Spruce tree-rings growth and Gilgit River flow correlation in Himalayan from Northern area of Pakistan

MUHAMMAD WAHAB[*, 1], MOINUDDIN AHMED[2], NASRULLAH KHAN[3] , SIRAJ AHMAD[4] HAFIZ ULLAH[5] and TURE JAN[6]

[1]*Department of Botany, Women University Swabi, Khyber Pakhtunkhwa, Pakistan.*

[2]*Federal Urdu University of Arts, Science and Technology, Gulshan-e-Iqbal Campus Karachi 75300, Pakistan.*

[3]*Department of Botany, University of Malakand, Khyber Pakhtunkhwa, Pakistan*.

[4]*Department of Botany, Government Jehanzeb Post Graduate College, Saidu Sharif Swat, Khyber Pakhtunkhwa, Pakistan.*

[*]Correspondence Author:

E-mail: m_wahabdir@yahoo.com

Tel.: 03432044432

Abstract

Picea smithiana (Wall.) Boiss trees were sampled from Jutial a nearby valley to Gilgit City. The forest was located on 2930 altitude between coordinates N 35.25˚ and E 74.10˚ in steep ridge of mountain. About 40 samples were taken from 20 old and healthy trees. These samples were prepared, cross matched and measured in the laboratory following standard Dendrochronological methods. The crossdating accuracy was confirmed by the Cofecha program. We obtained 0.67 series intercorrelation and 0.36 mean sensitivities. A higher values of inter serial correlation shows the strength of common climatic signal while mean sensitivity indicate high variability in ring-width patterns, although lower values are more desirable. A dated tree ring chronology of about last five hundred years (1518-2008A.D) was developed using tree ring software Arstan (a Standardized program). The stream water of the said valley falls in the river Hunza near Gilgit city. Recorded River flow data from the same river was handled of below nearest catchment from WAPDA. A twelve months river flow data of 38 years (1966-2004) of the above mentioned river Dainyor and residual chronology version tree-ring series relationship was established. Correlation coefficient indicated that water flow and trees radial growth has direct relationship in January and March. While water flow and growth showed negative response in the months of pervious November, current February and August. All of these significant months explained 39% variance. The rest of months have no significant relationship. However, this is the preliminary results, it is suggested that more sites and species should be explore for better achievements.

Keywords: Spruce, tree-ring chronology, Gilgit, river flow, correlation

Introduction

According to World Bank, 2005 report that Pakistan is included in the top most arid country of the world because it receives less rainfall. The people of Pakistan are greatly dependent on the annual rainfall for their economy. A severe decline in the rivers water flow created a great threat to Pakistan-especially ones of unprecedented severity and duration (so-called "mega droughts"). Some evidences has shown strong bad effect on the life of previous civilizations due to droughts that they faced in the past e.g. Indus. The study related to sustainable management of the water resources is of much importance to understand their natural fluctuation. Available instrumental river discharge records of the Indus River are very short interval less than 40 years and it is difficult to model about the future climatic conditions. And it is challenged of the world scientists. The alternate strategy as proxy climatic data to provide long records is adopted by USA experts and other developed countries scientists. The suitable proxy climatic records in the form of tree-rings have disclosed some valuable information about past and future climatic trends. The science which deals with various past climatic events with the help of tree-rings is called Dendrochronology and its sub branch is Dendrohydrology, which deals with hydrological problems, using annual growth rings of trees. In these studies stream flow, flood height, water table changes, drought years age of delta, sedimentary deposits or energy are determined or reconstructed. In Northern areas of Pakistan there are growing conifer forests in the wide range and we can obtain long tree-ring record. Ahmed. 1989; Ahmed & Naqvi. 2005; Ahmed & Sarangzai. 1991b developed Tree-rings chronologies of *Abies pindrow* and *Picea smithiana* respectively. It is used for determining age and growth rates of forests (Ahmed. 1988; Ahmed & Sarangzai. 1991a; Ahmed et al. 2009a; Wahab et al. 2012). Some workers evaluated a few conifers species growth with climate responses (Ahmed et al. 2009b; 2010a; 2010b; 2011; 2012). Climate of Northern Pakistan was also described by Esper. 2000; Esper et al. 1995 and Treydte et al. 2006. No dendrohydrological work has been carried out so far in Pakistan. In this paper, for the first time, a conifer species growth was correlated with river flow record. This study will tell us about the reconstruction of Hunza river flow and will also provide information for the management of the river as well as provide a baseline from which to evaluate scenarios of future climatic change.

Material and methods

A conifer forest of *Picea smithiana* from in the basin area of Hunza River near Gilgit City (Fig.1). Old and healthy trees were selected for sampling. Two cores from each tree were obtained. During field and laboratory works followed standard dendrochronological methods that mentioned by Stokes & Smiley. 1968; Fritts. 1976; Cook & Kairiukstis. 1990; Speer. 2010. All cores were visually crossdated under binocular microscope and measured on Velmex equipment. COFECHA software was used to confirm crossdating statistically (Holmes. 1983; Grissino-Mayer. 2001). Various versions of tree-ring chronologies (raw, standard, residual and arstan) were developed by applying computer program ARSTAN (Cook. 1985). Among various versions, residual tree-ring growth chronology and recorded data of river Hunza was examined by using the tree-ring software DPL (Dendrochronological Program Library) to find out their relationship. This program was designed by Holmes. 1992.

Result and discussion

Thirty seven cores out of forty were successfully crossdated. All samples showed some similar and some distinct characteristics. No missing or double rings were found in all cores. Some common extreme narrow rings (pointer years) were observed i.e. 1549, 1595, 1626, 1677, 1734, 1785, 1810, 1871, 1909, 1915, 1971, 1985, 2001 and 2008 (Fig .2). The important statistics of COFECHA program of each series are listed in Table.1. Low mean growth and high sensitivity of tree-rings are more valuable because they provide us the information about long record and growth variability. Here, I found the mean ring width and their standard deviation as 0.73-1.16 mm per year or ring and 0.302-0.694 respectively. The mean sensitivity was ranged about 0.249 to 0.407. The present site mean sensitivity is within the range of 0.150-0.650 that cover the value of various regional conifers chronologies that described by many workers (Ahmed et al. 2011; 2012; Khan. 2011; Wahab. 2011). The values of correlation with master series and autocorrelation were measured about 0.721-0.968 and 0.411-0.914 respectively. While the autocorrelation gives details about the effect of last year's growth on the present year's growth. It also varies site to site and species to species. After applying cofecha program, ring width series were subjected to ARSTAN (standardization program) to standardize the raw tree-ring width data of all samples. Here four different versions of chronologies were produced (Table.2 and Fig.3). Mean sensitivity was attained about 0.341 with serial correlation about 0.715. Similarly, skewness and kurtosis coefficients were calculated 1.355 and 5.569 respectively. In standard version of chronology the tree-ring measurements of samples were detrended by curve-fitting to remove a large part of the variance due to causes other than climate. Mean index of this standardized series was gained about 0.975 and standard deviation was attained 0.324. Mean sensitivity and serial correlation values were attained about 0.336 and 0.340 respectively. Similarly, skewness and kurtosis coefficients reduced to -0.107 and 3.118 respectively. In case of residual tree-ring chronology data was standardized statistically using autoregressive modeling to remove autocorrelation. Mean index of raw series was calculated 0.994 and standard deviation was determined 0.304. Mean sensitivity was attained slightly higher about 0.381 than other version of chronologies and serial correlation was compressed into -0.053 due to removing lag effect from series. Likewise, skewness also reduced to -0.438 and a kurtosis coefficient was obtained about 3.128. Such as arstan chronology contains stronger common signals among a large proportion of series as compare to residual. Here, the value of mean index was obtained about 0.995 with standard deviation was gained 0.330. Mean sensitivity become low about 0.322 and serial correlation increased of 0.390. I have obtained the values of skewness and kurtosis -0.083 and 3.128 respectively. In the next step, among various versions, residual chronology of *Picea smithiana* and river water flow data about 38 years (1966-2004) of nearest Catchment at Dainyor was correlated. The correlation coefficient explained total variances of 39%. The results declared that river flow in January and March showed positive relationship with forest growth. While water flow and growth showed negative correlation in the months of pervious November, current February and August (Fig.4). The present study, residual version chronology was correlated because this series does not contain lag effect of previous years. However, standard chronology does not have autoregressive modeling and the arstan chronology relatively contains strongest possible climate signals (Cook. 1985). The raw tree record contains unwanted frequencies related to trees age and undesirable environmental signals which need to remove or filter in time series analysis that provide us clear climatic indications (Cook & Kairiukstis. 1990). During January and March rapid water flow support growth may due to heavy rainfall in area. In November and August more water flow do not support growth due to melting of glacier in high temperature. These results are supported by the findings of Ahmed et al. (2010b; 2010a) from *Picea smithiana* at Astore, northern Pakistan and from *Abies pindrow* at Murree Ayubia in located in moist temperate region. While, the present forest is situated in dry temperate region relatively at high altitude. The current study revealed that theses two variable hold strong relationship and could be used for reconstruction of previous about five river flow proxy data.

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Table. 1. Summary of COFECHA Statistics of each core.

S.No	Cores	Years Interval	No of Years	[1]Mean Msmt	[2]Std dev	[3]Mean Sens	[4]Corr With master	[5]Auto Corr
1	psjl1.1	1552-2007	456	0.86	0.439	0.394	0.952	0.645
2	psjl1.2	1591-2005	415	0.92	0.433	0.407	0.945	0.517
3	psjl2.1	1568-2008	441	0.93	0.449	0.389	0.941	0.543
4	psjl2.2	1580-2008	429	0.9	0.413	0.396	0.935	0.496
5	psjl3.1	1535-2008	474	0.97	0.553	0.382	0.951	0.737
6	psjl3.2	1564-2008	445	0.9	0.455	0.369	0.952	0.63
7	psjl4.1	1613-2006	394	0.74	0.307	0.396	0.933	0.419
8	psjl4.2	1782-2007	226	0.73	0.328	0.403	0.849	0.532
9	psjl4.3	1570-1789	220	0.85	0.39	0.401	0.957	0.522
10	psjl5.1	1550-2008	459	0.8	0.424	0.39	0.941	0.66
11	psjl5.2	1523-2008	486	1.01	0.575	0.383	0.944	0.729
12	psjl6.1	1551-2008	458	0.8	0.377	0.39	0.962	0.554
13	psjl6.2	1537-2008	472	0.86	0.481	0.38	0.925	0.704
14	psjl7.1	1540-2008	469	0.82	0.451	0.386	0.961	0.71
15	psjl7.2	1531-2005	475	0.86	0.458	0.368	0.951	0.702
16	psjl8.1	1660-2008	349	0.76	0.302	0.39	0.959	0.411
17	psjl8.2	1530-2008	479	0.86	0.441	0.374	0.965	0.675
18	psjl9.1	1550-2005	456	0.84	0.395	0.375	0.948	0.594
19	psjl9.2	1548-2008	461	0.84	0.379	0.379	0.962	0.562
20	psjl10.1	1541-2008	468	0.85	0.476	0.361	0.957	0.738
21	psjl10.2	1560-2008	449	0.75	0.32	0.397	0.968	0.472
22	psjl11.1	1780-2008	229	0.88	0.419	0.317	0.743	0.725
23	psjl11.2	1740-2007	268	0.89	0.422	0.313	0.894	0.689
24	psjl12.1	1700-2008	309	1	0.559	0.33	0.882	0.707
25	psjl12.2	1724-2008	285	1.04	0.527	0.307	0.886	0.745
26	psjl13.1	1730-2008	279	0.9	0.431	0.303	0.893	0.716
27	psjl13.2	1710-2008	299	1.02	0.517	0.334	0.834	0.716
28	psjl14.1	1730-2008	279	0.98	0.469	0.322	0.892	0.699

29	psjl14.1	1710-2008	299	0.98	0.515	0.318	0.895	0.765
30	psjl16.1	1750-2008	259	0.87	0.515	0.312	0.891	0.835
31	psjl16.2	1716-2008	293	0.92	0.445	0.31	0.84	0.725
32	psjl17.2	1810-2006	197	0.96	0.5	0.35	0.813	0.696
33	psjl18.1	1730-2008	279	1.15	0.642	0.249	0.789	0.897
34	psjl18.2	1764-2008	245	0.95	0.43	0.268	0.807	0.798
35	psjl19.1	1837-2008	172	0.75	0.449	0.298	0.852	0.856
36	psjl20.1	1740-2008	269	1.16	0.694	0.253	0.814	0.906
37	psjl20.2	1741-2008	268	1.09	0.669	0.261	0.721	0.914

Note: 1= Mean ring width, 2 = Standard deviation, 3= Mean sensitivity, 4= correlation with master chronology, 5 = Autocorrelation,

Table 2. Summary Statistics of various chronologies of *Picea smithiana* developed by a tree-ring program ARSTAN (Autoregressive standardization).

Time Interval (Years)	Chronology	Mean index	Standard deviation	Skewness coefficient	Kurtosis coefficient	Mean sensitivity	Serial correlation
1523-2008.A.D (486)	Raw	0.929	0.465	1.355	5.569	0.341	0.715
	Standard	0.975	0.324	-0.107	3.118	0.336	0.340
	Residual	0.994	0.304	-0.438	3.331	0.381	-0.053
	Arstan	0.995	0.330	-0.083	3.128	0.322	0.390

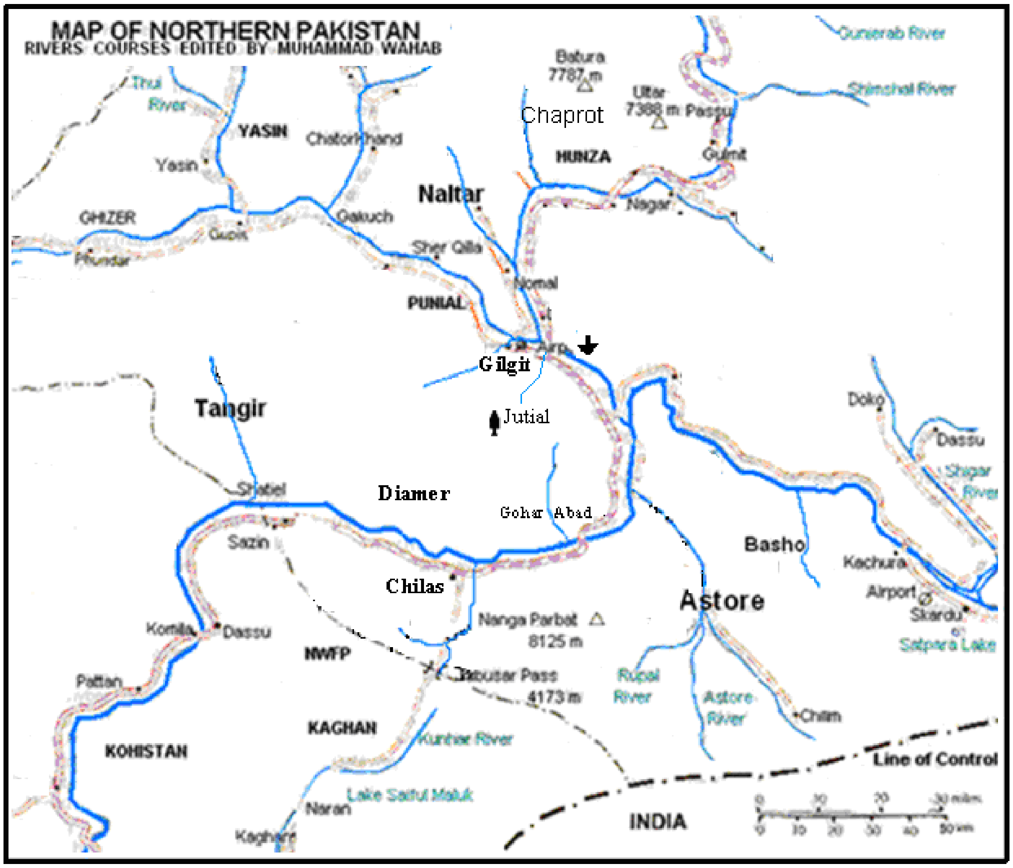

Fig.1. Map showing Sampling site (♟) and river flow catchment (⬇).

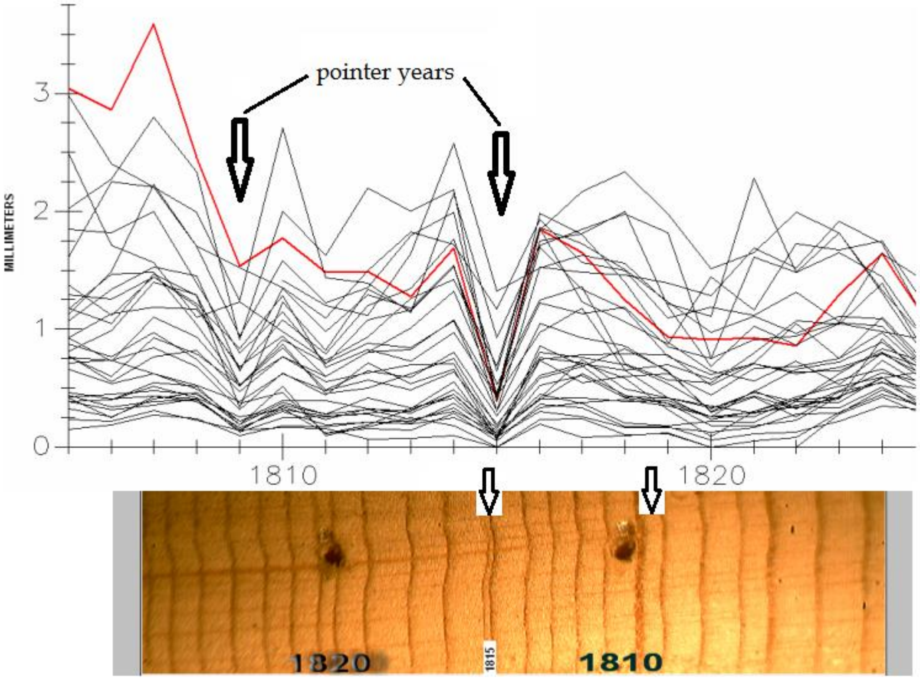

Fig.2. Magnifying pieces of core and line graph representation of all samples showing pointer years (1809 and 1815).

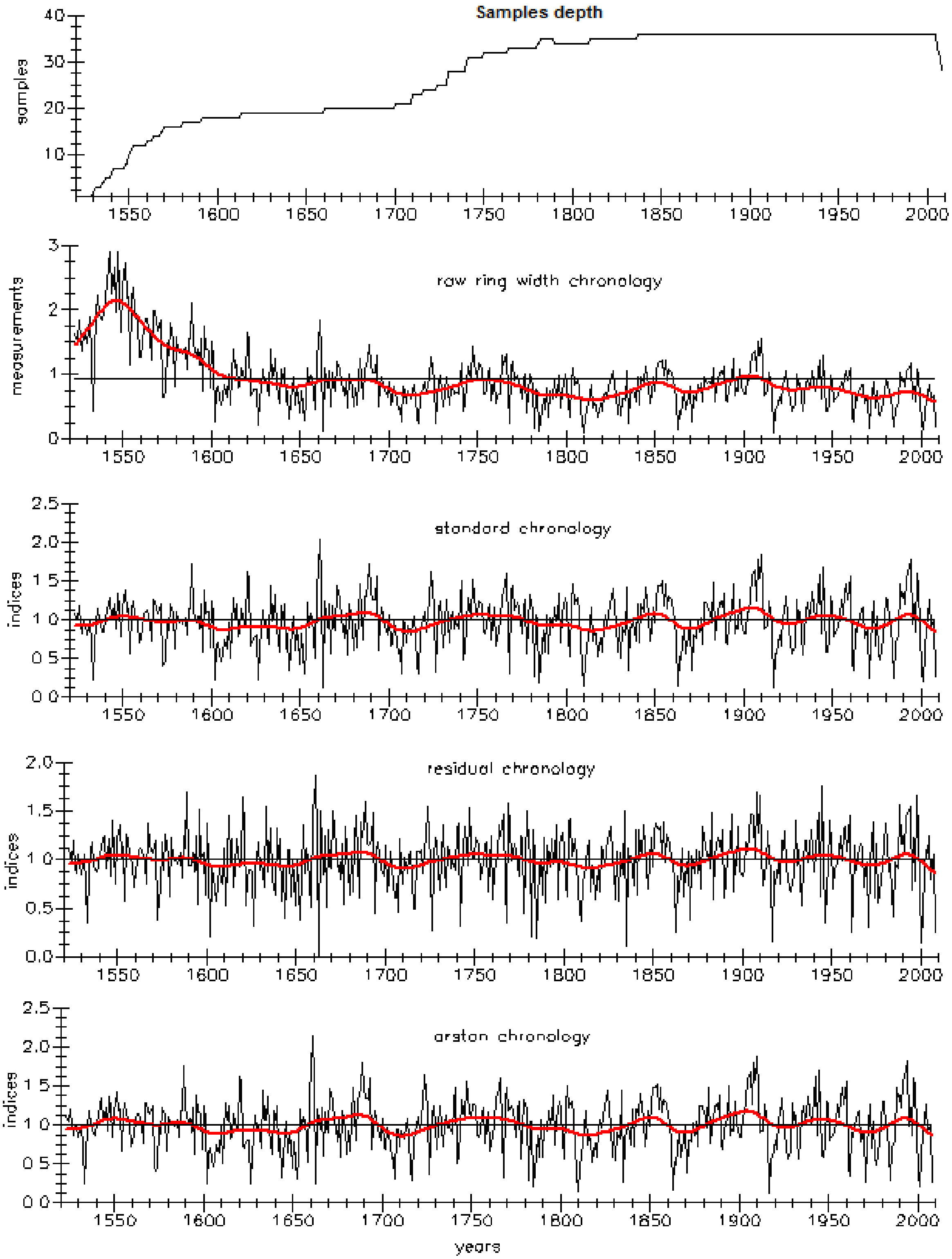

Fig. 3. Graphs showing about Jutial *Picea smithiana* samples size and its different versions of tree-ring width chronologies.

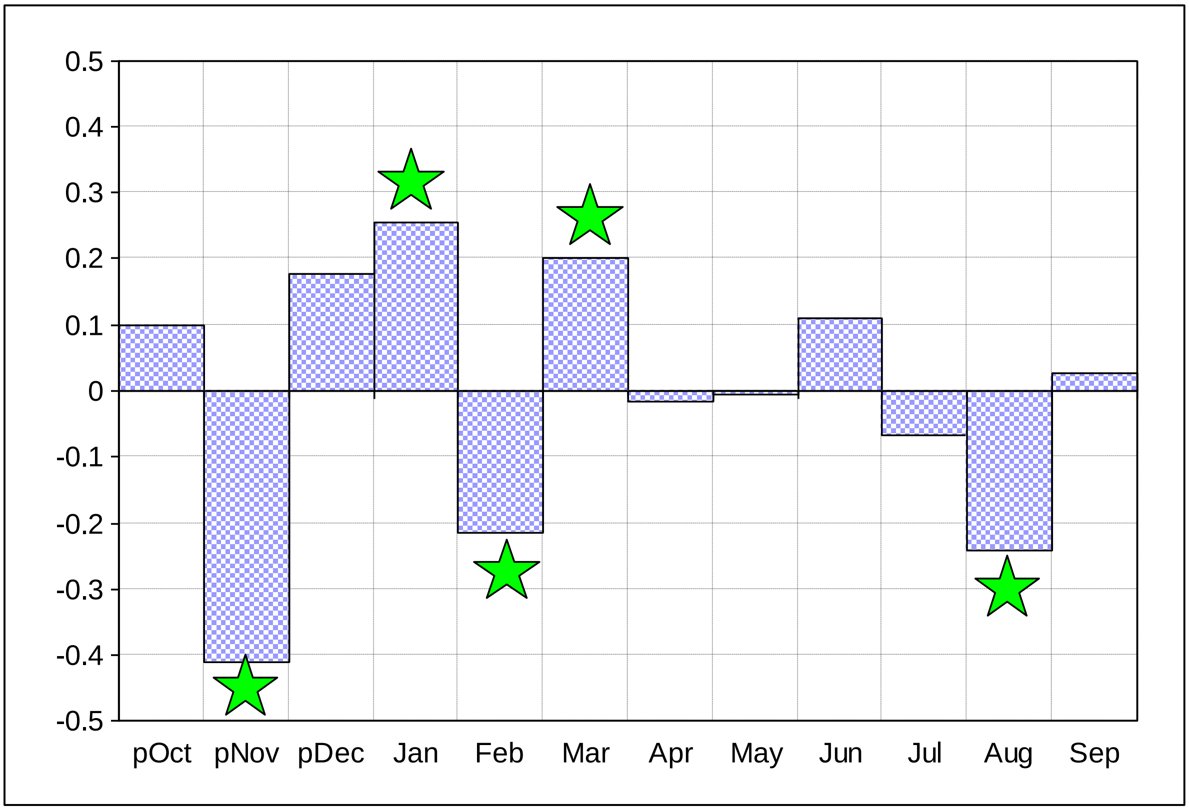

Fig.4. *Picea smithiana* tree-ring width residual chronology and Hunza river water flow correlation function.