Research Article

3000 Years Late Holocene Vegetation History and Dynamics of Gymnosperms and Herbs in the Hindu Kush Mountains of District Swat in Northern Pakistan

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Abstract | This Palaeoecological research project was carried out in the Kabal Valley of Swat District in Northern Pakistan, located in the Hindu Kush Phytogeographic region. Using a hand-operated Russian corer, a 150 cm long terrestrial soil core was taken and radiocarbon-dated. Application of Faegri and Iverson´s 1989 protocol on 38 soil samples (0.5 cm^3 each), followed by microscopic counting of preserved pollen on the slides revealed that Conifers like Pinus, Picea and Taxus remained temporally dominant species on these mountains, starting from present time (2022) going back till 500 calibrated years before present (cal.yrs. BP). A drastic decrease in the abundance of Conifers coupled with the simultaneous spread of different herb species, belonging to Poaceae, Cyperaceae, and Amaranthaceae families, was found from 500 back till 900 cal. yrs. BP. Further back in the late Holocene period from 900 to 2000 cal. yrs. BP, herbs belonging to Poaceae, Cyperaceae, and Amaranthaceae dominated these mountains with a little cover of Conifers represented by Taxus and Picea. Both Conifers and herbs remained frequent during the past from 2000 to 3000 to cal. yrs. BP. Finally, isolation of the different climate indicator species revealed that Pinus (among Conifers) and Poaceae species (among herbs) remained abundant during the past 3300 years, in the temporally fluctuating communities growing on these remote Hindu Kush mountains of South Asia.

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Introduction

Palaeoecological studies carried out in South Asia revealed that this region is represented by the Gondwana, Tethyan, and Boreal characteristics having a variety of flora and fauna (Shi *et al.*, 1995). Paleo-floristic and paleo-climatic findings in China have revealed a gradual increase in the intensity of

monsoons resulting in differential preservation of pollen grains in surface samples (Zhao *et al*., 2009; Wang, 1994). It has been reported that the Asian dipterocarps must have originated in Gondwana and later dispersed from India into the rest of Asia (Dutta *et al*., 2011). Evidence of this dispersal is revealed by the behavior of the Himalayan tree line ecotones which have been sensitive to Holocene climate change (Yadav *et al*., 2004; Schickhoff *et al*., 2016). Under the impact of climatic change coupled with increasing anthropogenic activities, forests in the Hindu Kush converted into dwarf shrublands (Miehe *et al*., 2009).

The Swat Valley (35.2227˚ N, 72.4258˚ E) is considered the isolated Hindu Kush (36.8922˚ N, 73.2633˚ E) heaps in Pakistan (Jan *et al*., 2015a, b, 2019). This valley is a standout amongst the scenic places of the sub-continent and is truly known as the Switzerland of the Asian sub-continent which is bounded by Ghizer and Chitral on the northern side, Shangla and Kohistan Indus present on the east, Malakand and Buner zone is present at the south while Dir is located on the West side (Sher and Al-Yemeni, 2011). The Hindukush-Himalayan belt extends over 3510 Km in Southern Asia (Shaheen and Shinwari, 2012). This phytogeographic zone remained susceptible to different environmental and anthropogenic activities during the Holocene, an epoch in the geologic time scale that started 12000 to 10000 years back at the extreme of the Paleolithic ice Age proceeding to the present time (Bagley, 2013). The Holocene vegetation is studied by Paleoecologists to know about the most recent environmental fluctuation in the ecosystem (Chen *et al*., 2006). The past vegetation history mainly, the macro and microfossils are studied, which is a condition fundamental for the utilization of plant macrofossils in the reconstruction of plant communities, and the major elements of flora must be abundantly preserved in identifiable conditions (Dunwiddie, 1983). As there is no considerable Palaeoecological study conducted in Pakistan except on the Karachi coast near the Arabian Sea in the extreme south of the country (Lézine, 2009) therefore this project aims to reconstruct the past vegetation of northern Pakistan for the first time which was associated with Lennart von Post published work. His work depended on various techniques for quantitative pollen statistics (Traverse and Sullivan, 1983).

This research project has been conducted on the Palaeoecological studies of Kabal Valley lies in District Swat of northern Pakistan. Pakistan is susceptible to the Indian monsoon system, which is subjected to changing vegetation patterns, climate changes, and trending to desertification (Claussen *et al*., 2003). This paper throws detailed light on our attempt to know about the past ecosystem and vegetation history of the area. Which plant species remained dominant during which specific periods of the Holocene? To date, no records are available about the past vegetation history of the Hindu Kush Phytogeographic region. So, the specific objective of this study is to document the history of Conifers and herbs in the research area. Moreover, we also want to know the exact periods when the grasslands shrank or expanded about Conifers on the surrounding Hindu Kush hills. This project could provide us an insight to investigate how the present-day ecosystem of the research area reached the existing state.

Materials and Methods

Geographical setting and targeting the coring site

Kabal Village in Swat Valley was selected for this research project which is located in the Northwestern part of Khyber Pakhtunkhwa province of Pakistan. It lies between 34˚34′ to 35˚55′ N latitude and 72˚08′ to 72˚ 50′ E longitude. The area of Kabal is situated on the Northern side of the Swat district which is located around 15 Km from Saidu Sharif in Khyber Pakhtunkhwa, Pakistan. The research area is located between 35˚41′ to 35˚61′ North and 72˚20′ to 72˚31′East in Swat Valley. This area comprises an average elevation of 996 to 2893 meters above sea level. The total land area of tehsil Kabal is 40025 hectares of which 20725 hectares are under cultivation, while 19300 hectares remain uncultivated. Swat Valley is stretched along a U-shaped Mountain series that is extended to the southern side of the Swat River, while the remaining three sides i.e., East, West, and North it is encompassed with a bend-formed arrangement of slopes having distinctive heights and characters. The series of hills are offshoots of the Hindu Kush Mountain range (Ilyas *et al*., 2015). The coring site in Kabal Valley of Swat Valley (34° 66`N 72°13`E) was selected for coring. The research area is unsuitable for coping with hand-operated instruments. A 150 cm core was taken from Kabal Valley in Swat Valley with the help of a Russian corer. The core was then covered with the help of split PVC pipes and plastic foils after coring and transported to Göttingen University Germany for storing and kept at 4°C.

Figure 1: *Map of Pakistan (shown in yellow) and the surrounding neighboring countries of the region. The coring site is located in northwestern Pakistan in Kabal village (star) in the Swat Valley.*

Retrieving general climate and vegetation data

Swat Valley lies in the temperate Zone of Pakistan. The shortest season of the Swat region is summer which is cool enough and refreshing in the high altitudes part of the Northern side.

June is the hottest month of all seasons recording a temperature between 16°C (mean) and 33°C (maximum temperature) (Jan and Tahirkheli, 1969). January is probably the coldest month in Swat with a minimum mean temperature equal to -2°C and a maximum mean temperature of 11°C respectively. The longest season of all the months is the winter season which is from November to March when most of the rain and snow fall. During the winter season, the level of precipitation is much higher than that of the summer season. The most abundant precipitation in the research area is recorded in March at about 243 mm. The whole valley of Swat is described by some of the heated summers and cold winters. The highest temperature in the summer season might be over 44°C and winter minimum beneath the freezing point. A portion of the rainfall during the winter months is in the form of snowfall at higher altitudes and on some terrestrial lands (Ali *et al*., 2012; Ullah *et al*., 2015). The vegetation of Swat comprises a diverse group of plant species covering the ground (Jan *et al*., 2015). Ilyas *et al*. (2015), reported 1551 flowering plants and 55 Pteridophyte species from Swat Valley. Vegetation of the valley is distinctive as the region is a nexus of three expansive mountain ranges i.e., the Karakorum, the Hindu-Kush, and the gigantic Himalayas. There are seven kinds of timberlands from tropical to snowcapped (Ilyas *et al*., 2015). A portion of the regular plants underneath the 4000-5000 m altitude are wide-foliated *Aesculus indica* (bankhor), *Quercus* species, *Juglans* species (walnut); and some small-leaved *Pinus* tree species. *Pinus wallichiana* (blue pine), *Juniperus communis* (juniper), *Abies webbiana* (silver fir), *Cedrus deodara* (deodar), *Abies pindrow* (palunder), and *Pinus gerardiana* (chalghoza), etc. are some of the typical trees of the higher altitudes (Lézine, 2009).

Radiocarbon dating of samples

20 samples were taken from the core soil starting from the ground surface (0 cm depth) downwards till 150 cm deep in the ground. These samples were then sent to the AMS (Accelerator Mass Spectrometry) radiocarbon dating laboratory in Taiwan University. Four samples were taken at the depths of 55, 82, 148, and 116.5 cm for C^{14} dating. Ages were then calculated from 0 cm to 148 cm respectively. R statistical program was used for 155 interpolations.

Data analysis and sample processing

Samples each 0.5 cm^3 were taken from the core every 4 cm, starting from the surface down to 150 cm to extract the pollens from the sample. For sample processing, the standard laboratory method (Faegri and Iversen, 1989) was used. To remove large silicate contents the samples were kept in Hydro Fluoric acid for two days. For calculation of pollen concentration and their influx values one *Lycopodium clavatum* marker tablet was also added. The extracted pollen was then placed in glycerin. The data of Conifers and herbs pollen were arranged in excel for further programs.

Pollen illustration

The pollen percentage diagram was designed with the help of the TILIA program (Grimm, 1987). The software helps us to gain an insight into the past pollen abundance structure.

Table 1: *Details of the total pollen abundance deposited during the past 3000 years.*

Depth (cm)	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76
Samples	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Age	-62	-8	47	101	156	210	265	319	373	428	482	546	637	729	907	1343	1779	2215	2651	3085
Kabal Swat																				
Pinus	41	36	57	30	17	14	21	26	21	16	21	17	9	10	7	8	6	7	18	8
Picea	37	33	24	32	27	43	25	13	15	18	12	18	9	11	8	8	6	16	12	19
Abies	21	27	13	15	33	12	14	16	13	11	9	8	10	12	13	4	2	1	13	4
Cedrus	18	21	17	14	21	28	32	28	28	29	16	18	13	10	10	9	6	5	9	6
Taxus	8	12	13	17	15	23	28	20	23	17	22	25	31	17	14	15	18	3	4	2
Cupressaceae	0	0	2	0	0	3	4	0	2	1	0	0	3	5	4	3	2	1	9	7
Poaceae	7	6	3	5	7	9	24	22	27	32	30	37	32	34	41	44	28	23	27	22
Cyperaceae	24	29	36	41	21	23	36	34	22	19	17	14	16	27	18	15	6	26	31	21
Amaranthaceae	8	2	7	10	8	15	13	11	16	10	13	19	18	9	16	9	16	18	16	11
Polygonum	14	21	17	15	18	21	16	13	21	11	12	6	8	9	3	6	4	2	1	0
Brassicaceae	4	2	3	2	1	3	2	7	5	1	6	14	17	5	8	9	8	4	4	3
Euphorbiaceae	2	3	6	5	2	1	7	6	2	9	11	0	10	10	4	8	2	3	3	2
Artemisia	11	9	3	8	6	9	2	3	5	7	9	13	12	7	14	17	13	12	6	1
Solanaceae	4	2	3	0	2	1	0	0	0	0	0	0	0	4	3	5	7	5	6	0
Fabaceae	8	5	4	3	4	1	0	2	1	0	1	0	5	4	6	7	4	4	0	2
Verbenaceae	6	3	8	5	9	3	5	4	2	0	0	2	3	1	0	0	0	0	0	0

Multivariate analysis

Multivariate data analysis was carried out on pollen percentage data using the program CANOCO (Canonical Community Coordination Package 05). The dominant herbs and Conifers were assigned to different age zones.

Results and Discussion

Diagrammatic representation of pollen

The pollen diagram (Figure 2) shows pollen taxa in two vegetation groups Conifers and herbs. The diagram also reveals the abundance of vegetation during a certain period.

Description of the pollen zone

Lowest pollen zone: This pollen zone is represented by the lowest 80-68 cm part of the core which revealed an age of 3000 to 2200 Cal. yrs. BP. Most of the herb's pollen grains are dominant in this zone including Poaceae (20-25%), Cyperaceae (20-30%), Amaranthaceae (10-15%) Brassicaceae (2-3%) and *Artemisia* (0-10%) while *Pinus* (7-19%), *Picea* (14-20%), *Abies* (0-14%), *Cedrus* (5-10%), *Taxus* (3-5%) and Cuperaceae (2-10%) are less dominated. From 3000 to 2100 Cal. yrs. BP the Cyperaceae and Poaceae along with some Conifers such as Pinus or Picea species were dominant indicating prevailing wind patterns of Monsoon for the dispersal of Coniferous pollens (Lézine, 2009). This also indicates that the research area has probably some little cover of forest along with some swampy vegetation.

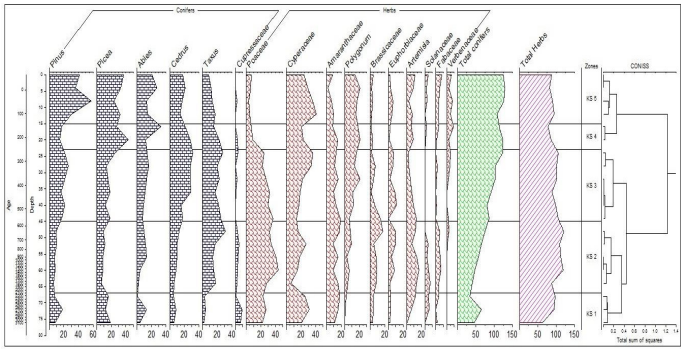

Figure 2: *Pollen diagram of Kabal Swat showing herbs and Conifers pollen.*

Second pollen zone

This pollen zone is represented 45cm to 67cm part of the core which revealed an age of 2200 to 550 Cal. yrs. BP. This zone is also dominated by herbs pollen including Poaceae (22-40%), Cyperaceae (5-25%), Amaranthaceae (12-14%), *Polygonum* (3-5%), Brassicaceae (5-15%), Euphorbiaceae (3-5%), *Artemisia* (6-15%), and Fabaceae (1-5%) while *Pinus* (5-14%), *Picea* (7-18%), *Abies* (1-15%), *Cedrus* (6-

14%), *Taxus* (7-26%) and Cuperaceae (1-5%) are less dominated. In herbs, the abundance (Poaceae, Amaranthaceae, Brassicaceae, and *Artemisia*) is notably increased as compared to zone 1. At a depth of 55cm to 60cm, having an age of 1600 to 1200 Cal. yrs. BP. there is a sharp increase in Poaceae, while the amount of *Taxus* also increases at 700 to 600 Cal. yrs. BP. in this zone. From 2000 to 600 Cal. yrs. BP Poaceae Amaranthaceae and Cyperaceae were dominated by the presence of no reasonable forest. This depth pollen zone shows a tremendous increase in grasslands which indicates that before 500 to 600 years the Kabal Swat was dominated by herbs (Fauquette and Suc, 1998).

Third pollen zone

This pollen zone is represented 23cm to 45cm part of the core which revealed an age of 570 to 250 Cal. yrs. BP. In this zone, the deposition of the Conifers and herbs shows an equal increase in the percentage of Poaceae (20-30%), Cyperaceae (15-30%), Amaranthaceae (10-15%), *Polygonum* (5-18%), Brassicaceae (2-10%), Euphorbiaceae (1-10%), *Artemisia* (3-10%). Conifers include *Pinus* (15-22%), *Picea* (13-20%), *Abies* (15-25%), *Cedrus* (16-24%) and *Taxus* (13-27%). Cyperaceae and Cedrus are the dominant family and genus of this zone. From 600 to 250 Cal. yrs. BP the Poaceae, Cyperaceae, Polygonum etc. was dominated but the massive increase of Conifers also occurred at this time probably due to some wet cooler shifts in environmental conditions.

Fourth pollen zone

This pollen zone is represented by a 15 cm to 23 cm part of the core which revealed an age of 250 to 150 Cal. yrs. BP. An abrupt increase in the abundance of *Picea* occurred in this zone while the Poaceae in the herbs showed a sharp decrease. This zone is of short interval about a hundred years in which the Conifers started to dominate but still some herbs are abundant. The percentage of different taxon of this zone include Poaceae (10-16%), Cyperaceae (16-20%), Amaranthaceae (7-13%), *Polygonum* (15-17%), Brassicaceae (1-4%), Euphorbiaceae (1-5%), *Artemisia* (5-8%) and Verbenaceae (4-10%). *Picea* and Verbenaceae showed a sharp increase during this time.

Fifth pollen zone

This pollen zone represents the 15cm to 0cm part of the core which revealed an age of 150 Cal. yrs. BP to the present age. This zone shows the recent depositions of the late Holocene period in the Kabal Swat region. The dominant taxa in this zone are Conifers which constitute *Pinus* (30-51%), *Picea* (20-33%), *Abies* (15-27%), *Cedrus* (16-21%), and *Taxus* (9-18%). Different herbs present in this zone include Poaceae (5-7%), Cyperaceae (24-41%), Amaranthaceae (3-9%), *Polygonum* (13-21%), Brassicaceae (2-4%), Euphorbiaceae (2-7%), *Artemisia* (4-12%), Fabaceae (4-8%), and Verbenaceae (3-8%). From 250 to the present age a tremendous increase occurs in the Conifers while contrary to this the herbs are shown to be depleted along with the increase of Conifers. A similar study was done for climatic reconstruction using pollen data in the Mediterranean Sea which shows progressively cooler and drier conditions through time (Fauquette et al., 1998). These depth pollen zones show the maximum shift in the climatic conditions or some other calamities in this ecosystem where the entire patterns of herbs and grasslands are shifted toward the forests (Sukumar *et al.*, 1995; Riaz *et al.*, 2021). The multivariate analysis revealed similar results as shown by the pollen diagram in Figure 3. The result of PCA on CONOCO revealed the steepest increase of Conifers and steepest decrease of herbs along time having Eigen values of 0.0595 and 0.0508. The different depth zones are also far apart in the diagram which shows major variability and fluctuations of herbs and Conifers over time (Anderson *et al.*, 2008). We also compare different age-depth zones to the present one which also reveals that there are continuous instabilities among the pollen depositions and the past vegetation climate. The comparison of different pollen depth zones also gives similar results as that of Tilia and CANOCO in Figure 4. The comparison of the present to the last 500 cal. Yr BP it is indicated that the major shifts of herbs are marked with Conifers. Figure 5 reveals the shrinkage and the expansion of herbs and Conifers during the past 900 Cal. yrs. BP.

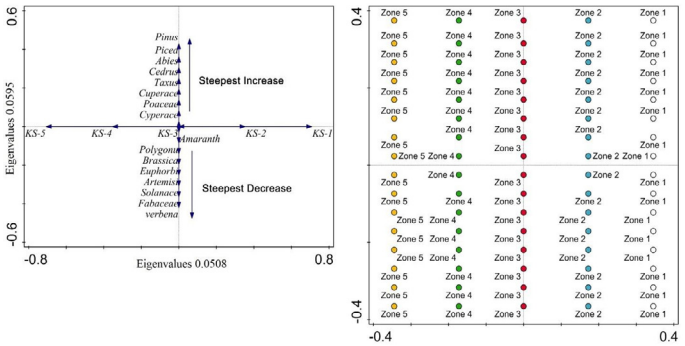

Figure 3: *Results of PCA on CANOCO showing the increasing and decreasing relationship.*

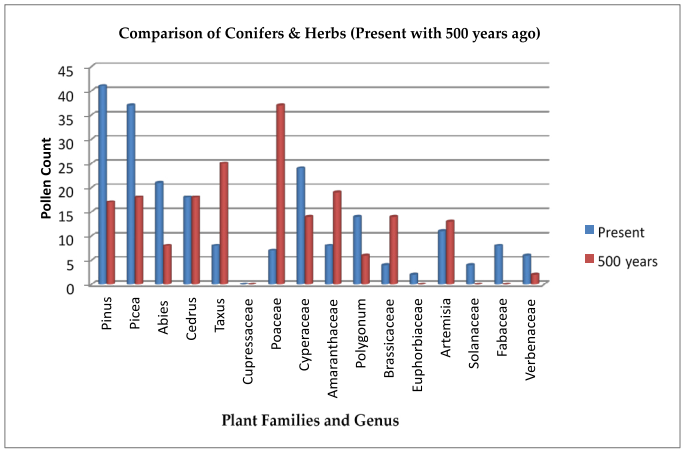

Figure 4: *The comparison of the present with the past (500 cal. Yrs).*

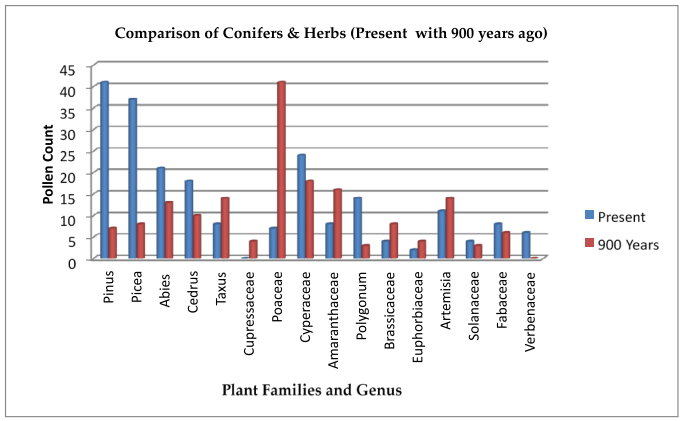

Figure 5: *The comparison of the present with the past (900 cal. Yrs).*

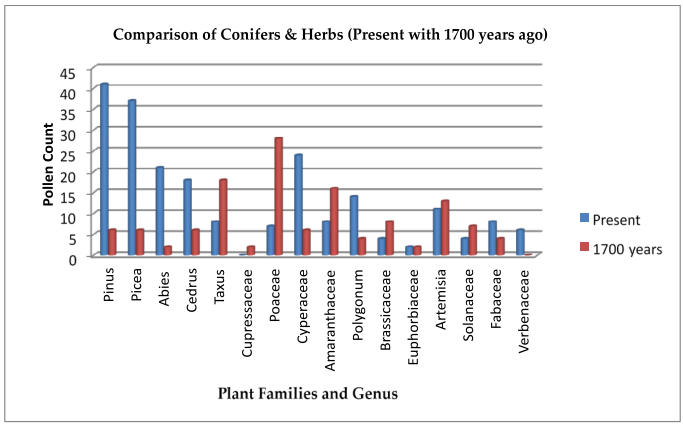

Figure 6: *The comparison of the present with the past (1700 cal. Yrs).*

The comparison of the present pollen data and the last 900 Cal. yrs. BP data shows some major expansion in the grassland due to the increase in herb pollens (Fauquette et al.,, 1998). Figures 6 and 7 also indicate the dominance of herbs compared to the present time. This indicates that the complete shifts of climate are probably due to less rainfall and high erosion (Chen *et al.*, 2006). Figure 8 reveals that the forests and herbs are side by side in the past 3000 Cal. yrs. BP which is again in line with the results we get on Tilia and CANOCO software. The reconstruction of the past environment by various climate indicator species was also done through dominated communities during 5 different periods. The communities at present reveal the dominance of Conifers including the Pinus and Picea which is reflected in the present-day vegetation in the Kabal Swat area (Ilyas *et al.*, 2015). A grassland ecosystem was found in the communities of 500 Cal. yrs. BP. The abundance of Poaceae and Amaranthaceae pollens clearly indicates a grassland vegetation which shows that the Kabal Swat area went through some drastic environmental changes. We made the past plant communities for the first time to introduce palaeoecological phytosociology due to the presence of past abundant pollens along a certain period.

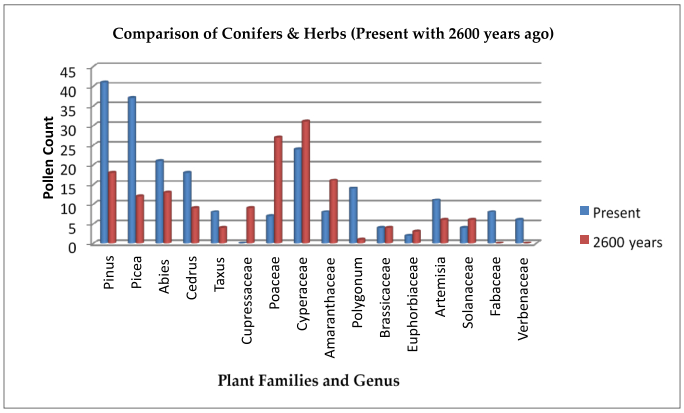

Figure 7: *The comparison of the present with the past (2600 cal. Yrs).*

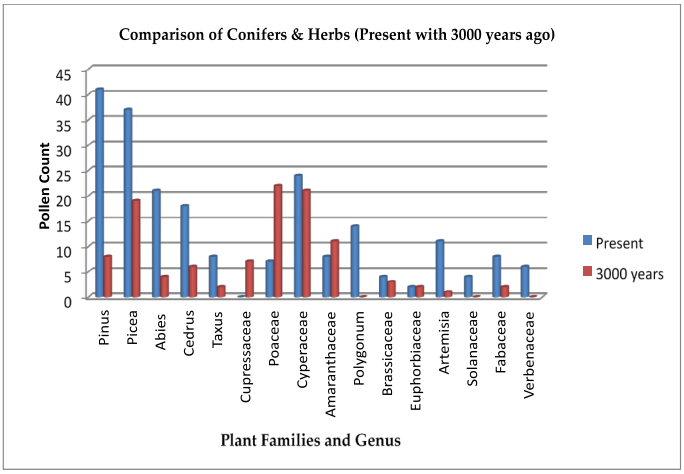

Figure 8: *The comparison of the present with the past (3000 cal. Yrs).*

Multivariate analysis

The principal component (PCA) analysis shows the variability among Conifers and herbs. The variability among different herbs and Conifers are calculated by

the eigen values as 0.0595 and 0.0508, respectively. The result reveals that there is a steep increase in the Conifer's vegetation as compared to herbs over the time. The herbs show a steep decrease with time. The different depth zones also show variability among them. The KS-1 represented a depth starting from 67cm to 78cm and KS-2 represented a depth of 45cm to 67cm showing some similarity as compared to the other depth zones. The KS-3 represents a depth of 23cm to 45cm and is a transition between all the zones having both the abundance of herbs and Conifers while the KS-4 represents a depth of 15cm to 23cm and KS-5 represents a depth of 15cm to 0cm is also closed to each other. Different colors are used for different depth zones (Yellow: depth zone 5, Green: depth zone 4, Red: depth zone 3, Blue: depth zone 2, White: depth zone 1) to show the relation between zones more clearly. The total variation among all the variables was 1680.000. The explained or cumulative variations among the two axes are 5.95 and 11.03.

Comparison of present vegetation to specific period holocene vegetation

Figure 4 shows the comparison of present pollen data with the past 500 Cal. yrs. BP. This reveals the vegetation fluctuations over time. There was a major shift in the vegetation history of the Kabal Swat area in the late Holocene period.

Figure 5 indicates the comparison of pollen data with the past 900 Cal. yrs. BP. This period showed the steepest increase in the Poaceae family and the sheer degradation of Coniferous forests. Figures 6, 7, and 8 also showed us fluctuations in the vegetation patterns probably due to dynamic environmental conditions. The Conifers show dominance over the present time in Kabal Swat. Pollen abundance for the family Pinaceae shows high peaks which is accomplished by Picea and Cyperaceae. In the past herbs are shown to be dominant which shows that the herbs are dominated by Conifers over the past 500 years. In the above graph, Pinus shows the highest peaks in the present while Cyperaceae shows most of the pollen depositions in the past.

The comparison of Conifers and herbs (Figure 5) shows that only Poaceae showed high peaks 900 years ago. The remaining families, especially Conifers show less pollen abundance. The maximum pollens recorded in the past and present are Cyperaceae and Poaceae which show the presence of grasslands in the past 900 years ago.

The comparison of Conifers and herbs in the past and present (Figure 6) shows that Pinus shows a decreasing trend and Poaceae shows an increasing trend along the time continuum. The comparison shows that only grasses were dominated in the past. The comparison of present pollen data with the past 2600 years (Figure 7) reveals that the Conifers show a decreasing trend while the herbs show an increasing trend. Poaceae and Genus Picea show the maximum peak values in the past while the others show minimum values. The comparison of present pollen data with the past 3000 years (Figure 4) shows that the Conifers are side by side with the herbs. Poaceae and Cyperaceae show the maximum peak values in herbs while the Picea shows maximum peak values in Conifers in the past.

Climate indicator species

Based on the pollen extracted data, we divided different pollen counts into their respective ages. From our pollen data, we took six plant communities in the context of pollen abundance to show the ecosystem and vegetation of that specific time.

Pinus-picea-cyperaceae community (present age)

The present age contributes 213 pollens out of which the Pinus, Picea and Cyperaceae are dominant containing 41, 37, and 24 pollens, respectively (Figure 9). The pollen collected from the surface shows the modern pollen rain in Kabal Swat. The community of these abundant plants shows a forest ecosystem.

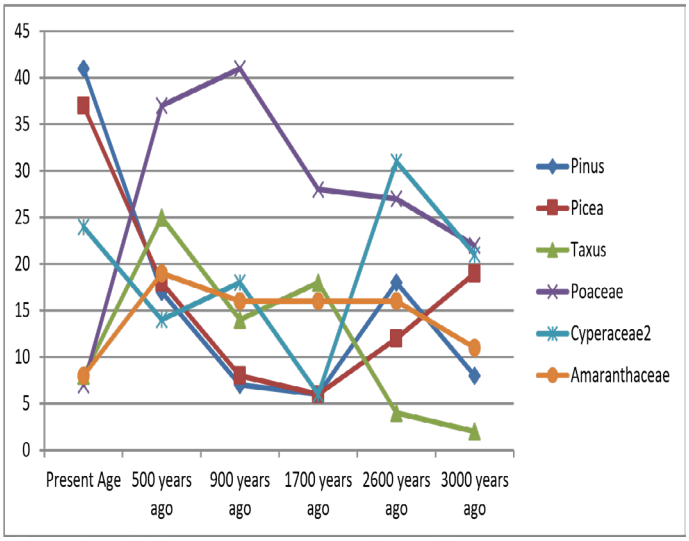

Figure 9: *Dominant plant communities over the past 3000 years.*

Poaceae-taxus-amaranthaceae community (500 years ago)
A total of 191 pollens were identified in a 500-year-old sample which shows that Kabal Swat was dominated by the Poaceae, Taxus, and Amaranthaceae families having 37, 25, and 19 pollens. The community shows a grassland ecosystem.

Poaceae-cyperaceae-amaranthaceae community (900 years ago)
A total of 169 pollens were identified in a 900-year-old sample which shows that Kabal Swat was dominated by the Poaceae, Cyperacae, and Amaranthaceae families having 41, 18, and 16 pollens. This community was also dominated by the grass at that time.

Poaceae-taxus-amaranthaceae community (1700 years ago)
A total of 128 pollens were identified in a 1700-year-old sample which shows that Kabal Swat was dominated by the Poaceae, Taxus, and Amaranthaceae families having 28, 18, and 16 pollens. The community was dominated by a lot of grasslands with some forests.

Cyperaceae-poaceae-pinus community (2600 years ago)
A total of 159 pollens were identified in the 2600-year-old sample which shows that Kabal Swat was dominated by the Cyperaceae, Poaceae, and Pinus families having 31, 27, and 18 pollens. The community shows the abundance of grasses with the presence of some Conifers.

Poaceae-cyperaceae-picea community (3000 years ago)
A total of 108 pollens were identified in a 3000-year-old sample which shows that Kabal Swat was dominated by the Poaceae, Cyperaceae, and Picea families having 22, 21, and 19 pollens. The community also shows the presence of a grassland ecosystem. The pollen abundance and climate indicator species in the late Holocene period in Kabal Swat Valley are shown collectively in Figure 9. The dark blue and light blue lines show the abundance of Pinus and Cyperaceae, while the purple line shows Poaceae, the green represents Taxus, and the orange line represents Amaranthaceae pollens. The highest peaks were achieved by the Pinus and Poaceae pollens with some uniform variations over time. Contemporary to that Taxus and Cyperaceae show some sharp changes occur along different age scales. Amaranthaceae remained consistent from 500 years to 2600 years with a slight variation. Picea pollens are sharply depleted from the present up to 1700 years which shows the unpredictable climate shift over time, and it becomes abundant from 1700 years to 3000 years which shows its rehabilitation. From the above figure, it is indicated that there are continuously changing environmental shifts which is the cause agent of the whole ecosystem changing. The dominancy to Poaceae in a certain period and then its changing to the Pinus dominancy indicate the major natural calamities and environmental shifts.

Conclusions and Recommendations

The deposition of pollen grains at different times is due to the pollen rain of the adjacent vegetation. The abundance of the pollens at different times shows what kind of vegetation was present during the late Holocene period (Mayewski et al., 2004). As a result, these vegetation types were indicators of past climatic conditions. Our work reveals the depositions of pollen around 3300 Cal. yrs. BP, which showed that the deposition of pollens along the time continuum was not uniform. Our pollen-based records show that the area of Kabal Swat passed through cooler and dryer climates. The forests of Conifers were high in the first zone, which were remarkably depleted and the drastic increase of herbs and grassland in zone two clearly shows that anthropogenic activities were high in that specific period probably due to agricultural activities. In zone three, we see a sharp increase in the Coniferous forests which clearly show the cooler environmental conditions at that specific period. At a glance over zone four, it is indicated that the decrease of herbs over time shows climate change probably due to some natural disasters. The most recent zone of our pollen data in the last Holocene period revealed a tremendous increase in the Conifers and herbs. The present-day ecosystem of Kabal area is dominated by Coniferous forests. Further detailed studies are required to know the exact pattern of vegetation dynamics which will help in determining the conservation issues.

Future outlook
More Palaeoecological work should be done in different regions of Pakistan to explore more shifts among plants across the Holocene period. Funds should be allocated by HEC to Universities to overcome the shortage of Palaeoecological equipment in Pakistan and Palaeoecological labs must be established in different universities to extend the circle of fossils study in Pakistan.

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Novelty Statement

The most recent zone of our pollen data in the last Holocene period revealed a tremendous increase in the Conifers and herbs. The present-day ecosystem of the Kabal area is dominated by Coniferous forests. The pollen-based records revealed that the area of Kabal Swat passed through cooler and dryer climates.

Author's Contribution

Abdur Rauf: MS drafting and proofreading.
Farooq Jan: Research supervision/Executed Experiment /MS drafting.
Muhammad Qayash, Muhammad Yasin, Fayaz Asad, Kashif Hayat and Muhammad Khalid: Proofreading.
Muhammad Luqman: Data analysis.
Ikramullah Khan: Proofreading/Data analysis.

Conflicts of interest
The authors have declared no conflict of interest.

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