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Significance of climate change in the emergence of human fascioliasis in Upper Egypt

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Abstract

Background Climate change in the upcoming years will raise the health burden of zoonotic parasites. As a liver fluke, *Fasciola* depends on certain climate conditions to complete its life cycle and is significantly influenced by climate changes. We aimed to investigate the relationship between the increasing prevalence of human fascioliasis and climate changes in Upper Egypt.

Methods Records of *Fasciola* cases in Assiut Governorate in Upper Egypt were evaluated between September 2018 and March 2023. The annual and monthly climate parameters of the region's temperature and humidity acquired from ERA5 and FLDAS were investigated between 2000 and 2023.

Results A total of 303 patients were included. The mean age was 33.9 ± 17.4 years; 57.1% were females, and the majority were rural residents. Positive correlations were found between temperature and the recorded cases in 2018, 2020, 2021, and 2022 ($r = 0.92, 0.41, 0.61$, and 0.60 , respectively). In 2018 and 2022, humidity and *Fasciola* frequency had a significant positive correlation ($r = 0.97$ and 0.49 , respectively). An outbreak of fascioliasis was recorded in September 2018, coinciding with the peak temperature and high humidity levels, exceeding the average climatology range from 2000 to 2017. The recorded cases exhibited a seasonal pattern, with peaks in hot, humid summer and autumn.

Conclusion The rise of human fascioliasis in Upper Egypt is influenced by local climate characteristics. A climate-based map of *Fasciola* distribution using forecast risk models is needed to predict future outbreaks and for better control.

Keywords *Fasciola*, Climate, Humidity, Temperature, Upper Egypt

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Introduction

Fasciola hepatica and *F. gigantica* cause a zoonotic disease affecting the liver and biliary ducts of humans and ruminants, leading to chronic hepatitis, obstructive jaundice, and cholangitis. This significantly impacts global livestock productivity, causing substantial economic losses. *Fasciola* is widely distributed geographically and represents a major parasitic disease [1, 2]. It undergoes different developmental stages and requires specific climatic and environmental conditions to complete its life-cycle. The infected hosts excrete eggs that hatch in water, releasing miracidia which infect snails. In snails, the parasites develop and release cercariae, which encyst on vegetation. Infection occurs through consuming plants containing these metacercariae [3].

The life cycle of the parasite *Fasciola hepatica* is greatly influenced by temperature and rainfall. In regions with an average temperature above 10°C for more than six months annually, the parasite becomes endemic, with a reported summer/winter cyclic pattern for snail infection [4]. However, in warmer climates, rainfall and moisture become limiting factors. Other factors such as soil properties [5], vegetation, and altitude may also influence the parasite's life cycle [6]. Permanent water sources and irrigation activities restrict the transmission of *Fasciola* to the wet season only [7]. Based on the United Nations Intergovernmental Panel on Climate Change (IPCC) findings, a rise in global temperatures by 1.8°C to 4.0°C is predicted in the next 90 years [8]. Increasing temperatures and changes in moisture levels can affect the transmission dynamics and distribution of *Fasciola*. The parasite's free-living stages and snail host require high moisture to complete their life cycle. So changes in moisture and humidity can influence the timing and frequency of *Fasciola* outbreaks [9].

Climate change and environmental factors have been widely reported to affect *Fasciola* developmental stages and snail vectors [10]. For instance, in the past years, there has been a progressive increase in rainfall in some parts of the Mediterranean region, resulting in a severe outbreak of acute fascioliasis in sheep in southern Italy [11] and in the UK [12]. Therefore, changes in environmental conditions can influence disease dynamics by supporting the growth of overwintering larvae [13]. Very few studies have investigated the impact of climate change on human fascioliasis. A recent review found that temperature variations significantly affected snail populations, parasite burden, and disease spread [14]. Hence, understanding this impact can help with prevention and control programs for fascioliasis, which has been reported as a re-emerging or emerging parasitic disease in various nations [15].

In the last 30 years, fascioliasis has become endemic in Egypt, with mild to severe cases reported, especially

in the Nile Delta region. The estimated infection rate in Egypt is about 5.7%. Cases in Upper Egypt are less common and often go unreported due to a lack of screening studies [16] and the subclinical nature of most cases [17, 18]. In Egypt, the risk of infection is linked to raising livestock near irrigation canals and drinking water from small water channels where *Lymnaeid* vectors are colonizing [19]. Egypt has a high infection rate (43.5%) of the *Fasciola* intermediate host snail species [20], increasing the likelihood of contamination of wild vegetables, cultivated plants, and drinking water [21].

Egypt has arid weather, so it is greatly influenced by climate change. A study on the temperature trends between 1950 and 2017 in eight sites across Egypt revealed that the daily maximum temperature levels increased by $1.3 \pm 0.1^\circ\text{C}$ and the daily minimum temperatures rose by $1.3 \pm 0.3^\circ\text{C}$ [22]. There is a lack of information regarding climate change's impact on Egypt's frequency and distribution of human fascioliasis. This study aimed to evaluate the relationship between climatic conditions and the occurrence of human fascioliasis in Assiut Governorate, which reported an outbreak of acute fascioliasis in 2018 [23].

Methodology

Study area and patients

The registered cases of *Fasciola* infection in the reports of the Ministry of Health and Population (MOP) from endemic disease clinics in Assiut Governorate and Assiut University Hospital between September 2018 and March 2023 were included in the study. Cases with incomplete data record were excluded. Assiut Governorate is one of the largest governorates in Upper Egypt, located at 27°11'N 31°10'E (Fig. 1). It is located on the west bank of the Nile River, approximately midway between Cairo and Aswan, about 375 km from Cairo. The total population reached 5,126,360 in 2024, according to CAPMAS [24].

Fasciola infection was diagnosed based on clinical manifestations, including fever, abdominal pain, jaundice, and hepatomegaly. In addition, hepatic focal lesions or visible worms in common bile ducts on imaging by abdominal ultrasound and/or computed tomography (CT), the presence of peripheral blood eosinophilia in the blood picture, and high titer of serum *Fasciola* antibody with or without *Fasciola* eggs in stool were used to confirm the diagnosis.

Demographic data regarding age, sex, residence, and the distribution among the governorate were recorded. Data regarding the type of clinical presentation of *Fasciola* and response to triclabendazole were also reported which was based on the initial clinical presentation and laboratory or imaging data for each patient.

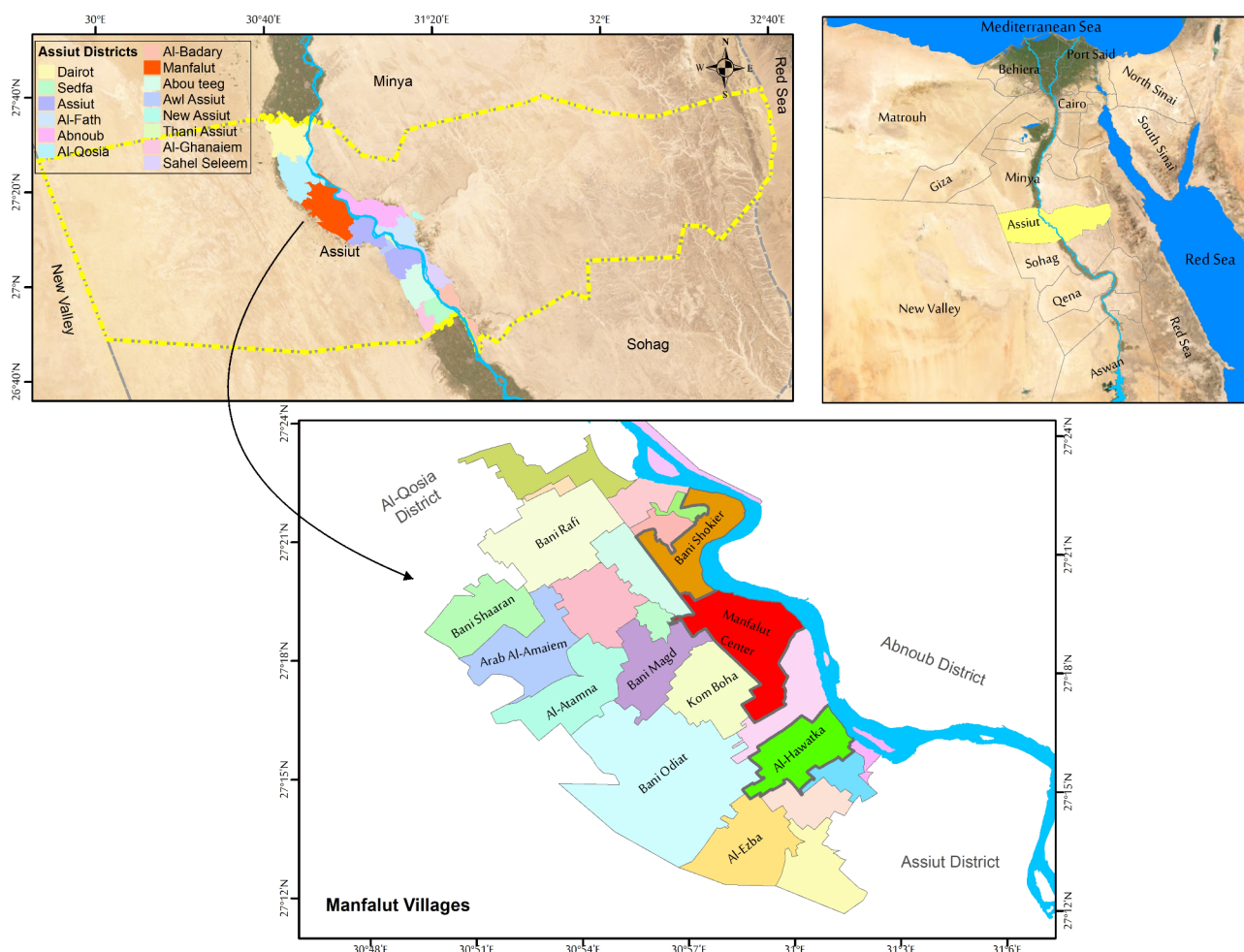


Fig. 1 Location map of Assiut Governorate, Egypt, highlights the governorate districts and Manfalut District (where the human fascioliasis outbreak occurred) in red color. Boundaries of districts with the highest cases are bold (Bani Shokier, Manfalut Center, and Al-Hawatka)

Climate datasets

This research used different climate datasets to detect the relation between climatic changes and *Fasciola* frequency in Assiut Governorate. Monthly temperature and humidity data were obtained for the last twenty-three years, from 2000 to 2023. The temperature data was obtained from the fifth-generation European Centre for Medium-Range Weather Forecasts (ECMWF), and atmospheric re-analysis (ERA5). This re-analysis dataset merges model data with observations from across the globe. It is created by applying the fundamental laws of physics, resulting in a complete and coherent dataset that spans several decades. This re-analysis data set provides an accurate description of past climate conditions. Moreover, the specific humidity levels were acquired from the Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System (FLDAS) dataset from NASA Land Information System at a spatial resolution of 0.01 degree between 2000 and 2023.

Statistical analysis

Data was analyzed using SPSS version 23. Categorical data were expressed as numbers and percentages, while continuous data were expressed as mean \pm SD. Spearman correlation analysis was used to determine the relationship between the number of recorded cases and the air temperature and humidity. A significant p-value was considered if the P-value < 0.05 . Furthermore, the Geographic Information Systems (GIS) platform (Arc GIS) was used to analyze the climate data, extract zonal statistics of temperature and humidity data for each district in Assiut Governorate, and study area mapping.

Results

Demographic and geographic data of the included patients

The annual prevalence showed that the largest recorded cases were in 2018 when an outbreak was reported in this region. The highest frequency of *Fasciola* was observed in Manfalut district, highlighted on the map. Manfalut

district is located on the west bank of the Nile River, in Assiut Governorate, 350 km south of the capital Cairo (Fig. 1).

Reports of three hundred and three *Fasciola* cases were enrolled in the study. Demographic and laboratory data are shown in Table 1. The mean age was 33.9 ± 17.4 years, with the majority having an age range between 21 and 40 years $n=132$ (43.6%), and females were predominant $n=173$ (57.1%). Most of the patients were rural residents ($n=224$, 73.9%). The majority of patients were residents of Manfalut district (89.1%). Acute fascioliasis was recorded in 94.4%, and the majority showed a response to triclabendazole ($n=229$, 75.6%). *Fasciola* eggs by stool microscopic examination were detected in a few cases $n=10$ (3.3%).

Data on climate change and its relation to the recorded cases of *Fasciola*:

Table 1 Demographic and laboratory data, and the response to treatment of the recorded *Fasciola* cases in the study area from September 2018 to March 2023

Data items	No (%)
Age in years (mean \pm SD)	33.9 ± 17.4
(Range)	(5–75)
5–20 years	74 (24.4)
21–40 years	132 (43.6)
41–60 years	73 (24.1)
≥ 61 years	24 (7.9)
Sex	
Males	130 (42.9)
Females	173 (57.1)
Residence	
Rural	224 (73.9)
Urban	79 (26.1)
Cases in districts of Assiut Governorate:	
Manfalut	270 (89.1)
Assiut	18 (5.9)
Abnoub	9 (3)
Dairut	3 (1)
Al-Fath	2 (0.7)
Al-Qosia	1 (0.3)
Acute fascioliasis	286 (94.4)
Response to triclabendazole	229 (75.6)
Eosinophilic count: median (IQR)	3.22 (6.31)
Eosinophilic percent: median (IQR)	31 (37.1)
Detection of diagnostic eggs in stool	10 (3.3)
Years of the study period:	
♣ From September 2018	237 (78.2)
♣ Year 2019	151 (49.8)
♣ Year 2020	121 (39.9)
♣ Year 2021	58 (19.1)
♣ Year 2022	57 (18.8)
♣ Up to March 2023	8 (2.6)

- **Annual analysis of temperature in relation to cases.**

Figure 2 presents an analysis of the temperature changes between 2000 and 2023. The highest temperatures were recorded in 2010 and 2018. The study focused on the frequency of *Fasciola* infection from 2018 to 2023 and found that the average temperature was the highest in 2018 at around 24.7°C , with a maximum of 32.24°C in July 2018 and a minimum of 13.48°C in January 2018.

The analysis was applied on a lower scale in Assiut districts. It was observed that Manfalut recorded the highest number of *Fasciola* cases during the study period (S1 Fig).

- **Monthly analysis of temperature in relation to cases.**

Figure 3A illustrates the monthly temperature changes between 2000 and 2017 and their relation to the temperature in the years of interest in the study when cases were recorded from 2018 to 2023. It can be observed that the temperature exceeded the average climatology values in most of the months, particularly in 2018.

Figure 3B displays the monthly temperature and distribution of *Fasciola* recorded cases in Assiut Governorate from September 2018 to March 2023. The analysis of Fig. 3B suggests that the highest increase in cases occurred during peak temperature in September 2018, decreased with the decline in temperature up to February 2019, and then re-increased up to March 2019 with the re-increase in the temperature. After that, a fluctuation in the recorded cases was seen up to March 2020, with a marked rise in recorded cases coinciding with the rise in the temperature in January 2020. Similarly, a rise in recorded cases was observed during rising temperatures between March and April and between September and October 2020, with the highest peak of recorded cases in September 2020. April to October 2021 and June to October 2022 observations indicated an association between high temperatures and increased *Fasciola* recorded cases. Also, the peak in cases in June 2021 and 2022 corresponded to the highest temperature recorded in June.

- **Annual analysis of humidity in relation to cases.**

The influence of humidity changes on *Fasciola* cases was investigated in Assiut Governorate by examining annual and monthly humidity variations. Figure 4 shows the annual variation in humidity from 2000 to 2023. The year 2018 showed the highest humidity levels of any year between 2018 and 2023.

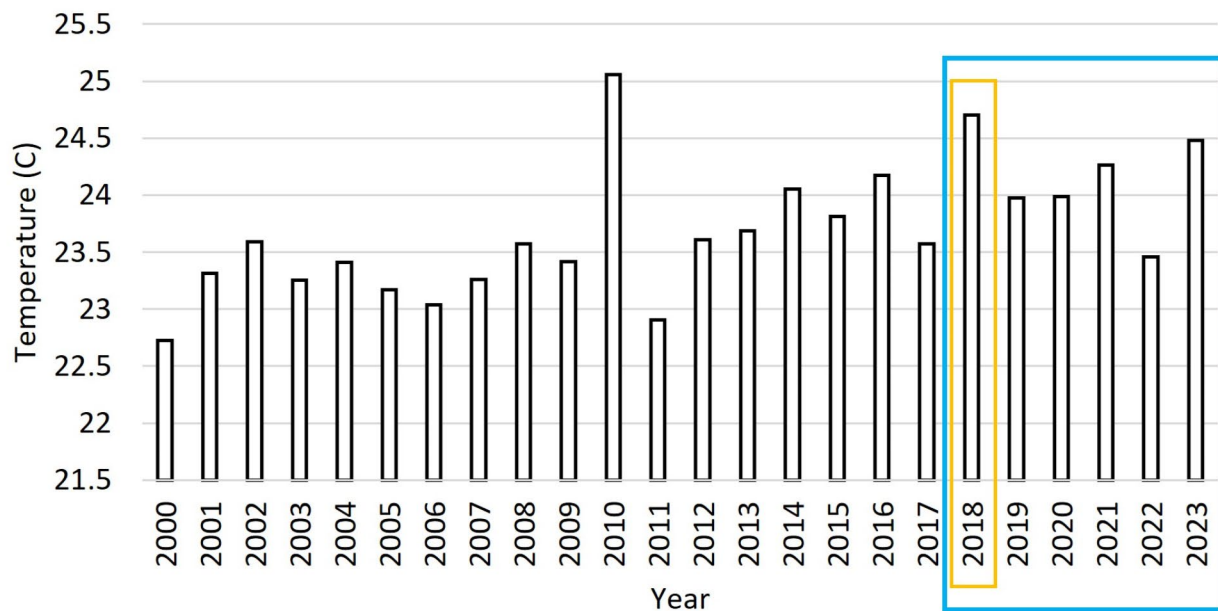


Fig. 2 The annual temperature variations in Assiut Governorate from 2000–2023 based on the ERA5 dataset

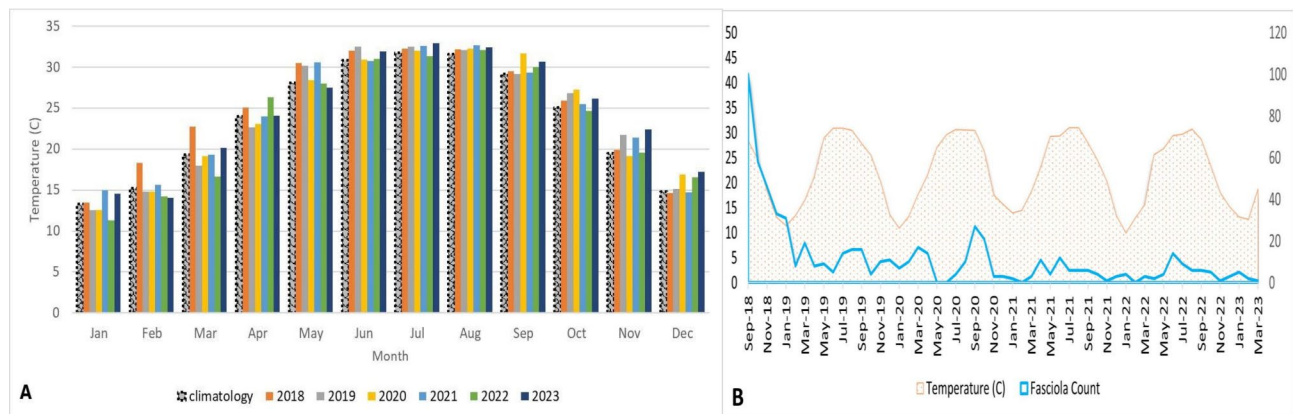


Fig. 3 The monthly temperature distribution in Assiut Governorate, A: from 2018 to 2023, and the climatology represents the average temperature from 2000–2017, B: from September 2018 to March 2023

A local scale study investigated the relation between atmospheric humidity and *Fasciola* recorded counts in Assiut districts. The study found a strong positive correlation between humidity and *Fasciola* counts, particularly in the four districts with the highest recorded cases: Manfalut Center, Al-Hawatka, Bani Shokier, and Gimris ($r=0.77$, $p=0.04$). These four districts are all part of the Manfalut district (Fig. S2 A, B).

• Monthly analysis of humidity in relation to cases.

The humidity levels during 2018–2023 were higher than the average recorded from 2000 to 2017, particularly from April to October 2018 (Fig. 5). During the

investigation, the highest humidity level detected was 0.0087 in September 2018, representing the month with the highest recorded cases of *Fasciola* during 2018–2023. By analyzing the subsequent monthly data, it was found that other small, not significant notches of the rise of the recorded cases occurred between July to October 2020 and May to October 2022, coinciding with high humidity levels (Fig. 6A, B).

Table 2 shows a strong positive correlation between temperature and the recorded cases of *Fasciola* in 2018, 2020, 2021, and 2022 ($r=0.92$, 0.41, 0.61, and 0.60, respectively). On the other hand, a non-significant negative correlation was detected in the year 2019 and the year 2023. In 2023, the correlation was negative as the

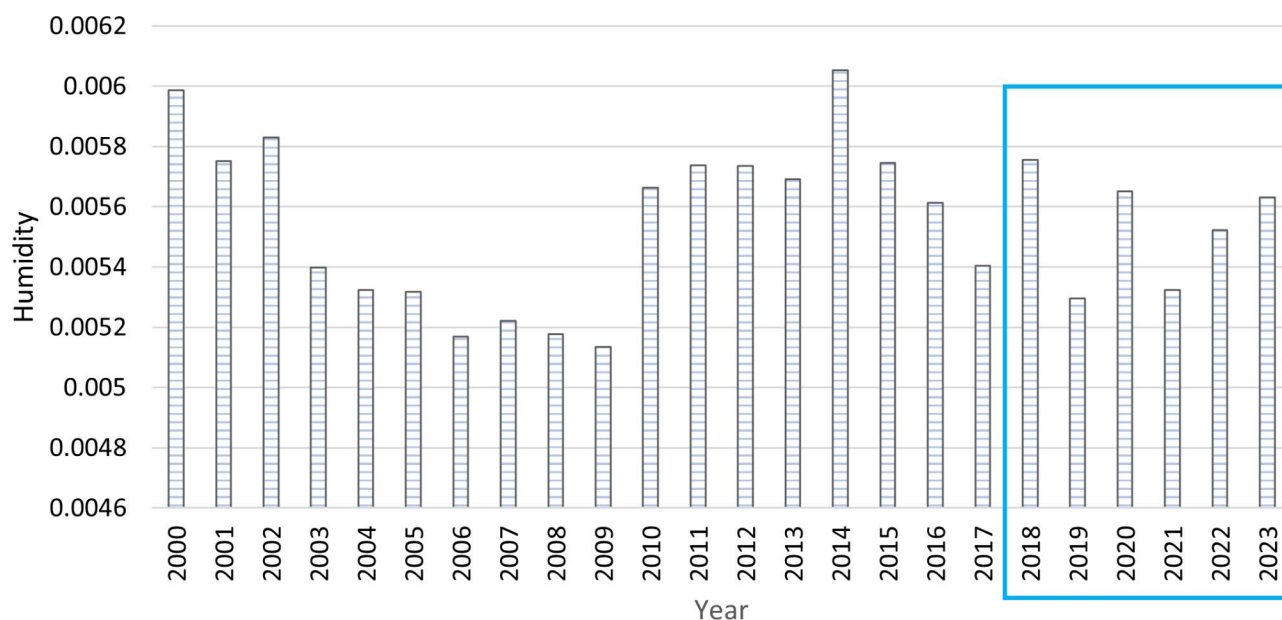


Fig. 4 The annual variation in humidity in Assiut Governorate for the period 2000–2023

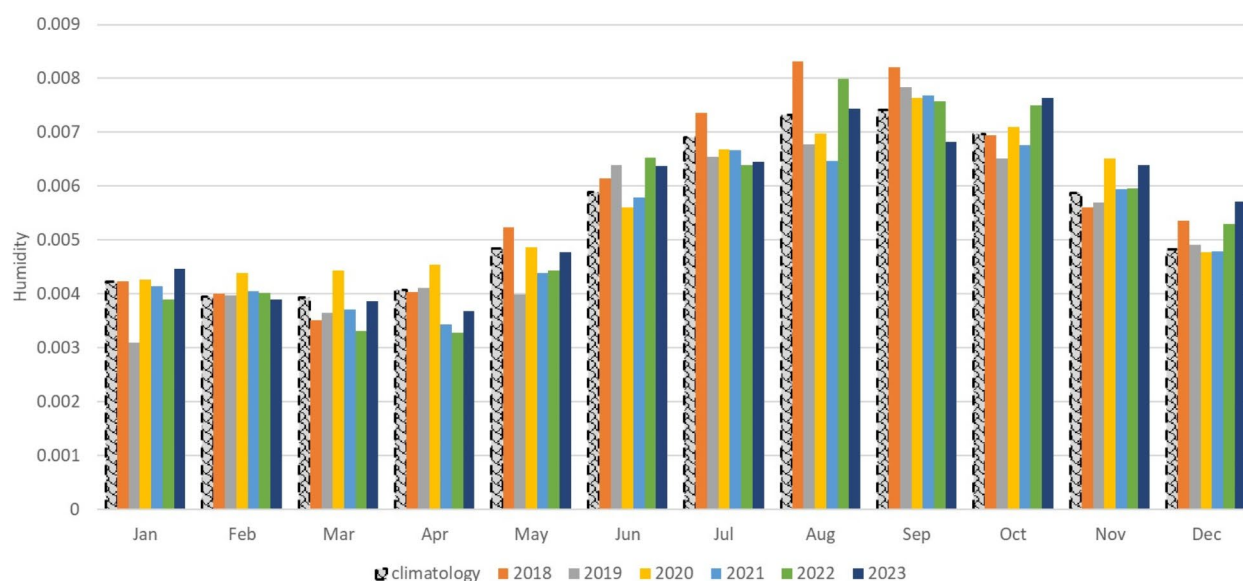


Fig. 5 Monthly distribution of humidity in Assiut Governorate for 2018–2023, and climatology data represents the average humidity for 2000–2017

analysis was applied to the winter months from January to March due to *Fasciola* data availability; during these months, the study area recorded lower temperatures.

Moreover, in 2018, humidity and *Fasciola* frequency had a significant strong positive correlation ($r=0.97$, $p=0.03$). In contrast, a non-significant negative correlation was found in 2019. A moderate positive correlation was found again in 2020, 2022, and 2023 ($r=0.36$, 0.49 , and 0.98 , respectively), with a significant difference in 2022. However, no correlation was found between humidity and *Fasciola* frequency in 2021 ($r=0.11$).

Discussion

Fascioliasis is a zoonotic disease transmitted by freshwater molluscs. Climate parameters significantly affect its prevalence in snails, humans, and livestock, making it important to study these effects for better control and prevention [25]. In this study, the patients were mainly rural residents of Assiut Governorate in Upper Egypt. The annual prevalence showed that the largest recorded cases were in 2018, when an outbreak was reported in this region, mainly from Manfalut district. Preventive measures, control programs, and community awareness

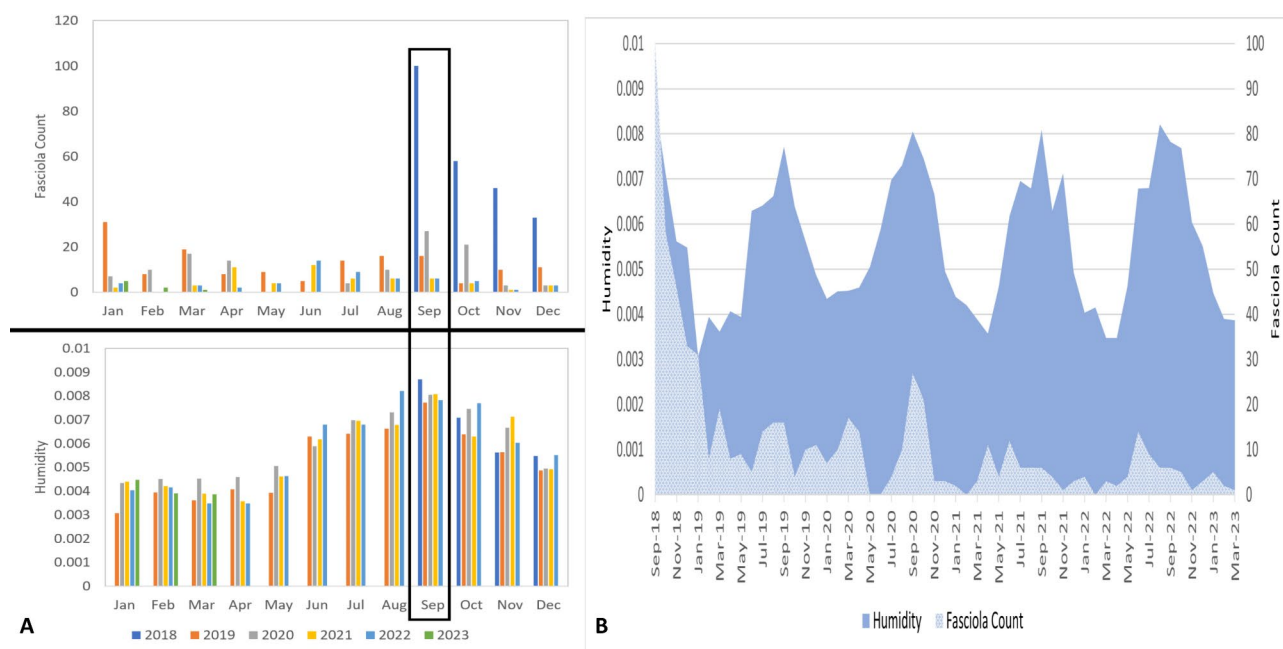


Fig. 6 Records of *Fasciola* cases and humidity levels, A: between 2018–2023, B: Monthly distribution of humidity and *Fasciola* recorded counts between September 2018 and March 2023

Table 2 Relationships between the annually recorded *Fasciola* cases and the atmospheric temperature and humidity during the study period between September 2018 to March 2023

Year	Air temperature		Specific humidity	
	r value	P-value	r value	P-value
2018	0.92	0.01*	0.97	0.03*
2019	-0.38	0.22	-0.31	0.32
2020	0.41	0.05	0.36	0.24
2021	0.61	0.04*	0.11	0.74
2022	0.60	0.04*	0.49	0.04*
2023	-0.63	0.57	0.98	0.12

* Significant p value

led to a decline in case numbers up to March 2023. Fascioliasis is linked with rural communities near irrigation canals, where human-made irrigation areas and livestock grazing are common [26]. Assiut Governorate lies near irrigation canals, showing the highest recorded cases from Manfalut Center, Al-Hawatka, Bani Shokier, and Gimris.

The severity of fascioliasis infection is linked to the proximity of people's homes to water sources inhabited by *Lymnaeid* snails [27]. The abundance of these snails is higher in areas where different species coexist, increasing the risk of disease transmission, as in the Nile Delta of Egypt, where the climate conditions promote the coexistence of *Galba* and *Radix* species [28]. Controlling the snail population is crucial to reducing the incidence of the disease.

The epidemiology of fascioliasis in Upper Egypt has changed significantly in recent years, with a rise in

human outbreaks or seasonal epidemics in certain districts as observed in this study [29, 30]. This may be due to global warming, as observed in previous reports in different parts of the world, such as Turkey [31], Ethiopia [32] Peru, and South America [33, 34].

In this study, a higher prevalence of fascioliasis was recorded in females compared to males, which coincides with previous studies conducted in Egypt [19, 21]. However, another systematic review reported lower prevalence rates in females [16], while a former study conducted in Peru showed no significant differences in patients' gender [35].

In the current study, the prevalence of fascioliasis was significantly influenced by temperature, showing a strong positive correlation with reported cases of *Fasciola* from 2018, 2020, and 2022. The peak temperature coincided with the highest increase in cases in 2018, and this observation was repeated in subsequent years, with temperatures exceeding the average climatology range in the same regions from 2000 to 2017.

These findings are consistent with previous studies in Italy, Ireland, and Mexico, where temperature significantly impacted the prevalence of animal fascioliasis compared to previous years [11, 36, 37]. Mas-Coma et al. found that temperature significantly affects the production and development of cercariae in intermediate snail hosts [38]. Nevertheless, these results disagree with studies in Malaysia and Pakistan, which found no significant correlation between animal fascioliasis prevalence and temperature changes [39, 40]. The conflicting results

may be due to significant temperature variations in those areas, with hot summers causing insufficient soil moisture and endangering *Fasciola* intermediate larval stages [4, 41]. These studies were referenced due to a lack of research papers on human fascioliasis.

In the same context, the incidence of *Fasciola* cases is positively correlated with humidity levels. The highest number of cases occurred during the period with the highest recorded humidity (September 2018). Similar findings have been reported in northwest Spain, where humidity and precipitation levels were found to influence the prevalence of *Fasciola* and gastrointestinal nematode infections in sheep [42]. Also, a systematic review of the epidemiology of fascioliasis in Bangladesh showed a significant increase in *Fasciola* infection in rainy seasons with high humidity that favours the growth of intermediate host snails [43].

It was found that the development of *Fasciola* larval stages in snails and snail reproduction are influenced by certain factors such as rainfall, humidity, and temperature. The optimal temperature range for snail development is 22–25°C, with 55–70% humidity [44]. Infection rates in *Lymnaea* snails are highest during rainy and summer seasons due to increased temperature, humidity, and rainfall [14, 44]. The risk of egg development is highest at around 30 °C, with a development period of 8–10 days. Several studies support the influence of climatic factors on the development of the parasite [42, 45, 46].

Notably, fasciolosis outbreaks show a seasonal pattern with two peak periods of infection in summer and winter [34, 47]. Snails get infected with *Fasciola* in late spring and early summer, and disease levels peak in late autumn or winter [48]. In the present study, most *Fasciola* cases exhibit a seasonal pattern, with infection peaks occurring in hot, humid months, mainly during the summer and autumn. This could be explained by the delayed egg development under unfavourable winter conditions. Once suitable environmental conditions arise, the infection manifests in the host between July and October [49]. Similar findings were observed in northeastern Punjab, Pakistan, where infection rates of human fascioliasis were significantly higher in the summer and autumn than in the winter and spring [50].

Seasonality of human infections of fascioliasis was found to be frequently associated with heavy rainfall years, as in Western Europe, where the disease occurs mainly during autumn (80.9% of cases) [51]. Nevertheless, sporadic infections could occur throughout the year due to the infective metacercariae's long survival [52]. Additionally, it was noted that human cases tend to occur during the watercress season from October to April [34].

In Egypt, human fascioliasis is described as an emerging zoonotic disease with a seasonal variation, with an infection peak occurring in August [34]. The summer/

autumn outbreaks observed in the present study could be linked to the increased participation of rural residents in field activities such as irrigation. Many farmers and their families wash their animals in canals along with vegetables, clothing, and utensils, particularly in warmer seasons [26]. Consequently, people often consume contaminated vegetables and water from these utensils. This aligns with the increase in temperature and humidity, leading to a monthly peak in *Fasciola* cases that occurred in September 2018, between July–October in 2020, and between May and October 2022.

Egypt's subtropical location results in varied weather conditions. Lower Egypt has mild winters with some rain, while Upper Egypt has a dry climate with warm days and cold nights. Summers are consistently hot and dry throughout the country [53]. Therefore, rainfall data was not considered significant during the peak months of *Fasciola* due to the hot and dry climate. So, the increase in *Fasciola* cases was primarily attributed to temperature and humidity fluctuations.

The study provides the first evidence of a correlation between climate change and human fascioliasis outbreaks in Upper Egypt. However, it has limitations, such as the retrospective nature of the study causing incomplete data of the patients, lack of snail population assessment, and lack of other environmental parameters that could affect the life cycle of *Fasciola*.

Consequently, it is encouraged to create a climate-based risk map of *Fasciola* epidemics using various forecast risk models to predict future outbreaks in humans and animals and properly manage control approaches. While the study provides correlative evidence of a potential causal relationship between climate change and infection rates, it emphasizes the need for further research to confirm a causal link. In addition, it is recommended to use more sensitive and specific diagnostic techniques, such as molecular methods, to improve the accuracy of case identification in future studies.

Conclusions

The transmission of human fascioliasis is rising in Upper Egypt and is influenced by local climate characteristics. The study found a strong positive correlation between temperature and humidity with the frequency of the recorded *Fasciola* cases, particularly in 2018 and the following years until 2023. Cases of *Fasciola* exhibit a seasonal pattern, with infection peaks occurring in hot and humid months, mainly in the summer and autumn seasons. Warmer temperatures and high humidity promote transmission and survival rates of parasitic disease, while high humidity levels create favorable conditions for the survival and transmission of *Fasciola* larval stages.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40794-024-00234-z>.

Supplementary Material 1

Supplementary Material 2

Author contributions

N.Z. and N.I. Data curation; Investigation, Resources, H.K. and A.A. Conceptualization, A.S. Supervision and Writing - review & editing. N.I. and A.A. Methodology of the study, N.Z., H.K., and A.A. writing the original draft. N.Z. and A.S. statistical analysis.

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Data availability

The data that support the findings of this study are not publicly available. The data are, however, available from the corresponding author upon reasonable request.

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

The study was approved by the Ethics Committee at the Central Directorate of Research and Health Development and Review in the Ministry of Health and Population, Egypt. The informed consent of the participants was waived due to the study's retrospective nature. The study was conducted following the Helsinki Declaration.

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