

Supplementary Material

Antonio Lara, Julia Jones, Christian Little, Nicolás Vergara

Streamflow response to native forest restoration in former *Eucalyptus* plantations in south central Chile

This supplement contains additional data on precipitation, runoff and vegetation in the study catchments. Supplemental information on precipitation and runoff includes: information about how the full precipitation record was created (Table S1), annual and seasonal runoff by catchment (Table S2), the fit of models used to predict streamflow from precipitation (Figure S1), a visualization of seasonal and interannual changes in precipitation and runoff in the study catchments (Figure S2), runoff ratios for the 2006-2019 water years for four study catchments by water year (April – March) and by season (Figure S4), seasonal base flow as a percentage of total flow for the study catchments (Figure S5), and standardized departures (Z scores) of seasonal base flow as a percentage of total flow (Figure S6). Supplemental information on vegetation includes percent cover of non-tree vegetation in clearcut and planted catchments, 2010-2020 (Table S3), a list of common names of native tree species that seeded into or sprouted from roots and stumps in the restoration treatment areas (Table S4), and the density of saplings of planted native trees, naturally regenerated native trees, and *Eucalyptus* in the restoration treatment areas of RC5, RC10, and RC11 in 2012, 2014, 2016 and 2020 (Figure S3).

Data on daily precipitation and streamflow covering the period April 2006 – March 2019 used in this study are available at: <http://www.cr2.cl/datos-cuencas-restauracion-reservavaldiviana/>

Table S1. Number of days of observations at the Cadillal precipitation gage and R^2 of regressions with five additional precipitation gages located in the Reserva Costera Valdiviana that were used to fill missing values to create a complete record of daily precipitation, 2006-2019, used in this study. Data for the period 2006 to 2008 were filled based on regression relationships with two rain gages located within a few kilometers of the Cadillal gage: Las Garzas and Oficina, both initiated on March 3, 2006. Other gages used to fill missing observations included Huiro (initiated April 3, 2009), Nocturno (initiated on June 14, 2017) and Máquina Quemada (initiated July 25, 2008).

Water year	N of days with observations	N of days filled based on relationships with other gages	R^2
2006	0	365	0.93
2007	0	366	0.93
2008	0	365	0.93
2009	344	21	0.94
2010	217	148	0.90
2011	365	0	
2012	366	0	
2013	344	21	0.93
2014	365	0	
2015	365	0	
2016	366	0	
2017	286	79	0.95
2018	354	11	0.98
2019	365	0	

Table S2. Annual and seasonal runoff (mm) by catchment. RC5, RC10 and RC11 (restoration); RC6 (*Eucalyptus*).

Year	RC5	RC6	RC10	RC11	Precipitation
<u>Annual</u>					
2006	1374	1469	1146	2299	3148
2007	739	943	701	1304	1558
2008	1329	1530	1034	1885	2427
2009	793	1526	1097	1923	2804
2010	590	1464	901	1873	2347
2011	714	1808	1961	2540	2694
2012	1371	1855	2168	2853	2806
2013	1120	1892	1767	2361	2603
2014	2088	2160	1845	2274	2725
2015	1168	1799	1582	2107	2554
2016	771	1090	870	1565	1977
2017	1605	2292	2138	2565	2916
2018	1200	2050	1616	2114	2385
2019	756	1677	1291	1866	2144
<u>Fall</u>					
2006	503	498	345	963	1478
2007	126	147	138	388	498
2008	277	299	209	545	823
2009	159	255	247	495	901
2010	118	366	226	762	767
2011	193	396	539	724	836
2012	486	575	814	1179	1017
2013	433	630	684	989	983
2014	891	667	761	921	1040
2015	354	414	406	592	854
2016	125	152	81	254	373
2017	442	645	620	785	906
2018	316	475	445	693	801
2019	227	435	383	676	824
<u>Winter</u>					
2006	570	637	593	889	994
2007	521	574	413	590	557
2008	958	1010	692	1047	1184
2009	368	584	564	832	840
2010	300	664	503	697	776

2011	408	999	1095	1083	1147
2012	707	906	1028	1097	970
2013	616	959	968	1023	874
2014	944	1020	922	1121	1209
2015	709	974	1048	1081	1078
2016	305	430	433	623	715
2017	668	904	933	984	987
2018	601	983	844	911	942
2019	413	869	770	879	820
<u>Spring</u>					
2006	233	253	173	338	473
2007	70	182	125	243	317
2008	85	144	102	197	200
2009	205	456	226	415	654
2010	118	287	134	300	463
2011	76	272	205	229	289
2012	151	252	246	373	552
2013	29	211	78	212	327
2014	250	352	161	232	364
2015	98	279	120	269	398
2016	216	303	254	425	563
2017	338	552	431	515	639
2018	246	463	303	421	483
2019	96	290	125	244	367
<u>Summer</u>					
2006	68	81	36	109	203
2007	22	40	24	83	186
2008	8	76	31	96	220
2009	61	231	60	181	409
2010	54	147	38	114	342
2011	37	141	121	504	422
2012	26	122	80	203	267
2013	41	92	36	136	419
2014	3	121	0	0	112
2015	7	132	9	164	224
2016	125	204	103	263	326
2017	157	192	155	281	384
2018	37	129	24	89	160
2019	20	83	13	68	133

Table S3. Percent cover of non-tree vegetation in clearcut and planted catchments, 2010-2020. RC5, RC10 and RC11 (restoration).

Year		RC5	RC10	RC11
2010	mean	60	104	86
	SD	27	10	52
2012	mean	38	70	51
	SD	10	20	21
2014	mean	67	124	88
	SD	3	8	32
2016	mean	102	162	119
	SD	21	24	26
2020	mean	42	37	83
	SD	14	13	38

Table S4. Sapling species naturally regenerated (except for *Nothofagus dombeyi* that was planted) ranked in order of declining mean density (N/ha) considering all the plots sampled in catchments RC5, RC10 and RC11 (restoration) in 2020. All species are native except for *Eucalyptus globulus*.

Ranking	Latin Name	Common Name
1	<i>Ovidia pillopillo</i>	Pillo-Pillo
2	<i>Raphithamnus spinosus</i>	Arrayán Macho
3	<i>Drimys winteri</i>	Canelo
4	<i>Embothrium coccineum</i>	Notro
5	<i>Nothofagus dombeyi</i>	Coihue
6	<i>Aristotelia chilensis</i>	Maqui
7	<i>Gevuina avellana</i>	Avellano
8	<i>Amomyrtus luma</i>	Luma
9	<i>Dasyphyllum diacanthoides</i>	Trevo
10	<i>Luma apiculata</i>	Arrayán
11	<i>Aextoxicon punctatum</i>	Olivillo
12	<i>Myrceugenia planipes</i>	Patagua
13	<i>Amomyrtus meli</i>	Meli
14	<i>Eucalyptus globulus</i>	Eucalyptus
15	<i>Eucryphia cordifolia</i>	Ulmo
16	<i>Lomatia ferruginea</i>	Fuinque

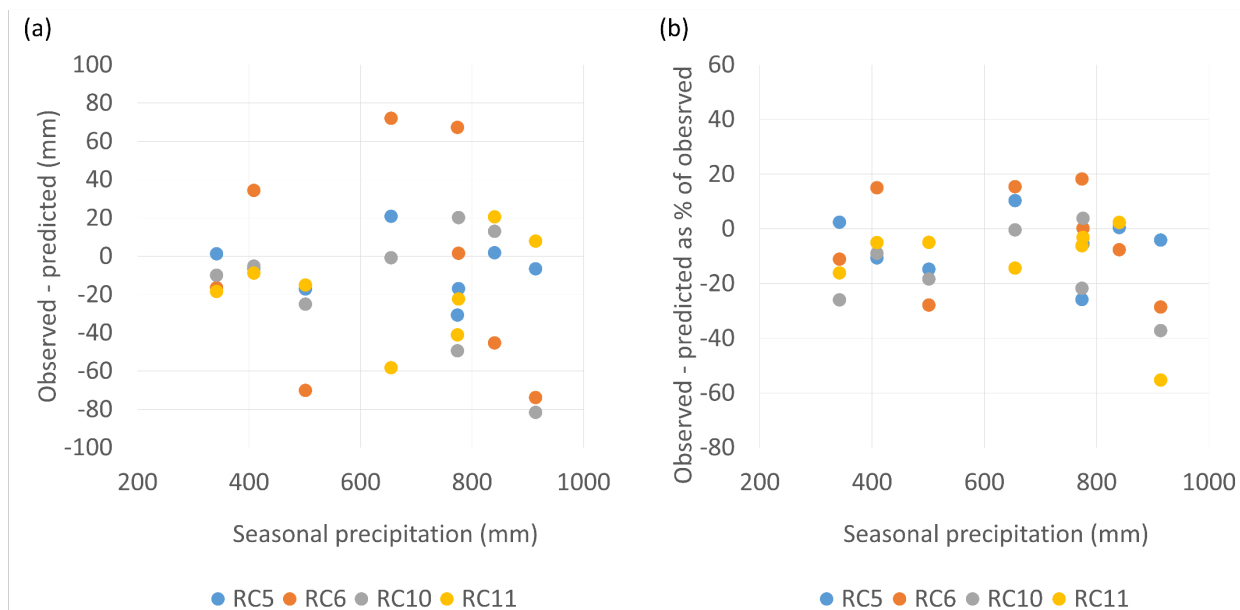


Figure S1. Observed and predicted seasonal streamflow as a function of seasonal precipitation for the pre-treatment period, 2009 and 2010. (a) observed minus predicted (mm), (b) observed minus predicted as % of observed. RC5, RC10 and RC11 (restoration); RC6 (*Eucalyptus*). Definitions of seasons and analysis procedures are described in the text.

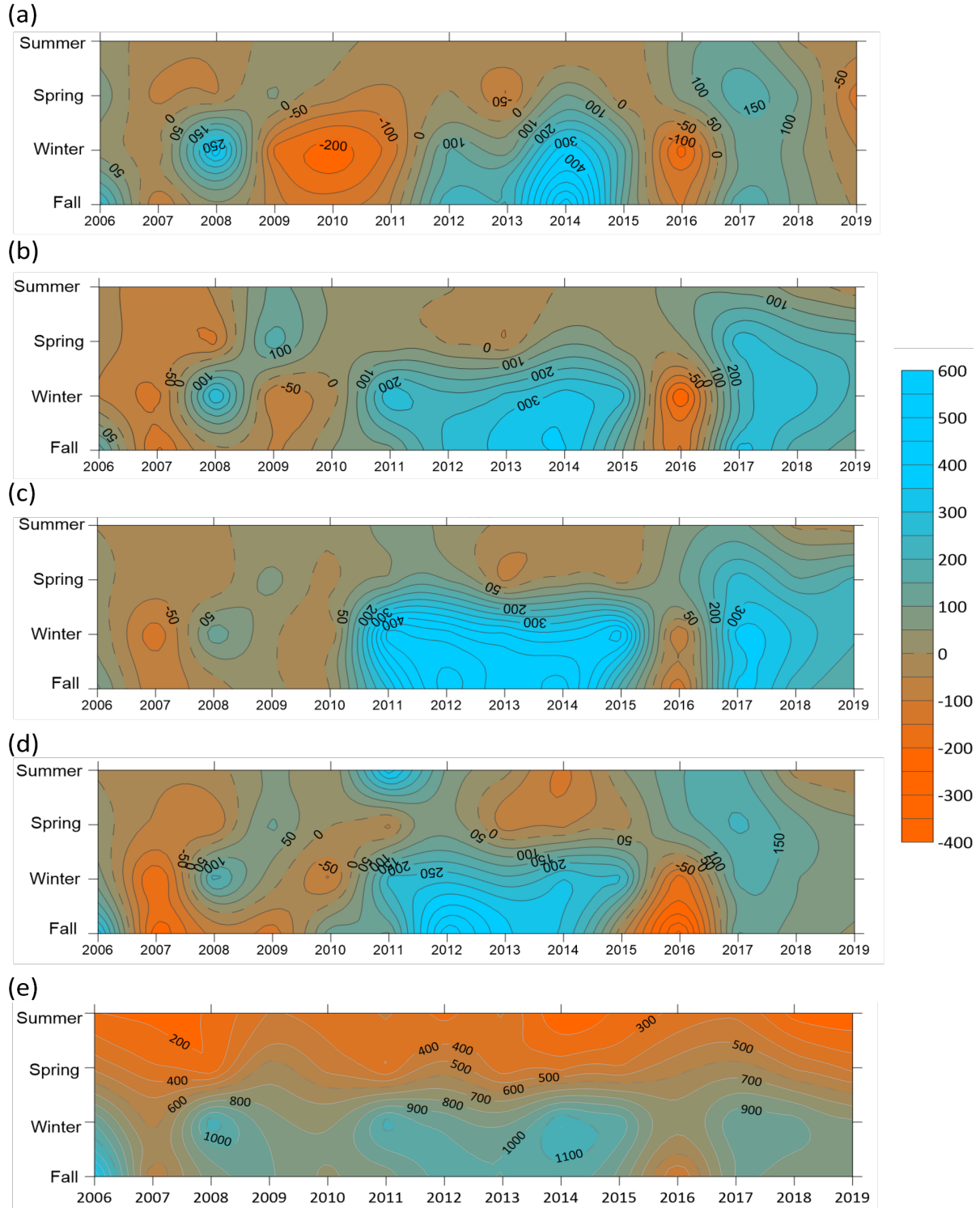


Figure S2. Interpolation (kriging) of precipitation and runoff (mm) for each catchment by year and season. (a) precipitation, (b) RC5, (c) RC6, (d) RC10 and (e) RC11. RC5, RC10, RC11 (restoration); RC6 (*Eucalyptus*). Streamflow is above the pre-treatment mean in fall and winter in all catchments from 2012 to 2015 and 2017 to 2019, and below the pre-treatment mean in 2016 the driest year in the 2011-2019 post-treatment period.

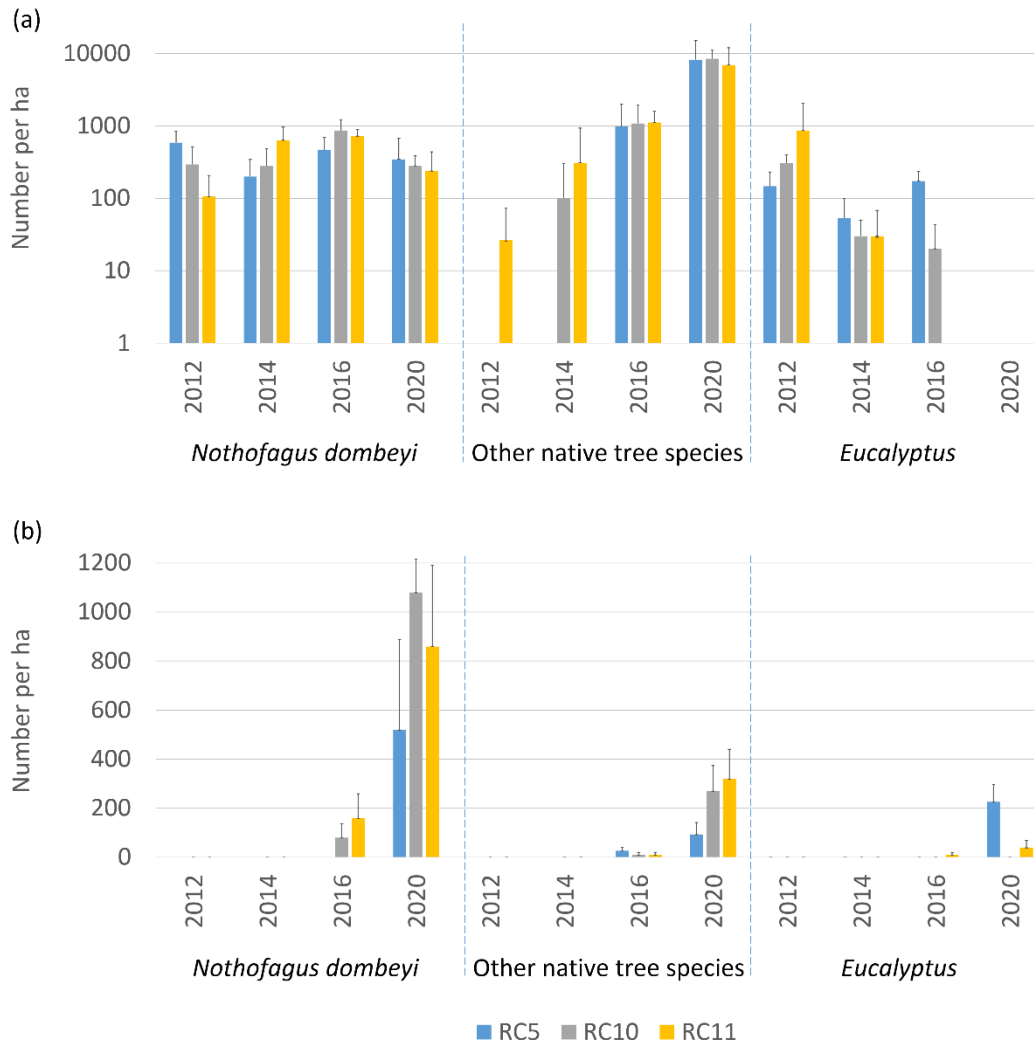


Figure S3. Numbers of (a) saplings (individuals ≥ 2 m height and < 5 cm dbh) and (b) trees (individuals ≥ 5 cm dbh) of *Nothofagus dombeyi*, other native tree species ($n=14$, Table S4), and *Eucalyptus* in 250 m^2 vegetation plots in three restored catchments in Reserva Costera Valdiviana (see methods). After sampling in 2012, 2014, and 2016, *Eucalyptus* saplings and trees were removed from the plots to enable assessment of the recovery potential of native species, whereas *Eucalyptus* was removed only in some portions of the remaining area of the catchments. Sampling in 2020 included some additional plots, which had not received the *Eucalyptus* removal treatments. In 2012, the density of *N. dombeyi* saplings was higher than *Eucalyptus* at RC5, lower than *Eucalyptus* at RC11, and about the same at RC10. From 2014 to 2020, the density of naturally recruited other native tree species ($n=14$, Table S4) increased by an order of magnitude. By 2020, many saplings of *N. dombeyi* and other native species had reached tree size, while *Eucalyptus* saplings and trees were absent except from vegetation plots in RC5.



Figure S4. (a) Annual precipitation (blue lines) and annual runoff ratios (Q/P ; colored bars) by water year (April 1 - March 31)", (b) Means and standard deviations of annual and seasonal runoff ratios (Q/P). Austral fall (April to June), austral winter (July to September, austral spring (October to December), and austral summer (January to March). RC5, RC10 and RC11 (restoration); RC6 (*Eucalyptus*).

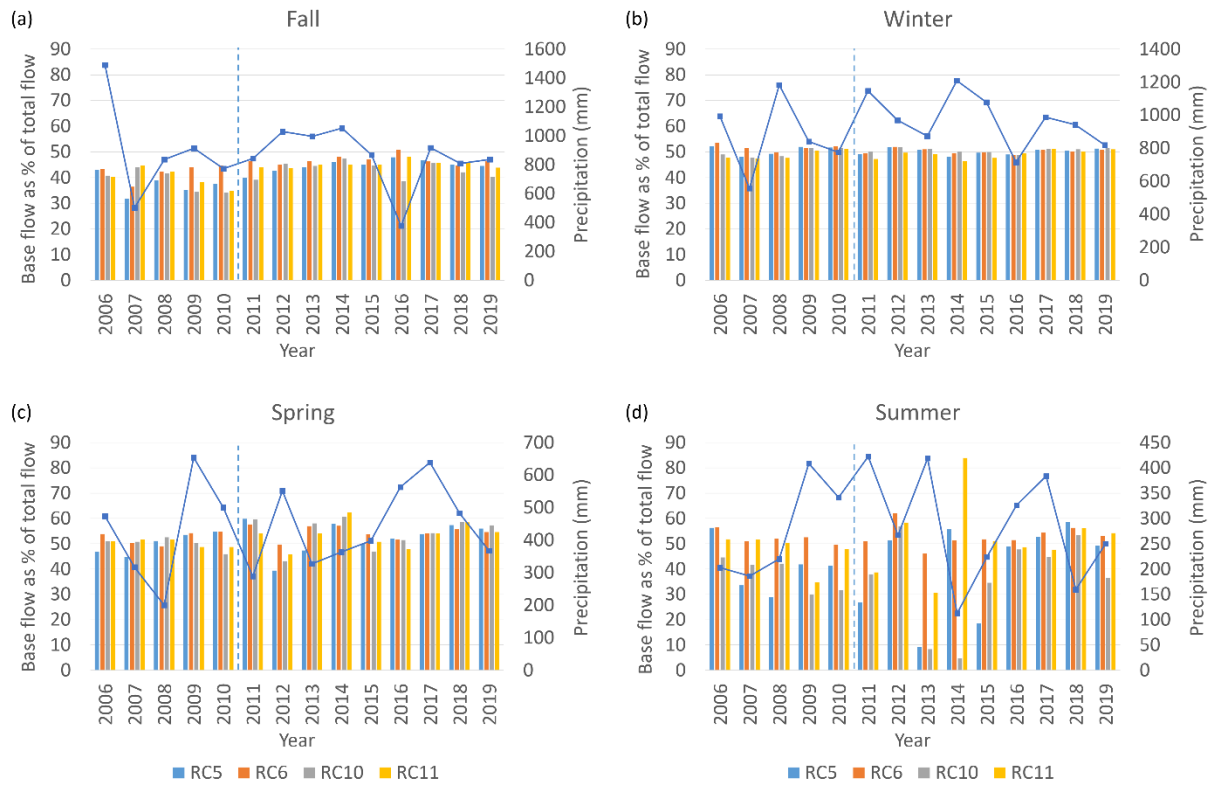


Figure S5. Seasonal precipitation (blue lines) and seasonal base flow (percent of total seasonal streamflow; colored bars) for watersheds RC5, RC10 and RC11 (restoration); and RC6 (*Eucalyptus*).

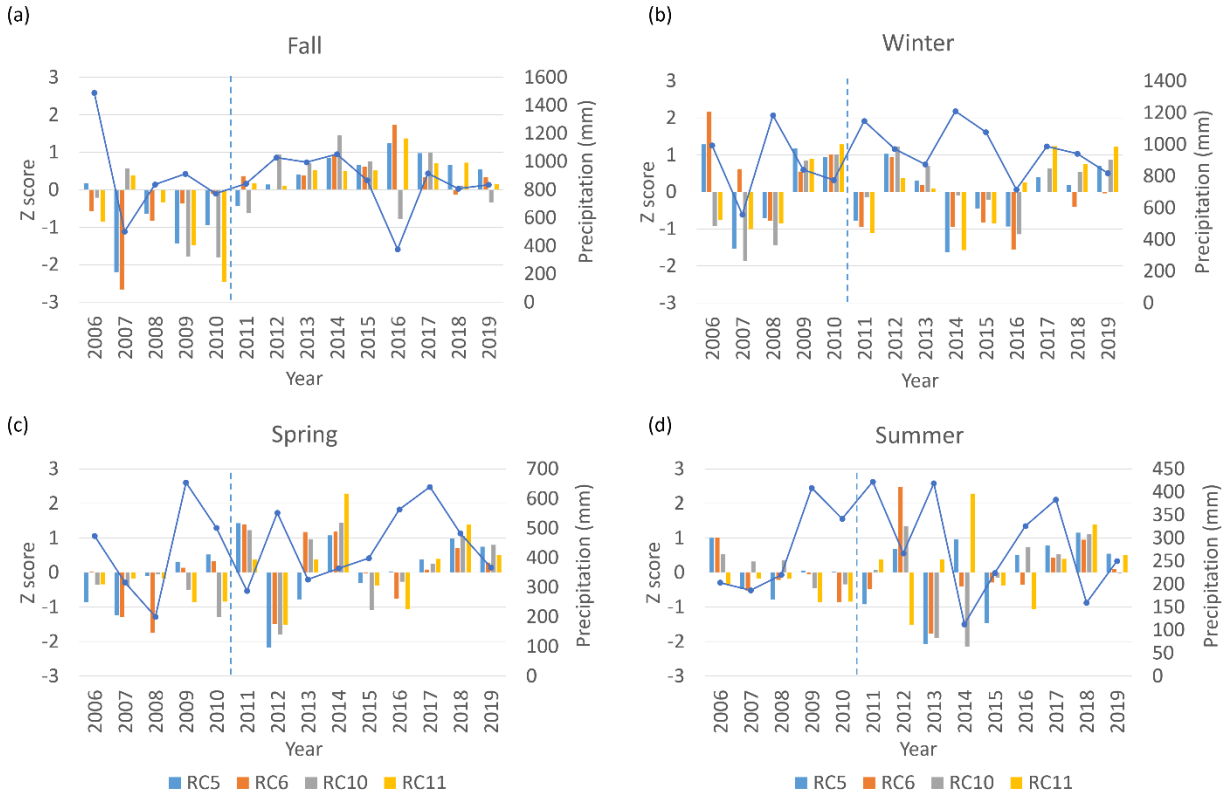


Figure S6. Seasonal precipitation (blue lines) and standardized departures (Z scores; colored bars) of seasonal base flow as a percentage of total flow for watersheds RC5, RC10 and RC11 (restoration); RC6 (*Eucalyptus*).