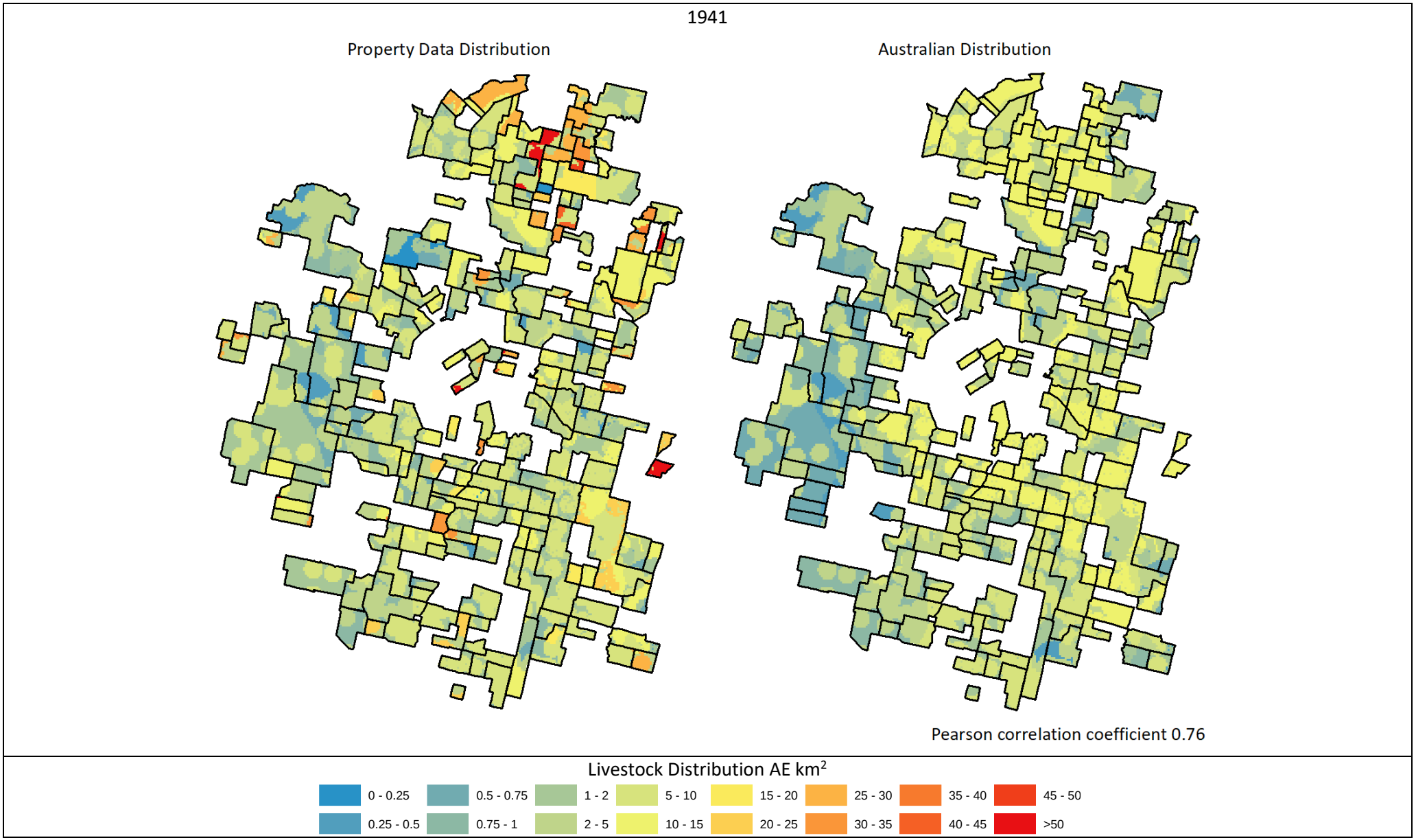


99

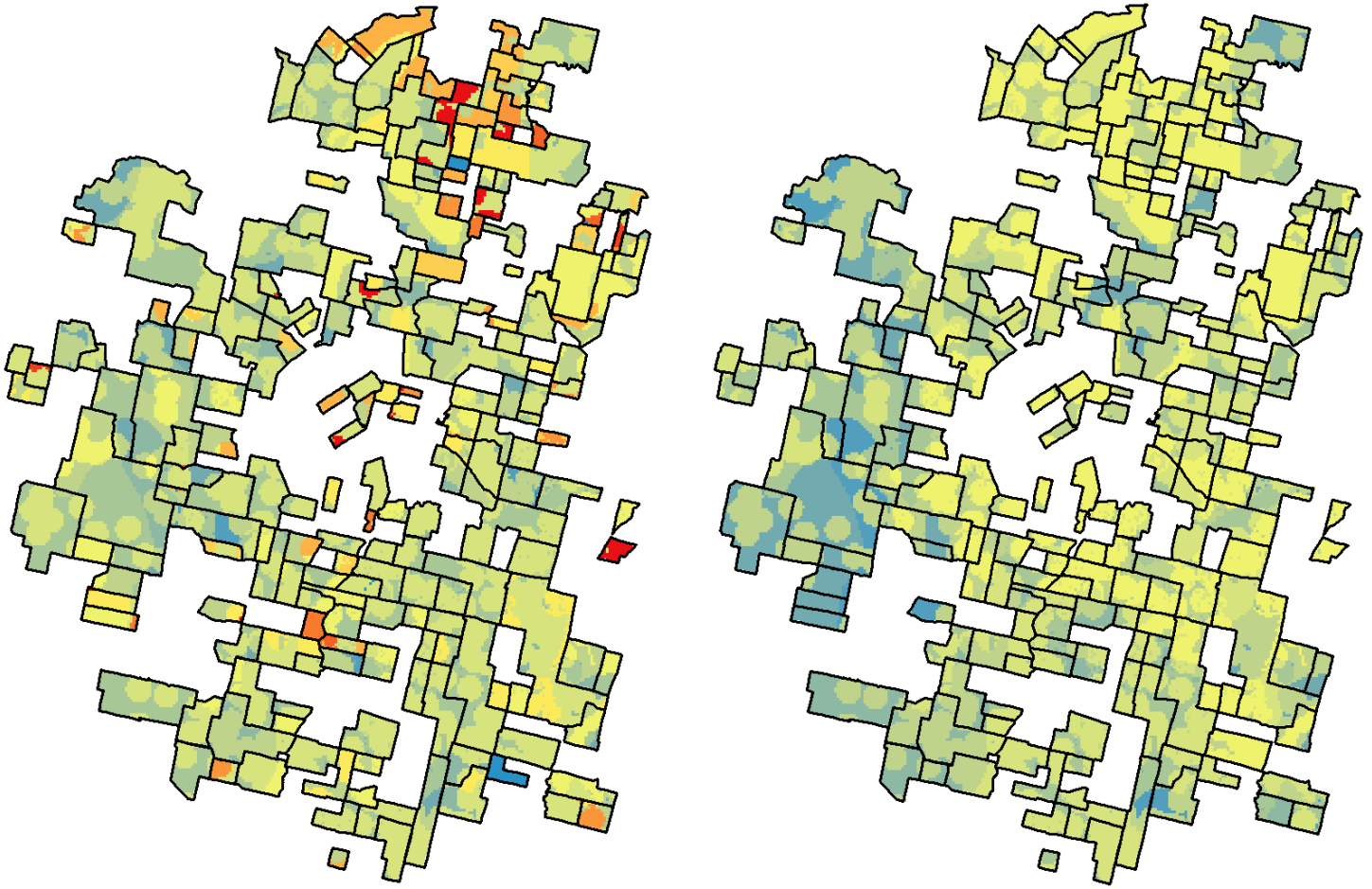
Pearson correlation coefficient 0.76

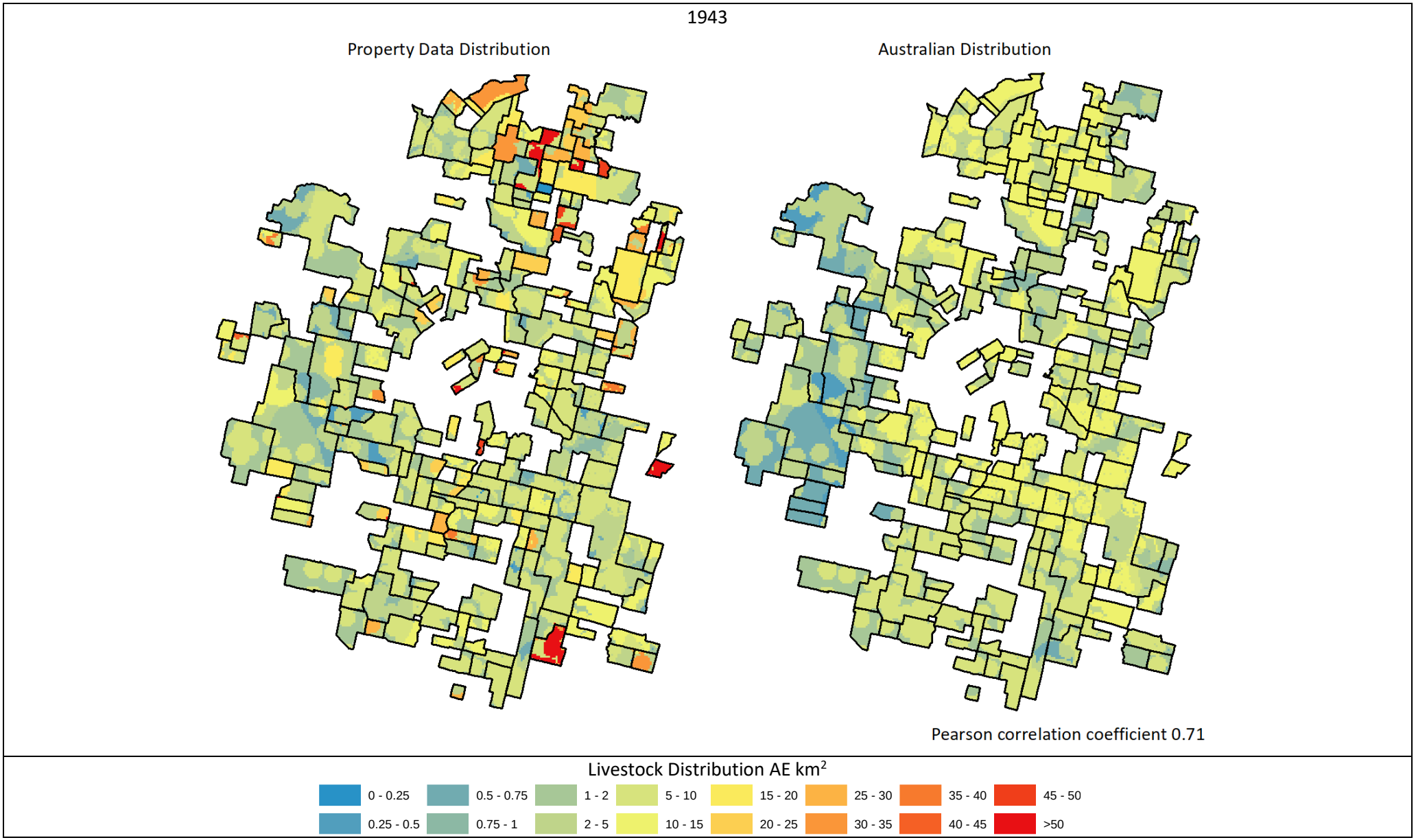
Livestock Distribution AE km^2

0 - 0.25	0.5 - 0.75	1 - 2	5 - 10	15 - 20	25 - 30	35 - 40	45 - 50
0.25 - 0.5	0.75 - 1	2 - 5	10 - 15	20 - 25	30 - 35	40 - 45	>50


1941
Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.76
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50

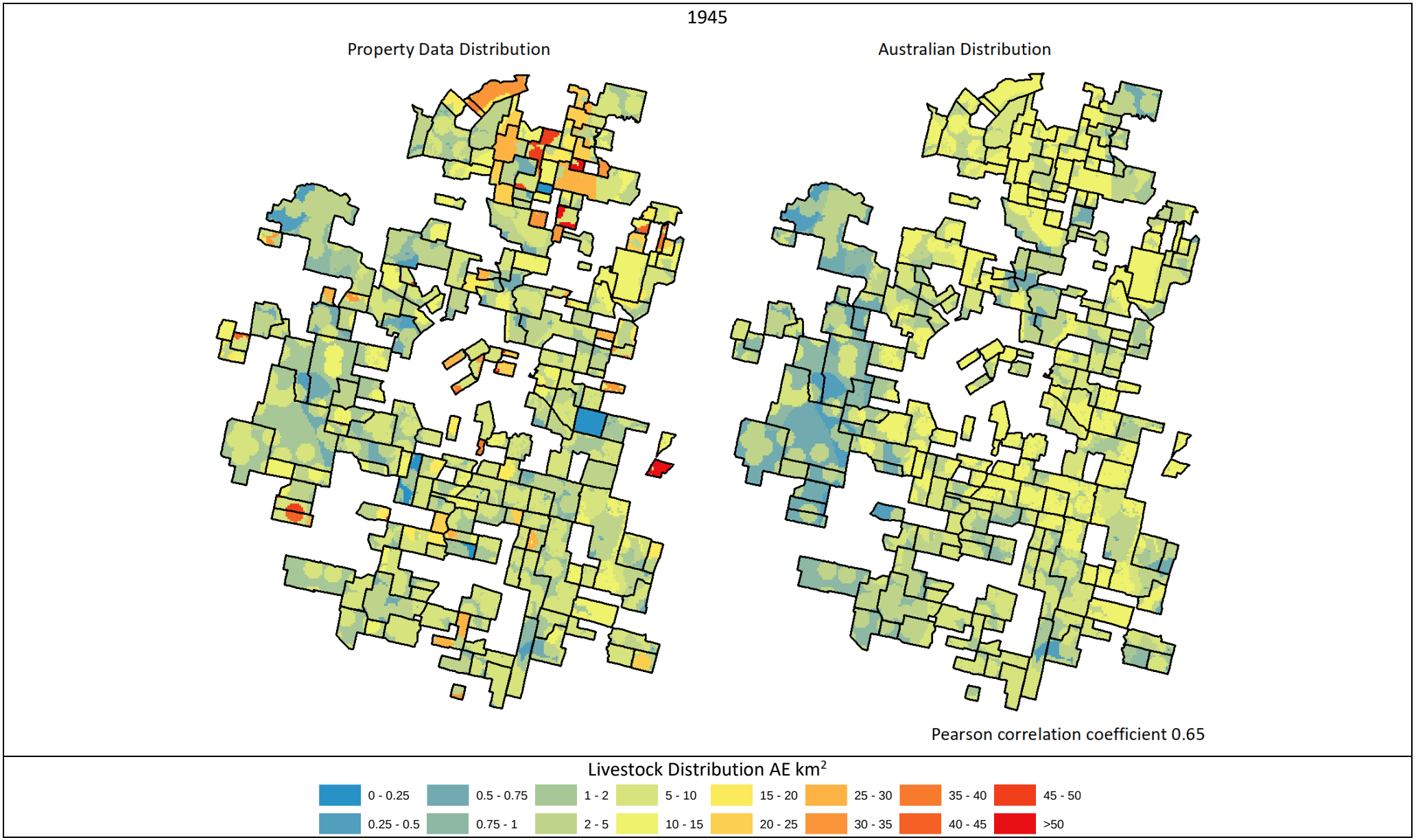
1942


Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.74
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50

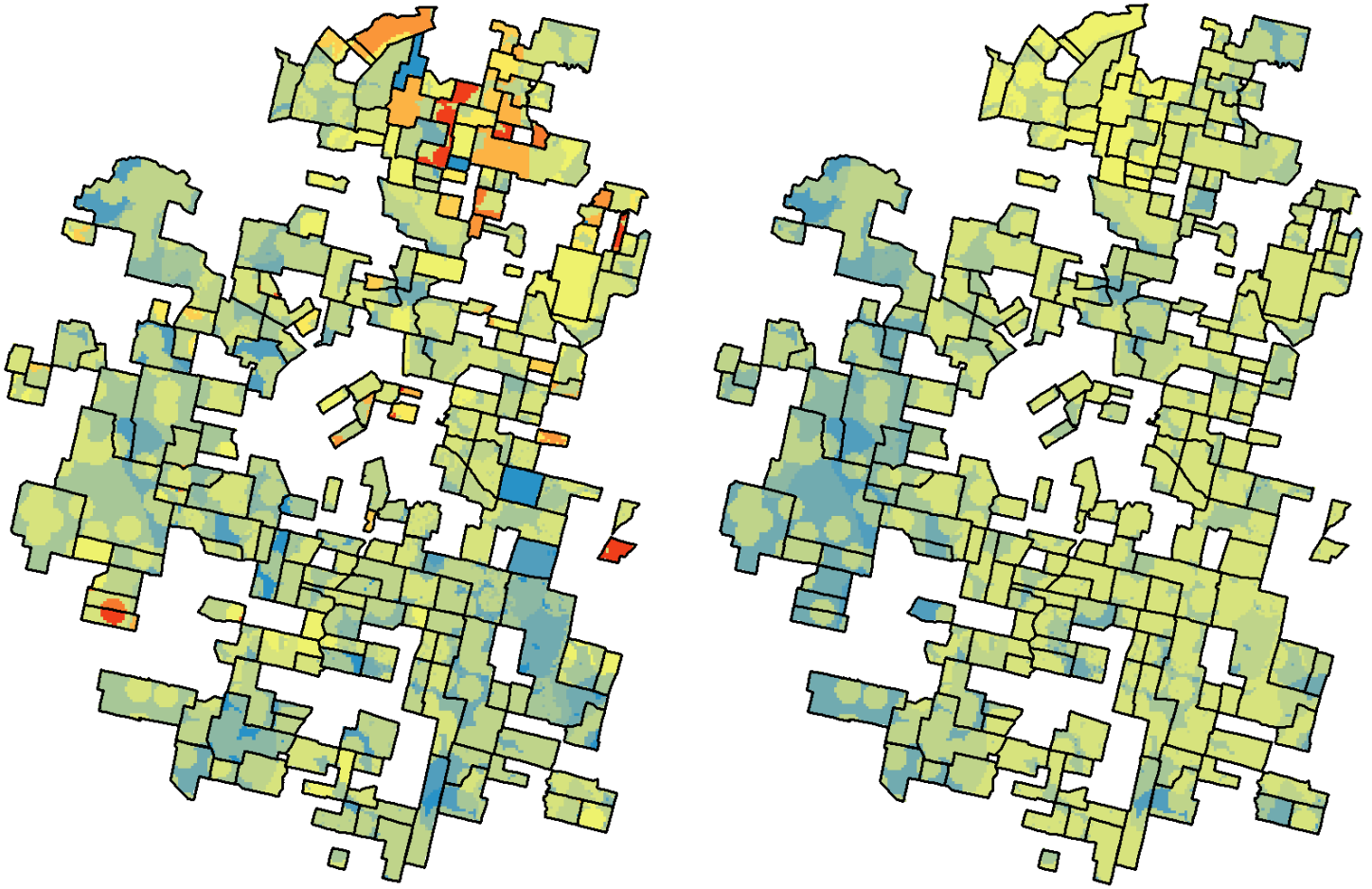

1943
Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.71
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50

1944

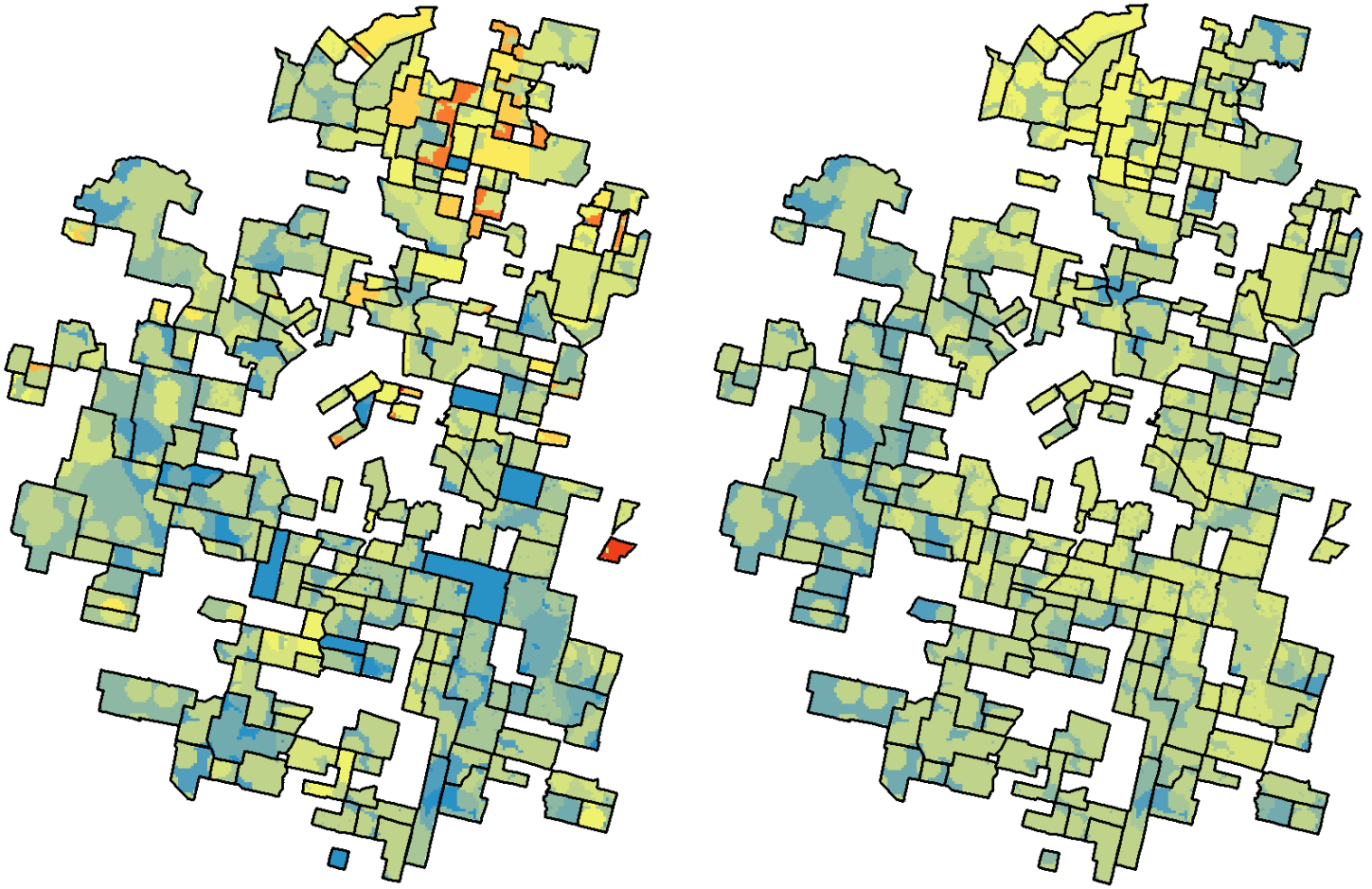

Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.63
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50


1945
Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.65
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50

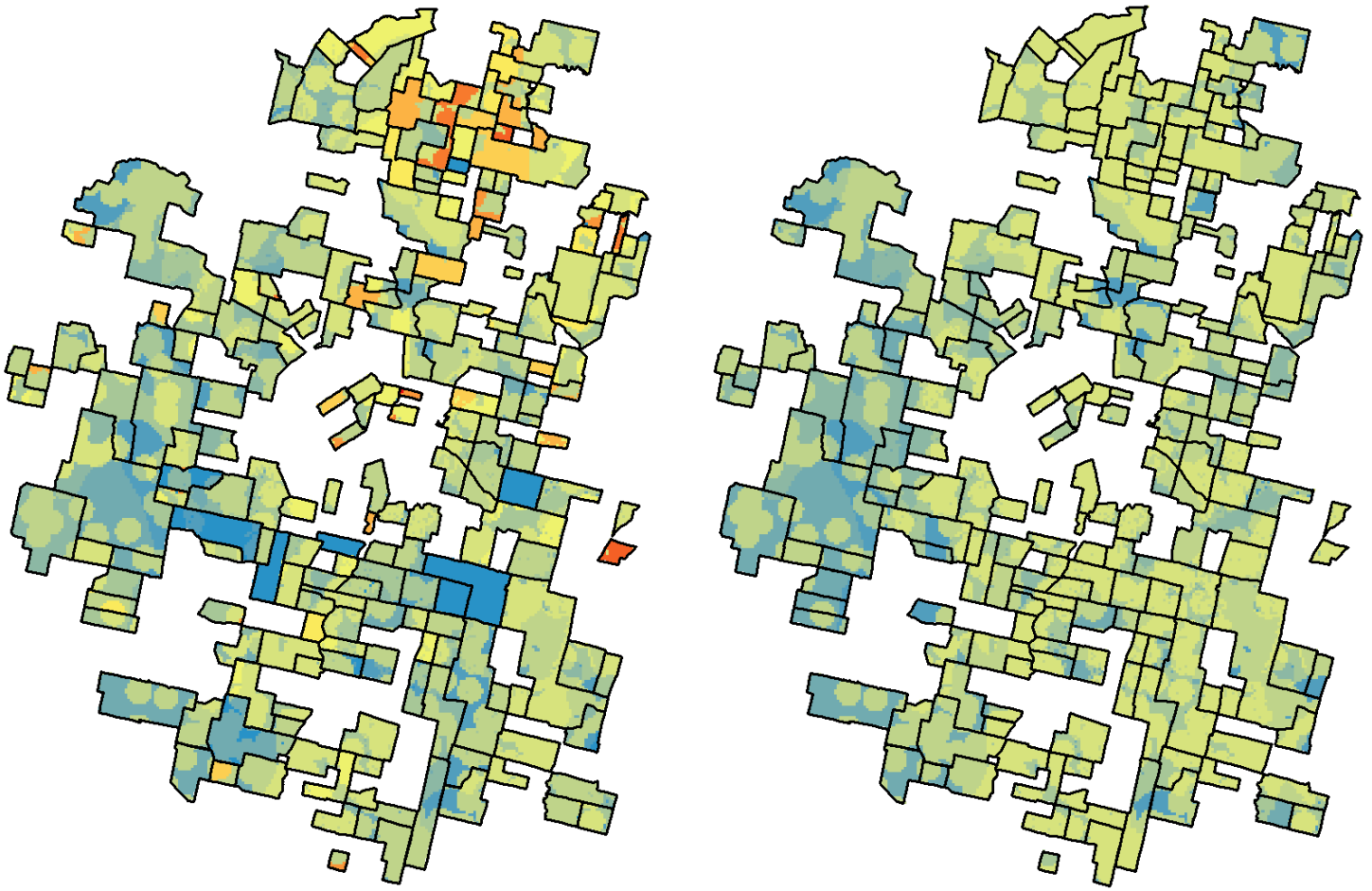
1946

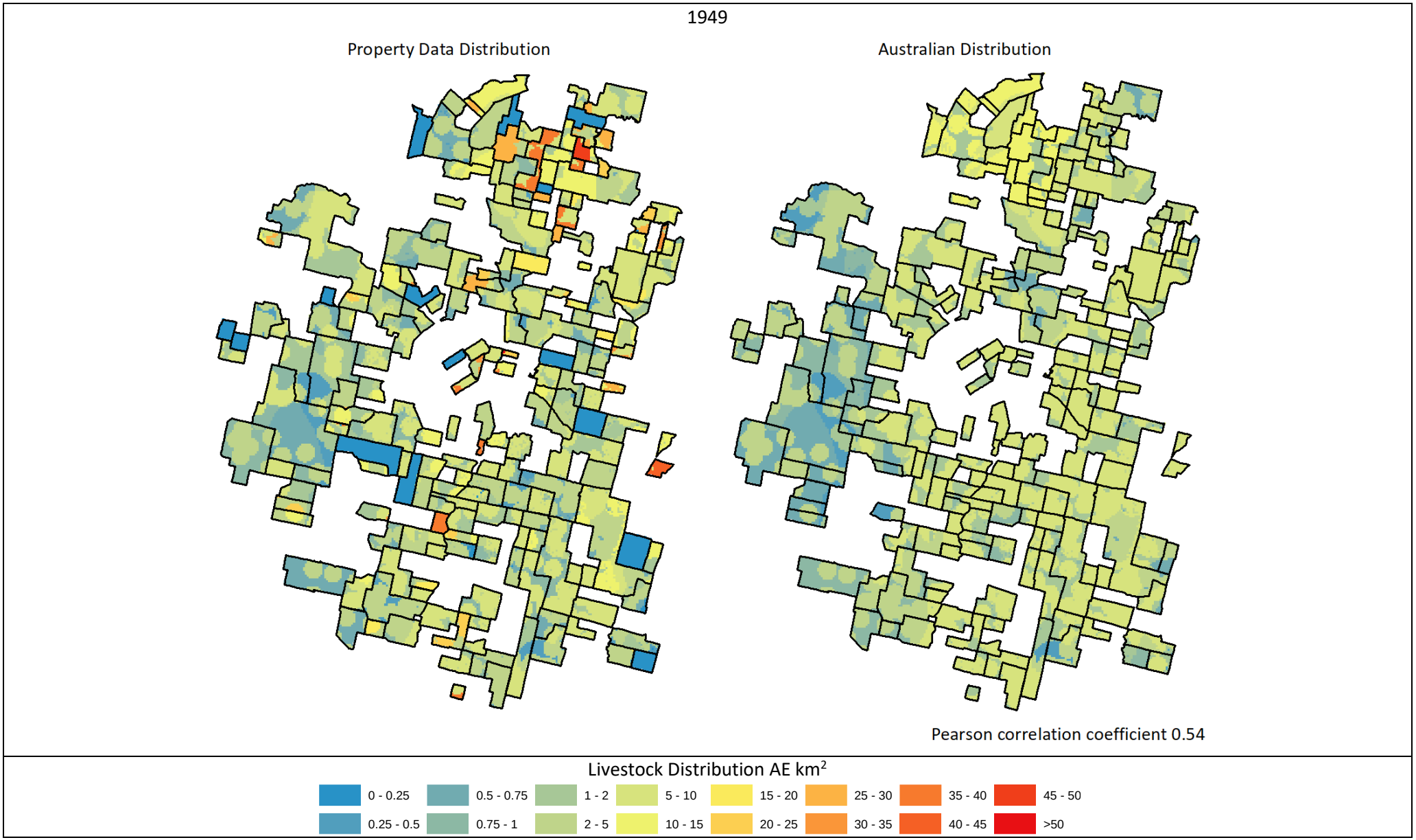

Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.54
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50

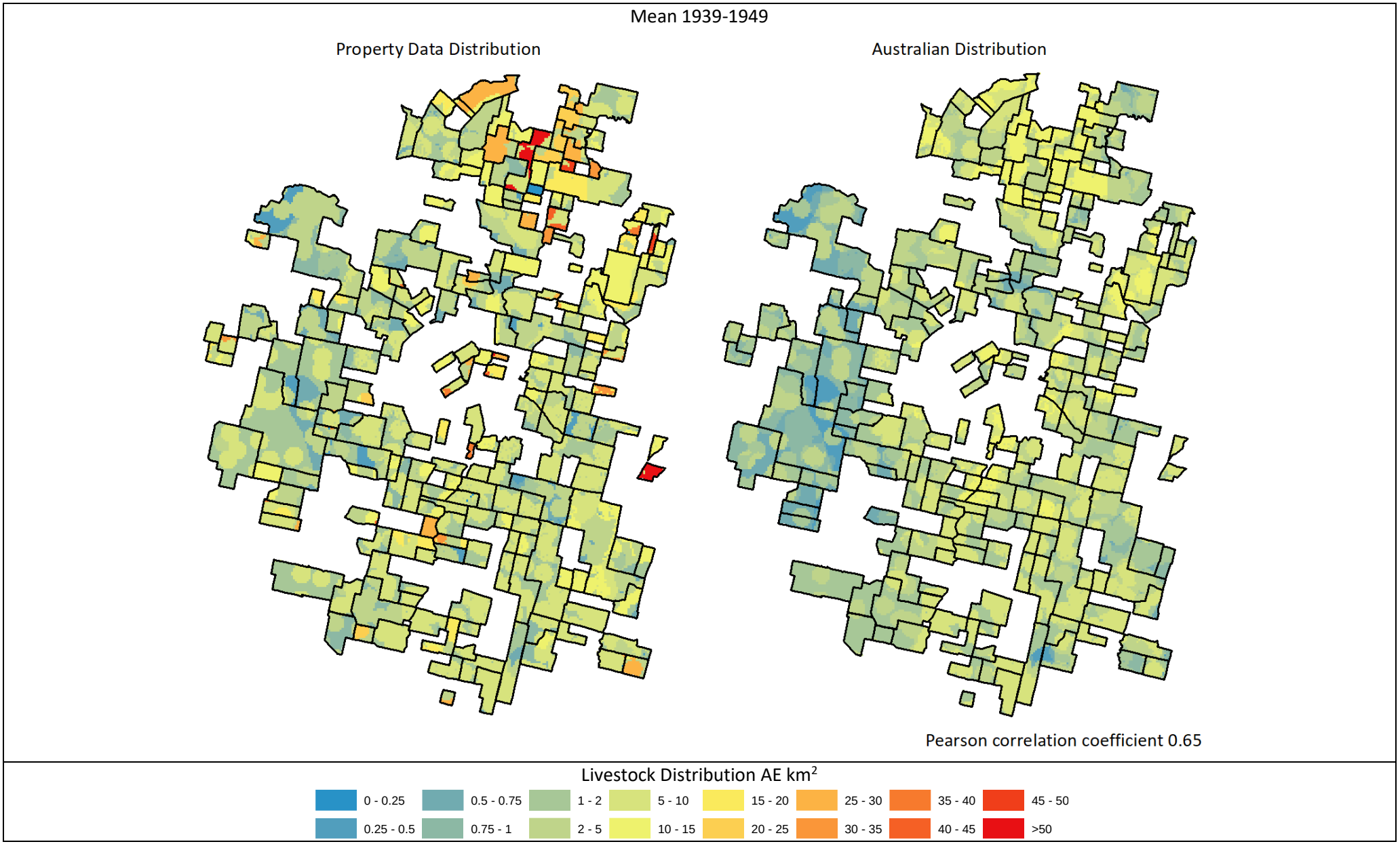
1947


Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.49
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50

1948


Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.47
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50


1949
Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.54
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50


Mean 1939-1949
Property Data Distribution
Australian Distribution
Pearson correlation coefficient 0.65
Livestock Distribution AE km²
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
>50