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Landscape and Distribution Patterns of Vegetation Mounds in the El Ga'ab Depression and their Significance for Archaeology

Introduction

Vegetation mounds are a desert phenomenon formed by wind-driven and loose sediments accumulated within long-living phreatophytic shrubs (mostly *Tamarix aphylla*), which form a sand mound or a hillock with an irregular shape known as *Tarabeel – nabkhas* or *nabkas* in Arabic (see El-Sheikh et al., 2010: 832; Li et al., 2008: 333; Madani et al., 2016: 127; Pokorna & Pokorny, 2013; Rahmonov et al., 2009: 359).

Vegetation mounds are extensively common throughout the global arid, semiarid, and subhumid regions (Nickling & Wolfe, 1994). Vegetation mounds have been found in playas (Khalaf et al., 1995; Wang et al., 2008), grasslands (Wang et al., 2006), dune systems (Hesp & Martinez, 2008; Nield & Baas, 2008), mound fields (Seifert et al., 2009), coastal areas (Tsoar et al., 2009), or evolved on parabolic dunes (Ardon et al., 2009).

The creation and evolution of vegetation mounds are closely related to vegetation formation, sediment availability, and wind activity (see Du et al., 2010; King et al., 2006; McKee, 1982; Nield & Baas, 2008). For instance, in Mopti, Mali, vegetation mounds developed on vacant cultivation lands (Nickling & Wolfe, 1994). In Tarim Basin, China, the formation processes of vegetation mounds consisted of combinations of sediment availability and wind activity (Li et al., 2010).

El-Bana et al. (2002: 283) suggested that the formation of vegetation mounds creates patches where microclimate and soil properties differ from inter-vegetation mound patches. Pokorný and Pokorná (2013: 114) connected the earliest formation stages of the vegetation mounds with the degradation of the cultural landscape, desiccation and reactivation of aeolian processes after artificial irrigation. Furthermore, several researchers (e.g., Khalaf et al., 1995; Nickling & Wolfe, 1994; Tengberg, 1994, 1995; Tengberg & Chen, 1998) classified vegetation mounds as a tool for reconstructing regional climate and environmental changes.

Vegetation mounds have therefore immense value for reconstructing the palaeoenvironment and as landmarks to observe the ancient irrigated agricultural schemes and archaeological sites. Moreover, it is a very rich resource for ancient biodiversity, for fauna and flora, due to e.g., the discovery of insects which were buried inside these mounds (Nasreldein, 2019).

This paper provides essential information about the existence and distribution of vegetation mounds in the El-Ga'ab depression in Northern Sudan. We aim to answer important questions such as the exact number of vegetation mounds in each surveyed area, the distribution of dead and live vegetation mounds, the categories of soil, and the where do they distribute in the study area?

Location of the El-Ga'ab depression

El-Ga'ab area is a depression located in the Northern part of Sudan; situated on the western bank of the Nile River south of the Third Cataract, parallel to the Dongola Region. The nearest point to the Nile River is about 6 km at its northern end, and the most distant point is 60 km in the south. The El Ga'ab depression extends for 123 km across the Western Desert in a N/E to S/W direction. Its width varies from 2 km to 8 km, and thus the El Ga'ab depression covers an area of approximately 700 km2 (Fig. 1; Mahmoud et al., 2015; Tahir, 2012, 2103).

The area is considered to be a paleolake connected to the Nile during the early Holocene and an old basin flooded by the Nile during the Mid-Holocene (Tahir, 2012: 99). The lowest portion of the area is 214 m above sea level. According to Madani et al. (2015), the larger part of the area is an absolute desert with almost no vegetation because the average annual precipitation is less than 0.1 mm. The El Ga'ab

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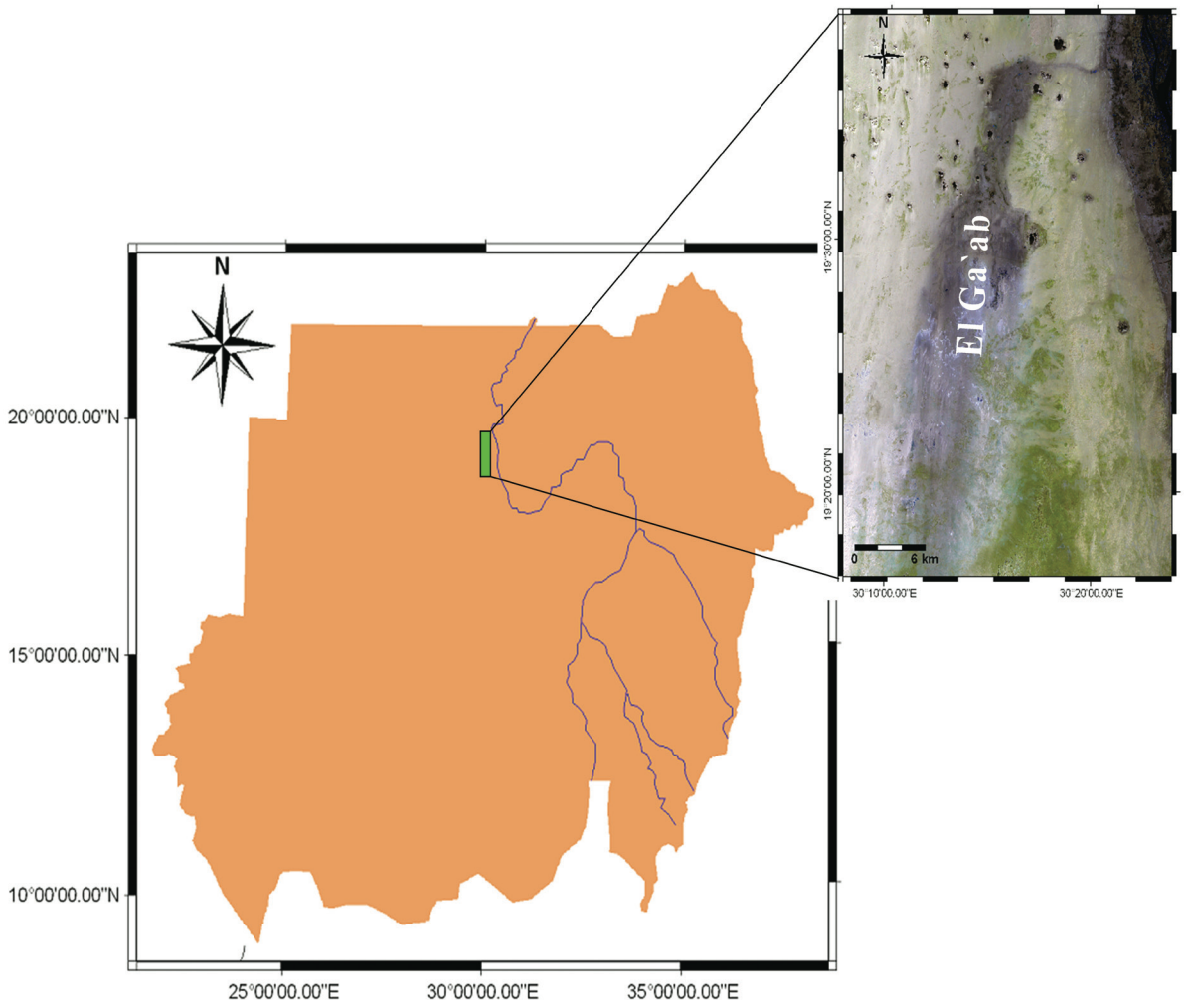

Fig. 1: Location map of El-Ga'ab depression (after Babiker & Mohammed, 2017: 9).

depression is a remote area that has several oases and wells which are providing a suitable living condition for nomadic people, such as El Kababish tribe.

Vegetation mounds in the El-Ga'ab depression

The vegetation mounds at El-Ga'ab were first observed in 2009 by Tahir (2009: 28), who described them as "unknown mounds consisting of mud and plant remains". In addition, the El-Ga'ab project team members conducted a systematic field survey in three seasons from 2013–2015. The survey aimed to investigate the distribution of vegetation mounds, morphometric aspects, and the interior structures of the vegetation mounds at the El-Ga'ab depression (Madani et al.; 2018).

Madani et al. (2015: 1–7) described the vegetation mounds as the most interesting landscape characteristics of the El-Ga'ab depression, which were noticeably recorded near old settlements. Moreover, archaeological remains from the interior of the vegetation mounds in the El-Ga'ab depression dating back to the Christian (AD 543–1324) and Early Islamic periods (AD 1504–1821) were discovered (Madani et al., 2018). These discoveries showed the significant contribution of the vegetation mounds to archaeological investigations in remote areas.

Nasreldein et al. (2021) conducted pollen grains analyses on animal coprolites preserved inside the vegetation mounds in the El-Ga'ab depression, which provided essential information on the plant consumption in the area during the late Christian and early Islamic periods (AD 1100–1300).

Materials and Methods

The archaeological survey of this research was conducted in February 2017. During this survey we aimed to focus on more detailed aspects, which were not previously considered, related to the distribution of the vegetation mounds across the El-Ga'ab

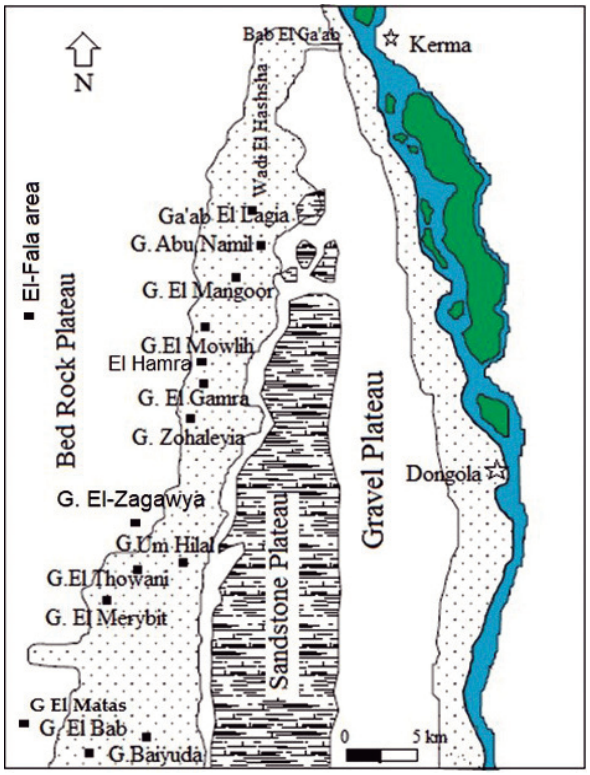

Fig. 2: The main sectors of the El-Ga'ab depression, and the location of the archaeological sites mentioned in the text (After Tahir, 2015).

depression. For instance, this survey aimed to investigate the archaeobotanical potential of the phenomena of vegetation mounds, as well as we surveyed other new areas such as El Fala and El Mats.

Vegetation mounds were counted in twelve areas within the El-Ga'ab depression. Our investigations aimed to report on the biological condition of the vegetation mounds (alive or dead). Live mounds refer to the living shrubs on their tops, confirming that their roots still reach the underground water. On the other hand, the dead mounds are considered a natural result of the shortage of underground water.

The distribution maps were designed at the lab of the G.I.S Department, Faculty of Geographical and Environmental Sciences, University of Khartoum. Coordinates of vegetation mounds were recorded on the field by a GPS device, which was subjected later to the software app Arch GIS. Then a satellite image was downloaded from the website U.S Geological survey map viewer, where a digital elevation image from a satellite called Astra with a resolution of 30 m. The baseline map was obtained from the Sudanese Survey Authority.

The distribution maps were designed to clarify the exact locations of the vegetation mounds in the study area, as well as to clarify other distribution factors, such as the categories of soils in the areas where they occur, elevations, and water resources.

RESULTS

Based on the survey results, we encountered 1219 vegetation mounds; the highest concentration of live mounds (living shrubs on their tops) was in the Ga'ab El Matas and Ga'ab El Bab areas. The live mounds represented 57% of the totality of vegetation mounds. In contrast, the highest concentrations of dead vegetation mounds were counted from Ga'ab El-Zagawya, and Um Hilal areas, representing 43% of the total.

Our survey results also showed the various categories of soils in the surveyed areas, representing that most vegetation mounds are located within the category of sandy clay loam.

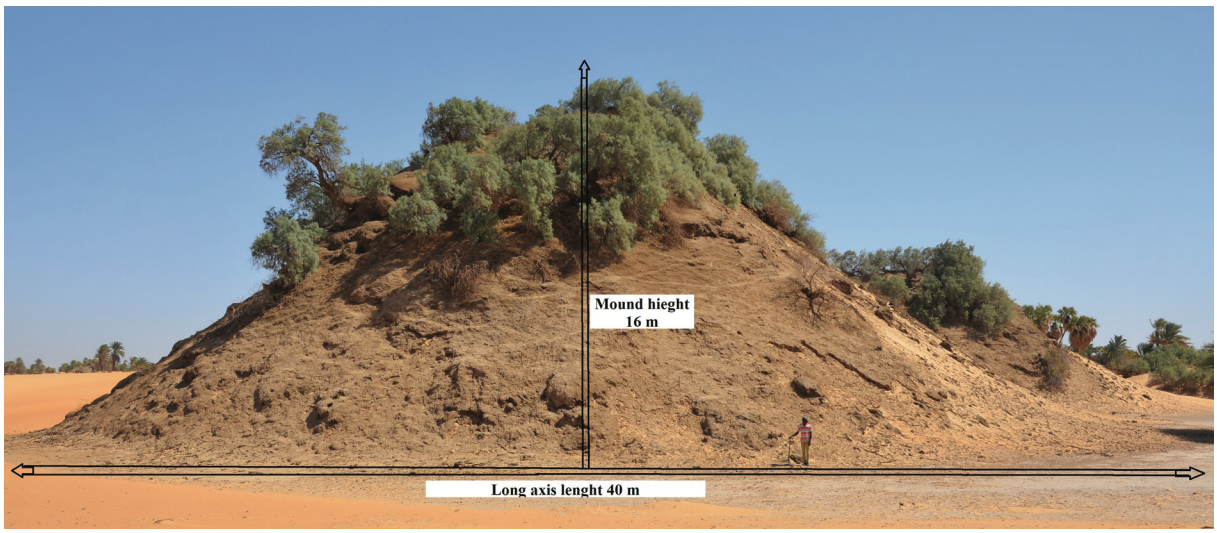

Fig. 3: An overview of a large vegetation mound from Ga'ab El-Bab at the Southern sector of the El-Ga'ab depression (Photo Hamad Hamdeen)

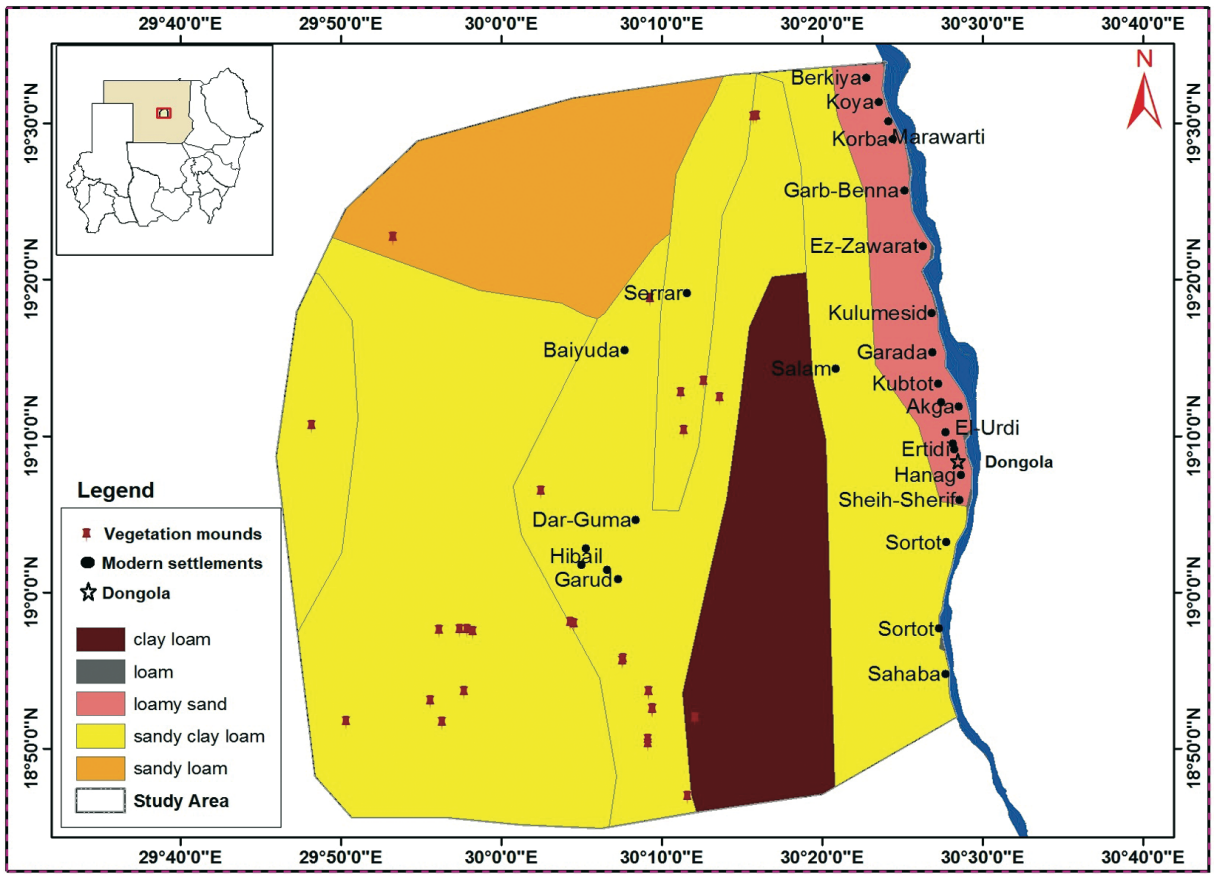

Fig. 4: Soil types of the study area, indicating that the vegetation mounds are mostly distributed within the category of sandy clay loam.

Based on the contour map (Fig. 5) it appears that the elevations in the surveyed areas varied between 215 and 270 meters above sea level. As a result, we consider Ga'ab El-Matas is one of the lowest parts of the El-Ga'ab depression, which varied between 215 and 225 meters above sea level. The high concentration of living vegetation mounds exists in the Ga'ab El-Matas area due to the availability of underground water.

Other areas such as El Hamra, Um Hilal, and El Merybit areas vary between 220 and 240 meters. The contour lines indicate that these areas are considered the lowest portions of the El-Ga'ab depression, which explains the high concentration of living vegetation mounds in these deserted areas. On the other hand, the high concentration of dead mounds were encountered in the following areas: Ga'ab El-Zagawya, Ga'ab EL-Zohaleyia, and El Gamra areas.

Based on the topographic satellite image, it appears clear that most of the vegetation mounds are located within the ancient channel of the El Ga'ab depression (Fig. 7). The distribution maps show that the vegetation mounds are located near water streams, for instance, at Ga'ab El Matas and El Merybit areas. During our field survey, we discovered that some seasonal branches are found throughout the region. We identified three of these small Wadis during our field visit, known locally as Wadi Abu Manakheer, Wadi Abu Aranib, and Wadi El Fala; the water comes from distant places through nearby streams (spread out).

Furthermore, our survey revealed new archaeological sites in the El-Ga'ab depression near the vegetation mounds in the following areas.

Ga'ab El Merybit (MRB)

About eight archaeological sites were registered at Ga'ab El Merybit, dated back to the Neolithic (4900–2700 BC) and Kerma civilisation (2500–1500 BC), with a majority of Christian sites (AD 580–1504) (Tahir 2015: 137-145). During our survey, another archaeological site, MRB 07-001, was registered nearest to one of the vegetation mounds (Fig. 8), in the coordinates 18°57'29.4" N / 29°57'52" E. The surface collections contained pottery sherds with remarkable Christian decorations and grinding stones; we assume that the site dates back to the Christian period (AD 580–1504) (Figs. 8, 9, and 10).

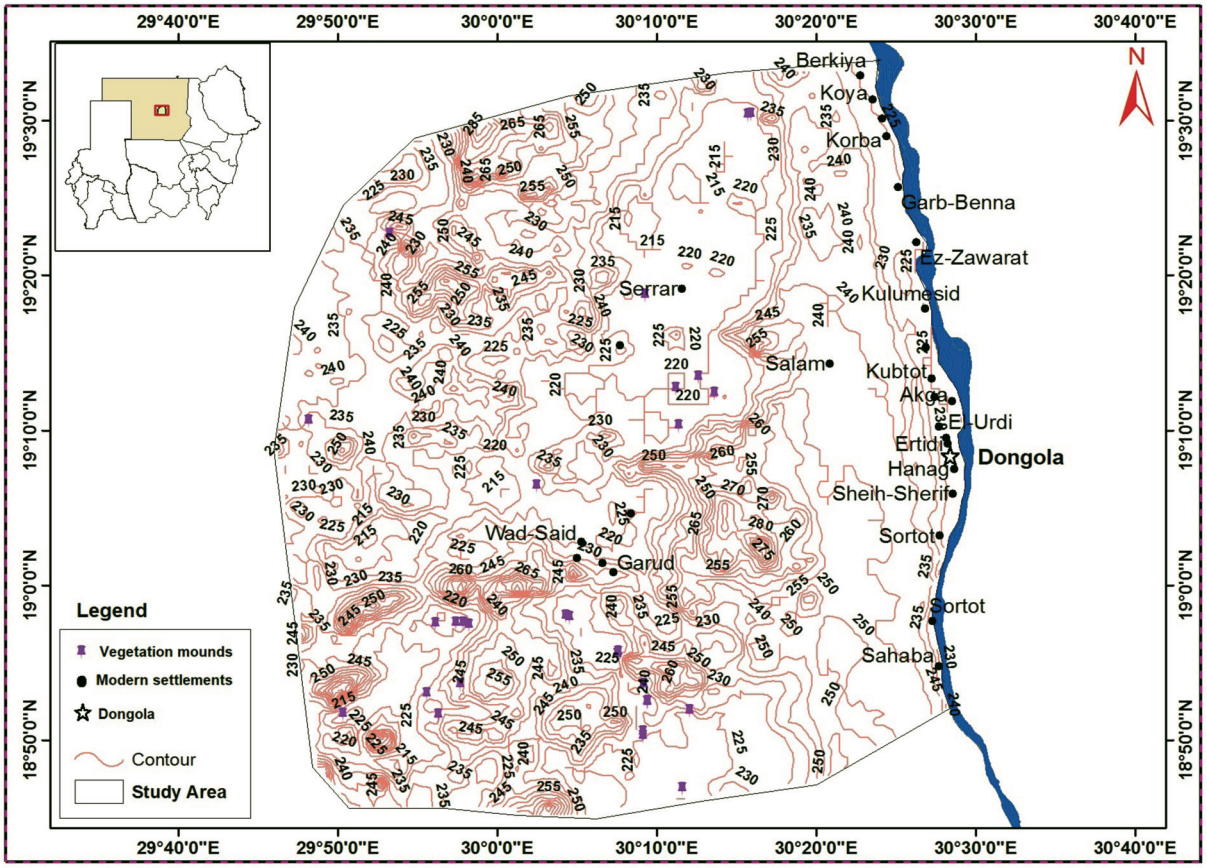

Fig. 5: Contour map and elevations of the El-Ga'ab depression showing the distribution of the vegetation mounds in areas locates between 215-240 meters above sea level.

El-Fala area (FLA)

The El-Fala area (60 km away from the Nile) is a depression surrounded by sandy hills and Nubian sandstone hilly mounds. The area is known by the local people as Wadi El-Fala (Fig. 1). Our survey revealed a new archaeological site FLA 07-003, which was located remarkably close to the vegetation mounds in the area in the coordinates 19°22'33" N / 29°53'17.6" E. Based on the surface collections, which contained ostrich eggshells, grinding stones, and pottery (Figs. 12, 13), we assume that this evidence indicates a settlement site from the early Islamic period (AD 1504–1821).

El-Zagawya (ZAG)

El-Zagawya area is a low area, where traces of an old valley occur. The surface consists of sandy ground with Nubian sandstone rubble distributed all over the surface. A new archaeological site, ZGA–07-001, was recorded in the area. Based on the surface collections, it appeared to be a settlement site surrounded by elevated hills on the coordinates 19°6'26.7" N / 30°2'46" E. On the surface pottery, grinding stones, shells, ostrich eggshells and tethering stones were visible (Fig. 14). Based on this evidence, the site could be dated to the Christian and Islamic periods.

Discussion

Despite the location of the El-Ga'ab depression in the Western Sudanese desert, there are several oases that still support life due to the availability of underground water and other natural resources, such as fertile agricultural lands. Therefore, some parts of the El-Ga'ab depression are still inhabited by El-Kababeesh settlers, which is a nomadic tribe that grazes animals and practices some other agricultural activities.

The distribution of vegetation mounds in the El-Ga'ab depression indicates their great significance to archaeology in various aspects. It provides essential information concerning irrigated schemes, agricultural production, vegetation cover, and plant consumption. According to Nasreldein et al. (2021), the study of pollen grains preserved inside the vegetation mounds at El-Ga'ab depression has revealed some

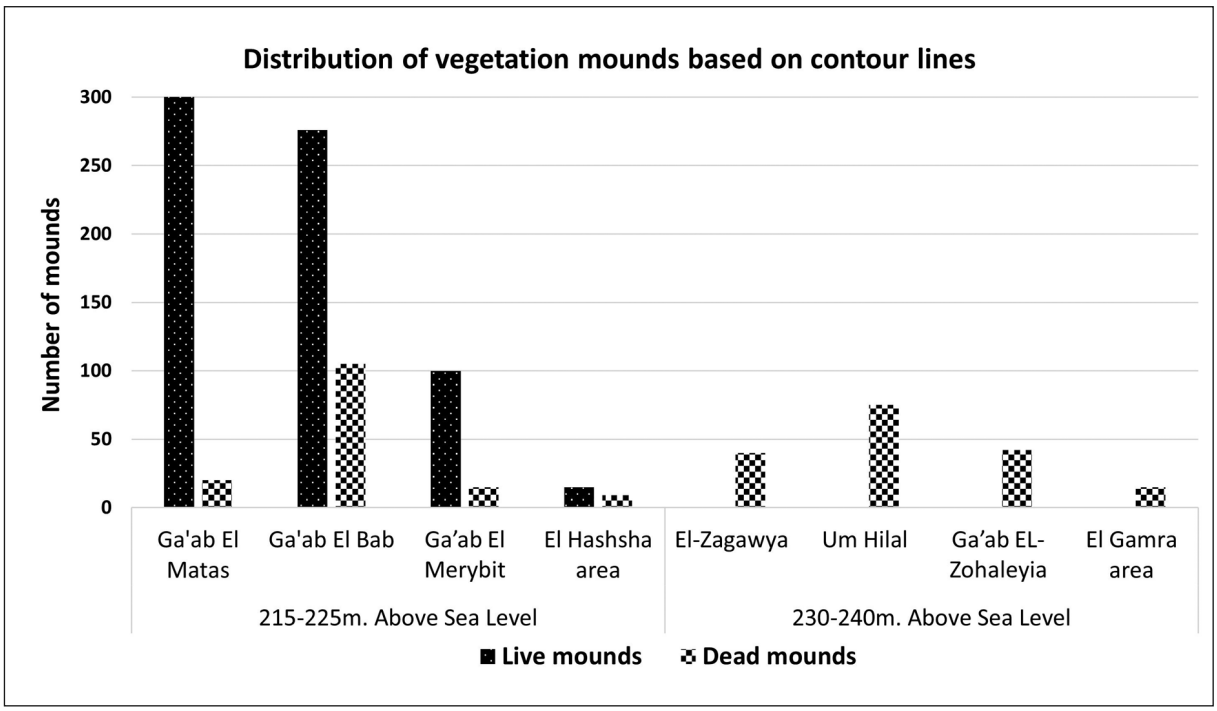

Fig. 6: A comparison between the live and dead vegetation mounds in different areas across El-Ga'ab depression, based on the contour lines and the elevations of the surveyed areas, indicating that the majority of the vegetation mounds are distributed in the areas between 215-225 meters above sea level.

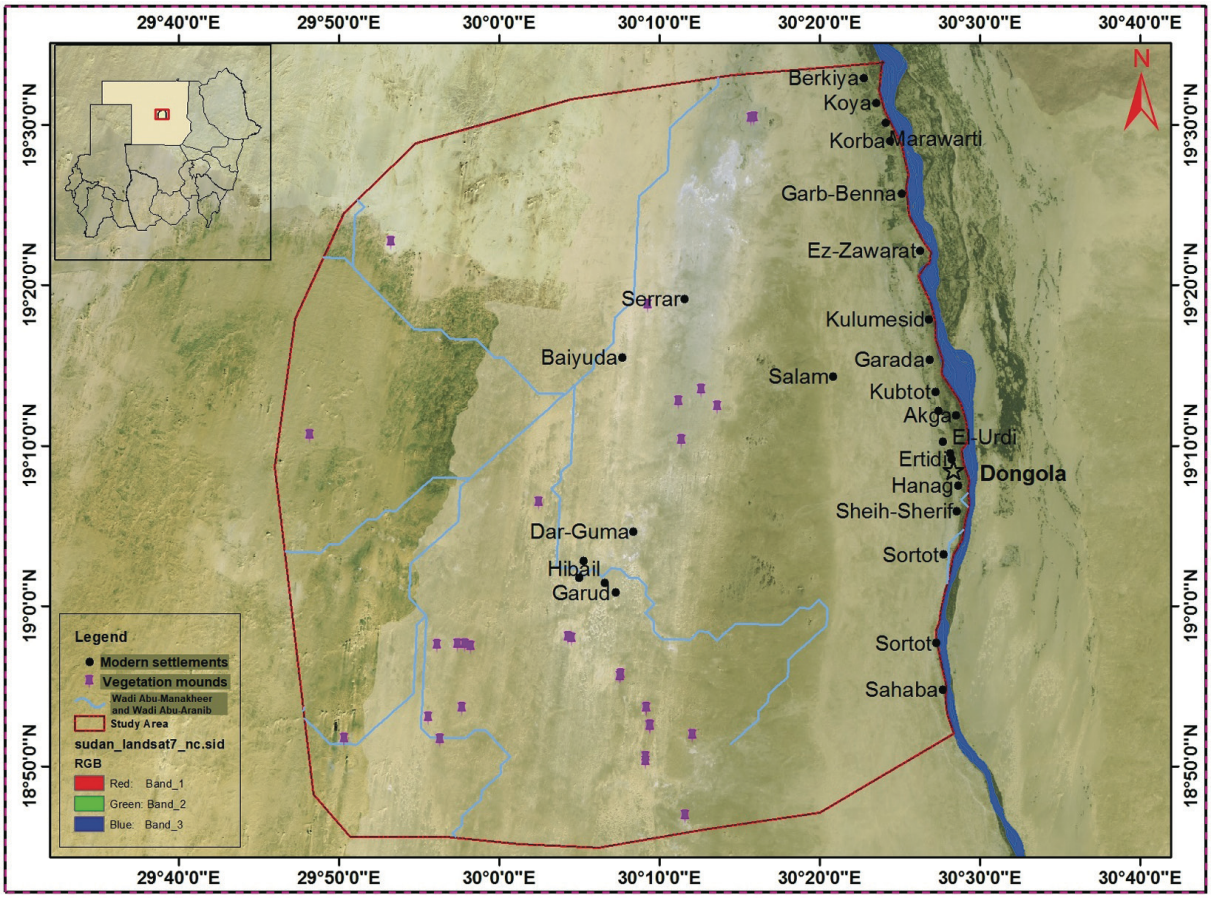

Fig. 7: Satellite image of the study area, indicating the distribution of vegetation mounds and locations of Wadi Abu Manakheer, Wadi Abu Aranib, and Wadi El Fala as shown in light blue colour.

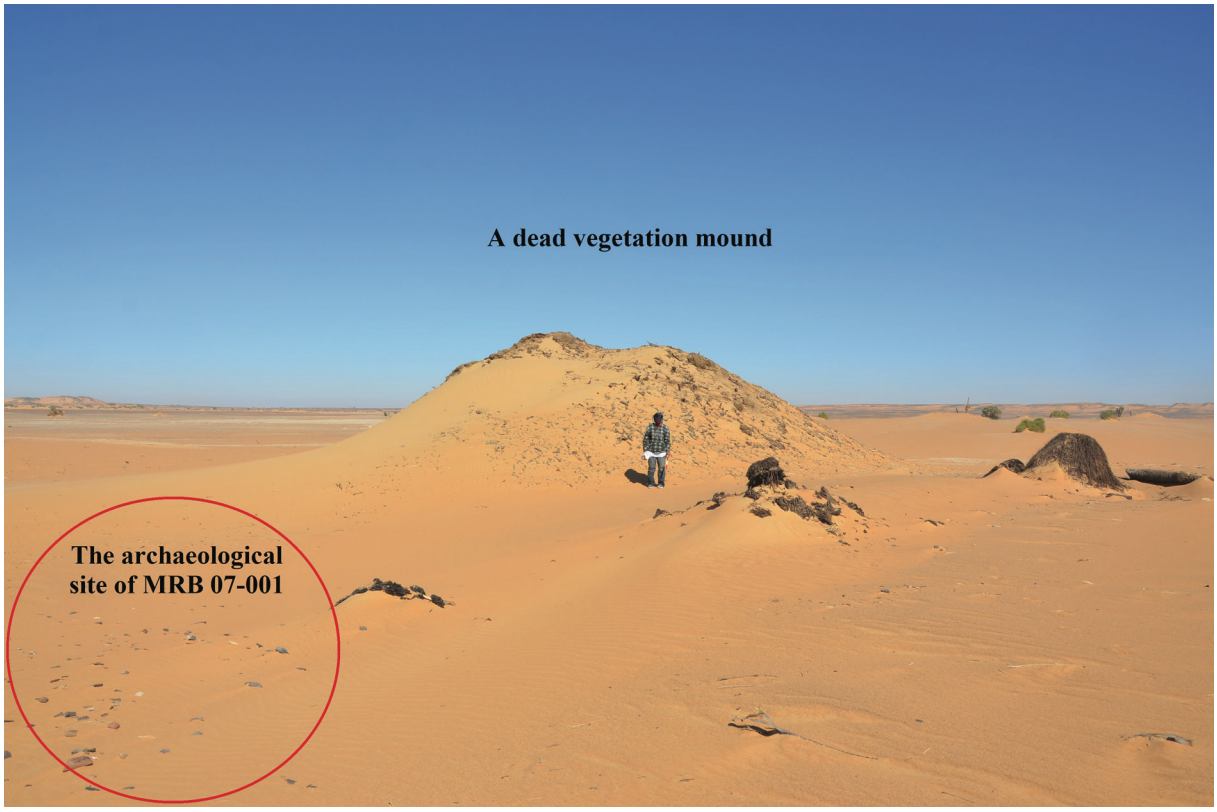

Fig. 8: A general view of the surface collections of the archaeological site MRB 07-001 next to one of the dead vegetation mounds in Ga'ab El Merybit (Photo Hamad Hamdeen).

evidences of cultivated crops and plants connected with cultivation, such as wheat (*Triticum sp*.) and the common weed (*Heliotropium parciflorum Mart.*). These results provided solid evidence for the presence of agricultural activities in these deserted areas, and cultivation of some cereals. In parallel, these results fits with what was discovered by Tahir (2011: 27); that there are some traces of *Saqia* (animal driven waterwheel) and *Matara* (waterwheel wells) in the El Hamra area dated to the Christian period. The *Saqia* is known for irrigating large agricultural lands, it was remarkably used by the Nubians during mediaeval and post mediaeval periods, until it was replaced by the diesel water pumps in the 1970s. Based on these results, we can argue that there were agricultural and cultivation activities taking place in the areas of the vegetation mounds as they could be an indicator of ancient agricultural schemes.

The previous studies (e.g. Madani et al., 2015, 2016, 2018; Pokorna & Pokorny, 2013) have shown that these mounds were formed many hundreds of years ago, and their distribution is connected with the topography of the ancient settlements. Our survey results concluded that the vegetation mounds are considered distinctive signs and landmarks that usually refer to the existence of archaeological sites and ancient settlements. This conclusion is based on the

Figs. 9,10: Pottery sherds and grinding stone from the surface collections of the archaeological site MRB 07-001 (Photo Hamad Hamdeen).

Fig. 11: General view of the two vegetation mounds in Wadi El-Fala (Photo Hamad Hamdeen).

natural habitat of the identified tree that formed this desert phenomenon known as the *Tamarix Aphylla* tree (*Tarffa* in Arabic). The tree is native to agricultural schemes, irrigated lands, and riverbanks, as it is always growing and distributed in inhabited areas.

In addition, large numbers of vegetation mounds were found in the El-Ga'ab depression near the archaeological sites, indicating that the area was inhabitable and provided an attractive place for living activities, for instance, agricultural and grazing fields.

Further, no recent settlements were found around the vegetation mounds, which supports the idea that they indicate desiccation and land degradation in the areas where they occur. As the vegetation mounds were present in large numbers in the surveyed area, we assume El-Ga'ab's palaeoenvironment was more hospitable and richer in natural resources than it is today.

Furthermore, the stratigraphy of the vegetation mounds is of great significance for archaeological investigations, as has provided important archaeological artefacts. For example, in the El-Hayz region of the Bahriya Oasis in Egypt, vegetation mounds were found to contain some buried mud-brick structures dated to the Roman and Early mediaeval periods (around AD 500) along with several archaeological and biological remains (Pokorna & Pokorny, 2013: 116). Additionally, Madani et al. (2016) discovered several buried archaeological remains inside one of the excavated vegetation mounds in Um Hilal area in the El Ga'ab depression, such as pottery, animal bones, and fireplaces dated to the Early Islamic period. Moreover, there was numerous Christian, and Early Islamic pottery found nearby the vegetation mounds. Fireplaces designed for cooking activities and food preparation were noticeably located opposite the wind direction (mostly the southern side of the mounds, thus protected from the northern winds).

According to the distribution maps of this study, it appeared clearly that the locations of mounds were found to be within the category of sandy-clayey loam, which formed a favourable condition for their existence. As shown in Fig. 4; the category of sandy-clay loam covers most of the El-Ga'ab depression. This was previously discussed by Barbour (1961: 52), who confirmed in his classification of soils of the Sudan that the vegetation mounds usually exist within the aeolian depositions.

Furthermore, based on the contour lines and elevation results, it appears clearly that the vegetation mounds only exist within the lowest parts of the study area. The results have shown that the contour lines vary between 215–270 metres above sea level. The high concentration of living vegetation mounds encountered in areas located between 215–225 meters (e.g., El Matas area). While the high

Figs. 12,13: General view of the archaeological site FLA 07-003, along with pottery sherds and ostrich eggshells from the surface collections (Photo Hamad Hamdeen).

concentration of dead (eroded) mounds locates in areas between 230–240 meters above sea level. Therefore, no vegetation mounds existed in areas higher than 250 meters above sea level.

Additionally, the topographic satellite image has shown that the vegetation mounds are located within paleo-channels and ancient streams. Subsequently, this could serve as direct proof of the land degradation and changes in the landscape. The survey results across the El-Ga'ab depression showed that the vegetation mounds distributed far from the modern settlements, which supports the idea that the vegetation mounds are signs of land degradation and desiccation. In contrast, they were recorded nearby the archaeological sites and ancient settlements, suggesting that the palaeoenvironment was totally different from the present. For instance, this evidence indicates that there were big water streams (wadi) that were rich in water, and they are supporting life activities of the ancient settlers of the El-Ga'ab depression.

Fig. 14: General view of the archaeological site ZGA–07-001, where a tethering stone on the surface and vegetation mounds appears in the background (Photo Hamad Hamdeen).

Conclusion

Vegetation mounds present a unique desert phenomenon with great potential to contribute to environmental and archaeological investigations. Formed over hundreds of years in remote regions, they can be widely used in landscape investigations. Given their significance, it is essential to prioritize efforts toward their protection and conservation. The phenomena of vegetation mounds deserve our attention and efforts to ensure their continued existence for future generations. They are facing imminent danger of erosion due to strong windy seasons in the study area. Several mounds were found to be nearly mostly eroded. They might disappear in areas with no possibility of underground water, as they only survive where the roots of Tamarix trees reach the level of underground water. Otherwise, the mound might get fully eroded due to seasonal winds.

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Zusammenfassung

Die Vegetationshügel im Paläosee El Ga'ab sind natürliche Phänomene, die von menschlichen Aktivitäten in einer als benachteiligt angesehenen Umgebung zeugen. Detaillierte Untersuchungen haben sowohl die Hügel als auch ihre Beziehung zu nahe gelegenen archäologischen Stätten rekonstruiert. Ziel dieser Forschung ist es, die frühere Umwelt in diesem Gebiet zu rekonstruieren und die Geschichte der Vegetationshügel und ihren möglichen Beitrag zu archäologischen Untersuchungen zu verstehen. In den untersuchten Gebieten wurden insgesamt 1219 Vegetationshügel gezählt, von denen 57 % solche waren, die aktuell noch Bewuchs zeigen. Unsere aktuelle Untersuchung hat gezeigt, wie wichtig diese Hügel für das Verständnis einer Umwelt sind, die bisher als feindlich angesehen wurde.