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Paleoclimatology of Fellaw Lake; area-Iraq: A review

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ABSTRACT

Pollen study is considered one of the most climate proxies distributed worldwide since the beginning of the last century. Some areas and regions still lack such proxy studies, the main objective behind this review is to investigate and draw a picture of the past climate and vegetation pattern in northeastern Iraq, where the area obtains only a few small in size natural Lakes, Fellaw Lake is the largest mountain natural Lake in the area considered within the study. In addition, there are tries to present the paleoclimate of the study area depending mostly on the bulk of research conducted near the area due to the nonexistence of pollen studies implemented on Fellaw Lake yet. Accordingly, and after matching the modern and past vegetation patterns of some adjacent lakes to the area such as Zaribar, Merabad Van Lake, and Akgol Lake, the area likely obtains to some extent a similar past climate trend and events and vegetation components, regardless of the factor of variation in latitude and topographic effects which in turn affect the precipitation amount that could lead possibly to variate of vegetation patterns in these conditions. Ultimately, the study area is located in a very climate-sensitive area, where it's situated among the following regions; Levantine from the west, Mesopotamia from the south, Anatolia from the north, and itself located in the eastern edge of the Irano-Turanian region. This in turn could consider the area to be a refuge for other regions in case of climate deterioration and fluctuations in the late Quaternary.

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1. Introduction

The Earth's climate has changed dramatically over the epochs, as the atmosphere continuously interacts with oceans, lithosphere, and biosphere over various timescales. Efforts to place recent climate observations into a longer-term context have been stimulated by concern over whether the twentieth-century global warming trend is part of natural climate variability or linked to increasing anthropogenic inputs of greenhouse gases into the atmosphere. The ability to decipher past climates has expanded in recent years with an improved understanding of present climatic processes and the development of more sophisticated analytical tools. Instrumental records go back only a century or two. Therefore, paleoclimatology could be defined as the pure study of past climates.

The study of pollen and spores has been recognized as a Palynology and used since its first development in the early years of the twentieth century to reconstruct past vegetation and climate (Lowe and Walker, 2014; Walzer and Hendel, 2023). Using pollen core samples from well-dated sediment cores enables Paleoclimatologists to obtain records of changes in vegetation going back hundreds of thousands, and even millions of years. Not only can pollen records tell us about the past climate, but they can also tell us how we are impacting our future climate. Moreover, terrestrial sedimentary basins and the ice caps of Greenland and Antarctica, and deep cores taken from ocean sediments, have contributed greatly to the advance of the investigations for Quaternary climate history.

Microfossil and chemical analysis of marine sediments in deep ocean cores have provided continuous, high-resolution records of glacial-interglacial cycles throughout the Quaternary (Imbrie et al., 1992). Imbrie, et al. suggested the replacement of the classical European and North American sequence of four glacial periods by more than twenty periods, at least six of which are recognized in the Sierra Nevada. The correlation of these time series of ocean properties with the Milinkovic cycles of orbital parameters has shed light on the behavior and origin of continental glaciations. As common knowledge, vegetation dynamics are influenced by climate circumstances, and the interpretation of climate change is considered a main factor for the reconstruction of paleo-vegetation. Therefore, there is a need for studies that explain the major concepts about the climatic trends and causes of the glacial-interglacial cycles and explain how effects on the global climate system that in turn could influence the climate of regions. The Late Quaternary was produced as a unique time toward the end of the earth's history, which was accompanied by a major glaciation. The continental glaciation initiation has been linked to changes in the coupled atmospheric and oceanic circulation system that are influenced by tectonic events such as the depositing of the tombolo for Panama and the uplift of the Himalaya-Tibetan plateau, Sierra Nevada, and other mountain ranges (Ruddiman and Kutzbach, 1989). Berger and Loutre (1991), addressed that the pattern of glacial oscillations is more likely assumed to be influenced by the latitudinal and seasonal distribution of incident solar radiation according to periodic variations in the sun-earth geometry. The 100,000-year cycle of the eccentricity of Earth's orbit, a 41,000-year cycle of Earth's obliquity about the ecliptic plane, and a 23,000-year precession of the equinoxes are considered the three major components, that drive all the previous glacial-interglacial cycles. The assures regarding the abovementioned three major components are acquired mostly from the climatic information collected from ocean sediments, Antarctic ice caps, ice cores taken from Greenland, and cores taken from terrestrial sedimentary basins. These samples altogether showed patterns that reflect these periodicities and substantiate their effects on phenomena responsive to climate change. The combined effect of these geometric relationships with the sun produced the strong 100 kyr glacial-interglacial rhythm, within these cycles, glacial periods averaged about 90 kyr and warm interglacial periods averaged approximately 10-20 kyr. Global ice volume grows with high winter insolation and low summer insolation. The absence or presence and limits of land and sea surface temperatures, sea ice, effective soil moisture, land albedo, composition of the atmosphere, and circulation of the oceans and atmosphere are other factors that behave as external forcing variables. Generally, internal controls operate on smaller scales while external controls lead to larger scale variations over space and time (Bartlein, 1977; Akinyoola et al., 2024). Through the glacial periods, the C^{13} record from benthic foraminifera shows that a shallower, but naturally stable mode of circulation was being driven by the release of formation and heat of deep water at least 20° further south than today, while during warm interglacial a stable circulation similar to that of today prevailed. The increase in summer insolation besides the conveyer, probably triggered deglaciations by heating the North Atlantic then leading to the retreat of the ice sheets. The climate of the Holocene has been comparatively stable, if compared to the climate of the past 120 kyr ago, regardless of that Holocene climate has also been fluctuating through cold and warm cycles at several time scales to the present day. Major trends in climatic components comprised of increases in sea surface temperatures, atmospheric dust, carbon dioxide, and an especially important component for vegetation change with seasonal variation in insolation then ultimately decreasing in land ice (Kutzbach and Guetter, 1986; COHMAP Members, 1988). An increase in summer solar radiation and a decrease in winter solar radiation occurred from near present levels at 18 ka to winter minimum at approximately -10 ka and a summer maximum in the northern hemisphere. Any Increase in global temperature will in turn affect atmospheric circulation then consequently, affect the orientation, position precipitation patterns, and steepness of temperature gradients on a regional scale (Davis and Sellers, 1986; Spiridonov et al., 2021). Moreover, General Circulation Models (GCMs) and empirical data provide a set of proves about environmental conditions during the glacial maximum (Kutzbach and Guetter, 1986). Global surface temperatures averaged 4° C less than of today, sea level was about 121 m below present sea level, ice covered one third of the land surface of the earth, and atmospheric circulation patterns were noticeably modified. In conclusion, the late Quaternary global climate was mainly a winter precipitation regime. The expanded land and sea ice empowered the latitudinal temperature gradient, shifting the westerlies southward and weakening the summer monsoon (Kutzbach and Guetter, 1986). The assumed links between variation in global insolation and changes in precipitation patterns and regional temperature are necessary for explaining a pollen-based vegetation record in terms of global climate change. In the case of regional vegetation ultimately responds to changes in global circulation, then the climatic signal interpreted from various radiocarbon isotope records present in the trends of most Lake pollen cores stratigraphy. Scale understanding is an important first step in the interpretation of a pollen record. The spatial scale resolved by pollen abundance relies on the size of any basin (Prentice, 1988). Therefore, more detail of the local vegetation will be recorded in the case of a smaller basin, as in Fellaw Lake area, at least in a closed-canopy forest where some local pollen might be filtered out. Reversely, larger basin sizes might receive a proportionally greater amount of regional and extra local pollen (Prentice, 1988). The problem in interpreting paleo-vegetation patterns is that they discriminate between the sources at local and regional scales, particularly when only a single pollen diagram from a region is available. However, the small area of Fellaw Lake, Fig. 1, which is about 430 m2 increases the problem of discriminating between the sources at local and regional scales, assuming that a larger source area is reflected in the pollen from the lake sediments. The relationship of basin size to source area is an important factor in determining the type of vegetation information to be obtained and analyzed from any pollen record. The study and analysis of proxy vegetation data have disclosed that biotic processes influence the smaller space and time scales, whereas other non-biotic and climatic processes are the forcing functions on larger scales (Graumlich and Davis, 1993). For instance, at the sub-continental or regional scale, adaptation in place, migrations, extinction, or shifts in range resulting from variations in climate will alter the structure, composition, and distribution of entire vegetation types (Delcourt, 1991). While, on intermediate scales, the distribution of vegetation that is climatically influenced is more constrained by substrates. However, at small scales, secondary succession produced from individual plant mortality or local events such as anthropogenic or fire effects will result in changing patterns of species abundance and composition (Graumlich and Davis, 1993). In case of Fellaw area vegetation types the influence of mountain-valley topography on local climate inaugurates a complexity into two components of the pollen deposition system: (1) pollen source represented by vegetation patterns, and (2) pollen dispersal represented by mesoscale wind patterns.

1. Vegetation diversity, persuaded by the latitudinal situation and topographic relief is an obstacle to precise reconstruction of paleo-vegetation. Daubenmire (1980) warns that vegetation zonation of a mountain range is a result of temperature and moisture gradients rather than a univariate elevation gradient; the differing microclimates constructed by slope and aspect, besides altitude, intergrade and reduce the distance among environmentally diverse species. Thus any reconstruction of mountain vegetation assuming a uniform altitude of a tree line will be incorrect.

2. If the geostrophic and westerlies are the prevailing winds of any study area. These areas will be modified at the surface by permanent and migratory pressure cells and topography. Mountains tend to deform the prevailing wind flow in an anticyclone direction. Pressure falls on the lee side causing subsidence with accompanying drying and warming often penetrating the valleys, therefore pollen dispersal will mostly be along the lake valley axis rather than from any other directions and might reflect to some extent the latitudinal movement of cold desert taxa during glacial cycles. These air circulation systems transport pollen in different paths but to a more restricted extent than previously noticed in the case of recent experiments are correct. A linear or exponential function is not suitable for downwind pollen deposition in a mountain region, rather pollen seems to be deposited in a stepwise manner with instantaneous decreases in frequency from the source and constant low frequencies afterward, disregarding distance (Markgraf, 1989; Solomon and Silkworth, 1986). The clarification is the existence of inversion layers or thermal barriers that prevent

downslope and upslope transport of pollen between mountain and valley air and separate pollen within each of these two atmospheric layers. Solomon and Silkworth (1986), referred to a number of air pollution researches supplying confirmations for these lids on vertical mixing. Markgraf (1989), also cites evidence for a reduction in the strength of upslope wind relative to prevailing winds flowing perpendicular to the slope at Montane. Investigations done in a small Swiss valley showed a stratification of night-time mesoscale winds with two zones of low velocity at mid-elevations and a third low-velocity zone at the ridgeline isolating the general and local flows. Accordingly, this stratification could be another limiting factor to pollen transferring if it also happened in the daytime. Long terrestrial pollen records spanning one to several glacial cycles, often including the entire Quaternary Period or more, are becoming more common. They have been approximately 12 retrieved from North America (Heusser, 1990; Davis and Moutoux, 1996; Adam, 1988; Adam et al., 1989) Europe (Van Der Hammen, 1971; Woillard, 1979; Beaulieu and Reille, 1984), South America (Hooghiemstra, 1989); Japan (Fuji, 1976) and Australia (Singh and Geissler, 1985). The primary value of these records is the long-term vegetation history that has been explained from them. Climate analysis and dynamics of the orbital signal through correlation with the marine isotope have been important as extra contributions, for example, Adam and West (1983), Guiot (1990), and Hooghiemstra and Melice (1993). Reversely, in the regions and areas near and around Fellaw Lake, most of the pollen cores extracted only extended to less than 40 000 years, (Van Zeist and Bottema, 1977; Van Zeist and Bottema, 1991; Djamali et al., 2008) while other cores extended only to less than 13000 years in the regions around the study area. (El-Moslimany, 1987; Al-Jubouri, 1997; Yasuda et al., 2000; AlDulaimy, 1999, 2003; Al-Tawash, 2011), the research objectives for this study are:

1) To explain and analyze the Fellaw Lake area paleoclimate in terms of vegetation change in the Choman district / Kurdistan of Iraq which was located within the Zagros Mountains chains for about 13 thousand years ago.

2) To reconstruct the vegetation-climate modern and history from other research conducted near the area such as Zaribar Lake, Van Lake, and Mirabad Lake, the aspect of chronostratigraphic of the Levantine and Mesopotamia area, as well as to demonstrate possible connections with global climate change. The Late Quaternary vegetation history of the Fellaw Lake area will be fully understood if it is linked to the route of the global climatic chronology.

The abbreviation of chronometric ages such as ka and Ma (thousand and million years, respectively, are measured from the present). Radiocarbon C^{14} ages are counted as years before A.D. 1950 (yr BP.); for instance, 1400 yr BP. Radiocarbon ages adjusted for the differences in the amount of 14C produced in the atmosphere by calibration with coral chronologies or tree-ring is given as cal yr. BP.

2. Material and Methods

2.1. Study Area

The research area is located geographically within the fringe of the Halgurd-Sakran Mountains in the north and Hassrock in the south, where both are considered as part of the Iranian-Iraqi Zagros mountains chain (Fig. 1-3).

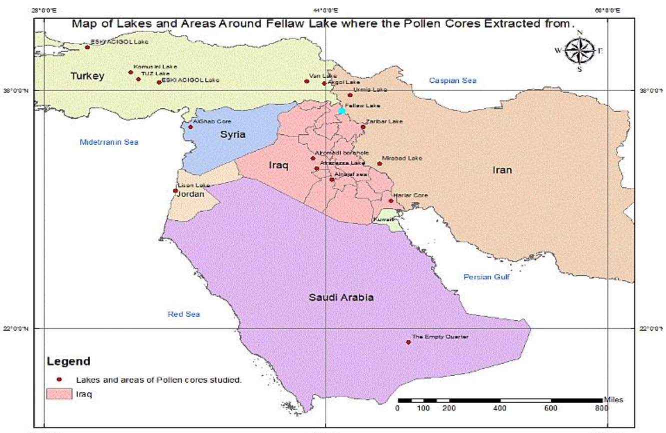

Fig. 1. Location of adjacent areas Pollen studies.

The area could be shown as a typical basin and range province characterized by a Horst and Graben system of subparallel, block-faulted mountain ranges, restricted sediment-filled basins, and hydrologically closed areas.

Fig. 2. Fellaw Lake is an area set on the fringe of the Halgurd-Sakran Mountains with a perfect alpine lake, a photo from

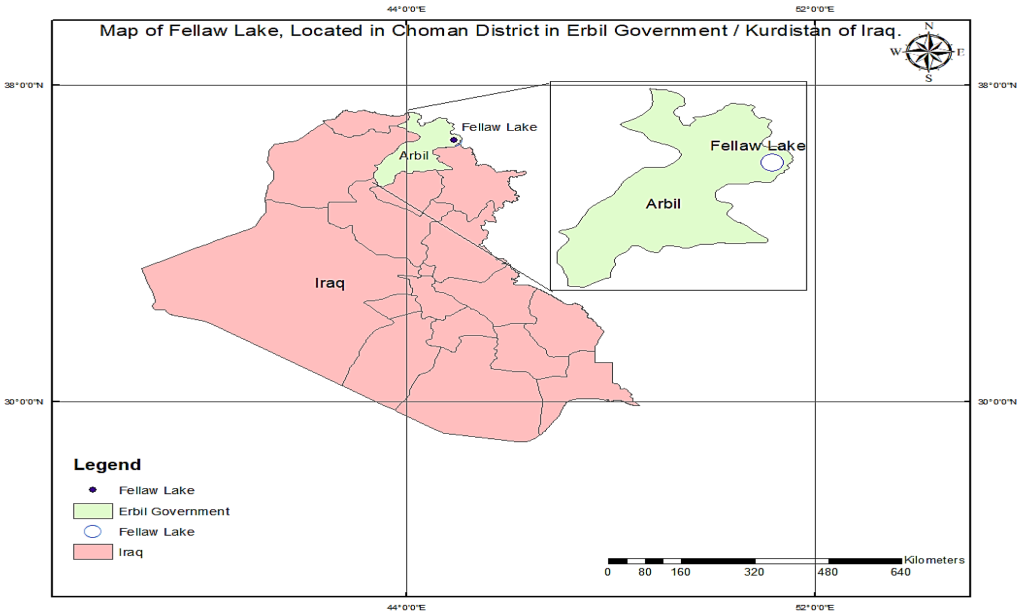

Fig. 3. Fellaw Lake study area.

The Zagros Mountains form part of the great Taurus-Zagros mountain arc, which extends from southwest Turkey through southeast Turkey and northern Iraq to southwest Iran. The Zagros Mountains have long parallel ridges and deep intermountain valleys. The ridges increase in height towards the Iran interior. The alternate ridges and valleys consist mainly of Cretaceous and Tertiary limestone and marls; metamorphic rocks are found in the highest parts of the mountains. The Khabur, Lesser Zab, Greater Zab, and Diyala tributaries drain the area, which cut transversely across the Zagros mountain ranges to join the Tigris River (Wright, 1961). The geology of the mountains surrounding Fellaw Lake consists of few basic igneous rocks, which exist in some area mountain peaks, radiolarian chert, siliceous and calcareous shale, metamorphic schist, and mostly limestone of different ages, and the soil types are serpentine, sandy clay, and clay. Fellaw Lake is about 430 m2 with an elevation of 1672 m above sea level. It is one of a series of Grabens extending from the north end of the Zagros Mountains to the range south of Fellaw Lake. The structure of these Grabens is asymmetric. Grabens differ in depth, from approximately 1 km in the north to 300 m in the southern basin. The Fellaw Valley watershed drains about 3 km2, with almost a hydrologic system closed, and a carbonate content (CO_3) of more than 60% in the sediments Al-Qayim (1989). The climatic diversity of the region is further enhanced by two overlapping precipitation high values. Winter is the season of the primary precipitation peak, delivered from the west and northwest interior possibly resulting from unstable Mediterranean air masses carried inland by the Westerlies and is largely convective, and a secondary late spring maximum resulted from northeast Siberian Cyclones tracked by the polar jet stream to the south and west. In continental climates, precipitation tends to be moderate in amount, concentrated mostly in the warmer months. Only a few areas in the mountains of the Pacific Northwest of North North America and Iran, Northern Iraq, and South-eastern Turkey, Afghanistan, Pakistan, and Central Asia show a winter maximum in precipitation. A portion of the annual precipitation falls as snowfall, and snow often remains on the ground for more than a month. Summers in continental climates can feature thunderstorms and frequent hot temperatures; however, summer weather is somewhat more stable than winter weather. Continental climates are considered temperate climate varieties due to their location in the temperate zones, in another words the climate of the area around the Lake is temperate with dry hot summers (Csa) according to the Koppen classification, besides the prevailing temperate zone and Irano-turanian vegetation type Fig. 4. (Climate around the world, 2016; Cath, 2018).

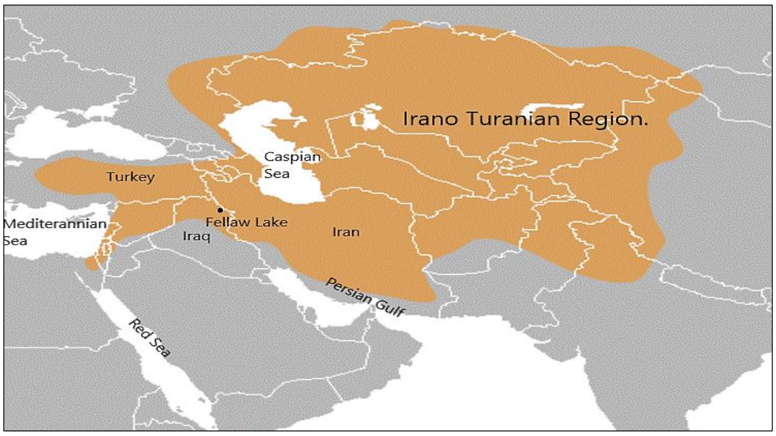

Fig. 4. The vegetation map of the Irano-Turanain region.

The only source of water flowing into Fellaw Lake is delivered by a spring draining the surrounding Hassarok Mountains snowpack. There is no outflow from the lake since the outlet from the Fellaw Lake sink is so high. The watershed average annual precipitation is 600 - 950 mm. Most precipitation and almost all recharge of groundwater occurs in the cool season months between October and March. Precipitation on the valley floor is highly variable from year to year. Mean temperatures in the valley are high in the summer, with a July maximum of approximately 39°C, and cool in the winter, with a January minimum of approximately -6°C. Xeric conditions in the summer are increased by low relative humidity and southerly winds of up to 17 – 30 kph, (Alessandrini, 2011).

2.2. Methodology

This paper is considered a preliminary study about the Paleoclimate for the north-eastern part of Kurdistan (North of Iraq) generally and for the Choman district where Fellaw Lake is located particularly. The maps provided in this study are prepared and designed using the ArcGIS 10.8 Programme. This study depends considerably on the bulk of research implemented in regions and countries near the Fellaw Lake area, Fig. 1. Where most of the findings are extracted from different papers and researches that are implemented near and around the area over the last century. Fortunately, most of the studies conducted in Iran and Turkey could be a good indicators for similar paleoclimate behavior due to the not long-distance between them and the study lake area, and as well most of these studied areas are located above the 36° where the study lake already exists. However, the other x`several pollen studies conducted in Iraq are more located in the center and south of the country, but still used in this study to reflect the paleoclimate of Mesopotamia area Fig 5, which is considered as well to some extent an adjacent area to the Choman District. According to the paleoclimate pollen studies constructed in most of the area shown in Fig. 1, some interesting findings have been used to draw approximately the past picture and climate story of the study area in the results section. Ultimately, the analysis of research discussed in this paper along with the situation of Lake Fellaw near the Fertile Crescent could represent a beginning step to apply an extensive study on the Lake using pollen core sediments in the future.

3. Results and discussion

3.1. Vegetation Patterns of Fellaw Lake area

The vegetation of the uplands and mountains around the Lake has probably not been significantly altered by human activity. The general pattern of vegetation along the axis of the valley is a highly diverse mosaic of plant associations transitional between Mountain Forest Vegetation-Oak Forests and Thorn-cushion vegetation (sub-alpine area). Fellaw Lake located above latitude 36º that considered more likely far from other studies conducted in Iraq that located beneath the 32º Latitude, Fig. 1, but still could be the transition zone center situated near Fellaw Lake, accordingly it is to some extent sensitive to climate change, the lake sediments provide a sensitive climatic record. Furthermore, the vegetation of the Fellaw Lake area is not so far from the Levantine and Mesopotamia vegetation types that both together form the Fertile Crescent, Fig. 5.

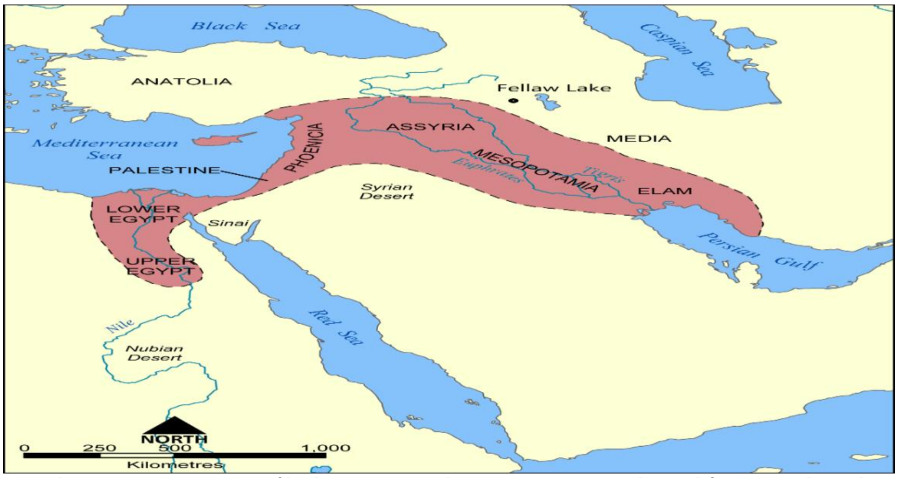

Fig. 5. The Fertile Crescent area consist of both Levantine and Mesopotamia. Map obtained from Encyclopaedia Britannica.

The study area includes a high number of plant species, approximately 146. Three waypoints were surveyed in the main area and consisted of the following vegetation types:

1) Mountain Forest Vegetation-Oak Forests (medium and highest), This habitat was characterized by Quercus aegilops, Q. infectoria and Q. libani as well as some associated plants such as Pistacia eurycarpa, Crataegus amorous, Pyrus syriaca, Prunus microcarpa, P. amygdalis, P. orientalis, Anagyris foetida, and Galium spp.

2) Thorn-cushion vegetation (sub-alpine area). This habitat was characterized by Astragalus sp., Acantholimon sp., and Rheum ribes. Characteristic species include Cousinia sp., Prangos pabularia, Rumex ribes, Daphne mucronata, Alkanna kotschyana, Ferulago angulata, and Biebersteinia multifida.

3) Mountain Forest Vegetation-Mountain Riverine Forest. This habitat was characterized by Populus Alba and Salix sp. The ecological condition was moderately disturbed, with an ecological scale of three. The slope was between moderate (6-14°) and very steep (45-69°). The site is located in the Zagros range, where the geology is sedimentary limestone, and the soil type is sandy clay. The non-vegetated area was less than 5% in the forests and 15% in the sub-alpine zone also called thorn-cushion vegetation (Alessandrini, 2011). Modem vegetation types of the area adjacent to Fellaw Lake include small oak scrub and alkali meadows and seeps. The moister margin of the lake with a high water table support halophytic plants such as Atriplex phyllostegia (arrowscale), A. parryi (Parry saltbush), Allenrolfea occidentalis (iodine bush), Typha latifolia and Phragmites australis (common reed). There are also winter-deciduous riparian and bottomland associations growing along Fellaw periphery, tributary streams, and associated alluvial flats are dominated by Salix spp. (willow). Forests have an understory of shrubs (Scirpus acutus (tule), Juncusbalticus,

and Carex spp. In addition, dense thickets of several species of shrubby willows, rose, Shepherdia Grataegus (hawthorn), and quercus libani (water birch), occur along gravel bars and alluvial terraces. At the elevation of about 2100 m a mosaic of sagebrush scrub, mountain Mahogany, and open conifer woodland forms the subalpine zone. The dominant woody shrub associates are Artemisia, Chrysothamnus, Riparian woodland and shrub of Populus trichocarpa, P. fremontii, Rosa woodsii, and Salix sp (Alessandrini, 2011).

3.2. Past Vegetation Distribution

According to the nearest pollen cores studies to the Fellaw Lake area represented by Zeribar Lake, Urmia Lake, and Akgol Lake respectively, this paper tried to draw a picture of the past climate of the study area. Even though the drawn picture might be to some extent blurry and lack robust evidence still it could convey at least some common past events that occurred in the area. The study area's modern vegetation pattern is similar to that of the Zaribar area despite the study area being more diverse and arboreal than of Zaribar and Mirabad vegetation. The increasing diversity and vegetation nowadays are more likely related to the precipitation and topography in the Fellaw area in the first degree and slightly to Latitudinal differences. Furthermore, the areas that are located on the western fringe of Zagros Mountain are exposed to more precipitation amount than the other lee side, Fig 6. Hence, there is a reasonable approach between the two area vegetation types regardless of the precipitation amount. In the case of the Merabad Lake area, the variation both in precipitation and Latitude are increasing and this is obvious in both area's modern vegetation contents and even past climate reconstruction drawn by Elmoslimany (1987).

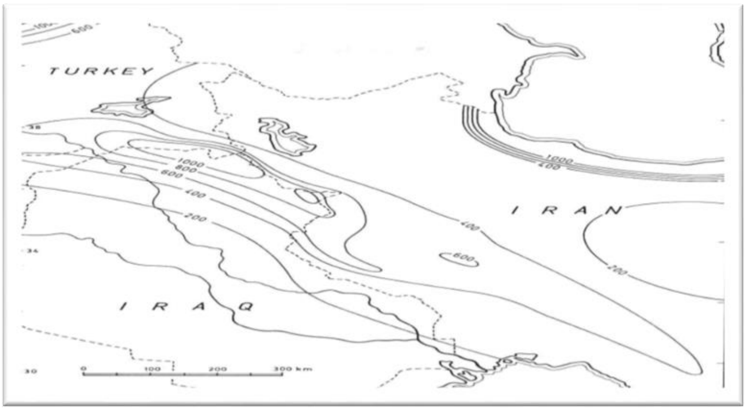

Fig. 6. Precipitation map of western Iran, the isohyets are largely after Wright (1961).

However, the Akgol Lake area is situated more in an eastern Anatolian area with a higher latitude and precipitation amount but is still located near the study area Fig. 1. According to the modern vegetation of both areas, there is a good match between them currently especially some non-arboreal vegetation. It's worth mentioning, that the study area is located in an adjacent area to each of the following:

Northern eastern of Levantine, North of Mesopotamia, and is located to the southeastern edges of the Irano-Turanian Region, Fig. 7. This location of the study area is considered so sensitive to any climatic change events in one of each of the previous regions and possibly could shed its effects on the areas around the study area. Despite this, some of the researchers considered the area as the best refuge place for the arboreal vegetation in case of paleoclimate deterioration due to its sensitive location among these regions especially for Levantine and Mesopotamia in pastimes of severe droughts such as Last Thermal Maxima (LTM) about 10000 years ago. Reversely, it is considered a refuge area for the arboreal vegetation types of northern latitude in case of glacial dominating and Albion ice sheets advancing such as in the time of Youngers Drays (YD) approximately 14000 years ago.

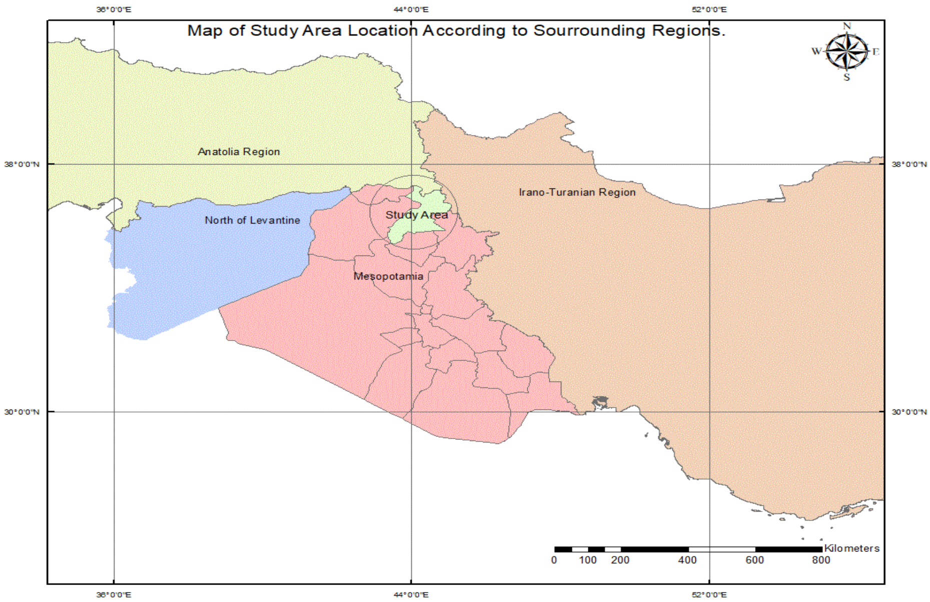

Fig. 7. Map of the Study Area Location According to Surrounding Regions.

The results show that the few long paleo-ecological records from elsewhere in the area neighboring are summarized to provide a large-scale, of glacial-interglacial conditions, with a focus on the past approximately 13 kyr. There is some literature on the climatic history and Late Quaternary vegetation of surrounding countries and regions of the study area that often produce conflicting discussions about the nature of that history. Different response functions of the climatic proxies are used, the several permutations of the precipitation-temperature ratio, regionalization of climatic patterns, and differences in methods of analysis and ecological interpretation are some of the causes of the variations in the area stories (Van Zeist and Bottema, 1967; Djamali et al., 2008; Kehl, 2009). For instance, Kehl (2009) addressed the modern and paleoclimate of Iran, he indicated that it's mostly Mediterranean and governed by the pressure systems of the Siberian High, the SW Monsoon, and the westerly depressions. The past intensities and locations of these systems changed probably causing climate change and influencing landscape evolution in this ecologically diverse country. Kehl (2009), briefly reviews the present state of knowledge and identifies future perspectives of paleo-climatic research in Iran. He found that in western and northern Iran some kilometers far from Fellaw the climate changed between cold and dry climatic conditions during the stadials and warm and moist conditions during the interglacial. Lake sediments and loess deposits also suggest moisture increases during interstadials of the Last and Penultimate Glacial. While in the western part of Iran, the Lower Holocene and the Younger Dryas were most probably characterized by dry climatic conditions. Ultimately Kehl, M. concluded that the climatic cycles and events known from other parts of the globe are rarely documented in Iran and our picture of past climate change there is incomplete and patchy. Where Djamali et al. (2008) presented a palynological study based on two 100-m long cores from Lake Urmia in northwestern Iran Fig. 1, provides a vegetation record spanning 200 ka, the longest pollen record for the continental interior of the Near East and to some extent near the Fellao lake area. He found that during both penultimate and last glaciations, a steppe of Poaceae and Artemisia dominated the upland vegetation with a high proportion of Chenopodiaceae in both upland and lowland saline ecosystems. While deciduous Quercus and Juniper trees were extremely rare and restricted to some refugia. A pronounced expansion in Ephedra shrub-steppe occurred at the end of the penultimate late-glacial period but was followed by extreme aridity that favored an Artemisia steppe. Djamali et al., (2008) also registered during his study a very high lake levels, indicated by both sedimentary markers and pollen, occurred during the late part of the penultimate glaciation and the middle of the last glaciation. The late-glacial to early Holocene transition is represented by a succession of Hippophaë, Ephedra, Pistacia, Betula, and finally Quercus and Juniperus. The last interglacial period

(Eemian), slightly moister and warmer than the Holocene, was succeeded by two interstadial phases equivalent in pattern to those recorded in the marine isotope and southern European pollen records and sequences. However, the last study focuses more on a microenvironment of an area that probably reflects more the microclimate of that area in the past but still could indicate to some extent the availability of some common plant species prevailing in the Fellaw study area at time between (10000-9000 YBP) represented mostly by Artemisia, chenopodicea and less in Poaceae. Van Zeist and Bottema (1967) reconstructed the history of western Iran vegetation in the late Quaternary in a pioneer study for the area. They discussed the results of the palynological investigation of sediment cores obtained from Lake Zeribar and Lake Mirabad, both situated in the Zagros Mountains of western Iran, where Zagros mountains are the same mountain chain that extent around the Fellaw Lake area but from the northwestern direction. Their findings are also approximately similar to the previous study findings of Artemisia, chenopodicea, and Poaceae at the same time mentioned above. Accordingly, in the Fellaw area, there is an expectation of findings of the same spices prevailing depending on the approaches of both areas. In addition to the distance factor the modern precipitation amounts of both areas are largely similar, Fig. 6 (Wright, 1961). The palynological examination of core sediment by Van Zeist and Bottema (1977) from Lake Zeribar and Lake Mirabad in the Zagros Mountains of western Iran according to Radiocarbon dates suggests that the Lake Zeribar pollen record covers the last 40,000 years, of Lake Mirabad the last 10,000 years. In the period of 40,000 to 10, 500 YBP open vegetation, in which Chenopodiaceae, Artemisia, and Umbelliferae played a primary part, prevailed in the Zagros Mountains. The high percentages for Umbelliferous pollen, among which a fairly large number of types could be distinguished, are a remarkable feature of the Zeribar pollen diagrams. Scattered tree stands were present in the Zeribar area in the period of 40,000-22,000 YBP., whereas between 22,000 and 14,000 YBP. trees had disappeared totally from the Zeribar area and supposable from the greater part of the Zagros Mountains. In the Pleniglacial times climatic dryness must have been a major limiting factor for tree growth in western Iran. After 14,000 YBP. pistachio was again present in the Zeribar area. Trees (Quercus, Pistacia, Acer, etc.) distended slowly in western Iran after 10,500 YBP., which led to forest-steppe vegetation. The nature of the herbaceous vegetation varied obviously from that in periglacial times. It was not until 5,500 YBP. that the present-day natural forest cover had established itself. In the upper sections of the Mirabad and Zeribar diagrams, different implications of human activity are registered. Van Zeist and Bottema (1967) also reach to a comparison of the Zeribar pollen record with that of sites in western Syria, south-western Turkey, and Greece and indicate that the Pleniglacial climate of continental western Iran should have been more diverse to arboreal growth than that of areas adjacent the Mediterranean coasts. Most pollen diagrams from the Eastern Mediterranean area indicate that the early postglacial climate was drier than that of today. Despite if this was due to drier summers or lower is not yet obvious. Ultimately, they reviewed the same archaeological inferences as the findings of the Palynological investigation. In another study, El-Moslimany (1987) addressed very interesting facts regarding past vegetation distribution by investigating the ratio among some arboreal and non-arboreal species, in the Zagros area. He found that Non-arboreal pollen groups have an advantage in that they are more likely to reflect populations that are in equilibrium with their environment than are tree populations which, due to their longer life cycles, are more affected by inertia or lag associated with immigration. The important non-arboreal pollen producers at Lake Zeribar vary in their ecological requirements, especially in their requirements of amount and seasonality of precipitation. Accordingly, possible climatic information is recorded in the presence and relative plentiful of their pollen. El-Moslimany (1987) indicated that the environment of Pleistocene Lake Zeribar may have been similar to the alpine zone of the modern Zagros Mountains. The dominance by pollen of Chenopodiaceae and Artemisia is illustrated by the low pollen production of high-altitude vegetation, where Fellaw Lake is located favoring the incorporation of pollen of late blooming vegetation into the sediments, and high production and long-distance transport of bottomland pollen. However, high percentages of Chenopodiaceae and Artemisia pollen do not inevitably denote low annual precipitation but a highly seasonal climate with hot, dry summers and cold winters. Such a climatic regime was in effect continuous except for a period beginning approximately 10600 YBP. during which decreased summer drought occurred. As a result of a change in seasonality, there was a dominance of Poaceae pollen and the initial expansion in arboreal pollen. A moisture curve based on the ratio between Chenopodiaceae and Artemisia pollen signifies a periglacial climate with late glacial, wet winters and an early Holocene climate with periods of intensive aridity. The climatic history displayed here is compatible with seasonality changes and with non-Palynological evidence of regional late Pleistocene climates suggested by climatic modeling based on orbital parameters, Fig. 8.

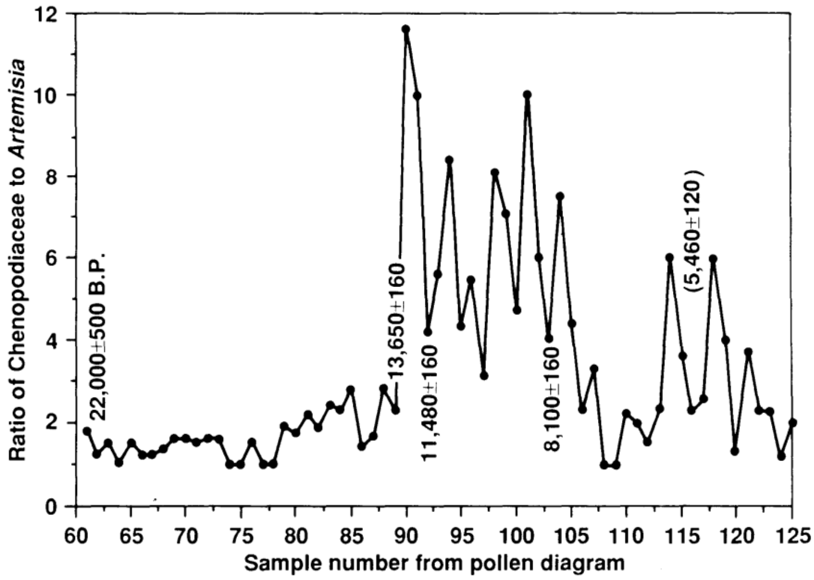

Fig. 8. Chenopodecea /Artimisia curve for Zeribar pollen diagram from - 22000 YBP. to 5500 YBP. After (El-Moslimany, 1987).

In a pioneer study by Van Zeist and Woldring (1978), a palynological examination was implemented on sediment cores from Lake Van in the eastern of Turkey, an area to the west of Fellaw Lake Fig. 1. According to varve counting the dates for the Lake Van pollen were recorded. The lower section of the pollen diagram presents predominantly desert-steppe vegetation, in which Ephedra, Chenopodiaceae, and Artemisia alternatively played a conspicuous part. They found that area aridity must have been the limiting factor for arboreal spread and growth. Reversely, and as a result of a significant increase in humidity the desert-steppe was progressively displaced by forest in the period of ca. 6400-3400 years to the west and south of the lake, which is similar to that of the area in northwest Iran. Plus, oak forest vegetation yielded its maximum expansion in southeast Turkey. A conspicuous feature of the postglacial history of vegetation in the Van Lake area is the delay in the expansion of the forest. Woldring and Bottema (2003) conducted very comprehensive research on the vegetation history of east Anatolian about ESKI ACIGOL lake pollen and sediments. They found that Steppe plant communities predominate during the Late Glacial, substantial values of Gramineae reveal relatively humid conditions for the earlier part, followed by an increase of Chenopodiaceae during the next period, which suggests increased summer drought. In the last phase of dominating steppe vegetation, Artemisia pollen values suggest low winter temperatures. Additionally, the patches of oak scrubland or woodland are present throughout the Late Glacial. A change from cold and drought-tolerant semi-desert vegetation to grass steppe and oak terebinth woodland indicates a shift towards a more humid and warmer climate. There is evidence from glacier lake sediments and the glaciers in the Kaçkar Mts, in Turkey the younger glacial advance and maximum in the Last Glacial Maximum (LGM) took place during the Late Glacial (Sarıkaya et al., 2011). The data of lake sediments in the south, central, and eastern Anatolia reveal that the past climate of these regions included some alterations between dry and wet periods since the Late Glacial and it's not as stable as those conditions of western Iran (Roberts et al., 2001; Wick et al., 2003; Roberts et al., 2011; Erginal et al., 2019). During the late glacial the climate was dry and cold and it was even drier and colder during the Younger Dries (Wick et al., 2003). However, lacustrine records and research from other parts of Anatolia are limited somewhat in describing past climate change in the southeastern Black Sea coast where the climate dynamics and current climate are quite different from the other parts of Anatolia (Turkes, 1996; Turkes and Erlat, 2003). The early Holocene distribution of Pistacia in the northern part of Levantine where they are parallel to the Fellaw area is represented by a typical feature in the diagrams of Acigol, AlGhab, and Van, and does not exist in the Pisidian diagrams. Moreover, Pistacia is also absent from several other diagrams coping this time, for instance: Ladik Gulo and Abant in the Pontic Mountains in northwest Turkey (Bottema, 1974). However, the southern latitudes illustrated an earlier development of Pistacia presented obviously in the pollen diagram predicted from Mirabad (Van Zeist and Bottema, 1977) that shows substantial values (c. 5%) from the start of sedimentation dated back to about 10,370 YBP, which refer to highly favorable Late Glacial conditions in the southern Zagros and southern Levant. The palynology data assume an eastern area favorable for the development of an oak-terebinth association. The oak-terebinth association existed in the Zagros Mountains, the Levant, and the highlands of Anatolian. Despite, Pistacia's absence in the western part of Turkey, some pollen diagrams from the Greek central land also explain the prevail of Pistacia at the beginning of the Holocene (Bottema, 1974). There is some expectation that we are here dealing with the same composition of vegetation species, since the Thermo-Mediterranean (Pistacia lentiscus) may have significantly participated in the production of Pistacia pollen. In conclusion, it can be suggested that the Near Eastern early Holocene spread of terebinths more likely coincides with the wild domain of cereal or the Fertile Crescent. The spatiotemporal distribution of Pistacia in the Late Glacial refers to higher warmth and humidity in the southern part of the Levantine, (fig. 4). From the hard-to-collect reasons for the absence of Pistacia in the pollen diagrams of southwestern and northwestern Turkey, it seems inaccurate that rainfall amounts were too low which means competition from other grass and woody species in the niches suitable for arboreal growth restricted the prevailing terebinths. Meanwhile, Pistacia is only found in some sheltered places such as the Nar Golu crater and Lake Ihlara Valley. Freitag (1977) addresses the prevention of Pistacia atlantica to sheltered habitats in some areas of Iran, where aridity restricts its general prevailing. The idea of such isolated occurrences in Central Anatolia during the early Holocene for example in the shelter of the Acigol Crater, has to be rejected since terebinth also dominates the botanical samples of archaeological sites like Musular and Asikli. Despite, Pistacia atlantica/terebinths being absent in the Akgol Adabag pollen record, its seeds and charcoal are uncovered at Neolithic Catal Hoyuk during the excavation campaigns of 1996-1999 (Hastorf and Near, 1997; Asouti et al., 1999). The terebinth absence in the pollen record refers to that these vegetation types were not growing in the Konya plain but in the state in the uplands surrounding the plain (Robert, 1980). In conclusion, Pistacia atlantica is considered to be the main indicator and producer of the early Holocene pollen in western Iran and on the Anatolian plateau (Van Zeist and Bottema, 1991). Currently, this species obtains a vast range of distribution that extends from northeastern Greece into the Iranian highlands (ssp. mutica, ssp. kurdica), Pakistan, and Afghanistan (ssp. cabulica) (Rechinger, 1969). Ssp. Mutica and ssp. kurdica range from 0 to 1720 m above sea level in Anatolia. The first subspecies spread in the western part of Anatolia, including Central Anatolia west of the 36° meridian, whereas ssp. kurdica (synonymous with P.eurycarpa) is prevented to the extreme southeast of Turkey (Davis, 1965-1988). Ssp. kurdica existed also in Iran, Syria, and Iraq. Another species with an ample large area of spreading is P. terebinthus ssp. palaestina (50-1500 m above sea level), occupying most of Anatolia, except the extreme southeast. This subspecies is also common in Lebanon and Syria, the western ssp. terebinths have a range of spreading from northwestern Turkey to France and Portuguese. P. khinjuk (1000- 1800 m above sea level) is fairly widespread in southeastern Anatolia particularly south of Van and northeast of Iran, Pakistan, and, Afghanistan. Ultimately, Pistacia lentiscus is prevented largely to the thermo-Mediterranean and does not grow above 600 m altitude, here it’s a reasonable conclusion to not grow in the Fellaw area. Terebinths generally flourish in calcareous soils, and are heliophilous and xerothennic (Browicz, 1982). It is obvious that the current area of Pistacia atlantica spreading in Anatolia almost dominates the area where it was missed in the early Holocene, despite all, it must be admitted that it is very unlikely that any pollen evidence is available for the central part of western Turkey. Unfortunately, subfossil and surface samples give the slightest information for a present distribution of Pistacia in the west of Turkey. Substantial Pistacia values were only registered in surface samples collected from thermo-Mediterranean maquis of southwestern Turkey with abundant Pistacia lentiscus (Van Zeist et al., 1975). Baruch (1999) suggested that P.terebinths ssp. palaestina is accompanied by evergreen oaks, whereas P.atlantica is accompanied by the Tabor oak (Quercus ithaburensis) in the Levant. In Turkey the distribution area of ssp. palaestina is substantially larger than that of evergreen oaks, especially spreading further inland with some area on the plateau. The ssp. palaestina is spread further east in Turkey than Pistacia atlantica (ssp. mutica) recently, assuming a certain tolerance of this subspecies to more continental conditions that are similar to of Fellaw area. Rossignol-Strick (1995) stated that higher humidity and lessened continentally favored the distribution and the early Holocene optimum of Pistacia. According to these conditions ssp. Palaestina, P. terebinthus, and P. atlantica ssp. mutica may have been more widely expanded in the early Holocene. The present peculiar occurrences and sporadic terebinths on the Central Anatolian plateau (e.g. Ihlara Gorge and Crater Lake Nar Golu) highlight the necessity of humidity. Maybe these are the last occurrences of a previously vaster area of expansion, which would indicate the increase of continentally towards current times. In Syria, also the Ghab area to the west of Fellaw, Fig. 1, studied by Yasuda et al. (2000), explains an increase of a regular pattern in the oaks deciduous since approximately 14,500 YBP, with maxima from about 12,500 to several centuries into the Holocene. The first Ghab diagram prepared from a coring situated 30 km north of the one by Yasuda, by Niklewski and Van Zeist, (1970) shows a quite abrupt tree expansion of about 11,000 BP, whereas an almost treeless landscape dominant in the previous millennia. The increase of Pistacia in Ghab diagrams almost parallels the oak's Late Glacial expansion. In other words, the oak-terebinth parkland existed much earlier in these latitudes than the one in the Anatolian plateau, where it prevailed by about 9000 BP. Accordingly, this vegetation type spread as the result of a warmer climate and more humid, and thus, the Levantine experienced a climate improvement approximately 5000 years earlier than the climate of the northern latitudes and northwestern Iran, the area near Fellaw Lake. However, in Van Lake, the most preferable climate for tree growth happened between approximately 7500 to 4000 YBP., where Ghab diagrams (Yasuda et al., 2000) reflect more favorable conditions in the Late Glacial than in later periods. Locally, and even though most of the research conducted in Iraq is around and beneath 32o Latitude, but still should be mentioned as a previous local study of the area since it is located in the same country. Al-Jubouri (1997) as a pioneer study, investigated the climatic changes and the plants in the Delta of the southern part of Mesopotamia during the Holocene and Late Pleistocene periods. Al-Jubouri (1997), mentioned that the area was affected by a warm and humid climate in the period (21000-18000 YBP) then followed by a cold and dry climatic during (18000-14000 YBP). These two periods mentioned by Al-Jubouri (1997) could be to some extent compatible with the global trend of climate represented by the last glacial Maxima (LGM) (21000-18000 YBP) and Younger Drays (YD) (18000-14000 YBP), (Perrott and Roberts, 1983; McClure, 1976 and Yan and Petite-Maire, 1994). AlDulaimy (2003) in a study on the sediments of the Euphrates floodplain west of Iraq studied the palynology of three boreholes in the area with depth ranging to about 21 meters. He divided each core sample into five palynological zones, Fig 9, the main findings of his study that zones 2 and 4 are witnessed more humid and warm conditions which led to the flourishing of some kinds of vegetation at the depth between (8-10) meter or the age of about (12000-11000 YBP.), such as Palmae, (R.absayae and Retimoncolites maxima) Taxodium, Betula and Pinus (Ulnus. Piceae), were the grasses species of the same depth were dominated by Monoporite. Zone 4, for the same mentioned above time, witnessed a high diversity in Polymorphs amount especially the aquatic species for instance Sphaginum, Deltoidospora, and Lycopodium which indicate the approaching of the Persian Gulf coastline more to the area, and this could be compatible with a study conducted to the area north-western of Iran by (Van Zeist snd Bottema, 1987). However, other zones represented by zones 1, 3, and 5 witnessed more dry and higher percentages of evaporations in the area, this can be inferred from the very few number and types of spices found in the deposits of the boreholes. Chenopodecia Sarcobatus was the most available type of these zones which is an ideal pointer to the deteriorating climate and as well of late Quaternary species prevailed. In Concluding, AlDulaimy (2003) found many climatic cycles passed the area, the oldest one detected in his study was during the period (21000-18000 YBP) at zone 4 when the climatic conditions were highly warm and humid with the possibility of summer precipitation as depicted by the wide distribution of Graminae pollen grains (Fig. 9). Furthermore, Benni and Al-Tawash (2011) studied the paleo-environmental and paleoclimate changes of the Bahr Al-Najaf Depression during the early Holocene and Late Pleistocene by using Palynological analysis for the sediments. Samples were collected from two sites (BN1 and BN2) in the depression, and 23 to 19 samples were collected from the first and second locations, respectively. These samples are prepared and studied to determine the content of spores, pollens, and marine organisms (Dinoflagellates). The study addressed environmental and climatic changes in the area during the Late Quaternary, where seven climatic zones were determined in the studied sequence, then correlated and compared with other areas inside and outside of Iraq. Benni and Al-Tawash (2011) conclude that the climate was pluvial with intervening dry periods in time around 18000 YBP. They revealed as well that an indication of some marine effects on the study area at the beginning of Holocene as a result of the global sea transgression inferred from the existence of some marine organisms, such as Dinoflagellates, there is a compatibility here with the past climate condition of warm and more precipitation found around Urmia Lake (Djmali, 1991). Furthermore, Al–Tawash (1996) recorded an increase in the water level of Razzazah Lake during the period around 12000 YBP, during their study on the lake deposits of the seventh zone represented by the depths 60-29 cm. with probable a time interval of 12000-5800 YBP, they found an increasing percentage of Graminae, Polygonium, Quercus, and the presence of Palmae, Artemisia, and Laevigatosporites with the aquatic palynomorphs acritarchs, and that fulfilled by dinoflagellates and foraminiferal test linings. Their study suggests a dense vegetation cover formed by a wet and warm climate with the existence of summer rainfall; i.e. a pluvial period generally. The peak of this pluvial period is estimated to have taken place during the time interval of about 9000-6000 YBP, as recorded by the sediments from depths 45-30 cm. These conditions led to the precipitation rates exceeding that of evaporation and caused to filling and recharging of the paleo-lake of Razzaza to a level of about 32 m. (a.s.l.) and probably caused its overflow and here it’s somewhat compatible with the spread of arboreal spices in north-western Iran.

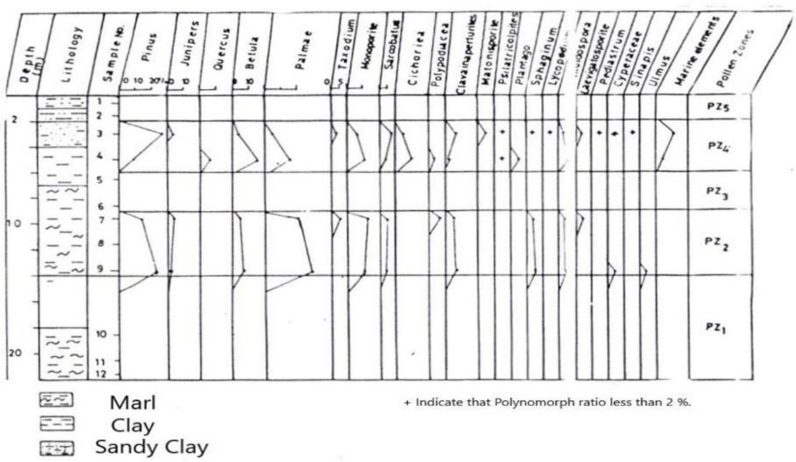

Fig. 9. Palenological Sketch for the Miocene Deposits of borehole for the Late Quaternary / Alromadi area, after (Al-Dulaimy, 1999).

In adjacent areas such as the empty-quarter desert, the Humidity increased during (12000-10000 YBP) which is referred to as a global trend of that time climate trend (Anton, 1989). However, the warm and the wet conditions returned to cover a vast area of Iraq and neighboring countries during (14000-11000 YBP), through the dominance of Graminae and the decreasing of Chenopodiacaeae in the Euphrates flood-plain (PZIII). (AlDulaimy, 1999, 2003). Humidity also increased in the empty-quarter desert during (12000-1000 YBP), (McClure, 1976; Anton, 1989). Abed (1998) suggested that the lake Lissan in Jordan experienced a server drought during (20000-16000 YBP), and the vegetation cover was dominated by steppe vegetation that resisted the cold and very dry climate. In many other studies, there is an indication that the warmth period followed (LGM) was irregular and fluctuated in the Arabian regions, and the more visible are two stages of Persian Gulf transgressions that covered the area due to the rise of sea level during (14000 and 11000 YBP) (Yan and Petite, 1994). However, many climatic changes might be located on a small scale in the Arab region, where the Iraq territory and the adjacent areas are subjected to high warmth and wet conditions, which is represented by prevailing Gramminae on the vegetation of the area with an obvious decline in Chenopodiaceous species and high diversity of area plants, with the finding of plamae pollens grains in good rates, and this was to some extent is compatible with most paleoclimates researches (Anton, 1989; Al-Dulaimy 2003), some of which predicted that the most African and Arabian deserts are subjected to Monsoon precipitation during (14000-11000 YBP), with the begging of the transgression of the Persian Gulf (Roberts, 1980). The most historical event that the Mesopotamian region was passed through, is what is believed to be the NOAH DELUGE about (11000-10000 YBP), which had a great impact on the existence of civilizations and human settlement. Al-Tawash's (1990) study on Razzazah Lake in central Iraq, Al-Jubouri (1997) study on the Mesopotamian plain south of Iraq, and Al-Dulaimy (2003) study on the Euphrates floodplain, and Benni and Al-Tawash (2011) study on Najaf Sea, all these studies shows altogether the existence of such a great event in the Mesopotamian region, through the existence of marine organisms such as (Dinoflagellate, Achritarch, Foraminiferal lining in the sediments of that period, where the impact of Persian Gulf transgression extends and reached the upper Mesopotamian region during the period(10500 YBP). The climate during this great event was mostly represented by more humidity and continuation of summer precipitation, with sediment evidence of this period referring to the presence of a high amount of grass plants (Gramminae) with an increased existence of pinus. These events chronically existed with a transitional period of Pleistocene–Holocene (11000-9000 YBP). (Al-Rawi et al., 2005). In a study conducted by Brooks (2006), there are indications that regions such as the Sahara were characterized by numerous water bodies and abundant humid climate fauna and flora, and rainfall with surface water more abundant throughout much of the northern hemisphere and particularly extra-tropical zone during (10000-6000 YBP). Al-Dulaimy (2003) as well during his study support the humid and rainy climate of the period (10000-6000. YBP) by the presence of pollens in the forest, particularly in the uplands areas around the Mesopotamian plain. This humid period extends to cover an area of the Empty-Quarter desert, where the water level of the lakes that existed there raised obviously (McClure, 1976), Robert (1980) referred to the Arabian deserts and most of the Fertile Crescent countries near the Fellaw area are effected by monsoon rains during the period (9000-6000 BP). However, Evans (1977) pointed out that the coast of the Persian Gulf located in the area between Baghdad-Samara during (7000-6000 BP), but the period (8000-7000 YBP), considered as an exception which was recorded in the Tigris floodplain, which pointed to dry and cold conditions with rare precipitation amounts, as indicated by dominance of Chenopodiaceae in addition to the distribution of Artemisia pollen which presence usually in a very high cold condition, noting that this stage was not recorded in Euphrates and Razzazah sediments by Al-Tawash (1996). Ultimately, the deteriorating and volatility of climate in the Mesopotamian plain and surrounding regions continued since the period (6000 YBP), this was obvious by the oscillation in the vegetation assemblages that existed in the sediments of the region and were dominated by the dry climatic conditions similar to that of current days, which indicated by the dominance of Palmae pollen, Chenopodiaceae, Centaurea, and Plantago which indicate the clear influence of human activities on the environment Al-Dulaimy (2003).

4. Conclusion

The vegetation of the uplands and mountains around the Lake has probably not been significantly altered by human activity. The general pattern of vegetation along the axis of the valley is a highly diverse mosaic of plant associations transitional between Mountain Forest Vegetation-Oak Forests and Thorn-cushion vegetation (sub-alpine area). Modem vegetation types of the area adjacent to Fellao Lake include small oak scrub and alkali meadows and seeps. The moister margin of the lake with a high water table supports halophytic plants such as Atriplex phyllostegia (arrowscale), A. parryi (Parry saltbush), Allenrolfea occidentalis (iodine bush), Typha latifolia and Phragmites australis (common reed). These above-mentioned vegetation types mostly exist due to the Semi Mediterranean climate of the area and as well the area governed by the pressure systems of the Siberian High, the SW Monsoon, and the westerly depressions. The past intensities and locations of these systems changed probably causing climate change and influencing landscape evolution. From most researchers involved in this study, the late Quaternary global climate was mainly a winter precipitation regime. The expanded land and sea ice empowered the latitudinal temperature gradient, shifting the westerlies southward and weakening the summer monsoon. Furthermore, the area in the early Holocene witnessed the spread of terebinths more likely coincides with the wild domain of cereal or the Fertile Crescent. The spatiotemporal distribution of Pistacia in the Late Glacial refers to higher warmth and humidity in the Levantine that in turn could reflect the similar species prevailing in the Fellaw Lake area. At the same time in the early Holocene, it was to collect reasons for the absence of Pistacia in the pollen diagrams of south-western and north-western Turkey, but it seems inaccurate that rainfall amounts were too low which means competition from other grass and woody species in the niches suitable for arboreal growth restricted the prevailing of terebinths. However, according to previous research, the climate was pluvial with intervening dry periods in the time around 18000 years; BP. They revealed as well that an indication of some marine effects on the study area at the beginning of Holocene as a result of the global sea transgression inferred from the existence of some marine organisms, such as Dinoflagellates, there is a compatibility here with the past climate condition of warm and more precipitation found around Urmia Lake. The deteriorating and volatility of climate in the north Mesopotamian plain and surrounding regions represented by Fellaw Lake area continued since the period (6000 YBP), this was obvious by the oscillation in the vegetation assemblages that existed in the sediments of the region and dominated by the dry climatic conditions similar to that of current days, which indicated by the dominance of Palmae pollen, Chenopodiaceae, Centaurea, and Plantago particularly in Mesopotamia which indicate the clear influence of human activities on the environment. Ultimately, the analysis of research discussed in this paper along with the situation of the Lake Fellaw near the Fertile Crescent could represent a beginning step to apply an extensive study on the Lake using pollen core sediments. In conclusion of this study, there is a need for extra geochronological data and proxy information. The sedimentary records of playas and lakes besides loess deposits hold a strong possibility to identify climate signals and the paleoclimate information of tree rings or speleothems has not yet been well investigated.

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