Response of agricultural and natural vegetation areas to groundwater and snow drought in central Chile

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ABSTRACT

Since 2010, Chile has been experiencing a megadrought. The possible influences of decreasing groundwater GW and snow cover on land use-cover have not been fully investigated worldwide. Therefore, the objective of this research is to analyze the relationship between GW and snow with agricultural AL and natural vegetation NV areas during drought in central Chile. Indicators of vegetation productivity, precipitation, GW, atmospheric evaporative demand and snow were analyzed on persistent of AL and NV areas since 2000. Statistical tests considering GW were carried out exclusively by hydrogeological sectors HS. A significant decrease in the GW and snow indicators were found. The snow content had a very positive correlation with the productivity of NV and inversely with AL, more evident in the avocado land. The HS with a higher proportion of AL presented a greater decrease in GW. The productivity of NV was affected by the drought but not in the spring seasons. These results imply the need for mitigation strategies to achieve resilience to drought.

INTRODUCTION

Issues related to climate change have been one of the major concerns among environmentalists and scientific societies at local and international considering its distinct and alarming consequences that alter the rainfall patterns, humidity, sea level, irregular seasons, flood, storm, and droughts [1]. Drought is recognized as a slow-onset natural hazard that originates from a deficiency of rainfall over a prolonged period and is also described as an inequality of water accessibility. It is known as the global costliest climatic hazard that destroys the agriculture and ecosystem in terms of economy, society, and nature [2]. Chile is among the most vulnerable countries to climate change and change in climatic conditions have already been observed in Central Chile. Since 2010, Central Chile has been experiencing an uninterrupted sequence of dry years that has been classified as Mega-drought [3]. The observed decline in rainfall over central Chile has been greatly accentuated with annual rainfall deficits ranging between 25% and 45% over the 2010–2019 period. According to the historical records, this was unprecedented and unusual over the last millennium. The mega-drought resulted in a diminished Andean snowpack, river discharge and reservoir volumes, groundwater levels, and difficulty for life systems for people across central Chile [4]. Previous research in the Aconcagua basin have investigated the drought relationship with water resources [3, 4]. However, more comprehensive analyses related to agriculture and the integrity of terrestrial ecosystems are needed to achieve drought resilience.

MATERIALS AND METHODS

Study area

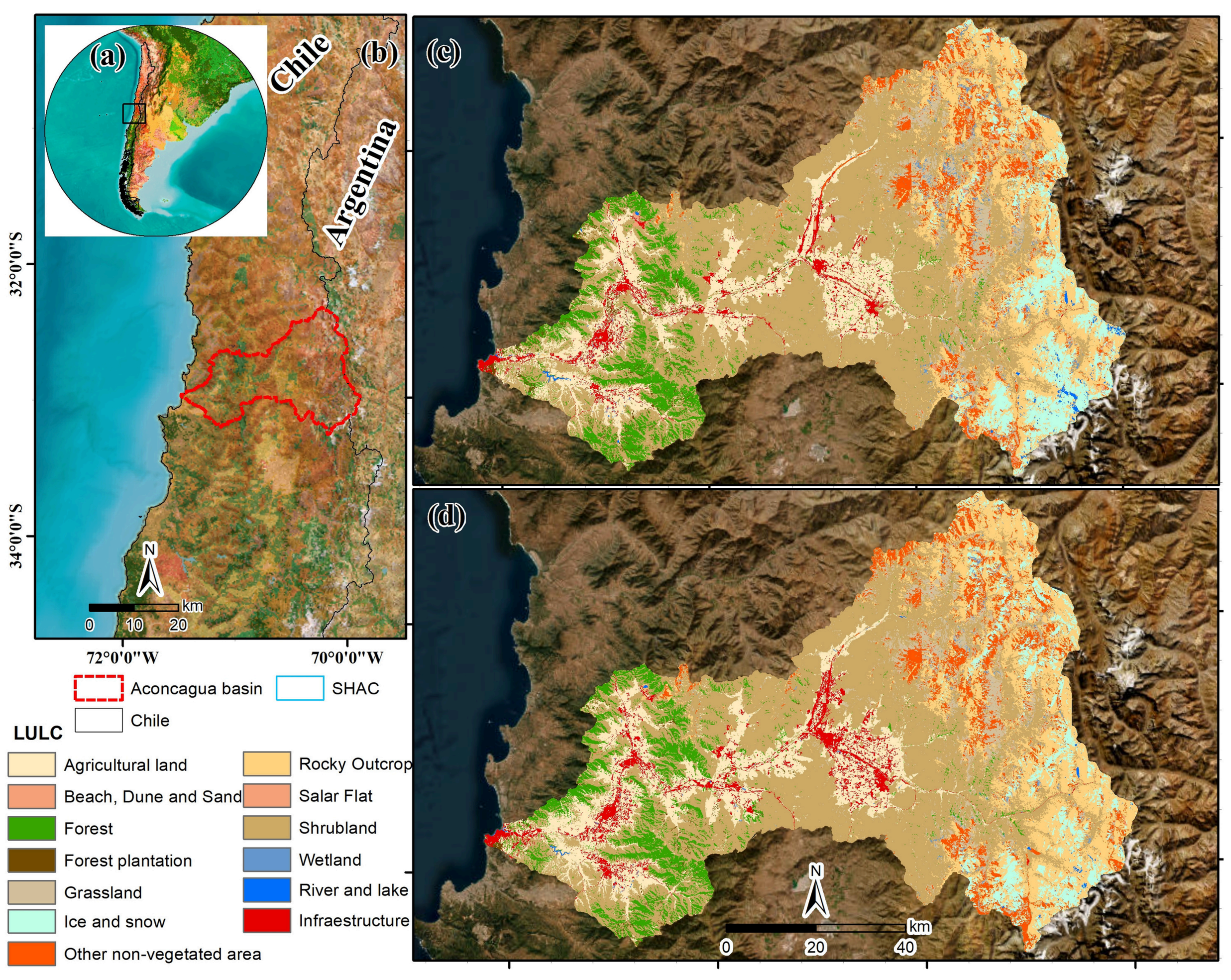

Figure 1. **Study area**. a) Represents the international context of Chile, b) is the Aconcagua basin context, and c-d) are the land use/cover (LULC) in 2000-2022.

Data, processing, and indices calculation

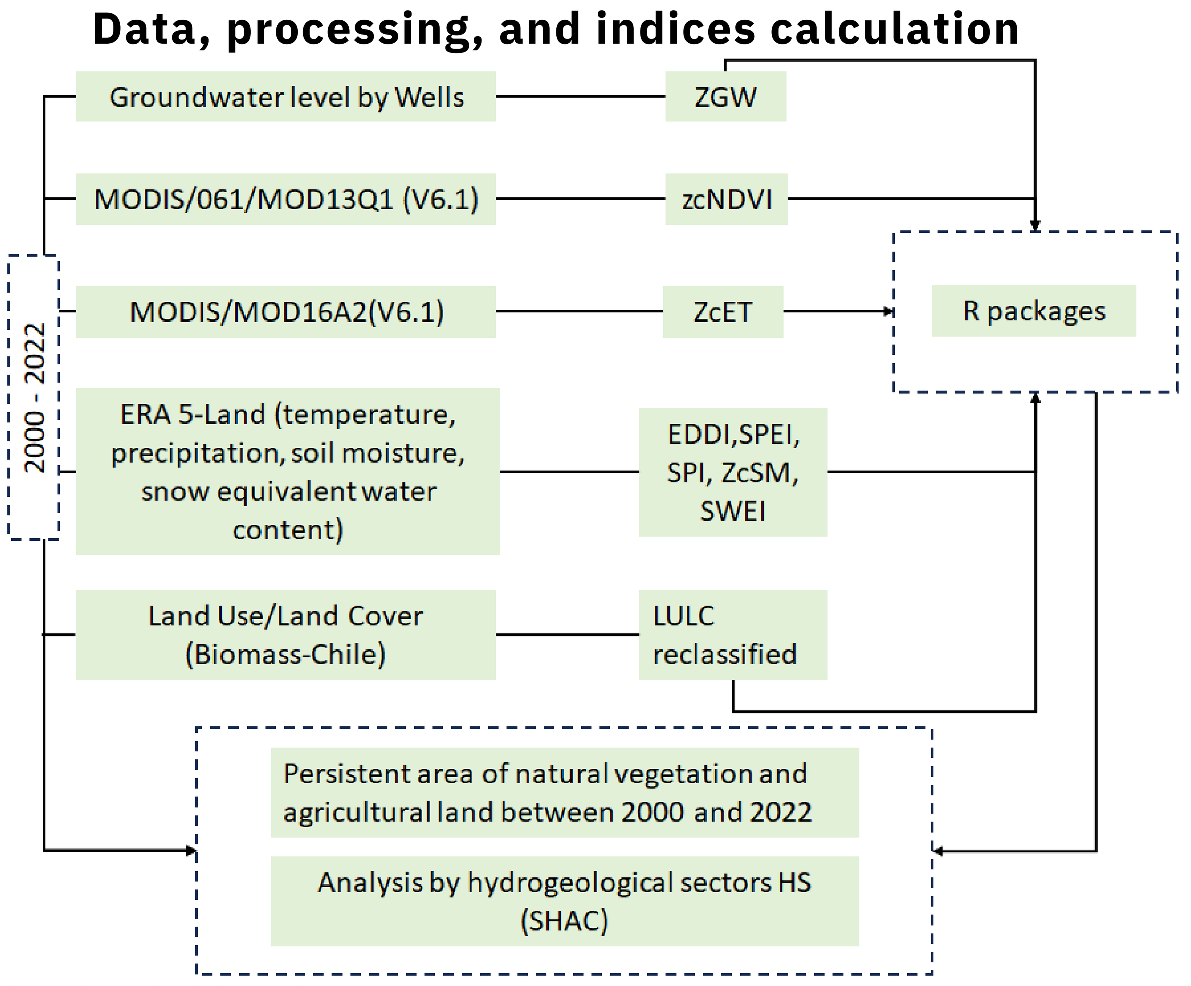

Figure 2. Methodology scheme.

RESULTS

Table 1. Trend analyses of average NDVI by hydrogeological sectors HS at annual and season during 2000–2022.

Season/HS		Agricultural land			Natural vegetation		
		L	M	H	L	M	H
Annual	p-Value	0,040	0,001	0,001	0,006	0,002	0,206
	Sen's slope	-0,003	-0,004	-0,003	-0,003	-0,004	-0,001
Summer	p-Value	0,031	0,008	0,001	0,021	<0,0001	0,004
	Sen's slope	-0,003	-0,002	-0,003	-0,003	-0,003	-0,002
Autumn	p-Value	0,016	0,006	0,000	0,003	0,000	0,004
	Sen's slope	-0,003	-0,002	-0,003	-0,004	-0,003	-0,002
Winter	p-Value	0,264	0,008	0,024	0,045	0,045	0,568
	Sen's slope	-0,002	-0,004	-0,004	-0,005	-0,004	0,001
Spring	p-Value	0,143	0,001	0,003	0,078	0,003	0,673
	Sen's slope	-0,001	-0,004	-0,003	-0,003	-0,004	0,000

Note: Bold values represent statistical significance at p-value < 0.05.

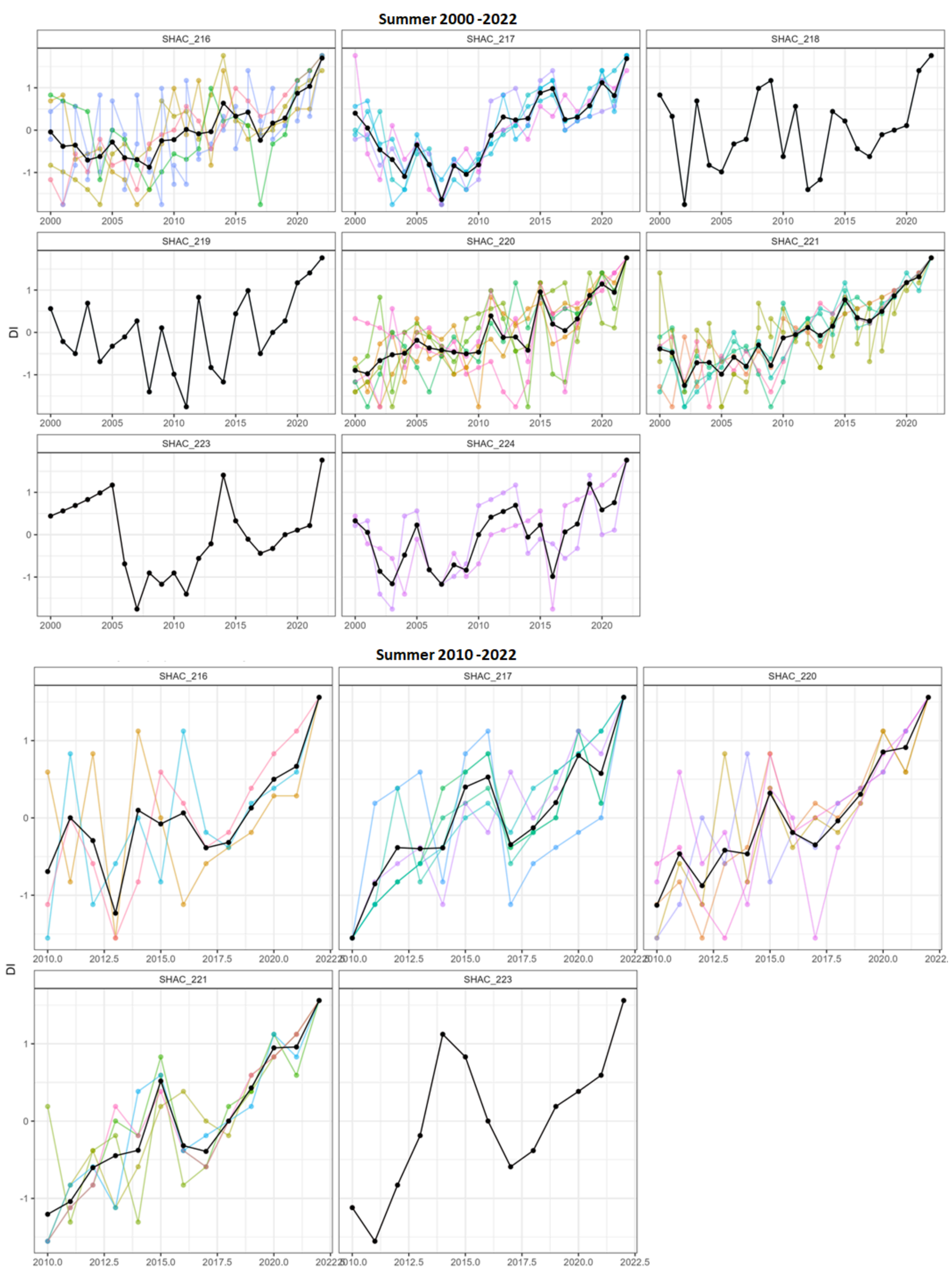

Figure 3. Trend of groundwater index ZGW by wells and Hydrogelogical sectors SHAC.

Figure 4. Indexes as EDDI, ZcSM and SWEI at 24 months scale by agricultural land AG and natural vegetation NV, and by Hydrogelogical sectors SHAC.

Figure 5. Agricultural and natural vegetation zones in the study area.

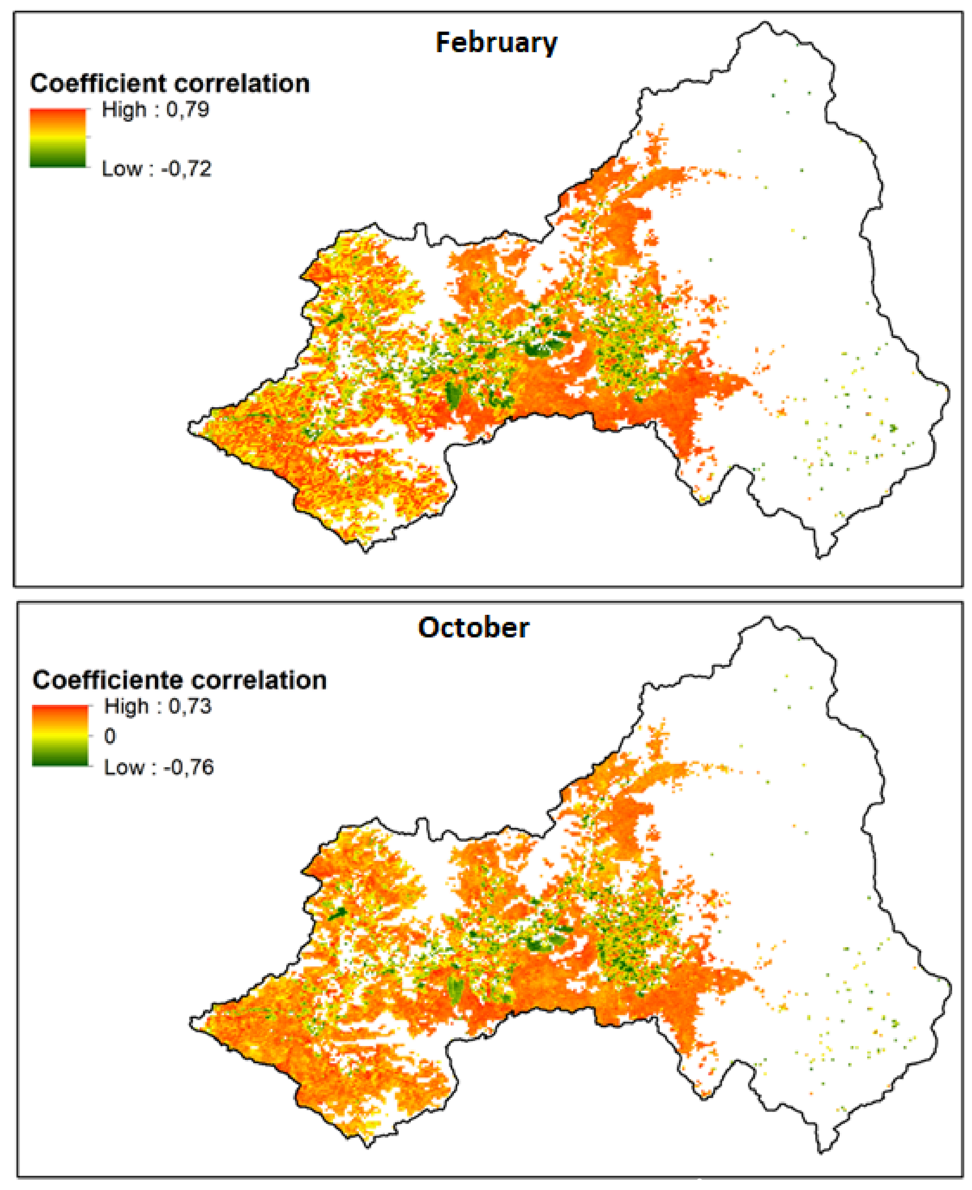

Figure 6. Coefficient correlation between ZcNDVI and SWEI.

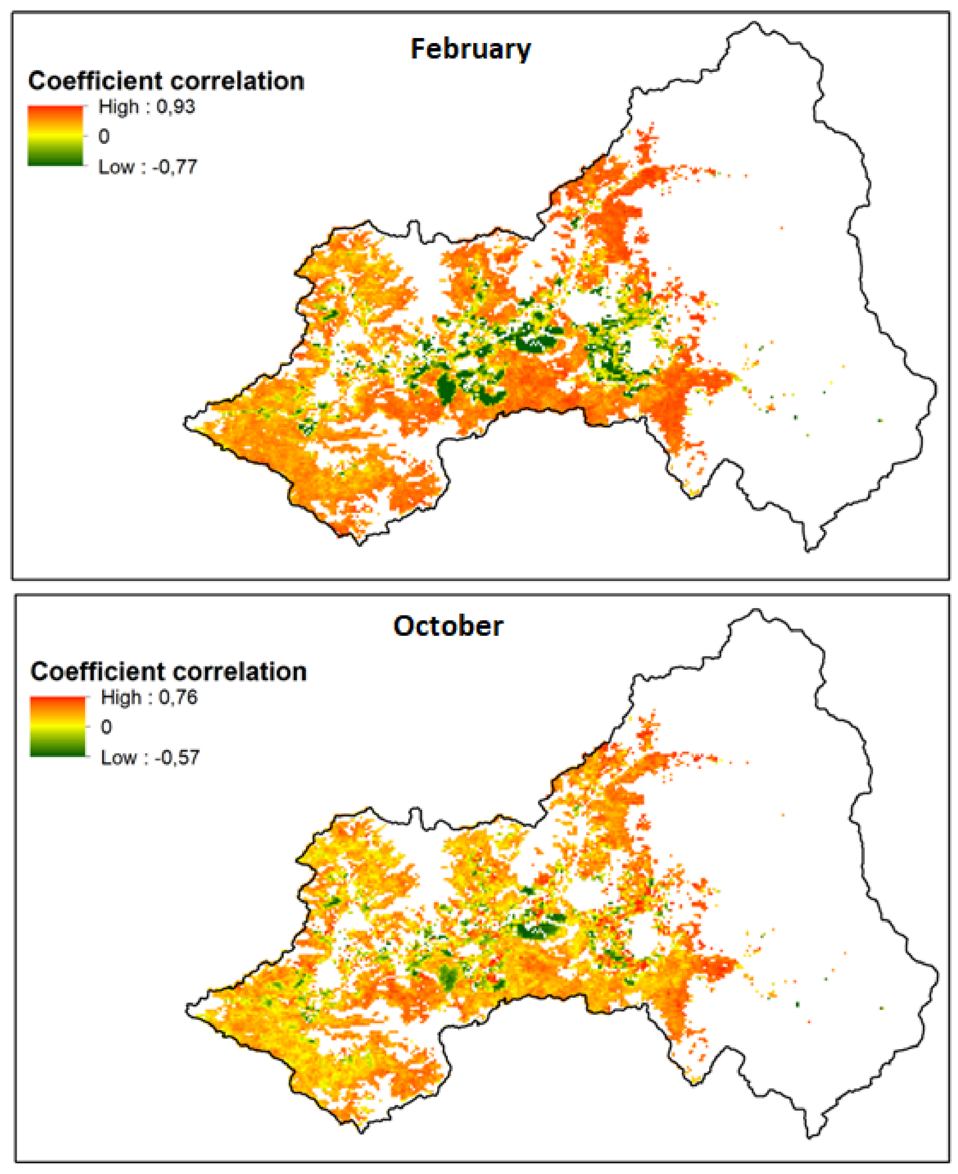

Figure 7. Coefficient correlation between ZcET and SWEI.

CONCLUSIONS

- NDVI and groundwater decreased significantly across the basin, especially in SHACs with larger agricultural areas.
- Vegetation productivity was highly correlated with evapotranspiration, groundwater, and snow.
- A sustainable management of the water resources and ecosystems of the Aconcagua River is essential.

POLICY MESSAGES

- Mitigation and adaptation strategies to climate and land cover changes to achieve resilience to drought in a context of global warming are necessary.The ecosystems response to groundwater and snow drought must be considered in new policy for adequate sustainable management.
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- A correct assessment of the relationship between groundwater and the ecosystems it supports is necessary to protect them during drought periods.Aquifer recharge can be considered a mitigation strategy to improve drought resilience in ecological and socioeconomic terms.

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