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CONTENT

INTERCONNECTIONS OF CLIMATE, VEGETATION INDEX, AND TREE GROWTH: INSIGHTS INTO SAMUR-YALAMA NATIONAL PARK, AZERBAIJAN

Yusif Abiyev[1], **Magsud Gurbanov**[2], **Farid Seyfullayev**[3]
[1,2,3] Institute of Botany of Ministry of Science and Education, Badamdar 40, AZ1004,
Baku, Azerbaijan
[1] Correspondence: yusif.abiyev@gmail.com

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Abstract. *This paper describes the complex relationships between climate variables, normalized difference vegetation index (NDVI) and annual tree growth patterns in Samur Yalama National Park in Azerbaijan. Using dendrochronology, Landsat remote sensing imagery, and statistical analysis, the study examines the growth dynamics of English oak (Quercus robur subsp. pedunculiflora) and chestnut oak (Quercus castaneifolia). Methodologically, tree-ring width orders were analysed, utilizing Principal Component Analysis (PCA) and Pearson correlation studies to discern the complex associations between climate factors (temperature, precipitation) and annual radial growth. The investigation also explored the linkages between NDVI and the radial growth of selected tree species in response to varying climatic conditions. Findings revealed distinct temperature-growth correlations across specific months, with positive associations in colder months stimulating growth and inverse relationships during warmer periods indicating differing growth responses. Precipitation analysis identified positive correlations during warmer months stimulating tree growth, contrasting with negative associations in transitional periods. Integration of NDVI data with tree-ring width indices uncovered subtle yet significant relationships, emphasizing NDVI's potential as a vegetation response indicator to climatic shifts. This study provides comprehensive insights into the profound impact of climate fluctuations and NDVI on tree growth dynamics, contributing to a foundational understanding of ecosystem resilience in Samur-Yalama National Park.*

Keywords: *Principal Component Analysis, CRU, NDVI, dendrochronology, Quercus robur subsp. pedunculiflora*

INTRODUCTION

Insights gleaned from vegetation phenology aid in comprehending the intricate interplay between vegetation, climate, and the exchange of energy and matter in terrestrial woodlands [Hmimina et all., 2013; Zhang et all., 2015]. The utilization of tree-ring width orders has long served in reconstructing past environments, understanding forest dynamics, gauging climatic responsiveness, and more recently, assessing carbon sequestration and wood efficiency [Levesque et all., 2019].

Over the last 40 to 50 years, satellite-based imagery with high temporal frequency has been extensively employed to grasp environmental processes and track vegetation dynamics in forest ecosystems [Higgins et all., 2023]. Dendrochronology methods, examining time series of tree ring widths (TRW) across multiple years, elucidate tree growth processes and their relationship to weather events [Frank et all., 2022]. These methods rely on the response of vegetation cover to radiation within the visible and near-infrared regions of the electromagnetic spectrum, with reflectance sensitivities to variations in forest growth parameters [Xu et all., 2019].

Various vegetation indices, including the widely used normalized difference vegetation index (NDVI), have been developed for monitoring and assessing vegetation status using spectral data. NDVI is particularly sensitive to alterations in plant canopy physiology, such as the development of pigment systems and leaf area, serving as a direct indicator of forest productivity [Wang et all., 2004a, 2004b]. Thus, integrating radial-increment dynamics data with remote sensing enhances the explanatory potential of these variables, facilitating the unravelling of ecological strategies employed by tree species to withstand drought stress [Siyum et all., 2018; Vicente-Serrano et al., 2020; Pompa-García et all., 2021]. Recent studies have underscored relationships between tree-ring growth and NDVI in forest ecosystems across diverse spatial and temporal scales [Kaufmann et all., 2004].

Pedunculated oak (Quercus robur subsp. pedunculiflora K. Koch) represents a primary species in dendrochronological studies globally [Cufar, 2014; Vicente, 2005; Árvai et al;., 2018; Puchałka et all., 2017]. Dendroclimatic investigations have highlighted the intricate growth responses of pedunculated oak to climate variations [Knysh & Yermokhin, 2023]. In the region under study, oak stands as a significant tree species within natural ecosystems, supporting species diversity, yet the growth dynamics of pedunculated oak remain unstudied in Azerbaijan [Abiyev et all., 2019].

This research aims to explore the potential relationship between annual growth patterns of dominant forest species, NDVI, and climatic factors. Additionally, the chestnut oak annual ring (previously collected from this area) ascertained a potential relationship with NDVI in PCA analysis. [Seyfullayev, 2013].

MATERIALS AND METHODS

Study area

Samur-Yalama National Park (SYNP), located in the Khachmaz district, approximately 200 km northeast of Baku, Azerbaijan, lies at an elevation ranging from -25 to 60 meters Above Sea Level (A.S.L.), with the Caspian Sea's actual level at -27 m A.S.L. The climate of SYNP is characterized by dry-warm summers and mild winters, representing a temperate-warm climate of semi-deserts and dry steppes, with predominantly dry summers and a limited continental influence. The average annual temperature stands at 13°C, with maximum temperatures reaching 17.5°C and minimum temperatures ranging between 1.0-1.2°C. Throughout the period from the second decade of May until the end of September (fire season), temperatures typically range from 22-24°C. Annual precipitation in SYNP averages between 300-400 mm, with 2021 recording 376.5 mm; however, evaporation rates are twice as high as precipitation levels, typical of arid regions. Solar radiation annually averages between 122-124 kilocalories/m2, while photosynthetic active radiation fluctuates between 62-64 kcal/m² yearly. Radiation intensity is notably lower under forest canopies, reducing by 3-15 times in comparison to open areas. Wind speed varies from 1 to 8 m/sec (averaging 3 to 6 m/sec) across different seasons. The coastal zone experiences an average wind speed of 5 m/sec, diminishing to 2 m/sec within forests. Prevailing winds generally blow from the northwest to southeast [Abiyev et all., 2020b].

The dominant tree species in SYNP forests include, Quercus robur subsp. pedunculiflora Carpinus betulus, and Populus hybrida. Additionally, abundant tree species such as Fraxinus excelsior, Alnus glutinosa subsp. barbata, Acer campestre, and others coexist within the local forest stands. Certain forest patches exhibit a mix of these dominant tree species (Figure 1) [Abiyev et al., 2019].

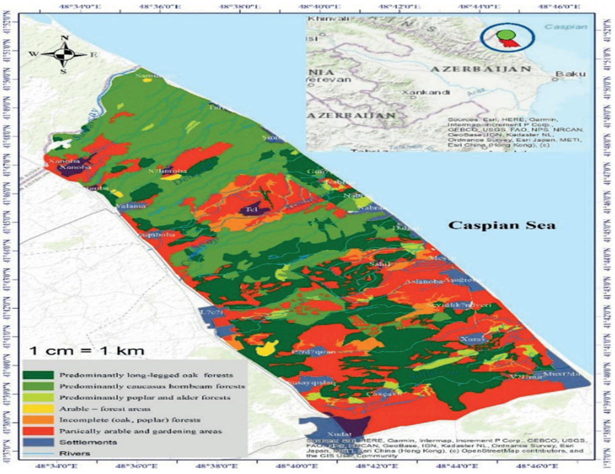

Figure 1. *Forest cover of Samur-Yalama National Park*

Collection and pre-processing of data

The sampling strategy aimed for territorial diversity within the ecosystem. One experimental area (200 m x 200 m) representing diverse ecosystems within SYNP were chosen. Increment cores were collected and air-dried, affixed onto wood mounts, and finely sanded to expose xylem structure and ring boundaries. Ring widths were visually cross-dated and measured to the nearest 0.001 mm using Lintab 6. Statistical validation of cross-dated measurements was performed using dedicated software.

Each ring-width series underwent detrending with a cubic smoothing spline, and a first-order autoregressive model was fitted in Arstan to eliminate non-climatic trends. Detrended and residual individual series were then averaged using a weighted robust mean to construct master chronologies for each species at each site. The Express Population Signal (EPS) was calculated using Cofecha to ensure adequate and representative tree sampling, with all tree-ring chronologies exhibiting EPS values ≥ 0.85, indicating a common signal among trees.

Multi-spectral images were acquired from Landsat 5 and Landsat 8 satellites at the Earth Resources Observation and Science (EROS) data centre between 1984-2019, ensuring clear sky conditions in the study area, with a preference for cloudless periods in June to maintain high plant vitality. Pre-processing techniques were applied to attenuate geometric and radiometric variations on satellite images [Abiyev et all., 2020b]. The study area boundary shapefile was utilized to extract the SYNP for band processing.

CRU TS V4 (Climatic Research Unit gridded Time Series) is a used in the analysis [Harris et all., 2020].

Analysis

Normalized Difference Vegetation Index (NDVI) calculations were performed using Landsat sensor-derived near-infrared (NIR) and red (RED) bands (Landsat 5 – Band 4/3; Landsat 8 – Band 5/4) following the formula

Temporal NDVI computations aimed to understand changes in land cover over the study period [Abiyev et all., 2020a].

Pearson correlation analysis between tree-ring width indices and NDVI spanning 1984–2019 was conducted.

Principal Component Analysis (PCA) is a multivariate statistical technique used to identify patterns in high-dimensional data and express the data in a more concise form by transforming the original variables into a set of linearly uncorrelated variables called principal components. The collected datasets, including tree ring, climate, and NDVI data, were imported into the Statistical Package for the Social Sciences (SPSS) software for analysis.

Before conducting PCA, the datasets were standardized within SPSS to ensure that all variables had a mean of 0 and a standard deviation of 1, thus removing scale effects.

Utilizing the built-in PCA procedure in SPSS, the principal components were computed based on the correlation matrix of the selected variables. In the context of PCA, rotation methods such as Varimax and Equimax were applied to enhance the interpretability of the derived principal components by altering the component loadings [Enright, 1984].

RESULTS OF STUDY

Temperature and TRW (1954-2019)

The examination of average temperatures across twelve months from 1954 to 2019 concerning the radial growth dynamics of pedunculated oak revealed notable findings through PCA analysis. This analytical approach uncovered a noteworthy connection between the annual growth rings and the climatic conditions prevailing during January, February, and March (Table 2). In addition, there is a moderate positive correlation between May and annual temperature and annual radial growth. Following this initial analysis, a subsequent rotated principal component analysis was conducted using the Varimax with Kaiser Normalization method. The outcomes of this analysis demonstrated a positive correlation between the annual growth rings and the temperatures observed in January and February. In contrast, there was an inverse relationship noted specifically concerning the months of August and September (Table 3, Figure 1). This outcome underscores the intricate relationship between the radial growth of pedunculated oak and the fluctuating temperature patterns across different months. The observed positive correlation between the annual rings and the temperatures in January and February suggests that higher temperatures during these months might stimulate or coincide with increased radial growth in pedunculated oak. Conversely, the inverse relationship noted in August and September might indicate a growth response influenced differently by lower temperatures during these months. In the other PCA columns shown in Table 1, monthly temperatures are correlated with each other, but not with annual radial growth.

It should be noted that no significant Pearson correlation has been found between the parameters. This is normal for tree species adapted to mild climate types. Considering the results of PCA, it can be concluded that extreme temperature degrees affect the growth dynamics of the pedunculated oak (Table 1). Each cell in the Table 1 represents the correlation coefficient between two variables. The values in the diagonal (where the variable is compared to itself) are always 1,000 since any variable is perfectly correlated with itself. The correlation values that are not on the diagonal indicate the strength and direction of the relationship between the respective variables.

Table 1.

Correlation between variables

Correlation	**Tree ring**	**Reproduced Correlations**	**Tree ring**
Tree ring	1.000	Tree ring	.359a
January	.197	January	.336
February	.086	February	.285
March	.121	March	.136
April	-.025	April	-.034
May	.144	May	.215
June	-.061	June	.024
July	-.093	July	-.094
August	-.070	August	-.248
September	-.179	September	-.324
October	.014	October	-.009
November	-.015	November	-.123
December	-.024	December	-.069
Yearly	.023	Yearly	.019

Table 2.

PCA among temperature and annual radial growth

Correlation	Component				
	1	2	3	4	5
Tree ring	-.271	.477	-.019	.015	-.237
January	-.057	.654	.257	.114	-.047
February	.199	.804	.068	-.066	.179
March	.412	.645	-.278	-.175	.267
April	.179	.117	.165	-.855	.106
May	.260	.315	-.206	.286	-.535
June	.568	.212	.017	.206	-.315
July	.694	.222	.016	.065	.050
August	.770	-.108	.014	.034	-.054
September	.762	-.112	.063	-.137	.253
October	-.080	-.028	.942	.086	.002
November	.131	.204	-.007	.135	.786
December	.360	.123	.150	.756	.163
Yearly	.304	.320	.829	-.275	.132

Table 3.

Rotated PCA between temperature and annual radial growth

	Component				
	1	2	3	4	5
Tree ring	-.002	.078	.570	-.080	.147
January	.362	.213	.572	.092	.010
February	.645	.165	.471	-.230	-.093
March	.662	-.092	.214	-.506	-.123
April	.256	.565	-.283	-.513	.295
May	.227	-.487	.357	.096	.390
June	.504	-.353	.037	.178	.312
July	.678	-.228	-.147	.008	.067
August	.537	-.308	-.426	.092	.189
September	.598	-.101	-.556	-.054	-.014
October	.137	.639	-.020	.687	.053
December	.419	-.381	.101	.555	-.356
November	.366	.098	-.056	-.124	-.730
Yearly	.624	.701	-.059	.266	.140

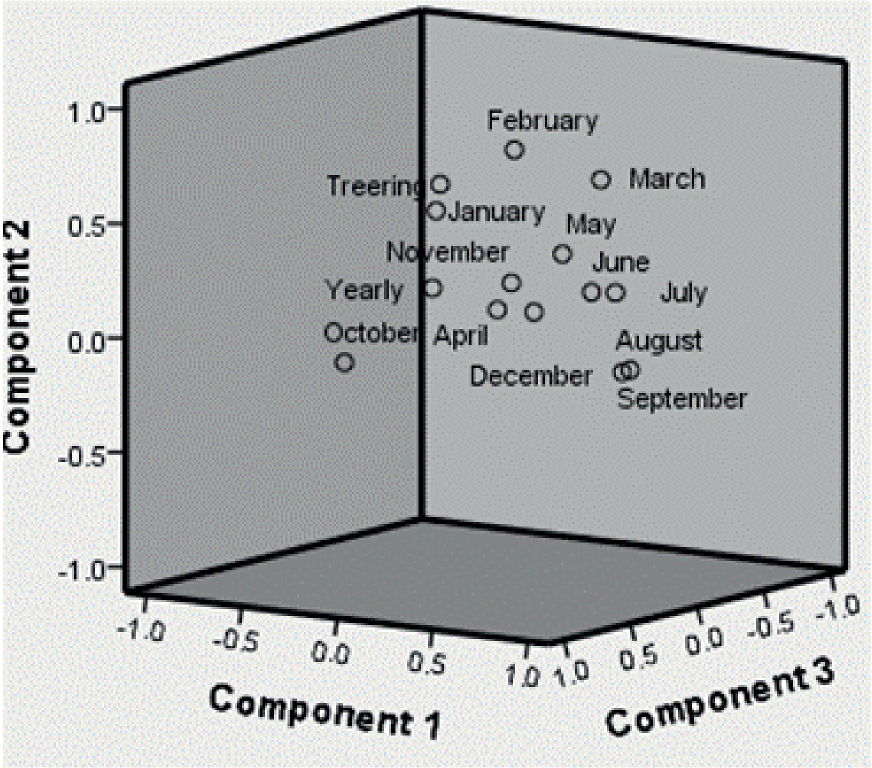

Figure 2. *Forest cover of Samur-Yalama National Park*

Precipitation and TRW (1954-2019)

The analysis conducted on annual rings of precipitation and the corresponding annual precipitation data spanning from 1954 to 2019 revealed noteworthy relationship between these variables. Specifically, a positive relationship was observed with the months of June, July, and August, indicating a potential influence of increased precipitation during these months on annual ring growth. Conversely, a negative relationship was identified with precipitation in February and October on PCA 1. According to PCA 2, there is a positive relationship with April and October, and a negative relationship with November. Other PCA columns have correlations below 0.400 (Table 5). Furthermore, utilizing the Varimax with Kaiser Normalization method in rotated PCA analysis unveiled a specific relationship between annual ring width and July precipitation. This isolated association highlights the potential dominance or singular impact of July precipitation on tree ring width, suggesting a stronger correlation between the growth patterns and precipitation during this particular month (Table 6, Figure 3). These findings suggest a seasonally dependent impact of precipitation on annual ring width, highlighting the significance of specific months in driving tree growth responses to varying precipitation patterns. The observed positive relationship between annual ring width and precipitation during June, July, and August aligns with the known periods of active growth for many tree species. Increased moisture availability during these warmer months could stimulate growth and lead to wider annual rings. Conversely, the negative relationship with precipitation in February and October may reflect contrasting growth responses, possibly due to variations in water availability and temperatures during these transitional periods.

Table 4.

Correlation between variables

Correlation	Tree ring	**Reproduced Correlations**	Tree ring
January	-.039	January	-.007
February	-.330	February	-.421
March	-.070	March	.018
April	.085	April	.098
May	-.131	May	-.281
June	.033	June	.105
July	.217	July	.353
August	.151	August	.197
September	-.010	September	-.056
October	.047	October	.152
November	-.185	November	-.277
December	.074	December	.117
Yearly	-.224	Yearly	-.253
Tree ring	1.000	Tree ring	.715a

Table 5.

PCA between precipitation and annual radial growth

Correlation	Component					
	1	2	3	4	5	6
January	.020	.154	.251	-.730	-.193	.285
February	.710	-.450	-.098	-.044	.003	.145
March	.665	.119	.022	.242	.113	.194
April	.433	.219	.433	-.087	-.016	-.048
May	.477	.219	.027	-.271	-.044	-.507
June	.062	.572	.070	-.291	.117	-.368
July	.090	.583	-.032	.292	-.232	.429
August	.231	.624	-.107	.286	.131	-.260
September	.236	-.035	.348	.170	-.609	.103
October	-.028	-.405	.497	.424	.298	-.297
November	.127	.132	-.772	.184	-.084	-.011
December	.221	-.005	-.114	-.311	.685	.351
Yearly	.956	-.083	.056	.081	.045	.056
Tree ring	-.306	.437	.410	.272	.309	.305

Table 6.

Rotated PCA between precipitation and annual radial growth

Correlation	Component					
	1	2	3	4	5	6
January	-.026	.084	-.017	.138	.843	.020
February	.760	-.189	-.347	-.056	.035	.031
March	.699	.093	.231	-.054	-.101	.031
April	.382	.346	.132	.322	.172	-.128
May	.267	.668	-.282	-.011	.072	-.077
June	-.134	.713	.093	.011	.150	.107
July	.127	.037	.718	-.286	.112	-.213
August	.110	.583	.376	-.205	-.291	.011
September	.258	-.090	.099	.130	.144	-.683
October	.061	-.109	-.125	.653	-.558	-.032
November	.074	.023	-.020	-.782	-.221	.063
December	.289	-.051	.061	.038	.191	.789
Yearly	.949	.165	-.079	.002	-.025	-.031
Tree ring	-.202	-.002	.723	.347	-.060	.164

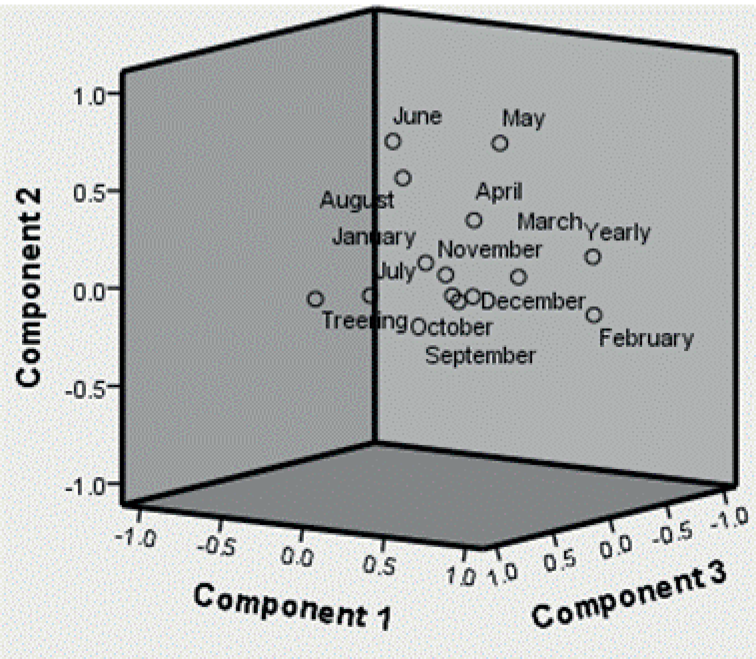

Figure 3. *Component plot in rotated space (Precipitation and TRW)*

NDVI and TRW (1984-2019)

The NDVI values collected within the sampled area exhibited a direct correlation below 0.40 with both the pedunculated oak, chestnut-leaved oak, and climate data. Despite this, the standard PCA analysis revealed a significant positive relationship between NDVI and the radial growth of pedunculated oak, particularly concerning the temperatures observed in October and November (Table 8). Additionally, upon employing a rotated analysis using the Equamax with Kaiser Normalization method, an evident link emerged between NDVI values and chestnut oak specifically concerning temperatures in October. Similarly, this analysis highlighted a positive correlation between NDVI and pedunculated oak, concurrently demonstrating a negative association with temperatures in August (Table 9, Figure 5). It can be said that there is a moderate Pearson correlation between the parameters. However, there is a moderate connection between the radial growth of the long-needle pine and the fir tree with NDVI, which is noticeable. Only the Reproduced Correlation shows a weak connection with some months.

Table 7.

Correlation between variables

Correlation	NDVI	PO	CO	**Reproduced Correlation**	NDVI	PO	CO
NDVI	1,000	,336	,334	NDVI	.745a	,403	,451
PO	,336	1,000	,057	PO	,403	.789a	-,011
CO	,334	,057	1,000	CO	,451	-,011	.643a
January	-,087	,014	,198	January	-,126	,046	,226
February	-,213	-,183	,082	February	-,226	-,219	,165
March	-,164	-,123	-,017	March	-,149	-,165	,008
April	-,286	-,133	-,237	April	-,342	-,163	-,276
May	,085	,039	,073	May	-,003	-,009	,163
June	,058	,170	,098	June	,054	,213	,239
July	-,203	,140	,037	July	-,235	,242	-,120
August	-,075	-,169	,282	August	-,089	-,295	,297
September	-,170	-,126	,016	September	-,206	-,115	-,059
October	,195	-,006	,157	October	,308	,091	,336
November	,126	,147	-,016	November	,186	,177	-,053
December	,132	,209	,132	December	,185	,312	,171
Yearly	-,277	-,109	-,119	Yearly	-,319	-,121	-,121

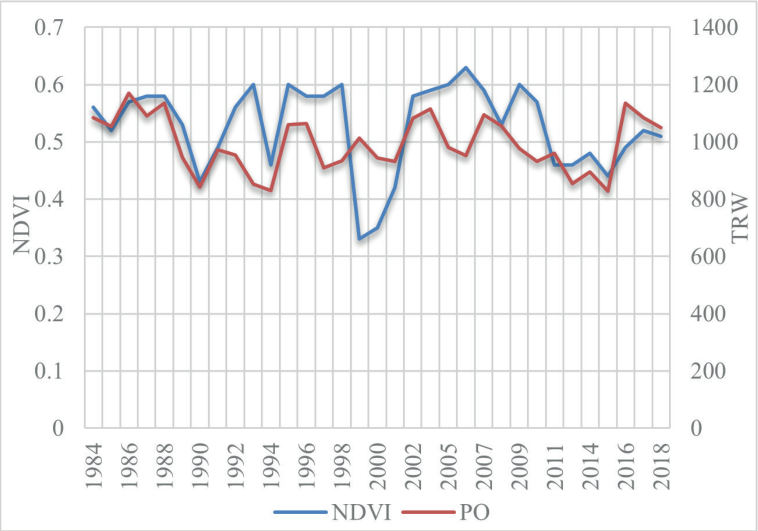

Figure 4. *Fluctuation of NDVI and TRW*

Table 5.

PCA among NDVI, TRW, monthly temperature

	Component					
	1	2	3	4	5	6
NDVI	-.357	.360	.658	-.098	.090	-.195
PO	-.193	.292	.551	.167	-.040	.577
CO	-.017	.472	.214	-.231	.427	-.371
January	.185	.159	-.181	.280	.785	.209
February	.626	.144	-.132	.462	.372	-.225
March	.731	.073	.109	.112	-.227	-.232
April	.572	-.686	.175	-.094	.105	.124
May	.139	.616	-.249	.200	-.159	-.112
June	.271	.382	.038	-.382	.234	.358
July	.563	.380	-.086	.030	-.206	.474
August	.467	.481	-.262	-.448	-.125	-.227
September	.634	.032	.021	-.258	-.271	.032
October	.317	.085	.479	-.414	.147	-.108
November	.297	-.044	.512	.567	-.223	-.241
December	.062	.741	.002	.280	-.190	.090
Yearly	.868	-.340	.183	.002	.110	.084

PO-Pedunculated oak, CO-Chesnut oak

Table 6.

Rotated PCA among NDVI, TRW, monthly temperature

Correlation	Component					
	1	2	3	4	5	6
NDVI	-.218	.143	.029	-.204	.687	.403
PO	.137	.110	.008	-.024	.093	.865
CO	-.028	.195	-.076	.216	.735	-.106
January	-.008	-.005	-.126	.898	.043	.077
February	.059	.130	.511	.693	.003	-.265
March	.374	.049	.674	.044	.032	-.265
April	.250	-.787	.356	.118	-.170	-.109
May	.162	.688	.108	.116	.005	-.122
June	.594	.037	-.233	.233	.264	.128
July	.730	.264	.186	.171	-.213	.157
August	.587	.330	.003	-.030	.276	-.506
September	.612	-.084	.317	-.109	-.002	-.224
October	.331	-.267	.169	-.046	.574	.022
November	-.183	.046	.835	-.028	.034	.215
December	.201	.742	.144	.089	.065	.228
Yearly	.478	-.511	.569	.293	-.059	-.142

Pedunculated oak, CO-Chesnut oak

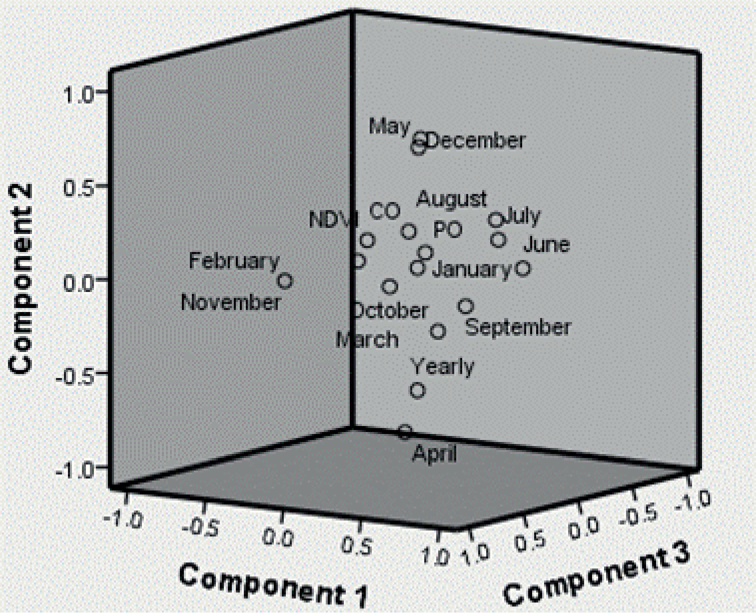

Figure 5.*Component plot in rotated space (NDVI, Temperature and TRW)*

DISCUSSION

The study's comprehensive approach integrating climate data, NDVI, and tree-ring width measurements unveiled complex and sometimes contrasting relationships. The findings suggest seasonally dependent impacts of temperature and precipitation on tree growth, highlighting specific months' significance in driving growth responses. The observed positive correlations during active growth periods align with known tree growth patterns influenced by moisture availability and temperature.

The moderate correlations between NDVI and tree growth suggest a more intricate relationship, possibly influenced by additional factors beyond the scope of this study. The significant associations with specific months further emphasize the need for a nuanced understanding of seasonal variations in environmental conditions for accurate predictions of tree growth dynamics.

Research in these types of forests has been limited in Azerbaijan and the Caucasus, so examples from similar works around the world are mainly referenced. However, in previous research on artificially planted Scots pine forests in the same area, no correlations were found between annual rings and climate. This is attributed to the proximity of groundwaters to the surface in the artificially planted Scots pine forest and the lack of stress on the trees [Seyfullayev, 2013]. Similar thoughts can be said for the longleaf pine. In the areas from the Caucasus Mountains to the Caspian Sea, both surface and groundwater approach the surface, resulting in a decrease in flow velocity. Also, when paying attention to climate values, it is evident that anomalous climate values are not a common occurrence in the area. In the future, it can be anticipated that a significant decrease in water reserves will affect the radial growth dynamics of plants.

The main correlation found in oak tree rings chronologies is a positive relationship with precipitation among hot months. However, the response to summer temperatures varies from site to site, with the correlation being either negative or positive [Cufar et al., 2008; Cufar et al., 2014; Netsvetov et al., 2017]. Cook et al. [2004] conducted a comprehensive dendroclimatology study examining the sensitivity of tree-ring growth to climate variability, highlighting the significance of temperature fluctuations in driving tree growth dynamics. Cook et al. [1999], Liu et al., [2019], Roibu et al., [2020], Yu et al., [2023] etc. conducted dendroclimatic analyses and observed a significant sensitivity of tree growth to temperature variations. They noted a positive correlation between warmer temperatures during the growing season and wider tree rings across diverse tree species. Conversely, colder temperatures or temperature extremes during crucial growth periods were associated with reduced radial growth. Hughes et al. [1984] emphasized the seasonality of temperature effects on tree growth. Their research highlighted the importance of differentiating temperature impacts during specific months of the year. For instance, warmer temperatures in the spring correlated positively with increased tree growth, while colder temperatures during the summer or autumn showed negative effects on radial growth patterns. Schweingruber [1988] documented dendrochronological studies conducted across various geographical regions, demonstrating that temperature influences tree growth differently based on local climate conditions. For example, in temperate regions, temperature primarily during the growing season significantly impacted tree-ring width. In contrast, in subarctic regions, the sensitivity of trees to temperature shifts varied based on factors like moisture availability and soil conditions.

O'Donnell et all. [2021]: Investigated tree-ring width responses to precipitation variability across continental regions, emphasizing the complex relationship between precipitation patterns and tree growth. Cook's research [Cook et all., 2004] has shown positive correlations between tree ring width and precipitation in certain regions. For instance, in some areas where precipitation positively influences tree growth, wider tree rings tend to occur during years with higher precipitation levels. These studies often involve dendroclimatology, which analyses tree rings as climate proxies. Roibu et all. [2020] reveal that oak tree rings, particularly the latewood (LW), exhibit a moderate negative correlation with maximum temperatures in July and a positive correlation with precipitation from the previous December through the current spring to June. These temperature influences induce physiological changes in both species, affecting transpiration rates and chloroplast function and ultimately impacting photosynthesis and radial growth.

Several investigations have highlighted the robust associations between NDVI and annual growth [Bunn et al., 2013; Vicente-Serrano et al., 2015]. A study focusing on the central Great Plains region of North America demonstrated a substantial correlation between Oak tree-ring width and NDVI [Wang et all., 2004a]. Vicente-Serrano et all. [2016] and Seiler et all., [2017] similarly observed an overarching positive link between inter-annual NDVI variability and annual tree growth in most global forests studied, although they noted significant disparities in the relationships between tree growth and NDVI values. In line with these findings, studies conducted in Siberia [Kirdyanov et all., 2007; Bunn et all., 2013], along with works Kaufmann et all., [2018], have also indicated positive connections between NDVI and tree growth, displaying varying strengths of correlations. Salzer et all. [2014] delved into the influence of temperature stress on tree growth via tree-ring analysis, underscoring NDVI's role as an indicator of vegetation response to climate shifts. Likewise, Levesque et all. [2019] explored the relationships between NDVI and tree growth across different forest ecosystems, emphasizing the correlation between NDVI fluctuations and tree-ring width.

CONCLUSION

The application of PCA analysis has been pivotal in uncovering profound insights into the intricate connections among tree growth dynamics, climate variables, and NDVI within the Samur-Yalama National Park. Notably, this study delineated the critical associations between annual growth rings and specific climatic conditions, emphasizing the paramount influence of temperature fluctuations and precipitation patterns on the radial growth of dominant tree species, specifically the pedunculated oak (Quercus robur subsp. pedunculiflora) and chestnut oak (Quercus castaneifolia).

Key Findings:

1. Temperature and Tree Ring Width (TRW) Relationship:

One of the key revelations lies in the distinct correlations observed between temperature and tree-ring width (TRW) across various months. Positive associations during January and February indicate a potential stimulative effect on pedunculated oak radial growth during these colder months, while inverse relationships with lower temperatures in August and September reveal a differing growth response during warmer periods. These findings underscore the nuanced relationship between temperature fluctuations and the growth dynamics of these tree species, particularly highlighting potential impacts during extreme temperature phases.

2. Precipitation and TRW Relationship:

Moreover, the study underscores the seasonally dependent influences of precipitation patterns on annual ring width. Positive correlations with precipitation during the warmer months of June, July, and August suggest significant stimulative effects on tree growth, aligning with periods of active growth. Conversely, negative associations with precipitation in February and October point to contrasting growth responses, possibly influenced by variations in water availability and transitional temperatures.

3. NDVI and TRW Relationship:

Integration of NDVI data with tree-ring width indices revealed a moderate Pearson correlation. Specifically, significant positive correlations were identified between NDVI and the radial growth of pedunculated oak and chestnut oak concerning specific temperature patterns, highlighting the potential of NDVI as an indicator of vegetation response to climatic shifts.

The study's findings serve as a crucial foundation for further exploration into the ecological strategies employed by dominant tree species in adapting to environmental stressors.

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