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Marine and Freshwater Research

Supplementary Material

Sedimentation from landscape clearance-induced soil erosion threatens waterhole persistence in a semi-arid river system, southern Queensland, Australia

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Table S1. Locations and dimensions of the fifteen largest waterholes in the Moonie River system

Site number	Site name	Latitude	Longitude	Average width (m)	Length (m)	Volume (m^3)	Surface area (m^2)	Max. depth at cease-to-flow (m)	Persistence (days until empty)
4172022	Moonie river at Kurmala	–27.78753	149.95719	29.3	5996	223818	148614	4.8	826
4172017	Moonie river at Verena	–27.89481	149.55989	23.8	724	15463	13849	2.8	508
4172018	Moonie river at Kooroon waterhole	–27.95667	149.38264	24.4	2630	88004	53863	4.7	798
4172021	Moonie river at Altonvale	–27.97181	149.27575	12.2	410	3802	4569	3.3	422
4172016	Moonie river waterhole 1 at Warrie	–28.08964	148.99386	20.7	873	21040	17352	2.9	606
4172020	Moonie river waterhole 2 at Warrie	–28.09329	148.98672	26.4	1592	48596	38574	3.1	525
4172019	Moonie river at Carbeen Waterhole	–28.17589	148.93589	22.1	829	13416	15980	3.6	622
4172009	Moonie river at Kurrajong	–28.25881	148.87289	22.1	588	8997	10757	2.1	349
4172010	Moonie river at Appletree	–28.32331	148.84650	28.0	3829	151807	92486	3.9	591
417201A	Moonie river at Nindi pub	–28.35731	148.81725	28.1	2746	74493	63098	3.6	563
417201B	Moonie river at Nindigully	–28.42883	148.81739	28.5	629	12863	16145	2	345
4172008	Moonie river at Bullamon Plains Regulator	–28.57331	148.83750	37.6	8673	182447	265853	2.5	460
4172011	Moonie river at Broadwater	–28.62681	148.85081	36.2	2321	83594	62872	3.3	609
4172002	Moonie river at Nullera	–28.64565	148.85809	53.5	2303	111419	67945	4.2	742
417204A	Moonie river at Fenton	–28.93458	148.73814	30.6	1554	47380	41865	3.1	528

Table S2. Radiometric dating results.

Site (and date cored)	Sample depth	Material dated	^{14}C years BP or percentage modern	$^{13}C/^{12}C$	Two sigma age range (and probability) years BP	Minimum sedimentation rate
Kooroon (2008 core)	127–128 cm	Bark	107.6 ± 0.4%		1957.94–1958.49 (0.127) **2003.08–2003.28 (0.014)** 2003.57–2006.37 (0.858) 2006.78–2006.79 (0.001)	25 cm year^{-1}
Kooroon (2008 core)	202–203 cm	Leaf and twig	114.9 ± 0.4%		**1959.43–1959.59 (0.045)** 1990.32–1993.06 (0.942) 1993.70–1993.80 (0.013)	1.6 cm year^{-1} (1960–2008)
Kooroon (2011 core)	87.5–88.5 cm	Wood fragment	105.5 ± 0.4%	–28.3 ±0.2%	**1957.51–1957.92 (0.057)** 2007.01–2007.21 (0.011) 2007.69–2011.84 (0.931)	1.7 cm year^{-1} (1960–2011)
Kooroon (2011 core)	169–171 cm	Wood fragment	195 ± 27 years BP	–26.6 ±0.2%	1667– 1712 (0.245) 1717– 1788 (0.374) 1791– 1814 (0.124) 1834– 1891 (0.161) 1923– 1950[A] (0.096) Median Probability: 1764	
Kooroon (2011 core)	189–193 cm	Wood fragment	189 ± 28 BP	–26.1 ±0.2%	1668– 1785 (0.554) 1793– 1817 (0.115) 1831– 1892 (0.213) 1922– 1950[A] (0.119) Median Probability: 1776	
Verena (2011 core)	35.5–37 cm	Wood fragment	172 ± 28 BP	–26.1 ±0.2%	1672– 1742 (0.334) 1754– 1765 (0.022) 1773– 1781 (0.016) 1797– 1896 (0.445) 1903– 1915 (0.020) 1918– 1950[A] (0.164) Median Probability: 1828	
Verena (2011 core)	179–183.5 cm	Wood fragment	196 ± 28 BP	–25.2 ±0.2%	1666– 1712 (0.241) 1717– 1814 (0.507) 1834– 1891 (0.158) 1923– 1950[A] (0.094) Median Probability: 1764	
Verena (2011 core)	197.5–198 cm	Wood fragment	156 ± 27 BP	–26.0 ±0.2%	1682– 1732 (0.256) 1803– 1950[A] (0.744) Median Probability: 1846	

Radiocarbon ages are presented as years ‘before present’ (BP) where ‘present’ is 1950. The post-1950 ages are not expressed using this convention. The calibrated age used in sedimentation rate calculations is shown in bold.

[A]Ages may extend beyond 1950 CE.

Table S3. ^{210}Pb and ^{137}Cs results for the 2011 Kooroon core.

Sample name	Start depth (cm)	End depth (cm)	Mass (g)	^{210}Pb	se	$^{210}Pb_{ex}$	se	$^{210}Pb_{ex}$ detected	^{137}Cs	se	^{137}Cs detected?	Minimum sedimentation rate
Kooroon - Core 3												
K1	0	6	22.003	27.9	2.4	0.8	2.5		1.12	0.22	Y	
K2	21	27	27.899	33.6	2.3	2.4	2.4		2.9	0.21	Y	
K3	42	48	19.694	35.4	2.7	5.8	2.7		2.96	0.28	Y	
K4	63	69	26.005	39.9	2.5	7.2	2.5	**Y**	6	0.31	Y	
K5	84	90	21.455	40.8	3.9				7.21	0.5	Y	
			21.455	41.3	2.7	11.6	2.7	**Y**	7.03	0.33	Y	
K6	105	111	31.131	38.4	3.4				4.35	0.32	Y	
			31.131	34.8	2.2	2.6	2.3		4.45	0.25	Y	2.0 cm year^{-1}
K7	126	132	40.501	27.1	2.8				0.09	0.23		
			40.501	29.9	1.5	–2	1.6		-0.06	0.1		
K8	147	153	26.667	32.9	1.8	1.4	1.8		0.07	0.13		
K9	168	173	30.82	31.4	1.7	0.4	1.7		-0.08	0.13		

We defined the detection limit as twice the standard measurement error. Minimum sedimentation rates were calculated using the years elapsed between coring and the maximum possible age (i.e. 1955 for ^{137}Cs and 150 years ago for $^{210}Pb_{ex}$) divided by the maximum depth at which the radionuclides could have been deposited (i.e. the bottom centimetre of the sample range). Start and ended depths are rounded to the nearest 0.5 cm.

Table S4. ^{210}Pb and ^{137}Cs results for the 2011 Verena core.

Sample name	Start depth (cm)	End depth (cm)	Mass (g)	^{210}Pb	se	$^{210}Pb_{ex}$	se	$^{210}Pb_{ex}$ detected	^{137}Cs	se	^{137}Cs detected?	Minimum sedimentation rate
Verena - Core 1												
V1	0	8	19.944	20.6	2	3.9	2.1		0.89	0.22	Y	
V2	23	31	36.932	21.8	1.7	3.7	1.8	**Y**	2.25	0.16	Y	
V3	46	54	28.966	27.6	3.9				3.51	0.46	Y	
			28.966	27.4	2.1	5.3	2.2	**Y**	3.61	0.24	Y	
V4	69	77	33.9	32.8	2.5				2.3	0.24	Y	
			33.9	28.8	2	3.7	2		2.53	0.2	Y	1.2 cm $year^{-1}$
V5	92	100	26.89	32	2.9				0.03	0.22		
			26.89	31.9	2.3	5	2.3	**Y**	0.03	0.17		
V6	106	112	40.3	32.8	2				0.03	0.15		
			40.3	32.8	2				0.03	0.15		
V7	128	134	35.005	29.1	3.5	4.1	3.6		-0.05	0.42		
			35.005	35.6	2.1	5.1	2.2	**Y**	0.23	0.17		0.5 cm $year^{-1}$
V8	150	156	49.2	21.1	2.8					0.36		
			49.2	22.2	1.6	2	1.6		0.01	0.11		
V9	172	178	31.48	28.9	2.1	1.8	2.1		-0.25	0.17		

We defined the detection limit as twice the standard measurement error. Minimum sedimentation rates were calculated using the years elapsed between coring and the maximum possible age (i.e. 1955 for ^{137}Cs and 150 years ago for $^{210}Pb_{ex}$) divided by the maximum depth at which the radionuclides could have been deposited (i.e. the bottom centimetre of the sample range). Start and ended depths are rounded to the nearest 0.5 cm.

Fig. S1. Magnetic susceptibility for the Kooroon Waterhole 2010 cores.

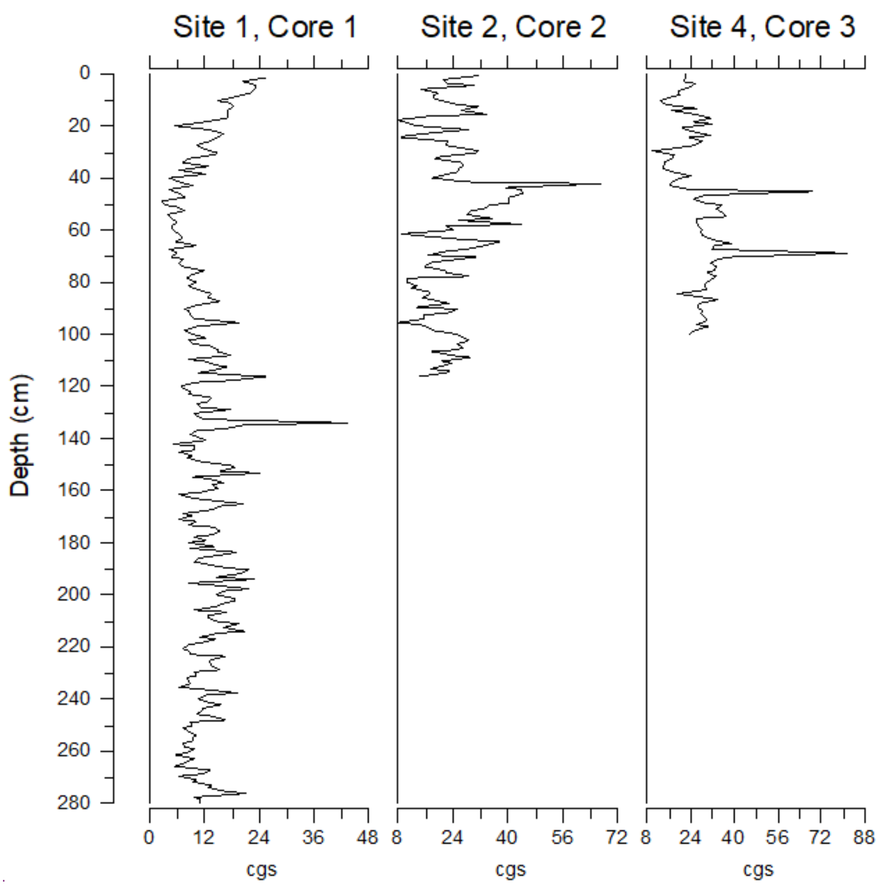


Fig. S2. Magnetic susceptibility for the Kooroon Waterhole 2011 cores.

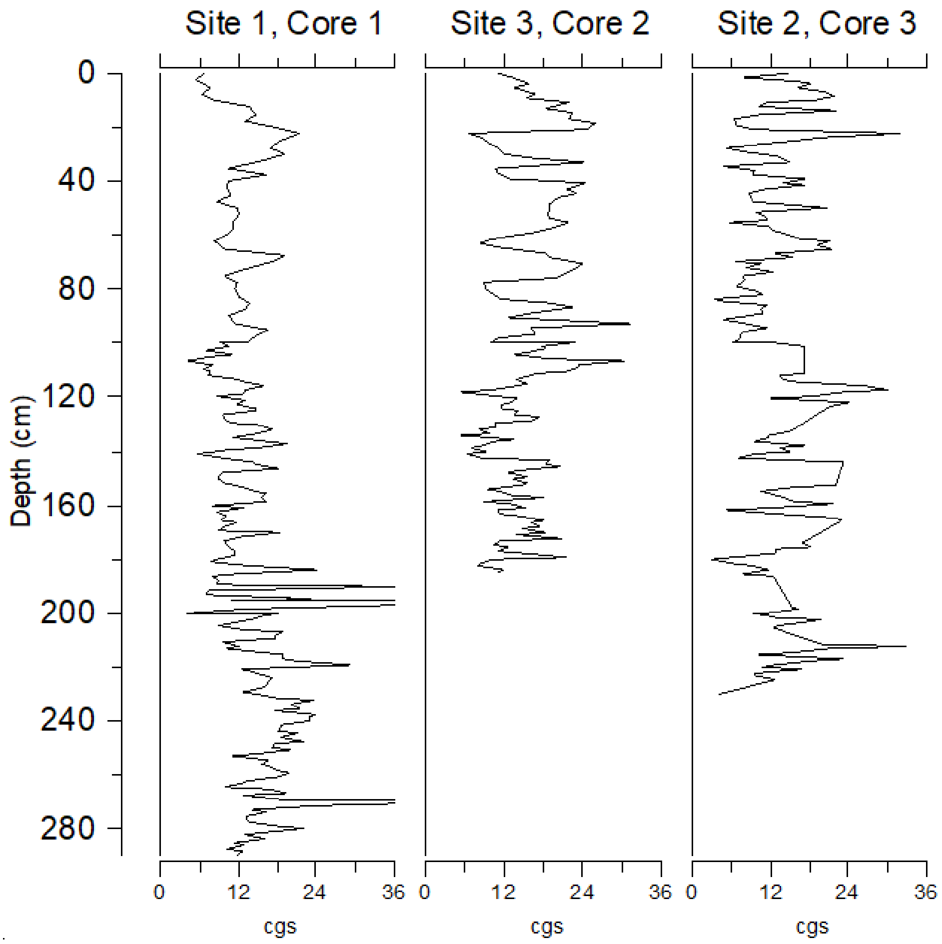


Fig. S3. Magnetic susceptibility for Kooroon Waterhole Site 1 in 2008, 2010 and 2011 cores. These cores were taken in approximately the same position.

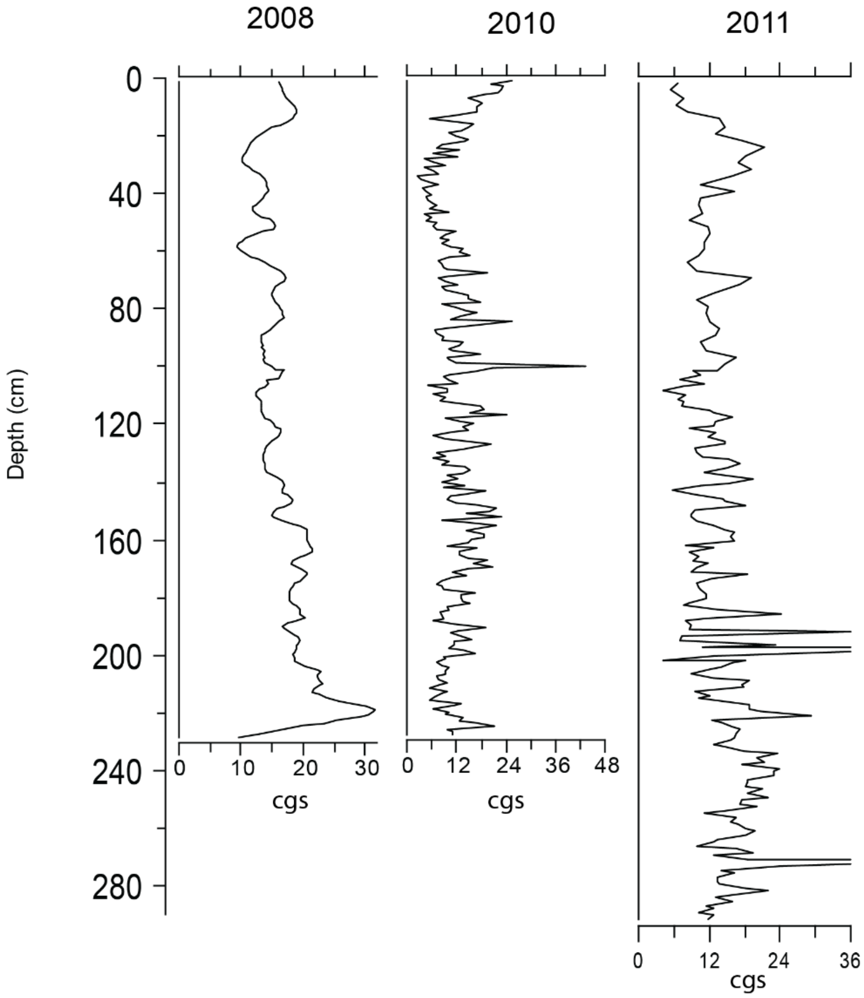


Fig. S4. Magnetic susceptibility for the Verena Waterhole 2010 and 2011 cores, which were taken in approximately the same position. Note that in 2010, a log was struck between 100- and 110-cm depth and no further penetration was possible.

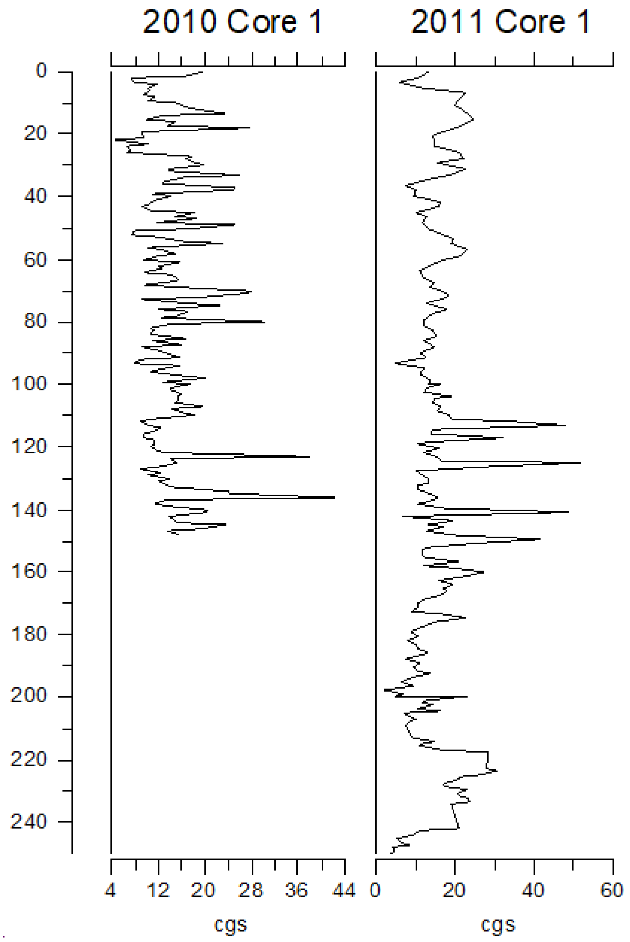


Fig. S5. Magnetic susceptibility for the Kurmala Waterhole 2010 core.

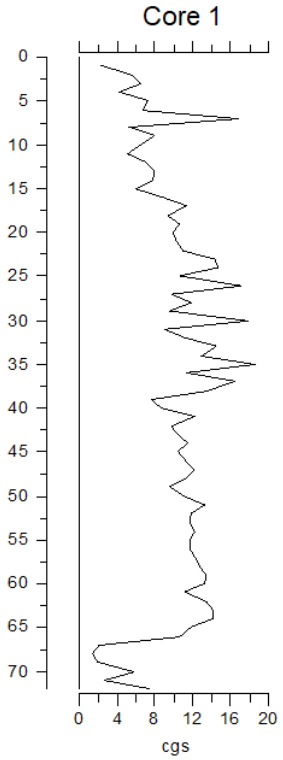


Fig. S6. Diatom stratigraphy from the 2008 Kooroon core. Taxa with relative abundance >2% are shown. Aerophilic diatoms are often found growing on soils.

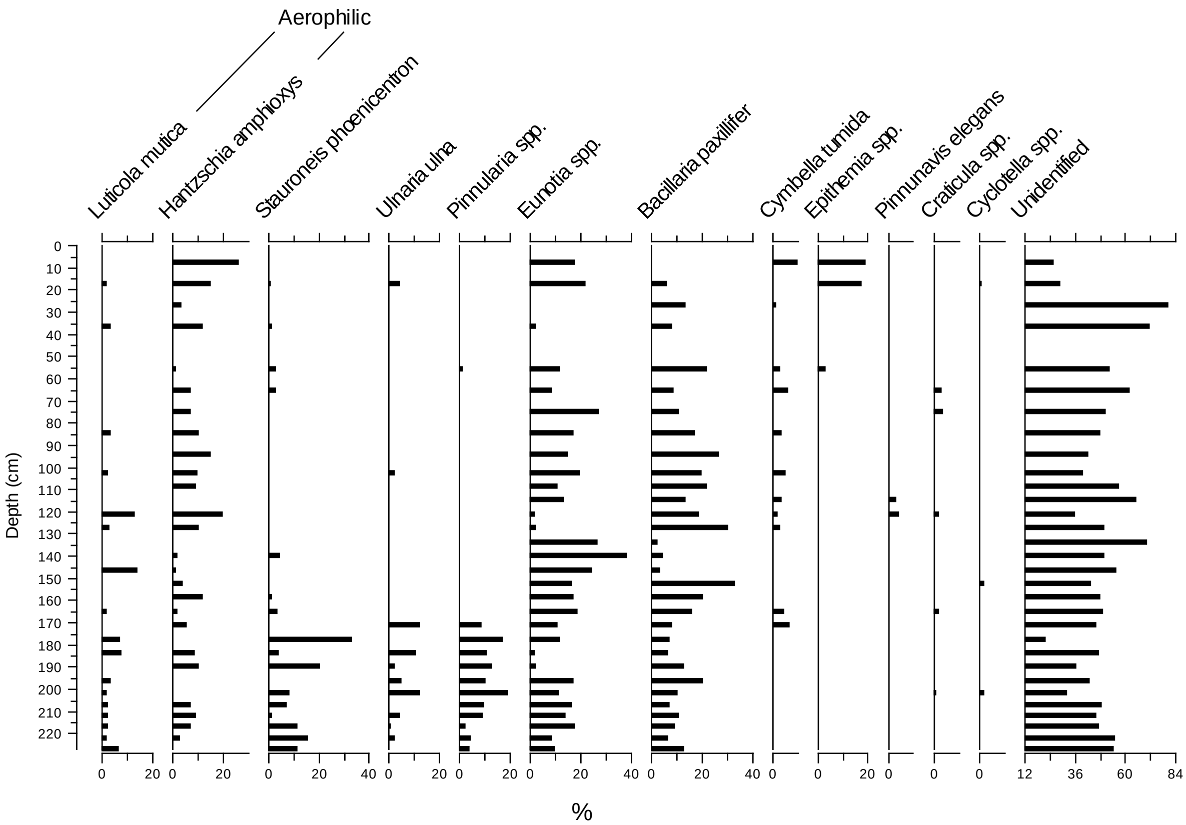
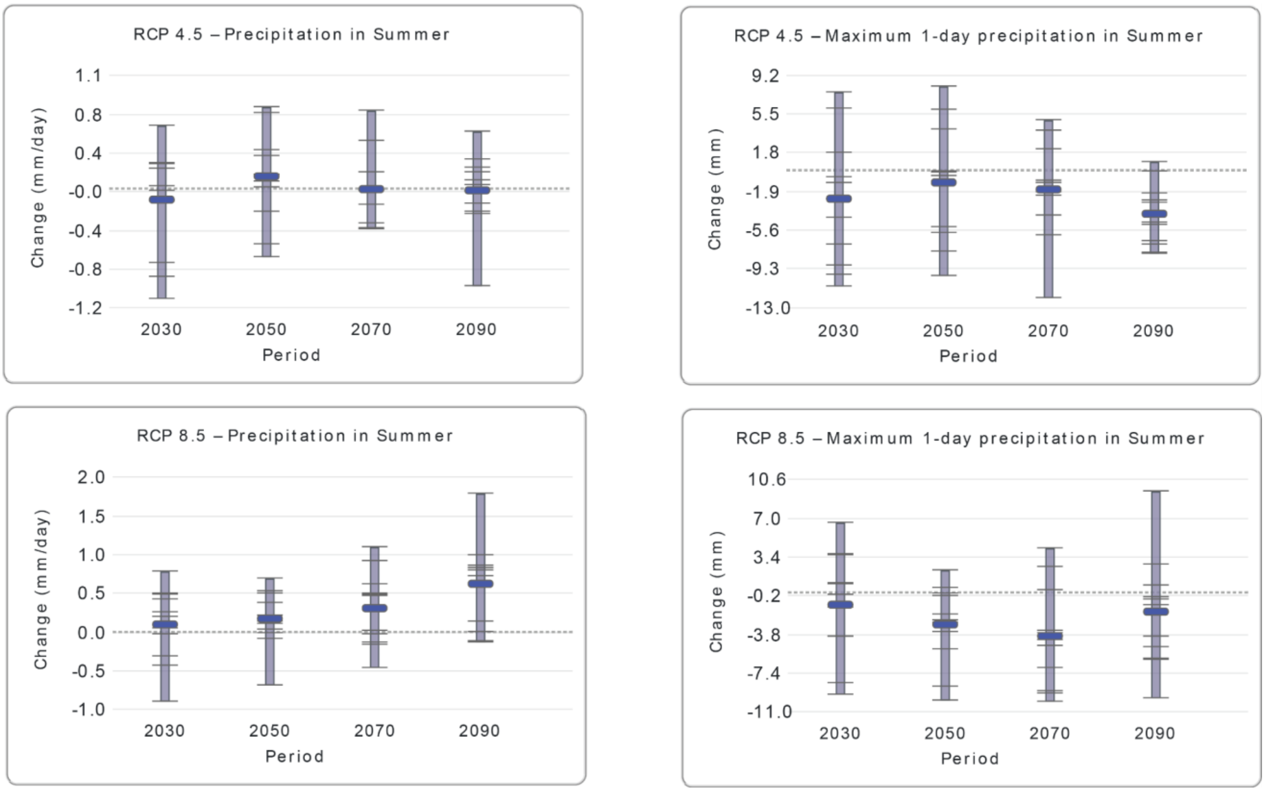


Fig. S7. Downscaled projections of future summer rainfall and maximum one day summer rainfall for the Moonie catchment using Representative Concentration Pathways (RCP) 4.5 and 8.5. Plots were generated on 27 June 2022 using the Queensland Future Climate tool (https://www.longpaddock.qld.gov.au/qld-future-climate/; Syktus *et al*. 2020).



Reference

Syktus J, Trancoso R, Ahrens D, Toombs N, Wong K (2020) The Long Paddock: Queensland future climate. (The State of Queensland) Available at https://www.longpaddock.qld.gov.au/qld-future-climate [Verified 14 June 2023]