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Research paper

Associations between green space, and blue space and mental health outcomes in regional Australia: Cross-sectional and longitudinal analyses

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ABSTRACT

Objective: The aim of this study is to examine the relationships between green, blue, and green-blue space (GBS) with depression or anxiety in regional areas of Australia.
Methods: Cross-sectional and longitudinal analyses were conducted using data from Waves 17 and 21 of the HILDA Survey of Australian adults living in regional areas. Self-reported diagnosis of depression or anxiety was assessed at baseline (Wave 17) and follow-up (wave 21). Green space and GBS were quantified as land cover, and blue space as the presence of inland water in residential areas. Generalised estimating equation models assessed association of green space, blue and GBS with prevalent and incident depression or anxiety.
Results: Among, 5212 participants (mean age 49.12 ± 18.73) years; 53 % female) at baseline, 931 (17.86 %) reported depression or anxiety. The 4-year cumulative incidence of depression or anxiety was 8.03 %. No associations were observed between green space, blue space, or GBS and prevalent depression or anxiety. At follow-up, GBS coverage of ≥41 % was associated with a 37 % lower risk of incident depression or anxiety (OR = 0.63, 95 % CI: 0.42, 0.98). Gender-stratified analyses, blue space was protective for females at baseline (OR = 0.80, 95 % CI: 0.65, 0.98), while green space (OR = 0.35, 95 % CI: 0.15, 0.82) and GBS (OR = 0.32, 95 % CI: 0.14, 0.74) were proactive for males at follow-up.
Conclusion: GBS may reduce the risk of depression or anxiety in regional Australia adults. Blue space may reduce symptoms of depression or anxiety in females, while green space and GBS benefits males over time.

1. Introduction

Mental health disorders are major contributors to the global disease burden, affecting approximately 14 % of individuals across all age groups worldwide (Institute For Health Metrics and Evaluation, 2022; WHO, 2022). In 2021, these disorders accounted for 17.2 % of the total disability-adjusted life years (DALYs), a 55 % increase since 1990, with depression and anxiety disorders being the main contributors (GBD 2019 Mental Disorders Collaborators, 2022; Institute For Health Metrics and Evaluation, 2022; Javaid et al., 2023). In Australia, approximately 19 % of people reported having been diagnosed with depression, anxiety, or other severe mental illnesses in 2021, with an 8 % increase from 11 % in 2009 (Australian Institute of Health and Welfare, 2024). Moreover, the lifetime prevalence of mental disorders in Australian adults is 43 % (Australian Institute of Health and Welfare, 2024). This underscores the significant and growing burden of mental health conditions worldwide and within Australia.

A growing body of literature highlights the potential benefits of exposure to natural elements, such as green and blue spaces, on mental health and well-being (Georgiou et al., 2021; Zhang et al., 2021). Evidence suggests that access to neighbourhood green spaces may significantly reduce the risk of depression and anxiety (Liu et al., 2023). A review of experimental studies further indicated that walking in natural settings may alleviate symptoms of both depression and anxiety (Siah

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et al., 2023). Similarly, exposure to blue spaces, such as rivers, lakes, or coastlines, through viewing or visitation, has been associated with lower depressive symptoms in adults and older adults (Smith et al., 2021). Additionally, research in urban contexts indicates that green and blue spaces promote physical activity, enhance social cohesion, mitigate environmental stressors, and improve air quality, all of which may indirectly contribute to improved mental health and well-being (Georgiou et al., 2021; Markevych et al., 2017).

However, current evidence on the effects of green and blue spaces on mental health remains inconclusive (Garrett et al., 2023; Geary et al., 2023a; Geneshka et al., 2021; Liu et al., 2023). For example, a synthesis of longitudinal studies by Geneshka et al. (2021) found no consistent beneficial association between exposure to green or blue spaces and mental health outcomes (Geneshka et al., 2021). This review also noted a dearth of research on blue spaces, limiting definitive conclusions about their impacts. Although urban studies have demonstrated the beneficial effects of green and blue spaces (Lin et al., 2023; Mouly et al., 2023), there is a notable scarcity of research examining their relationship with mental health outcomes in regional settings. Extrapolating findings from metropolitan areas to regional contexts may be misleading because of differences in environmental exposure, such as air pollution, noise and heat (Browning et al., 2022) as well as social and demographic factors, including population density and access to services (Ambrey, 2016; Butterworth et al., 2024). Furthermore, urban green spaces are typically designed, built, and limited in availability (Veitch et al., 2013), whereas regional and rural areas are characterised by spaces with low developmental intensity and abundant natural features, including forests, reserves, blue spaces, and agricultural lands (Butterworth et al., 2024). These disparities highlight the need for context-specific research to elucidate the role of natural features in the residential environment on mental health.

The current study, therefore, addresses these gaps by investigating the associations between green space, blue space, and combined green-blue space (GBS) and depression or anxiety in regional Australia, using a subset of nationally representative data. By focusing on regional settings, this study seeks to determine whether these elements of the natural environment influence mental health outcomes in settings outside major urban areas.

2. Methods

2.1. Data sources and sample selection

This study used data from the Household, Income, and Labour Dynamics in Australia (HILDA) Survey waves 17–21, 2017–2021. The sample consisted of individuals 18 years and older and living in regional areas as of Wave 17 (2017), including the inner and outer regional, remote, and very remote areas defined by the Australian Statistical Geographic Standard (ASGS) 2016 Remoteness Structure (ABS, 2016). This structure classifies geographic remoteness across Australia into five categories based on access to services: major cities, inner regional, outer regional, remote, and very remote areas (ABS, 2016).

At baseline (wave 17), 23,442 individuals participated in the HILDA Survey, with green or blue space data available for $n = 23,437$. Data from participants without a self-completion questionnaire (SCQ) ($n = 7300$), those living in major cities ($n = 10,669$), and those aged under 18 years ($n = 253$) were excluded from the analysis. Additionally, participants with unknown depression or anxiety status ($n = 3$) were excluded. Thus, the analytical sample for the baseline analysis consisted of 5212 individuals. These individuals were then followed up in Wave 21 (2021) for incidence analyses.

For incidence analyses (i.e., that pertaining to a new onset of depression or anxiety after baseline), further exclusion criteria were applied: individuals with existing depression or anxiety at Wave 17 (2017), individuals with missing data on depression or anxiety at Wave 21 (2021), and those who had relocated and were living in major cities at Wave 21 (2021). This resulted in a final sample for the incidence analysis consisting of data from 3325 participants. (See Fig. 1).

2.2. Mental health outcomes

The outcomes of this study were the prevalence and incidence of self-reported physician−/nurse-diagnosed depression or anxiety. In both Wave 17 (2017) and Wave 21 (2021) of the HILDA Survey, participants were asked to report whether a doctor or nurse had diagnosed them with mental health conditions and whether these conditions were being managed by medications. Since Wave 9, the HILDA Survey has derived a single dichotomous variable (yes/no) for "depression or anxiety" from the responses to these items, which were updated at five-year intervals. In this study, the baseline prevalence of depression or anxiety was assessed at Wave 17, whereas the incidence was determined at Wave 21.

2.3. Exposure variables

In this study, three exposure variables: 1) green space, 2) blue space and 3) combined green-blue space (GBS) were derived from 2016 Mesh Blocks Data of the Australian Bureau of Statistics (ABS). Mesh Blocks are the smallest geographic units in the Australian Statistical Geographic Standard (ASGS) and are designed to represent a single dominant land use, such as residential, commercial, industrial, parkland, education, hospital/medical, transport, primary production, water, and other categories (ABS, 2016). The parkland category includes parks, natural reserves, public open spaces, and sports facilities, whereas the water category mainly includes inland water bodies such as lakes, rivers, and canals. Data on green and blue spaces were extracted and integrated with the HILDA Survey using the Statistical Areas Level 1 (SA1s) identifier. SA1s are geographic areas built from Mesh Blocks.

Green space quantity was measured as the percentage of land use designated as parkland within the Statistical Area Level 2 (SA2s) of participants' residence at Wave 17 (2017). SA2s are medium-sized, general-purpose geographic units built up from SA1s, which represent local communities, commercial hubs, or service centres with an average population of 10,000. Similarly, green-blue space (GBS) was quantified as the percentage of land use covered by a combination of parkland and water within the SA2s. For analysis, green space and GBS coverage were classified into five categories based on thresholds used in prior studies (Astell-Burt and Feng, 2019; Feng and Astell-Burt, 2018a, 2019): 1) 0–5 %,2) 6–10 %, 3) 11–20 %, 4) 21–40 %, and 5) ≥41 %. This classification is potentially policy-relevant and informed by urban planning practices, such as those in Perth, Western Australia, where 10 % of subdivisible land is allocated to public park and open space (Barnett, 2001). A higher percentage indicates higher green space or GBS coverage. Given that many SA2s have zero blue space cover, we adopted a binary category based approach used in the literature (Li et al., 2023; White et al., 2021) to capture the presence of inland blue space within SA2: no blue space (coded as 0) versus blue space present (>0, coded as 1).

2.4. Covariates

Potential confounding factors, including sociodemographic, lifestyle, and health-related factors, sleep duration and quality, and perceptions of neighbourhood environment, were selected based their availability and established associations with mental health outcome and green space, as documented in prior studies (Astell-Burt and Feng, 2019; Jamalishahni et al., 2023; Li et al., 2023; Zhang and Luo, 2024). Baseline sociodemographic factors (Wave 17, 2017) included gender (male/female), age (categorised as 18–34, 35–54, and ≥ 55 years), marital status (partnered/not partnered), highest education level completed (year 12 or below, Certificate/diploma, or university degree), employment status (employed/unemployed), region of residence or remoteness (inner regional, or outer regional and remote areas), household annual disposable income derived using the Organisation of Economic Co-

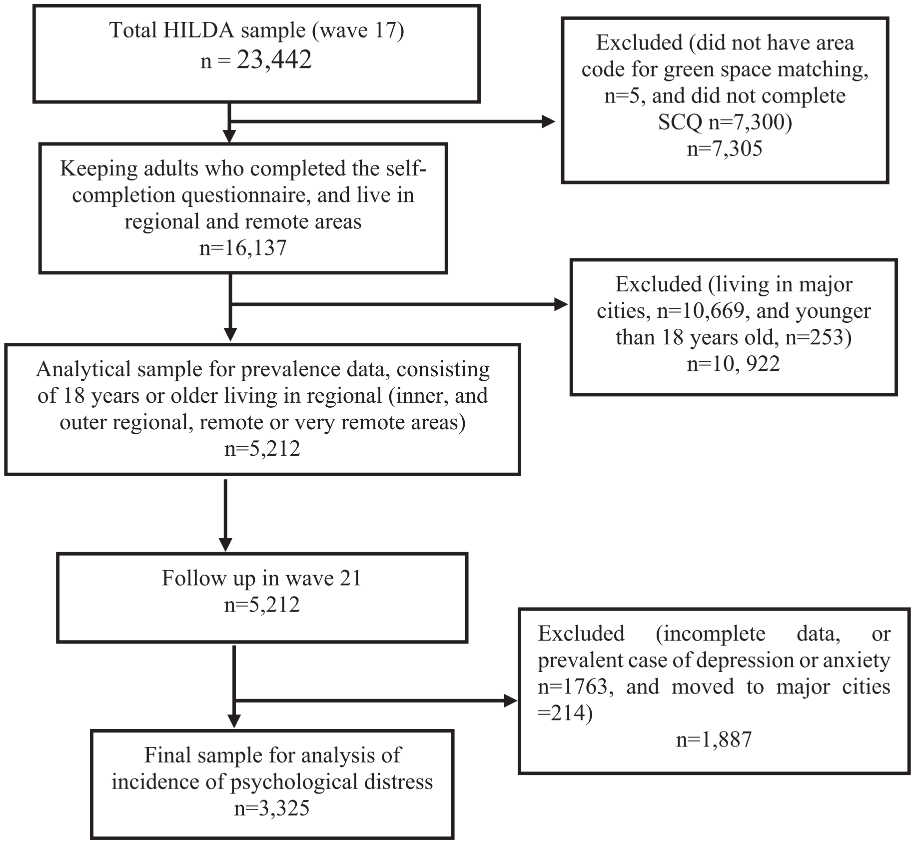

Fig. 1. Sample selection flow for prevalence and incidence analysis.

operation and Development (OECD) scale and categorised into quintiles (1–5, from poorest to richest), and neighbourhood socioeconomic disadvantage status, assessed using the 2011 Socio-Economic Indexes of Areas (SEIFA) Index of Relative Socio-economic Advantaged/Disadvantage (IRSAD), categorised into quintiles (quantile 1–5, from most to least disadvantaged).

Lifestyle factors included self-reported physical activity, assessed by the International Physical Activity Questionnaire and categorised as either not meeting guidelines or meeting guidelines for moderate-to-vigorous physical activity (MVPA) (Wooden, 2014), smoking cigarettes (no or yes), and alcohol consumption (no or yes). Health-related outcomes comprised body mass index (BMI) (underweight, healthy weight, overweight, or obese), and morbidity status, categorised as no morbidity, single morbidity, or multiple morbidity. Self-reported sleep duration per day was estimated from weekly sleep hours and categorised as short, recommended, or long, according to the National Sleep Foundation guidelines (Hirshkowitz et al., 2015). Sleep quality (good or poor) was assessed using the self-rated sleep quality, difficult sleep and sleep disturbances (Lallukka et al., 2018). Previous studies have demonstrated that sleep duration and quality are associated with both mental health outcomes and green space (Martin et al., 2024).

Perceptions of neighbourhood environment, including perceived social cohesion, noise disturbance, and poor physical conditions, have been shown to be associated with mental health (Shields et al., 2009). As the Wave 17 survey did not collect data on these factors, data from Wave 16 (2016) were used, consistent with previous research by Edmed et al. (2024). Perceived social cohesion was derived from two items: “neighbours help each other out” and “neighbourhood do things together.” Noise disturbance was assessed based on traffic noise and noise from aeroplanes, trains, and industry. Neighbourhood physical condition was assessed by using two items: “homes and gardens in bad condition” and “rubbish and litter lying around.” All items were measured on a 5-point scale (1 = never happens, 5 = very common). For each neighbourhood characteristic, the scores of the two items were summed and categorised into tertiles (tertile 1 (lowest), tertile 2 and tertile 3 (highest), following the approach of Echeverría et al. (2008). The highest tertile indicates greater social connection, the highest noise disturbance, and the worst neighbourhood physical conditions. Further details are provided in the Appendix (Table 1 and 2).

2.5. Data analysis

The characteristics of the study participants at baseline and follow-up were summarised using frequency distributions. We estimated the baseline prevalence of depression or anxiety and the 4-year cumulative incidence at follow-up (Wave 21, 2021), with corresponding 95 % (CI) confidence intervals. Bivariate analyses were performed using chi-square tests to examine the relationships between each of the exposure variables (green space, blue space, GBS) and potential confounding variables, and both prevalent and incident depression or anxiety.

We employed Generalised Estimating Equation (GEE) with a logistic link to analyse repeated or clustered data (Household), estimating population-average effects exposure variables on prevalent and incident depression or anxiety. The GEE approach account for withing-subject correlations and provides robust estimates of average effects across population (Wang, 2014). A series of Generalised Estimating Equation (GEE) models were fitted to assess the independent associations between green space, blue space, GBS, and both baseline and incident depression or anxiety. For baseline depression or anxiety, five models (models 0–4) examined the relationships between green and blue spaces, while five separate models (models 5–9) were fitted to assess the associations between GBS and depression or anxiety to mitigate potential multicollinearity (Supplementary Tables 1 and 2). Similarly, five models (models 10–14) assessed the associations between green and blue spaces

Table 1
Baseline characteristics and distribution of prevalent and incident depression or anxiety among study participants.

	Baseline (Wave 17 m 2017) (n = 5212)				Follow up (Wave 21, 2021) (n = 3325)		
		Prevalent depression or anxiety			Incident depression or anxiety		
Characteristics	Total, n (%)	Yes, n (%)	No, n (%)	*p*-value	Yes, n (%)	No, n (%)	p-value
Green and blue space coverage							
Green space							
0 %–5 %	1815 (34.82)	329 (35.34)	1486 (34.71)		98 (36.70)	1055 (34.50)	
6 %–10 %	782 (15.00)	141 (15.15)	641 (14.97)		37 (13.86)	472 (15.43)	
11 %–20 %	787 (15.10)	138 (14.82)	649 (15.16)	0.995	42 (15.73)	479 (15.66)	0.312
21 %–40 %	1064 (20.41)	188 (20.19)	876 (20.46)		61 (22.85)	598 (19.56)	
41 % or more	764 (14.66)	135 (14.50)	629 (14.69)		29 (10.86)	454 (14.85)	
Blue space							
Yes	2168 (41.60)	366 (39.31)	1802 (42.09)	0.119	109 (40.82)	1328 (43.43)	0.410
No	3044 (58.40)	565 (60.69)	2479 (57.91)		158 (59.18)	1730 (56.57)	
GBS							
0 %–5 %	1675 (32.14)	302 (32.44)	1373 (32.07)		91 (34.08)	983 (32.15)	
6 %–10 %	762 (14.62)	142 (15.25)	620 (14.48)		35 (13.11)	448 (14.65)	
11 %–20 %	825 (15.83)	142 (15.25)	683 (15.95)	0.961	46 (17.23)	499 (16.32)	0.252
21 %–40 %	1155 (22.16)	204 (21.91)	951 (22.21)		66 (24.72)	657 (21.48)	
41 % or more	795 (15.25)	141 (15.15)	654 (15.28)		29 (10.86)	471 (15.40)	
Sociodemographic characteristics							
Age, year							
Mean (sd)	49.12 (18.73)	46.57 (17.77)	49.68 (18.89)	0.000	–	–	–
18–34	1457 (27.95)	291 (31.26)	1166 (27.24)	0.001	93 (34.83)	748 (24.46)	
35–54	1601 (30.72)	306 (32.87)	1295 (30.25)		93 (34.83)	940 (30.74)	0.000
55 and older	2154 (41.33)	334 (35.88)	1882 (42.51)		81 (30.34)	1370 (44.40)	
Gender							
Male	2430 (46.62)	322 (34.59)	2108 (49.24)	0.000	108 (40.45)	1503 (49.15)	0.006
Female	2782 (53.38)	609 (65.41)	2173 (50.76)		159 (59.55)	1555 (50.85)	
Marital status							
Not partnered	1651 (31.68)	420 (45.11)	1231 (28.75)	0.000	92 (34.46)	789 (25.80)	0.002
Partnered	3561 (68.32)	511 (54.89)	3050 (71.25)		175 (65.54)	2269 (74.20)	
Dependent under 15							
Yes	1493 (28.65)	275 (29.54)	1218 (81.58)	0.506	95 (35.58)	885 (28.94)	0.022
No	3719 (71.35)	656 (70.46)	3063 (82.36)		172 (64.42)	2173 (71.06)	
Highest education level							
Year 12 or below	2297 (44.07)	475 (51.02)	1822 (42.56)		108 (40.45)	1245 (40.71)	
Certificate/diploma	1978 (37.95)	344 (36.95)	1634 (38.17)	0.000	115 (43.07)	1180 (38.59)	0.181
University degree	937 (17.98)	112 (12.03)	825 (19.27)		44 (16.48)	633 (20.70)	
Employment status							
Employed	3044 (58.40)	394 (42.32)	2650 (61.90)	0.000	167 (62.55)	1933 (63.21)	0.829
Unemployed	2168 (41.60)	537 (57.68)	1631 (38.10)		100 (37.45)	1125 (36.79)	
Annual income (quintile)							
5 (highest)	1.042 (19.99)	113 (12.14)	929 (21.70)		42 (15.73)	623 (20.37)	
4	1042 (19.99)	134 (14.39)	908 (21.21)		42 (15.73)	623 (20.37)	0.046
3	1043 (20.01)	159 (17.08)	884 (21.65)	0.000	65 (24.34)	600 (19.62)	
2	1042 (19.99)	259 (27.39)	787 (18.38)		62 (23.22)	603 (19.72)	
1(lowest)	1043 (20.01)	270 (29.00)	773 (18.06)		56 (20.97)	609 (19.91)	
SEIFA (quintile)							
5 (highest)	1042 (19.99)	124 (13.32)	918 (21.44)		41 (15.36)	624 (20.41)	
4	1042 (19.99)	172 (18.47)	870 (20.32)	0.000	52 (19.48)	613 (20.05)	0.111
3	1043 (20.01)	179 (19.23)	864 (20.18)		63 (23.60)	602 (19.69)	
2	1041 (19.97)	185 (19.87)	856 (20.00)		48 (17.98)	617 (20.18)	
1 (lowest)	1044 (20.03)	271 (29.11)	773 (18.06)		63 (23.60)	602 (19.69)	
Remoteness							
Inner regional	3453 (66.25)	664 (71.32)	2789 (65.15)		177 (66.29)	2040 (66.71)	
Outer and remote areas	1759 (33.75)	267 (28.68)	1492 (34.85)	0.000	90 (33.71)	1018 (33.29)	0.889
Lifestyle factors							
Physical activity							
Insufficient	1668 (32.00)	393 (42.21)	1275 (29.78)		89 (33.33)	864 28.25)	
MVPA	3486 (66.88)	528 (56.71)	2958 (69.10)	0.000	177 (66.29)	2159 (70.60)	0.122
missing	58 (1.11)	10 (1.07)	48 (1.12)		1 (0.37)	35 (1.14)	
Smoking status							
Smoker	1085 (20.82)	304 (32.65)	781 (18.24)	0.000	66 (24.72)	503 (16.45)	0.003
Non-smoker	4056 (77.82)	616 (66.17)	3440 (80.36)		198 (74.16)	2523 (82.50)	
Missing	71 (1.36)	11 (1.18)	60 (1.40)		3 (1.12)	32 (1.05)	
Alcohol consumption							
Non-drinker	959 (18.40)	217 (23.31)	742 (17.33)		44 (16.48)	508 (16.61)	
Drinker	4176 (80.12)	702 (75.40)	3474 (81.15)	0.000	219 (82.02)	2510 (82.08)	0.966
Missing	77 (1.48)	12 (1.29)	65 (1.52)		4 (1.50)	40 (1.31)	

(*continued on next page*)

Table 1 (*continued*)

	Baseline (Wave 17 m 2017) (n = 5212)				Follow up (Wave 21, 2021) (n = 3325)		
Sleep duration and quality							
Sleep duration							
Short	1578 (30.28)	364 (39.10)	1214 (28.36)		104 (38.95)	853 (27.89)	
Recommended	3303 (63.37)	487 (52.31)	2812 (65.78)	0.000	152 (56.93)	2047 (66.94)	0.001
Long	298 (5.72)	78 (8.38)	220 (5.14)		8 (3.00)	140 (4.58)	
Missing	33 (0.63)	2 (0.21)	31 (0.72)		3 (1.12)	18 (0.59)	
Sleep quality							
Poor	1209 (23.20)	357 (38.35)	852 (19.90)		95 (35.58)	567 (18.54)	
Good	3940 (75.59)	561 (60.26)	3379 (78.93)	0.000	171 (64.04)	2463 (80.54)	0.000
Missing	63 (1.21)	13 (1.40)	50 (1.17)		1 (0.37)	28 (0.92)	
Health-related factors							
Body mass index (BMI)							
Underweight	89 (1.71)	24 (2.58)	65 (1.52)		5 (1.87)	42 (1.37)	
Healthy weight	1571 (30.14)	241 (25.89)	1330 (31.07)	0.000	83 (31.09)	922 (30.15)	0.224
Overweight	1763 (33.83)	236 (25.35)	1527 (35.67)		80 (29.96)	1121 (36.66)	
Obese	1550 (29.74)	369 (39.63)	1181 (27.59)		89 (33.33)	870 (28.45)	
Missing	239 (4.59)	61 (6.55)	178 (4.16)		10 (0.75)	103 (3.37)	
Morbidity							
No morbidity	2786 (53.45)	339 (36.41)	2447 (57.16)		139 (52.06)	1764 (57.68)	
One condition	1385 (26.57)	284 (30.50)	1101 (25.72)	0.000	69 (25.84)	799 (26.13)	0.039
Multiple conditions	1041 (19.97)	308 (33.08)	733 (17.12)		59 (22.10)	495 (16.19)	
Perceptions of neighbourhood environment							
Social cohesion (tertile)							
1 (Lowest)	1682 (32.27)	357 (38.35)	1325 (30.95)		99 (37.08)	941 (30.77)	
2	1688 (32.39)	252 (27.07)	1436 (33.54)	0.000	78 (29.21)	1068 (34.92)	0.020
3 (Highest)	910 (17.46)	115 (12.35)	795 (18.57)		41 (15.36)	598 (19.56)	
Missing	932 (17.88)	207 (22.23)	725 (16.94)		49 (18.35)	451 (14.75)	
Neighbourhood noise							
1 (Lowest)	1976 (37.91)	290 (31.15)	1686 (39.38)		91 (34.08)	1261 (41.24)	
2	1729 (33.17)	292 (31.36)	1437 (33.57)	0.000	88 (32.96)	1040 (34.01)	0.010
3 (Highest)	1026 (19.69)	220 (23.63)	806 (18.83)		61 (22.85)	567 (18.54)	
Missing	481 (9.23)	129 (13.86)	352 (8.22)		27 (10.11)	190 (6.21)	
Physical condition							
1 (Lowest)	1914 (36.72)	306 (32.87)	1608 (37.56)		77 (28.84)	1182 (38.65)	
2	2125 (40.77)	341 (36.63)	1784 (41.67)		114 (42.70)	1307 (42.74)	0.000
3 (Highest)	611 (11.72)	138 (14.82)	473 (11.05)	0.000	45 (16.85)	332 (10.96)	
Missing	562 (10.78)	146 (15.68)	416 (9.72)		31 (11.61)	237 (7.75)	

Note: SEIFA: Socio-Economic Index of Area.

and the incidence of depression or anxiety, and five models (models 15–19) evaluated the association of GBS with the incidence of depression or anxiety (Supplementary Tables 3 and 4). We also conducted sex-stratified analyses assess if there are differences in the effects of green space, blue space and GBS on prevalent and incident depression or anxiety. Furthermore, for green space and GBS, p-trend was estimated using median value of each category to evaluate dose-response trends. All multivariable analyses included baseline covariates, and results were reported as odds ratios (OR) with 95 % confidence intervals (CIs), and statistical significance set at $p < 0.05$. All analyses were conducted using Stata 17.

Missing data on covariates were imputed using multiple imputations by the chained equation (MICE). The imputations were performed using Stata's "mi impute chained" command, which involved a sequence of univariate imputations with conditional specification of the prediction models. Each variable with missing values was imputed based on the observed values of other variables in the dataset (Azur et al., 2011). The imputation consisted of 20 iterations to create 20 imputed datasets. The imputed datasets were validated by comparing the distributions of covariates before and after the imputation. The quality of the imputations was further assessed using relative increases in variance, fraction of missing information, degrees of freedom, relative efficiency, and between-imputation and within-imputation variances. Additionally, we conducted regression analyses for both the complete-case and the imputed data to compared results. All regression analysis results presented in this study are based on imputed data.

3. Results

3.1. Sample characteristics

A total of 5212 participants nested in 696 SA2 areas were included at baseline. The mean age was 49.12 years (SD = 18.73), with 41 % (*n* = 2154) aged 55 years or older. More than half (53 %) of the participants were female, 68 % were partnered, 44 % had completed year 12 or lower, 58 % were employed, and 66 % lived in inner regional areas. Approximately 35 % lived in areas with 0–5 % green space coverage, and 15 % in areas with ≥41 % coverage. Additionally, 42 % of participants lived in areas with blue spaces. About 32 % of participants lived in areas with 0–5 % GBS cover, and 15 % lived in areas with ≥41 % GBS coverage (Table 1).

3.2. Prevalence of depression or anxiety

At baseline (wave 17, 2017), of the 5212 participants included, 931 reported a diagnosis of depression or anxiety, resulting in an overall prevalence of 17.61 % (95 % CI: 16.83, 18.93). Table 1 present the distribution of depression or anxiety with respect participants baseline characteristic. Participants with depression or anxiety were more likely to female and older age group (≥55 years). Highest prevalence (35.3 %) was observed in areas with 0–5 % green space cover with lowest in areas with ≥41 % cover. Higher prevalence (60.7 %) among participant who lived in areas with no blue spaces. For GBs cover, prevalence was highest (32.4 %) in areas with 0–5 % coverage and the lowest (14.6) in areas with ≥41 % cover. Bivariate analyses showed no statistically significant associations between green space, blue space or GBS and baseline depression or anxiety (Table 1).

3.3. Incidence of depression or anxiety

Of the 3325 participants followed, 267 new cases of depression or anxiety occurred between 2017 and 2021, resulting in a 4-years cumulative incidence of 8.03 % (955 CI: 7.13, 9.00). Incidence of was notably higher in female and younger participants. The highest incidence (36.7 %) was observed in areas with minimal green space coverage (0–5 %), while the lowest (10.9 %) occurred in areas with ≥41 % coverage. However, bivariate analysis indicates no statistically significant association between green space and incidence depression or anxiety ($p < 0.412$). The incidence was higher among participants who lived in areas with no blue space (59.25), but blue space was not association with incidence depression or anxiety (0.252). For GBS, the highest incidence (32.2 %) was observed in areas with 0–5 % cover, and the lowest (14.7 %) in areas with 6–10 % cover. No association was observed between GBS and incident depression or anxiety ($p < 0.252$) (Table 1).

3.4. Association between green space, blue space and GBS with baseline depression and anxiety

Table 2a shows the association between green space, blue space and depression or anxiety at baseline (Wave 17, 2017). No statistically significant associations were observed between green space exposure and depression or anxiety across the crude, partially adjusted, or fully adjusted models. Additionally, no clear patterns of green space effects on depression or anxiety were evident across these all models (p-trend>0.05). The relationship between blue space and depression or anxiety was in the expected direction, although none of these associations reached statistical significance. (Table 2a and Supplementary Tables 1).

Table 2b presents association between GBS and baseline depression or anxiety at baseline (Wave 17, 2017). No significant association was observed between GBS and depression or anxiety across all models (Models 5–9), with no clear patterns of effects (p-trend>0.05). Table 2b and Supplementary Table 2).

3.5. Association between green spaces, blue space and GBS with the incidence of depression or anxiety

Table 3a shows the results of the generalised estimating equation models (Model 10–14) examining the associations between green space, blue space and incident depression or anxiety at follow up (Wave 17, 2021). No association was found between green space and incident depression or anxiety, with no clear patterns of effect (all p-trend>0.05). Odds of incident depression or anxiety were consistently and lightly lower for blue space across all models, though none reached statistical significance level. (Table 3a and Supplementary Table 3).

Table 3b shows association between GBS and incidence of repression or anxiety (Wave 21, 2021). The analyses revealed that GBS has a protective effect against incident depression or anxiety. Compared to 0–5 %, GBS cover of 41 % or more was associated with a 36 % lower incidence of depression or anxiety in the fully adjusted model (OR = 0.64, 95 % CI: 0.42, 0.99). Odds ratios show statistically non-significant protective effects of GBS cover of 6–10 %, 11–20 %, and 41 % in all models, however no clear patterns of effect observed (p-trend >0.05).

3.6. Associations between green space, blue space and GBS and prevalent and incident depression or anxiety stratified by gender

Table 4 presents the results of fully adjusted model of stratified analyses by gender examining associations between green space, blue space, and green-blue space (GBS) and prevalent and incident depression or anxiety. In men (n = 2430), no significant associations were observed between green space, blue space, or GBS and prevalent depression or anxiety at baseline. At follow-up (n = 1611), green space coverage ≥41 % was associated with lower odds of incident depression or anxiety in men (OR = 0.35, 95 % CI: 0.15–0.82), as was GBS coverage of 6–10 % (OR = 0.46, 95 % CI: 0.21–0.97) and ≥ 41 % (OR = 0.32, 95 % CI: 0.14–0.74). In women (n = 2782), blue space exposure at baseline was associated with lower odds of prevalent depression or anxiety (OR = 0.80, 95 % CI: 0.65–0.98); no significant associations were observed for green space or GBS. Similarly, at follow-up (n = 1714), no significant associations were found between green space, blue space, or GBS and incident depression or anxiety in women. (Table 4).

4. Discussion

This study examined the cross-sectional and longitudinal associations between green, blue, and green-blue space (GBS) and depression or anxiety in regional Australian populations. Our findings showed that the

Table 2a
association between green space, blue space and baseline repression or anxiety (Wave 17, 2017) (n = 5212).

Exposure	Model 0		Model 1		Model 2		Model 3		Model 4	
	OR (95 % CI)	p-trend	OR (95 % CI)	p-trend	OR (95 % CI)	p-trend	OR (95 % CI)	p-trend	OR (95 % CI)	p-trend
Green space										
0–5 %	Ref.		Ref.		Ref.		Ref.		Ref.	
6–10 %	1.02 (0.81, 1.28)	1.00	1.02 (0.81, 1.29)	0.861	0.99 (0.78, 1.25)	0.518	0.96 (0.76, 1.22)		0.95 (0.74, 1.22)	
11–20 %	0.97 (0.76, 1.24)		0.97 (0.76, 1.25)		1.01 (0.79,1.28)		0.97 (0.75, 1.24)	0.280	0.94 (0.73, 1.21)	0.298
21–40 %	0.99 (0.80, 1.23)		1.01 (0.81, 1.25)		1.05 (0.84,1.29)		1.04 (0.83, 1.29)		0.99 (0.79, 1.25)	
41 + %	1.00 (0.79, 1.27)		1.02 (0.81, 1.30)		1.06 (0.83,1.35)		1.12 (0.88, 1.43)		1.13 (0.88, 1.45)	
Blue space										
No	Ref.	na	Ref.	na	Ref.	na	Ref.		Ref.	
Yes	0.89 (0.76, 1.05)		0.91 (0.77, 1.06)		0.94 (0.80, 1.11)		0.90 (0.76, 1.06)	na	0.89 (0.75, 1.05)	na

Note: na: not applicable, OR = Odds ratio; CI, confidence interval; Ref. =reference category,
Model 0: depression or anxiety + green space and blue space.
Model 1: Adjusted for age and sex.
Model 2: Adjusted for age, sex physical activity, and social connection.
Model 3: Adjusted for age, sex physical activity, and social connection, marital status, under 15 dependents, education level, employment status, income, SEIFA, and remoteness.
Model 4 (Fully Adjusted): Adjusted for age, sex physical activity, and social connection, marital status, under 15 dependents, education level, employment status, income, SEIFA, and remoteness, smoking status, alcohol consumption, sleep duration, BMI, comorbidity, neighbourhood noise, and physical condition.

Table 2b
Association between green-blue space (GBS) and baseline repression or anxiety (Wave 17, 2017) ($n = 5212$).

	Mode 5		Mode 6		Mode 7		Mode 8		Mode 9	
	OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend
GBS										
0–5 %	Ref.		Ref.		Ref.		Ref.		Ref.	
6–10 %	1.06 (0.84, 1.34)		1.05 (0.83, 1.34)		1.05 (0.83, 1.33)		1.03 (0.81, 1.31)		1.03 (0.81, 1.32)	
11–20 %	0.95 (0.75, 1.22)	0.867	0.95 (0.74, 1.22)	0.964	0.98 (0.76,1.25)	0.533	0.93 (0.73, 1.20)	0.418	0.90 (0.70, 1.17)	0.453
21–40 %	0.99 (0.81, 1.22)		1.01 (0.81, 1.25)		1.05 (0.85,1.30)		1.02 (0.82, 1.27)		0.98 (0.78, 1.22)	
41 + %	0.99 (0.79, 1.26)		1.01 (0.80, 1.28)		1.07 (0.84,1.36)		1.10 (0.86, 1.41)		1.11 (0.87, 1.42)	

Note: OR = Odds ratio; CI, confidence interval; Ref. =reference category,
Model 5: depression or anxiety + green-blue space (GBS).
Model 6: Adjusted for age and sex.
Model 7: Adjusted for age, sex physical activity, and social connection.
Model 8: Adjusted for age, sex physical activity, and social connection, marital status, under 15 dependents, education level, employment status, income, SEIFA, and remoteness.
Model 9 (Fully Adjusted): Adjusted for age, sex physical activity, and social connection, marital status, under 15 dependents, education level, employment status, income, SEIFA, and remoteness, smoking status, alcohol consumption, sleep duration, BMI, comorbidity, neighbourhood noise, and physical condition.

Table 3a
Association between green space, blue space and incidence of repression or anxiety (Wave 21, 2021) ($n = 3325$).

Exposure	Model 10		Model 11		Model 12		Model 13		Model 14	
	OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend
Green space										
0–5 %	Ref.		Ref.		Ref.		Ref.		Ref.	
6–10 %	0.86 (0.57, 1.29)		0.87 (0.58, 1.31)		0.86 (0.57, 1.29)		0.83 (0.55, 1.25)		0.77 (0.51, 1.18)	
11–20 %	0.95 (0.64, 1.40)	0.313	0.97 (0.66, 1.44)	0.384	0.99 (0.67,1.46)	0.447	0.97 (0.65, 1.44)	0.344	0.91 (0.61, 1.36)	0.227
21–40 %	1.11 (0.78, 1.57)		1.14 (0.80, 1.61)		1.16 (0.82,1.64)		1.11 (0.77, 1.58)		1.06 (0.73, 1.52)	
41 + %	0.71 (0.46, 1.10)		0.73 (0.47, 1.13)		0.74 (0.47,1.14)		0.71 (0.46, 1.11)		0.66 (0.42, 1.03)	
Blue space										
No	Ref.	na	Ref.	na	Ref.	na	Ref.	na	Ref.	na
Yes	0.92 (0.70, 1.20)		0.96 (0.73, 1.25)		0.98 (0.75, 1.28)		0.97 (0.74, 1.27)		0.95 (0.72, 1.25)	

Note: na: not applicable OR = Odds Ratio; CI: Confidence Interval; Ref. =Reference category,
Model 10: depression or anxiety + green space and blue space.
Model 11: Adjusted for age and sex.
Model 12: Adjusted for age, sex, physical activity and social connection.
Model 13: Adjusted for age, sex, physical activity and social connection, marital status, under 15 dependents, education level, employment status, income, SEIFA, and remoteness.
Model 14 (Full adjusted): Adjusted for age, sex, physical activity and social connection, marital status, under 15 dependents, education level, employment status, income, SEIFA, and remoteness, smoking status, alcohol consumption, sleep duration, BMI, comorbidity, neighbourhood noise, and physical condition.

Table 3b
Association between green space, blue space and incidence of repression or anxiety (Wave 21, 2021) ($n = 3325$).

	Mode 15		Mode 16		Mode 17		Mode 18		Mode 19	
	OR (95 % CI)	p-trend	OR (95 % CI)	p-trend	OR (95 % CI)	p-trend	OR (95 % CI)	p-trend	OR (95 % CI)	p-trend
GBS										
0–5 %	Ref.		Ref.		Ref.		Ref.		Ref.	
6–10 %	0.86 (0.57, 1.31)		0.87 (0.57, 1.32)		0.86 (0.56, 1.30)		0.82 (0.54, 1.25)		0.78 (0.51, 1.20)	0.150
11–20 %	0.99 (0.68, 1.46)	0.181	1.01 (0.69, 1.48)	0.262	1.03 (0.70, 1.51)	0.333	1.00 (0.68, 1.48)	0.243	0.93 (0.62, 1.37)	
21–40 %	1.09 (0.77, 1.53)		1.13 (0.80, 1.60)		1.16 (0.82, 1.64)		1.11 (0.78, 1.58)		1.05 (0.73, 1.50)	
41 + %	0.68 (0.44, 1.05)		0.70 (0.45, 1.09)		0.71 (0.46, 1.11)		0.69 (0.44, 1.07)		**0.64 (0.41, 0.99)***	

Note: OR = Odds ratio; CI, confidence interval; Ref. =reference category, * $p < 0.05$.
Model 15: Unadjusted model.
Model 16: Adjusted for age and sex.
Model 17: Adjusted for age, sex, physical activity, and social connection.
Model 18: Adjusted for age, sex, physical activity, social connection, marital status, highest education level, current labour status, income, SEIFA.
Model 19 (Fully Adjusted): Adjusted for age, sex, physical activity, social connection, marital status, highest education level, current labour status, income, SEIFA, Remoteness, smoking status, alcohol consumption, sleep duration, BMI, comorbidity, noise, and physical condition.

prevalence of depression or anxiety was not associated with green space, blue space, GBS, and baseline depression or anxiety. Similarly, neither green space nor the presence of blue space was associated with the incidence of depression or anxiety. However, GBS coverage of 41 % or higher was significantly associated with a lower incidence of depression or anxiety. In sex-stratified analyses, blue space exhibited a protective effect against prevalent depression or anxiety in females, whereas both green space and GBS were strongly associated with lower odds of incident depression or anxiety in males.

In unstratified analyses, we observed no associated between green space and prevalent or incident depression or anxiety. These findings are consistent with an urban Australian study by Astell-Burt and Feng (2019), which reported no association between green space (total, tree, grass, and low-lying vegetation) and prevalent or incident depression or

Table 4
Stratified analyses of association between green space, blue space, and GBS and prevalent and incident depression or anxiety by gender.

Gender	Exposure	Categories	Depression or anxiety			
			Prevalence		Incidence	
			OR (95 % CI)	*p*-trend	OR (95 % CI)	*p*-trend
Male	Green space	0–5 %	Ref.		Ref.	
		6–10 %	1.10 (0.75, 1.62)		0.52 (0.25, 1.08)	
		11–20 %	0.84 (0.56,1.27)	0.532	1.03 (0.57,1.84)	0.532
		21–40 %	0.90 (0.62, 1.31)		1.16 (0.67, 2.02)	
		≥41 %	1.19 (0.82, 1.75)		0.35 (0.15, 0.82)*	
	Blue space	No	Ref.		Ref.	
		Yes	1.06 (0.82, 1.38)	na	0.92 (0.52, 1.43)	na
	GBS	0–5 %	Ref.		Ref.	
		6–10 %	1.13 (0.77, 1.66)		0.46 (0.21, 0.97)*	
		11–20 %	0.85 (0.57, 1.29)	0.274	1.00 (0.56, 1.78)	0.274
		21–40 %	0.90 (0.63, 1.30)		1.03 (0.59, 1.79)	
		≥41 %	1.30 (0.89, 1.90)		0.32 (0.14, 0.74)**	
Female	Green space	0–5 %	Ref.		Ref.	
		6–10 %	0.90 (0.66, 1.24)		0.94 (0.56, 1.58)	
		11–20 %	1.04 (0.77, 0.41)	0.317	0.78 (0.45, 1.34)	0.317
		21–40 %	1.06 (0.81, 1.40)		0.95 (0.58, 1.53)	
		≥41 + %	1.13 (0.83, 1.54)		0.83 (0.49, 1.42)	
	Blue space	No	Ref.		Ref.	
		Yes	0.80 (0.65, 0.98)*	na	0.98 (0.70, 1.39)	na
	GBS	0–5 %	Ref.		Ref.	
		6–10 %	0.99 (0.72, 1.36)		1.02 (0.61, 1.72)	
		11–20 %	0.95 (0.70, 1.30)		0.82 (0.48, 1.40)	0.750
		21–40 %	1.03 (0.79, 1.36)	0.750	1.04 (0.65, 1.67)	
		≥41 %	1.03 (0.76, 1.41)		0.84 (0.49, 1.45)	

Note: na: not applicable, $P < 0.05$, *$P < 0.005$; CI = confidence interval; *P*-trend = p-value for trend; Ref = reference category.

anxiety. Similar results have been observed in studies from other countries, including the United States (Bustamante et al., 2022; Werder et al., 2024), the United Kindom (Sarkar et al., 2018), the Netherlands (Generaal et al., 2019), Belgium (Aerts et al., 2022) and Japan (Nishigaki et al., 2020), which found no association between green space cover or greenness (measured by NDVI or EVI) and prevalent or incident depression, anxiety, or the need for mood disorder medications in adults or older adults. In contrast, previous studies in Australian cities have shown that greater of residential green space, higher visit frequency, and longer visit duration are associated with lower levels of depression or anxiety (Lin et al., 2023; Mouly et al., 2023). Similarly, a cohort study in China (Di et al., 2020) and ecological studies in the United State (Ryan et al., 2024, 2023) suggest that higher green space is linked to a reduce risk of depression and anxiety in rural settings. The observed discrepancies may arise from unmeasured factors, such as green space quality, distance, or usage patterns, which could have obscured potential benefits (Nguyen et al., 2021). Moreover, effects of green space may not be easily detected using current methodologies, relatively short follow-up period or, equally, other mental health determinants, such as demographic and socioeconomic factors may have greater power.

Blue space exposure showed a consistent but non-significant protective effects against both baseline and incident depression or anxiety. This finding mirror studies from Australia (Murrin et al., 2023), England (Garrett et al., 2019), and Ireland (Dempsey et al., 2018), where proximity to coastal or inland waters showed no significant mental health benefits. A multi-country study by White et al. (2021) further supports our findings, reporting no association between inland blue spaces and the use of anti-depression or anxiety medication use. In contrast, Garrett et al. (2019) found that greater freshwater coverage associated with lower depression or anxiety, and Liu et al. (2024) found higher blue space cover associated with a lower incidence of anxiety. The inconsistency in the relationships between blue space and mental health suggests that the effects of blue space may depend on factors such as types (e.g., coastal vs inland), quality, and measures used to assess blue space exposure, as well as the scale used to measure mental health outcomes. The lack of statistically significant association in this study may be stemmed from limited variability in blue space exposure, as dichotomised categories (present or absent) do not differentiate between smaller and large water bodies, which might have diluted effects in regional Australia. Additionally, in our study, blue space exposure was determined in a relatively larger geographic unity, statistical Areas Level 2 (SA2s), which may be coarse and not reflect individual access or use patterns.

Greater green-blue space (GBS) was significantly associated with a reduced incidence of depression or anxiety, but it showed no effect on baseline depression or anxiety. Similarly, a cohort study by Liu et al. (2024) found that increased access to natural environments (GBS) within a 1000-m buffer around residential locations associated with lower incidence of common mental disorders. This association might be attributed to synergistic restorative effects of green space and blue space, both of which are key elements of natura environmental (Liu et al., 2022). Natural environments are known to mitigate chronic stress and mental fatigue while replenishing directed attention (Kaplan, 1995; Ulrich et al., 1991). Additionally, beneficial effects of GBS may be derived from frequent recreational visits, and potentially through increased physical activity and social interaction (White et al., 2021). In contrast, Garrett et al. (2023) found no association between GBS proximity and mental well-being, while Geary et al. (2023a, 2023b) reported increased odds of seeking treatment for common mental disorders in rural areas with greater GBS access. These discrepancies may arise from variations in GBS exposure metrics, mental health outcome definitions, or population characteristics (Frumkin et al., 2017). For example, Geary et al. (2023a, 2023b) used general practice records and a distance-based GBS accessibility index, ulike coverage-based metrics used in our study. Our findings suggest that GBS is a promising environmental feature for preventing depression or anxiety. However, further research is needed to elucidate the effects GBS exposure on mental health outcomes across diverse settings, refine measurements scale to optimize GBS as a mental health resource (Labib et al., 2020). It is also important to understand how people with existing depression or anxiety might use these space for recover (Geary et al., 2023b).

Consistent with previous research in Australia (Astell-Burt et al., 2014) and elsewhere (Bahriny and Bell, 2020; Dadvand et al., 2019;

Toutakhane, 2020), our finding indicate a protective effect of green space against incident repression or anxiety at follow-up in men, but no in women, suggesting a sex-specific effect. This disparity may be attributed to differences in how men and women engage green spaces. For example, men are more likely to use green space for physical activity, leveraging features such as sport facilities that promote exercise (Rivera et al., 2021). In contrast, neighbourhood factors, including safety concerns and poor maintenance of green space may have reduced women's use of green spaces, limiting their potential health benefits (Aliyas, 2020; Koohsari et al., 2013). However, findings systematic reviews by Sillman et al. (2022) and Núñez et al. (Fernández Núñez et al., 2022) suggest that green spaces may improve general health and reduce depressive symptoms and psychological distress in women, although findings across studies are consistent. The observed discrepancy may be attributed to differences in study populations, settings, indicators of green space (accessibility, quality, or type), and the specific mental health outcomes assessed, underscoring the need for further investigation to understand sex-specific effects of green space.

Blue space, such as freshwater and coastal environment, are recognised for their therapeutic benefits in promoting mental health (Pasanen et al., 2019). However, research on their impacts, particularly regarding sex difference, remains limited (Zhang et al., 2025). Stratified analysis in this study revealed blue space exposure at baseline was associated with a lower odds of depression or anxiety in women but not in men at baseline. This sex-specific effect may be attributed to restorative properties of bleus spaces, promote calmness more significantly in women, as men may require greater exposure to achieve comparable health benefits (Zhang et al., 2025). Women's greater susceptibility to negative emotion and affective disorder (Yuan et al., 2009) may enhance their responsiveness to these environment. Additionally, women's leisure activities, such as walking or socialising, may enhance restorative quality of blue spaces compared to men, who often engage in physical activity (Elliott et al., 2018; White et al., 2020). Although the current study suggests effects blue space may not be uniform across sexes, further researcher in needed to elucidate sex-specific responses and geographic contexts.

Growing body of evidence suggests exposure to green-blue space (GBS) is greater associated with mental health and well-being (Garrett et al., 2023; Geary et al., 2023a). Although evidence on sex-specific disparity in effect of GBS is limited, our analyses revealed that GBS coverage of 6–10 % and $\geq$ 41 % was associated with lower incidence of depression or anxiety in males, with higher coverage ($\geq$41 %) conferring stronger protective effects. In contrast, no such association as observed in females. The beneficial effects of GBS on mental health may be attributed mechanisms shared with green or blue spaces, such as stress reduction and psychological restoration, physical activity and social cohesion (Georgiou et al., 2021; Zhang et al., 2021). However, sex-specific differences may be attributed to GBS quality features, including facilities, lighting, and perceived safety, which influence use and activities, particularly for female (Henderson-Wilson et al., 2017; Kelly et al., 2022; Veitch et al., 2022). Further research is needed to clarify these sex-specific effects and to explore whether similar patterns emerge across diverse geographic and cultural contexts.

This study has several strengths that enhance its contribution to the field. First, provides comprehensive assessment of natural environment, including green spaces, blue spaces, and their combined effects (GBS), on depression or anxiety. Second, bey employing both cross-sectional and longitudinal analyses, we assessed both the snapshot and long-term effects of green spaces, blue space and GBS in an understudied setting, regional areas of Australia. However, limitations of this study must be acknowledged. The under-representation of remote and very remote areas in our nationally representative data may limit the generalisability. Additionally, green space, blue space, and GBS exposure metrics estimated at the SA2 level, a relatively large geographic unit, may tempered the observed relationships, potentially contributing to the statistically non-significant findings in some analyses (Feng and Astell-Burt, 2018b). Furthermore, the short follow-up duration may have limited ability to detect smaller effect sizes for green space and blue spaces.

5. Conclusion

In conclusion, this cross-sectional and longitudinal study investigated the relationship between elements of natural environment and mental health in regional Australia. While green and blue space individually showed no significant association with the prevalent or incident depression or anxiety, GBS significantly linked to a reduced incidence of depression or anxiety. These findings suggest that combined green and blue spaces may play a preventive role in mental health, potentially through synergistic environmental effects, although they do not appear to influence the baseline mental health. The blue space may reduce existing depression or anxiety in females, whereas green space and GBS may prevent new onset of depression or anxiety in males. As urbanization continues to reshape our environment, these insights highlight the potential value of integrated green and blue spaces in promoting mental health resilience. Future research should prioritise longitudinal studies with refined measures of GBS exposure, including proximity, quality, and usage patterns, to better clarify its preventive potential across diverse regional settings. For policymakers and urban planners in regional areas, preserving or enhancing natural environment may serve as a strategy to support mental health.

CRediT authorship contribution statement

Hirbo Shore Roba: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tracy Kolbe-Alexander:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Dolly Baliunas:** Writing – review & editing, Methodology, Formal analysis. **Stuart J.H. Biddle:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Ethical approval

This study received an ethical exemption from the Human Research Ethical Committee of the University of Southern Queensland (UniSQ), Queensland, Australia, as it used de-identified unit record from the HILDA survey. The HILDA Survey was approved by the Human Research Ethics Committee of the University of Melbourne in February 2025 (Ethics ID: 31363). Authors completed and signed the Confidentiality Deed Poll before data access approval. Therefore, datasets analysed and/or generated during this study are subject to the signed confidentiality deed.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2025.119685.

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